## Cambridge AS Level 9701 Syllabus

# CHEMISTY

# TOPICAL PAPER 1


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# Physical Chemistry

1
TOPIC

# Atomic Structure



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**1 9701/1/M/J/02/Q1**

In the radioactive decay of an isotope of lead to an isotope of bismuth, a particle $^{0}_{-1}X$ is emitted.

Which particle is $^{0}_{-1}X$?

**A** electron **B** ion **C** neutron **D** proton

**2 9701/1/O/N/02/Q2**

One of the most important chemical species responsible for the removal of ozone from the stratosphere is a free radical of chlorine, $^{35}Cl^{\bullet}$.

What does $^{35}Cl^{\bullet}$ contain?

| | protons | neutrons | electrons |
|---|---|---|---|
| **A** | 17 | 18 | 16 |
| **B** | 17 | 18 | 17 |
| **C** | 18 | 17 | 17 |
| **D** | 18 | 17 | 18 |

**3 9701/1/O/N/02/Q3**

*Use of the Data Booklet is relevant to this question.*

In the gas phase, aluminium and a transition element require the same amount of energy to form one mole of an ion with a 2+ charge.

What is the transition element?

**A** Co **B** Cr **C** Cu **D** Ni

**4 9701/1/M/J/03/Q3**

Which isotope of an element in the third period of the Periodic Table contains the same number of neutrons as $^{32}_{16}S$?

**A** $^{23}_{11}Na$ **B** $^{24}_{12}Mg$ **C** $^{28}_{14}Si$ **D** $^{31}_{15}P$

**5 9701/1/M/J/03/Q4**

The successive ionisation energies, in kJ mol$^{-1}$, of an element **X** are given below.

870 1800 3000 3600 5800 7000 13 200

What is **X**?

**A** $_{33}As$ **B** $_{40}Zr$ **C** $_{52}Te$ **D** $_{53}I$



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**6 9701/01/M/J/05/Q3**

The first six ionisation energies of four elements, **A** to **D**, are given.

Which element is most likely to be in Group IV of the Periodic Table?

| ionisation energy / kJ mol$^{-1}$ | 1st | 2nd | 3rd | 4th | 5th | 6th |
|---|---|---|---|---|---|---|
| **A** | 494 | 4560 | 6940 | 9540 | 13400 | 16600 |
| **B** | 736 | 1450 | 7740 | 10500 | 13600 | 18000 |
| **C** | 1090 | 2350 | 4610 | 6220 | 37800 | 47000 |
| **D** | 1400 | 2860 | 4590 | 7480 | 9400 | 53200 |

**7 9701/01/M/J/05/Q4**

In which species are the numbers of electrons and neutrons equal?

**A** $^{9}_{4}Be$ **B** $^{19}_{9}F$ **C** $^{23}_{11}Na^{+}$ **D** $^{18}_{8}O^{2-}$

**8 9701/01/O/N/05/Q1**

What is the electronic configuration of an element with a **second** ionisation energy higher than that of each of its neighbours in the Periodic Table?

**A** $1s^2 2s^2 2p^6 3s^2$

**B** $1s^2 2s^2 2p^6 3s^2 3p^1$

**C** $1s^2 2s^2 2p^6 3s^2 3p^2$

**D** $1s^2 2s^2 2p^6 3s^2 3p^3$

**9 9701/01/M/J/06/Q3**

Gallium nitride, GaN, could revolutionise the design of electric light bulbs because only a small length used as a filament gives excellent light at low cost.

Gallium nitride is an ionic compound containing the $Ga^{3+}$ ion.

What is the electron arrangement of the nitrogen ion in gallium nitride?

**A** $1s^2\ 2s^2$ **B** $1s^2\ 2s^2\ 2p^3$ **C** $1s^2\ 2s^2\ 2p^4$ **D** $1s^2\ 2s^2\ 2p^6$

**10 9701/01/M/J/06/Q4**

A radioactive isotope of thallium, $^{201}_{81}Tl$, is used to assess damage in heart muscles after a heart attack.

Which statement about $^{201}_{81}Tl$ is correct?

**A** This isotope has a nucleon number of 120.

**B** The number of electrons in one atom of this isotope is 81.

**C** The number of neutrons in one atom of this isotope is 201.

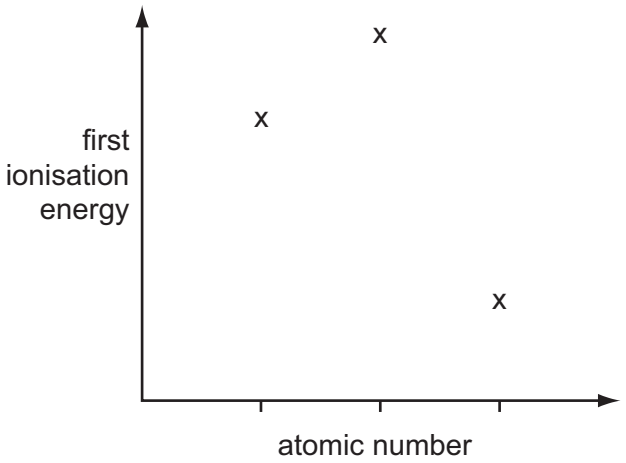
**D** $^{201}_{82}X$ is an isotope of $^{201}_{81}Tl$.



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**11 9701/01/O/N/06/Q2**

Three successive elements in the Periodic Table have first ionisation energies which have the pattern shown in the diagram.




What could be the first element of this sequence?

**A** C **B** N

**C** F **D** Na

**12 9701/01/O/N/06/Q3**

*Use of the Data Booklet is relevant to this question.*

The electronic structures of calcium, krypton, phosphorus and an element **X** are shown.

Which electronic structure is that of element **X**?

**A** $1s^2 2s^2 2p^6 3s^2 3p^3$ **C** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$

**B** $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ **D** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

**13 9701/01/M/J/07/Q23**

John Dalton's atomic theory, published in 1808, contained four predictions about atoms.

Which of his predictions is still considered to be correct?

**A** Atoms are very small in size.

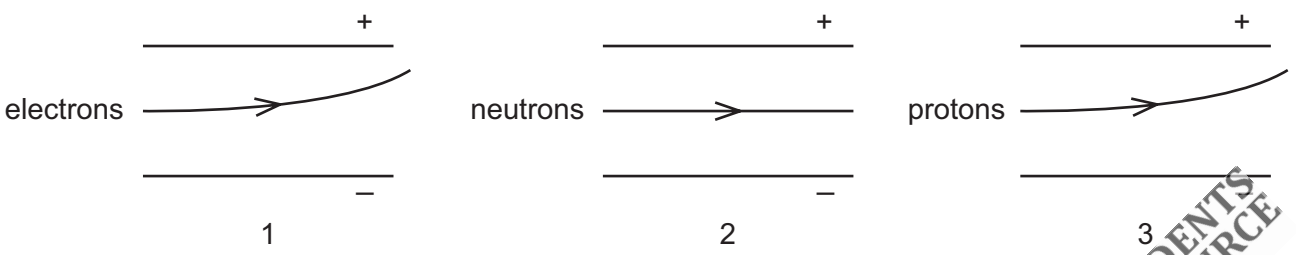
**B** No atom can be split into simpler parts.

**C** All the atoms of a particular element have the same mass.

**D** All the atoms of one element are different in mass from all the atoms of other elements.

**14 9701/01/M/J/07/Q4**

The diagrams show the possible paths of subatomic particles moving in an electric field in a vacuum.




Which diagrams are correct?

**A** 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 1, 2 and 3

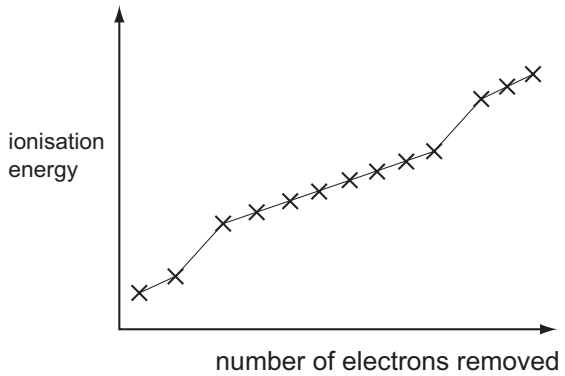
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**15 9701/01/O/N/07/Q4**

The graph shows the first thirteen ionisation energies for element **X**.




What can be deduced about element **X** from the graph?

**A** It is in the second period (Li to Ne) of the Periodic Table.
**B** It is a d-block element.
**C** It is in Group II of the Periodic Table.
**D** It is in Group III of the Periodic Table.

**16 9701/01/M/J/08/Q3**

Skin cancer can be treated using a radioactive isotope of phosphorus, $^{32}_{15}P$. A compound containing the phosphide ion $^{32}_{15}P^{3-}$, wrapped in a plastic sheet, is strapped to the affected area.

What is the composition of the phosphide ion, $^{32}_{15}P^{3-}$?

| | protons | neutrons | electrons |
|---|---|---|---|
| **A** | 15 | 17 | 18 |
| **B** | 15 | 17 | 32 |
| **C** | 17 | 15 | 17 |
| **D** | 32 | 17 | 15 |

**17 9701/01/O/N/08/Q3**

In which pair do both atoms have one electron only in an s orbital in their ground states?

**A** Ca, Sc **B** Cu, Be **C** H, He **D** Li, Cr

**18 9701/01/O/N/08/Q4**

*Use of the Data Booklet is relevant to this question.*

Hard water contains calcium ions and hydrogencarbonate ions arising from dissolved calcium hydrogencarbonate, $Ca(HCO_3)_2$.

How many electrons are present in the hydrogencarbonate anion?

**A** 30 **B** 31 **C** 32 **D** 33

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**19 9701/01/M/J/09/Q3**

The first seven ionisation energies of an element between lithium and neon in the Periodic Table are as follows.

1310 3390 5320 7450 11 000 13 300 71 000 $kJ\,mol^{-1}$

What is the outer electronic configuration of the element?

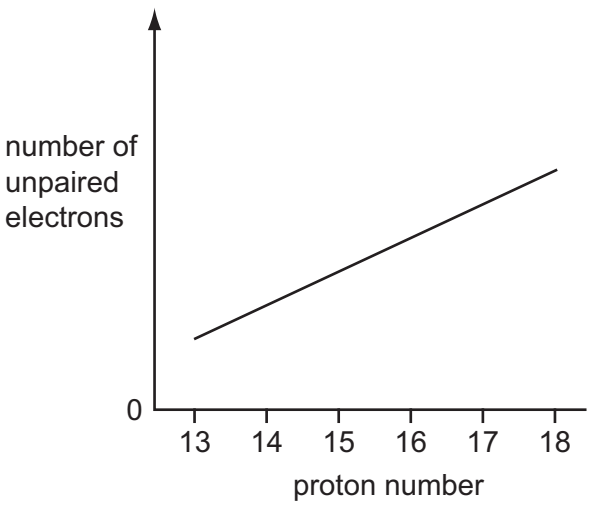
**A** $2s^2$ **B** $2s^22p^1$ **C** $2s^22p^4$ **D** $2s^22p^6$

**20 9701/01/M/J/09/Q4**

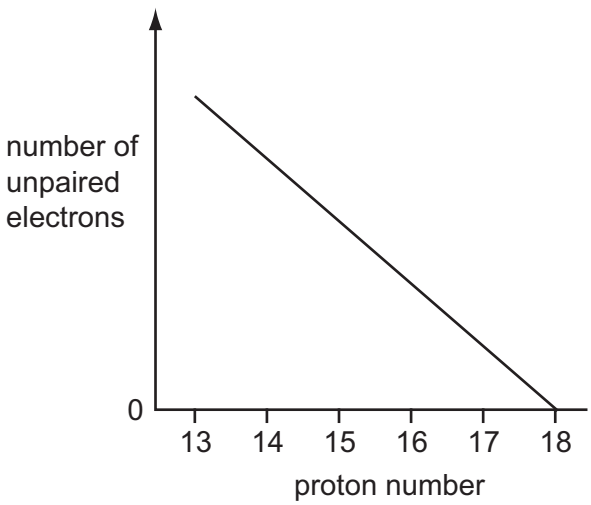
*Use of the Data Booklet is relevant to this question.*

Which graph represents the number of unpaired p orbital electrons for atoms with proton numbers 13 to 18?

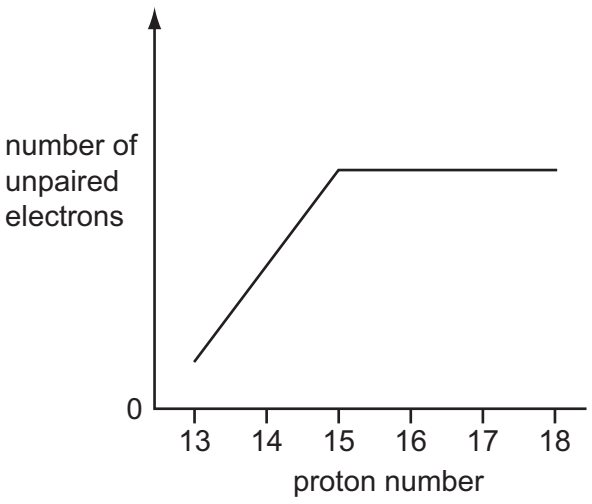
**A**



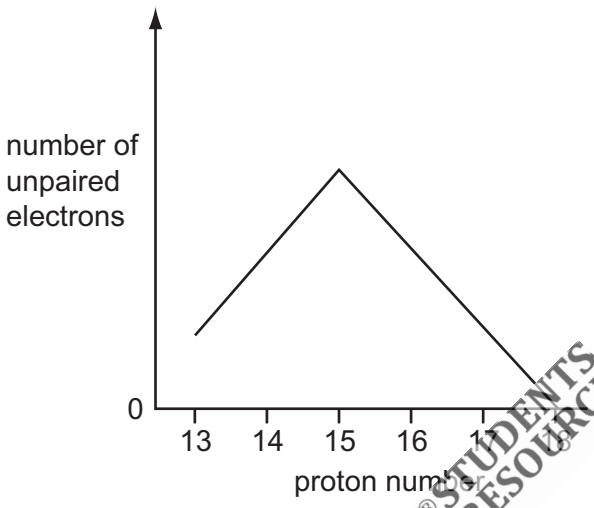

**B**




**C**




**D**




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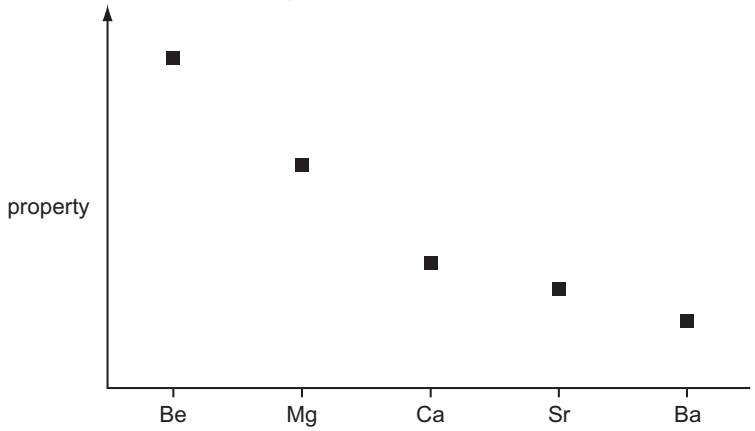


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**21 9701/12/O/N/09/Q2**

*Use of the Data Booklet is relevant to this question.*

The graph represents the variation of a property of the Group II elements.




What is this property?

**A** ionic radius
**B** ionisation energy
**C** neutron / proton ratio
**D** rate of reaction with water

**22 9701/13/O/N/10/Q3**

Which ion has more electrons than protons and more protons than neutrons?

[H = $^{1}_{1}H$ ; D = $^{2}_{1}H$ ; O = $^{16}_{8}O$]

**A** $D^-$ **B** $H_3O^+$ **C** $OD^-$ **D** $OH^-$

**23 9701/12/M/J/10/Q29**

*Use of the Data Booklet is relevant to this question*.

What could be the proton number of an element that has three unpaired electrons in each of its atoms?

**A** 5 **B** 13 **C** 15 **D** 21

**24 9701/12/M/J/10/Q3**

*Use of the Data Booklet is relevant to this question*.

The elements radon (Rn), francium (Fr) and radium (Ra) have consecutive proton numbers in the Periodic Table.

What is the order of their first ionisation energies?

| | least endothermic ⟶ | | most endothermic |
|---|---|---|---|
| **A** | Fr | Ra | Rn |
| **B** | Fr | Rn | Ra |
| **C** | Ra | Fr | Rn |
| **D** | Rn | Ra | Fr |

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**25 9701/12/M/J/11/Q1**

Helium, He, is the second element in the Periodic Table.

Tritium is the isotope of hydrogen $^{3}H$.

What is the same in an atom of $^{4}He$ and an atom of $^{3}H$?

**A** the number of electrons **B** the number of neutrons

**C** the number of protons **D** the relative atomic mass

**26 9701/12/O/N/11/Q3**

*Use of the Data Booklet is relevant to this question.*

From which particle is the removal of an electron the most difficult?

**A** $Cl^{-}(g)$ **B** $F^{-}(g)$ **C** $K^{+}(g)$ **D** $Na^{+}(g)$

**27 9701/12/M/J/13/Q3**

Which ion has more electrons than protons and more protons than neutrons?
[H = $^{1}_{1}H$ ; D = $^{2}_{1}H$ ; O = $^{16}_{8}O$]

**A** $D^{-}$ **B** $H_3O^{+}$ **C** $OD^{-}$ **D** $OH^{-}$

**28 9701/12/O/N/13/Q4**

In which set do all species contain the same number of electrons?

**A** $Co^{2+}$, $Co^{3+}$, $Co^{4+}$ **C** $Na^{+}$, $Mg^{2+}$, $Al^{3+}$

**B** $F^{-}$, $Br^{-}$, $Cl^{-}$ **D** $K_2SO_4$, $K_2SeO_4$, $K_2TeO_4$

**29 9701/12/M/J/15/Q1**

In which option do all three particles have the same electronic configuration **and** the same number of neutrons?

**A** $^{15}N^{3-}$ $^{16}O^{2-}$ $^{19}F^{-}$ **C** $^{19}F^{-}$ $^{20}Ne$ $^{23}Na^{+}$

**B** $^{18}O^{2-}$ $^{19}F^{-}$ $^{20}Ne$ **D** $^{22}Ne$ $^{23}Na$ $^{24}Mg^{2+}$

**30 9701/12/M/J/15/Q1**

In which option do all three particles have the same electronic configuration **and** the same number of neutrons?

**A** $^{15}N^{3-}$ $^{16}O^{2-}$ $^{19}F^{-}$ **C** $^{19}F^{-}$ $^{20}Ne$ $^{23}Na^{+}$

**B** $^{18}O^{2-}$ $^{19}F^{-}$ $^{20}Ne$ **D** $^{22}Ne$ $^{23}Na$ $^{24}Mg^{2+}$

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**31** **9701/12/F/M/16/Q2**

For the element sulfur, which pair of ionisation energies has the largest difference between them?

**A** third and fourth ionisation energies

**B** fourth and fifth ionisation energies

**C** fifth and sixth ionisation energies

**D** sixth and seventh ionisation energies

**32** **9701/12/F/M/16/Q3**

Which ion has both more electrons than protons and more protons than neutrons?
[H = $^{1}_{1}H$; D = $^{2}_{1}H$; O = $^{16}_{8}O$]

**A** $D^-$ **B** $H_3O^+$ **C** $OD^-$ **D** $OH^-$

**33** **9701/12/F/M/16/Q4**

Which species contains the smallest number of electrons?

**A** $B^{3+}$ **B** $Be^{2+}$ **C** $H^-$ **D** $He^+$

**34** **9701/13/M/J/16/Q6**

Carbon and silicon have the same outer electronic structure.

Why is a Si–Si bond weaker than a C–C bond?

**A** Silicon atoms have a larger atomic radius than carbon atoms.

**B** Silicon has a greater nuclear charge than carbon.

**C** Silicon has a smaller first ionisation energy than carbon.

**D** Silicon is more metallic than carbon.

**35** **9701/11/O/N/16/Q5**

*Use of the Data Booklet is relevant to this question.*

The $^{68}Ge$ isotope is medically useful because it undergoes a natural radioactive process to give a gallium isotope, $^{68}Ga$, which can be used to detect tumours. This transformation of $^{68}Ge$ occurs when an electron enters the nucleus, changing a proton into a neutron.

Which statement about the composition of an atom of the $^{68}Ga$ isotope is correct?

**A** It has 4 electrons in its outer p subshell.

**B** It has 13 electrons in its outer shell.

**C** It has 37 neutrons.

**D** Its proton number is 32.



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**36 9701/11/M/J/16/Q4**

When nuclear reactions take place, the elements produced are different from the elements that reacted. Nuclear equations, such as the one below, are used to represent the changes that occur.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n$$

The nucleon (mass) number total is constant at 236 and the proton number total is constant at 92.

In another nuclear reaction, uranium-238 is reacted with deuterium atoms, $^{2}_{1}H$. An isotope of a new element, **J**, is formed as well as two neutrons.

$$^{238}_{92}U + {}^{2}_{1}H \rightarrow \mathbf{J} + 2\,{}^{1}_{0}n$$

What is isotope **J**?

**A** $^{238}Np$ **B** $^{238}Pu$ **C** $^{240}Np$ **D** $^{240}Pu$

**37 9701/12/M/J/16/Q2**

Four electronic configurations are shown below. Three of these configurations belong to atoms of the elements chlorine, sodium and vanadium.

Which electronic configuration belongs to an atom of another element?

**A** $1s^2 2s^2 2p^6 3s^1$

**B** $1s^2 2s^2 2p^6 3s^2 3p^5$

**C** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$

**D** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$

**38 9701/12/M/J/16/Q3**

Elements X and Y are in the same group of the Periodic Table.

The table shows the first six ionisation energies of X and Y in $kJ\,mol^{-1}$.

| | 1st | 2nd | 3rd | 4th | 5th | 6th |
|---|---|---|---|---|---|---|
| X | 800 | 1600 | 2400 | 4300 | 5400 | 10400 |
| Y | 1000 | 1800 | 2700 | 4800 | 6000 | 12300 |

What could be the identities of X and Y?

| | X | Y |
|---|---|---|
| **A** | antimony, Sb | arsenic, As |
| **B** | arsenic, As | antimony, Sb |
| **C** | selenium, Se | tellurium, Te |
| **D** | tellurium, Te | selenium, Se |

**39 9701/13/M/J/16/Q5**

Which isolated gaseous atom has a total of five electrons occupying spherically shaped orbitals?

**A** boron **B** fluorine **C** sodium **D** potassium

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**40** **9701/12/F/M/17/Q1**

Which ion has the same electronic configuration as $Cl^-$?

**A** $F^-$ **B** $P^+$ **C** $Sc^{3+}$ **D** $Si^{4+}$

**41** **9701/12/F/M/17/Q14**

Why does barium react more rapidly with cold water than magnesium does?

**A** Barium atoms are larger and form ions more easily than magnesium atoms.

**B** Barium floats on the surface of the water but magnesium sinks in the water.

**C** Barium hydroxide is less soluble than magnesium hydroxide.

**D** The sum of the 1st and 2nd ionisation energies of barium is more than that for magnesium.

**42** **9701/11/M/J/17/Q1**

Which molecule contains six bonding electrons?

**A** $C_2H_4$ **B** $H_2S$ **C** $NCl_3$ **D** $SF_6$

**43** **9701/11/M/J/17/Q4**

Which property of an atom does **not** affect its first ionisation energy?

**A** the atomic radius **C** the number of neutrons

**B** the number of electron shells **D** the number of protons

**44** **9701/12/M/J/17/Q1**

In which species are the numbers of protons, neutrons and electrons **all** different?

**A** $^{19}_{9}F^-$ **B** $^{23}_{11}Na^+$ **C** $^{31}_{15}P$ **D** $^{32}_{16}S^{2-}$

**45** **9701/12/M/J/17/Q5**

At a temperature of 2500 K and a pressure of $1.00 \times 10^{-4}$ Pa a sample of 0.321 g of sulfur vapour has a volume of $2.08 \times 10^{6}\ m^3$.

What is the molecular formula of sulfur under these conditions?

**A** S **B** $S_2$ **C** $S_4$ **D** $S_8$

**46** **9701/13/M/J/17/Q1**

The ion $Y^{3-}$ contains 18 electrons and has a mass number of 31.

How many protons and neutrons does $Y_{3-}$ contain?

| | protons | neutrons |
|---|---|---|
| **A** | 15 | 16 |
| **B** | 15 | 18 |
| **C** | 18 | 13 |
| **D** | 21 | 10 |

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**47 9701/11/O/N/18/Q1**

The first four ionisation energies for element X are shown in the table.

| ionisation energy | 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| value / kJ mol$^{-1}$ | 577 | 1980 | 2960 | 6190 |

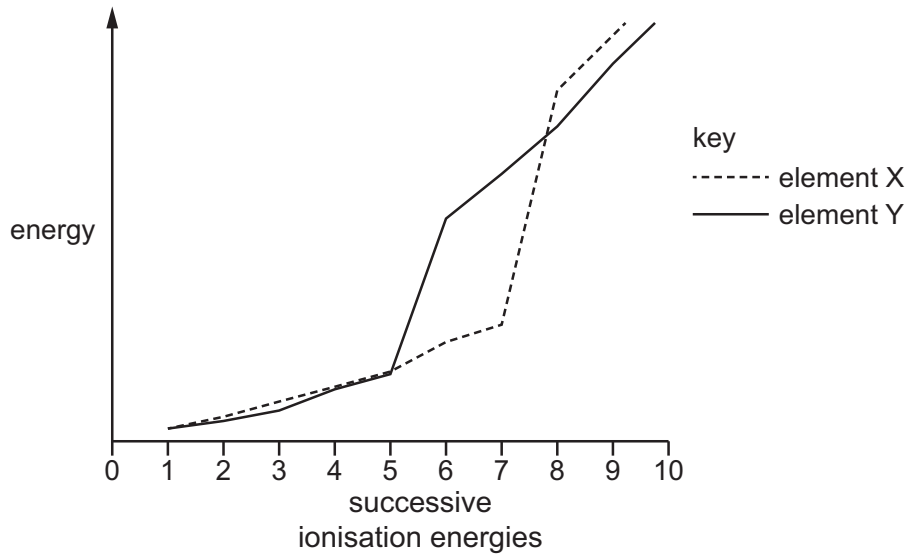
Which ion of X is produced by removing an electron from a filled shell?

**A** $X^{+}$ **B** $X^{2+}$ **C** $X^{3+}$ **D** $X^{4+}$

**48 9701/12/O/N/19/Q3**

The graph shows the successive ionisation energies of element X and element Y.

Both elements are in Period 3.




Which statement is correct?

**A** An atom of element X needs one extra electron for a full outer shell; an atom of element Y needs three extra electrons for a full outer shell.

**B** An atom of element Y has five electrons in the 3p subshell.

**C** Element X has an oxidation number of +7 in most of its compounds.

**D** When element X combines with element Y, the bonding is ionic.

**49 9701/12/O/N/19/Q4**

Which statement about the electrons in a ground state carbon atom is correct?

**A** Electrons are present in four different energy levels.

**B** There are more electrons in p orbitals than there are in s orbitals.

**C** The occupied orbital of highest energy is spherical.

**D** The occupied orbital of lowest energy is spherical.



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**50** **9701/12/F/M/19/Q3**

Which statement about a 3p orbital is correct?

**A** It can hold a maximum of 6 electrons.

**B** It has the highest energy of the orbitals with principal quantum number 3.

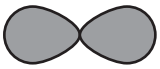
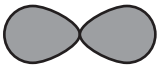
**C** It is at a higher energy level than a 3s orbital but has the same shape.

**D** It is occupied by one electron in an isolated phosphorus atom.

**51** **9701/11/M/J/19/Q4**

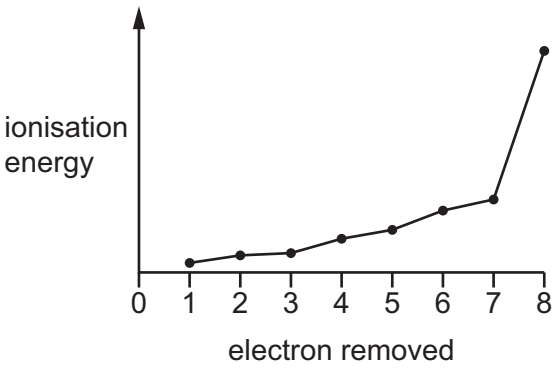
The outermost electron in an atom of neon occupies a particular orbital.

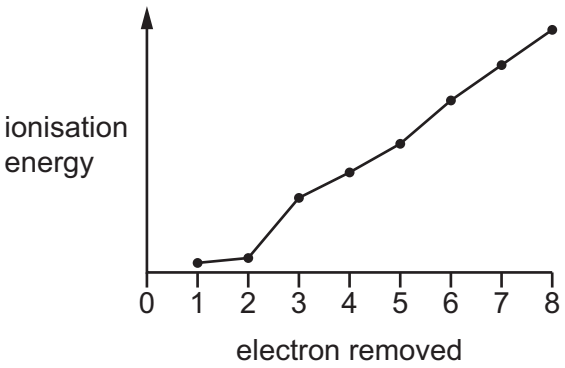
Which row shows the relative energy and shape of this orbital?

| | energy of orbital relative to other occupied orbitals | shape of orbital |
|---|---|---|
| **A** | higher or equal |  |
| **B** | higher or equal |  |
| **C** | lower or equal |  |
| **D** | lower or equal |  |

**52** **9701/12/M/J/19/Q3**

The first eight successive ionisation energies for two elements of Period 3 of the Periodic Table are shown in the graphs.




What is the formula of the ionic compound formed from these elements?

**A** $MgCl_2$ **B** $CaBr_2$ **C** $Na_2S$ **D** $K_2Se$



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**53** **9701/12/F/M/20/Q1**

What number of protons, neutrons and electrons are present in the ion $^{54}Fe^{3+}$?

| | protons | neutrons | electrons |
|---|---|---|---|
| **A** | 26 | 28 | 23 |
| **B** | 26 | 28 | 29 |
| **C** | 29 | 25 | 23 |
| **D** | 29 | 25 | 26 |

**54** **9701/11/M/J/20/Q10**

In which pair does each species have the same number of unpaired electrons?

**A** A$l$ and $Cu^{2+}$ **B** Ca and $Cr^{3+}$ **C** Ca and $Ni^{2+}$ **D** $Fe^{3+}$ and $O^{2-}$

**55** **9701/12/M/J/20/Q12**

The fifth to eighth ionisation energies of four elements in Period 3 of the Periodic Table are shown.

Which row refers to chlorine?

| | ionisation energies / kJ mol$^{-1}$ | | | |
|---|---|---|---|---|
| | fifth | sixth | seventh | eighth |
| **A** | 6280 | 21 200 | 25 900 | 30 500 |
| **B** | 6990 | 8 490 | 27 100 | 31 700 |
| **C** | 6540 | 9 330 | 11 000 | 33 600 |
| **D** | 7240 | 8 790 | 12 000 | 13 800 |

**56** **9701/13/M/J/20/Q1**

Which particle has equal numbers of protons and neutrons and an electronic structure of $1s^2 2s^2 2p^6 3s^2 3p^6$?

**A** $^{39}_{18}Ar$ **B** $^{40}_{20}Ca^{2+}$ **C** $^{16}_{8}O^{2-}$ **D** $^{32}_{16}S$

**57** **9701/13/M/J/20/Q8**

What is the electronic configuration of an isolated $Ni^{2+}$ ion?

**A** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$

**B** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^1$

**C** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

**D** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$

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Physical Chemistry




# Atoms, Molecules and Stoichiometry



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**1 9701/1/M/J/02/Q2**

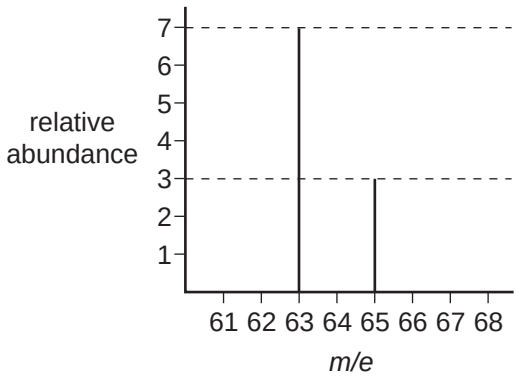
As a simplification, an adult human can be considered to have a daily diet of 1.80 kg of carbohydrate (empirical formula $CH_2O$).

Which mass of carbon dioxide does a person produce each day if all the carbohydrate eaten is digested and oxidised?

**A** 0.267 kg **B** 0.800 kg **C** 1.32 kg **D** 2.64 kg

**2 9701/1/M/J/02/Q3**

The diagram shows the mass spectrum of a sample of naturally-occurring copper.




What is the relative atomic mass of this copper?

**A** 63.3 **B** 63.5 **C** 63.6 **D** 64.0

**3 9701/1/O/N/02/Q1**

A mixture of 10 $cm^3$ of methane and 10 $cm^3$ of ethane was sparked with an excess of oxygen. After cooling to room temperature, the residual gas was passed through aqueous potassium hydroxide.

What volume of gas was absorbed by the alkali?

**A** 15 $cm^3$ **B** 20 $cm^3$ **C** 30 $cm^3$ **D** 40 $cm^3$

**4 9701/1/M/J/03/Q1**

*The use of the Data Booklet is relevant to this question.*

What is the number of molecules in 500 $cm^3$ of oxygen under room conditions?

**A** $1.25 \times 10^{22}$

**B** $1.34 \times 10^{22}$

**C** $3.0 \times 10^{22}$

**D** $3.0 \times 10^{26}$



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**5 9701/01/M/J/04/Q1**

Which of these samples of gas contains the same number of atoms as 1g of hydrogen ($M_r$ : $H_2$, 2)?

**A** 22 g of carbon dioxide ($M_r$ : $CO_2$, 44)
**B** 8 g of methane ($M_r$ : $CH_4$, 16)
**C** 20 g of neon ($M_r$ : Ne, 20)
**D** 8 g of ozone ($M_r$ : $O_3$, 48)

**6 9701/01/M/J/04/Q3**

*Use of the Data Booklet is relevant to this question.*

Most modern cars are fitted with airbags. These work by decomposing sodium azide to liberate nitrogen gas, which inflates the bag.

$$2NaN_3 \rightarrow 3N_2 + 2Na$$

A typical driver's airbag contains 50 g of sodium azide.

Calculate the volume of nitrogen this will produce at room temperature.

**A** 9.2 $dm^3$ **B** 13.9 $dm^3$ **C** 27.7 $dm^3$ **D** 72.0 $dm^3$

**7 9701/01/O/N/04/Q1**

Granular urea, $CON_2H_4$, can be used to remove $NO_2$ from the flue gases of power stations, converting it into harmless nitrogen.

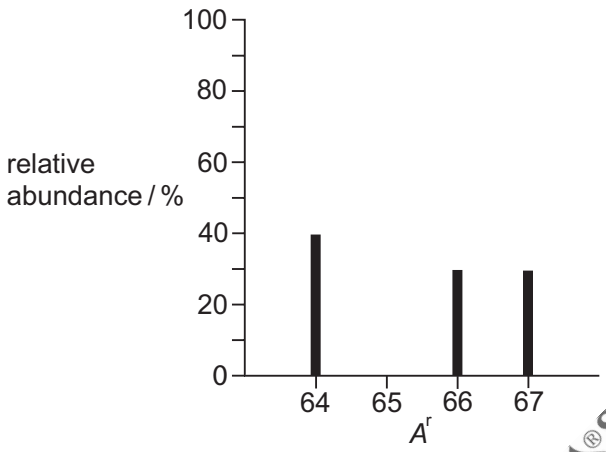
$$2CON_2H_4 + x\,NO_2 \rightarrow 2CO_2 + y\,H_2O + z\,N_2$$

What are the values of *x*, *y* and *z* in a balanced equation?

| | *x* | *y* | *z* |
|---|---|---|---|
| **A** | 1½ | 2 | 1¼ |
| **B** | 2 | 4 | 3 |
| **C** | 3 | 4 | 3½ |
| **D** | 3 | 4 | 3 |

**8 9701/01/O/N/04Q2**

The diagram shows the mass spectrum of a sample of zinc. Use the data to calculate the relative atomic mass of the sample.




**A** 65 **B** 65.25
**C** 65.5 **D** 66.65



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**9 9701/01/M/J/04/Q2**

Self-igniting flares contain $Mg_3P_2$. With water this produces diphosphane, $P_2H_4$, which is spontaneously flammable in air.

Which equation that includes the formation of diphosphane is balanced?

**A** $Mg_3P_2 + 6H_2O \rightarrow 3Mg(OH)_2 + P_2H_4$

**B** $Mg_3P_2 + 6H_2O \rightarrow 3Mg(OH)_2 + P_2H_4 + H_2$

**C** $2Mg_3P_2 + 12H_2O \rightarrow 6Mg(OH)_2 + P_2H_4 + 2PH_3$

**D** $2Mg_3P_2 + 12H_2O \rightarrow 6Mg(OH)_2 + 3P_2H_4$

**10 9701/01/O/N/04/Q3**

The foul smell that skunks spray is due to a number of thiols, one of which is methanethiol, $CH_3SH$, which burns as follows.

$$CH_3SH + 3O_2 \rightarrow CO_2 + SO_2 + 2H_2O$$

A sample of 10 $cm^3$ of methanethiol was exploded with 60 $cm^3$ of oxygen.

What would be the final volume of the resultant mixture of gases when cooled to room temperature?

**A** 20 $cm^3$ **B** 30 $cm^3$ **C** 50 $cm^3$ **D** 70 $cm^3$

**11 9701/01/M/J/05/Q1**

A pure hydrocarbon is used in bottled gas for cooking and heating.

When 10 $cm^3$ of the hydrocarbon is burned in 70 $cm^3$ of oxygen (an excess), the final gaseous mixture contains 30 $cm^3$ of carbon dioxide and 20 $cm^3$ of unreacted oxygen. All gaseous volumes were measured under identical conditions.

What is the formula of the hydrocarbon?

**A** $C_2H_6$ **B** $C_3H_6$ **C** $C_3H_8$ **D** $C_4H_{10}$

**12 9701/01/M/J/05/Q2**

On collision, airbags in cars inflate rapidly due to the production of nitrogen.

The nitrogen is formed according to the following equations.

$$2NaN_3 \rightarrow 2Na + 3N_2$$

$$10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$$

How many moles of nitrogen gas are produced from 1 mol of sodium azide, $NaN_3$?

**A** 1.5 **B** 1.6 **C** 3.2 **D** 4.0



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**13 9701/01/O/N/05/Q1**

The petrol additive tetraethyl-lead(IV), $Pb(C_2H_5)_4$, is now banned in many countries. When it is completely burned in air, lead(II) oxide, $CO_2$ and $H_2O$ are formed.

How many moles of oxygen are required to burn one mole of $Pb(C_2H_5)_4$?

**A** 9.5 **B** 11 **C** 13.5 **D** 27

**14 9701/01/O/N/05/Q15**

*Use of the Data Booklet is relevant to this question.*

What volume of oxygen, measured under room conditions, can be obtained from the thermal decomposition of 8.2 g of calcium nitrate ($M_r$ = 164)?

**A** 150 $cm^3$ **B** 300 $cm^3$ **C** 600 $cm^3$ **D** 1200 $cm^3$

**15 9701/01/M/J/06/Q1**

$N_2O_4$ is a poisonous gas. It can be disposed of safely by reaction with sodium hydroxide.

$$N_2O_4(g) + 2NaOH(aq) \rightarrow NaNO_3(aq) + NaNO_2(aq) + H_2O(l)$$

What is the minimum volume of 0.5 mol $dm^{-3}$ NaOH(aq) needed to dispose of 0.02 mol of $N_2O_4$?

**A** 8 $cm^3$ **B** 12.5 $cm^3$ **C** 40 $cm^3$ **D** 80 $cm^3$

**16 9701/01/M/J/06/Q2**

A sample of chlorine containing isotopes of mass numbers 35 and 37 was analysed in a mass-spectrometer.

How many peaks corresponding to $Cl_2^+$ were recorded?

**A** 2 **B** 3 **C** 4 **D** 5

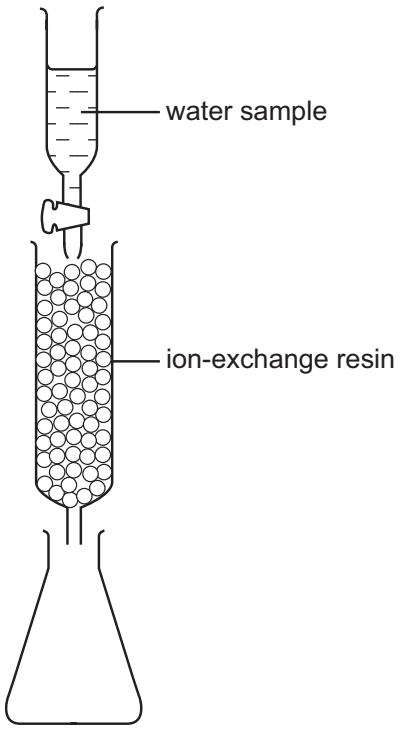
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**17 9701/01/O/N/06/Q1**

The amount of calcium ions in a sample of natural water can be determined by using an ion-exchange column as shown in the diagram.




A 50 $cm^3$ sample of water containing dissolved calcium sulphate was passed through the ion-exchange resin. Each calcium ion in the sample was exchanged for two hydrogen ions. The resulting acidic solution collected in the flask required 25 $cm^3$ of $1.0 \times 10^{-2}$ mol $dm^{-3}$ potassium hydroxide for complete neutralisation.

What was the concentration of the calcium sulphate in the original sample?

**A** $2.5 \times 10^{-3}$ mol $dm^{-3}$

**B** $1.0 \times 10^{-2}$ mol $dm^{-3}$

**C** $2.0 \times 10^{-2}$ mol $dm^{-3}$

**D** $4.0 \times 10^{-2}$ mol $dm^{-3}$



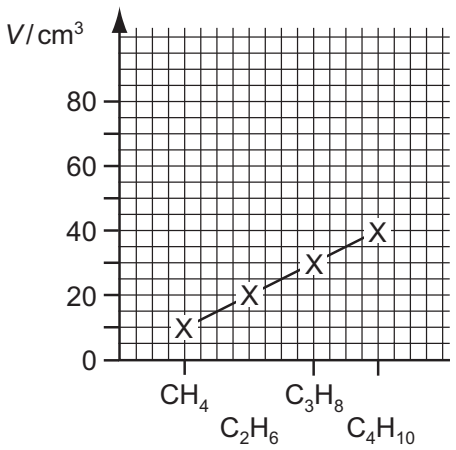
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**18 9701/01/O/N/06/Q4**

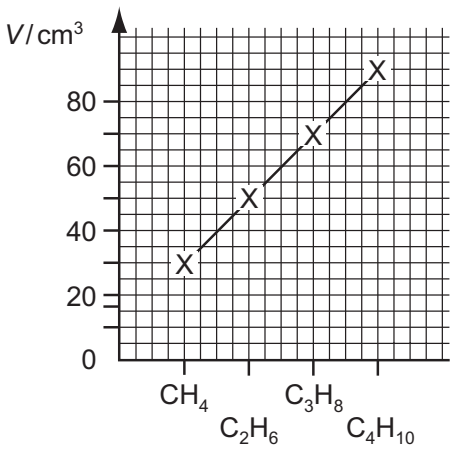
Samples of 10 $cm^3$ of each of the first four members of the alkane series are separately mixed with 70 $cm^3$ of oxygen. Each is then burned and the total volume, *V*, of residual gas measured again at room temperature and pressure.

Which graph represents the results that would be obtained?

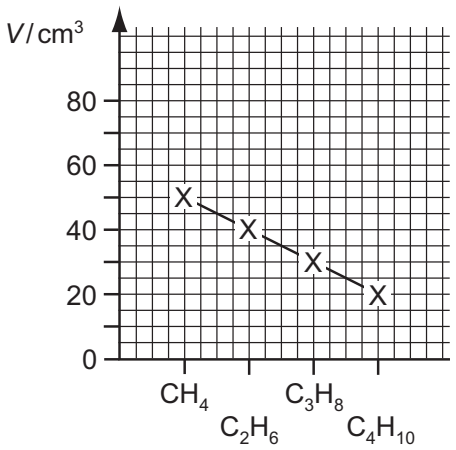
**A**



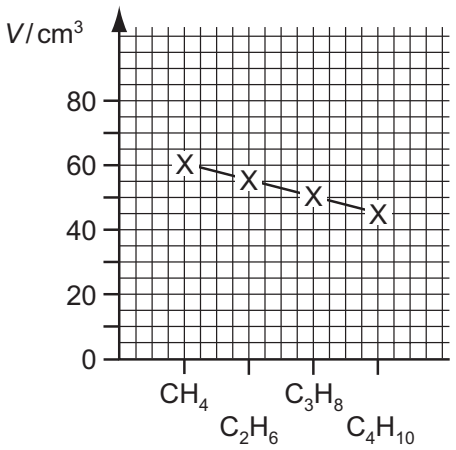

**B**




**C**

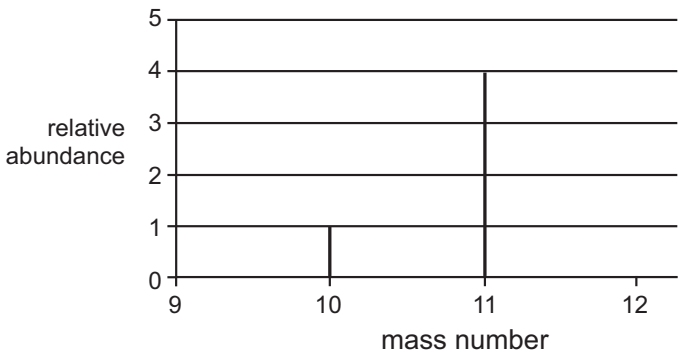



**D**




**19 9701/01/M/J/07/Q1**

The isotopic composition of an element is indicated below.




What is the relative atomic mass of the element?

**A** 10.2 **B** 10.5 **C** 10.8 **D** 11.0



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**20 9701/01/M/J/07/Q2**

*Use of the Data Booklet is relevant to this question.*

Oxides of nitrogen are pollutant gases which are emitted from car exhausts.

In urban traffic, when a car travels one kilometre, it releases 0.23 g of an oxide of nitrogen $N_xO_y$, which occupies 120 $cm^3$.

What are the values of *x* and *y*?
(Assume 1 mol of gas molecules occupies 24.0 $dm^3$.)

**A** $x = 1, y = 1$ **B** $x = 1, y = 2$ **C** $x = 2, y = 1$ **D** $x = 2, y = 4$

**21 9701/01/O/N/07/Q1**

*Use of the Data Booklet is relevant to this question.*

When a sports medal with a total surface area of 150 $cm^2$ was evenly coated with silver, using electrolysis, its mass increased by 0.216 g.

How many atoms of silver were deposited per $cm^2$ on the surface of the medal?

**A** $8.0 \times 10^{18}$ **B** $1.8 \times 10^{19}$ **C** $1.2 \times 10^{21}$ **D** $4.1 \times 10^{22}$

**22 9701/01/M/J/08/Q1**

In the Basic Oxygen steel-making process the $P_4O_{10}$ impurity is removed by reacting it with calcium oxide. The only product of this reaction is the salt calcium phosphate, $Ca_3(PO_4)_2$.

In this reaction, how many moles of calcium oxide react with one mole of $P_4O_{10}$?

**A** 1 **B** 1.5 **C** 3 **D** 6

**23 9701/01/M/J/08/Q2**

*Use of the Data Booklet is relevant to this question.*

A typical solid fertiliser for use with household plants and shrubs contains the elements N, P, and K in the ratio of 15 g : 30 g : 15 g per 100 g of fertiliser. The recommended usage of fertiliser is 14 g of fertiliser per 5 $dm^3$ of water.

What is the concentration of nitrogen atoms in this solution?

**A** 0.03 mol $dm^{-3}$ **B** 0.05 mol $dm^{-3}$ **C** 0.42 mol $dm^{-3}$ **D** 0.75 mol $dm^{-3}$

**24 9701/01/O/N/08/Q1**

*Use of the Data Booklet is relevant to this question.*

Titanium(IV) oxide, $TiO_2$, is brilliantly white and much of the oxide produced is used in the manufacture of paint.

What is the maximum amount of $TiO_2$ obtainable from 19.0 tonnes of the ore ilmenite, $FeTiO_3$?

**A** 10.0 tonnes **B** 12.7 tonnes **C** 14.0 tonnes **D** 17.7 tonnes

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**25 9701/01/O/N/08/Q2**

Carbon disulphide vapour burns in oxygen according to the following equation.

$$CS_2(g) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$$

A sample of 10 $cm^3$ of carbon disulphide was burned in 50 $cm^3$ of oxygen. After measuring the volume of gas remaining, the product was treated with an excess of aqueous sodium hydroxide and the volume of gas measured again. All measurements were made at the same temperature and pressure, under such conditions that carbon disulphide was gaseous.

What were the measured volumes?

| | volume of gas after burning / $cm^3$ | volume of gas after adding NaOH(aq) / $cm^3$ |
|---|---|---|
| **A** | 30 | 0 |
| **B** | 30 | 20 |
| **C** | 50 | 20 |
| **D** | 50 | 40 |

**26 9701/01/M/J/09/Q1**

*Use of the Data Booklet is relevant to this question.*

In leaded petrol there is an additive composed of lead, carbon and hydrogen only. This compound contains 29.7 % carbon and 6.19 % hydrogen by mass.

What is the value of **x** in the empirical formula $PbC_8H_x$?

**A** 5 **B** 6 **C** 16 **D** 20

**27 9701/01/M/J/09/Q2**

A household bleach contains sodium chlorate(I), NaC*l*O, as its active ingredient. The concentration of NaC*l*O in the bleach can be determined by reacting a known amount with aqueous hydrogen peroxide, $H_2O_2$.

$$NaClO(aq) + H_2O_2(aq) \rightarrow NaCl(aq) + O_2(g) + H_2O(l)$$

When 25.0 $cm^3$ of bleach is treated with an excess of aqueous $H_2O_2$, 0.0350 mol of oxygen gas is given off.

What is the concentration of NaC*l*O in the bleach?

**A** $8.75 \times 10^{-4}\,mol\,dm^{-3}$ **B** $0.700\,mol\,dm^{-3}$

**C** $0.875\,mol\,dm^{-3}$ **D** $1.40\,mol\,dm^{-3}$

**28 9701/12/O/N/09/Q1**

0.200 mol of a hydrocarbon undergo complete combustion to give 35.2 g of carbon dioxide and 14.4 g of water as the only products.

What is the molecular formula of the hydrocarbon?

**A** $C_2H_4$ **B** $C_2H_6$ **C** $C_4H_4$ **D** $C_4H_8$

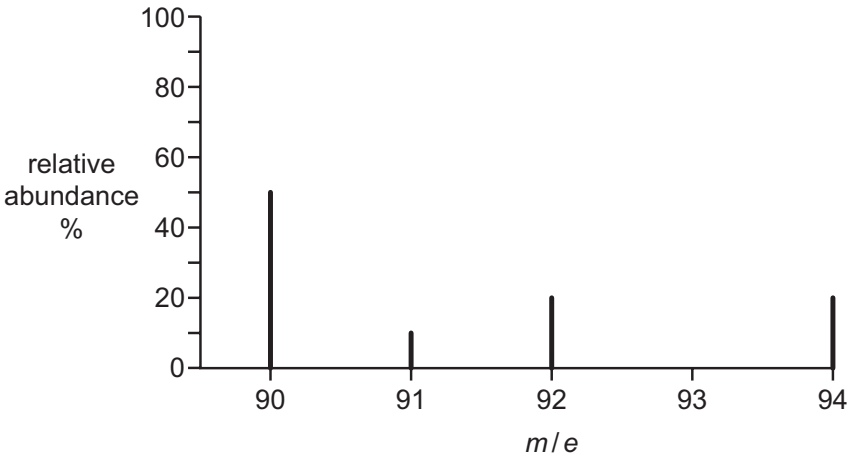
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**29 9701/12/O/N/09/Q30**

An element **X** consists of four isotopes. The mass spectrum of **X** is shown in the diagram.




What is the relative atomic mass of **X**?

**A** 91.00 **B** 91.30 **C** 91.75 **D** 92.00

**30 9701/12/M/J/10/Q7**

Which mass of gas would occupy a volume of 3 $dm^3$ at 25 °C and 1 atmosphere pressure?
[1 mol of gas occupies 24 $dm^3$ at 25 °C and 1 atmosphere pressure.]

**A** 3.2 g $O_2$ gas **B** 5.6 g $N_2$ gas **C** 8.0 g $SO_2$ gas **D** 11.0 g $CO_2$ gas

**31 9701/12/M/J/11/Q10**

Tanzanite is used as a gemstone for jewellery. It is a hydrated calcium aluminium silicate mineral with a chemical formula $Ca_2Al_xSi_yO_{12}(OH).6½H_2O$. Tanzanite has $M_r$ of 571.5.

Its chemical composition is 14.04 % calcium, 14.17 % aluminium, 14.75 % silicon, 54.59 % oxygen and 2.45 % hydrogen.

($A_r$ values: H = 1.0, O = 16.0, Al = 27.0, Si = 28.1, Ca = 40.1)

What are the values of x and y?

| | x | y |
|---|---|---|
| **A** | 1 | 1 |
| **B** | 2 | 3 |
| **C** | 3 | 3 |
| **D** | 6 | 1 |

**32 9701/12/O/N/11/Q3**

The following equations the letters **W**, **X**, **Y** and **Z** all represent whole numbers.

When correctly balanced, which equation requires one of letters **W**, **X**, **Y** or **Z** to be 5?

**A** $\mathbf{W}C_3H_7COOH + \mathbf{X}O_2 \rightarrow \mathbf{Y}CO_2 + \mathbf{Z}H_2O$ **B** $\mathbf{W}C_4H_8 + \mathbf{X}O_2 \rightarrow \mathbf{Y}CO_2 + \mathbf{Z}H_2O$

**C** $\mathbf{W}H_3PO_4 + \mathbf{X}NaOH \rightarrow \mathbf{Y}Na_2HPO_4 + \mathbf{Z}H_2O$ **D** $\mathbf{W}NH_3 + \mathbf{X}O_2 \rightarrow \mathbf{Y}N_2 + \mathbf{Z}H_2O$

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**33 9701/12/O/N/13/Q10**

*Use of the Data Booklet is relevant to this question.*

Which sodium compound contains 74.2 % by mass of sodium?

**A** sodium carbonate **B** sodium chloride

**C** sodium hydroxide **D** sodium oxide

**34 9701/12/M/J/13/Q13**

*Use of the Data Booklet is relevant to this question.*

Magnesium nitrate, $Mg(NO_3)_2$, will decompose when heated to give a white solid and a mixture of gases. One of the gases released is oxygen.

29.7 g of anhydrous magnesium nitrate is heated until no further reaction takes place.

What mass of oxygen is produced?

**A** 3.2 g **B** 6.4 g **C** 12.8 g **D** 19.2 g

**35 9701/13/O/N/14/Q6**

*Use of the Data Booklet is relevant to this question.*

In some countries, anhydrous calcium chloride is used as a drying agent to reduce dampness in houses. The anhydrous salt absorbs enough water to form the dihydrate $CaCl_2.2H_2O$.

What is the percentage increase in mass?

**A** 14% **B** 24% **C** 32% **D** 36%

**36 9701/12/M/J/14/Q9**

*Use of the Data Booklet is relevant to this question.*

In an experiment, 12.0 $dm^3$ of oxygen, measured under room conditions, is used to burn completely 0.10 mol of propan-1-ol.

What is the final volume of gas, measured under room conditions?

**A** 7.20 $dm^3$ **B** 8.40 $dm^3$ **C** 16.8 $dm^3$ **D** 18.00 $dm^3$

**37 9701/12/O/N/14/Q15**

*Use of the Data Booklet is relevant to this question.*

A sample of potassium oxide, $K_2O$, is dissolved in 250 $cm^3$ of distilled water. 25.0 $cm^3$ of this solution is titrated against sulfuric acid of concentration 2.00 mol $dm^{-3}$. 15.0 $cm^3$ of this sulfuric acid is needed for complete neutralisation.

Which mass of potassium oxide was originally dissolved in 250 $cm^3$ of distilled water?

**A** 2.83 g **B** 28.3 g **C** 47.1 g **D** 56.6 g

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**38 9701/13/O/N/15/Q26**

*Use of the Data Booklet is relevant to this question.*

Which volume of oxygen measured at room temperature and pressure is needed for complete combustion of 0.1 mol of propan-1-ol?

**A** 10.8 $dm^3$ **B** 12.0 $dm^3$ **C** 21.6 $dm^3$ **D** 24.0 $dm^3$

**39 9701/11/M/J/15/Q3**

*Use of the Data Booklet is relevant to this question*.

1.00 g of carbon is combusted in a limited supply of pure oxygen. 0.50 g of the carbon combusts to form $CO_2$ and 0.50 g of the carbon combusts to form CO.

The resultant mixture of $CO_2$ and CO is passed through excess NaOH(aq) and the remaining gas is then dried and collected.

What is the volume of the remaining gas? (All gas volumes are measured at 25 °C and 1 atmosphere pressure.)

**A** $\sqrt[3]{1}$ dm **B** $\sqrt[3]{1.5}$ dm **C** $\sqrt[3]{2}$ dm **D** $\sqrt[3]{3}$ dm

**40 9701/12/M/J/15/Q2**

The shell of a chicken's egg makes up 5% of the mass of an average egg. An average egg has a mass of 50 g.

Assume the egg shell is pure calcium carbonate.

How many complete chicken's egg shells would be needed to neutralise 50 $cm^3$ of 2.0 mol $dm^{-3}$ ethanoic acid?

**A** 1 **B** 2 **C** 3 **D** 4

**41 9701/12/M/J/16/Q14**

A 0.005 mol sample of anhydrous calcium carbonate was completely thermally decomposed to give 100 $cm^3$ of gas measured at a certain temperature and pressure.

In a separate experiment carried out at the same temperature and pressure, a 0.005 mol sample of anhydrous calcium nitrate was completely thermally decomposed. The volume of gaseous products was measured.

What total volume of gaseous products was produced from the calcium nitrate?

**A** 50 $cm^3$ **B** 100 $cm^3$ **C** 200 $cm^3$ **D** 250 $cm^3$

**42 9701/13/M/J/16/Q3**

Which mass of urea, $CO(NH_2)_2$, contains the same mass of nitrogen as 101.1 g of potassium nitrate?

**A** 22 g **B** 30 g **C** 44 g **D** 60 g

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**43 9701/11/M/J/16/Q3**

Tetraethyl lead, $Pb(C_2H_5)_4$, has been used as a petrol additive.

What is the percentage by mass of carbon in tetraethyl lead?

**A** 10.2 **B** 14.9 **C** 29.7 **D** 32.0

**44 9701/11/M/J/16/Q6**

A white powder is known to be a mixture of magnesium oxide and aluminium oxide.

100 $cm^3$ of 2 mol $dm^{-3}$ NaOH(aq) is just sufficient to cause the aluminium oxide in *x* grams of the mixture to dissolve.

The reaction occurring is $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$.

800 $cm^3$ of 2 mol $dm^{-3}$ HCl(aq) is just sufficient to cause **all** of the oxide in *x* grams of the mixture to dissolve.

The reactions occurring are $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$
and $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$.

How many moles of each oxide are present in *x* grams of the mixture?

| | aluminium oxide | magnesium oxide |
|---|---|---|
| **A** | 0.05 | 0.25 |
| **B** | 0.05 | 0.50 |
| **C** | 0.10 | 0.25 |
| **D** | 0.10 | 0.50 |

**45 9701/11/M/J/16/Q17**

A piece of rock has a mass of 2.00 g. It contains calcium carbonate, but no other basic substances. It neutralises exactly 36.0 $cm^3$ of 0.500 mol $dm^{-3}$ hydrochloric acid.

What is the percentage of calcium carbonate in the 2.00 g piece of rock?

**A** 22.5% **B** 45.0% **C** 72.0% **D** 90.1%

**46 9701/12/M/J/16/Q4**

In China, the concentration of blood glucose, $C_6H_{12}O_6$, is measured in mmol / *l*. In Pakistan, the concentration of blood glucose is measured in mg / d*l*.

The unit *l* is a litre (1 $dm^3$). The unit d*l* is a decilitre (0.1 $dm^3$).

A blood glucose concentration of 18.5 mmol / *l* indicates a health problem.

What is 18.5 mmol / *l* converted to mg / d*l*?

**A** 33.3 mg / d*l* **B** 178 mg / d*l* **C** 333 mg / d*l* **D** 3330 mg / d*l*

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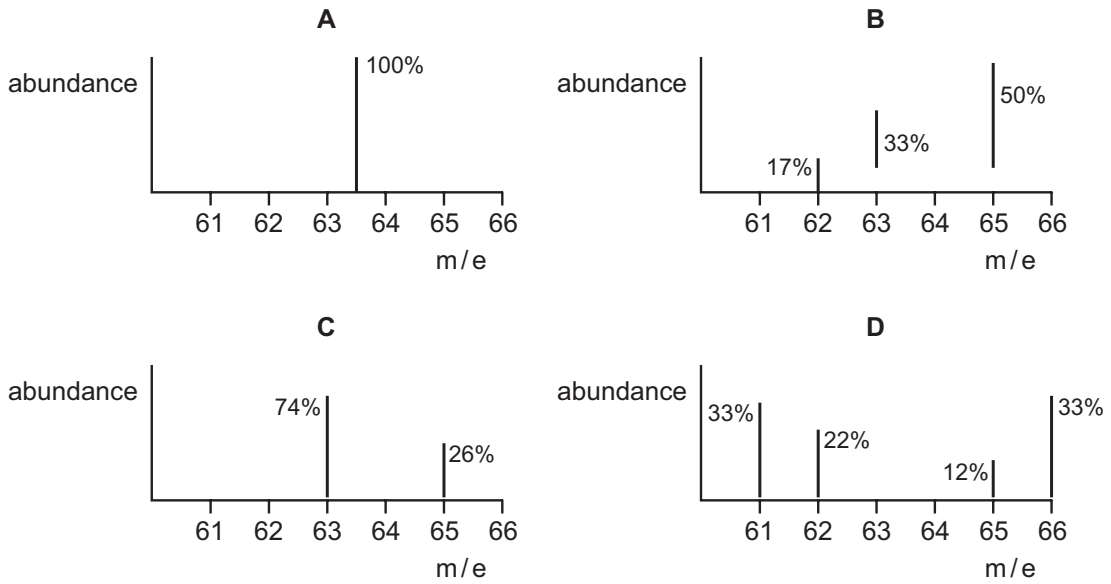


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**47 9701/13/M/J/16/Q4**

The relative atomic mass of copper is 63.5.

Which chart is a correct mass spectrum that would lead to this value?




**48 9701/12/M/J/16/Q14**

A 0.005 mol sample of anhydrous calcium carbonate was completely thermally decomposed to give 100 $cm^3$ of gas measured at a certain temperature and pressure.

In a separate experiment carried out at the same temperature and pressure, a 0.005 mol sample of anhydrous calcium nitrate was completely thermally decomposed. The volume of gaseous products was measured.

What total volume of gaseous products was produced from the calcium nitrate?

**A** 50 $cm^3$ **B** 100 $cm^3$ **C** 200 $cm^3$ **D** 250 $cm^3$

**49 9701/13/M/J/16/Q3**

Which mass of urea, $CO(NH_2)_2$, contains the same mass of nitrogen as 101.1 g of potassium nitrate?

**A** 22 g **B** 30 g **C** 44 g **D** 60 g

**50 9701/12/F/M/17/Q2**

Compounds J and K each contain 40% carbon by mass.

What could J and K be?

| | J | K |
|---|---|---|
| **A** | a hexose, $C_6H_{12}O_6$ | starch, $(C_6H_{10}O_5)_n$ |
| **B** | a pentose, $C_5H_{10}O_5$ | a hexose, $C_6H_{12}O_6$ |
| **C** | a pentose, $C_5H_{10}O_5$ | sucrose, $C_{12}H_{22}O_{11}$ |
| **D** | starch, $(C_6H_{10}O_5)_n$ | sucrose, $C_{12}H_{22}O_{11}$ |

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**51 9701/12/F/M/17/Q6**

Which gas sample contains the **fewest** molecules?

**A** 1.00 $dm^3$ of carbon dioxide at 27 °C and 2.0 kPa

**B** 1.00 $dm^3$ of hydrogen at 100 °C and 2.0 kPa

**C** 1.00 $dm^3$ of nitrogen at 300 °C and 4.0 kPa

**D** 1.00 $dm^3$ of oxygen at 250 °C and 3.0 kPa

**52 9701/11/M/J/17/Q2**

The mass spectrum of a sample of lithium shows that it contains two isotopes, $^6Li$ and $^7Li$.

The isotopic abundances are shown in the table.

| isotope | isotopic abundance |
|---|---|
| $^6Li$ | 7.42% |
| $^7Li$ | 92.58% |

What is the relative atomic mass of this sample of lithium, given to three significant figures?

**A** 6.07 **B** 6.50 **C** 6.90 **D** 6.93

**53 9701/11/M/J/17/Q3**

A sports medal has a total surface area of 150 $cm^2$. It was evenly coated with silver by electrolysis. Its mass increased by 0.216 g.

How many atoms of silver were deposited per $cm^2$ on the surface of the medal?

**A** $8.0 \times 10^{18}$ **B** $1.8 \times 10^{19}$ **C** $8.7 \times 10^{20}$ **D** $1.2 \times 10^{21}$

**54 9701/11/M/J/17/Q6**

The complete combustion of 2 moles of a straight chain alkane produces 400 $dm^3$ of carbon dioxide measured at 301 K and $1 \times 10^5$ Pa. Carbon dioxide can be assumed to behave as an ideal gas under these conditions.

What is the formula of the straight chain alkane?

**A** $C_8H_{18}$ **B** $C_{16}H_{34}$ **C** $C_{20}H_{42}$ **D** $C_{40}H_{82}$

**55 9701/12/M/J/17/Q2**

Which would contain $9.03 \times 10^{23}$ oxygen atoms?

**A** 0.25 mol aluminium oxide

**B** 0.75 mol sulfur dioxide

**C** 1.5 mol sulfur trioxide

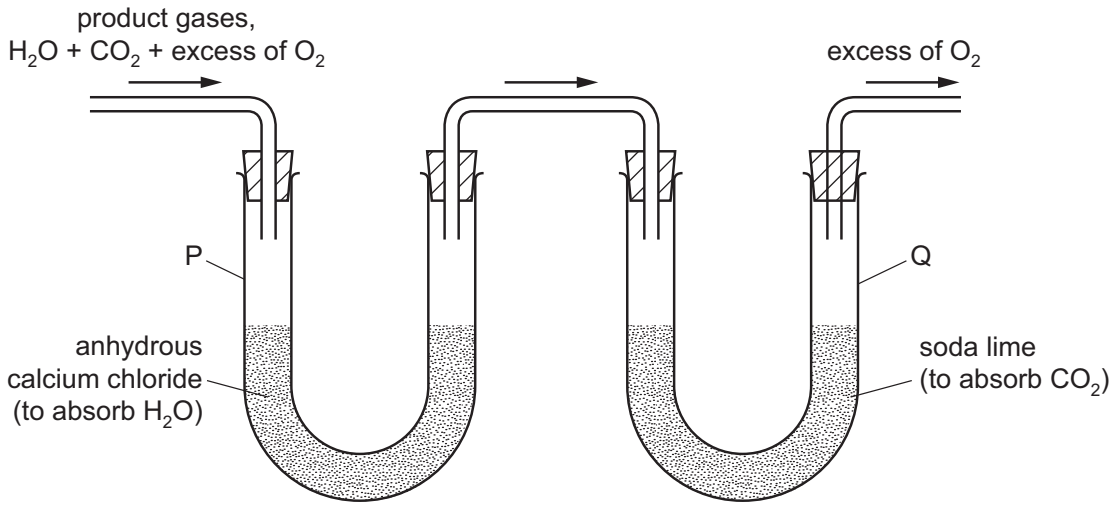
**D** 3.0 mol water



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**56 9701/11/O/N/18/Q3**

A sample of the hydrocarbon $C_6H_{12}$ is completely burned in dry oxygen and the product gases are collected as shown.




The increases in mass of the collecting vessels P and Q are $M_P$ and $M_Q$, respectively.

What is the ratio $M_P / M_Q$?

**A** 0.41 **B** 0.82 **C** 1.2 **D** 2.4

**57 9701/12/O/N/18/Q31**

Zinc reacts with hydrochloric acid according to the following equation.

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Which statements are correct?

**1** A 3.27 g sample of zinc reacts with an excess of hydrochloric acid to give 0.0500 mol of zinc chloride.

**2** A 6.54 g sample of zinc reacts completely with exactly 100 $cm^3$ of 1.00 mol $dm^{-3}$ hydrochloric acid.

**3** A 13.08 g sample of zinc reacts with an excess of hydrochloric acid to give 9.60 $dm^3$ of hydrogen, measured at room conditions.

**58 9701/12/O/N/18/Q2**

Beams of charged particles are deflected by an electrical field. The angle of deflection of a particle is proportional to its charge / mass ratio.

In an experiment protons are deflected by an angle of +15°. In another experiment under identical conditions $^2H^-$ ions are deflected by an angle of Y°.

What is the value of Y?

**A** –30.0 **B** –7.5 **C** +7.5 **D** +30.0

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**59 9701/13/O/N/19/Q2**

Diamond is a pure form of carbon. The mass of a diamond can be measured in carats. One carat is 0.200 g of carbon.

Which expression gives the number of carats that contain $6.02 \times 10^{23}$ carbon atoms?

**A** $0.200 \times 12.0$

**B** $\frac{0.200}{12.0}$

**C** $\frac{12.0}{0.200}$

**D** $\frac{0.200}{6.02 \times 10^{23}} \times 12.0$

**60 9701/11/M/J/19/Q3**

A washing powder contains sodium hydrogencarbonate, $NaHCO_3$, as one of the ingredients.

In a titration, a solution containing 1.00 g of this washing powder requires 7.15 $cm^3$ of 0.100 mol $dm^{-3}$ sulfuric acid for complete reaction. The sodium hydrogencarbonate is the only ingredient that reacts with the acid.

What is the percentage by mass of sodium hydrogencarbonate in the washing powder?

**A** 3.0% **B** 6.0% **C** 12.0% **D** 24.0%

**61 9701/12/F/M/20/Q2**

For which hydrocarbon are the molecular and empirical formulae the same?

**A** butane **B** ethane **C** pent-1-ene **D** propane

**62 9701/11/M/J/20/Q11**

A sample of solid ammonium chloride decomposes on heating.

solid ammonium chloride $\rightarrow$ ammonia gas + hydrogen chloride gas

A total of $2.4 \times 10^{21}$ molecules of gas is formed.

How many hydrogen atoms are present in the gaseous products?

**A** $1.2 \times 10^{21}$ **B** $2.4 \times 10^{21}$ **C** $4.8 \times 10^{21}$ **D** $9.6 \times 10^{21}$

**63 9701/12/M/J/20/Q2**

A copper ore contains 3.00% of copper carbonate, $CuCO_3$, by mass.

Which mass of copper would be obtained from 1 tonne of the ore?

**A** 1.91 kg **B** 3.71 kg **C** 15.4 kg **D** 58.4 kg



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# Physical Chemistry

3
TOPIC

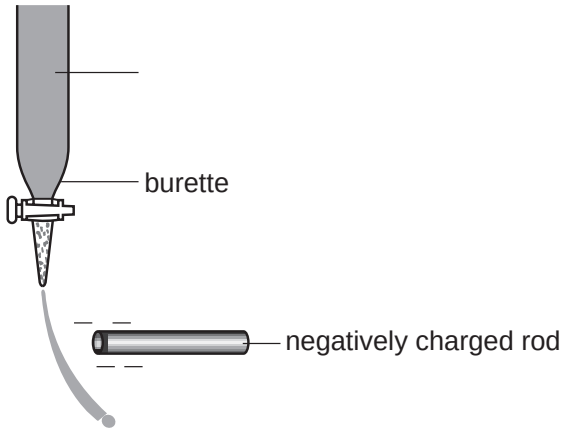
# Chemical Bonding



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**1 9701/1/M/J/02/Q4**

A slow stream of water from a tap can be deflected by an electrostatically charged plastic rod because water is a polar molecule.




Why is a water molecule polar?

**A** Molecules are bonded together by hydrogen bonds.

**B** The oxygen and hydrogen atoms have different electronegativities.

**C** The oxygen atom has two lone pairs of electrons.

**D** Water is able to dissociate into ions.

**2 9701/1/O/N/02/Q4**

The African weaver ant defends its territory by spraying an intruder with a mixture of compounds. The ease by which these compounds are detected by other ants depends upon the volatility, which decreases as the strength of the intermolecular forces in the compound increases.

Which compound would be the most volatile?

**A** $CH_3CH_2CH_2CH_2CH_2CH_3$

**B** $CH_3CH_2CH_2CH_2CH_2CHO$

**C** $CH_3CH_2CH_2CH_2CH_2NH_2$

**D** $CH_3CH_2CH_2CH_2CH_2OH$

**3 9701/1/O/N/02/Q5**

Which of the following molecules has **no** permanent dipole?

**A** $CCl_2F_2$ **B** $CHCl_3$ **C** $C_2Cl_4$ **D** $C_2H_5Cl$

**П 9701/1/O/N/02/Q23**

Chloroethene, $CH_2$=$CHCl$, is the monomer of PVC.

What are the C–C–C bond angles along the polymeric chain in PVC?

**A** They are all 109.5°.

**B** Half are 109.5° and half are 120°.

**C** They are all 120°.

**D** They are all 180°.

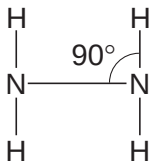


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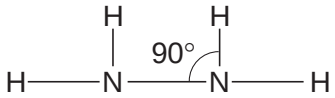
**p** **9701/1/O/N/0/Q6**

Which is the most likely shape of a molecule of hydrazine, $N_2H_4$?

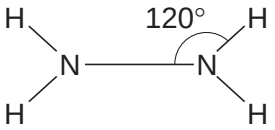
**A**



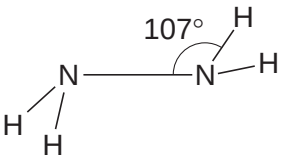

**B**




**C**




**D**




**c** **9701/1/O/N/02/Q23**

Chloroethene, $CH_2$=CHC*l*, is the monomer of pvc.

What are the C–C–C bond angles along the polymeric chain in pvc?

**A** They are all 109 °.

**B** Half are 109 ° and half are 120 °.

**C** They are all 120 °.

**D** They are all 180 °.

**T** **9701/01/M/J/04/Q5**

Which of the following particles would, on losing an electron, have a half-filled set of p orbitals?

**A** $C^-$ **B** N **C** $N^-$ **D** $O^+$

**y** **9701/01/M/J/04/Q6**

Magnesium oxide is used to line industrial furnaces because it has a very high melting point.

Which type of bond needs to be broken for magnesium oxide to melt?

**A** co-ordinate **B** covalent **C** ionic **D** metallic

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ϕ **9701/01/M/J/04/Q7**

Which solid exhibits more than one kind of chemical bonding?

**A** brass **B** copper **C** diamond **D** ice

МЛ **9701/01/M/J/04/Q20**

Which molecule is planar?

**A** $NF_3$ **B** $C_2Cl_4$ **C** $C_3H_6$ **D** $C_3H_8$

ММ **9701/01/O/N/04/Q6**

The gecko, a small lizard, can climb up a smooth glass window. The gecko has millions of microscopic hairs on its toes and each hair has thousands of pads at its tip. The result is that the molecules in the pads are extremely close to the glass surface on which the gecko is climbing.

What is the attraction between the gecko's toe pads and the glass surface?

**A** co-ordinate bonds **C** ionic bonds

**B** covalent bonds **D** van der Waals' forces

МН **9701/01/O/N/04/Q7**

What are the bond angles in the $PH_3$ molecule likely to be?

**A** 90° **B** 104° **C** 109° **D** 120°

МО **9701/01/M/J/05/Q6**

Three substances, *R*, *S*, *T*, have physical properties as shown.

| substance | mp / °C | bp / °C | electrical conductivity | |
|---|---|---|---|---|
| | | | of solid | of liquid |
| *R* | 801 | 1413 | poor | good |
| *S* | 2852 | 3600 | poor | good |
| *T* | 3550 | 4827 | good | not known |

What could be the identities of *R*, *S* and *T* ?

| | *R* | *S* | *T* |
|---|---|---|---|
| **A** | NaF | KCl | Cu |
| **B** | NaBr | BaO | $SiO_2$ |
| **C** | NaCl | MgO | C [graphite] |
| **D** | NaBr | CaO | C [diamond] |



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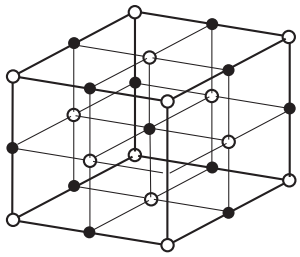
**МП 9701/01/O/N/05/Q4**

Which compound has a boiling point that is influenced by hydrogen bonding?

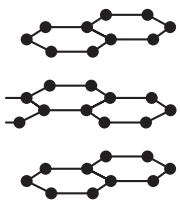
**A** $CH_3CHO$ **B** $CH_3OCH_3$ **C** $HCO_2H$ **D** $HCO_2CH_3$

**Мр 9701/01/M/J/06/Q7**

The diagram shows part of the lattice structures of solids **X** and **Y**. [In **X**, ○ and ● represent particles of different elements.]



**X**



**Y**

What are the types of bonding present in **X** and **Y**?

| | X | Y |
|---|---|---|
| **A** | covalent | metallic |
| **B** | ionic | covalent |
| **C** | ionic | metallic |
| **D** | metallic | ionic |

**МС 9701/01/O/N/06/Q7**

Magnesium oxide may be used for the lining of an electric furnace for making crockery.
Which properties of magnesium oxide help to explain this use?

| | strong forces between particles | ionic bonding | electrical conductor |
|---|---|---|---|
| **A** | yes | yes | no |
| **B** | yes | no | yes |
| **C** | no | yes | no |
| **D** | no | no | yes |

**МТ 9701/01/M/J/07/Q5**

The $CN^-$ ion is widely used in the synthesis of organic compounds.

What is the pattern of electron pairs in this ion?

| | bonding pairs of electrons | lone pairs on carbon atom | lone pairs on nitrogen atom |
|---|---|---|---|
| **A** | 2 | 1 | 1 |
| **B** | 2 | 2 | 1 |
| **C** | 3 | 1 | 1 |
| **D** | 3 | 1 | 2 |



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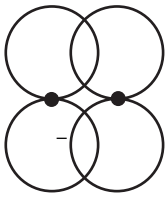
**18 9701/01/O/N/06/Q5**

Which diagram describes the formation of a π bond from the overlap of its orbitals?

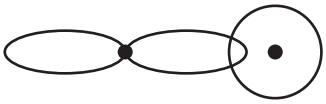
**A**



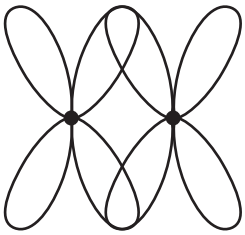
**B**



**C**

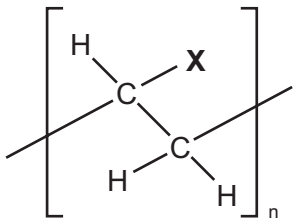


**D**



**МФ 9701/01/M/J/07/Q6**

Plastic bottles for 'fizzy drinks' are made from a polymer with the following structure.




The ability of the polymer to prevent escape of carbon dioxide through the wall of the bottle depends on the ability of the group **X** to form hydrogen bonds with the carbon dioxide in the drink.

Which group **X** best prevents loss of carbon dioxide?

**A** C*l* **B** CN **C** $CO_2CH_3$ **D** OH

**НЛ 9701/01/O/N/07/Q5**

Hydrogen bonding can occur between molecules of methanal, HCHO, and molecules of liquid **Y**.

What could liquid **Y** be?

**A** $CH_3OH$

**B** $CH_3CHO$

**C** $CH_3COCH_3$

**D** $CH_3CO_2CH_3$

**НМ 9701/01/O/N/07/Q6**

*Lycra*® is a polyurethane fibre used in the fashion industry. It is a polymer made from two monomers, one of which has the following formula.

$$O{=}C{=}N{-}(CH_2)_n{-}N{=}C{=}O$$

What is the O–C–N bond angle in this molecule?

**A** 90° **B** 109° **C** 120° **D** 180°

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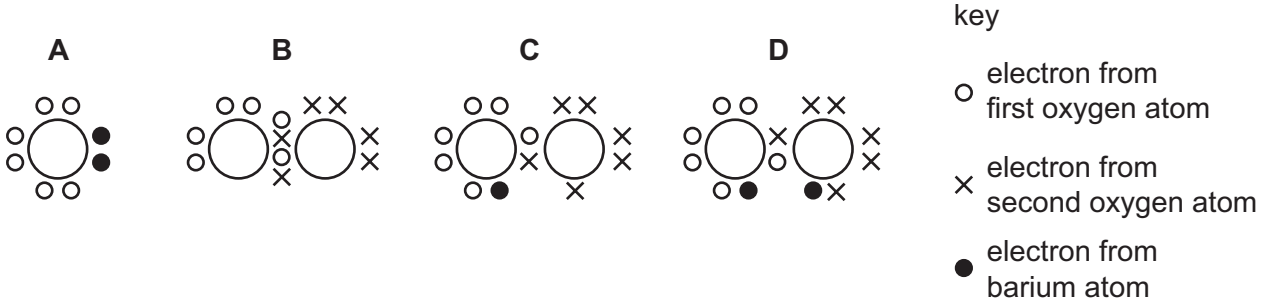


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**HH** **9701/01/M/J/08/Q4**

When barium metal burns in oxygen, the ionic compound barium peroxide, $BaO_2$, is formed.

Which dot-and-cross diagram represents the electronic structure of the peroxide anion in $BaO_2$?

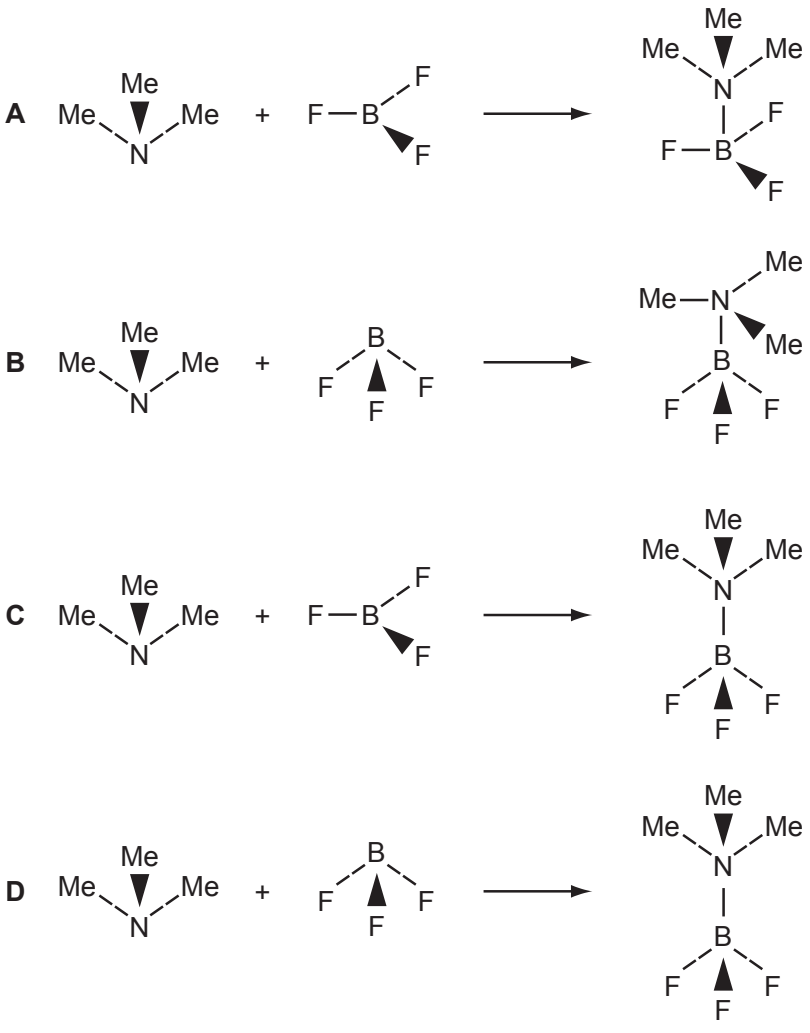



**HO** **9701/01/M/J/08/Q5**

In this question, the methyl group, $CH_3$, is represented by Me.

Trimethylamine, $Me_3N$, reacts with boron trifluoride, $BF_3$, to form a compound of formula $Me_3N.BF_3$.

How may this reaction be written in terms of the shapes of the reactants and products?






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**НП 9701/01/M/J/08/Q7**

Which pair of elements have bonds of the same type between their atoms in the solid state?

**A** aluminium and phosphorus
**B** chlorine and argon
**C** magnesium and silicon
**D** sulphur and chlorine

**НР 9701/01/M/J/09/Q5**

Which statement explains why the boiling point of methane is higher than that of neon?
[$A_r$: H, 1; C, 12; Ne, 20]

**A** A molecule of methane has a greater mass than a molecule of neon.
**B** Molecules of methane form hydrogen bonds, but those of neon do not.
**C** Molecules of methane have stronger intermolecular forces than those of neon.
**D** The molecule of methane is polar, but that of neon is not.

**НС 9701/01/M/J/09/Q7**

A crystal of iodine produces a purple vapour when gently heated.

Which pair of statements correctly describes this process?

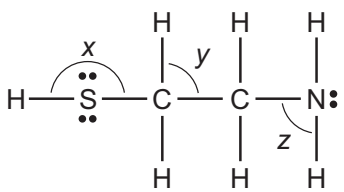
| | type of bond broken | formula of purple species |
|---|---|---|
| **A** | covalent | I |
| **B** | covalent | $I_2$ |
| **C** | induced dipole-dipole | $I_2$ |
| **D** | permanent dipole-dipole | $I_2$ |

**27 9701/12/O/N/09/Q3**

The antidote molecule shown can help to prevent liver damage if someone takes too many paracetamol tablets.

What is the order of **decreasing** size of the bond angles *x*, *y* and *z*?

| | largest ⟶ | | smallest |
|---|---|---|---|
| **A** | *x* | *y* | *z* |
| **B** | *x* | *z* | *y* |
| **C** | *y* | *z* | *x* |
| **D** | *z* | *y* | *x* |




: represents a lone pair

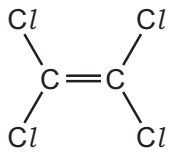


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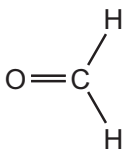
**28 9701/12/O/N/09/Q4**

Which molecule has the largest overall dipole?

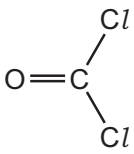
**A**



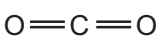
**B**



**C**



**D**



**29 9701/12/O/N/09/Q8**

$PCl_5$ dissociates as follows.

$$PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$$

The extent of dissociation is 13 % at 160 °C and 100 % at 300 °C.

Which pair of statements about this formation of $PCl_3$ is correct?

| | shape of $PCl_3$ molecule | the reaction is |
|---|---|---|
| **A** | pyramidal | endothermic |
| **B** | pyramidal | exothermic |
| **C** | trigonal | endothermic |
| **D** | trigonal | exothermic |

**30 9701/12/O/N/10/Q1**

The ability of an atom in a covalent bond to attract electrons to itself is called its electronegativity.

The greater the difference between the electronegativities of the two atoms in the bond, the more polar is the bond.

Which pair will form the most polar covalent bond between the atoms?

**A** chlorine and bromine **C** fluorine and chlorine

**B** chlorine and iodine **D** fluorine and iodine

**31 9701/12/O/N/10/Q10**

Which molecule or structure does **not** contain three atoms bonded at an angle between 109° and 110°?

**A** ethanoic acid **B** graphite **C** propane **D** silicon(IV) oxide



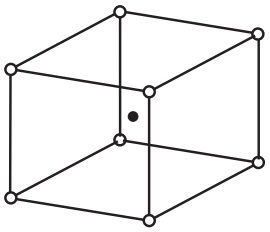
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**32** **9701/12/O/N/10/Q3**

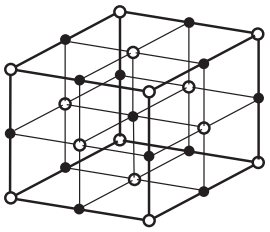
The table gives the radii, in pm, of some ions. [1 pm = $10^{-12}$ m]

| ion | radii |
|---|---|
| $Na^+$ | 102 |
| $Mg^{2+}$ | 72 |
| $Cs^+$ | 167 |
| $Cl^-$ | 181 |
| $O^{2-}$ | 140 |

Caesium chloride, CsC*l*, has a different lattice structure from both sodium chloride, NaC*l*, and magnesium oxide, MgO.



CsC*l* lattice



NaC*l* and MgO lattice

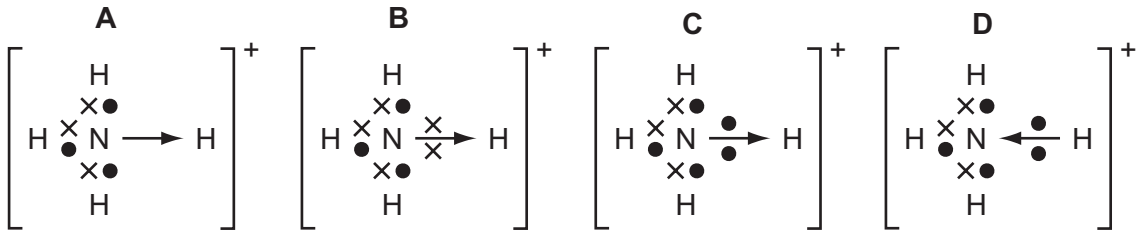
Which factor appears to determine the type of lattice for these three compounds?

**A** the charge on the cation
**B** the ratio of the ionic charges
**C** the ratio of the ionic radii
**D** the sum of the ionic charges

**33** **9701/12/M/J/11/Q2**

Which diagram correctly shows the bonding in the ammonium ion, $NH_4^+$?

key
● N electron
× H electron




**34** **9701/12/O/N/11/Q5**

The presence of dipoles helps to explain why the element $Br_2$ and the compound CHC$l_3$ exist as liquids at room temperature.

Which types of dipole are involved?

| | $Br_2$ | CHC$l_3$ |
|---|---|---|
| **A** | induced dipoles and permanent dipoles | induced dipoles and permanent dipoles |
| **B** | induced dipoles and permanent dipoles | induced dipoles only |
| **C** | induced dipoles only | induced dipoles and permanent dipoles |
| **D** | induced dipoles only | induced dipoles only |

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**35 9701/12/O/N/11/Q6**

Three compounds have the physical properties shown in the table.

| compound | P | Q | R |
|---|---|---|---|
| melting point / °C | 2852 | 993 | –119 |
| boiling point / °C | 3600 | 1695 | 39 |
| conductivity (solid) | poor | poor | poor |
| conductivity (liquid) | good | good | poor |
| conductivity (aqueous) | insoluble | good | insoluble |

What might be the identities of **P**, **Q** and **R**?

| | P | Q | R |
|---|---|---|---|
| **A** | MgO | KC$l$ | $NH_3$ |
| **B** | MgO | NaF | $C_2H_5Br$ |
| **C** | $SiO_2$ | KC$l$ | $C_2H_5Br$ |
| **D** | $SiO_2$ | NaF | HC$l$ |

**36 9701/12/O/N/12/Q3**

Sodium borohydride, $NaBH_4$, and boron trifluoride, $BF_3$, are compounds of boron.
What are the shapes around boron in the borohydride ion and in boron trifluoride?

| | borohydride ion | boron trifluoride |
|---|---|---|
| **A** | square planar | pyramidal |
| **B** | square planar | trigonal planar |
| **C** | tetrahedral | pyramidal |
| **D** | tetrahedral | trigonal planar |

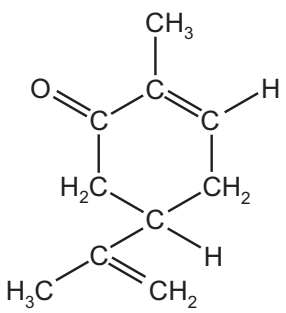
**37 9701/12/O/N/12/Q12**

In which pair do the molecules have the same shape as each other?

**A** $H_2O$ and $CO_2$ **B** $H_2O$ and SC$l_2$ **C** $NH_3$ and $BH_3$ **D** SC$l_2$ and BeC$l_2$

**38 9701/12/O/N/12/Q20**

Carvone is found in spearmint.
How many σ and π bonds are present in this molecule?



carvone

| | σ | π |
|---|---|---|
| **A** | 13 | 3 |
| **B** | 22 | 3 |
| **C** | 22 | 6 |
| **D** | 25 | 3 |

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**39 9701/12/M/J/13/Q9**

Dicarbon monoxide, $C_2O$, is found in dust clouds in space. Analysis of it shows that the sequence of atoms in this molecule is C – C – O. All bonds are double bonds and there are no unpaired electrons.

How many lone pairs of electrons are present in a molecule of $C_2O$?

**A** 1 **B** 2 **C** 3 **D** 4

**40 9701/12/O/N/13/Q30**

Which types of bond breakage and bond formation occur in the addition polymerisation of alkenes?

| | bond breakage | bond formation |
|---|---|---|
| **A** | π only | σ only |
| **B** | π only | σ and π |
| **C** | σ and π | σ only |
| **D** | σ and π | σ and π |

**41 9701/12/M/J/14/Q2**

Substances X, Y and Z are all solids. Some of their physical properties are given in the table.

| substance | X | Y | Z |
|---|---|---|---|
| melting point / °C | 772 | 114 | 1610 |
| boiling point / °C | 1407 | 183 | 2205 |
| electrical conductivity of the liquid state | conducts | does not conduct | does not conduct |

What type of lattice could each substance have?

| | X | Y | Z |
|---|---|---|---|
| **A** | giant molecular | simple molecular | ionic |
| **B** | ionic | giant molecular | simple molecular |
| **C** | ionic | simple molecular | giant molecular |
| **D** | simple molecular | ionic | giant molecular |



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**42 9701/12/O/N/14/Q5**

The table shows the physical properties of four substances.

Which substance could be hydrogen chloride?

| | melting point / °C | electrical conductivity of solid | electrical conductivity of liquid | electrical conductivity of aqueous solution |
|---|---|---|---|---|
| **A** | –119 | poor | poor | insoluble |
| **B** | –115 | poor | poor | good |
| **C** | –50 | poor | poor | poor |
| **D** | 993 | poor | good | good |

**43 9701/12/M/J/15/Q17**

Which statement about the ammonium ion, $NH_4^+$, is correct?

**A** All bond angles are 107°.

**B** Ammonium ions are formed when ammonia behaves as an acid.

**C** Ammonium ions are unreactive when heated with NaOH(aq).

**D** The bonds are all the same length.

**44 9701/11/M/J/15/Q2**

Which quantity gives the best indication of the relative strengths of the hydrogen bonds between the molecules in liquid hydrogen halides?

**A** bond dissociation energies

**B** enthalpy changes of formation

**C** enthalpy changes of solution

**D** enthalpy changes of vaporisation

**45 9701/11/M/J/15/Q10**

The double bond between the two carbon atoms in an ethene molecule consists of one σ bond and one π bond.

Which orbitals overlap to form each of these bonds?

| | σ bond | π bond |
|---|---|---|
| **A** | $sp^2$–$sp^2$ | p–p |
| **B** | $sp^2$–$sp^2$ | $sp^2$–$sp^2$ |
| **C** | $sp^3$–$sp^3$ | p–p |
| **D** | $sp^3$–$sp^3$ | $sp^2$–$sp^2$ |



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**46 9701/12/M/J/15/Q3**

Phosphorus forms a compound with hydrogen called phosphine, $PH_3$. This compound can react with a hydrogen ion, $H^+$.

Which type of interaction occurs between $PH_3$ and $H^+$?

**A** dative covalent bond
**B** dipole-dipole forces
**C** hydrogen bond
**D** ionic bond

**47 9701/12/F/M/16/Q15**

Which row of the table is correct?

| | shape | | bonds present | |
|---|---|---|---|---|
| | ammonia molecule | ammonium ion | ammonia molecule | ammonium ion |
| **A** | pyramidal | regular tetrahedral | σ | σ |
| **B** | pyramidal | regular tetrahedral | σ | π |
| **C** | regular tetrahedral | pyramidal | σ | σ |
| **D** | regular tetrahedral | pyramidal | π | σ |

**48 9701/11/M/J/16/Q2**

What is the correct number of bonds of each type in the $Al_2Cl_6$ molecule?

| | covalent | co-ordinate (dative covalent) |
|---|---|---|
| **A** | 6 | 1 |
| **B** | 6 | 2 |
| **C** | 7 | 0 |
| **D** | 7 | 1 |

**49 9701/11/M/J/1/Q5**

Dicarbon monoxide, $C_2O$, is found in dust clouds in space. The structure of this molecule is C=C=O. The molecule contains no unpaired electrons.

How many lone pairs of electrons are present in a molecule of $C_2O$?

**A** 1 **B** 2 **C** 3 **D** 4

**50 9701/11/M/J/16/Q7**

At room temperature and pressure, $H_2O$ is a liquid and $H_2S$ is a gas.

What is the reason for this difference?

**A** O has higher first and second ionisation energies than S.
**B** The covalent bond between O and H is stronger than the covalent bond between S and H.
**C** There is significant hydrogen bonding between $H_2O$ molecules but not between $H_2S$ molecules.
**D** The instantaneous dipole-induced dipole forces between $H_2O$ molecules are stronger than the instantaneous dipole-induced dipole forces between $H_2S$ molecules.

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**51 9701/12/M/J/16/Q5**

Each of the four species in this question are isolated and gaseous.

Which species is **not** planar?

**A** $BF_3$ **B** $CH_3^+$ **C** $C_2H_4$ **D** $NH_3$

**52 9701/12/F/M/16/Q6**

Which series shows molecules in order of increasing bond angle?

**A** $CH_4 \rightarrow BF_3 \rightarrow NH_3$

**B** $H_2O \rightarrow CO_2 \rightarrow BF_3$

**C** $NH_3 \rightarrow CH_4 \rightarrow CO_2$

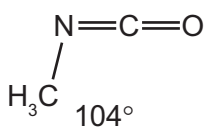
**D** $NH_3 \rightarrow CH_4 \rightarrow H_2O$

**53 9701/13/M/J/16/Q7**

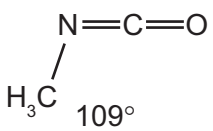
Methyl isocyanate, $CH_3NCO$, is a toxic liquid which is used in the manufacture of some pesticides.

What is the approximate angle between the bonds formed by the N atom in a molecule of methyl isocyanate?

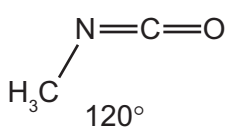
**A**



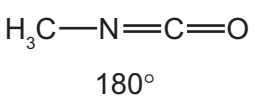

**B**




**C**




**D**




**54 9701/12/F/M/17/Q4**

The boiling points of methane, ethane, propane and butane are given.

| compound | $CH_4$ | $CH_3CH_3$ | $CH_3CH_2CH_3$ | $CH_3CH_2CH_2CH_3$ |
|---|---|---|---|---|
| boiling point / K | 112 | 185 | 231 | 273 |

Which statement explains the increase in boiling point from methane to butane?

**A** Closer packing of molecules results in stronger van der Waals' forces.

**B** More covalent bonds are present and therefore more energy is required to break the bonds.

**C** More electrons in the molecules results in stronger van der Waals' forces.

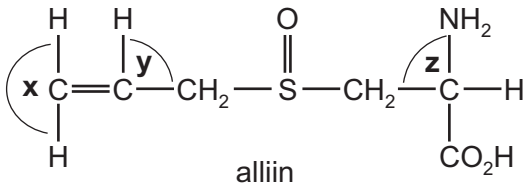
**D** More hydrogen atoms in the molecules results in stronger hydrogen bonding.

**55 9701/12/F/M/17/Q5**

The characteristic smell of garlic is due to alliin.

What are the approximate bond angles **x**, **y** and **z** in a molecule of alliin?

| | **x** | **y** | **z** |
|---|---|---|---|
| **A** | 90° | 90° | 109° |
| **B** | 120° | 109° | 90° |
| **C** | 120° | 120° | 109° |
| **D** | 180° | 109° | 109° |




alliin

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**56 9701/12/F/M/17/Q12**

The electrical conductivities of two compounds, Y and Z, are shown in the table.

| | Y | Z |
|---|---|---|
| conductivity of the compound in the liquid state | good | does not conduct |
| conductivity of the mixture obtained by adding the compound to water | good | good |

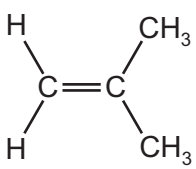
What could compounds Y and Z be?

| | Y | Z |
|---|---|---|
| **A** | $Al_2O_3$ | $SiCl_4$ |
| **B** | NaF | $Al_2O_3$ |
| **C** | NaF | $SiCl_4$ |
| **D** | $SiCl_4$ | $Al_2O_3$ |

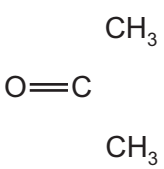
**57 9701/11/M/J/17/Q5**

Which molecule has the largest overall dipole?

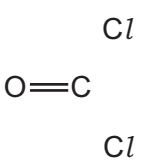
**A**



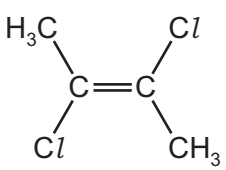
**B**



**C**



**D**



**58 9701/12/M/J/17/Q4**

Which organic compound has the highest boiling point?

**A** $C(CH_3)_4$

**B** $CH_3CH_2CH_2CH_2CH_3$

**C** $CH_3COCH_2CH_3$

**D** $CH_3CH(OH)CH_2CH_3$

**59 9701/13/M/J/17/Q4**

Two conversions are shown.

$$NH_4^+ \rightarrow NH_3$$

$$C_2H_4 \rightarrow C_2H_6$$

Which similar feature do these two conversions have?

**A** change in oxidation state of an element

**B** decrease in bond angle

**C** formation of a lone pair of electrons

**D** loss of a $\pi$ bond

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**60** **9701/11/O/N/18/Q2**

What is a basic assumption of the kinetic theory, as applied to an ideal gas?

**A** Collisions between gas molecules are elastic.

**B** Each gas molecule occupies a finite volume.

**C** Gases consist of particles that experience the force of gravity.

**D** Gas molecules attract each other with weak intermolecular forces.

**61** **9701/12/O/N/18/Q4**

In which set do all the molecules have all their atoms arranged in one plane?

**A** $AlCl_3$, $BF_3$, $PH_3$

**B** $AlCl_3$, $CO_2$, $NH_3$

**C** $BF_3$, $C_2H_4$, $C_3H_6$

**D** $C_2H_4$, $CO_2$, $H_2O$

**62** **9701/12/F/M/19/Q4**

The eight species that follow all have covalent bonds.

In which pair do the species have different shapes from each other?

**A** $BeCl_2$ and $CO_2$

**B** $CH_4$ and $NH_4^+$

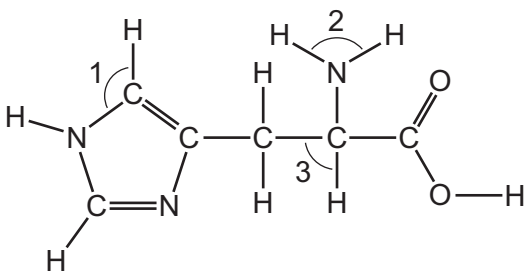
**C** $NH_3$ and $BF_3$

**D** $SCl_2$ and $H_2O$

**63** **9701/12/F/M/10/Q5**

Histidine is an amino acid.

histidine




What are the approximate bond angles 1, 2, and 3?

| | 1 | 2 | 3 |
|---|---|---|---|
| **A** | 109.5 | 107 | 90 |
| **B** | 120 | 107 | 109.5 |
| **C** | 120 | 120 | 90 |
| **D** | 120 | 120 | 109.5 |



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**64** **9701/11/M/J/19/Q5**

In which species is there a lone pair of electrons?

**A** $CH_3$ **B** $CH_3^+$ **C** $CH_3^-$ **D** $CH_4$

**65** **9701/12/M/J/19/Q4**

A σ bond is made between two carbon atoms in a molecule of ethene.

Which diagram shows the orbital overlap that occurs to form this bond?

**A** **B** **C** **D**



**66** **9701/12/M/J/19/Q5**

The table shows some properties of four substances.

Which substance could be potassium iodide?

| | melting point of solid / °C | electrical conductivity when molten |
|---|---|---|
| **A** | –66 | poor |
| **B** | –39 | good |
| **C** | 680 | good |
| **D** | 1600 | poor |

**67** **9701/11/O/N/19/Q3**

Which molecule or ion contains the smallest bond angle?

**A** $C_2H_4$ **B** $CH_3COCH_3$ **C** $NH_4^+$ **D** $NH_3$

**68** **9701/11/O/N/19/Q4**

Four compounds are shown.

$C_2H_4$ $C_2H_5OH$ $CH_3CHO$ $CH_3CO_2H$

How many of these compounds have an odd number of σ bonds?

**A** 1 **B** 2 **C** 3 **D** 4



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**69 9701/11/O/N/19/Q5**

Ethanal, $CH_3CHO$, ethanol, $C_2H_5OH$, and methoxymethane, $CH_3OCH_3$, are three organic compounds.

Which compound has the highest boiling point and what is the interaction that causes this boiling point to be the highest?

| | highest boiling point | interaction |
|---|---|---|
| **A** | methoxymethane | permanent dipole-dipole forces |
| **B** | ethanal | hydrogen bonds |
| **C** | ethanol | hydrogen bonds |
| **D** | ethanal | permanent dipole-dipole forces |

**70 9701/12/F/M/20/Q3**

Which molecule does **not** have any 90° or 180° bond angles?

**A** $C_2H_6$ **B** $CO_2$ **C** $PF_5$ **D** $SF_6$

**71 9701/12/F/M/20/Q8**

A stable ion $N_{5+}$ has been produced by research chemists.

Which structure is most likely to show the electron arrangement of this ion?

**A**



**B**



**C**



**D**





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**72 9701/11/M/J/20/Q3**

When considering one molecule of ethene, which row describes both the hybridisation of the atomic orbitals in the carbon atoms and the overall bonding?

| | hybridisation | bonding |
|---|---|---|
| **A** | $sp^2$ | 4 $\sigma$ bonds 1 $\pi$ bond |
| **B** | $sp^2$ | 5 $\sigma$ bonds 1 $\pi$ bond |
| **C** | $sp^3$ | 4 $\sigma$ bonds 1 $\pi$ bond |
| **D** | $sp^3$ | 5 $\sigma$ bonds 1 $\pi$ bond |

**73 9701/13/M/J/20/Q2**

Which molecule contains six bonding electrons?

**A** $NCl_3$ **B** $H_2S$ **C** $C_2H_4$ **D** $SF_6$

**74 9701/13/M/J/20/Q3**

Solid carbon dioxide, $CO_2$, is similar to solid iodine, $I_2$, in its structure.

Which statement about solid $CO_2$ and solid $SiO_2$ is correct?

**A** Both solid $CO_2$ and solid $SiO_2$ exist in a lattice structure.

**B** Both solid $CO_2$ and solid $SiO_2$ have a simple molecular structure.

**C** Both solid $CO_2$ and solid $SiO_2$ have atoms joined by single covalent bonds.

**D** Both solid $CO_2$ and solid $SiO_2$ change spontaneously to gas at s.t.p..

**75 9701/13/M/J/20/Q9**

At 200 °C aluminium chloride is a gas with $M_r$ = 267.

What is the number of covalent bonds, dative covalent bonds and lone pairs of electrons in one molecule of aluminium chloride at 200 °C?

| | covalent bonds | dative covalent bonds | lone pairs |
|---|---|---|---|
| **A** | 6 | 2 | 0 |
| **B** | 6 | 2 | 16 |
| **C** | 6 | 2 | 18 |
| **D** | 3 | 0 | 9 |

STUDENTS RESOURCE



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# Physical Chemistry

4
TOPIC

# States of Matter



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**1 9701/1/M/J/02/Q7**

When heated, solid iodine readily forms iodine vapour.

What does this information suggest about the nature of the particles in these two physical states of iodine?

| | *Solid* | *Vapour* |
|---|---|---|
| | | |
| **B** | Ionic | Molecular |
| **C** | Molecular | Atomic |
| **D** | Molecular | Molecular |

**2 9701/1/M/J/02/Q5**

Why does copper wire conduct electricity when a potential difference is applied?

**A** Bonding electrons in the crystal lattice move.

**B** Copper(II) ions move to the cathode.

**C** The atoms of copper become ionised.

**D** The crystal lattice breaks down.

**3 9701/1/M/J/02/Q6**

Flask X contains 1 $dm^3$ of helium at 2 kPa pressure and flask Y contains 2 $dm^3$ of neon at 1 kPa pressure.

If the flasks are connected at constant temperature, what is the final pressure?

**A** $1\frac{1}{3}$ kPa **B** $1\frac{1}{2}$ kPa **C** $1\frac{2}{3}$ kPa **D** 2 kPa

**4 9701/1/O/N/02/Q7**

Which of the following exists in the solid state as a giant covalent lattice?

**A** ice

**B** iodine

**C** silicon(IV) oxide

**D** tin(IV) chloride

**5 9701/1/O/N/02/Q8**

A 2 g sample of hydrogen at temperature *T* and of volume *V* exerts a pressure *p*.
Deuterium, $^{2}_{1}H$, is an isotope of hydrogen.

Which of the following would also exert a pressure *p* at the same temperature *T*?

**A** 2 g of deuterium of volume *V*

**B** 4 g of deuterium of volume $\frac{V}{2}$

**C** a mixture of 1 g of hydrogen and 2 g of deuterium of total volume *V*

**D** a mixture of 2 g of hydrogen and 1 g of deuterium of total volume 2 *V*



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**6 9701/1/M/J/03/Q5**

Which of the following solids has a simple molecular lattice?

**A** magnesium oxide

**B** sodium

**C** silicon(IV) oxide

**D** sulphur

**7 9701/1/M/J/03/Q6**

Measured values of the pressure, volume and temperature of a known mass of a gaseous compound are to be substituted into the equation

$$pV = nRT$$

in order to calculate the relative molecular mass, $M_r$, of the compound.

Which conditions of pressure and temperature would give the most accurate value of $M_r$?

| | pressure | temperature |
|---|---|---|
| **A** | high | high |
| **B** | high | low |
| **C** | low | high |
| **D** | low | low |

**8 9701/1/O/N/03/Q8**

A substance commonly found in the house or garden has the following properties.

- It is combustible.
- It is an electrical insulator.
- It melts over a range of temperature.

What could the substance be?

**A** brass

**B** paper

**C** poly(ethene)

**D** silicon(IV) oxide



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**9 9701/01/O/N/04/Q8**

*Use of the Data Booklet is relevant to this question.*

Which expression gives the pressure exerted by $1.6 \times 10^{-3}$ mol of $N_2$ in a container of volume $3.0\,dm^3$ at 273 °C?

**A** $\frac{1.6 \times 10^{-3} \times 8.31 \times 273}{3.0 \times 10^{-6}}$ Pa

**B** $\frac{1.6 \times 10^{-3} \times 8.31 \times (273 + 273)}{3.0 \times 10^{-6}}$ Pa

**C** $\frac{1.6 \times 10^{-3} \times 8.31 \times 273}{3.0 \times 10^{-3}}$ Pa

**D** $\frac{1.6 \times 10^{-3} \times 8.31 \times (273 + 273)}{3.0 \times 10^{-3}}$ Pa

**10 9701/01/O/N/05/Q5**

Which gas is likely to deviate most from ideal gas behaviour?

**A** $HCl$ **B** He **C** $CH_4$ **D** $N_2$

**11 9701/01/M/J/06/Q6**

Which of the following least resembles an ideal gas?

**A** ammonia **B** helium **C** hydrogen **D** trichloromethane

**12 9701/01/O/N/07/Q7**

What are the lattice structures of solid diamond, iodine and silicon(IV) oxide?

| | giant molecular | simple molecular |
|---|---|---|
| **A** | diamond, silicon(IV) oxide | iodine |
| **B** | diamond, iodine | silicon(IV) oxide |
| **C** | iodine | diamond, silicon(IV) oxide |
| **D** | silicon(IV) oxide | diamond, iodine |

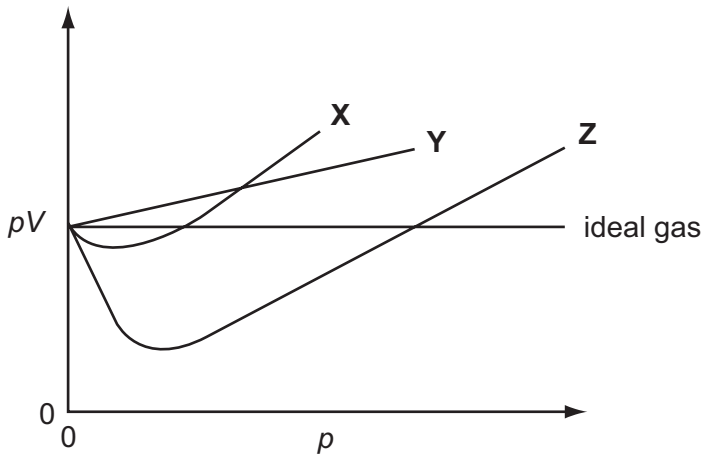


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**13 9701/01/O/N/06/Q6**

For an ideal gas, the plot of $pV$ against $p$ is a straight line. For a real gas, such a plot shows a deviation from ideal behaviour. The plots of $pV$ against $p$ for three real gases are shown below.

The gases represented are ammonia, hydrogen and nitrogen.




What are the identities of the gases **X**, **Y** and **Z**?

| | X | Y | Z |
|---|---|---|---|
| **A** | ammonia | nitrogen | hydrogen |
| **B** | hydrogen | nitrogen | ammonia |
| **C** | nitrogen | ammonia | hydrogen |
| **D** | nitrogen | hydrogen | ammonia |

**14 9701/01/M/J/08/Q6**

The density of ice is 1.00 g $cm^{-3}$.

What is the volume of steam produced when 1.00 $cm^3$ of ice is heated to 323 °C (596 K) at a pressure of one atmosphere (101 kPa)?

[1 mol of a gas occupies 24.0 $dm^3$ at 25 °C (298 K) and one atmosphere.]

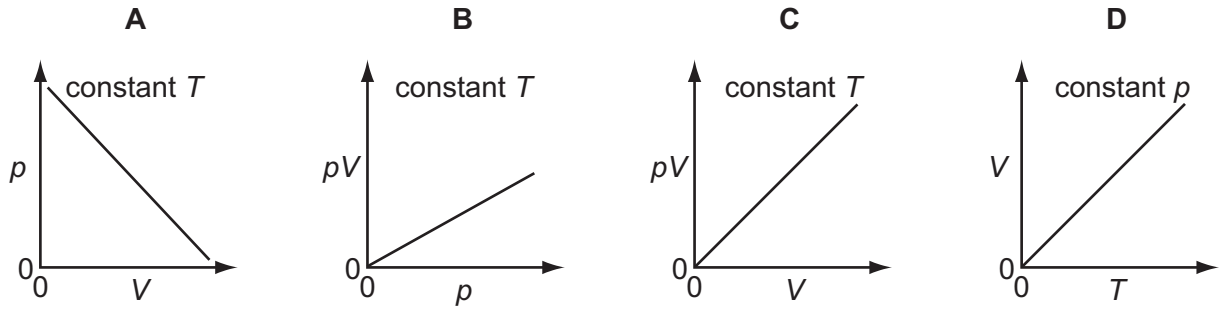
**A** 0.267 $dm^3$ **B** 1.33 $dm^3$ **C** 2.67 $dm^3$ **D** 48.0 $dm^3$



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**15 9701/01/M/J/08/Q8**

Which diagram correctly describes the behaviour of a fixed mass of an ideal gas? (*T* is measured in K.)




**16 9701/01/O/N/08/Q7**

Which of the following would behave most like an ideal gas at room temperature?

**A** carbon dioxide **B** helium **C** hydrogen **D** nitrogen

**17 9701/12/O/N/10/Q7**

Flask X contains 5 $dm^3$ of helium at 12 kPa pressure and flask Y contains 10 $dm^3$ of neon at 6 kPa pressure.

If the flasks are connected at constant temperature, what is the final pressure?

**A** 8 kPa **B** 9 kPa **C** 10 kPa **D** 11 kPa

**18 9701/12/O/N/11/Q4**

*Use of the Data Booklet is relevant to this question.*

560 kg of nitrogen and 120 kg of hydrogen are pressurised, heated and passed over an iron catalyst. When the mixture of gases reaches equilibrium, it contains 96 kg of hydrogen.

Which mass of ammonia does it contain?

**A** 24 kg **B** 68 kg **C** 136 kg **D** 680 kg

**19 9701/12/O/N/12/Q17**

*Use of the Data Booklet is relevant to this question.*

1.15 g of a metallic element reacts with 300 $cm^3$ of oxygen at 298 K and 1 atm pressure, to form an oxide which contains $O^{2-}$ ions.

What could be the identity of the metal?

**A** calcium **B** magnesium **C** potassium **D** sodium



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**20 9701/12/M/J/12/Q6**

*Use of the Data Booklet is relevant to this question.*

The gas laws can be summarised in the ideal gas equation.

$$pV = nRT$$

0.96 g of oxygen gas is contained in a glass vessel of volume 7000 $cm^3$ at a temperature of 30 °C.

What is the pressure in the vessel?

**A** 1.1 kPa **B** 2.1 kPa **C** 10.8 kPa **D** 21.6 kPa

**21 9701/12/O/N/12/Q6**

The volume of a sample of ammonia is measured at a temperature of 60 °C and a pressure of 103 kPa. The volume measured is $5.37 \times 10^{-3}$ $m^3$.

What is the mass of the sample of ammonia, given to two significant figures?

**A** 0.00019 g **B** 0.0034 g **C** 0.19 g **D** 3.4 g

**22 9701/12/O/N/12/Q8**

Some car paints contain small flakes of silica, $SiO_2$.

In the structure of solid $SiO_2$

- each silicon atom is bonded to **x** oxygen atoms,
- each oxygen atom is bonded to **y** silicon atoms,
- each bond is a **z** type bond.

What is the correct combination of **x**, **y** and **z** in this statement?

| | x | y | z |
|---|---|---|---|
| **A** | 2 | 1 | covalent |
| **B** | 2 | 1 | ionic |
| **C** | 4 | 2 | covalent |
| **D** | 4 | 2 | ionic |

**23 9701/12/O/N/12/Q9**

John Dalton's atomic theory, published in 1808, contained four predictions about atoms.

Which of his predictions is still considered to be correct?

**A** All atoms are very small in size.

**B** All the atoms of a particular element have the same mass.

**C** All the atoms of one element are different in mass from all the atoms of other elements.

**D** No atom can be split into simpler parts.



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**24 9701/12/M/J/13/Q7**

Ethanol has a boiling point of 78 °C. At 101 kPa and 79 °C ethanol vapour does not perfectly obey the gas equation $pV = nRT$.

What is the reason for this?

**A** Ethanol vapour is in equilibrium with ethanol liquid at 79 °C.

**B** There are intermolecular forces between the molecules of ethanol vapour.

**C** The vapourisation of ethanol liquid is an endothermic process.

**D** Vapours will not obey the gas equation perfectly at such a low pressure.

**25 9701/12/O/N/13/Q8**

*Use of the Data Booklet is relevant to this question.*

The approximate percentage composition of the atmosphere on four different planets is given in the table below.

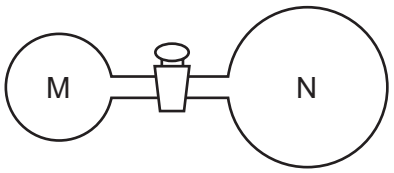
The density of a gas may be defined as the mass of 1 $dm^3$ of the gas measured at s.t.p.

Which mixture of gases has the greatest density?

| | planet | major gases / % by number of molecules |
|---|---|---|
| **A** | Jupiter | $H_2$ 89.8, He 10.2 |
| **B** | Neptune | $H_2$ 80.0, He 19.0, $CH_4$ 1.0 |
| **C** | Saturn | $H_2$ 96.3, He 3.25, $CH_4$ 0.45 |
| **D** | Uranus | $H_2$ 82.5, He 15.2, $CH_4$ 2.3 |

**26 9701/12/O/N/14/Q4**

Two glass vessels M and N are connected by a closed valve.




M contains helium at 20 °C at a pressure of $1 \times 10^5$ Pa. N has been evacuated, and has three times the volume of M. In an experiment, the valve is opened and the temperature of the whole apparatus is raised to 100 °C.

What is the final pressure in the system?

**A** $3.18 \times 10^4$ Pa **B** $4.24 \times 10^4$ Pa **C** $1.25 \times 10^5$ Pa **D** $5.09 \times 10^5$ Pa



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**27** **9701/12/M/J/15/Q4**

Which solid has a simple molecular lattice?

**A** calcium fluoride **B** nickel **C** silicon(IV) oxide **D** sulfur

**28** **9701/12/M/J/15/Q4**

Which solid has a simple molecular lattice?

**A** calcium fluoride **B** nickel **C** silicon(IV) oxide **D** sulfur

**29** **9701/12/M/J/15/Q5**

*Use of the Data Booklet is relevant to this question.*

The gas laws can be summarised in the ideal gas equation below.

$$pV = nRT$$

The volume of a sample of methane is measured at a temperature of 60 °C and a pressure of 103 kPa. The volume measured is $5.37 \times 10^{-3}$ m$^3$.

Assume the gas behaves as an ideal gas.

What is the mass of the sample of methane, given to two significant figures?

**A** 0.00018 g **B** 0.0032 g **C** 0.18 g **D** 3.2 g

**30** **9701/12/F/M/16/Q7**

What is the volume of steam produced when 1.00 g of ice is heated to 323 °C at a pressure of 101 kPa?

**A** 0.27 dm$^3$ **B** 1.3 dm$^3$ **C** 2.7 dm$^3$ **D** 48 dm$^3$

**31** **9701/12/F/M/16/Q8**

Solid carbon dioxide, $CO_2$, is similar to solid iodine, $I_2$, in its structure and properties. Carbon is in Group 14. Silica, $SiO_2$, is a Group 14 compound.

Which statement about solid $CO_2$ and solid $SiO_2$ is correct?

**A** Both solids exist in a lattice structure.

**B** Both solids have a simple molecular structure.

**C** Both solids have atoms joined by single covalent bonds.

**D** Both solids change spontaneously to gas at s.t.p.

**32** **9701/12/F/M/16/Q9**

An article in a science magazine contains the following statement.

'It is lighter than a feather, stronger than steel, yet incredibly flexible and more conductive than copper.'

Which form of carbon is being described?

**A** buckminsterfullerene **B** diamond **C** graphene **D** graphite

STUDENTS RESOURCE



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**33 9701/12/M/J/16/Q6**

Argon is a gas used to fill electric light bulbs.

Under which conditions of pressure and temperature will argon behave most like an ideal gas?

| | pressure | temperature |
|---|---|---|
| **A** | high | high |
| **B** | high | low |
| **C** | low | high |
| **D** | low | low |

**34 9701/12/M/J/16/Q7**

0.10 g of the volatile liquid X formed 0.025 $dm^3$ of vapour at 100 °C and atmospheric pressure.

1 mol of vapour occupies 22.4 $dm^3$ at 0 °C and atmospheric pressure.

What is the relative molecular mass of X?

**A** $\frac{0.025 \times 273 \times 22.4}{0.10 \times 373}$

**B** $\frac{0.025 \times 373 \times 22.4}{0.10 \times 273}$

**C** $\frac{0.10 \times 273 \times 22.4}{0.025 \times 373}$

**D** $\frac{0.10 \times 373 \times 22.4}{0.025 \times 273}$

**35 9701/13/M/J/17/Q5**

All gases listed are at the same pressure.

Which gas will most closely approach ideal behaviour?

**A** ammonia at 100 K

**B** ammonia at 500 K

**C** neon at 100 K

**D** neon at 500 K

**36 9701/11/O/N/18/Q5**

In this question you should assume methane behaves as an ideal gas.

The gas laws can be summarised in the ideal gas equation below.

$$pV = nRT$$

The volume of a sample of methane is measured at a temperature of 60 °C and a pressure of 103 kPa. The volume measured is $5.37 \times 10^{-3}$ $m^3$.

What is the mass of the sample of methane, given to two significant figures?

**A** 0.0032 g **B** 0.018 g **C** 3.2 g **D** 18 g

**37 9701/12/O/N/18/Q5**

Flask X contains 5 $dm^3$ of helium at 12 kPa pressure and flask Y contains 10 $dm^3$ of neon at 6 kPa pressure.

If the flasks are connected at constant temperature, what is the final pressure?

**A** 8 kPa **B** 9 kPa **C** 10 kPa **D** 11 kPa



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**38 9701/12/F/M/19/Q6**

A sample of gas occupies 240 $cm^3$ at 37 °C and 100 kPa.

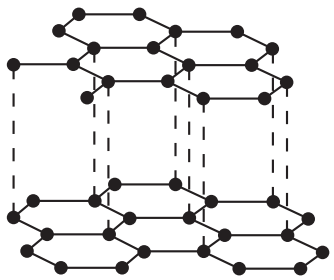
How many moles of gas are present in the sample?

**A** $9.32 \times 10^{-6}$ **B** $9.32 \times 10^{-3}$ **C** 0.0781 **D** 78.1

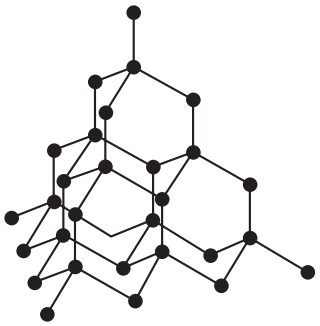
**39 9701/12/F/M/19/Q7**

P, Q and R represent three different structures of an element.

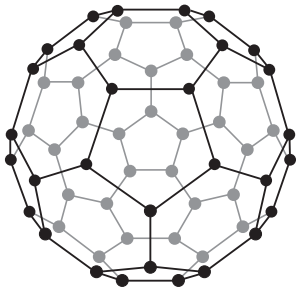
P



Q



R



Which structures are giant molecular?

**A** P, Q and R **C** P and R only

**B** P and Q only **D** Q and R only

**40 9701/11/M/J/19/Q6**

When an evacuated tube of volume 400 $cm^3$ is filled with gas at 300 K and 101 kPa, the mass of the tube increases by 0.65 g.

Assume the gas behaves as an ideal gas.

What could be the identity of the gas?

**A** argon **B** helium **C** krypton **D** neon

**41 9701/11/M/J/19/Q7**

Under which conditions will nitrogen behave most like an ideal gas?

| | temperature | pressure |
|---|---|---|
| **A** | low | high |
| **B** | high | low |
| **C** | low | low |
| **D** | high | high |



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**42 9701/12/M/J/19/Q6**

X, Y and Z are all gases that behave ideally and react according to the equation shown.

$$X(g) + 2Y(g) \rightarrow 2Z(g)$$

When 3.0 mol of X and 3.0 mol of Y are placed inside a container with a volume of 1.0 $dm^3$, they react to form the maximum amount of Z.

The final temperature of the reaction vessel is 120 °C.

What is the final pressure inside the reaction vessel?

**A** $4.49 \times 10^6$ Pa **C** $1.47 \times 10^7$ Pa

**B** $9.80 \times 10^6$ Pa **D** $1.96 \times 10^7$ Pa

**43 9701/12/M/J/19/Q7**

Which pair of substances are both simple molecular?

**A** $C_{60}$ and graphene **C** graphene and graphite

**B** $C_{60}$ and iodine **D** graphite and iodine

**44 9701/12/O/N/19/Q5**

In this question you should assume the vapour behaves as an ideal gas.

0.175 g of a volatile liquid produces a vapour of volume $4.50 \times 10^{-5}$ $m^3$ at 100 °C and pressure of $1.013 \times 10^5$ Pa.

What is the $M_r$ of the liquid?

**A** 31.9 **B** 87.1 **C** 119 **D** 127

**45 9701/12/F/M/20/Q9**

1.8 g of water, heated to 227 °C in a sealed container, turns to steam with a pressure of 200 kPa.

What is the approximate volume of the container?

**A** $9 \times 10^{-4}$ $m^3$ **B** $2 \times 10^{-3}$ $m^3$ **C** 2 $m^3$ **D** $8 \times 10^7$ $m^3$

**46 9701/11/M/J/20/Q4**

10 $cm^3$ of ethane is burned in 45 $cm^3$ of oxygen at a pressure of 101 kPa and a temperature of 200 °C. Complete combustion takes place.

What is the total volume of gas present when the reaction is complete, measured under the same conditions?

**A** 30 $cm^3$ **B** 50 $cm^3$ **C** 55 $cm^3$ **D** 60 $cm^3$



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**47 9701/11/M/J/20/Q9**

A sample of argon gas has a mass of 0.20 g, at a pressure of 100 000 Pa and a temperature of 12 °C.

Which volume does the gas occupy?

**A** $1.2 \times 10^{-4}\,cm^3$ **B** $5.0\,cm^3$ **C** $59\,cm^3$ **D** $119\,cm^3$

**48 9701/12/M/J/20/Q1**

In which carbon allotrope are all electrons localised?

**A** buckminsterfullerene **B** diamond **C** graphite **D** graphene

**49 9701/12/M/J/20/Q9**

The complete combustion of 2 moles of an alkane produces 400 $dm^3$ of carbon dioxide measured at 301 K and $1 \times 10^5$ Pa. Carbon dioxide can be assumed to behave as an ideal gas under these conditions.

What is the formula of the alkane?

**A** $C_8H_{18}$ **B** $C_{16}H_{34}$ **C** $C_{20}H_{42}$ **D** $C_{40}H_{82}$



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Physical Chemistry

5
TOPIC

# Chemical Energetics

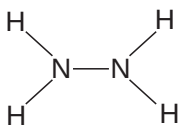


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**1 9701/1/M/J/02/Q9**

*Use of the Data Booklet is relevant to this question.*

Hydrazine was used as a fuel for the Messerschmidt 163 rocket fighter in World War II and for the American Gemini and Apollo spacecraft. It has the following formula.




What is the enthalpy change of atomisation of 1 mol of gaseous hydrazine?

**A** 550 kJ

**B** 1720 kJ

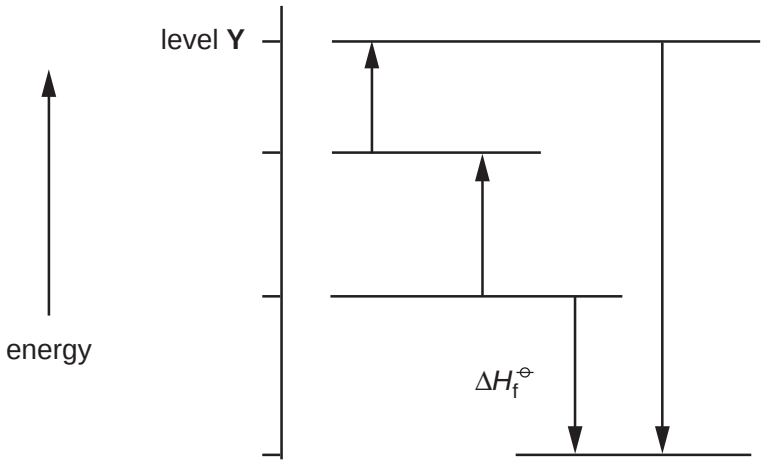
**C** 1970 kJ

**D** 2554 kJ

**2 9701/1/O/N/02/Q9**

The following energy cycle represents the enthalpy changes in the formation of carbon dioxide from its constituent elements in their standard states.

What substances are present at level **Y** in this diagram?




**A** C(g) + 2O(g)

**B** C(g) + $O_2$(g)

**C** C(s) + $O_2$(g)

**D** $CO_2$(g)

**3 9701/1/O/N/02/Q17**

The standard enthalpy changes of formation of HC*l* and HI are –92 kJ mol$^{-1}$ and +26 kJ mol$^{-1}$ respectively.

Which statement is **most** important in explaining this difference?

**A** Chlorine is more electronegative than iodine.

**B** The activation energy for the $H_2$/$Cl_2$ reaction is much less than that for the $H_2$/$I_2$ reaction.

**C** The bond energy of HI is smaller than the bond energy of HC*l*.

**D** The bond energy of $I_2$ is smaller than the bond energy of $Cl_2$.

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**4 9701/1/M/J/02/Q8**

Which statement about the standard enthalpy change of formation of carbon dioxide is correct?

**A** It is equal to the standard enthalpy change of combustion of carbon.

**B** It is equal to twice the bond energy of the C=O bond.

**C** It is the energy released when one mole of carbon dioxide is formed from carbon at the temperature of combustion of the carbon.

**D** It is the same for carbon dioxide produced from graphite and from diamond.

**5 9701/1/O/N/02/Q17**

The standard enthalpy changes of formation of HC*l* and HI are –92 kJ mol$^{-1}$ and +26 kJ mol$^{-1}$ respectively.

Which statement is **most** important in explaining this difference?

**A** Chlorine is more electronegative than iodine.

**B** The activation energy for the $H_2 + Cl_2$ reaction is much less than that for the $H_2 + I_2$ reaction.

**C** The bond energy of HI is smaller than the bond energy of HC*l*.

**D** The bond energy of $I_2$ is smaller than the bond energy of $Cl_2$.

**6 9701/1/M/J/03/7**

Gaseous phosphorus pentachloride can be decomposed into gaseous phosphorus trichloride and chlorine by heating. The table below gives the bond energies.

| bond | bond energy / kJ mol$^{-1}$ |
|---|---|
| P-C*l* (in both chlorides) | 330 |
| C*l*-C*l* | 240 |

What is the enthalpy change in the decomposition of $PCl_5$ to $PCl_3$ and $Cl_2$?

**A** –420 kJ mol$^{-1}$ **B** –90 kJ mol$^{-1}$ **C** +90 kJ mol$^{-1}$ **D** +420 kJ mol$^{-1}$

**7 9701/01/M/J/04/Q8**

The standard enthalpy changes of formation of iron( ) oxide, FeO(s), and aluminium oxide, $Al_2O_3$(s), are –266 kJ mol$^{-1}$ and –1676 kJ mol$^{-1}$ respectively.

What is the enthalpy change under standard conditions for the following reaction?

$$3FeO(s) + 2Al(s) \rightarrow 3Fe(s) + Al_2O_3(s)$$

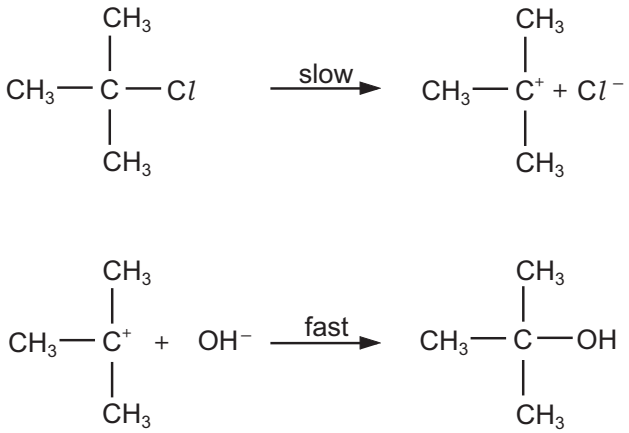
**A** +878 kJ **B** –878 kJ **C** –1942 kJ **D** –2474 kJ



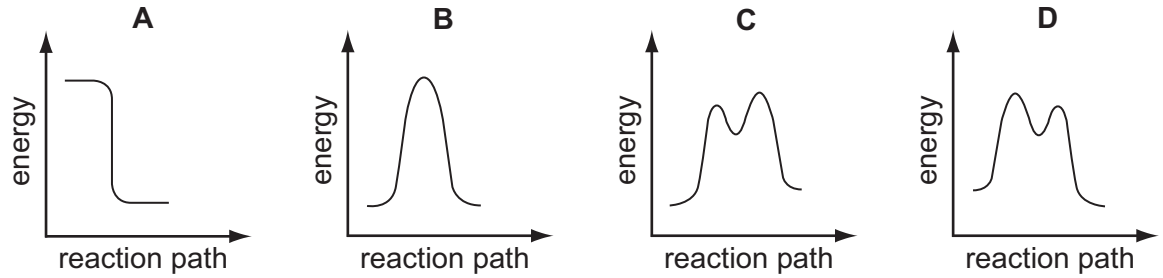
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**8 9701/01/M/J/04/Q26**

A possible mechanism of the hydrolysis of 2-chloro-2-methylpropane is shown.




Which diagram represents the reaction profile for this mechanism?




**9 9701/01/M/J/05/Q7**

Iodine trichloride, $ICl_3$, is made by reacting iodine with chlorine.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(s) \;\; ; \;\; \Delta H^{\ominus} = +14\,kJ\,mol^{-1}$$

$$ICl(s) + Cl_2(g) \rightarrow ICl_3(s) \;\; ; \;\; \Delta H^{\ominus} = -88\,kJ\,mol^{-1}$$

By using the data above, what is the enthalpy change of the formation for solid iodine trichloride?

**A** $-60\,kJ\,mol^{-1}$ **B** $-74\,kJ\,mol^{-1}$ **C** $-81\,kJ\,mol^{-1}$ **D** $-162\,kJ\,mol^{-1}$

**10 9701/01/O/N/05/Q6**

Given $S(s) + O_2(g) \rightarrow SO_2(g)$, $\Delta H_f^{\ominus} = -297\,kJ\,mol^{-1}$

and $S(s) + 1\frac{1}{2}O_2(g) \rightarrow SO_3(g)$ $\Delta H_f^{\ominus} = -395\,kJ\,mol^{-1}$

what is the enthalpy change of reaction, $\Delta H^{\ominus}$, of $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$?

**A** $-196\,kJ\,mol^{-1}$ **B** $-98\,kJ\,mol^{-1}$ **C** $+98\,kJ\,mol^{-1}$ **D** $+196\,kJ\,mol^{-1}$

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**11 9701/01/O/N/05/Q7**

The table shows the enthalpy change of neutralisation per mole of water formed, $\Delta H$, for various acids and bases.

| acid | base | $\Delta H$ / kJ mol$^{-1}$ |
|---|---|---|
| hydrochloric acid | sodium hydroxide | –57.0 |
| **P** | sodium hydroxide | –54.0 |
| hydrochloric acid | **Q** | –52.0 |
| nitric acid | **R** | –57.0 |

What are **P**, **Q** and **R**?

| | P | Q | R |
|---|---|---|---|
| **A** | ethanoic acid | ammonia | potassium hydroxide |
| **B** | ethanoic acid | sodium hydroxide | ammonia |
| **C** | sulphuric acid | ammonia | potassium hydroxide |
| **D** | sulphuric acid | sodium hydroxide | ammonia |

**12 9701/01/M/J/06/Q5**

In which process are hydrogen bonds broken?

**A** $H_2(l) \rightarrow H_2(g)$ **B** $NH_3(l) \rightarrow NH_3(g)$

**C** $2HI(g) \rightarrow H_2(g) + I_2(g)$ **D** $CH_4(g) \rightarrow C(g) + 4H(g)$

**13 9701/01/O/N/06/Q8**

For which equation is the enthalpy change correctly described as an enthalpy change of formation?

**A** $2NO(g) \rightarrow N_2(g) + O_2(g)$ **C** $H_2O(l) + NaCl(s) \rightarrow NaCl(aq)$

**B** $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ **D** $K(s) + Mn(s) + 2O_2(g) \rightarrow KMnO_4(s)$

**14 9701/01/O/N/06/Q9**

Given $CO(g) + \frac{1}{2} O_2(g) \rightarrow CO_2(g)$ $\Delta H^{\ominus} = -283$ kJ mol$^{-1}$

$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$ $\Delta H^{\ominus} = -286$ kJ mol$^{-1}$

$H_2O(g) \rightarrow H_2O(l)$ $\Delta H^{\ominus} = -44$ kJ mol$^{-1}$

what is the change in enthalpy, $\Delta H^{\ominus}$, for the following reaction?

$$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$$

**A** –525 kJ mol$^{-1}$ **B** –41 kJ mol$^{-1}$ **C** +41 kJ mol$^{-1}$ **D** +525 kJ mol$^{-1}$



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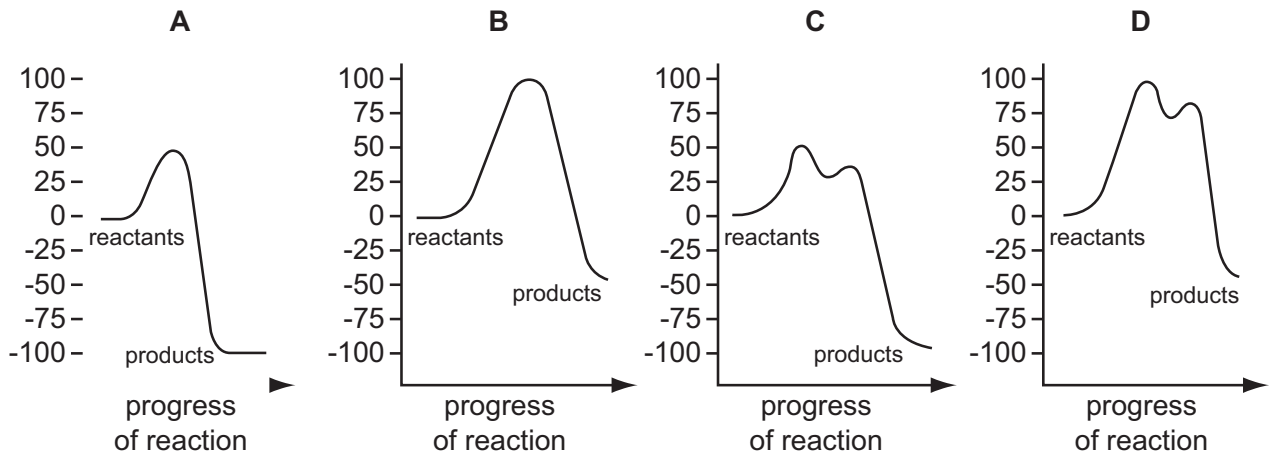
**15 9701/01/M/J/07/Q7**

An exothermic chemical reaction proceeds by two stages.

$$\text{reactants} \xrightarrow{\text{stage 1}} \text{intermediate} \xrightarrow{\text{stage 2}} \text{products}$$

The activation energy of stage 1 is 50 kJ mol$^{-1}$. The overall enthalpy change of reaction is –100 kJ mol$^{-1}$.

Which diagram represents the reaction pathway for this reaction?




**16 9701/01/M/J/07/Q8**

Skiers trapped by snowstorms use heat packs to keep warm. The heat may be generated by the reaction below.

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s) \quad ; \quad \Delta H^{\ominus} = -1648\ kJ$$

What is the standard enthalpy change of formation of iron(III) oxide?

**A** 0 kJ mol$^{-1}$ **B** –824 kJ mol$^{-1}$ **C** –1648 kJ mol$^{-1}$ **D** –3296 kJ mol$^{-1}$

**17 9701/01/O/N/07/Q8**

Which equation represents the standard enthalpy change of atomisation of bromine?

**A** $Br_2(l) \rightarrow 2Br(g)$ **B** $Br_2(g) \rightarrow 2Br(g)$ **C** $\frac{1}{2}Br_2(l) \rightarrow Br(g)$ **D** $\frac{1}{2}Br_2(g) \rightarrow Br(g)$

**18 9701/01/M/J/08/Q9**

For which equation does the enthalpy change correspond to the enthalpy change of atomisation of iodine?

**A** $\frac{1}{2}I_2(s) \rightarrow I(s)$

**B** $\frac{1}{2}I_2(s) \rightarrow I(g)$

**C** $I_2(g) \rightarrow 2I(g)$

**D** $I_2(s) \rightarrow 2I(g)$

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**19 9701/01/M/J/08/Q10**

Titanium occurs naturally as the mineral rutile, $TiO_2$. One possible method of extraction of titanium is to reduce the rutile by heating with carbon.

$$TiO_2(s) + 2C(s) \rightarrow Ti(s) + 2CO(g)$$

The standard enthalpy changes of formation of $TiO_2(s)$ and $CO(g)$ are –940 kJ $mol^{-1}$ and $-110\,kJ\,mol^{-1}$ respectively.

What is the standard enthalpy change of this reaction?

**A** $-830\,kJ\,mol^{-1}$ **C** $+720\,kJ\,mol^{-1}$

**B** $-720\,kJ\,mol^{-1}$ **D** $+830\,kJ\,mol^{-1}$

**20 9701/01/O/N/08/Q5**

Which quantity would best indicate the relative strengths of the hydrogen bonds between the molecules in liquid hydrogen halides?

**A** bond dissociation energies **B** enthalpy changes of solution

**C** enthalpy changes of formation **D** enthalpy changes of vaporisation

**21 9701/01/O/N/08/Q8**

Red lead oxide, $Pb_3O_4$, is used in metal priming paints. It can be made by heating PbO in air.

$$6PbO(s) + O_2(g) \rightarrow 2Pb_3O_4(s)$$

Which two values are needed to calculate the enthalpy change for this reaction?

**A** enthalpy change of combustion of lead and enthalpy change of formation of $Pb_3O_4$

**B** enthalpy change of combustion of PbO and enthalpy change of formation of $Pb_3O_4$

**C** enthalpy change of formation of PbO and enthalpy change of atomisation of $O_2$

**D** enthalpy change of formation of PbO and enthalpy change of formation of $Pb_3O_4$

**22 9701/12/O/N/10/Q4**

Methanol may be prepared by the reaction between carbon monoxide and hydrogen.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

The relevant average bond energies are given below.

$E(C\equiv O)$ $1077\,kJ\,mol^{-1}$ $E(C-H)$ $410\,kJ\,mol^{-1}$

$E(C-O)$ $360\,kJ\,mol^{-1}$ $E(H-H)$ $436\,kJ\,mol^{-1}$ $E(O-H)$ $460\,kJ\,mol^{-1}$

What is the enthalpy change of this reaction?

**A** $-537\,kJ\,mol^{-1}$ **B** $-101\,kJ\,mol^{-1}$ **C** $+101\,kJ\,mol^{-1}$ **D** $+537\,kJ\,mol^{-1}$

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**23 9701/12/M/J/10/Q4**

Some bond energy values are listed below.

| bond | bond energy / kJ mol$^{-1}$ |
|---|---|
| C–H | 410 |
| C–C*l* | 340 |
| C*l*–C*l* | 244 |
| Br–Br | 193 |

These bond energy values relate to the following four reactions.

P $Br_2 \rightarrow 2Br$ Q $2Cl \rightarrow Cl_2$ R $CH_3 + Cl \rightarrow CH_3Cl$ S $CH_4 \rightarrow CH_3 + H$

What is the order of enthalpy changes of these reactions from most negative to most positive?

**A** P → Q → R → S **B** Q → R → S → P **C** R → Q → P → S **D** S → P → Q → R

**24 9701/12/M/J/10/Q5**

Given the following enthalpy changes,

$$I_2(g) + 3Cl_2(g) \rightarrow 2ICl_3(s) \qquad \Delta H^{\ominus} = -214\ \text{kJ mol}^{-1}$$

$$I_2(s) \rightarrow I_2(g) \qquad \Delta H^{\ominus} = +38\ \text{kJ mol}^{-1}$$

What is the standard enthalpy change of formation of iodine trichloride, $ICl_3(s)$?

**A** +176 kJ mol$^{-1}$ **B** –88 kJ mol$^{-1}$ **C** –176 kJ mol$^{-1}$ **D** –214 kJ mol$^{-1}$

**25 9701/12/O/N/10/Q4**

Methanol may be prepared by the reaction between carbon monoxide and hydrogen.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

The relevant average bond energies are given below.

$E$(C≡O) 1077 kJ mol$^{-1}$
$E$(C–O) 360 kJ mol$^{-1}$
$E$(C–H) 410 kJ mol$^{-1}$
$E$(H–H) 436 kJ mol$^{-1}$
$E$(O–H) 460 kJ mol$^{-1}$

What is the enthalpy change of this reaction?

**A** –537 kJ mol$^{-1}$ **B** –101 kJ mol$^{-1}$ **C** +101 kJ mol$^{-1}$ **D** +537 kJ mol$^{-1}$

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**26 9701/12/O/N/10/Q8**

*Use of the Data Booklet is relevant to this question.*

The enthalpy change of formation, $\Delta H_f$, of hydrated calcium ions is the enthalpy change of the following reaction.

$$Ca(s) + aq - 2e^- \rightarrow Ca^{2+}(aq)$$

The following enthalpy changes are **not** quoted in the *Data Booklet*.

$$Ca(s) \rightarrow Ca(g) \qquad \Delta H_a = 177\,kJ\,mol^{-1}$$

$$Ca^{2+}(g) + aq \rightarrow Ca^{2+}(aq) \qquad \Delta H_{hyd} = -1565\,kJ\,mol^{-1}$$

What is the enthalpy change of formation of hydrated calcium ions?

**A** $-1388\,kJ\,mol^{-1}$ **B** $-798\,kJ\,mol^{-1}$ **C** $-238\,kJ\,mol^{-1}$ **D** $+352\,kJ\,mol^{-1}$

**27 9701/12/M/J/11/Q7**

Titanium occurs naturally as the mineral rutile, $TiO_2$. One possible method of extraction of titanium is to reduce the rutile by heating with carbon.

$$TiO_2(s) + 2C(s) \rightarrow Ti(s) + 2CO(g)$$

The standard enthalpy changes of formation of $TiO_2(s)$ and $CO(g)$ are –940 kJ $mol^{-1}$ and $-110\,kJ\,mol^{-1}$ respectively.

What is the standard enthalpy change of this reaction?

**A** $-830\,kJ\,mol^{-1}$ **B** $-720\,kJ\,mol^{-1}$ **C** $+720\,kJ\,mol^{-1}$ **D** $+830\,kJ\,mol^{-1}$

**28 9701/13/M/J/Q11**

Which reaction has an enthalpy change equal to the standard enthalpy change of formation of propane?

**A** $3C(g) + 4H_2(g) \rightarrow C_3H_8(g)$ **C** $3C(s) + 4H_2(g) \rightarrow C_3H_8(g)$

**B** $3C(g) + 8H(g) \rightarrow C_3H_8(g)$ **D** $3C(s) + 4H_2(g) \rightarrow C_3H_8(l)$

**29 9701/12/M/J/11/Q9**

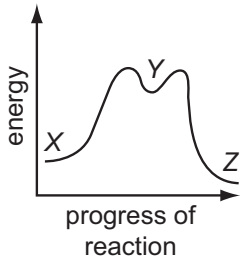
In the conversion of compound *X* into compound *Z*, it was found that the reaction proceeded by way of compound *Y*, which could be isolated. The following steps were involved.

$X \rightarrow Y$ ; $\Delta H$, positive

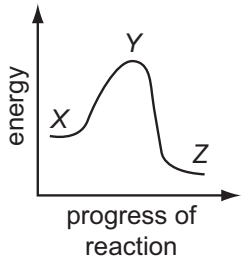
$Y \rightarrow Z$ ; $\Delta H$, negative

Which reaction profile fits these data?

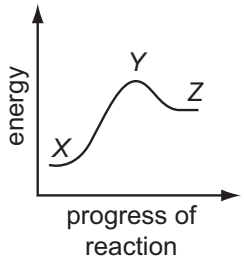
**A**



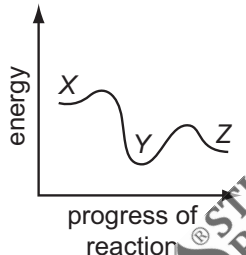

**B**




**C**




**D**




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**30 9701/12/O/N/11/Q10**

Hess's Law can be used to calculate the average C-H bond energy in methane.

$\Delta H^{\ominus}_{at}$ = standard enthalpy change of atomisation
$\Delta H^{\ominus}_{f}$ = standard enthalpy change of formation
$\Delta H^{-}_{c}$ = standard enthalpy change of combustion

Which data values are needed in order to perform the calculation?

**A** $\Delta H^{\ominus}_{at}$ (C), $\Delta H^{\ominus}_{at}$ (H), $\Delta H^{\ominus}_{f}$ ($CH_4$)

**B** $\Delta H^{\ominus}_{c}$ (C), $\Delta H^{\ominus}_{c}$ ($H_2$), $\Delta H^{\ominus}_{c}$ ($CH_4$)

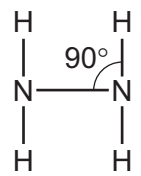
**C** $\Delta H^{\ominus}_{c}$ (C), $\Delta H^{\ominus}_{c}$ ($H_2$), $\Delta H^{\ominus}_{f}$ ($CH_4$)

**D** $\Delta H^{\ominus}_{f}$ ($CH_4$) only, as $\Delta H^{\ominus}_{f}$ (C), and $\Delta H^{\ominus}_{f}$ ($H_2$), are defined as zero

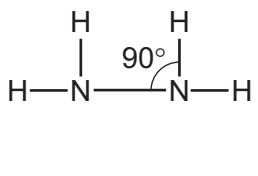
**31 9701/12/M/J/12/Q3**

What is the **most** likely shape of a molecule of hydrazine, $N_2H_4$?

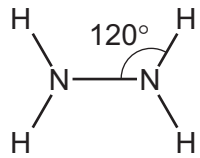
**A**



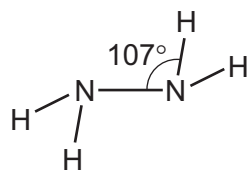

**B**




**C**




**D**




**32 9701/12/M/J/12/Q4**

In which species does the underlined atom have an incomplete outer shell?

**A** $\underline{Al}_2Cl_6$ **B** $\underline{C}H_3^+$ **C** $Cl_2\underline{O}$ **D** $H_2\underline{Cl}C\bullet$

**33 9701/12/M/J/12/Q14**

Slaked lime, $Ca(OH)_2$, may be made from limestone, $CaCO_3$.

On heating in a lime kiln at 1000 °C, limestone decomposes as follows.

reaction 1 $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Water is then reacted with calcium oxide, CaO, as follows.

reaction 2 $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

What are the enthalpy changes of these reactions?

| | reaction 1 | reaction 2 |
|---|---|---|
| **A** | endothermic | endothermic |
| **B** | endothermic | exothermic |
| **C** | exothermic | endothermic |
| **D** | exothermic | exothermic |



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**34 9701/12/M/J/12/Q5**

Which solid contains more than one kind of bonding?

**A** iodine **B** silicon dioxide **C** sodium chloride **D** zinc

**35 9701/12/M/J/12/Q8**

The value of the third ionisation energy of aluminium is 2740 kJ mol$^{-1}$.

Which correctly represents this statement?

**A** $Al(g) \rightarrow Al^{3+}(g) + 3e^-$ $\Delta H^{\ominus} = -2740\,kJ\,mol^{-1}$

**B** $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$ $\Delta H^{\ominus} = -2740\,kJ\,mol^{-1}$

**C** $Al(g) \rightarrow Al^{3+}(g) + 3e^-$ $\Delta H^{\ominus} = +2740\,kJ\,mol^{-1}$

**D** $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$ $\Delta H^{\ominus} = +2740\,kJ\,mol^{-1}$

**36 9701/12/M/J/12/Q12**

Red lead oxide, $Pb_3O_4$, is used in metal priming paints. It can be made by heating PbO in air.

$$6PbO(s) + O_2(g) \rightarrow 2Pb_3O_4(s)$$

Which two values are needed to calculate the enthalpy change for this reaction?

**A** enthalpy change of atomisation of $O_2$ and enthalpy change of formation of $Pb_3O_4$

**B** enthalpy change of formation of $O_2$ and enthalpy change of formation of $Pb_3O_4$

**C** enthalpy change of formation of PbO and enthalpy change of atomisation of $O_2$

**D** enthalpy change of formation of PbO and enthalpy change of formation of $Pb_3O_4$

**37 9701/12/O/N/12/Q4**

*Use of the Data Booklet is relevant to this question.*

A reaction which causes the presence of oxides of nitrogen in car exhausts is the formation of NO.

$$N_2 + O_2 \rightarrow 2NO \qquad \Delta H = +180\,kJ\,mol^{-1}$$

What is the bond energy in kJ mol$^{-1}$ of the bond between the atoms in NO?

**A** 655 **B** 835 **C** 1310 **D** 1670



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**38 9701/12/O/N/12/Q5**

In the table below,

- '+' means that this type of standard enthalpy change can **only** have positive values,
- '–' means that this type of standard enthalpy change can **only** have negative values,
- '+/–' means that **either** positive **or** negative values are possible.

Which row is correct?

| | atomisation | formation | solution |
|---|---|---|---|
| **A** | + | + | +/– |
| **B** | + | +/– | +/– |
| **C** | – | +/– | – |
| **D** | – | – | + |

**39 9701/12/O/N/12/Q10**

A student calculated the standard enthalpy change of formation of ethane, $C_2H_6$, using a method based on standard enthalpy changes of combustion.

He used correct values for the standard enthalpy change of combustion of ethane ($-1560\ kJ\ mol^{-1}$) and hydrogen ($-286\ kJ\ mol^{-1}$) but he used an incorrect value for the standard enthalpy change of combustion of carbon. He then performed his calculation correctly. His final answer was $-158\ kJ\ mol^{-1}$.

What did he use for the standard enthalpy change of combustion of carbon?

**A** $-1432\ kJ\ mol^{-1}$ **B** $-860\ kJ\ mol^{-1}$ **C** $-430\ kJ\ mol^{-1}$ **D** $-272\ kJ\ mol^{-1}$

**40 9701/12/O/N/12/Q11**

Which process could be used to calculate the bond energy for the covalent bond X-Y by dividing its $\Delta H$ by n?

**A** $XY_n(g) \rightarrow X(g) + nY(g)$

**B** $2XY_n(g) \rightarrow 2XY_{n-1}(g) + Y_2(g)$

**C** $Y(g) + XY_{n-1}(g) \rightarrow XY_n(g)$

**D** $nXY(g) \rightarrow nX(g) + \frac{n}{2}Y_2(g)$

**41 9701/12/M/J/13/Q2**

Equations involving four enthalpy changes are shown.

$Na(g) \rightarrow Na^+(g) + e^-$ $\Delta H = W$

$Na(g) \rightarrow Na^{2+}(g) + 2e^-$ $\Delta H = X$

$Na(s) \rightarrow Na(g)$ $\Delta H = Y$

$Na(s) \rightarrow Na^{2+}(g) + 2e^-$ $\Delta H = Z$

What is the second ionisation energy of sodium?

**A** X **B** X – W **C** Y – W **D** Z – Y



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**42 9701/12/M/J/13/Q11**

Which energy change corresponds to the enthalpy change of atomisation of hydrogen at 298 K?

**A** the bond energy of a H – H bond
**B** half the bond energy of a H – H bond
**C** minus half the bond energy of a H – H bond
**D** minus the bond energy of a H – H bond

**43 9701/12/M/J/13/Q10**

*Use of the Data Booklet is relevant to this question.*

A student mixed 25 $cm^3$ of 0.10 mol $dm^{-3}$ sodium hydroxide solution with 25 $cm^3$ of 0.10 mol $dm^{-3}$ hydrochloric acid and noted a temperature rise of 2.5 °C.

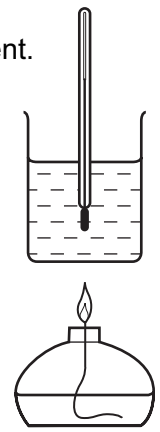
What is the enthalpy change of the reaction per mole of NaOH?

**A** –209 kJ $mol^{-1}$ **B** –104.5 kJ $mol^{-1}$ **C** –209 J $mol^{-1}$ **D** –522.5 J $mol^{-1}$

**44 9701/12/O/N/13/Q11**

A student carried out an experiment to determine the enthalpy change for the combustion of methanol.

The following results were obtained by the student.



| | |
|---|---|
| start temperature of the water | 20 °C |
| final temperature of the water | 53 °C |
| mass of alcohol burner before burning | 259.65 g |
| mass of alcohol burner after burning | 259.15 g |
| mass of glass beaker plus water | 150.00 g |
| mass of glass beaker | 50.00 g |

How much of the heat energy produced by the burning of methanol went into the water?

**A** 209 J **B** 13 794 J **C** 20 691 J **D** 22 154 J

**45 9701/12/M/J/14/Q3**

The enthalpy change of formation of carbon dioxide is –394 kJ $mol^{-1}$.

The enthalpy change of formation of water is –286 kJ $mol^{-1}$.

The enthalpy change of formation of methane is –74 kJ $mol^{-1}$.

What is the enthalpy change of combustion of methane?

**A** –892 kJ $mol^{-1}$ **B** –606 kJ $mol^{-1}$ **C** +606 kJ $mol^{-1}$ **D** +892 kJ $mol^{-1}$

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**46 9701/12/M/J/14/Q8**

Which equation represents the standard enthalpy change of formation of ethanol, $C_2H_5OH$?

**A** $2C(g) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$

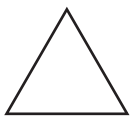
**B** $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$

**C** $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(g)$

**D** $2C(g) + 6H(g) + O(g) \rightarrow C_2H_5OH(l)$

**47 9701/12/M/J/14/Q11**

The diagram shows the skeletal formula of cyclopropane.



The enthalpy change of formation of cyclopropane is +53.3 kJ mol$^{-1}$ and the enthalpy change of atomisation of graphite is +717 kJ mol$^{-1}$.

The bond enthalpy of H – H is 436 kJ mol$^{-1}$ and of C – H is 410 kJ mol$^{-1}$.

What value for the average bond enthalpy of the C – C bond in cyclopropane can be calculated from this data?

**A** 187 kJ mol$^{-1}$ **B** 315 kJ mol$^{-1}$ **C** 351 kJ mol$^{-1}$ **D** 946 kJ mol$^{-1}$

**48 9701/12/O/N/14/Q3**

Ethanol is increasingly being used as a fuel for cars.

The standard enthalpy change of formation of carbon dioxide is –393 kJ mol$^{-1}$.
The standard enthalpy change of formation of water is –286 kJ mol$^{-1}$.
The standard enthalpy change of formation of ethanol is –277 kJ mol$^{-1}$.

What is the standard enthalpy change of combustion of ethanol?

**A** –1921 kJ mol$^{-1}$

**B** –1367 kJ mol$^{-1}$

**C** –956 kJ mol$^{-1}$

**D** –402 kJ mol$^{-1}$

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**49 9701/12/O/N/14/Q7**

In an experiment to calculate the enthalpy change of combustion of a fuel, 1.5 g (0.0326 mol) of the fuel was used to heat 200 g of water. The temperature of the water rose from 25 °C to 55 °C. The specific heat capacity of water is $4.18\,J\,g^{-1}\,K^{-1}$.

There is significant heat loss in this experiment. Therefore, the experimental value for the enthalpy change of combustion, $\Delta H_c$, of the fuel will be different from the theoretical value.

Using the information above, what is the experimental value for the enthalpy change of combustion, $\Delta H_c$, of the fuel?

**A** $-1410\,kJ\,mol^{-1}$ **C** $-30.7\,kJ\,mol^{-1}$

**B** $-769\,kJ\,mol^{-1}$ **D** $-16.7\,kJ\,mol^{-1}$

**50 9701/12/O/N/14/Q11**

For which equation is the enthalpy change correctly described as an enthalpy change of formation?

**A** $C(g) + O_2(g) \rightarrow CO_2(g)$ **C** $2N(g) + 4O(g) \rightarrow N_2O_4(g)$

**B** $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ **D** $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

**51 9701/13/O/N/14/Q4**

Impure copper is purified by electrolysis. The electrolyte used in this process is aqueous copper(II) sulfate.

Which reaction takes place at the anode?

**A** $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ **C** $2OH^-(aq) \rightarrow \frac{1}{2}O_2(g) + H_2O(l) + 2e^-$

**B** $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ **D** $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

**52 9701/11/M/J/15/Q7**

The standard enthalpy changes of combustion of glucose and ethanol are given as –2820 and $-1368\,kJ\,mol^{-1}$ respectively.

Glucose, $C_6H_{12}O_6$, can be converted into ethanol.

$$C_6H_{12}O_6(s) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$$

What is the standard enthalpy change for this reaction?

**A** $-1452\,kJ\,mol^{-1}$ **B** $-84\,kJ\,mol^{-1}$ **C** $+84\,kJ\,mol^{-1}$ **D** $+1452\,kJ\,mol^{-1}$



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**53 9701/11/M/J/15/Q7**

The standard enthalpy changes of combustion of glucose and ethanol are given as –2820 and –1368 kJ mol$^{-1}$ respectively.

Glucose, $C_6H_{12}O_6$, can be converted into ethanol.

$$C_6H_{12}O_6(s) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$$

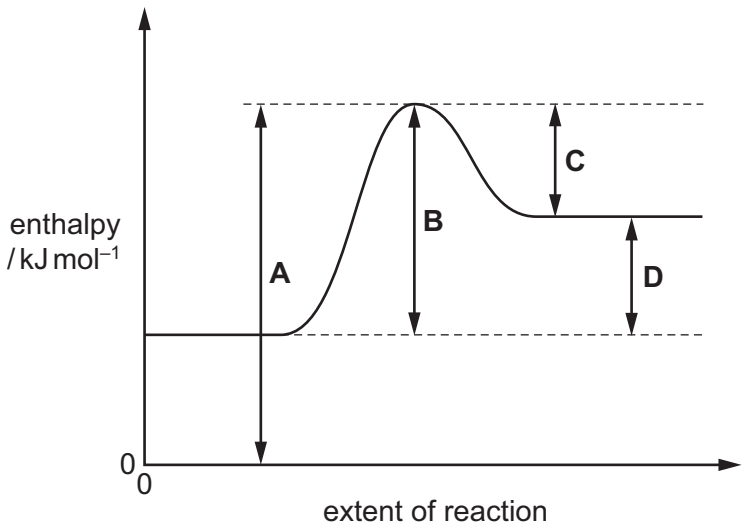
What is the standard enthalpy change for this reaction?

**A** –1452 kJ mol$^{-1}$ **B** –84 kJ mol$^{-1}$ **C** +84 kJ mol$^{-1}$ **D** +1452 kJ mol$^{-1}$

**54 9701/11/M/J/15/Q11**

The diagram shows a reaction pathway for an endothermic reaction.

Which arrow represents the activation energy for the forward reaction?




**55 9701/12/M/J/15/Q6**

Metaldehyde, $(CH_3CHO)_4$, is used as a solid fuel for camping stoves. The equation for the complete combustion of metaldehyde is shown.

$$(CH_3CHO)_4(s) + 10\,O_2(g) \rightarrow 8CO_2(g) + 8H_2O(l)$$

$\Delta H_c^{\ominus}$ = standard enthalpy change of combustion.

Which expression will give a correct value for the enthalpy change of formation of metaldehyde?

**A** $\Delta H_c^{\ominus}$metaldehyde – ($8\Delta H_c^{\ominus}$carbon + $8\Delta H_c^{\ominus}$hydrogen)

**B** $\Delta H_c^{\ominus}$metaldehyde – ($8\Delta H_c^{\ominus}$carbon + $16\Delta H_c^{\ominus}$hydrogen)

**C** ($8\Delta H_c^{\ominus}$carbon + $8\Delta H_c^{\ominus}$hydrogen) – $\Delta H_c^{\ominus}$metaldehyde

**D** ($8\Delta H_c^{\ominus}$carbon + $16\Delta H_c^{\ominus}$hydrogen) – $\Delta H_c^{\ominus}$metaldehyde



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**56 9701/11/M/J/15/Q7**

The standard enthalpy changes of combustion of glucose and ethanol are given as –2820 and –1368 kJ mol$^{-1}$ respectively.

Glucose, $C_6H_{12}O_6$, can be converted into ethanol.

$$C_6H_{12}O_6(s) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$$

What is the standard enthalpy change for this reaction?

**A** –1452 kJ mol$^{-1}$ **B** –84 kJ mol$^{-1}$ **C** +84 kJ mol$^{-1}$ **D** +1452 kJ mol$^{-1}$

**57 9701/13/M/J/16/Q1**

Enthalpy changes, $\Delta H$, can be positive or negative.

Which row is correct?

| | $\Delta H$ positive | $\Delta H$ negative |
|---|---|---|
| **A** | atomisation | bond breaking |
| **B** | bond breaking | neutralisation |
| **C** | bond making | combustion |
| **D** | combustion | bond making |

**58 9701/12/F/M/16/Q5**

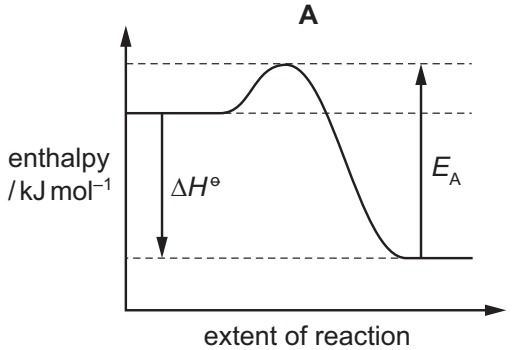
Nitric oxide, NO, and bromine vapour react together according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H^{\ominus} = -23 \text{ kJ mol}^{-1}$$

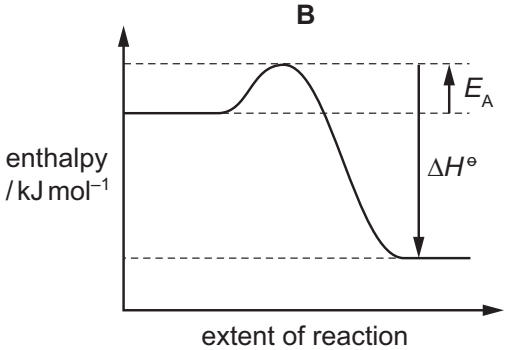
The reaction has an activation energy of +5.4 kJ mol$^{-1}$.

What is the correct reaction pathway diagram for this reaction?

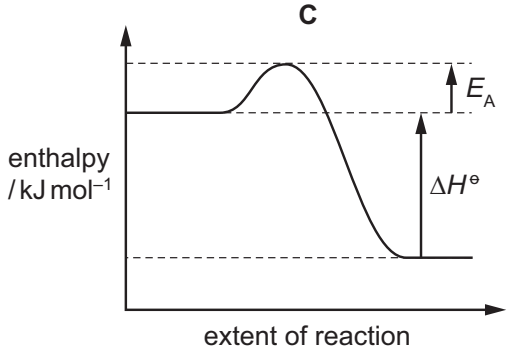
**A**



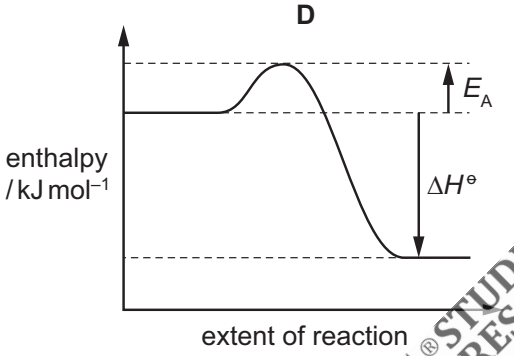

**B**




**C**




**D**




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**59 9701/12/F/M/16/Q10**

Which equation has an enthalpy change of reaction which corresponds to the standard enthalpy change of atomisation of chlorine?

**A** $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$ **B** $\frac{1}{2}Cl_2(l) \rightarrow Cl(g)$ **C** $Cl_2(g) \rightarrow 2Cl(g)$ **D** $Cl_2(l) \rightarrow 2Cl(g)$

**9701/11/M/J/16/Q8**

Gaseous phosphorus pentachloride can be decomposed into gaseous phosphorus trichloride and chlorine by heating. The table gives the bond energies.

| bond | bond energy / kJ mol$^{-1}$ |
|---|---|
| P–C$l$ (in both chlorides) | 330 |
| C$l$–C$l$ | 242 |

What is the enthalpy change for the decomposition of $PCl_5$ to $PCl_3$ and $Cl_2$?

**A** –418 kJ mol$^{-1}$ **C** +88 kJ mol$^{-1}$

**B** –88 kJ mol$^{-1}$ **D** +418 kJ mol$^{-1}$

**60 9701/12/M/J/16/Q8**

The equation for the complete combustion of propan-1-ol is shown.

$$CH_3CH_2CH_2OH(l) + 4\tfrac{1}{2}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

Standard enthalpy changes of formation are given.

| compound | $CH_3CH_2CH_2OH(l)$ | $CO_2(g)$ | $H_2O(l)$ |
|---|---|---|---|
| $\Delta H_f^{\ominus}$ | –303 kJ mol$^{-1}$ | –394 kJ mol$^{-1}$ | –286 kJ mol$^{-1}$ |

What is the standard enthalpy change of combustion of propan-1-ol, in kJ mol$^{-1}$?

**A** –394 – 286 – 303 **C** 394 + 286 – 303

**B** 303 – (4 × 286) – (3 × 394) **D** (3 × 394) + (4 × 286) + 303

**61 9701/12/F/M/17/Q7**

A student mixed 25.0 cm$^3$ of 4.00 mol dm$^{-3}$ hydrochloric acid with an equal volume of 4.00 mol dm$^{-3}$ sodium hydroxide. The initial temperature of both solutions was 15.0 °C. The maximum temperature recorded was 30.0 °C.

Using these results, what is the enthalpy change of neutralisation of hydrochloric acid?

**A** –62.7 kJ mol$^{-1}$ **C** –15.7 kJ mol$^{-1}$

**B** –31.4 kJ mol$^{-1}$ **D** –3.14 kJ mol$^{-1}$



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**62 9701/12/F/M/17/Q9**

All the reactants and products of an exothermic reaction are gaseous.

Which statement about this reaction is correct?

**A** The total bond energy of the products is less than the total bond energy of the reactants, and $\Delta H$ for the reaction is negative.

**B** The total bond energy of the products is less than the total bond energy of the reactants, and $\Delta H$ for the reaction is positive.

**C** The total bond energy of the products is more than the total bond energy of the reactants, and $\Delta H$ for the reaction is negative.

**D** The total bond energy of the products is more than the total bond energy of the reactants, and $\Delta H$ for the reaction is positive.

**63 9701/11/M/J/17/Q7**

Which expression gives the standard enthalpy change of combustion of methane?

**A** $\Delta H_f^\ominus(CH_4) + \Delta H_f^\ominus(CO_2) - 2\Delta H_f^\ominus(H_2O)$

**B** $\Delta H_f^\ominus(CO_2) + 2\Delta H_f^\ominus(H_2O) + \Delta H_f^\ominus(CH_4)$

**C** $\Delta \ {}_f^\ominus(CH_4) + 2\Delta H_f^\ominus(H_2O) - \Delta H_f^\ominus(CO_2)$

**D** $\Delta H_f^\ominus(CO_2) + 2\Delta H_f^\ominus(H_2O) - \Delta H_f^\ominus(CH_4)$

**64 9701/13/M/J/17/Q6**

The following data are needed for this question.

$\Delta H_f^\ominus(CO(g)) = -111\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(CO_2(g)) = -394\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(Fe_2O_3(s)) = -822\,kJ\,mol^{-1}$

Carbon monoxide reacts with iron(III) oxide.

$$3CO(g) + Fe_2O_3(s) \rightarrow 3CO_2(g) + 2Fe(s)$$

What is the enthalpy change when 55.8 g of iron are produced by this reaction?

**A** –27.0 kJ **B** –13.5 kJ **C** +13.5 kJ **D** +27.0 kJ



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**65 9701/11/O/N/18/Q6**

A butane burner is used to heat water. The $M_r$ of butane is 58.

- $\Delta H_c^{\ominus}$ of butane is –2877 kJ mol$^{-1}$.
- 250 g of water is heated from 12 °C to 100 °C.
- The burner transfers 47% of the heat released from the burning fuel to the water.

Assume that the butane undergoes complete combustion and none of the water evaporates.

What is the minimum mass of butane that must be burnt?

**A** 0.068 g **B** 1.85 g **C** 3.94 g **D** 4.48 g

**66 9701/12/O/N/18/Q1**

Which statement about enthalpy changes is correct?

**A** Enthalpy changes of atomisation are always negative.

**B** Enthalpy changes of combustion are always positive.

**C** Enthalpy changes of formation are always positive.

**D** Enthalpy changes of neutralisation are always negative.

**67 9701/12/O/N/18/Q7**

Ethanol is increasingly being used as a fuel for cars.

The standard enthalpy change of formation of carbon dioxide is –393 kJ mol$^{-1}$.

The standard enthalpy change of formation of water is –286 kJ mol$^{-1}$.

The standard enthalpy change of formation of ethanol is –277 kJ mol$^{-1}$.

What is the standard enthalpy change of combustion of ethanol?

**A** –1921 kJ mol$^{-1}$

**B** –1367 kJ mol$^{-1}$

**C** –956 kJ mol$^{-1}$

**D** –402 kJ mol$^{-1}$



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**68 9701/12/F/M/19/Q8**

The standard enthalpy changes of combustion of carbon, hydrogen and methanol are shown.

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H_c^{\ominus} = -394\,kJ\,mol^{-1}$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H_c^{\ominus} = -286\,kJ\,mol^{-1}$$

$$CH_3OH(l) + 1\tfrac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H_c^{\ominus} = -726\,kJ\,mol^{-1}$$

Which expression gives the standard enthalpy change of formation of methanol in $kJ\,mol^{-1}$?

**A** –394 + (–286) – (–726)

**B** –394 + (–286 × 2) – 726

**C** –394 + (–286 × 2) – (–726)

**D** –726 – (–394) – (–286 × 2)

**69 9701/12/F/M/19/Q9**

The equation for a chemical reaction is shown. All substances are in their standard states.

$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$

Which statement describes the standard enthalpy change of reaction for this reaction?

**A** the enthalpy change when a total of one mole of products is produced

**B** the enthalpy change when a total of one mole of reactants is reacted

**C** the enthalpy change when one mole of water reacts

**D** the enthalpy change when six moles of hydrogen fluoride are produced

**70 9701/11/M/J/19/Q8**

Two reactions and their enthalpy changes are shown.

$$2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H^{\ominus} = +52.2\,kJ\,mol^{-1}$$

$$_2H_2(g) + H_2(g) \rightarrow C_2H_4(g) \qquad \Delta H^{\ominus} = -175.8\,kJ\,mol^{-1}$$

These data can be used to calculate the enthalpy change for the reaction shown.

$$2C(s) + H_2(g) \rightarrow C_2H_2(g) \qquad \Delta H^{\ominus} = X$$

What is the value of X?

**A** $-228.0\,kJ\,mol^{-1}$

**B** $-123.6\,kJ\,mol^{-1}$

**C** $+123.6\,kJ\,mol^{-1}$

**D** $+228.0\,kJ\,mol^{-1}$

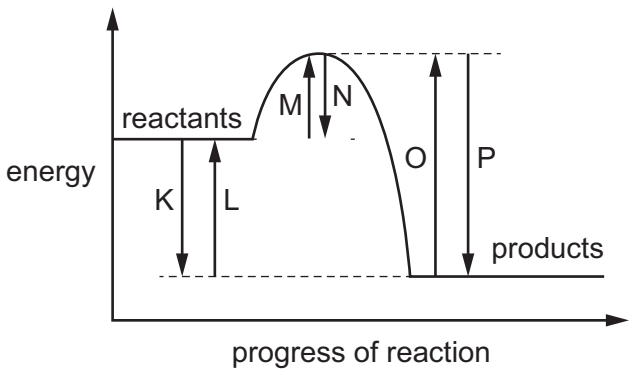
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**71 9701/12/M/J/19/Q8**

A reaction pathway diagram is shown.




Which row is correct?

| | enthalpy change of the forward reaction | activation energy of the reverse reaction |
|---|---|---|
| **A** | K | M |
| **B** | K | O |
| **C** | L | O |
| **D** | P | M |

**72 9701/11/O/N/19/Q7**

The following data are needed for this question.

$\Delta H_f^\ominus(N_2H_4(l)) = 50.6\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(N_2O_4(g)) = 9.2\,kJ\,mol^{-1}$

$\Delta H_f^\ominus(H_2O(g)) = -241.8\,kJ\,mol^{-1}$

Hydrazine, $N_2H_4(l)$, reacts with dinitrogen tetraoxide, $N_2O_4(g)$, to form nitrogen gas and water vapour.

$$2N_2H_4(l) + N_2O_4(g) \rightarrow 3N_2(g) + 4H_2O(g)$$

What is the enthalpy change for this reaction?

**A** $-1077.6\,kJ\,mol^{-1}$

**B** $-856.8\,kJ\,mol^{-1}$

**C** $-301.6\,kJ\,mol^{-1}$

**D** $-182.0\,kJ\,mol^{-1}$



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**73 9701/11/O/N/19/Q8**

Sodium burns in oxygen giving out heat energy and forming the compound $Na_2O$. The equation for this reaction is shown.

$$2Na(s) + \tfrac{1}{2}O_2(g) \rightarrow Na_2O(s)$$

Which statement about the reaction is correct?

**A** $\Delta H^{\ominus}$ for the reaction is equal to twice the bond energy of the Na–O bond.

**B** $\Delta H^{\ominus}$ for the reaction is positive.

**C** The equation represents the standard enthalpy change of combustion of sodium.

**D** The equation represents the standard enthalpy change of formation of sodium oxide.

**74 9701/12/O/N/19/Q6**

Which reaction is endothermic?

**A** $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$

**B** $2Cl(g) \rightarrow Cl_2(g)$

**C** $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$

**D** $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

**75 9701/12/O/N/19/Q7**

Which equation correctly represents the standard enthalpy change of atomisation of the given element?

**A** $\tfrac{1}{2}I_2(g) \rightarrow I(g)$

**B** $Na(s) \rightarrow Na(g)$

**C** $Cl_2(g) \rightarrow 2Cl(g)$

**D** $Na(g) \rightarrow Na^+(g) + e^-$

$(NH_4)_2Cr_2O_7$ decomposes when heated.

**76 9701/12/F/M/20/Q4**

The following data are needed for this question.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = -38.97\,kJ\,mol^{-1}$$

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = -96.59\,kJ\,mol^{-1}$$

On heating, sodium hydrogencarbonate decomposes as shown.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

What is the enthalpy change for this decomposition?

**A** $-57.62\,kJ\,mol^{-1}$

**B** $-18.65\,kJ\,mol^{-1}$

**C** $18.65\,kJ\,mol^{-1}$

**D** $57.62\,kJ\,mol^{-1}$

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**77 9701/11/M/J/20/Q5**

Two reactions are shown.

$$H_2(g) \rightarrow 2H(g)$$

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g)$$

If molar amounts are used, how can the two energy changes associated with these reactions be described?

**A** enthalpy of atomisation and enthalpy of combustion

**B** enthalpy of atomisation and enthalpy of formation

**C** bond energy and enthalpy of combustion

**D** bond energy and enthalpy of formation

**78 9701/12/M/J/20/Q4**

Solid sulfur consists of $S_8$ molecules.

Which equation represents the standard enthalpy of atomisation of sulfur?

**A** $\tfrac{1}{8}S_8(s) \rightarrow S(g)$

**B** $\tfrac{1}{8}S_8(g) \rightarrow S(g)$

**C** $S_8(s) \rightarrow 8S(g)$

**D** $S_8(g) \rightarrow 8S(g)$

**79 9701/13/M/J/20/Q4**

The enthalpy changes of two reactions are shown.

$$K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = -34.0\,kJ\,mol^{-1}$$

$$KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H = +32.8\,kJ\,mol^{-1}$$

What is the enthalpy change for the reaction shown?

$$2KHCO_3(s) \rightarrow K_2CO_3(s) + H_2O(l) + CO_2(g)$$

**A** $-31.6\,kJ\,mol^{-1}$

**B** $1.2\,kJ\,mol^{-1}$

**C** $66.8\,kJ\,mol^{-1}$

**D** $99.6\,kJ\,mol^{-1}$



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# Physical Chemistry

6
TOPIC

# Electrochemistry

## Syllabus Content

This topic illustrates the relationship between electricity and chemical changes. Chemical reactions can be investigated by looking at electrode potentials.

| | Learning outcomes<br>Candidates should be able to: |
|---|---|
| 6.1 Redox processes: electron transfer and changes in oxidation number (oxidation state) | a) calculate oxidation numbers of elements in compounds and ions<br>b) describe and explain redox processes in terms of electron transfer and changes in oxidation number<br>c) use changes in oxidation numbers to help balance chemical equations |

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**1 9701/1/M/J/02/Q16**

During electrolysis of brine in a diaphragm cell, chlorine, hydrogen and sodium hydroxide are produced.

What is the molar ratio of these products?

| | chlorine | hydrogen | sodium hydroxide |
|---|---|---|---|
| **A** | 1 | 1 | 1 |
| **B** | 1 | 1 | 2 |
| **C** | 2 | 1 | 1 |
| **D** | 2 | 2 | 1 |

**2 9701/1/O/N/02/Q16**

In the industrial electrolysis of brine to manufacture chlorine, the diaphragm used is a porous screen which allows the flow of electrolytes but keeps other chemicals separate.

Which substance needs to be kept separate from the chlorine by the diaphragm?

**A** hydrogen **B** sodium hydroxide **C** sodium chloride **D** water

**3 9701/1/M/J/03/Q8**

When ammonia is converted into nitric acid on a commercial scale, the following reactions can occur.

In which reaction does the greatest change in oxidation number of the nitrogen occur?

| reaction | |
|---|---|
| **A** | $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$ |
| **B** | $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$ |
| **C** | $2NO + O_2 \rightarrow 2NO_2$ |
| **D** | $4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O$ |

**4 9701/01/M/J/04/Q18**

*Use of the Data Booklet is relevant to this question.*

In the commercial electrolysis of brine, the products are chlorine, hydrogen and sodium hydroxide.

What is the maximum yield of each of these products when 58.5 kg of sodium chloride are electrolysed as brine?

| | yield of chlorine / kg | yield of hydrogen / kg | yield of sodium hydroxide / kg |
|---|---|---|---|
| **A** | 35.5 | 1 | 40 |
| **B** | 35.5 | 2 | 40 |
| **C** | 71 | 1 | 40 |
| **D** | 71 | 2 | 80 |



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**5 9701/01/M/J/05/Q8**

In the extraction of aluminium by electrolysis, why is it necessary to dissolve aluminium oxide in molten cryolite?

**A** to reduce the very high melting point of the electrolyte

**B** cryolite provides the ions needed to carry the current

**C** cryolite reacts with the aluminium oxide to form ions

**D** molten aluminium oxide alone would not conduct electricity

**6 9701/01/M/J/05/Q9**

A cheap carbon monoxide detector for a gas heater consists of a patch containing palladium chloride crystals. When carbon monoxide is present, the crystals turn from orange to black as the following reaction takes place.

$$\underset{\text{orange}}{CO(g) + PdCl_2(s)} + H_2O(l) \rightarrow CO_2(g) + \underset{\text{black}}{Pd(s)} + 2HCl(aq)$$

Which is the element whose oxidation number **decreases** in this reaction?

**A** carbon **C** hydrogen

**B** chlorine **D** palladium

**7 9701/01/O/N/05/Q8**

During the electrolysis of brine using a diaphragm cell, which reaction occurs at the cathode?

**A** $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

**B** $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

**C** $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

**D** $Na^+(aq) + e^- \rightarrow Na(s)$

**8 9701/01/O/N/06/Q10**

In some early paintings, lead(II) carbonate was used as a white pigment. In the 19th century hydrogen sulphide from burning coal reacted with this pigment to form black lead(II) sulphide, PbS. The original colour of the painting may be restored by carefully treating the area with dilute hydrogen peroxide, producing lead(II) sulphate which is also white.

What is the role of the hydrogen peroxide?

**A** catalyst **B** oxidising agent **C** reducing agent **D** solvent



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**9 9701/01/M/J/06/Q9**

The nickel-cadmium rechargeable battery is based upon the following overall reaction.

$$Cd + 2NiOOH + 4H_2O \rightarrow Cd(OH)_2 + 2Ni(OH)_2.H_2O$$

What is the oxidation number of nickel at the beginning and at the end of the reaction?

| | beginning | end |
|---|---|---|
| **A** | +1.5 | +2 |
| **B** | +2 | +3 |
| **C** | +3 | +2 |
| **D** | +3 | +4 |

**10 9701/01/O/N/07/Q9**

In an experiment, 50.0 cm$^3$ of a 0.10 mol dm$^{-3}$ solution of a metallic salt reacted exactly with 25.0 cm$^3$ of 0.10 mol dm$^{-3}$ aqueous sodium sulphite.

The half-equation for oxidation of sulphite ion is shown below.

$$SO_3^{2-}(aq) + H_2O(l) \rightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$$

If the original oxidation number of the metal in the salt was +3, what would be the new oxidation number of the metal?

**A** +1 **B** +2 **C** +4 **D** +5

**11 9701/01/M/J/09/Q9**

When copper is extracted from its ores, the metal is not pure enough for electrical uses. The impure copper, which contains small amounts of silver and gold, is purified by electrolysis. During this process a 'sludge' forms beneath the anode which is found to contain silver and traces of gold.

Why is silver found in this sludge?

**A** Silver is less electropositive than copper.

**B** Silver is more dense than copper and falls off the cathode.

**C** Silver reacts with the electrolyte to form an insoluble chloride salt.

**D** Silver reacts with the electrolyte to form an insoluble sulfate salt.

**12 9701/12/O/N/09/Q6**

Which conversion involves a reduction of chromium?

**A** $CrO_4^{2-} \rightarrow CrO_3$ **B** $CrO_4^{2-} \rightarrow Cr_2O_7^{2-}$

**C** $CrO_2Cl_2 \rightarrow CrO_4^{2-}$ **D** $CrO_2Cl_2 \rightarrow Cr_2O_3$



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**13 9701/12/O/N/09/Q15**

During electrolysis of brine in a diaphragm cell, chlorine, hydrogen and sodium hydroxide are produced.

What is the molar ratio of these products?

| | chlorine | hydrogen | sodium hydroxide |
|---|---|---|---|
| **A** | 1 | 1 | 1 |
| **B** | 1 | 1 | 2 |
| **C** | 2 | 1 | 1 |
| **D** | 2 | 2 | 1 |

**14 9701/12/M/J/10/Q6**

Ammonium nitrate, $NH_4NO_3$, can decompose explosively when heated.

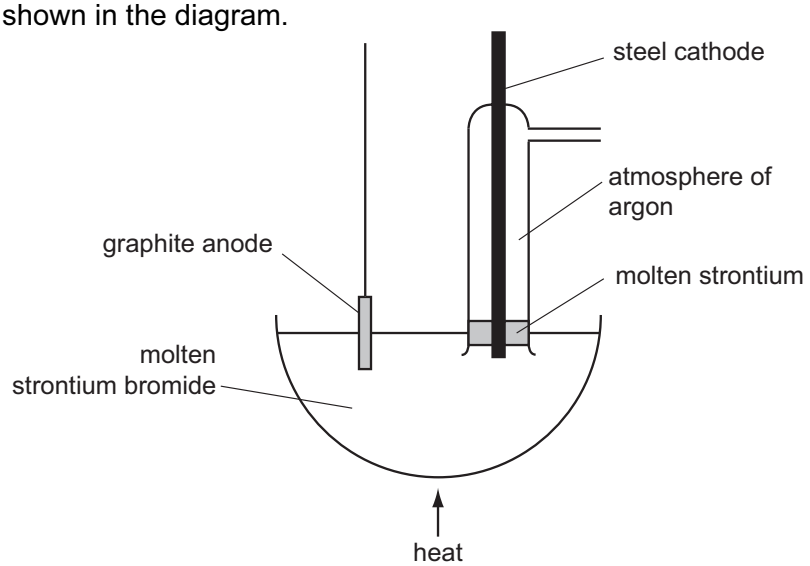
$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

What are the changes in the oxidation numbers of the two nitrogen atoms in $NH_4NO_3$ when this reaction proceeds?

**A** –2, –4 **B** +2, +6 **C** +4, –6 **D** +4, –4

**15 9701/12/O/N/10/Q17**

Strontium metal can be obtained by the electrolysis of molten strontium bromide, $SrBr_2$, using the apparatus shown in the diagram.




Why is an atmosphere of argon used around the cathode?

**A** A thin film of a compound of strontium and argon forms on the surface protecting the freshly formed metal.

**B** The argon keeps the strontium molten.

**C** The argon stops the molten strontium rising too high in the tube.

**D** Without the argon, strontium oxide would form in the air.



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**16 9701/12/M/J/11/Q19**

Which compound contains two different elements with identical oxidation states?

**A** $HCl O$ **B** $Mg(OH)_2$ **C** $Na_2SO_4$ **D** $NH_4Cl$

**17 9701/12/M/J/11/Q3**

Aluminium is the most abundant metal in the Earth's crust. The extraction of aluminium is carried out by the electrolysis of aluminium oxide dissolved in molten cryolite.

Which material is used for each of the electrodes in this electrolysis?

| | anode | cathode |
|---|---|---|
| **A** | aluminium | carbon |
| **B** | carbon | carbon |
| **C** | carbon | steel |
| **D** | steel | aluminium |

**18 9701/12/O/N/11/Q11**

The amount of titanium dioxide in an ore can be determined by using the following reaction.

$$3TiO_2 + 4BrF_3 \rightarrow 3TiF_4 + 2Br_2 + 3O_2$$

Which element increases in oxidation number in this reaction?

**A** bromine **B** fluorine **C** oxygen **D** titanium

**19 9701/12/O/N/12/Q11**

In which reaction does an element undergo the largest change in oxidation state?

**A** $Cl_2 + 2OH^- \rightarrow OCl^- + Cl^- + H_2O$

**B** $3Cl_2 + 6OH^- \rightarrow ClO_3^- + 5Cl^- + 3H_2O$

**C** $Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

**D** $3MnO_4^{2-} + 4H^+ \rightarrow MnO_2 + 2MnO_4^- + 2H_2O$

**20 9701/12/O/N/12/Q7**

Aluminium is extracted by the electrolysis of a molten mixture containing aluminium oxide. By a similar method, magnesium is extracted by the electrolysis of a molten mixture containing magnesium chloride.

Which statement about the extraction of magnesium is correct?

**A** Magnesium ions travel to the anode and are oxidised to magnesium metal.
**B** Magnesium ions travel to the anode and are reduced to magnesium metal.
**C** Magnesium ions travel to the cathode and are oxidised to magnesium metal.
**D** Magnesium ions travel to the cathode and are reduced to magnesium metal.

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**21 9701/11/M/J/13/Q1**

Solutions containing chlorate(I) ions are used as household bleaches and disinfectants. These solutions decompose on heating as shown.

$$3ClO^- \rightarrow ClO_3^- + 2Cl^-$$

Which oxidation state is shown by chlorine in each of these three ions?

| | $ClO^-$ | $ClO_3^-$ | $Cl^-$ |
|---|---|---|---|
| **A** | +1 | +3 | –1 |
| **B** | –1 | +3 | +1 |
| **C** | +1 | +5 | –1 |
| **D** | –1 | +5 | +1 |

**22 9701/12/M/J/13/Q1**

During the electrolysis of molten aluminium oxide to produce aluminium, using carbon electrodes, two consecutive reactions occur at the anode, each producing a different gas.

How does the oxidation number of oxygen change in these reactions?

**A** decreases by 2, then increases by 2
**B** increases by 2, then decreases by 2
**C** increases by 2, then decreases by 4
**D** no change, then decreases by 2

**23 9701/12/O/N/13/Q1**

At the age of 17, in a woodshed in Ohio, Charles Martin Hall discovered the commercial process for the production of aluminium metal by the electrolysis of a mixture of bauxite, $Al_2O_3$, and cryolite, $Na_3AlF_6$.

What is the main purpose of the cryolite?

**A** $Al_2O_3$ is covalent, and $AlF_6^{3-}$ ions interact with it to produce $Al^{3+}$ ions which can be discharged at the cathode.

**B** Cryolite is a base, forming $NaAlO_2$ with bauxite, enabling aluminium to be discharged at the anode. $\rightleftharpoons$

**C** Cryolite minimises the release of $O^{2-}$ ions at the graphite anodes, which are otherwise burnt away to CO.

**D** Cryolite reduces the melting point of the bauxite.

**24 9701/12/O/N/13/Q2**

In which reaction does a single nitrogen atom have the greatest change in oxidation number?

**A** $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

**B** $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$

**C** $2NO + O_2 \rightarrow 2NO_2$

**D** $4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O$

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**25 9701/12/M/J/13/Q1**

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**26 9701/12/O/N/13/Q1**

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**C** Cryolite minimises the release of $O^{2-}$ ions at the graphite anodes, which are otherwise burnt away to CO.

**D** Cryolite reduces the melting point of the bauxite.

**27 9701/12/O/N/13/Q2**

In which reaction does a single nitrogen atom have the greatest change in oxidation number?

**A** $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

**B** $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$

**C** $2NO + O_2 \rightarrow 2NO_2$

**D** $4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O$

**28 9701/12/O/N/13/Q3**

The following half reactions occur when potassium iodate(V), $KIO_3$, in hydrochloric acid solution oxidises iodine to $ICl_2^-$.

$$IO_3^- + 2Cl^- + 6H^+ + 4e^- \rightarrow ICl_2^- + 3H_2O$$

$$I_2 + 4Cl^- \rightarrow 2ICl_2^- + 2e^-$$

What is the ratio of $IO_3^-$ to $I_2$ in the balanced chemical equation for the overall reaction?

**A** 1 : 1 **B** 1 : 2 **C** 1 : 4 **D** 2 : 1

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**29 9701/12/O/N/13/Q16**

Solid potassium halides react with concentrated sulfuric acid, according to the following equations.

reaction 1 $2KCl + H_2SO_4 \rightarrow K_2SO_4 + 2HCl$

reaction 2 $2KBr + 2H_2SO_4 \rightarrow K_2SO_4 + SO_2 + Br_2 + 2H_2O$

reaction 3 $8KI + 5H_2SO_4 \rightarrow 4K_2SO_4 + H_2S + 4I_2 + 4H_2O$

What is the largest **change** in the oxidation number of sulfur in each of these reactions?

| | reaction 1 | reaction 2 | reaction 3 |
|---|---|---|---|
| **A** | 0 | 0 | 4 |
| **B** | 0 | 2 | 4 |
| **C** | 0 | 2 | 8 |
| **D** | 0 | 4 | 8 |

**30 9701/12/O/N/14/Q16**

Chlorine gas reacts with cold aqueous sodium hydroxide. It can also react with hot aqueous sodium hydroxide.

What are the oxidation numbers of chlorine in the products of these reactions?

| | cold aqueous sodium hydroxide | hot aqueous sodium hydroxide |
|---|---|---|
| **A** | –1, +1 | –1, +5 |
| **B** | –1, +1 | +1, +6 |
| **C** | –1, +2 | –1, +5 |
| **D** | –1, +2 | +1, +6 |

**31 9701/12/M/J/14/Q6**

In which reaction is the species in **bold** acting as an oxidising agent?

**A** $\mathbf{2Ca} + O_2 \rightarrow 2CaO$

**B** $Cr_2O_7^{2-} + 8H^+ + \mathbf{3SO_3^{2-}} \rightarrow 2Cr^{3+} + 4H_2O + 3SO_4^{2-}$

**C** $Mg + \mathbf{Fe^{2+}} \rightarrow Mg^{2+} + Fe$

**D** $\mathbf{SO_2} + 2H_2O + 2Cu^{2+} + 2Cl^- \rightarrow H_2SO_4 + 2H^+ + 2CuCl$

**32 9701/12/O/N/14/Q2**

In which reaction does hydrogen behave as an oxidising agent?

**A** $H_2 + Cl_2 \rightarrow 2HCl$ **B** $C_2H_4 + H_2 \rightarrow C_2H_6$

**C** $N_2 + 3H_2 \rightarrow 2NH_3$ **D** $2Na + H_2 \rightarrow 2NaH$



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**33 9701/12/O/N/14/Q10**

Which row correctly describes the electrodes used in the electrolysis cell for the production of aluminium?

| | anode | cathode |
|---|---|---|
| **A** | carbon | carbon |
| **B** | carbon | steel |
| **C** | steel | carbon |
| **D** | steel | steel |

**34 9701/12/O/N/14/Q17**

Under standard conditions, which statement is correct?

**A** $Cl^-$(aq) can oxidise $Br_2$(aq).

**B** $Cl^-$(aq) can reduce $Br_2$(aq).

**C** $Cl_2$(aq) can oxidise $Br^-$(aq).

**D** $Cl_2$(aq) can reduce $Br^-$(aq).

**35 9701/12/M/J/15/Q7**

In industry, copper metal is purified by electrolysis.

Which changes occur to the masses of the electrodes and to the colour of the electrolyte during this process?

| | mass of anode | mass of cathode | colour of electrolyte |
|---|---|---|---|
| **A** | decrease | increase | little or no change occurs |
| **B** | decrease | increase | pale blue to blue |
| **C** | increase | decrease | little or no change occurs |
| **D** | increase | decrease | blue to pale blue |

**36 9701/12/M/J/15/Q19**

Chlorate(V) ions, $ClO_3^-$, are produced in the redox reaction between chlorine and hot aqueous sodium hydroxide. Oxidation numbers can be used to help balance the equation for this reaction.

What will be the values of coefficients **v**, **x** and **y** in the balanced equation?

$$\mathbf{v}Cl_2(g) + \mathbf{w}OH^-(aq) \rightarrow \mathbf{x}Cl^-(aq) + \mathbf{y}ClO_3^-(aq) + \mathbf{z}H_2O(l)$$

| | **v** | **x** | **y** |
|---|---|---|---|
| **A** | 2 | 3 | 1 |
| **B** | 3 | 4 | 2 |
| **C** | 3 | 5 | 1 |
| **D** | 7 | 12 | 2 |

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**37 9701/12/F/M/17/Q8**

HOC$l$(aq) is the molecule that kills bacteria when chlorine is added to water.

The following reaction produces this molecule.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HOCl(aq) + H^+(aq) + Cl^-(aq)$$

Which statement about this reaction is correct?

**A** Chlorine is both oxidised and reduced.

**B** Chlorine is oxidised but not reduced.

**C** Hydrogen is both oxidised and reduced.

**D** Hydrogen is oxidised but not reduced.

**38 9701/11/M/J/17/Q9**

When $K_2MnO_4$ is dissolved in water, the following reaction occurs.

$$a\,MnO_4^{2-}(aq) + b\,H_2O(l) \rightarrow c\,MnO_4^-(aq) + d\,MnO_2(s) + e\,OH^-(aq)$$

What are the values of *a* and *c* in the balanced chemical equation?

| | *a* | *c* |
|---|---|---|
| **A** | 2 | 1 |
| **B** | 3 | 2 |
| **C** | 4 | 3 |
| **D** | 5 | 4 |

**39 9701/13/M/J/17/Q7**

Vanadium reacts with dilute sulfuric acid to form $V_2(SO_4)_3$ and hydrogen gas.

What happens to vanadium atoms in this reaction?

**A** They lose three electrons and are oxidised.

**B** They lose three electrons and are reduced.

**C** They lose two electrons and are oxidised.

**D** They lose two electrons and are reduced.

**40 9701/13/M/J/17/Q8**

$Na_2S_2O_3$ reacts with HC$l$ as shown.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$$

When calculating the oxidation number of sulfur in $Na_2S_2O_3$, the **average** oxidation number of the two sulfur atoms should be found.

What is the oxidation number of sulfur in each of $Na_2S_2O_3$, $SO_2$, and S?

| | $Na_2S_2O_3$ | $SO_2$ | S |
|---|---|---|---|
| **A** | +2 | +2 | +1 |
| **C** | +4 | +4 | 0 |
| **D** | +5 | +4 | 0 |



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**41 9701/11/O/N/18/Q8**

A transition metal ion, $M^{2+}$, reacts with acidified dichromate(VI) ions to form $M^{4+}$ ions, $Cr^{3+}$ ions, and $H_2O$.

Which equation correctly represents this reaction?

**A** $Cr_2O_7^{2-} + 14H^+ + M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + M^{4+}$

**B** $Cr_2O_7^{2-} + 14H^+ + 2M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 2M^{4+}$

**C** $Cr_2O_7^{2-} + 14H^+ + 3M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 3M^{4+}$

**D** $Cr_2O_7^{2-} + 14H^+ + 6M^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6M^{4+}$

**42 9701/11/O/N/18/Q19**

Transition elements and their compounds are widely used as catalysts.

What is the identity and what is the oxidation number of the element present in the catalyst used in the Contact process?

| | element | oxidation number |
|---|---|---|
| **A** | iron | 0 |
| **B** | iron | +3 |
| **C** | vanadium | 0 |
| **D** | vanadium | +5 |

**43 9701/12/O/N/18/Q8**

Ammonium metavanadate, $NH_4VO_3$, can be used to make a solution containing $VO_2Cl$, which contains chloride ions.

What is the **change** in the oxidation number of vanadium in this reaction?

**A** –1 **B** 0 **C** +1 **D** +2

**44 9701/12/F/M/19/Q10**

Acidified potassium manganate(VII) reacts with iron(II) ethanedioate, $FeC_2O_4$.

The reactions taking place are shown.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

How many moles of iron(II) ethanedioate react with **one** mole of potassium manganate(VII)?

**A** 0.60 **B** 1.67 **C** 2.50 **D** 5.00



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**45 9701/11/M/J/19/Q9**

Ethanedioic acid, $HO_2CCO_2H$, can be oxidised by $KMnO_4$ in dilute sulfuric acid. The products of this reaction are carbon dioxide, water, potassium sulfate and manganese(II) sulfate.

In this reaction each ethanedioic acid molecule loses two electrons as it is oxidised. A half-equation for this process is shown.

$$HO_2CCO_2H \rightarrow 2CO_2 + 2H^+ + 2e^-$$

How many water molecules are produced when five ethanedioic acid molecules are oxidised by $KMnO_4$ in dilute sulfuric acid?

**A** 5 **B** 8 **C** 10 **D** 16

**46 9701/11/O/N/19/Q6**

What is the oxidation number of sulfur in each species?

| | $H_2S$ | $SO_2$ | $H_2SO_3$ |
|---|---|---|---|
| **A** | –2 | +4 | +4 |
| **B** | –2 | +4 | +6 |
| **C** | +2 | –4 | +4 |
| **D** | +2 | –4 | +6 |

**47 9701/11/O/N/19/Q9**

In the chemical equation, w, x, y and z are all whole numbers.

$$wCl O_3^- + xMnO_4^- + yH^+ \rightarrow wCl O_4^- + xMnO_2 + zH_2O$$

When the equation is balanced, what are w, x and y?

| | w | x | y |
|---|---|---|---|
| **A** | 1 | 1 | 2 |
| **B** | 2 | 2 | 2 |
| **C** | 2 | 3 | 8 |
| **D** | 3 | 2 | 2 |



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**48 9701/12/F/M/20/Q5**

In the redox reaction shown, how do the oxidation states of vanadium and sulfur change?

$$VO_2^+ + SO_2 \rightarrow V^{3+} + SO_4^{2-}$$

| | vanadium | | sulfur | |
|---|---|---|---|---|
| | from | to | from | to |
| **A** | +1 | +3 | 0 | –2 |
| **B** | +1 | +3 | +4 | +6 |
| **C** | +5 | +3 | 0 | –2 |
| **D** | +5 | +3 | +4 | +6 |

**49 9701/12/F/M/20/Q10**

When the equation is correctly balanced, what is the value of *c*?

$$aC_2H_4 + bH_2O + cH^+ + 2MnO_4^- \rightarrow dC_2H_6O_2 + eMn^{2+}$$

**A** 3 **B** 4 **C** 5 **D** 6

**50 9701/11/M/J/20/Q2**

Cobalt can form the positive ion $Co(NH_3)_4Cl_2^+$.

What is the oxidation number of cobalt in this ion?

**A** +1 **B** +2 **C** +3 **D** +6

**51 9701/11/M/J/20/Q8**

In this question you should use changes in oxidation numbers to balance a chemical equation.

Acidified potassium dichromate(VI) solution can oxidise a solution of $V^{2+}$ ions. The equation for this reaction is shown.

$$a\,Cr_2O_7^{2-} + b\,V^{2+} + c\,H^+ \rightarrow d\,Cr^{3+} + e\,VO_3^- + f\,H_2O$$

What is the ratio *a* : *b* in the correctly balanced equation?

**A** 1 : 1 **B** 1 : 2 **C** 2 : 1 **D** 4 : 1



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**52 9701/11/M/J/20/Q17**

0.25 g of anhydrous magnesium nitrate is heated strongly until it completely decomposes.

What is the total volume of gas produced, measured under room conditions?

**A** 40 $cm^3$ **B** 81 $cm^3$ **C** 101 $cm^3$ **D** 202 $cm^3$

**53 9701/12/M/J/20/Q5**

In this question you should use changes in oxidation numbers to balance a chemical equation.

The following reaction occurs when $MnO_2$ is warmed with dilute $H_2SO_4$.

$$a\ MnO_2 + b\ H^+ \rightarrow c\ Mn^{2+} + d\ MnO_4^- + e\ H_2O$$

What is the ratio of *c* : *d* in the correctly balanced equation?

**A** 1 : 1 **B** 1 : 2 **C** 2 : 3 **D** 3 : 2

**54 9701/12/M/J/20/Q10**

In which reaction does an element undergo the largest change in oxidation number?

**A** $Cl_2 + 2OH^- \rightarrow OCl^- + Cl^- + H_2O$

**B** $3Cl_2 + 6OH^- \rightarrow ClO_3^- + 5Cl^- + 3H_2O$

**C** $Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

**D** $3MnO_4^{2-} + 4H^+ \rightarrow MnO_2 + 2MnO_4^- + 2H_2O$

**55 9701/13/M/J/20/Q10**

When solid $KClO_3$ is heated in the absence of air, a mixture of two chlorine compounds in the mole ratio of 3 : 1 is formed. Chlorine is the only element whose oxidation number changes in this reaction.

What could be the oxidation numbers of chlorine in the two compounds that are formed?

**A** +3 and –1 **B** +6 and +4 **C** +7 and –1 **D** +7 and +1



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# Physical Chemistry

7
TOPIC

# Equilibria



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**1 9701/1/O/N/02/Q11**

In an experiment, *b* mol of hydrogen iodide were put into a sealed vessel under pressure p. At equilibrium, *x* mol of the hydrogen iodide had dissociated, the reaction being represented by the following equation.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

Which expression for $K_p$ is correct?

**A** $\dfrac{x^2}{(b-x)^2}$

**B** $\dfrac{x^2p^2}{(b-x)^2}$

**C** $\dfrac{x^2p^2}{4b(b-x)}$

**D** $\dfrac{x^2}{4(b-x)^2}$

**2 9701/1/M/J/02/Q10**

For which equilibrium does $K_c$ have *no units*?

**A** $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

**B** $CH_3OH(l) + CH_3CO_2H(l) \rightleftharpoons CH_3CO_2CH_3(l) + H_2O(l)$

**C** $Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$

**D** $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

**3 9701/1/M/J/03/Q11**

Why is ethanoic acid a stronger acid in liquid ammonia than in aqueous solution?

**A** Ammonia is a stronger base than water.

**B** Ammonium ethanoate is completely ionised in aqueous solution.

**C** Ammonium ethanoate is strongly acidic in aqueous solution.

**D** Liquid ammonia is a more polar solvent than water.

**4 9701/01/M/J/04/Q9**

Which substance, in 1 mol $dm^{-3}$ aqueous solution, would have the same hydrogen ion concentration as 1 mol $dm^{-3}$ of hydrochloric acid?

**A** ethanoic acid **B** nitric acid **C** sodium hydroxide **D** sulphuric acid

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**5 9701/01/M/J/04/Q10**

When vanadium(II) compounds are dissolved in water, the following equilibrium is established.

$$V^{2+} + H_2O \rightleftharpoons V^{3+} + \tfrac{1}{2}H_2 + OH^-$$

What would alter the composition of the equilibrium mixture in favour of the $V^{2+}$ ions?

**A** adding an acid

**B** adding a reagent that selectively precipitates $V^{3+}$ ions

**C** allowing the hydrogen to escape as it forms

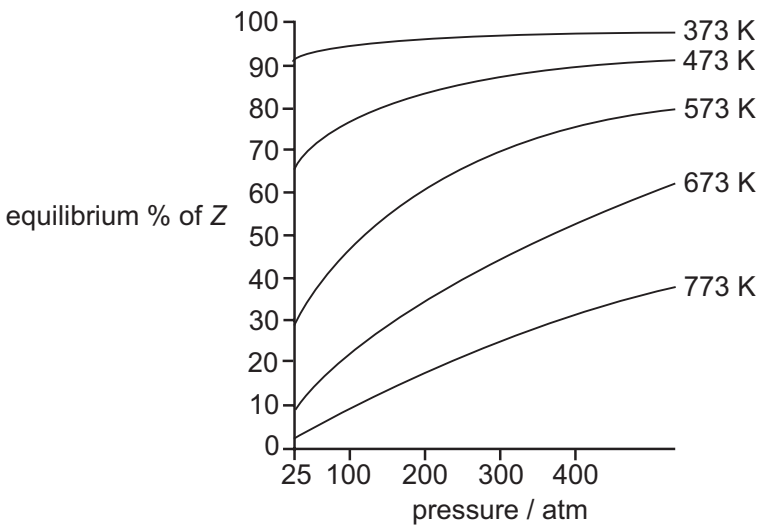
**D** making the solution more alkaline

**6 9701/01/M/J/04/Q11**

In an industrial process, two gases *X* and *Y* react together to form a single gaseous product *Z*.

$$X(g) + Y(g) \rightleftharpoons Z(g)$$

The percentage yield of product *Z* varies according to the pressure and the temperature as shown in the graphs.






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**7 9701/01/O/N/04/Q10**

At high temperatures, steam decomposes into its elements according to the following equation.

$$2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$$

In one experiment at 1 atm pressure, it was found that 20 % of the steam had been converted into hydrogen and oxygen.

What are the values of the equilibrium partial pressures, in atm, of the components of this equilibrium?

| | partial pressure of steam | partial pressure of hydrogen | partial pressure of oxygen |
|---|---|---|---|
| **A** | $\frac{0.80 \times 1}{1.0}$ | $\frac{0.10 \times 1}{1.0}$ | $\frac{0.10 \times 1}{1.0}$ |
| **B** | $\frac{0.80 \times 1}{1.0}$ | $\frac{0.133 \times 1}{1.0}$ | $\frac{0.067 \times 1}{1.0}$ |
| **C** | $\frac{0.80 \times 1}{1.0}$ | $\frac{0.20 \times 1}{1.0}$ | $\frac{0.10 \times 1}{1.0}$ |
| **D** | $\frac{0.80 \times 1}{1.1}$ | $\frac{0.20 \times 1}{1.1}$ | $\frac{0.10 \times 1}{1.1}$ |

**8 9701/01/O/N/04/Q11**

Which statement concerning the equilibrium reaction below is true?

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

**A** An increase in acid concentration will result in an increase in the concentration of $Cr_2O_7^{2-}(aq)$.

**B** A redox reaction is taking place.

**C** The addition of a catalyst will result in an increase in the concentration of $Cr_2O_7^{2-}(aq)$ .

**D** The equilibrium constant, $K_c$, has no units.

**9 9701/01/O/N/04/Q13**

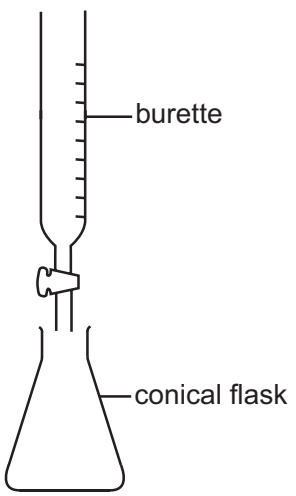
Which of these acid-base (neutralisation) reactions could be titrated using the apparatus shown above to give a sharp end-point?

**A** sulphuric acid and aluminium oxide

**B** sulphuric acid and magnesium hydroxide

**C** sulphuric acid and magnesium oxide

**D** sulphuric acid and sodium hydroxide





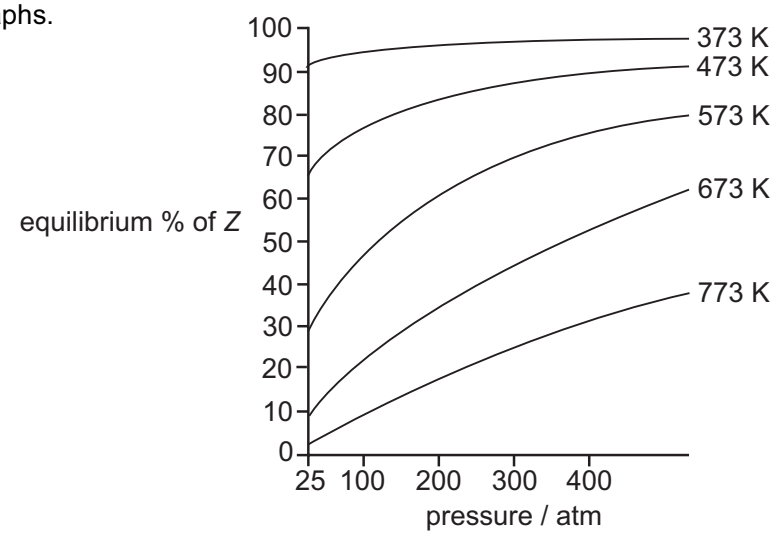

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**10 9701/01/M/J/04/Q11**

In an industrial process, two gases *X* and *Y* react together to form a single gaseous product *Z*.

$$X(g) + Y(g) \quad Z(g)$$

The percentage yield of product *Z* varies according to the pressure and the temperature as shown in the graphs.




Which statement about this equilibrium reaction is correct?

**A** Decreasing the temperature decreases the value of the equilibrium constant.

**B** Decreasing the temperature increases the rate of this reaction.

**C** Increasing the pressure increases the value of the equilibrium constant.

**D** The reaction is exothermic in the forward direction.

**11 9701/01/O/N/04/Q10**

At high temperatures, steam decomposes into its elements according to the following equation.

$$2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$$

In one experiment at 1 atm pressure, it was found that 20 % of the steam had been converted into hydrogen and oxygen.

What are the values of the equilibrium partial pressures, in atm, of the components of this equilibrium?

| | partial pressure of steam | partial pressure of hydrogen | partial pressure of oxygen |
|---|---|---|---|
| **A** | $\frac{0.80 \times 1}{1.0}$ | $\frac{0.10 \times 1}{1.0}$ | $\frac{0.10 \times 1}{1.0}$ |
| **B** | $\frac{0.80 \times 1}{1.0}$ | $\frac{0.133 \times 1}{1.0}$ | $\frac{0.067 \times 1}{1.0}$ |
| **C** | $\frac{0.80 \times 1}{1.0}$ | $\frac{0.20 \times 1}{1.0}$ | $\frac{0.10 \times 1}{1.0}$ |
| **D** | $\frac{0.80 \times 1}{1.1}$ | $\frac{0.20 \times 1}{1.1}$ | $\frac{0.10 \times 1}{1.1}$ |



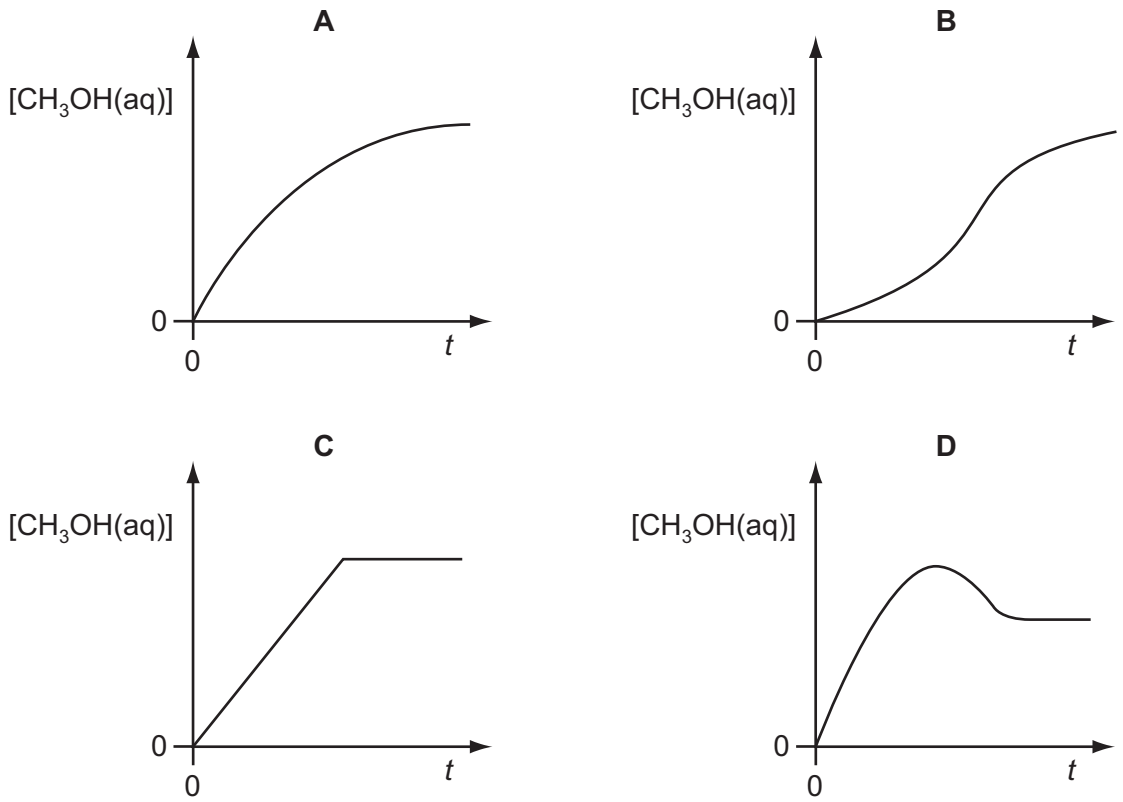
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**12 9701/01/M/J/05/Q11**

The reaction represented by the following equation was carried out.

$$HCO_2CH_3(aq) + NaOH(aq) \rightarrow HCO_2Na(aq) + CH_3OH(aq)$$

Which graph best shows the relationship between $[CH_3OH(aq)]$ and $t$, the time from mixing of the reactants?




**13 9701/01/O/N/05/Q10**

An experiment is set up to measure the rate of hydrolysis of methyl ethanoate.

$$CH_3CO_2CH_3 + H_2O \rightleftharpoons CH_3CO_2H + CH_3OH$$

The hydrolysis is found to be slow in neutral aqueous solution but it proceeds at a measurable rate when the solution is acidified with hydrochloric acid.

What is the function of the hydrochloric acid?

**A** to dissolve the methyl ethanoate

**B** to ensure that the reaction reaches equilibrium

**C** to increase the reaction rate by catalytic action

**D** to suppress ionisation of the ethanoic acid formed

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**14 9701/01/M/J/06/Q10**

At a total pressure of 1.0 atm, dinitrogen tetraoxide is 50 % dissociated at a temperature of 60 °C, according to the following equation.

$$N_2O_4 \rightleftharpoons 2NO_2$$

What is the value of the equilibrium constant, $K_p$, for this reaction at 60 °C?

**A** $^1/_3$ atm **B** $^2/_3$ atm **C** $^4/_3$ atm **D** 2 atm

**15 9701/01/O/N/06/Q11**

The equilibrium constant, $K_c$, for the reaction to form ethyl ethanoate from ethanol and ethanoic acid, $C_2H_5OH + CH_3CO_2H \rightleftharpoons CH_3CO_2C_2H_5 + H_2O$, at 60 °C is 4.00.

When 1.00 mol each of ethanol and ethanoic acid are allowed to reach equilibrium at 60 °C, what is the number of moles of ethyl ethanoate formed?

**A** $\frac{1}{3}$ **B** $\frac{2}{3}$ **C** $\frac{1}{4}$ **D** $\frac{3}{4}$

**16 9701/01/M/J/06Q11**

Swimming pool water can be kept free of harmful bacteria by adding aqueous sodium chlorate(I), NaOC*l*. This reacts with water to produce HOC*l* molecules which kill bacteria.

$$OCl^-(aq) + H_2O \rightleftharpoons OH^-(aq) + HOCl(aq)$$

In bright sunshine, the $OCl^-$ ion is broken down by ultra-violet light.

$$OCl^-(aq) + \text{uv light} \rightarrow Cl^-(aq) + \tfrac{1}{2}O_2(g)$$

Which method would maintain the highest concentration of HOC*l*(aq)?

**A** acidify the pool water
**B** add a solution of chloride ions
**C** add a solution of hydroxide ions
**D** bubble air through the water

**17 9701/01/M/J/07/Q9**

Two equilibria are shown below.

reaction I $2X_2(g) + Y_2(g) \rightleftharpoons 2X_2Y(g)$

reaction II $X_2Y(g) \rightleftharpoons X_2(g) + \frac{1}{2}Y_2(g)$

The numerical value of $K_c$ for reaction I is 2.

Under the same conditions, what is the numerical value of $K_c$ for reaction II?

**A** $\frac{1}{\sqrt{2}}$ **B** $\frac{1}{2}$ **C** $\frac{1}{4}$ **D** –2



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**18 9701/01/O/N/07/Q10**

Nitrogen dioxide decomposes on heating according to the following equation.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 4 mol of nitrogen dioxide were put into a 1 $dm^3$ container and heated to a constant temperature, the equilibrium mixture contained 0.8 mol of oxygen.

What is the value of the equilibrium constant, $K_c$, at the temperature of the experiment?

**A** $\frac{0.8^2 \times 0.8}{4^2}$ **B** $\frac{1.6 \times 0.8}{2.4^2}$ **C** $\frac{1.6^2 \times 0.8}{4^2}$ **D** $\frac{1.6^2 \times 0.8}{2.4^2}$

**19 9701/01/O/N/08/Q11**

Dinitrogen tetroxide dissociates into nitrogen dioxide on heating.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

In an experiment the partial pressures of the gases at equilibrium were found to be $NO_2$, 0.33 atm; $N_2O_4$, 0.67 atm.

What is the numerical value of $K_p$ at the temperature of the experiment?

**A** 0.16 **B** 0.49 **C** 0.65 **D** 2.03

**20 9701/12/O/N/09/Q7**

The equilibrium

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H = +180\,kJ\,mol^{-1}$$

contributes to a series of reactions producing photochemical smog.

Which factors would affect the value of $K_p$ of the above equilibrium?

| | change in pressure | change in temperature | presence or absence of a catalyst |
|---|---|---|---|
| **A** | ✓ | ✓ | ✗ |
| **B** | ✓ | ✗ | ✓ |
| **C** | ✗ | ✓ | ✓ |
| **D** | ✗ | ✓ | ✗ |



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**21 9701/12/O/N/09/Q10**

Photochromic glass, used for sunglasses, darkens when exposed to bright light and becomes more transparent again when the light is less bright. The depth of colour of the glass is related to the concentration of silver atoms.

The following reactions are involved.

reaction 1 $Ag^+ + Cl^- \rightleftharpoons Ag + Cl$

reaction 2 $Cu^+ + Cl \rightarrow Cu^{2+} + Cl^-$

reaction 3 $Cu^{2+} + Ag \rightarrow Cu^+ + Ag^+$

Which statement about these reactions is correct?

**A** $Cu^+$ and $Cu^{2+}$ ions act as catalysts.

**B** $Cu^+$ ions act as an oxidising agent in reaction 2.

**C** Reaction 2 is the one in which light is absorbed.

**D** $Ag^+$ ions are oxidised in reaction 1.

**22 9701/12/M/J/10/Q9**

The table gives the concentrations and pH values of the aqueous solutions of two compounds, X and Y. Either compound could be an acid or a base.

| | X | Y |
|---|---|---|
| concentration | $2\,mol\,dm^{-3}$ | $2\,mol\,dm^{-3}$ |
| pH | 6 | 9 |

Student P concluded that X is a strong acid.

Student Q concluded that the extent of dissociation is lower in X(aq) than in Y(aq).

Which of the students are correct?

**A** both P and Q **B** neither P nor Q **C** P only **D** Q only

**23 9701/12/O/N/10/Q9**

The following equilibrium is set up in a mixture of concentrated nitric and sulfuric acids.

$$HNO_3 + H_2SO_4 \rightleftharpoons$$

| | | | | |
|---|---|---|---|---|
| **A** | acid | acid | base | base |
| **B** | acid | base | base | acid |
| **C** | base | acid | acid | base |
| **D** | base | acid | base | acid |



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**24 9701/12/M/J/10/Q10**

The Haber process for the manufacture of ammonia is represented by the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Which statement is correct about this reaction when the temperature is increased?

**A** Both forward and backward rates increase.

**B** The backward rate only increases.

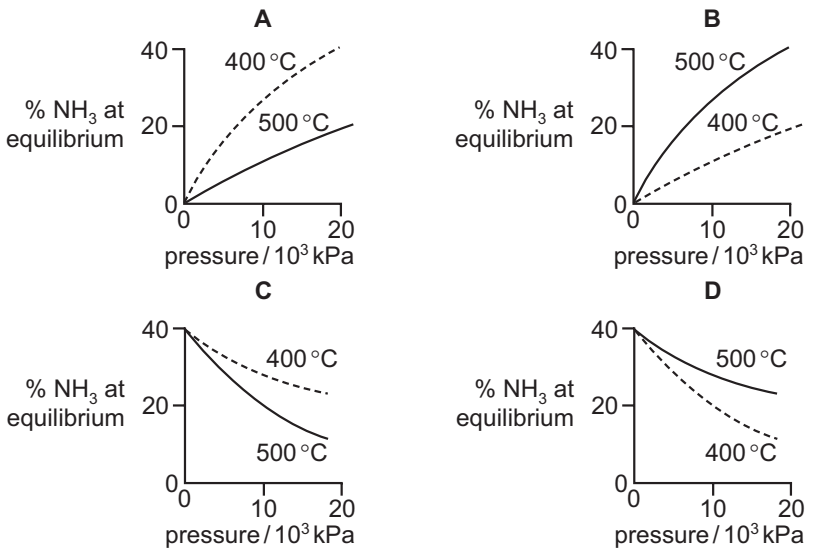
**C** The forward rate only increases.

**D** There is no effect on the backward or forward rate.

**25 9701/12/M/J/10/Q11**

The percentage of ammonia obtainable, if equilibrium were established during the Haber process, is plotted against the operating pressure for two temperatures, 400 °C and 500 °C.

Which diagram correctly represents the two graphs?




**26 9701/12/M/J/10/Q12**

Swimming pool water can be kept free of harmful bacteria by adding aqueous sodium chlorate( ), I NaOC*l*. This reacts with water to produce HOC*l* molecules which kill bacteria.

$$OCl^-(aq) + H_2O \rightleftharpoons OH^-(aq) + HOCl(aq)$$

In bright sunshine, the $OCl^-$ ion is broken down by ultra-violet light.

$$OCl^-(aq) + \text{uv light} \rightarrow Cl^-(aq) + \tfrac{1}{2}O_2(g)$$

Which method would maintain the highest concentration of HOC*l*(aq)?

**A** acidify the pool water

**B** add a solution of chloride ions

**C** add a solution of hydroxide ions

**D** bubble air through the water

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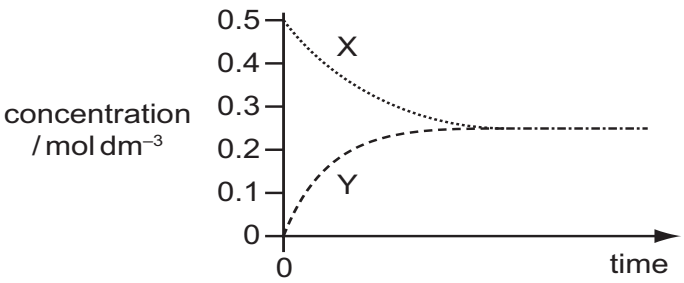
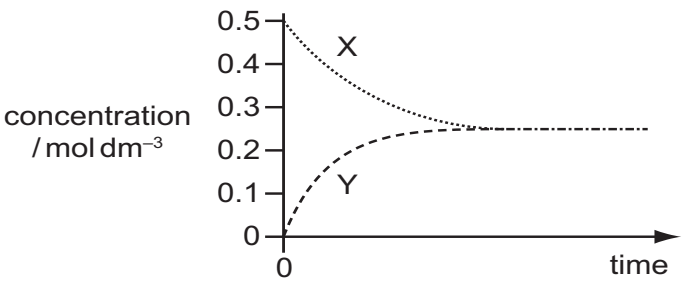
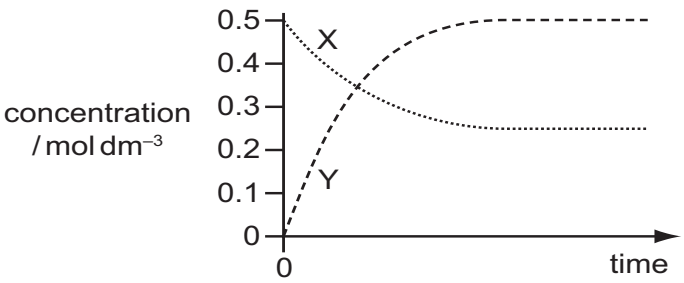
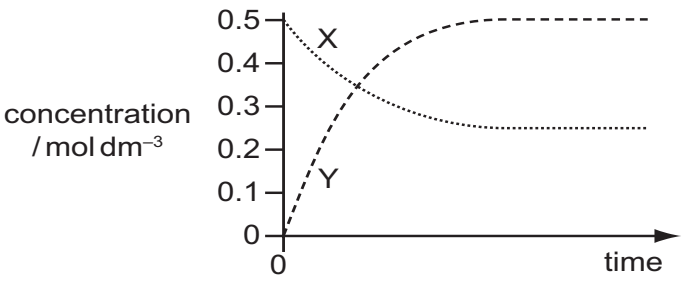
**27** **9701/12/O/N/10/Q11**

A dimer, X, is stable when solid but a dynamic equilibrium is set up in solution.

$$X(aq) \rightleftharpoons 2Y(aq)$$

A solution of X has an initial concentration of 0.50 mol dm$^{-3}$. When equilibrium has been reached [X(aq)] has fallen to 0.25 mol dm$^{-3}$.

The changes in [X(aq)] and [Y(aq)] are plotted against time until equilibrium is reached. The value of $K_c$ is then calculated. Which graph and value for $K_c$ are correct?

| | graph | $K_c$ / mol dm$^{-3}$ |
|---|---|---|
| **A** |   | 1 |
| **B** |   | 2 |
| **C** |   | 1 |
| **D** |   | 2 |

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**28 9701/12/O/N/11/Q12**

For the reaction

$$W(aq) + 2X(aq) \rightleftharpoons 2Y(aq) + 3Z(aq)$$

what are the correct units for the equilibrium constant $K_c$?

**A** $mol\,dm^{-3}$ **B** $mol^2\,dm^{-6}$ **C** $mol^{-1}\,dm^3$ **D** $mol^{-2}\,dm^6$

**29 9701/12/O/N/11/Q7**

For the equilibrium $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, what will change the value of $K_p$?

**A** adding a catalyst
**B** adding more $O_2$
**C** increasing the pressure
**D** increasing the temperature

**30 9701/12/O/N/11/Q11**

For the reaction $W(aq) + 2X(aq) \rightleftharpoons 2Y(aq) + 3Z(aq)$

what are the correct units for the equilibrium constant $K_c$?

**A** $mol\,dm^{-3}$ **B** $mol^2\,dm^{-6}$ **C** $mol^{-1}\,dm^3$ **D** $mol^{-2}\,dm^6$

**31 9701/12/M/J/11/Q4**

The esterification reaction ethanol + ethanoic acid $\rightleftharpoons$ ethyl ethanoate + water

is an equilibrium. The forward reaction is exothermic.

How can the value of the equilibrium constant $K_C$ be increased?

**A** by adding a little concentrated sulfuric acid as a catalyst
**B** by increasing the initial concentration of ethanol
**C** by lowering the temperature
**D** by raising the temperature

**32 9701/12/M/J/12/Q7**

Two moles of compound P were placed in a vessel. The vessel was heated and compound P was partly decomposed to produce Q and R. A dynamic equilibrium between chemicals P, Q and R was established.

At equilibrium $x$ moles of R were present and the total number of moles present was $(2 + \frac{x}{2})$.

What is the equation for this equilibrium reaction?

**A** $P \rightleftharpoons 2Q + R$
**B** $2P \rightleftharpoons 2Q + R$
**C** $2P \rightleftharpoons Q + R$
**D** $2P \rightleftharpoons Q + 2R$

STUDENTS RESOURCE



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**33 9701/12/M/J/12/Q9**

Methanol is manufactured by reacting carbon dioxide and hydrogen.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -49\,kJ\,mol^{-1}$$

What would increase the equilibrium yield of methanol in this process?

**A** adding a catalyst
**B** adding an excess of steam
**C** increasing the pressure
**D** increasing the temperature

**34 9701/12/M/J/13/Q8**

The reaction between sulfur dioxide and oxygen is a dynamic equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

What happens when the pressure of the system is increased?

**A** The rate of reaction will decrease and the position of the equilibrium will move to the left.

**B** The rate of reaction will decrease and the position of the equilibrium will move to the right.

**C** The rate of reaction will increase and the position of the equilibrium will move to the left.

**D** The rate of reaction will increase and the position of the equilibrium will move to the right.

**35 9701/12/O/N/13/Q9**

Nitrogen reacts with hydrogen to produce ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

A mixture of 2.00 mol of nitrogen, 6.00 mol of hydrogen, and 2.40 mol of ammonia is allowed to reach equilibrium in a sealed vessel of volume 1 $dm^3$ under certain conditions. It was found that 2.32 mol of nitrogen were present in the equilibrium mixture.

What is the value of $K_c$ under these conditions?

**A** $\dfrac{(1.76)^2}{(2.32)(6.96)^3}$ **B** $\dfrac{(1.76)^2}{(2.32)(6.32)^3}$

**C** $\dfrac{(2.08)^2}{(2.32)(6.32)^3}$ **D** $\dfrac{(2.40)^2}{(2.32)(6.00)^3}$



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**36 9701/12/O/N/13/Q18**

Transition metals and their compounds are used as catalysts.

Which row is correct?

| | transition metal present in the catalyst used in the Contact process | transition metal present in the catalyst used in the Haber process |
|---|---|---|
| **A** | iron | iron |
| **B** | iron | vanadium |
| **C** | vanadium | iron |
| **D** | vanadium | vanadium |

**37 9701/12/M/J/14/Q4**

Hydrogen and carbon dioxide gases are mixed in equal molar amounts at 800 K. A reversible reaction takes place.

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

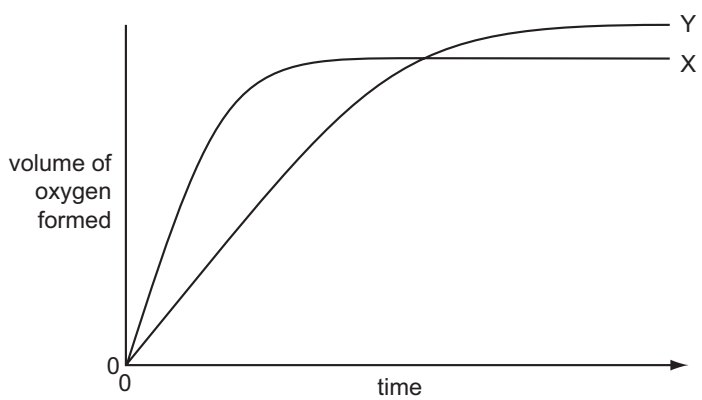
At equilibrium, the partial pressures of $H_2$ and $CO_2$ are both 10.0 kPa. $K_p$ is 0.288 at 800 K.

What is the partial pressure of CO in the equilibrium mixture?

**A** 5.37 kPa **B** 18.6 kPa **C** 28.8 kPa **D** 347 kPa

**38 9701/12/M/J/14/Q5**

In the diagram, curve X was obtained by observing the decomposition of 100 $cm^3$ of 1.0 mol $dm^{-3}$ hydrogen peroxide, catalysed by manganese(IV) oxide.




Which alteration to the original experimental conditions would produce curve Y?

**A** adding more manganese(IV) oxide

**B** adding some 0.1 mol $dm^{-3}$ hydrogen peroxide

**C** adding water

**D** raising the temperature

STUDENTS RESOURCE



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**39 9701/12/M/J/14/Q7**

The formation of hydrogen and ethyne, $C_2H_2$, from methane reaches dynamic equilibrium.

$$2CH_4(g) \rightleftharpoons 3H_2(g) + C_2H_2(g)$$

What are the units of $K_c$?

**A** $mol\,dm^{-3}$ **B** $mol^2\,dm^{-6}$ **C** $mol^3\,dm^{-9}$ **D** $mol^4\,dm^{-12}$

**40 9701/12/M/J/15/Q10**

Photochromic glass, used for sunglasses, darkens when exposed to bright light and becomes more transparent again when the light is less bright. The darkness of the glass is related to the concentration of silver atoms.

The following reactions are involved.

reaction 1 $Ag^+ + Cl^- \rightleftharpoons Ag + Cl$

reaction 2 $Cu^+ + Cl \rightarrow Cu^{2+} + Cl^-$

reaction 3 $Cu^{2+} + Ag \rightarrow Cu^+ + Ag^+$

Which statement about these reactions is correct?

**A** $Cu^+$ and $Cu^{2+}$ ions act as catalysts.

**B** $Cu^+$ ions act as an oxidising agent in reaction 2.

**C** Reaction 3 increases the darkness of the glass.

**D** Silver atoms are reduced in reaction 3.

**41 9701/12/M/J/15/Q9**

When a sample of HI is warmed to a particular temperature the equilibrium below is established.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

At this temperature, it is found that the partial pressure of HI(g) is 28 times the partial pressure of $H_2(g)$.

What is the value of $K_p$ at this temperature?

**A** $1.28 \times 10^{-3}$ **B** 0.035 **C** 28 **D** 784

**42 9701/11/M/J/15/Q8**

In which reaction is the underlined substance acting as a base?

**A** $HNO_3 + \underline{H_2SO_4} \rightarrow H_2NO_3^+ + HSO_4^-$

**B** $HSiO_3^- + \underline{HCN} \rightarrow CN^- + H_2O + SiO_2$

**C** $HNO_2 + \underline{HCO_3^-} \rightarrow H_2O + CO_2 + NO_2^-$

**D** $C_6H_5O^- + \underline{CH_2ClCO_2H} \rightarrow C_6H_5OH + CH_2ClCO_2^-$

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**43 9701/12/M/J/15/Q8**

Nitrogen dioxide, $NO_2$, exists in equilibrium with dinitrogen tetroxide, $N_2O_4$.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57\,kJ\,mol^{-1}$$

Which conditions give the greatest percentage of $N_2O_4(g)$ at equilibrium?

| | pressure | temperature |
|---|---|---|
| **A** | high | high |
| **B** | high | low |
| **C** | low | high |
| **D** | low | low |

**44 9701/11/M/J/15/Q9**

One molecule of haemoglobin, Hb, can bind with four molecules of oxygen according to the following equation.

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$$

When the equilibrium concentration of $O_2$ is $7.6 \times 10^{-6}\,mol\,dm^{-3}$, the equilibrium concentrations of Hb and $Hb(O_2)_4$ are equal.

What is the value of $K_c$ for this equilibrium?

**A** $3.0 \times 10^{20}$ **B** $1.3 \times 10^{5}$ **C** $7.6 \times 10^{-6}$ **D** $3.3 \times 10^{-21}$

**45 9701/12/F/M/17/Q3**

Two moles of compound P were placed in a sealed container. The container was heated and P was partially decomposed to produce Q and R only. A dynamic equilibrium between P, Q and R was established.

At equilibrium *x* moles of R were present and the total number of moles present was $\left(2 + \frac{x}{2}\right)$.

What is the equation for this reversible reaction?

**A** $P \rightleftharpoons 2Q + R$

**B** $2P \rightleftharpoons 2Q + R$

**C** $2P \rightleftharpoons Q + R$

**D** $2P \rightleftharpoons Q + 2R$

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**46 9701/12/F/M/17/Q11**

Ammonia is manufactured from nitrogen and hydrogen using the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

What is the expression for $K_c$ for this equilibrium?

**A** $\dfrac{2[NH_3(g)]}{[N_2(g)] + 3[H_2(g)]}$

**B** $\dfrac{2[NH_3(g)]}{[N_2(g)] \times 3[H_2(g)]}$

**C** $\dfrac{[NH_3(g)]^2}{[N_2(g)] + [H_2(g)]^3}$

**D** $\dfrac{[NH_3(g)]^2}{[N_2(g)] \times [H_2(g)]^3}$

**47 9701/11/M/J/17/Q10**

Methanol can be produced from hydrogen and carbon monoxide.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$

What is the expression for $K_p$ for this reaction?

**A** $K_p = \dfrac{(2p_{H_2})^2 \times p_{CO}}{p_{CH_3OH}}$

**B** $K_p = \dfrac{(p_{H_2})^2 \times p_{CO}}{p_{CH_3OH}}$

**C** $K_p = \dfrac{p_{CH_3OH}}{(p_{H_2})^2 \times p_{CO}}$

**D** $K_p = \dfrac{p_{CH_3OH}}{p_{CO} \times (2p_{H_2})^2}$

**48 9701/12/M/J/17/Q9**

Hydrogen and carbon dioxide gases are mixed at 800 K. A reversible reaction takes place.

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

At equilibrium, the partial pressures of $H_2$ and $CO_2$ are both 10.0 kPa. $K_p$ is 0.288 at 800 K.

What is the partial pressure of CO in the equilibrium mixture?

**A** 5.37 kPa **B** 18.6 kPa **C** 28.8 kPa **D** 347 kPa



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**49 9701/12/M/J/17/Q7**

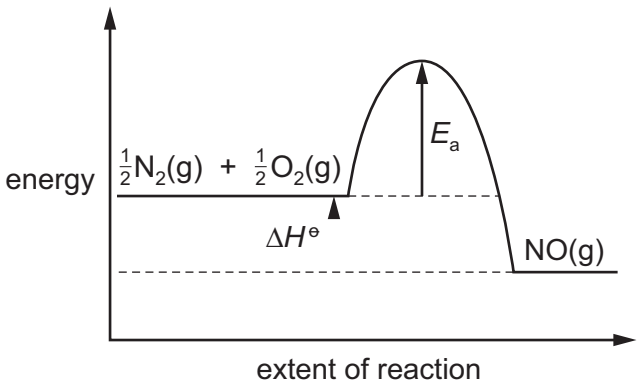
In the high temperatures of car engines, nitrogen reacts with oxygen to give nitrogen monoxide.

$$\tfrac{1}{2}N_2(g) + \tfrac{1}{2}O_2(g) \rightarrow NO(g) \qquad \Delta H^{\ominus} = +90\,kJ\,mol^{-1}$$

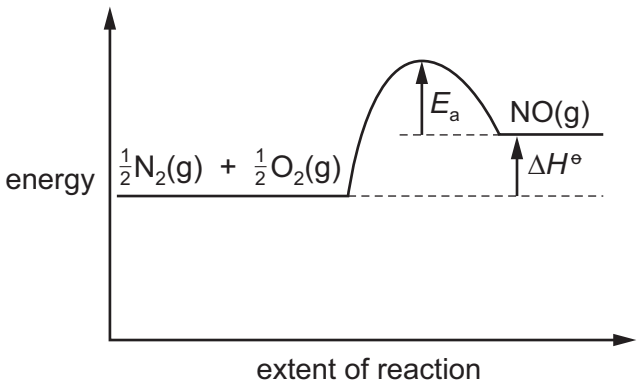
This reaction has activation energy $E_a$.

Which reaction pathway diagram could correctly represent this reaction?

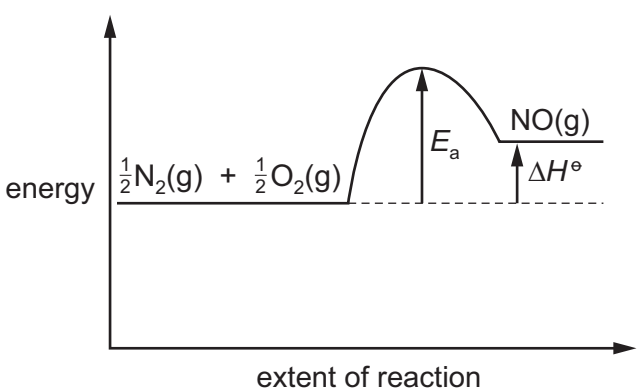
**A**



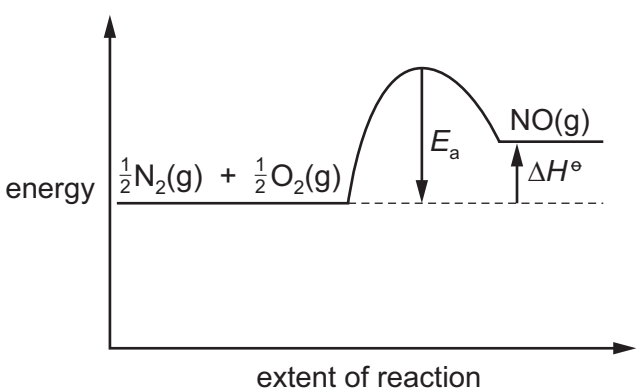

**B**




**C**




**D**






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**50 9701/12/M/J/17/Q10**

A reaction involved in the Contact process is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = -197\,kJ\,mol^{-1}$$

The reaction is investigated at 200 kPa and 700 K and the value of the equilibrium constant, $K_p$, is found to be Y. The reaction is then investigated at 1000 kPa and 700 K and the value of $K_p$ is found to be Z.

Which statement comparing Y and Z is correct?

**A** Y and Z are the same.

**B** Y is greater than Z.

**C** Z is 2.2 times greater than Y.

**D** Z is 5.0 times greater than Y.

**51 9701/13/M/J/17/Q9**

Ammonia is produced by the Haber process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H^{\ominus} = -92\,kJ\,mol^{-1}$$

A fault in the temperature control during the process resulted in the temperature changing to 600 °C for two hours.

What effect did this have on the ammonia production during this time?

**A** Ammonia was formed faster. The equilibrium yield decreased.

**B** Ammonia was formed faster. The equilibrium yield increased.

**C** Ammonia was formed slower. The equilibrium yield decreased.

**D** Ammonia was formed slower. The equilibrium yield increased.

**52 9701/13/M/J/17/Q10**

For the reaction shown, an equilibrium is established at a temperature of 700 K.

The equilibrium constant, $K_p$, for the reaction is 9.80 kPa. The partial pressure of $N_2O_4$ at equilibrium is 80.0 kPa.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

What is the partial pressure of $NO_2$ at equilibrium?

**A** 8.16 kPa **B** 28.0 kPa **C** 66.6 kPa **D** 784 kPa

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**53 9701/11/O/N/18/Q9**

In this question you should assume that all gases behave ideally.

Hydrogen and iodine react reversibly in the following reaction. The system reaches dynamic equilibrium.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.5\,kJ\,mol^{-1}$$

Which statement **must** be true for the $K_p$ of this equilibrium to be constant?

**A** The partial pressures of $H_2$, $I_2$ and HI are equal.

**B** The external pressure is constant.

**C** The forward and reverse reactions have stopped.

**D** The temperature is constant.

**54 9701/12/O/N/18/Q9**

In this question, all pressures are measured in atm.

The equation represents the equilibrium between three gaseous substances X, Y and Z.

$$X + 3Y \rightleftharpoons 2Z$$

At temperature $T_1$, the numerical value of $K_p$, the equilibrium constant, is 2.

At a higher temperature $T_2$, the partial pressures at equilibrium are as shown.

| X | Y | Z |
|---|---|---|
| 2 | 3 | 5 |

Which row is correct?

| | the numerical value of $K_p$ at $T_2$ | the forward reaction is |
|---|---|---|
| **A** | 54 / 25 | endothermic |
| **B** | 54 / 25 | exothermic |
| **C** | 25 / 54 | endothermic |
| **D** | 25 / 54 | exothermic |

**55 9701/12/F/M/19/Q11**

When copper is added to a solution of silver ions, the following equilibrium is established.

$$Cu(s) + 2Ag^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2Ag(s) \qquad K_c = 1.0 \times 10^5$$

What is the concentration of silver ions at equilibrium when $[Cu^{2+}] = 0.10\,mol\,dm^{-3}$?

**A** $5.0 \times 10^{-7}\,mol\,dm^{-3}$

**B** $5.0 \times 10^{-4}\,mol\,dm^{-3}$

**C** $1.0 \times 10^{-3}\,mol\,dm^{-3}$

**D** $1.0 \times 10^{2}\,mol\,dm^{-3}$

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**56 9701/11/M/J/19/Q10**

Hydrogen iodide gas decomposes reversibly producing iodine vapour and hydrogen.

$$2HI(g) \rightleftharpoons I_2(g) + H_2(g) \qquad \Delta H = +12\,kJ\,mol^{-1}$$

The position of the equilibrium for this reaction may be altered by changing the external conditions.

Which row correctly describes the change in position of equilibrium?

| | effect of increasing the pressure | effect of increasing the temperature |
|---|---|---|
| **A** | moves to the right | moves to the right |
| **B** | moves to the right | moves to the left |
| **C** | no change | moves to the right |
| **D** | no change | moves to the left |

**57 9701/12/M/J/19/Q10**

Ethyl ethanoate undergoes the following reaction.

$$CH_3CO_2C_2H_5 + H_2O \rightleftharpoons C_2H_5OH + CH_3CO_2H \qquad K_c = 0.27$$

Equal amounts of ethanoic acid and ethanol were mixed together and allowed to reach equilibrium.

At equilibrium, the concentrations of both ethanoic acid and ethanol were $0.42\,mol\,dm^{-3}$.

What is the concentration of ethyl ethanoate at equilibrium?

**A** $0.22\,mol\,dm^{-3}$

**B** $0.65\,mol\,dm^{-3}$

**C** $0.81\,mol\,dm^{-3}$

**D** $1.54\,mol\,dm^{-3}$



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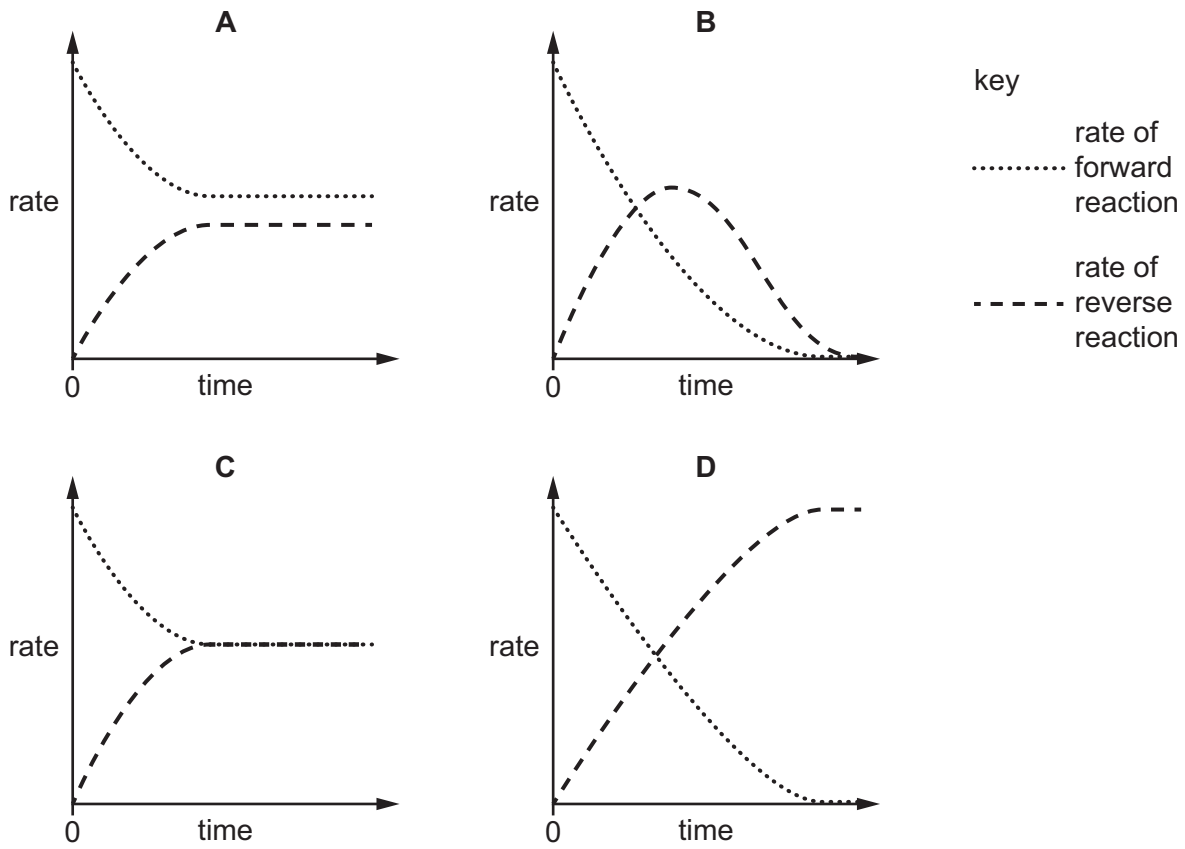
**58 9701/11/O/N/19/Q10**

Two compounds X and Y react to produce compound Z. The reaction is reversible.

$$X + Y \rightleftharpoons Z$$

When X and Y are mixed together in a closed system a dynamic equilibrium is gradually established.

Which graph could represent the change in the rates of the forward and reverse reactions over time?




**59 9701/11/O/N/19/Q11**

The reaction between sulfur dioxide and oxygen is reversible.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 280\,mol^{-1}\,dm^3 \text{ at } 1000\,K$$

In an equilibrium mixture at 1000 K the sulfur dioxide concentration is 0.200 mol dm$^{-3}$ and the oxygen concentration is 0.100 mol dm$^{-3}$.

What is the sulfur trioxide concentration?

**A** 1.058 mol dm$^{-3}$

**B** 1.120 mol dm$^{-3}$

**C** 2.366 mol dm$^{-3}$

**D** 5.600 mol dm$^{-3}$



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**60 9701/12/O/N/19/Q10**

The decomposition of $SO_3(g)$ is a dynamic equilibrium.

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$$

What happens when the pressure of the system is increased?

**A** The rate of reaction will decrease and the position of the equilibrium will move to the left.

**B** The rate of reaction will decrease and the position of the equilibrium will move to the right.

**C** The rate of reaction will increase and the position of the equilibrium will move to the left.

**D** The rate of reaction will increase and the position of the equilibrium will move to the right.

**61 9701/12/F/M/20/Q6**

The equation for the reaction between silver chloride and aqueous ammonia is shown.

$$AgCl(s) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) + Cl^-(aq)$$

What are the units of $K_c$ for this reaction?

**A** no units **B** $mol^{-1}\,dm^3$ **C** $mol\,dm^{-3}$ **D** $mol^2\,dm^{-6}$

**62 9701/13/M/J/20/Q11**

Two reactions are shown.

reaction 1 $X_2(g) + Y_2(g) \rightleftharpoons 2XY(g)$

reaction 2 $XY(g) \rightleftharpoons \frac{1}{2}X_2(g) + \frac{1}{2}Y_2(g)$

The equilibrium constant, $K_p$, for reaction 1 is 0.0052.

What is $K_p$ for reaction 2?

**A** $2.6 \times 10^{-3}$ **B** 13.9 **C** 192.3 **D** 384.6



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**63 9701/12/F/M/20/Q11**

The main stage in the Contact process is an equilibrium reaction.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

Which row describes the effect of the named condition on the equilibrium yield?

| | presence of catalyst | high pressure | high temperature |
|---|---|---|---|
| **A** | no effect on yield | decreases yield | increases yield |
| **B** | no effect on yield | increases yield | decreases yield |
| **C** | increases yield | decreases yield | increases yield |
| **D** | increases yield | increases yield | decreases yield |

**64 9701/11/M/J/20/Q1**

Ethene can be oxidised to form epoxyethane, $C_2H_4O$.

$$C_2H_4(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons C_2H_4O(g) \qquad \Delta H^{\ominus} = -107\,kJ\,mol^{-1}$$

Which set of conditions gives the greatest yield of epoxyethane at equilibrium?

| | pressure | temperature / °C |
|---|---|---|
| **A** | high | 100 |
| **B** | high | 200 |
| **C** | low | 100 |
| **D** | low | 200 |

**65 9701/11/M/J/20/Q7**

What are the units of $K_p$ for the reaction shown?

$$H_2O(g) + C(s) \rightleftharpoons H_2(g) + CO(g)$$

**A** $Pa^{-1}$ **B** Pa **C** $Pa^2$ **D** no units



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**66 9701/12/M/J/20/Q3**

The catalysed formation of ammonia by the Haber process can be represented by the equation shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Which change in conditions will increase both the rate of formation and the equilibrium yield of ammonia?

**A** decrease in the temperature

**B** increase in the temperature

**C** increase in the pressure

**D** increase in the surface area of the catalyst

**67 9701/12/M/J/20/Q11**

$PCl_5$ decomposes as shown.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

1.0 mol of $PCl_5(g)$, 1.0 mol of $PCl_3(g)$ and 1.0 mol of $Cl_2(g)$ are placed in a container of volume 1 $dm^3$ at 250 °C and allowed to reach equilibrium.

At this temperature, the equilibrium mixture contains 1.8 moles of $PCl_3$.

What is the value of $K_c$ at 250 °C?

**A** 1 **B** 1.8 **C** 9 **D** 16.2

**68 9701/12/M/J/20/Q15**

Ammonium carbonate is a crystalline solid. On gentle warming a reaction occurs, forming ammonia as one product.

How are the carbonate ions behaving during this reaction?

**A** Brønsted-Lowry acid

**B** Brønsted-Lowry base

**C** oxidising agent

**D** reducing agent

**69 9701/13/M/J/20/Q6**

Which solution has the lowest pH value?

**A** 0.01 mol $dm^{-3}$ butanoic acid

**B** 0.01 mol $dm^{-3}$ ethanoic acid

**C** 0.01 mol $dm^{-3}$ hydrochloric acid

**D** 0.01 mol $dm^{-3}$ sulfuric acid

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**70 9701/13/M/J/20/Q7**

The element sulfur produces a mass spectrum with the following peaks.

| *m* / *e* value of peak | relative abundance |
|---|---|
| 32 | 95.02 |
| 33 | 0.76 |
| 34 | 4.20 |

Which relative atomic mass of sulfur can be calculated from these data, given to four significant figures?

**A** 32.07 **B** 32.08 **C** 32.09 **D** 32.10



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# Physical Chemistry

8
TOPIC

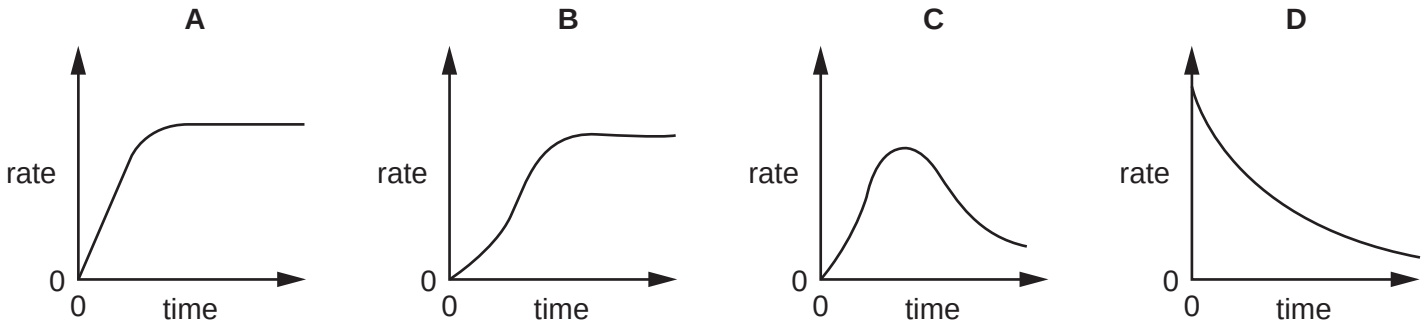
# Reaction Kinetics



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**1 9701/1/M/J/02/Q11**

Which curve is obtained if the rate of reaction is plotted against time for an autocatalytic reaction (i.e. a reaction in which one of the products catalyses the reaction)?




**2 9701/1/O/N/02/Q10**

At 600 °C oxides of nitrogen react with unburnt hydrocarbons in a catalytic converter in a car exhaust. The equation using methane as representative of a hydrocarbon molecule would be as follows.

$$4NO + CH_4 \rightarrow 2N_2 + CO_2 + 2H_2O$$

Which statement is likely to be true about the energy change of this reaction?

**A** It is endothermic as heat energy is converted into chemical energy.

**B** It is exothermic as a high temperature is required.

**C** It is exothermic as the triple bond $N \rightleftharpoons O$ is broken.

**D** It is exothermic as the products have large negative enthalpy changes of formation.

**3 9701/1/O/N/02/Q12**

A piece of zinc foil dissolved completely in 20 $cm^3$ of a dilute sulphuric acid solution and the volume of hydrogen evolved was noted at equal, short time intervals. Another piece of zinc foil of the same surface area and mass was added to 40 $cm^3$ of the same solution of dilute sulphuric acid.

How will the initial rate of reaction and the total volume of hydrogen evolved in this second experiment compare to the first experiment?

| | *initial rate of reaction* | *total volume of hydrogen evolved* |
|---|---|---|
| **A** | no change | decrease |
| **B** | no change | no change |
| **C** | increase | no change |
| **D** | increase | increase |



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**4 9701/1/M/J/03/Q12**

It is often said that the rate of a typical reaction is roughly doubled by raising the temperature by 10 °C.

What explains this observation?

**A** Raising the temperature by 10 °C doubles the average energy of each molecule.

**B** Raising the temperature by 10 °C doubles the average velocity of the molecules.

**C** Raising the temperature by 10 °C doubles the number of molecular collisions in a given time.

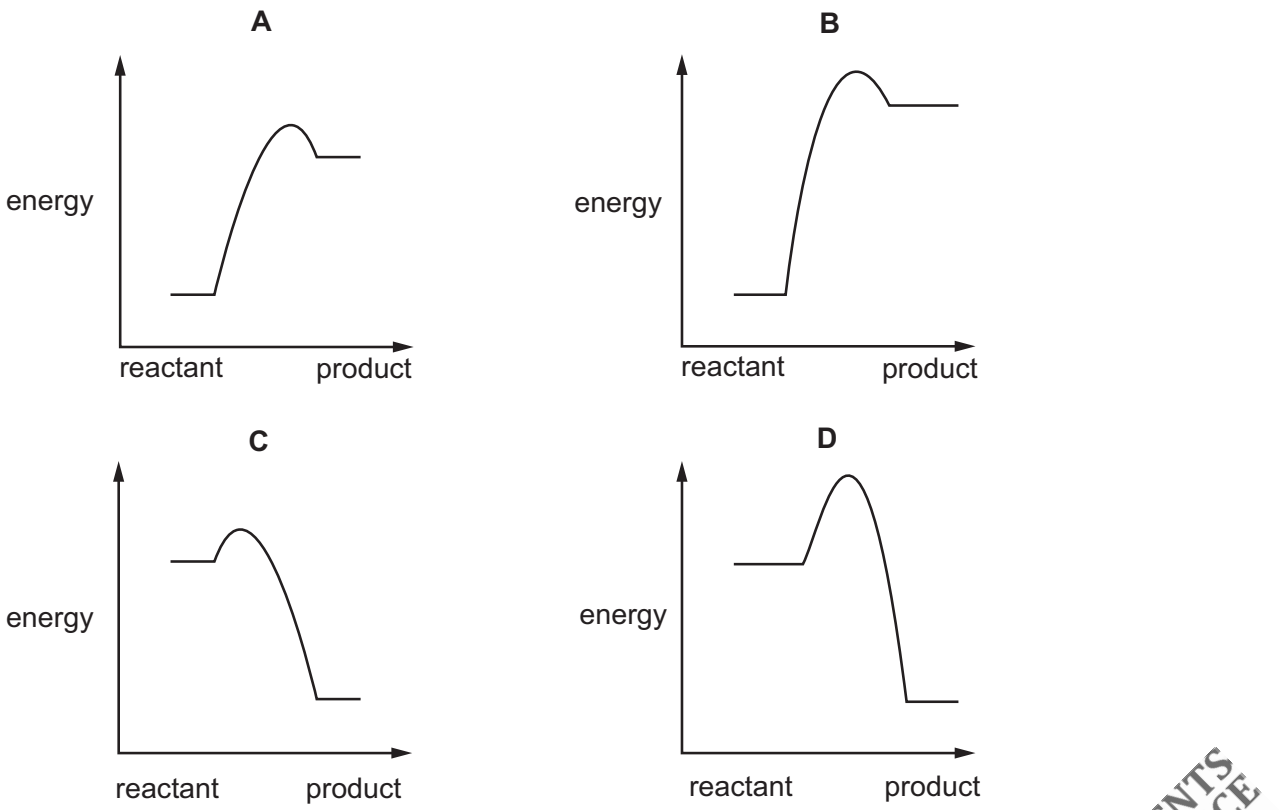
**D** Raising the temperature by 10 °C doubles the number of molecules having more than a certain minimum energy.

**5 9701/01/M/J/04/Q12**

Four reactions of the type shown are studied at the same temperature.

$$X(g) + Y(g) \rightarrow Z(g)$$

Which is the correct reaction pathway diagram for the reaction that would proceed most rapidly and with good yield?

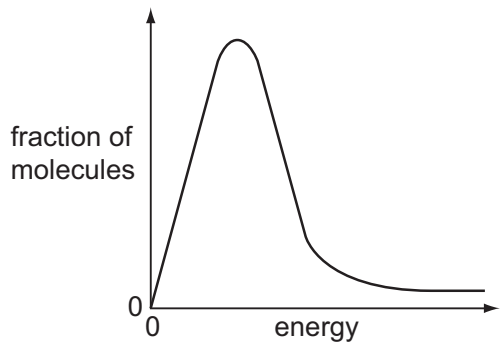





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**6 9701/01/O/N/04/Q12**

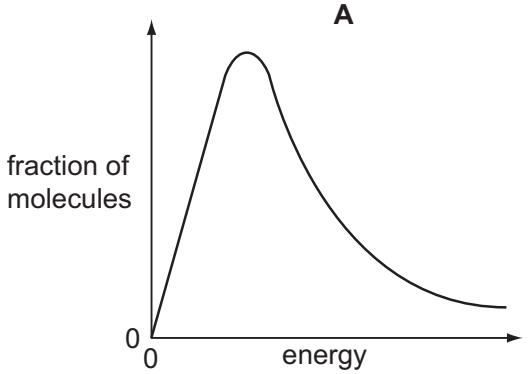
The diagram shows the Boltzmann distribution for air at room temperature.



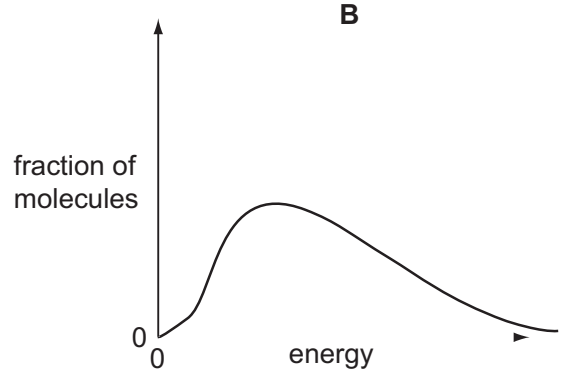

Air inside a car engine can reach a temperature of about 500 °C, enabling nitrogen to react with oxygen to form nitrogen oxides.

What would be the Boltzmann distribution for the air inside this car engine?

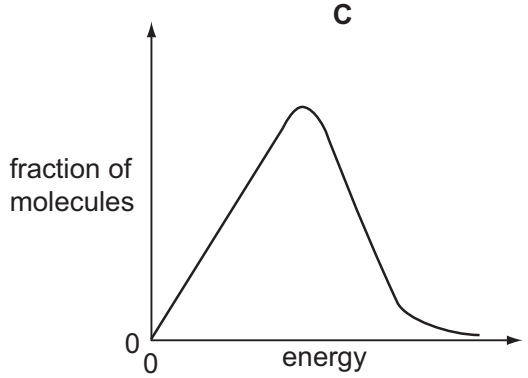
**A**



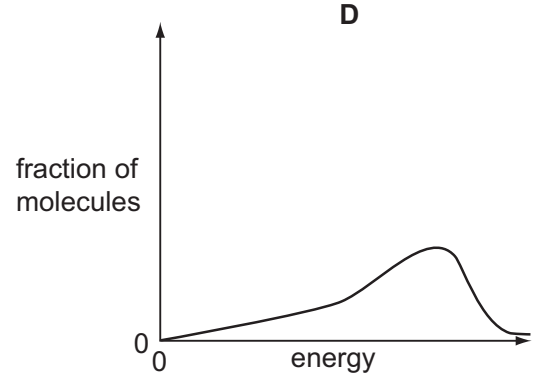

**B**




**C**




**D**

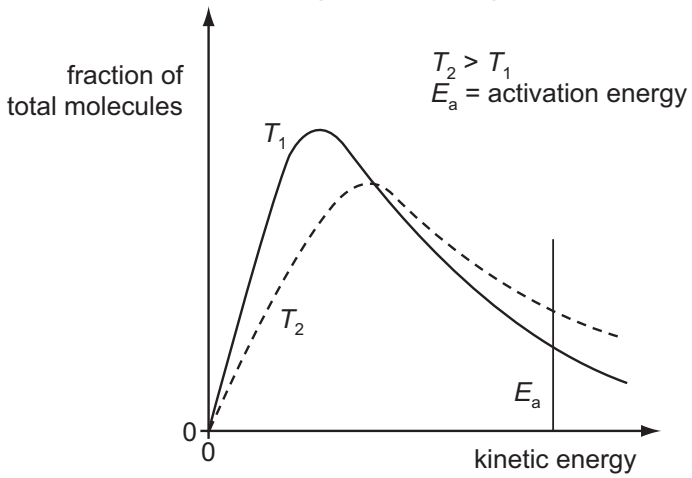





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**7 9701/01/O/N/05/Q11**

The distribution of molecular kinetic energies within a gas at temperature $T_1$ and $T_2$ are shown in the diagram.




Which statement correctly explains why a small increase in temperature leads to a significant increase in the rate of a gaseous reaction?

**A** The frequency of collisions between molecules is greater at a higher temperature.

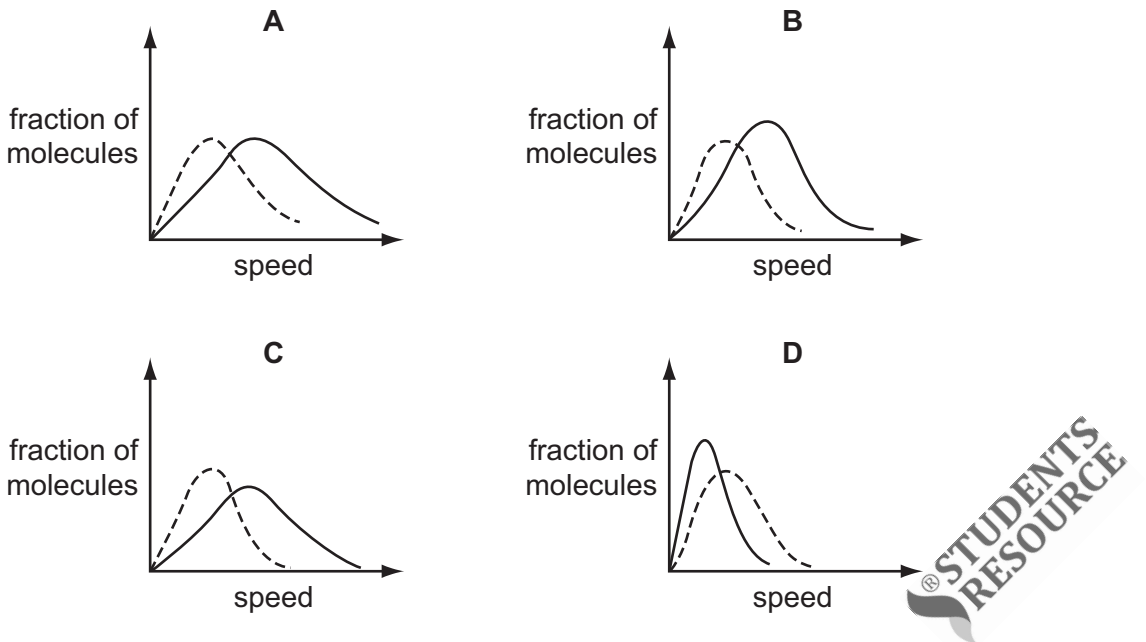
**B** The activation energy of the reaction is less when the gases are at a higher temperature.

**C** The frequency of collisions between molecules with kinetic energy greater than the activation energy is greater at higher temperature.

**D** The proportion of molecules with more kinetic energy than the activation energy is lower at a higher temperature.

**8 9701/01/M/J/06/Q12**

Which solid-line curve most accurately represents the distribution of molecular speeds in a gas at 500 K if the dotted-line curve represents the corresponding distribution for the same gas at 300 K?

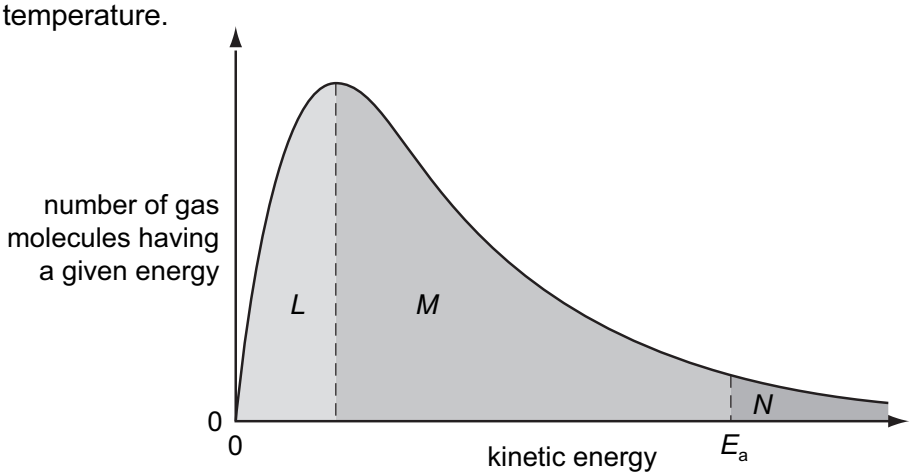





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**9 9701/01/M/J/07/Q10**

The Boltzmann distribution shows the number of molecules having a particular kinetic energy at constant temperature.

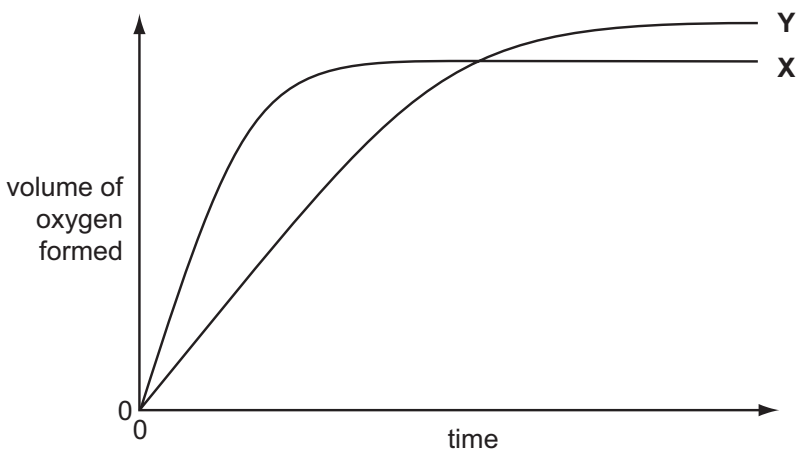



If the temperature is decreased by 10 °C, what happens to the size of the areas labelled *L*, *M* and *N*?

| | *L* | *M* | *N* |
|---|---|---|---|
| **A** | decreases | decreases | decreases |
| **B** | decreases | increases | decreases |
| **C** | increases | decreases | decreases |
| **D** | increases | decreases | increases |

**10 9701/01/M/J/07/Q11**

In the diagram, curve **X** was obtained by observing the decomposition of 100 $cm^3$ of 1.0 mol $dm^{-3}$ hydrogen peroxide, catalysed by manganese(IV) oxide.




Which alteration to the original experimental conditions would produce curve **Y**?

**A** adding water

**B** adding some 0.1 mol $dm^{-3}$ hydrogen peroxide

**C** using less manganese(IV) oxide

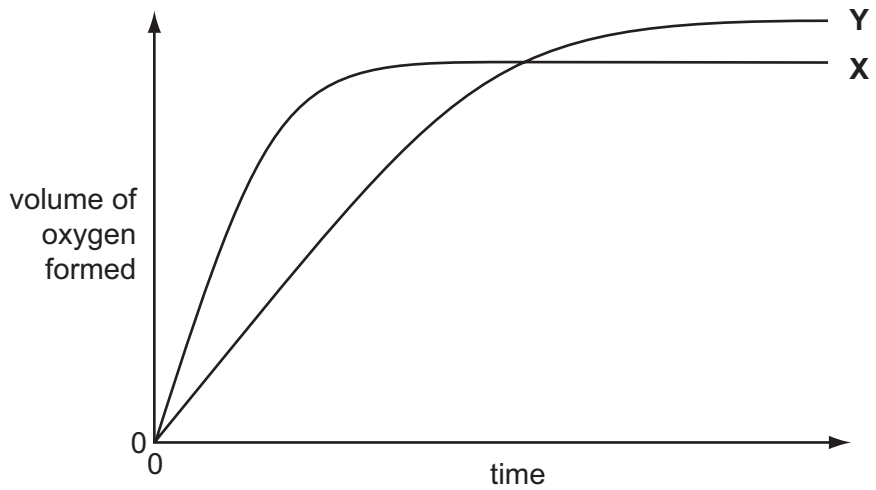
**D** lowering the temperature



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**11 9701/01/M/J/07/Q11**

In the diagram, curve **X** was obtained by observing the decomposition of 100 cm$^3$ of 1.0 mol dm$^{-3}$ hydrogen peroxide, catalysed by manganese(IV) oxide.




Which alteration to the original experimental conditions would produce curve **Y**?

**A** adding water

**B** adding some 0.1 mol dm$^{-3}$ hydrogen peroxide

**C** using less manganese(IV) oxide

**D** lowering the temperature

**12 9701/01/O/N/07/Q11**

It is often said that the rate of a typical reaction is roughly doubled by raising the temperature by 10 °C.

What explains this observation?

**A** Raising the temperature by 10 °C doubles the average kinetic energy of each molecule.

**B** Raising the temperature by 10 °C doubles the average velocity of the molecules.

**C** Raising the temperature by 10 °C doubles the number of molecular collisions in a given time.

**D** Raising the temperature by 10 °C doubles the number of molecules having more than a certain minimum energy.



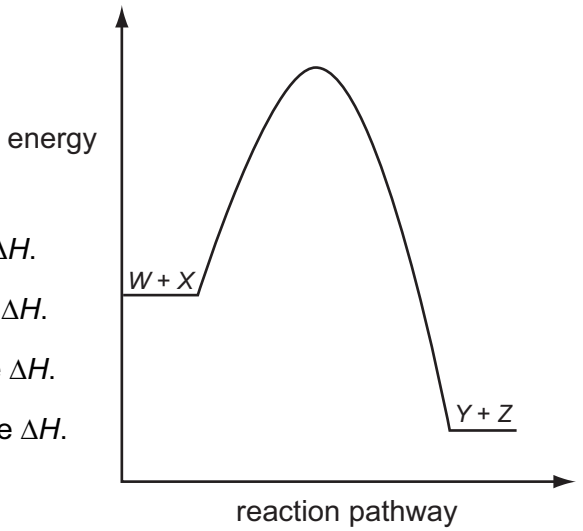
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**13 9701/01/O/N/08/Q9**

The diagram represents the reaction pathway for the following reaction.

$$W(g) + X(g) \rightarrow Y(g) + Z(g)$$

What statement can be made about the reverse reaction, $Y(g) + Z(g) \rightarrow W(g) + X(g)$?




**A** It will have a larger activation energy and a positive $\Delta H$.

**B** It will have a larger activation energy and a negative $\Delta H$.

**C** It will have a smaller activation energy and a positive $\Delta H$.

**D** It will have a smaller activation energy and a negative $\Delta H$.

**14 9701/12/O/N/09/Q33**

Why does a mixture of hydrogen gas and bromine gas react together faster at a temperature of 500 K than it does at a temperature of 400 K?

**1** A higher proportion of effective collisions occurs at 500 K.

**2** Hydrogen molecules and bromine molecules collide more frequently at 500 K.

**3** The activation energy of the reaction is lower at 500 K.



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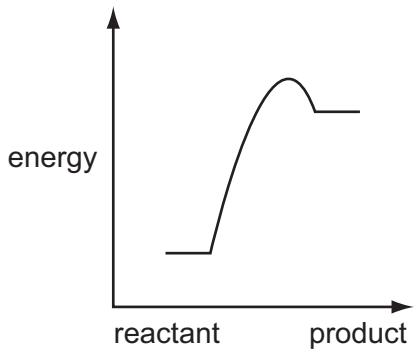
**15 9701/12/O/N/09/Q9**

Four reactions of the type shown are studied at the same temperature.

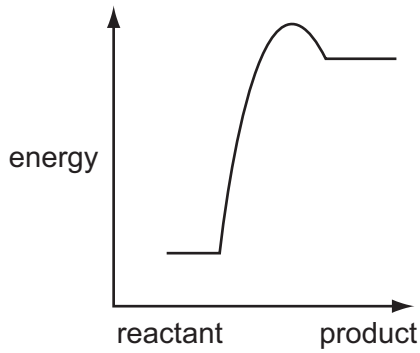
$$X(g) + Y(g) \rightarrow Z(g)$$

Which is the correct reaction pathway diagram for the reaction that would proceed **most** rapidly and with the **highest** yield?

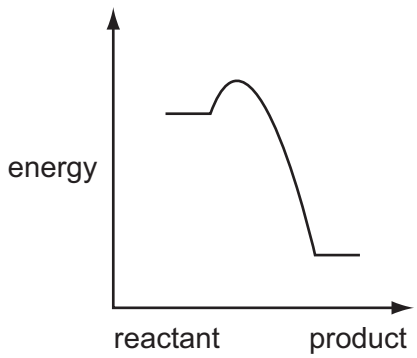
**A**



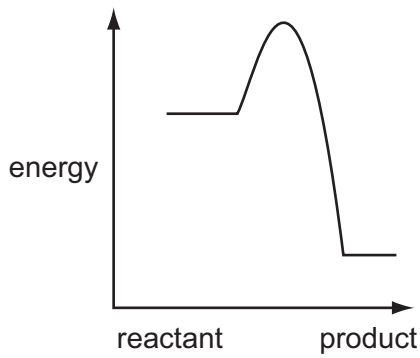

**B**




**C**




**D**

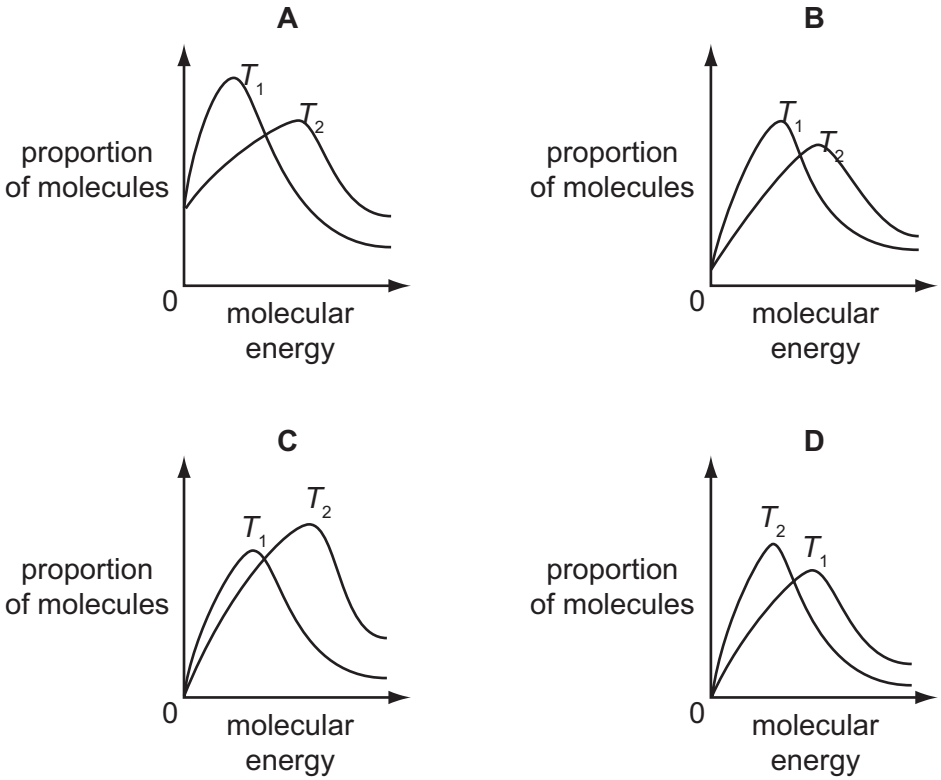





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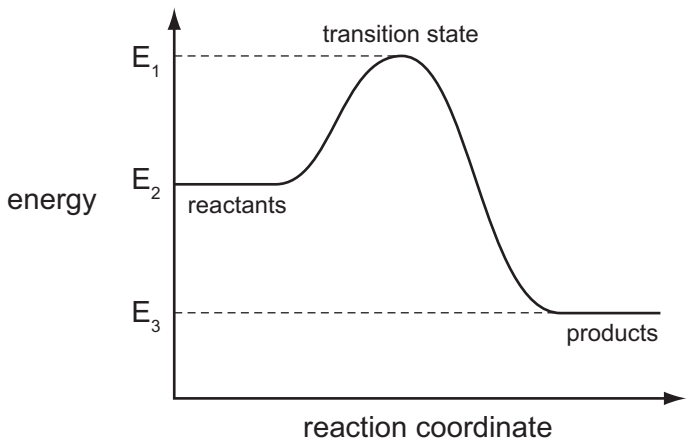
**16 9701/12/O/N/10/Q2**

Which diagram correctly represents the Boltzmann distribution of molecular energies at two temperatures $T_1$ and $T_2$, where $T_1$ = 300 K and $T_2$ = 310 K?




**17 9701/12/O/N/10/Q6**

The reaction pathway diagram below illustrates the energies of reactants, products and the transition state of a reaction.




Which expression represents the activation energy of the forward reaction?

**A** $E_1 - E_2$ **B** $E_1 - E_3$ **C** $E_2 - E_3$ **D** $(E_1 - E_2) - (E_2 - E_3)$

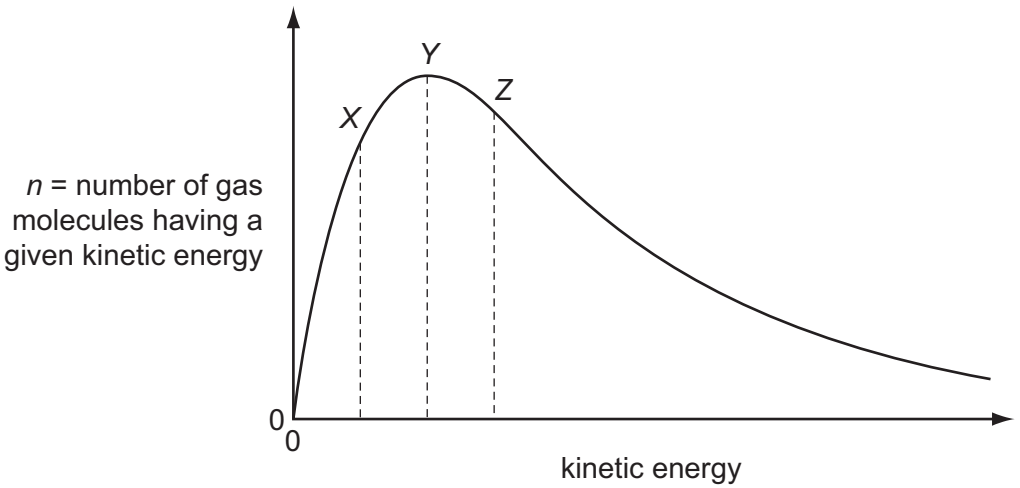
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**18 9701/12/M/J/11/Q6**

The Boltzmann distribution for a gas at constant temperature is shown below.




If the temperature of the gas is **reduced** by 10 °C the graph changes shape.

What happens to the values of *n* for the points marked *X*, *Y* and *Z*?

| | *X* | *Y* | *Z* |
|---|---|---|---|
| **A** | higher | lower | higher |
| **B** | higher | lower | lower |
| **C** | lower | higher | lower |
| **D** | lower | lower | lower |

**19 9701/12/O/N/11/Q1**

In the Haber process for the manufacture of ammonia, why is the heterogeneous catalyst iron in a finely divided state?

**A** to increase its surface area

**B** to produce the maximum reduction in the activation energy

**C** to reduce its loss during the reaction

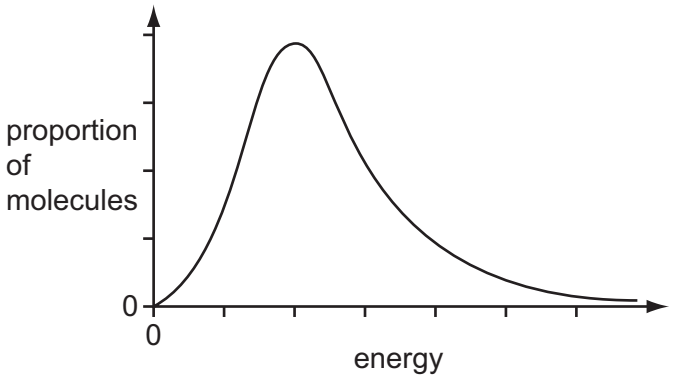
**D** to reduce its surface area



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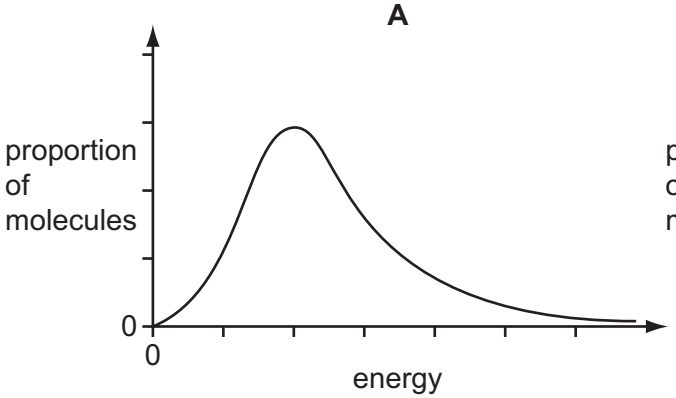
**20 9701/12/M/J/12/Q1**

The molecular energy distribution curve represents the variation in energy of the molecules of a gas at room temperature.

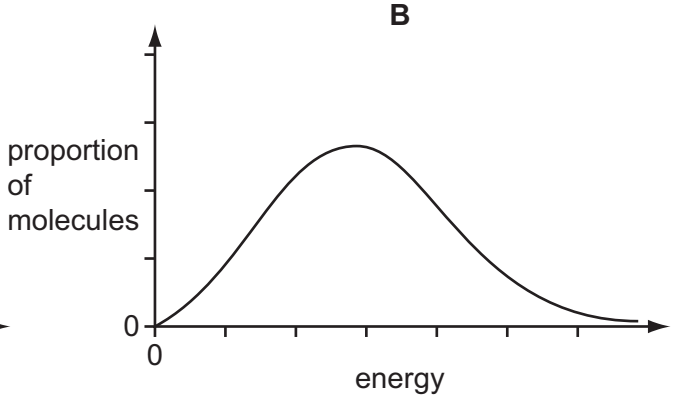



Which curve applies for the same gas at a lower temperature?

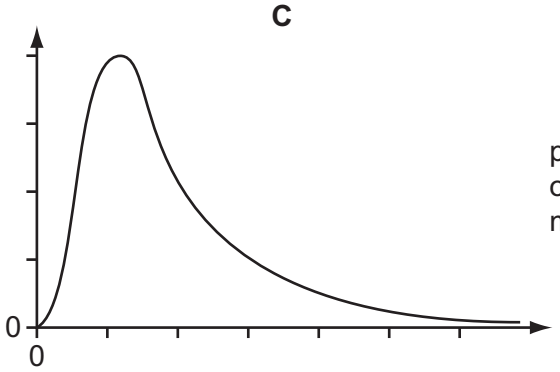
**A**



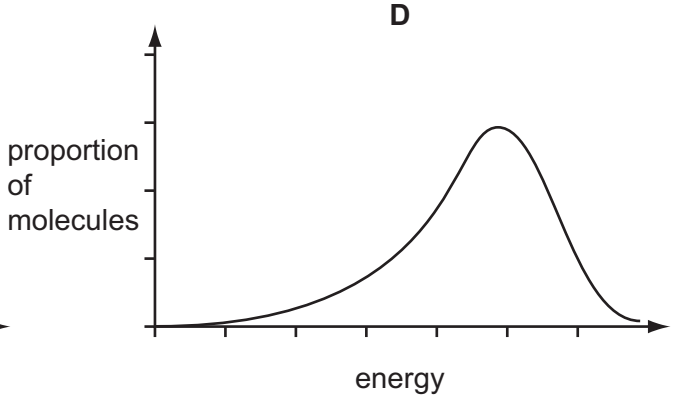

**B**




**C**




**D**




**21 9701/12/M/J/13/Q4**

Which factor can affect the value of the activation energy of a reaction?

**A** changes in concentration of the reactants

**B** decrease in temperature

**C** increase in temperature

**D** the presence of a catalyst

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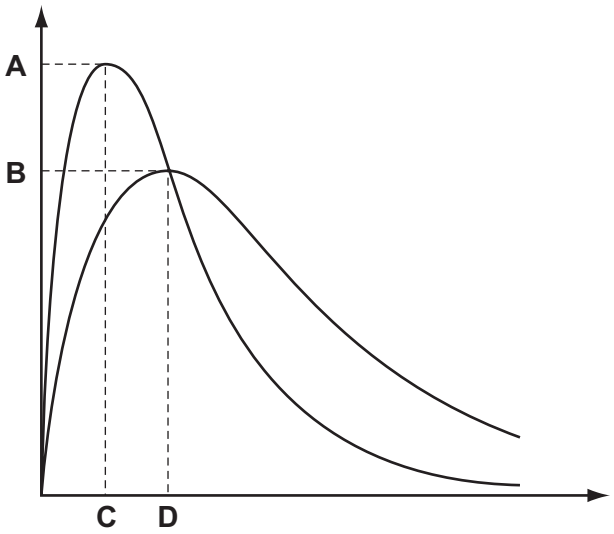


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**22 9701/12/M/J/13/Q5**

The diagram shows the Maxwell-Boltzmann energy distribution curves for molecules of a sample of a gas at two different temperatures.

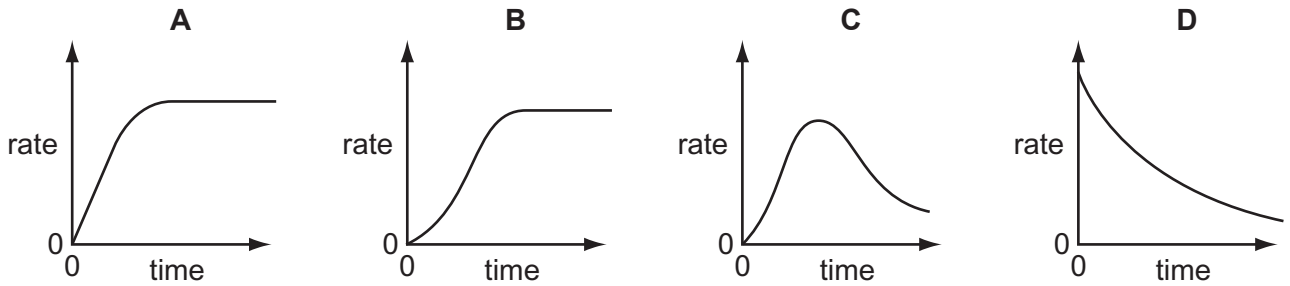
Which letter on the axes represents the most probable energy of the molecules at the **lower** temperature?




**23 9701/12/O/N/13/Q5**

An autocatalytic reaction is a reaction in which one of the products catalyses the reaction.

Which curve was obtained if the rate of reaction was plotted against time for an autocatalytic reaction?






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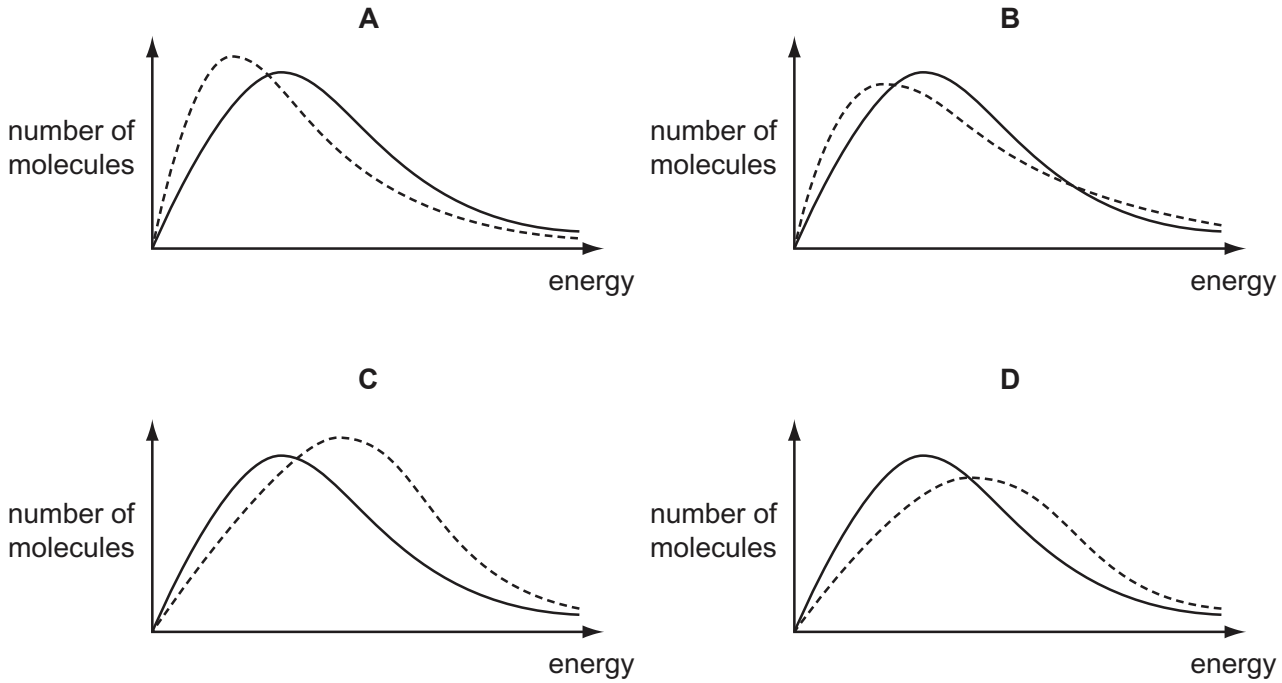
**24 9701/12/O/N/13/Q6**

The diagrams below show the Boltzmann distribution for air at two temperatures.

The solid line represents the distribution at –20 °C.

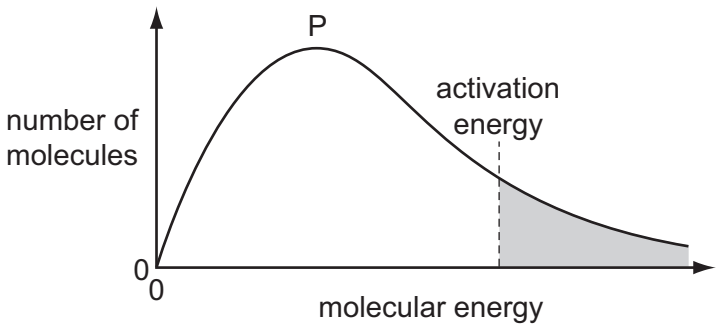
The dotted line represents the distribution at –10 °C.

Which diagram is correct?




**25 9701/12/M/J/14/Q1**

The diagram shows a Boltzmann distribution of molecular energies for a gaseous mixture. The distribution has a peak, labelled P on the diagram.




What happens when the temperature of the mixture increases?

**A** The height of the peak, P, decreases and the activation energy moves to the left.

**B** The height of the peak, P, decreases and the activation energy moves to the right.

**C** The height of the peak, P, decreases and the activation energy does not change.

**D** The height of the peak, P, increases and the activation energy moves to the left.

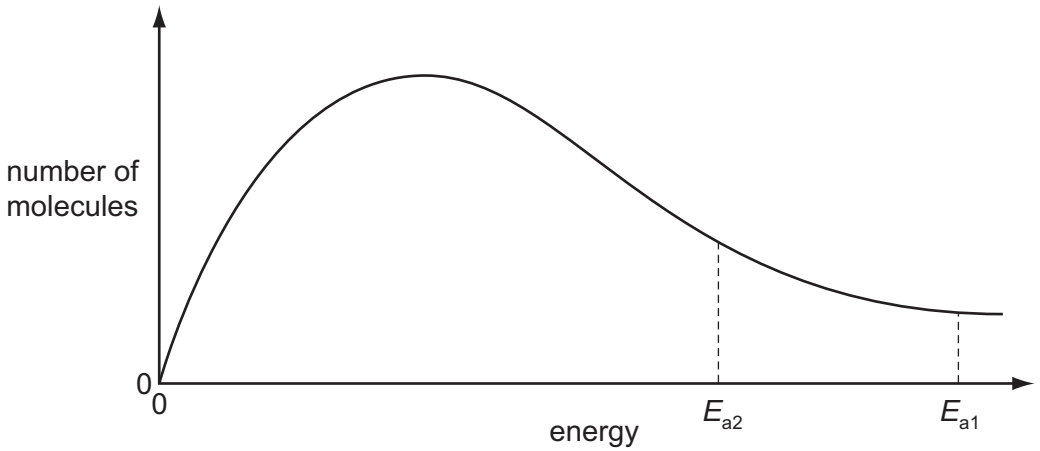
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**26 9701/01/M/J//Q10**

The diagram shows the Maxwell-Boltzmann energy distribution curve for molecules of a mixture of two gases at a given temperature. For a reaction to occur the molecules must collide together with sufficient energy.




$E_a$ is the activation energy for the reaction between the gases. Of the two values shown, one is for a catalysed reaction, the other for an uncatalysed one.

Which pair of statements is correct when a catalyst is used?

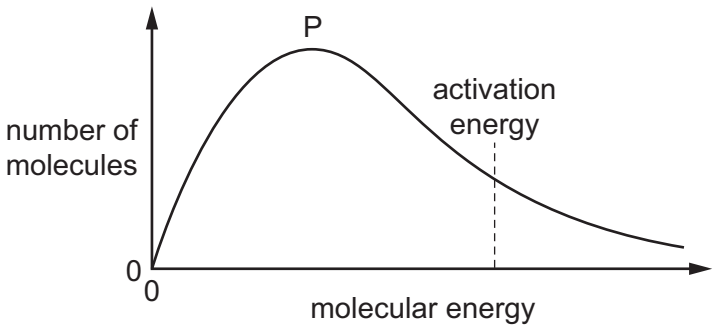
| | | |
|---|---|---|
| **A** | $E_{a1}$ catalysed reaction<br>fewer effective collisions | $E_{a2}$ uncatalysed reaction<br>more effective collisions |
| | | |
| **C** | $E_{a1}$ catalysed reaction<br>more effective collisions | $E_{a2}$ uncatalysed reaction<br>fewer effective collisions |
| **D** | $E_{a1}$ uncatalysed reaction<br>more effective collisions | $E_{a2}$ catalysed reaction<br>fewer effective collisions |



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**27 9701/11/M/J/15/Q1**

The diagram shows a Boltzmann distribution of molecular energies for a gaseous mixture. The distribution has a peak, labelled P on the diagram.




What happens when an effective catalyst is added to the mixture?

**A** The height of the peak decreases and the activation energy moves to the right.

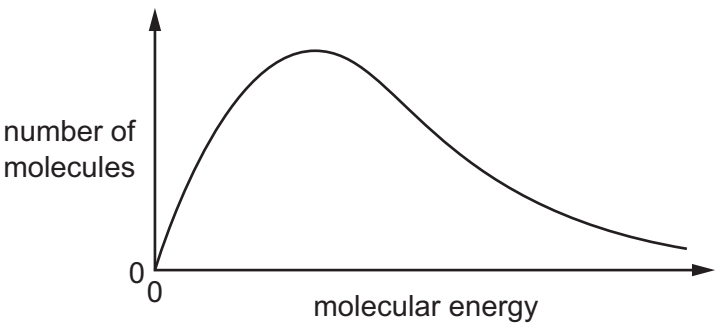
**B** The height of the peak decreases and the activation energy moves to the left.

**C** The height of the peak remains the same and the activation energy moves to the right.

**D** The height of the peak remains the same and the activation energy moves to the left.

**28 9701/12/M/J/15/Q11**

The Boltzmann distribution below shows the distribution of molecular energies in a sample of a gas at a given temperature.




Which statement correctly describes the change in such a distribution if the temperature is increased?

**A** Fewer molecules possess the most probable energy value and this value shifts to the left.

**B** Fewer molecules possess the most probable energy value and this value shifts to the right.

**C** More molecules possess the most probable energy value and this value shifts to the left.

**D** The area under the curve of the distribution increases.

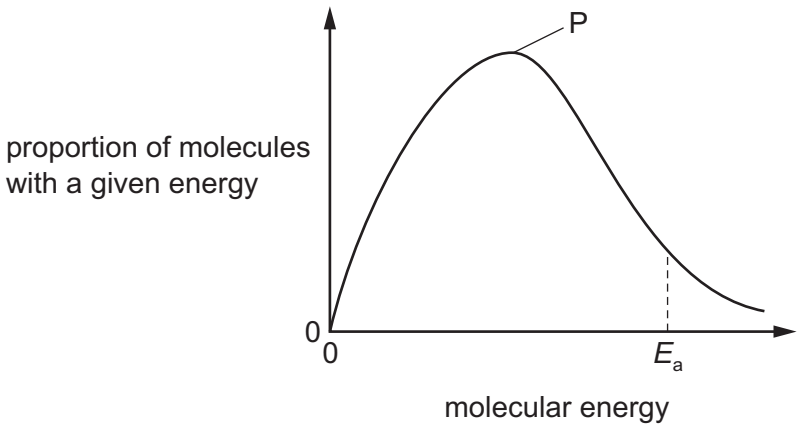
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**29 9701/12/M/J/16/Q1**

The diagram shows the Boltzmann distribution of energies in 1 mole of a gas. The gas can take part in a reaction with an activation energy, $E_a$.




Which statement correctly describes the effect of an increase in temperature?

**A** Peak P will be higher and fewer molecules will have energy > $E_a$.

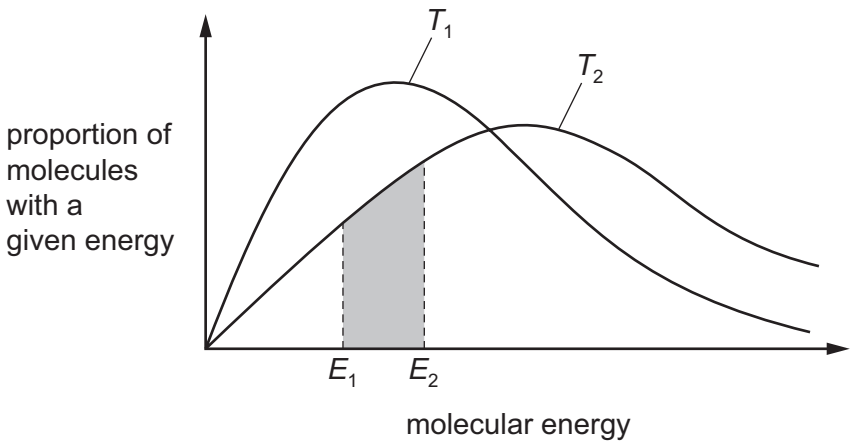
**B** Peak P will be higher and more molecules will have energy > $E_a$.

**C** Peak P will be lower and fewer molecules will have energy > $E_a$.

**D** Peak P will be lower and more molecules will have energy > $E_a$.

**30 9701/13/M/J/16/Q33**

The diagram shows the Boltzmann distribution of molecular energies in one mole of a gas at two temperatures, $T_1$ and $T_2$.




Which statements are correct?

**1** The shaded area represents the proportion of molecules with energies between $E_1$ and $E_2$ at temperature $T_2$.

**2** No particles have zero energy at either temperature.

**3** $T_2$ is a lower temperature than $T_1$.

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**31 9701/11/M/J/16/Q11**

Enzymes are biological catalysts. Many enzymes show specificity. An example of an enzyme which shows specificity is glucokinase. Glucokinase is involved in the metabolism of glucose.

What does specificity mean in this context?

**A** Glucokinase is most effective as a catalyst over a narrow pH range.

**B** Glucokinase is most effective as a catalyst over a narrow range of temperatures.

**C** Glucokinase only operates on a narrow range of substrate molecules.

**D** Glucokinase provides an alternative route for the reactions it catalyses.

**32 9701/11/M/J/17/Q11**

When 4 g of powdered calcium carbonate, $M_r$ = 100, were added to 100 $cm^3$ of 0.10 $mol\,dm^{-3}$ hydrochloric acid the volume of carbon dioxide produced was recorded.

| time / s | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 |
|---|---|---|---|---|---|---|---|---|
| total volume of carbon dioxide given off / $cm^3$ | 40 | 70 | 88 | 101 | 110 | 116 | 120 | 120 |

Which row gives the correct explanations about these results?

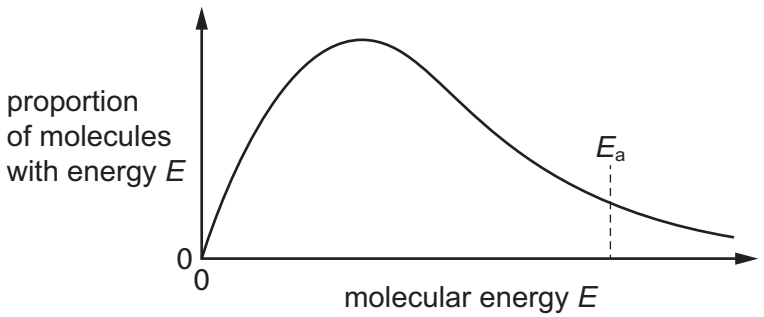
| | why the rate of the reaction changes with time | why the reaction stops |
|---|---|---|
| **A** | fewer collisions between reacting molecules occur | the calcium carbonate is used up |
| **C** | more collisions between reacting molecules occur | the calcium carbonate is used up |
| **D** | more collisions between reacting molecules occur | the hydrochloric acid is used up |



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**33 9701/12/M/J/17//Q11**

The Boltzmann distribution for the hydrogenation of an alkene at a particular temperature in the absence of a catalyst is shown.




Which row correctly describes the effects of adding nickel to the reaction vessel?

| | the shape of the Boltzmann distribution | activation energy, $E_a$ |
|---|---|---|
| **A** | changes | decreases |
| **B** | changes | increases |
| **C** | does not change | decreases |
| **D** | does not change | increases |

**34 9701/11/O/N/18/Q10**

0.200 mol of sulfur dioxide and 0.200 mol of oxygen are placed in a 1.00 $dm^3$ sealed container. The gases are allowed to react until equilibrium is reached.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

At equilibrium there is 0.100 mol of $SO_3$ in the container.

What is the value of $K_c$?

**A** 0.150 $mol\,dm^{-3}$

**B** 0.800 $mol\,dm^{-3}$

**C** 1.25 $mol^{-1}\,dm^3$

**D** 6.67 $mol^{-1}\,dm^3$



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**35 9701/11/M/J/19/Q11**

The reaction between sulfur dioxide and oxygen is reversible.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 280\,mol^{-1}\,dm^3 \text{ at } 1000\,K$$

In an equilibrium mixture at 1000 K the sulfur trioxide concentration is 6.00 mol dm$^{-3}$.
The sulfur dioxide concentration is twice the oxygen concentration.
What is the sulfur dioxide concentration?

**A** 0.175 mol dm$^{-3}$ **C** 0.318 mol dm$^{-3}$

**B** 0.254 mol dm$^{-3}$ **D** 0.636 mol dm$^{-3}$

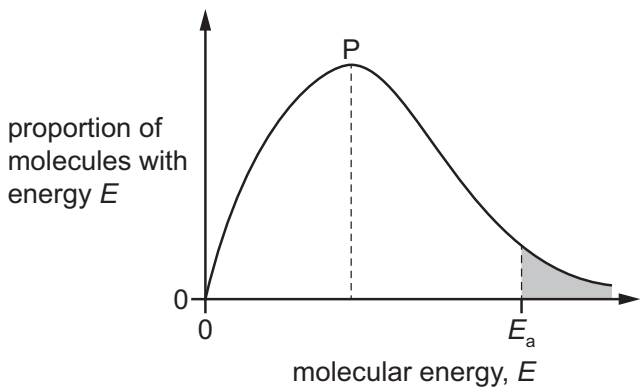
**36 9701/12/M/J/19/Q11**

Which row is an example of heterogeneous catalysis?

| | reaction | catalyst |
|---|---|---|
| **A** | esterification | sulfuric acid |
| **C** | destruction of the ozone layer | chlorine radicals |
| **D** | atmospheric formation of sulfur trioxide | nitrogen dioxide |

**37 9701/11/O/N/19/Q1**

The diagram shows the Boltzmann distribution of energies in a gas. The gas undergoes a reaction with an activation energy, $E_a$. The peak of the distribution is labelled P.




If the same reaction is carried out in the presence of a catalyst, which statement is correct?

**A** The peak P is at a lower height and the position of $E_a$ moves to the left.

**B** The peak P is at a lower height and the position of $E_a$ moves to the right.

**C** The peak P remains at the same height and the position of $E_a$ moves to the left.

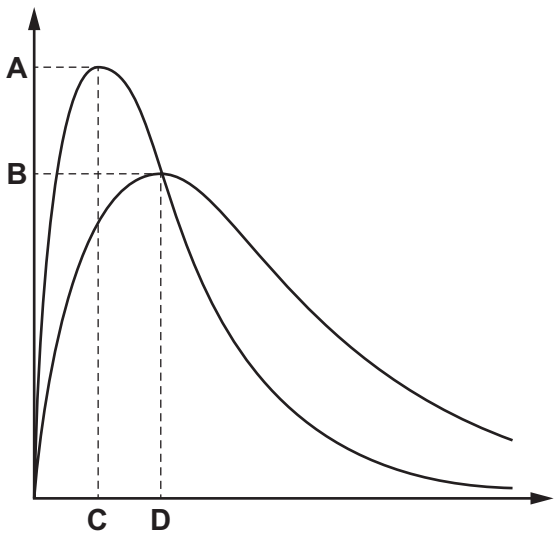
**D** The peak P remains at the same height and the position of $E_a$ moves to the right.

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**38 9701/11/M/J/20/Q6**






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Inorganic Chemistry

9
TOPIC

# The Periodic Table
# Chemical Periodicity



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**1 9701/1/M/J/02/Q12**

Which species represented by the following formulae has the largest radius?

**A** $P^{3-}$ **B** $Cl^-$ **C** Ar **D** $K^+$

**2 9701/1/M/J/02/Q13**

Which of the following oxides is **unlikely** to dissolve in aqueous sodium hydroxide?

**A** $Al_2O_3$ **B** MgO **C** $SO_2$ **D** $SiO_2$

**3 9701/1/M/J/02/Q14**

An element of the third period (Na to S) is heated in chlorine. The product is pur added to water. The resulting solution is found to be neutral.

What is the element?

**A** sodium **B** aluminium **C** silicon **D** phosphorus

**4 9701/1/M/J/02/Q17**

Which statement explains the observation that magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride?

**A** The ionic radius of the $NH_4^+$ ion is similar to that of $Mg^{2+}$ but not that of $Na^+$.

**B** $NH_4Cl$ dissociates less fully than NaCl.

**C** The ions $Na^+$ and $Mg^{2+}$ are isoelectronic (have the same number of electrons).

**D** The ion $NH_4^+$ acts as an acid.

**5 9701/1/M/J/02/Q13**

Which of the following oxides is **unlikely** to dissolve in aqueous sodium hydroxide?

**A** $Al_2O_3$ **B** MgO **C** $SO_2$ **D** $SiO_2$

**6 9701/1/M/J/02/Q14**

An element of the third period (Na to S) is heated in chlorine. The product is purified and then added to water. The resulting solution is found to be neutral.

What is the element?

**A** sodium **B** aluminium **C** silicon **D** phosphorus

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**7 9701/1/O/N/02/Q13**

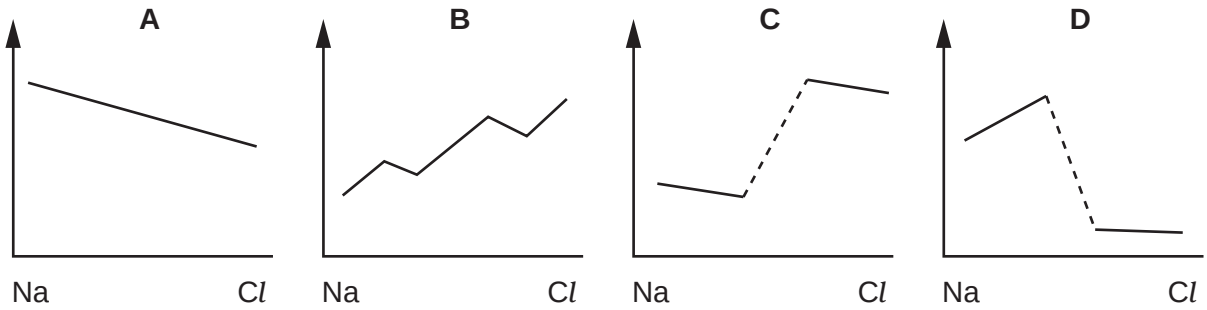
The chloride of element **Q** is hydrolysed by water to form an acidic solution and its oxide reacts with acid to form a salt.

What could be the element **Q**?

**A** magnesium **B** aluminium **C** silicon **D** phosphorus

**8 9701/1/O/N/02/Q14**

Which diagram represents the change in ionic radius of the elements across the third period (Na to C*l*)?




**9 9701/1/O/N/02/Q13**

The chloride of element **Q** is hydrolysed by water to form an acidic solution and its oxide reacts with acid to form a salt.

What could be the element **Q**?

**A** magnesium **B** aluminium **C** silicon **D** phosphorus

**10 9701/1/O/N/02/Q15**

The propellant used in the solid rocket booster of a space shuttle is a mixture of aluminium and compound **X**. Compound **X** contains chlorine in an oxidation state of +7.

Which of the following could be compound **X**?

**A** $NH_4Cl$ **B** $NH_4ClO_3$ **C** $NH_4ClO_4$ **D** $N_2H_5Cl$

**11 9701/1/O/N/02/Q15**

The propellant used in the solid rocket booster of a space shuttle is a mixture of aluminium and compound **X**. Compound **X** contains chlorine in an oxidation state of +7.

Which of the following could be compound **X**?

**A** $NH_4Cl$ **B** $NH_4ClO_3$ **C** $NH_4ClO_4$ **D** $N_2H_5Cl$



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**12 9701/1/M/J/03/Q13**

A mixture of the oxides of two elements of the third period is dissolved in water. The solution is approximately neutral.

What could be the constituents of the mixture?

**A** $Al_2O_3$ and MgO

**B** $Na_2O$ and MgO

**C** $Na_2O$ and $P_4O_{10}$

**D** $SO_3$ and $P_4O_{10}$

**13 9701/01/M/J/05/Q12**

The following species contain the same number of electrons.

In which order do their radii increase?

| | smallest radius ⟶ | | largest radius |
|---|---|---|---|
| **A** | Ar | $K^+$ | $Ca^{2+}$ |
| **B** | $Ca^{2+}$ | Ar | $K^+$ |
| **C** | $Ca^{2+}$ | $K^+$ | Ar |
| **D** | $K^+$ | Ar | $Ca^{2+}$ |

**14 9701/01/O/N/05/Q13**

In 1999, researchers working in the USA believed that they had made a new element and that it had the following electronic configuration.

$$[Rn]\ 5f^{14}6d^{10}7s^27p^6$$

In which Group of the Periodic Table would you expect to find this element?

**A** II **B** IV **C** VI **D** 0

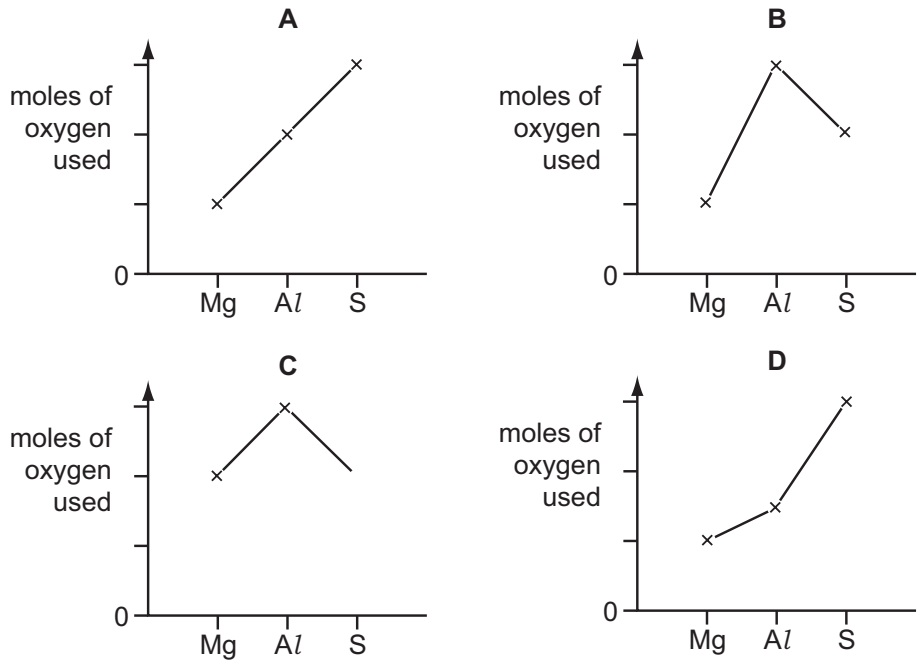


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**15 9701/01/O/N/05/Q12**

One mole of magnesium, aluminium and sulphur are each completely burned in an excess of oxygen gas.

Which graph shows the moles of oxygen used in each case?




**16 9701/01/O/N/05/Q13**

In 1999, researchers working in the USA believed that they had made a new element and that it had the following electronic structure.

$$[Rn]\ 5f^{14}6d^{10}7s^{2}7p^{6}$$

In which Group of the Periodic Table would you expect to find this element?

**A** II **B** IV **C** VI **D** 0

**17 9701/01/O/N/05/Q14**

Consecutive elements *X*, *Y*, *Z* are in Period 3 of the Periodic Table. Element *Y* has the highest first ionisation energy and the lowest melting point.

What could be the identities of *X*, *Y* and *Z*?

**A** sodium, magnesium, aluminium

**B** magnesium, aluminium, silicon

**C** aluminium, silicon, phosphorus

**D** silicon, phosphorus, sulphur

**18 9701/01/M/J/06/Q13**

In which pair is the radius of the second atom greater than that of the first atom?

**A** Na, Mg **B** Sr, Ca **C** P, N **D** C*l*, Br



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**19 9701/01/M/J/06/Q13**

In which pair is the radius of the second atom greater than that of the first atom?

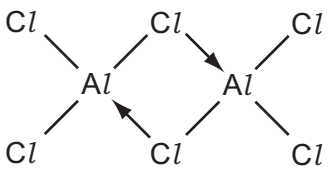
**A** Na, Mg **B** Sr, Ca **C** P, N **D** C*l*, Br

**20 9701/01/M/J/06/Q15**

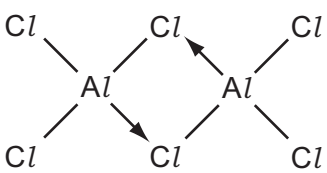
Aluminium chloride sublimes at 178 °C.

Which structure best represents the species in the vapour at this temperature?

**A**




**B**




**C** $Al^{\bullet} + 3Cl^{\bullet}$

**D** $Al^{3+}(Cl^{-})_3$

**21 9701/01/M/J/06/Q14**

The oxide and chloride of an element **X** are separately mixed with water. The two resulting solutions have the same effect on litmus.

What is element **X**?

**A** sodium **B** magnesium **C** aluminium **D** phosphorus

**22 9701/01/M/J/07/Q12**

Which chlorine compound has bonding that can be described as ionic with some covalent character?

**A** NaC*l* **B** $MgCl_2$ **C** $AlCl_3$ **D** $SiCl_4$

**23 9701/01/M/J/07/Q13**

$AlCl_3$ reacts with $LiAlH_4$ and $(CH_3)_3N$ to give $(CH_3)_3NAlH_3$.

Which statement about $(CH_3)_3NAlH_3$ is correct?

**A** It contains hydrogen bonding.
**B** It is dimeric.
**C** The A*l* atom has an incomplete octet of electrons.
**D** The bonds around the A*l* atom are tetrahedrally arranged.



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**24** **9701/01/O/N/07/Q13**

Which species has the largest radius?

**A** $P^{3-}$ **B** $Cl^-$ **C** Ar **D** $K^+$

**25** **9701/01/M/J/08/Q13**

In an experiment, 0.1 g samples of $Na_2O$, MgO, $P_4O_{10}$ and $SO_2$ are added to separate 100 $cm_3$ volumes of water.

For which oxide is the resulting mixture most alkaline?

**A** $Na_2O$ **B** MgO **C** $P_4O_{10}$ **D** $SO_2$

**26** **9701/01/M/J/08/Q14**

Which element is expected to show the greatest tendency to form some covalent compounds?

**A** aluminium **B** calcium **C** magnesium **D** sodium

**27** **9701/01/O/N/08/Q13**

Which oxide, when mixed with water, will produce the most acidic solution?

**A** CO **B** $CO_2$ **C** $SiO_2$ **D** $P_2O_5$

**28** **9701/01/O/N/8/Q16**

Due to their similar ionic radii, the reactions of lithium and magnesium and their corresponding compounds are very similar.

Which statement concerning the reactions of lithium and its compounds is correct?

**A** Lithium carbonate decomposes on heating at a relatively low temperature, forming lithium oxide and carbon dioxide.

**B** Lithium nitrate decomposes on heating, forming lithium nitrite and oxygen.

**C** Lithium burns only slowly in oxygen.

**D** Lithium reacts violently with cold water, liberating hydrogen.



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**29 9701/01/O/N/08/Q15**

Aluminium chloride catalyses certain reactions by forming carbocations (carbonium ions) with chloroalkanes as shown.

$$RCl + AlCl_3 \rightarrow R^+ + AlCl_4^-$$

Which property makes this reaction possible?

**A** $AlCl_3$ is a covalent molecule.

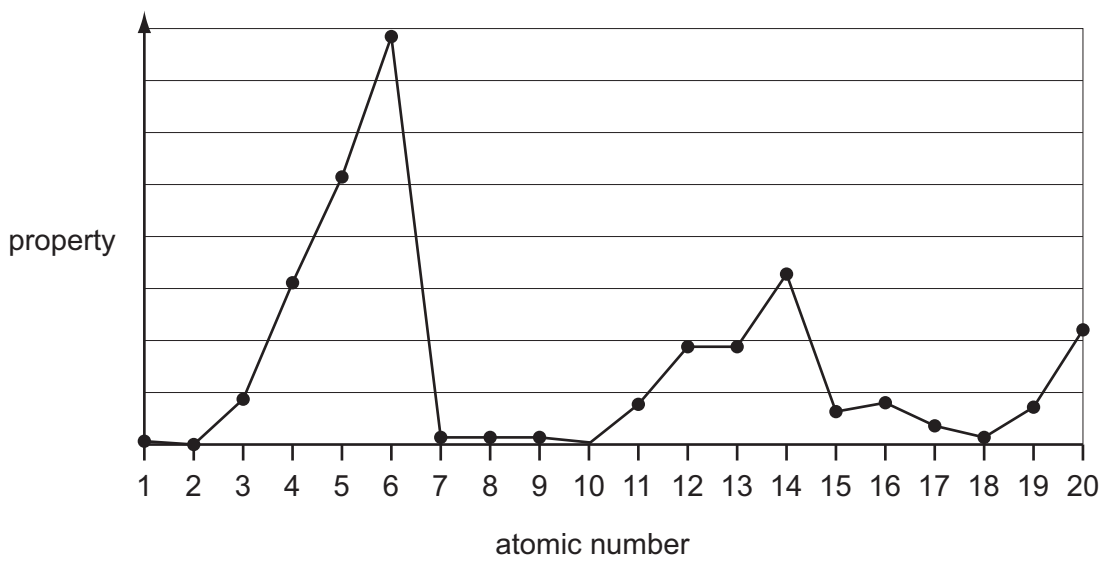
**B** $AlCl_3$ exists as the dimer $Al_2Cl_6$ in the vapour.

**C** The aluminium atom in $AlCl_3$ has an incomplete octet of electrons.

**D** The chlorine atom in $RCl$ has a vacant p orbital.

**30 9701/12/O/N/09/Q11**

The following graph shows the variation of a property of the first 20 elements in the Periodic Table with the atomic number of the element.




What is the property?

**A** atomic radius **B** first ionisation energy **C** ionic radius **D** melting point

**31 9701/12/O/N/09/Q12**

Which statement correctly describes what happens when silicon tetrachloride is added to water?

**A** The $SiCl_4$ dissolves to give a neutral solution only.

**B** The $SiCl_4$ reacts to give an acidic solution only.

**C** The $SiCl_4$ reacts to give a precipitate and an acidic solution.

**D** The $SiCl_4$ reacts to give a precipitate and a neutral solution.



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**32 9701/01/M/J/09/Q11**

In some fireworks there is a reaction between powdered aluminium and powdered barium nitrate in which heat is evolved and an unreactive gas is produced.

What is the equation for this reaction?

**A** $2Al + Ba(NO_3)_2 \rightarrow Al_2O_3 + BaO + 2NO$

**B** $4Al + 4Ba(NO_3)_2 \rightarrow 2Al_2O_3 + 4Ba(NO_2)_2 + O_2$

**C** $10Al + 3Ba(NO_3)_2 \rightarrow 5Al_2O_3 + 3BaO + 3N_2$

**D** $10Al + 18Ba(NO_3)_2 \rightarrow 10Al(NO_3)_3 + 18BaO + 3N_2$

**33 9701/01/M/J/09/Q12**

Which group of particles is in order of increasing size?

**A** N O F

**B** $N^{3-}$ $O^{2-}$ $F^-$

**C** $Na^+$ $Mg^{2+}$ $Al^{3+}$

**D** $Na^+$ Ne $F^-$

**34 9701/12/O/N/10/Q15**

Which statement explains the observation that magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride?

**A** The ionic radius of the $NH_4^+$ ion is similar to that of $Mg^{2+}$ but not that of $Na^+$.

**B** $NH_4Cl$ dissociates less fully than $NaCl$.

**C** The $Na^+$ and $Mg^{2+}$ ions are isoelectronic (have the same number of electrons).

**D** The $NH_4^+$ ion acts as an acid.

**35 9701/12/M/J/10/Q16**

Which element of the third period requires the least number of moles of oxygen for the complete combustion of 1 mol of the element?

**A** aluminium **B** magnesium **C** phosphorus **D** sodium



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**36 9701/12/M/J/10/Q17**

Two properties of non-metallic elements and their atoms are as follows.

property 1 has an oxide that can form a strong acid in water
property 2 has **no** paired 3p electrons

Which properties do phosphorus and sulfur have?

| | phosphorus | sulfur |
|---|---|---|
| **A** | 1 and 2 | 1 only |
| **B** | 1 only | 1 and 2 |
| **C** | 1 and 2 | 1 and 2 |
| **D** | 2 only | 1 only |

**37 9701/12/M/J/10/Q18**

Consecutive elements X, Y, Z are in the third period of the Periodic Table. Element Y has the highest first ionisation energy and the lowest melting point.

What could be the identities of X, Y and Z?

**A** aluminium, silicon, phosphorus
**B** magnesium, aluminium, silicon
**C** silicon, phosphorus, sulfur
**D** sodium, magnesium, aluminium

**38 9701/12/M/J/11/Q11**

0.144 g of an aluminium compound **X** react with an excess of water, to produce a gas. This gas burns completely in $O_2$ to form $H_2O$ and 72 $cm^3$ of $CO_2$ only. The volume of $CO_2$ was measured at room temperature and pressure.

What could be the formula of **X**?

[C = 12.0, Al = 27.0; 1 mole of any gas occupies 24 $dm^3$ at room temperature and pressure]

**A** $Al_2C_3$ **B** $Al_3C_4$ **C** $Al_4C_3$ **D** $Al_5C_3$

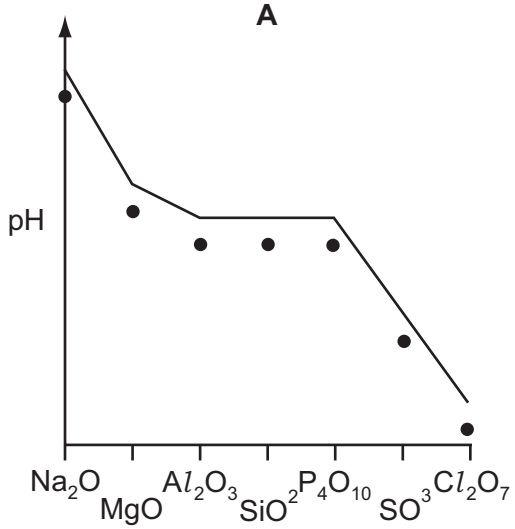


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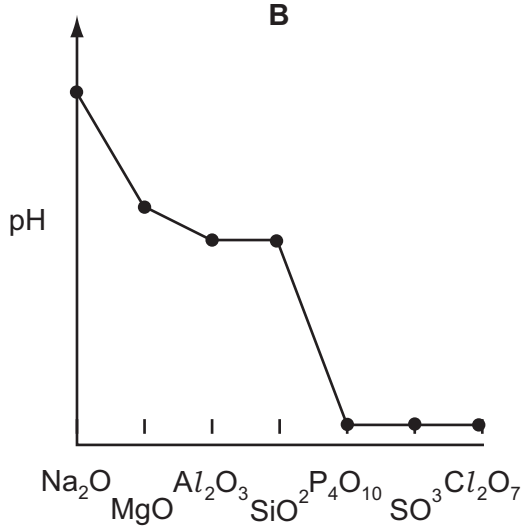
**39 9701/12/M/J/11/Q14**

The highest oxides of the elements sodium to chlorine are separately added to water.
Which diagram best represents the pH of the resulting mixtures?

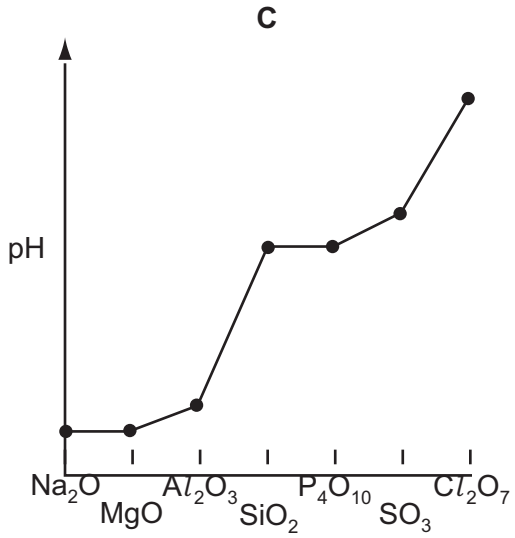
**A**



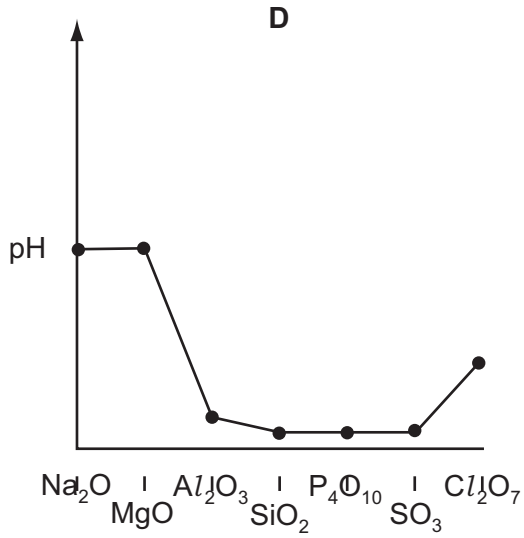

**B**




**C**




**D**

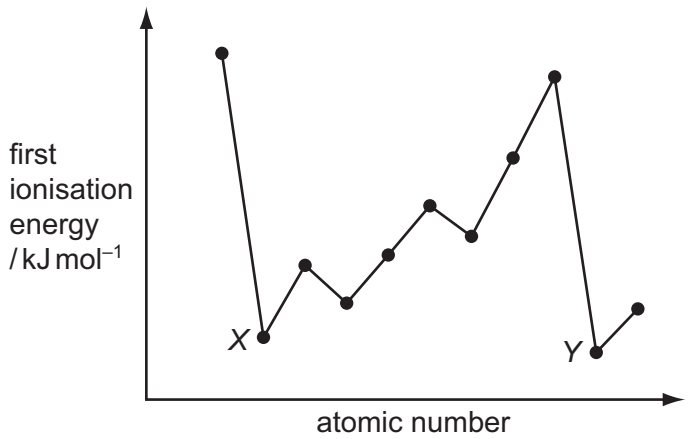





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**40** **9701/12/M/J/11/Q15**

The diagram shows the first ionisation energies of 11 consecutive elements.




Which type of elements are labelled *X* and *Y*?

**A** Group I metals **B** Group II metals **C** halogens **D** noble gases

**41** **9701/12/M/J/11/Q16**

Why does aluminium oxide dissolve in sodium hydroxide solution?

**A** Aluminium oxide can behave as a base.
**B** Aluminium oxide can behave as an acid.
**C** Aluminium oxide has a giant structure.
**D** The bonding in aluminium oxide is ionic.

**42** **9701/12/M/J/11/Q18**

In the Contact process, what is the nature of the gaseous product and what is the identity of the catalyst?

| | nature of gaseous product | catalyst |
|---|---|---|
| **A** | acidic | Fe |
| **B** | acidic | $V_2O_5$ |
| **C** | basic | Fe |
| **D** | basic | $V_2O_5$ |



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**43 9701/12/O/N/11/Q19**

Ar, $Ca^{2+}$ and $K^{+}$, contain the same number of electrons.

In which order do their radii increase?

| | smallest radius ⟶ | | largest radius |
|---|---|---|---|
| **A** | Ar | $K^+$ | $Ca^{2+}$ |
| **B** | $Ca^{2+}$ | Ar | $K^+$ |
| **C** | $Ca^{2+}$ | $K^+$ | Ar |
| **D** | $K^+$ | Ar | $Ca^{2+}$ |

**44 9701/12/M/J/12/Q15**

The period 4 elements gallium (Ga), germanium (Ge), arsenic (As) and selenium (Se) are the elements below aluminium, silicon, phosphorus and sulfur in the Periodic Table, a portion of which is shown below.

| | | | | |
|---|---|---|---|---|
| period 3 elements | A*l* | Si | P | S |
| period 4 elements | Ga | Ge | As | Se |

The properties of each period 4 element resemble those of the period 3 element directly above it.

Which period 4 elements form oxides that dissolve in water to give an acid solution?

**A** As and Se **B** Ga and Ge **C** Ga and Se **D** Se only

**45 9701/12/M/J/12/Q17**

What can be seen when a piece of magnesium ribbon is placed in cold water?

**A** A vigorous effervescence occurs.

**B** Bubbles of gas form slowly on the magnesium.

**C** The magnesium floats on the surface of the water and reacts quickly.

**D** The magnesium glows and a white solid is produced.

**46 9701/12/M/J/12/Q18**

*Use of the Data Booklet is relevant to this question.*

Sodium and sulfur react together to form sodium sulfide, $Na_2S$.

How do the atomic radius and ionic radius of sodium compare with those of sulfur?

| | atomic radius | ionic radius |
|---|---|---|
| **A** | sodium > sulfur | sodium > sulfur |
| **B** | sodium > sulfur | sodium < sulfur |
| **C** | sodium < sulfur | sodium > sulfur |
| **D** | sodium < sulfur | sodium < sulfur |



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**47 9701/12/O/N/12/Q13**

Why is the ionic radius of a chloride ion larger than the ionic radius of a sodium ion?

**A** A chloride ion has one more occupied electron shell than a sodium ion.

**B** Chlorine has a higher proton number than sodium.

**C** Ionic radius increases regularly across the third period.

**D** Sodium is a metal, chlorine is a non-metal.

**48 9701/12/O/N/12/Q13**

Why is the ionic radius of a chloride ion larger than the ionic radius of a sodium ion?

**A** A chloride ion has one more occupied electron shell than a sodium ion.

**B** Chlorine has a higher proton number than sodium.

**C** Ionic radius increases regularly across the third period.

**D** Sodium is a metal, chlorine is a non-metal.

**49 9701/12/O/N/12/Q19**

Elements **X** and **Y** are both in period three.

When the chloride of **X** is added to water, it reacts and a solution of pH 2 is produced.

When the chloride of **Y** is added to water, it dissolves and a solution of pH 7 is produced.

Which statement explains these observations?

**A** Both chlorides hydrolyse in water.

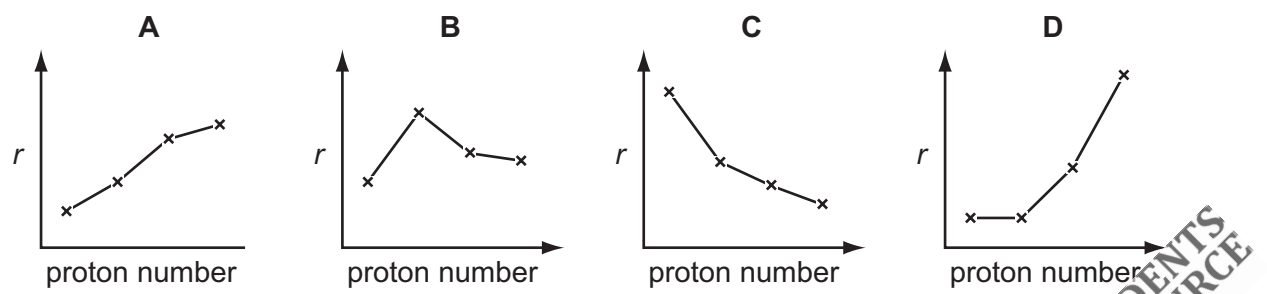
**B** **X** is phosphorus and **Y** is aluminium.

**C** **X** is silicon and **Y** is sodium.

**D** **X** is sodium and **Y** is phosphorus.

**50 9701/12/O/N/12/Q19**

Which diagram shows the variation of the metallic radius *r* of the Group I elements, Li, Na, K and Rb, with increasing proton (atomic) number?




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**51 9701/12/O/N/14/Q6**

Aluminium carbide, $Al_4C_3$, reacts readily with aqueous sodium hydroxide. The two products of the reaction are $NaAlO_2$ and a hydrocarbon. Water molecules are also involved as reactants.

What is the formula of the hydrocarbon?

**A** $CH_4$ **B** $C_2H_6$ **C** $C_3H_8$ **D** $C_6H_{12}$

**52 9701/12/O/N/13/Q13**

A metal, **X**, reacts with water to produce a colourless solution which gives a white precipitate when mixed with aqueous sulfuric acid. What is metal **X**?

**A** barium **B** magnesium **C** potassium **D** sodium

**53 9701/12/O/N/13/Q17**

Which statement explains the observation that magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride?

**A** The ionic radius of the $NH_4^+$ ion is similar to that of $Mg^{2+}$ but not that of $Na^+$.

**B** $NH_4Cl$ dissociates less fully than $NaCl$.

**C** The $Na^+$ and $Mg^{2+}$ ions have the same number of electrons.

**D** The $NH_4^+$ ion can donate a proton.

**54 9701/12/O/N/13/Q19**

Consecutive elements **X**, **Y** and **Z** are in the third period of the Periodic Table. Element **Y** has the highest first ionisation energy and the lowest melting point of these three elements.

What could be the identities of **X**, **Y** and **Z**?

**A** sodium, magnesium, aluminium
**B** magnesium, aluminium, silicon
**C** aluminium, silicon, phosphorus
**D** silicon, phosphorus, sulfur

**55 9701/12/O/N/13/Q17**

Which statement explains the observation that magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride?

**A** The ionic radius of the $NH_4^+$ ion is similar to that of $Mg^{2+}$ but not that of $Na^+$.

**B** $NH_4Cl$ dissociates less fully than $NaCl$.

**C** The $Na^+$ and $Mg^{2+}$ ions have the same number of electrons.

**D** The $NH_4^+$ ion can donate a proton.



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**56** **9701/12/O/N/13/Q19**

Consecutive elements **X**, **Y** and **Z** are in the third period of the Periodic Table. Element **Y** has the highest first ionisation energy and the lowest melting point of these three elements.

What could be the identities of **X**, **Y** and **Z**?

**A** sodium, magnesium, aluminium

**B** magnesium, aluminium, silicon

**C** aluminium, silicon, phosphorus

**D** silicon, phosphorus, sulfur

**57** **9701/12/M/J/13/Q6**

Which pair of elements has chemical bonds of the same type between their atoms in the solid state?

**A** aluminium and phosphorus

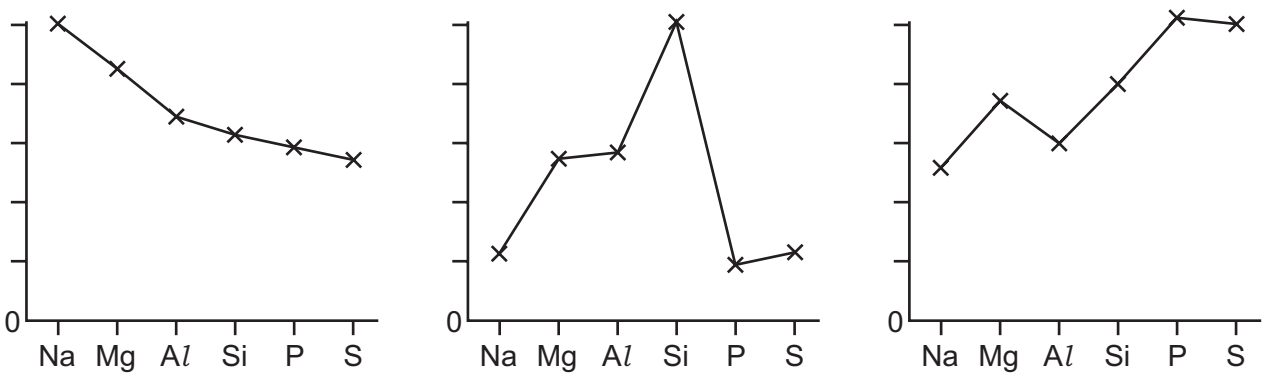
**B** chlorine and argon

**C** magnesium and silicon

**D** sulfur and chlorine

**58** **9701/12/M/J/13/Q16**

The trends in three physical properties of the elements Na, Mg, A*l*, Si, P and S are shown in the graphs.




Which physical property is **not** illustrated?

**A** atomic radius

**B** electrical conductivity

**C** first ionisation energy

**D** melting point

**59** **9701/12/O/N/14/Q14**

*Use of the Data Booklet is relevant to this question.*

Sir Humphrey Davy discovered boron, calcium, magnesium and sodium.

Which of these elements has the **second** smallest atomic radius in its group and the **third** lowest first ionisation energy in its period?

**A** boron

**B** calcium

**C** magnesium

**D** sodium

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**60** **9701/12/O/N/14/Q19**

Which oxide does **not** react with cold dilute sodium hydroxide to produce a salt?

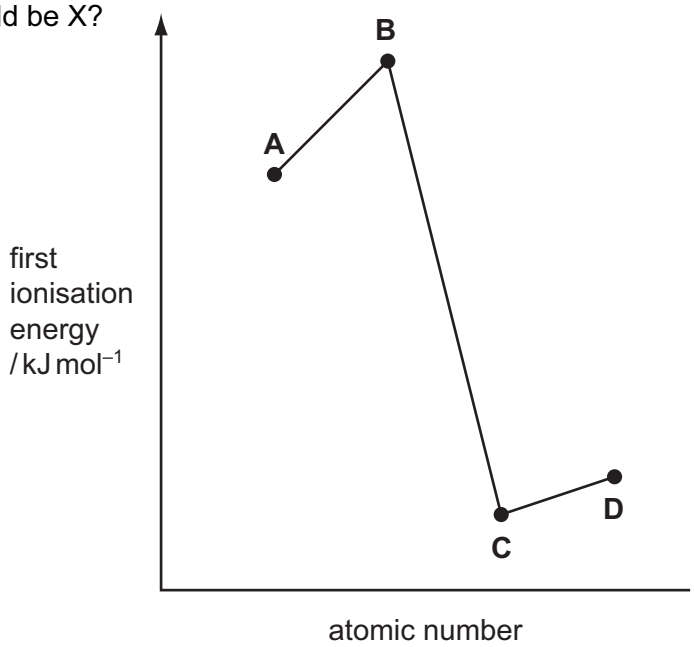
**A** $Al_2O_3$ **B** $P_4O_{10}$ **C** $SO_2$ **D** $SiO_2$

**61** **9701/12/M/J/14/Q10**

Shown on the graph are the relative values of the first ionisation energies of four elements that have consecutive atomic numbers.

One of the elements reacts with hydrogen to form a covalent compound with formula HX.

Which element could be X?




**62** **9701/12/M/J/14/Q14**

Ammonium sulfate in the soil is slowly oxidised by air, producing sulfuric acid, nitric acid and water as the only products.

How many moles of oxygen gas are needed for the complete oxidation of one mole of ammonium sulfate?

**A** 1 **B** 2 **C** 3 **D** 4



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**63 9701/12/M/J/14/Q13**

X and Y are oxides of different Period 3 elements.

If one mole of Y is added to water, the solution formed is neutralised by exactly one mole of X.

What could be the identities of X and Y?

| | X | Y |
|---|---|---|
| **A** | $Al_2O_3$ | $P_4O_{10}$ |
| **B** | $Al_2O_3$ | $SO_3$ |
| **C** | $Na_2O$ | $P_4O_{10}$ |
| **D** | $Na_2O$ | $SO_3$ |

**64 9701/12/M/J/14/Q15**

Which statement about the oxides and hydroxides of the Group II elements Mg, Ca, Sr and Ba is correct?

**A** Each of the oxides reacts readily with water to form a solution of pH 12 or above.

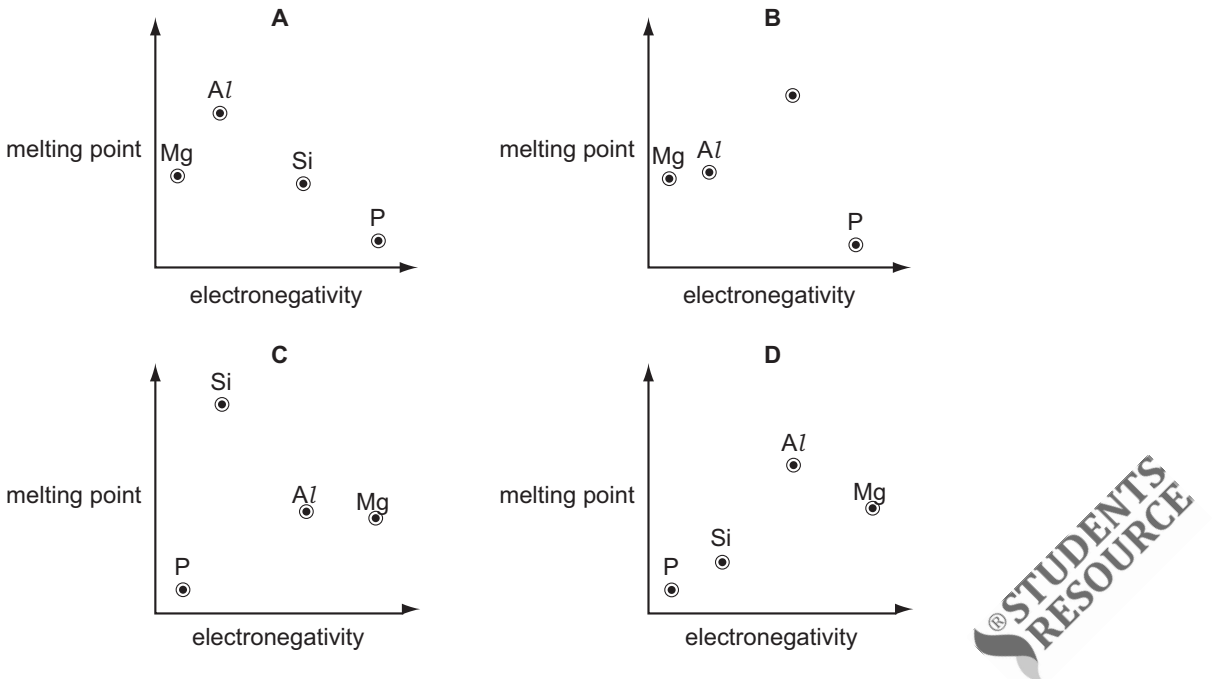
**B** Magnesium oxide is used as a furnace lining because it has a giant molecular structure and hence a high melting point.

**C** The hydroxides are produced directly by the thermal decomposition of the corresponding nitrates.

**D** The solubility of the hydroxides increases from $Mg(OH)_2$ to $Ba(OH)_2$.

**65 9701/12/M/J/14/Q16**

Which graph correctly shows the relative melting points of the elements Mg, Al, Si and P plotted against their relative electronegativities?

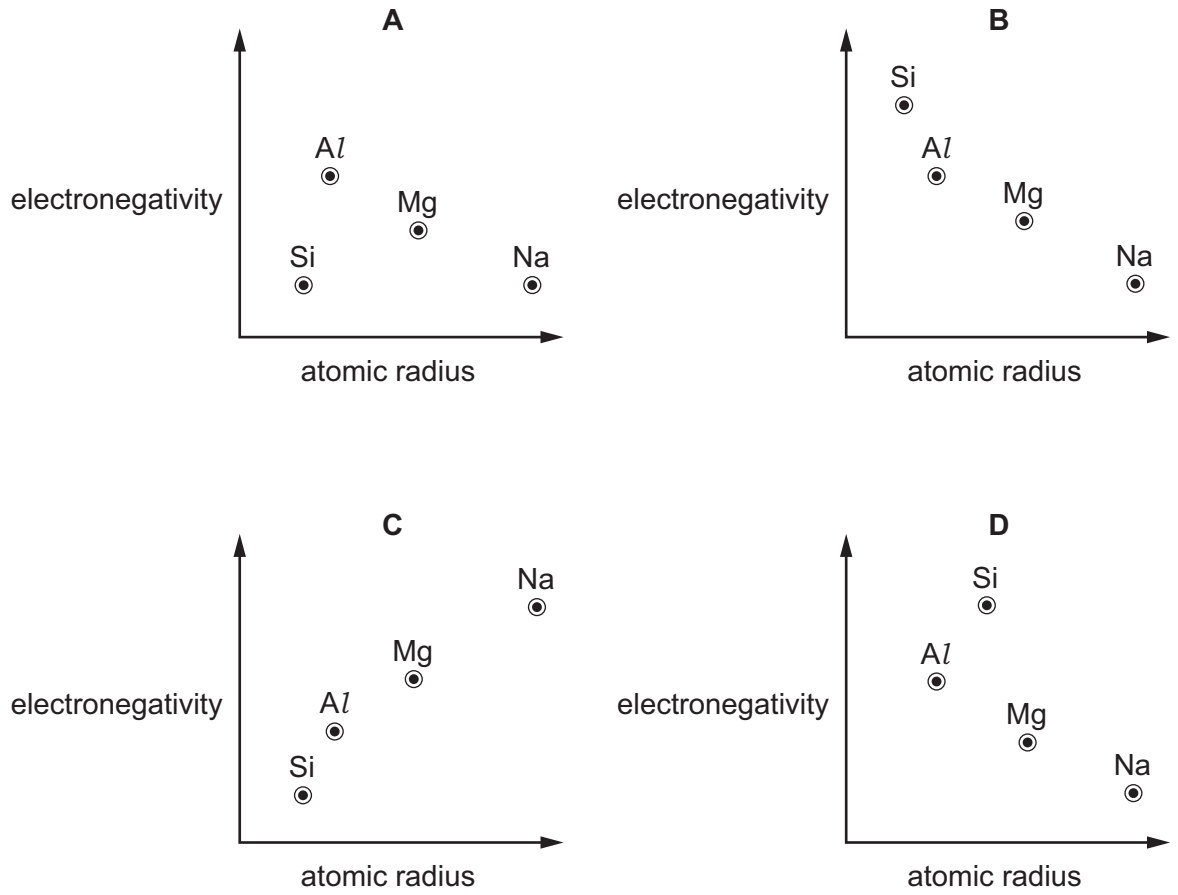





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**66 9701/11/M/J/14/Q19**

Which graph correctly shows relative electronegativity plotted against relative atomic radius for the elements Na, Mg, A*l* and Si?




**67 9701/12/O/N/14/Q12**

Element **X**, in Period 3, has the following properties.

- Its oxide has a giant structure.
- It forms covalent bonds with chlorine.
- Its oxide will neutralise HC*l*(aq).

What is element **X**?

**A** Mg **B** A*l* **C** Si **D** P

**68 9701/12/O/N/14/Q13**

Which property is **not** associated with the element sodium?

**A** It can react with cold water to form hydrogen.
**B** It forms a basic oxide.
**C** It forms a neutral chloride.
**D** It is an oxidising agent.

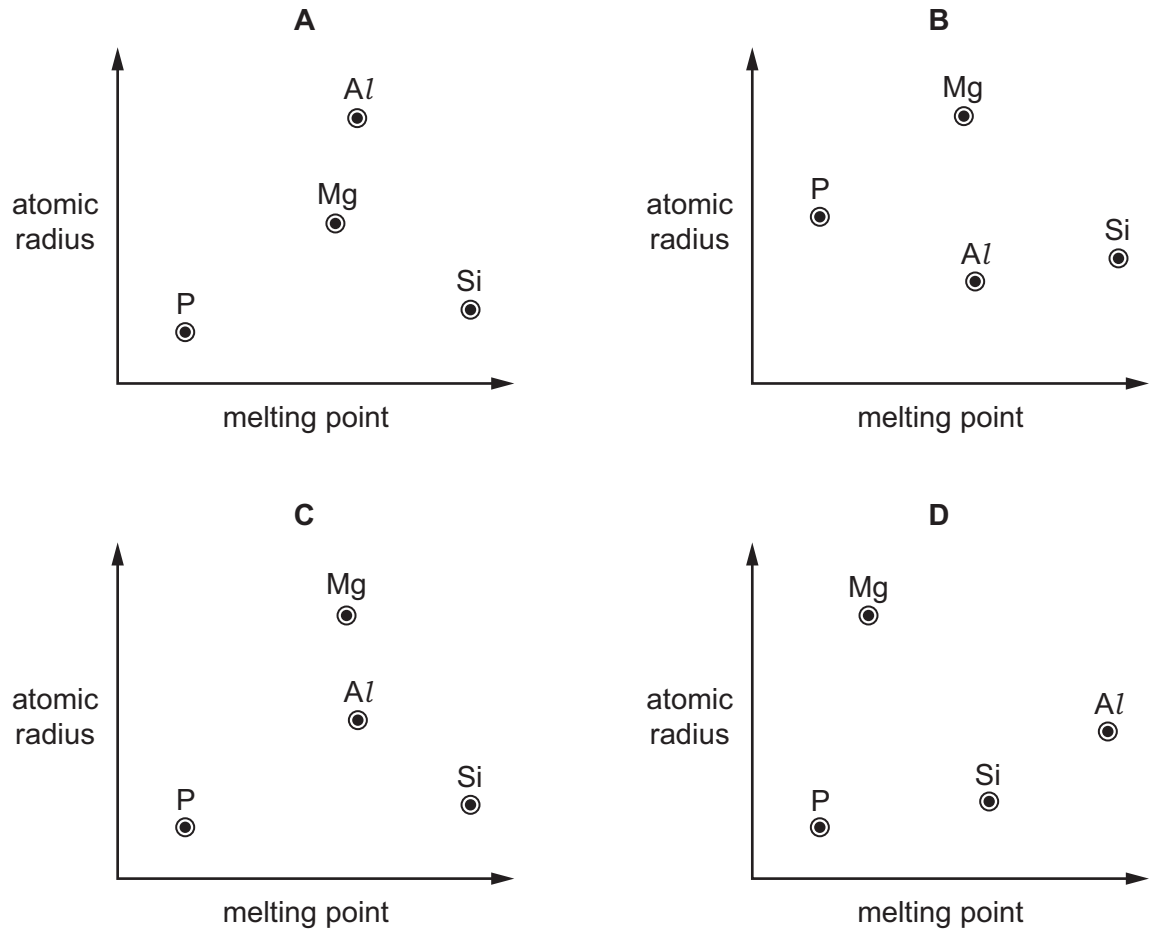


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**69 9701/11/M/J/15/Q15**

*Use of the Data Booklet is relevant to this question.*

Which diagram correctly shows the atomic radii of the elements Mg, A*l*, Si and P plotted against their melting points?




**70 9701/11/M/J/15/Q14**

Which observations are made when a sample of silicon chloride, $SiCl_4$, is added to a beaker of water?

**A** No visible changes are observed.
**B** Steamy fumes and a white precipitate are both observed.
**C** The appearance of a white precipitate is the only observation.
**D** The appearance of steamy fumes is the only observation.

**71 9701/12/F/M/16/Q1**

Which compound contains two different elements with identical oxidation states?

**A** HC*l*O **B** $Mg(OH)_2$ **C** $Na_2SO_4$ **D** $NH_4Cl$

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**72** **9701/12/F/M/16/Q13**

When dealing with a spillage of metallic sodium it is important that no toxic or flammable products are formed.

Which material should be used if there is a spillage of metallic sodium?

**A** dilute hydrochloric acid
**B** ethanol
**C** sand
**D** water spray

**73** **9701/12/F/M/16/Q12**

Consecutive elements **X**, **Y** and **Z** are in Period 3 of the Periodic Table. Element **Y** has the highest first ionisation energy and the lowest melting point of these three elements.

What are the identities of **X**, **Y** and **Z**?

**A** sodium, magnesium, aluminium
**B** magnesium, aluminium, silicon
**C** aluminium, silicon, phosphorus
**D** silicon, phosphorus, sulfur

**74** **9701/11/M/J/16/Q13**

Elements D and E are both in Period 3. Element D has the smallest atomic radius in Period 3. There are only two elements in Period 3 which have a lower melting point than element E. Elements D and E react together to form compound L.

Which compound could be L?

**A** $MgCl_2$ **B** MgS **C** $Na_2S$ **D** $PCl_3$

**75** **9701/13/M/J/16/Q13**

Each pair below consists of a sample of two separate elements. Each element is in its standard state at room temperature and pressure.

Which pair of elements has chemical bonds of the same type between their atoms?

**A** aluminium and phosphorus
**B** chlorine and argon
**C** magnesium and silicon
**D** sulfur and chlorine

**76** **9701/12/M/J/16/Q12**

Sodium and sulfur react together to form sodium sulfide, $Na_2S$.

How do the atomic radius and ionic radius of sodium compare with those of sulfur?

| | atomic radius | ionic radius |
|---|---|---|
| **A** | sodium < sulfur | sodium > sulfur |
| **B** | sodium < sulfur | sodium < sulfur |
| **C** | sodium > sulfur | sodium > sulfur |
| **D** | sodium > sulfur | sodium < sulfur |



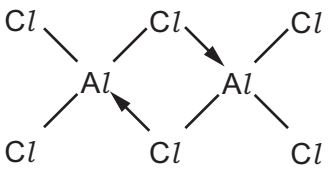
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**77 9701/12/M/J/16/Q13**

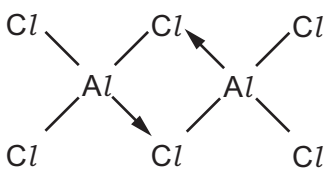
Solid aluminium chloride sublimes at 178 °C.

Which structure best represents the species in the vapour at this temperature?

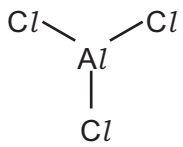
**A**




**B**




**C**




**D**

$Al^{3+}(Cl^{-})_3$

**78 9701/13/M/J/16/Q12**

The oxide and chloride of an element **X** are separately mixed with water. The two resulting solutions have the same effect on litmus.

What could element **X** be?

**A** Al **B** Ca **C** Na **D** P

**79 9701/12/F/M/17/Q10**

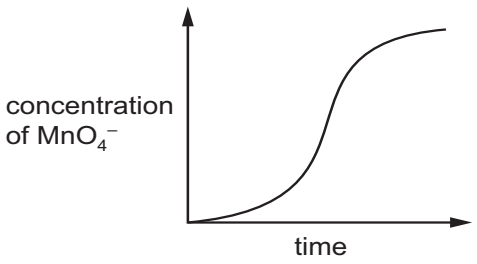
Oxidation of ethanedioate ions by acidified manganate(VII) ions is very slow at room temperature.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

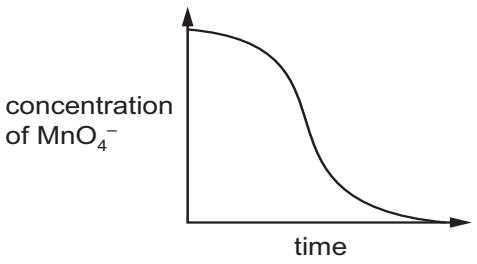
$Mn^{2+}$ ions catalyse this reaction.

Which graph shows how the concentration of acidified manganate(VII) ions varies after ethanedioate ions are added?

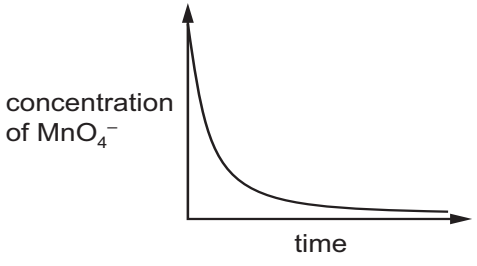
**A**



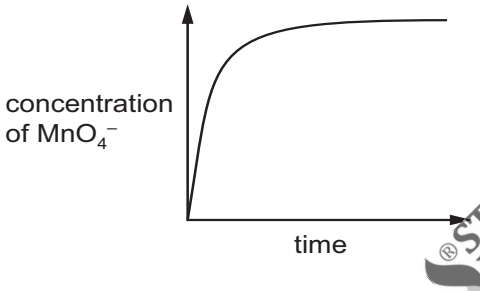

**B**




**C**




**D**




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**80 9701/12/F/M/17/Q13**

Which reagent, when mixed with ammonium sulfate and then heated, liberates ammonia?

**A** aqueous bromine

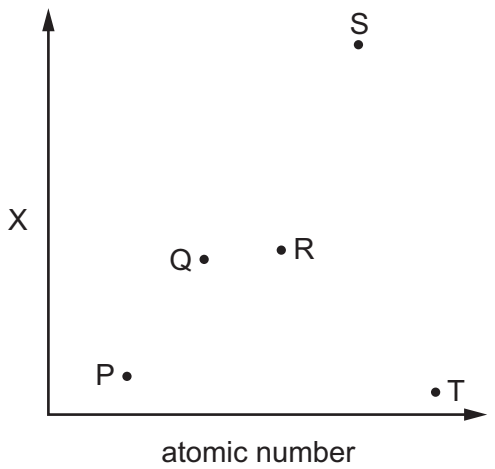
**B** dilute hydrochloric acid

**C** limewater

**D** potassium dichromate(VI) in acidic solution

**81 9701/12/F/M/17/Q15**

The magnitude of property X of five elements from the third period of the Periodic Table, P, Q, R, S and T is shown. P, Q, R, S and T have consecutive atomic numbers. The letters do not represent the symbols of the elements.




Which row correctly identifies property X and element R?

| | property X | element R |
|---|---|---|
| **A** | electrical conductivity | Al |
| **B** | electronegativity | Si |
| **C** | melting point | Al |
| **D** | melting point | Si |

**82 9701/11/M/J/17/Q12**

Why is the second ionisation energy of sodium larger than the second ionisation energy of magnesium?

**A** The attraction between the nucleus and the outer electron is greater in $Na^+$ than in $Mg^+$.

**B** The nuclear charge of $Na^+$ is greater than that of $Mg^+$.

**C** The outer electron of $Na^+$ is more shielded than the outer electron of $Mg^+$.

**D** The outer electron of Na is in the same orbital as the outer electron of Mg.

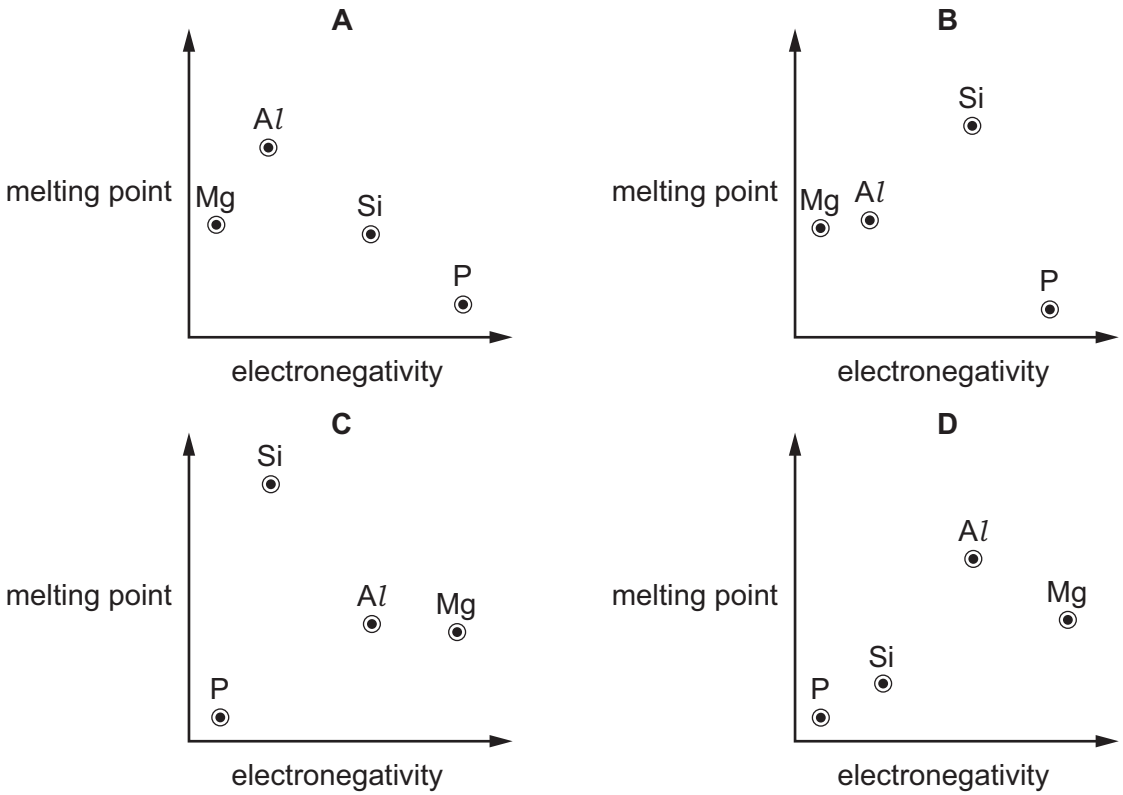
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**83 9701/11/M/J/17/Q13**

Which graph correctly shows the relative melting points of the elements Mg, A$l$, Si and P plotted against their relative electronegativities?




**84 9701/12/M/J/17/Q3**

In some fireworks there is a reaction between powdered aluminium and powdered barium nitrate. Heat is evolved, an unreactive gas is produced, and all nitrogen atoms are reduced.

What is the equation for this reaction?

**A** $2Al + Ba(NO_3)_2 \rightarrow Al_2O_3 + BaO + 2NO$

**B** $4Al + 4Ba(NO_3)_2 \rightarrow 2Al_2O_3 + 4Ba(NO_2)_2 + O_2$

**C** $10Al + 3Ba(NO_3)_2 \rightarrow 5Al_2O_3 + 3BaO + 3N_2$

**D** $10Al + 18Ba(NO_3)_2 \rightarrow 10Al(NO_3)_3 + 18BaO + 3N_2$



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**85 9701/12/M/J/17/Q12**

The elements magnesium and sulfur each form doubly charged ions.

How do the atomic radii and ionic radii of these elements compare?

| | atomic radius | | ionic radius | atomic radius | | ionic radius |
|---|---|---|---|---|---|---|
| **A** | Mg | > | $Mg^{2+}$ | S | > | $S^{2-}$ |
| **B** | Mg | > | $Mg^{2+}$ | S | < | $S^{2-}$ |
| **C** | Mg | < | $Mg^{2+}$ | S | > | $S^{2-}$ |
| **D** | Mg | < | $Mg^{2+}$ | S | < | $S^{2-}$ |

**86 9701/13/M/J/17/Q2**

A 0.216 g sample of an aluminium compound X reacts with an excess of water to produce a single hydrocarbon gas. This gas burns completely in $O_2$ to form $H_2O$ and $CO_2$ only. The volume of $CO_2$ at room temperature and pressure is 108 $cm^3$.

What is the formula of X?

**A** $Al_2C_3$ **B** $Al_3C_2$ **C** $Al_3C_4$ **D** $Al_4C_3$

**87 9701/13/M/J/17/Q12**

Magnesium chloride, $MgCl_2$, and silicon tetrachloride, $SiCl_4$, are separately added to water.

What are the approximate pH values of the solutions formed?

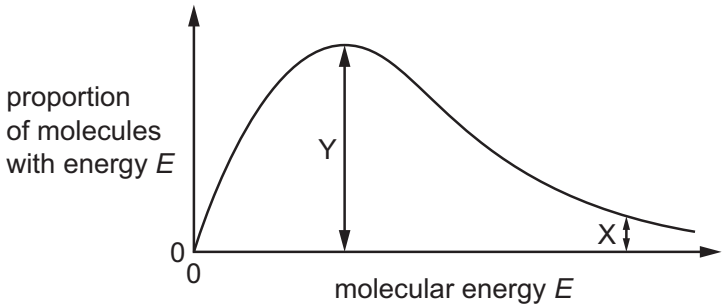
| | $MgCl_2$ | $SiCl_4$ |
|---|---|---|
| **A** | 0–3 | 0–3 |
| **B** | 0–3 | 6–7 |
| **C** | 6–7 | 0–3 |
| **D** | 6–7 | 6–7 |



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**88 9701/13/M/J/17/Q11**

The diagram shows the Boltzmann distribution of the energy of gaseous molecules at a particular temperature.




Which statement is correct?

**A** If the temperature of the gas is raised, the height of the maximum of the curve increases.

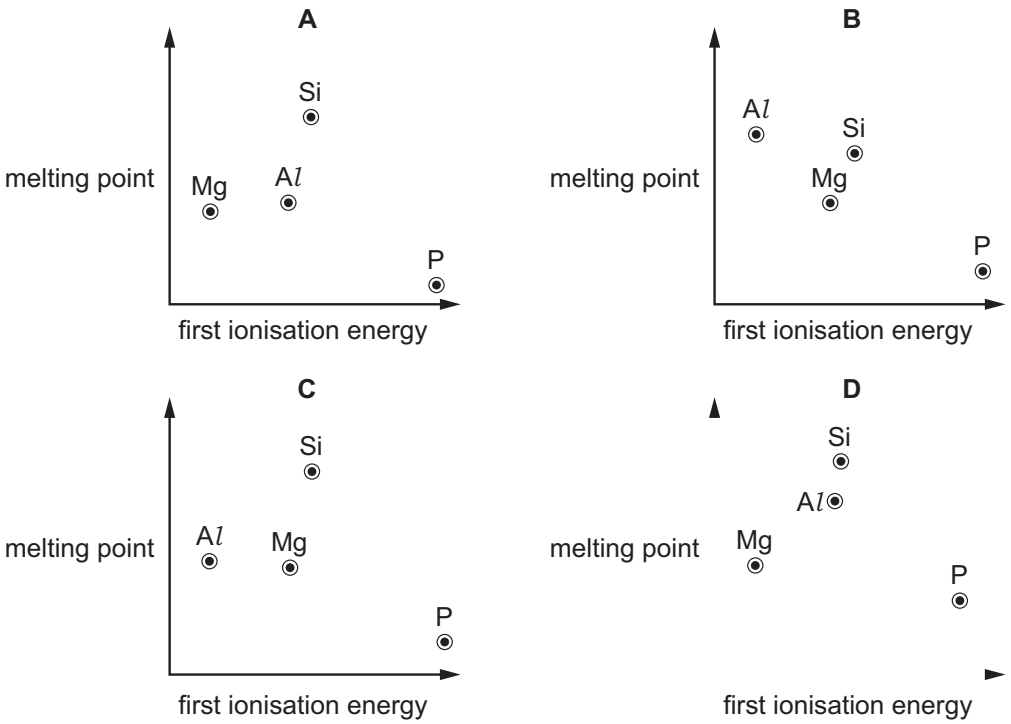
**B** If the temperature of the gas is raised, the maximum of the curve moves to the right.

**C** The length of the line labelled X shows the activation energy for the reaction.

**D** The length of the line labelled Y shows the enthalpy change of the reaction.

**89 9701/13/M/J/17/Q13**

Which graph correctly shows the relative melting points of the elements Mg, A*l*, Si and P plotted against their relative first ionisation energies?






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**90 9701/11/O/N/18/Q13**

X and Y are elements in Period 3 of the Periodic Table.

- The oxide of X is a solid at room temperature. This oxide has a giant structure.
- The chloride of X does not react with water.
- Argon is the only element in Period 3 with a lower melting point than Y.

What could be the formula of a compound formed between elements X and Y?

**A** $Al_2S_3$ **B** MgS **C** NaCl **D** $PCl_5$

**91 9701/11/O/N/18/Q14**

Which row describes the structure and bonding of $SiO_2$ and $SiCl_4$?

| | $SiO_2$ | | $SiCl_4$ | |
|---|---|---|---|---|
| | bonding | structure | bonding | structure |
| **A** | covalent | giant | covalent | giant |
| **B** | covalent | giant | covalent | simple |
| **C** | ionic | giant | covalent | giant |
| **D** | ionic | giant | covalent | simple |

**92 9701/11/O/N/18/Q18**

Which statement explains the observation that magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride?

**A** The ionic radius of the $NH_4^+$ ion is similar to that of $Mg^{2+}$ but not that of $Na^+$.

**B** $NH_4Cl$ dissociates less fully than NaCl.

**C** The $Na^+$ and $Mg^{2+}$ ions have the same number of electrons.

**D** The $NH_4^+$ ion can donate a proton.

**93 9701/12/O/N/18/Q10**

In a chemical system the particles involved have a range of energies. This can be shown on a graph called the Boltzmann distribution.

Which statement correctly explains the effect of a catalyst on the particles in a chemical system?

**A** A catalyst enables particles with a lower energy to collide successfully.

**B** A catalyst increases the number of particles with higher energies.

**C** A catalyst increases the number of particles with the most probable energy value.

**D** A catalyst increases the value of the most probable particle energy.

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**94 9701/12/O/N/18/Q12**

The melting points of the Period 3 elements phosphorus to argon are shown in the table.

| element | P | S | C$l$ | Ar |
|---|---|---|---|---|
| mp / K | 317 | 392 | 172 | 84 |

Which factor explains the changes in melting points from phosphorus to argon?

**A** the changes in electronegativity from phosphorus to argon

**B** the changes in first ionisation energy from phosphorus to argon

**C** the increase in the number of electrons in each atom from phosphorus to argon

**D** the number of atoms in each molecule of the element from phosphorus to argon

**95 9701/12/O/N/18/Q13**

Which observations are made when a sample of silicon chloride, Si$Cl_4$, is added to a beaker of water?

**A** No visible change is observed.

**B** Steamy fumes and a precipitate are both observed.

**C** The appearance of a precipitate is the only observation.

**D** The appearance of steamy fumes is the only observation.

**96 9701/12/F/M/19/Q12**

X, Y and Z are elements in Period 3 of the Periodic Table. The results of some experiments carried out with compounds of these elements are shown.

| element | result of adding the oxide of the element to $H_2O$(l) | result of adding the chloride of the element to $H_2O$(l) | result of adding the oxide of the element to HC$l$(aq) |
|---|---|---|---|
| X | no reaction | hydrolyses | forms chloride salt |
| Y | forms hydroxide | dissolves | forms chloride salt |
| Z | forms acid | hydrolyses | hydrolyses |

Which statement could be correct?

**A** X is A$l$ and Y is Mg.

**B** X is Si and Y is Na.

**C** Y is A$l$ and Z is P.

**D** Y is Na and Z is A$l$.



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**97 9701/12/F/M/19/Q13**

A solid Period 3 element, Q, is reacted with oxygen gas. Compound R is formed.

When R is added to water the pH decreases.

What could be the empirical formula of R?

**A** $Q_2O_4$ **B** $Q_2O_5$ **C** $Q_4O_{10}$ **D** $Q_5O_2$

**98 9701/11/M/J/19/Q1**

The temperature of a sample of an inert gas is increased.

What effect does this have on the number of molecules with the most probable energy and on the number of molecules with high energy?

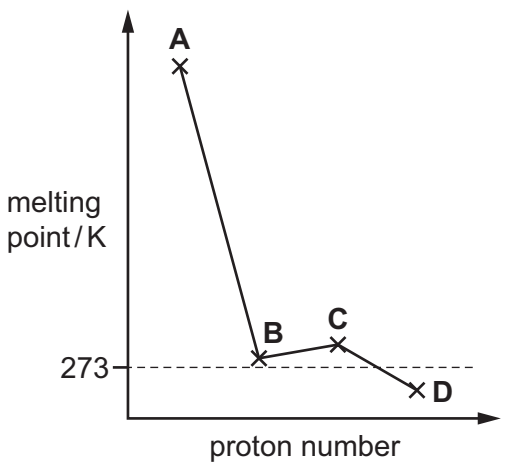
| | number of molecules with the most probable energy | number of molecules with high energy |
|---|---|---|
| **A** | decreases | decreases |
| **B** | decreases | increases |
| **C** | increases | decreases |
| **D** | increases | increases |

**99 9701/11/M/J/19/Q13**

The relative melting points of four consecutive elements in the Periodic Table are shown in the graph.

The elements all have proton numbers less than 20.

Which element is in Group 16?






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**100 9701/12/M/J/19/Q12**

Element Q readily oxidises in air. The oxide produced reacts with water to form a solution of very low pH.

Where could element Q be found in the Periodic Table?

| | period | group |
|---|---|---|
| **A** | 2 | 1 |
| **B** | 2 | 14 |
| **C** | 3 | 14 |
| **D** | 3 | 15 |

**101 9701/12/M/J/19/Q13**

The eight elements sodium to argon are in the same period of the Periodic Table.

The equation corresponding to the first ionisation energy is shown.

$$X(g) \rightarrow X^{+}(g) + e^{-}$$

For which of these eight elements is the electron in this equation removed from a filled orbital?

**A** Mg, A*l*, Si, P, S, C*l* and Ar

**B** A*l*, Si, P, S, C*l* and Ar only

**C** Mg, S, C*l* and Ar only

**D** S, C*l* and Ar only

**102 9701/12/M/J/19/Q14**

Elements D and E are both in Period 3. Element D has the smallest atomic radius in Period 3. There are only two elements in Period 3 which have a lower melting point than element E. Elements D and E react together to form compound L.

Which compound could be L?

**A** $MgCl_2$ **B** MgS **C** $Na_2S$ **D** $PCl_3$

**103 9701/11/O/N/19/Q12**

Which oxide will cause an increase in pH when added to water?

**A** MgO **B** $Al_2O_3$ **C** $SiO_2$ **D** $SO_2$



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**104 9701/12/O/N/19/Q9**

When lead(II) sulfide, PbS, is heated in air, sulfur dioxide and lead(II) oxide are formed.

What is the equation for the reaction between PbS and oxygen?

**A** $PbS + 2O_2 \rightarrow SO_2 + PbO_2$

**B** $PbS + 2\frac{1}{2}O_2 \rightarrow SO_3 + PbO_2$

**C** $PbS + 1\frac{1}{2}O_2 \rightarrow SO_2 + PbO$

**D** $PbS + 2O_2 \rightarrow SO_3 + PbO$

**105 9701/12/O/N/19/Q11**

Hydrated aluminium ions undergo the following reaction.

$$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5OH]^{2+}(aq) + H_3O^+(aq)$$

Which statement about this reaction is correct?

**A** $H_2O(l)$ and $[Al(H_2O)_5OH]^{2+}(aq)$ are a conjugate acid-base pair.

**B** $H_2O(l)$ is acting as an acid as it is donating $H^+$ ions.

**C** If $OH^-(aq)$ is added, the equilibrium will move to the right.

**D** $K_c$ varies as the pH is varied.

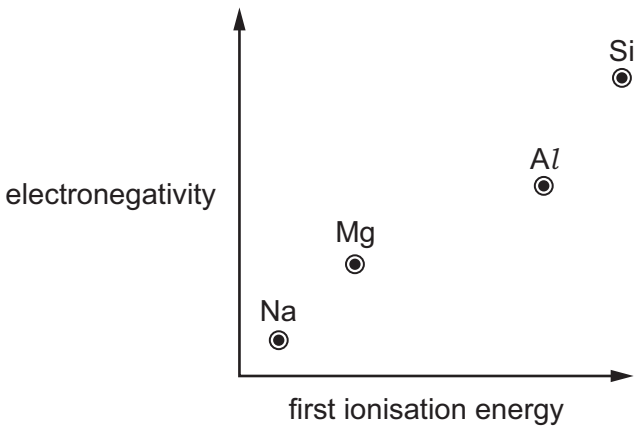


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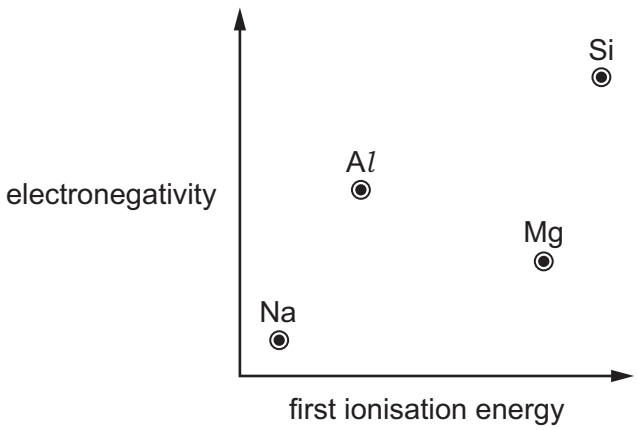
**106 9701/12/O/N/19/Q12**

Which diagram correctly shows the electronegativity of the elements Na, Mg, A*l* and Si plotted against their first ionisation energies?

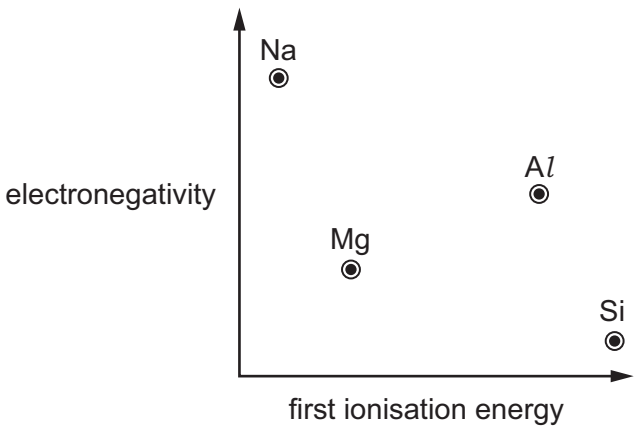
**A**



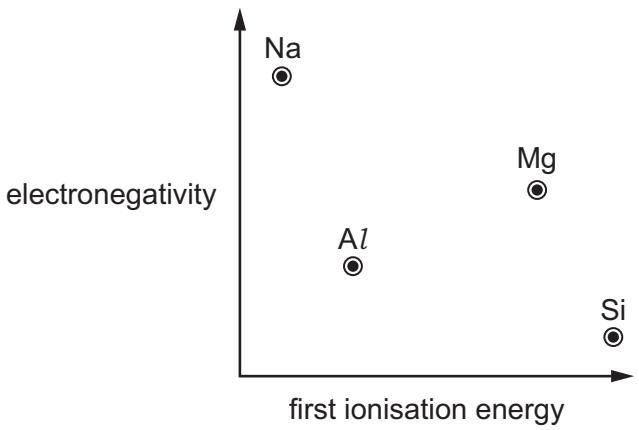

**B**




**C**




**D**






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**107 9701/12/F/M/20/Q12**

X and Y are oxides of different Period 3 elements.

If one mole of X is added to water, the solution formed is neutralised by exactly one mole of Y.

What could be the identities of X and Y?

| | X | Y |
|---|---|---|
| **A** | $P_4O_{10}$ | $Al_2O_3$ |
| **B** | $SO_3$ | $Al_2O_3$ |
| **C** | $P_4O_{10}$ | $Na_2O$ |
| **D** | $SO_3$ | $Na_2O$ |

**108 9701/12/F/M/20/Q16**

Sodium, magnesium and aluminium are three elements in Period 3 of the Periodic Table. Each element forms an oxide.

Which row is correct?

| | sodium oxide | magnesium oxide | aluminium oxide |
|---|---|---|---|
| **A** | basic | amphoteric | amphoteric |
| **B** | giant ionic | giant ionic | simple molecular |
| **C** | high melting point | high melting point | low melting point |
| **D** | readily reacts with water | slight reaction with water | no reaction with water |

**109 9701/11/M/J/20/Q15**

Element Z has a giant structure.

The chloride of Z reacts with water to give a solution with a pH less than 5.

Which pair shows two elements which could be Z?

**A** aluminium, magnesium

**B** aluminium, silicon

**C** phosphorus, magnesium

**D** phosphorus, silicon



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**110 9701/11/M/J/20/Q16**

Sodium, aluminium and silicon are three elements in Period 3. Each element forms an oxide.

Which row has three correct properties of these oxides?

| | sodium oxide | aluminium oxide | silicon dioxide |
|---|---|---|---|
| **A** | basic | basic | amphoteric |
| **B** | giant ionic | giant ionic | simple molecular |
| **C** | high melting point | low melting point | high melting point |
| **D** | reacts with water | no reaction with water | no reaction with water |

**111 9701/11/M/J/20/Q19**

What is the order of increasing melting point of the three chlorides shown?

$CCl_4$ $MgCl_2$ $PCl_5$

| | lowest melting point → | | highest melting point |
|---|---|---|---|
| **A** | $CCl_4$ | $PCl_5$ | $MgCl_2$ |
| **B** | $MgCl_2$ | $CCl_4$ | $PCl_5$ |
| **C** | $MgCl_2$ | $PCl_5$ | $CCl_4$ |
| **D** | $PCl_5$ | $CCl_4$ | $MgCl_2$ |

**112 9701/12/M/J/20/Q16**

One molecule of an oxide of element Z reacts with six molecules of water to produce an acidic compound.

What is element Z?

**A** aluminium **B** phosphorus **C** silicon **D** sulfur

**113 9701/13/M/J/20/Q19**

Element X is in Period 3. It reacts rapidly with water to form an alkaline solution.

Which statement about the **chloride** of element X is correct?

**A** It conducts electricity when molten.

**B** It has a melting point of less than 100 °C.

**C** It has covalent bonding.

**D** It reacts rapidly with cold water.



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# Inorganic Chemistry

10
TOPIC

# Group 2



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**1 9701/1/M/J/02/Q15**

Which equation represents the reaction that occurs when calcium nitrate is heated strongly?

**A** $Ca(NO_3)_2 \rightarrow Ca(NO_2)_2 + O_2$

**B** $Ca(NO_3)_2 \rightarrow CaO + N_2O + 2O_2$

**C** $Ca(NO_3)_2 \rightarrow CaO_2 + 2NO_2$

**D** $2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$

**2 9701/1/O/N/02/Q16**

River water in a chalky agricultural area may contain Ca , $Mg^{2+}$, $CO_3^{2+}$, $HCO_3^{2-}$, $Cl^-$, and $NO_3^-$ ions. In a waterworks, such water is treated by adding a calculated quantity of calcium hydroxide.

What will be precipitated following the addition of calcium hydroxide?

**A** $CaCl_2$

**B** $CaCO_3$

**C** $MgCO_3$

**D** $Mg(NO_3)_2$

**3 9701/1/M/J/03/Q15**

What are the products of the thermal decomposition of magnesium nitrate?

**A** magnesium nitride and oxygen

**B** magnesium oxide and nitrogen

**C** magnesium oxide, nitrogen and oxygen

**D** magnesium oxide, nitrogen dioxide and oxygen

**4 9701/1/M/J/03/Q18**

Which reagent, when mixed and heated with ammonium sulphate, liberates ammonia?

**A** aqueous bromine

**B** dilute hydrochloric acid

**C** limewater

**D** acidified potassium dichromate(VI)

**5 9701/01/M/J/04/Q14**

Which ion is most polarising?

**A** $Al^{3+}$

**B** $Ba^{2+}$

**C** $Mg^{2+}$

**D** $Na^+$



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**6 9701/01/M/J/04/Q15**

Which element has the same oxidation number in all of its known compounds?

**A** beryllium **C** nitrogen

**B** chlorine **D** sulphur

**7 9701/01/M/J/04/Q16**

Due to their similar ionic radii, the reactions of lithium and magnesium and their corresponding compounds are very similar.

Which statement concerning the reactions of lithium and its compounds is correct?

**A** Lithium carbonate decomposes on heating at a relatively low temperature, forming lithium oxide and carbon dioxide.

**B** Lithium nitrate decomposes on heating, forming lithium nitrite and oxygen.

**C** Lithium only burns slowly in oxygen.

**D** Lithium reacts violently with cold water, liberating hydrogen.

**8 9701/01/M/J/05/Q13**

*Use of the Data Booklet is relevant to this question.*

Which element is likely to have an electronegativity similar to that of aluminium?

**A** barium **B** beryllium **C** magnesium **D** strontium

**9 9701/01/M/J/05/Q13**

*Use of the Data Booklet is relevant to this question.*

Which element is likely to have an electronegativity similar to that of aluminium?

**A** barium **B** beryllium **C** magnesium **D** strontium

**10 9701/01/M/J/05/Q14**

*Use of the Data Booklet is relevant to this question.*

Which is true for calcium or its compounds compared with the corresponding statements for magnesium?

**A** Calcium has a smaller atomic radius.

**B** Calcium oxide reacts less vigorously with water.

**C** Calcium reacts more vigorously with water.

**D** The sum of the first two ionisation energies of calcium is greater.



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**11 9701/01/M/J/05/Q13**

*Use of the Data Booklet is relevant to this question.*

Which element is likely to have an electronegativity similar to that of aluminium?

**A** barium **B** beryllium **C** magnesium **D** strontium

**12 9701/01/M/J/05/Q13**

*Use of the Data Booklet is relevant to this question.*

Which element is likely to have an electronegativity similar to that of aluminium?

**A** barium **B** beryllium **C** magnesium **D** strontium

**13 9701/01/M/J/05/Q14**

*Use of the Data Booklet is relevant to this question.*

Which is true for calcium or its compounds compared with the corresponding statements for magnesium?

**A** Calcium has a smaller atomic radius.

**B** Calcium oxide reacts less vigorously with water.

**C** Calcium reacts more vigorously with water.

**D** The sum of the first two ionisation energies of calcium is greater.

**14 9701/01/M/J/05/Q17**

Limestone, $CaCO_3$, has been used as a building material for thousands of years, and was used on the Pyramids in Egypt. In the past hundred years many limestone buildings have begun to suffer damage.

What is the cause of this damage?

**A** hydrocarbon emissions from motor vehicles

**B** increased temperature due to global warming

**C** increased ultraviolet radiation as the ozone layer is destroyed

**D** sulphur dioxide from fossil fuels forming 'acid rain'

**15 9701/01/O/N/05/Q16**

When a mineral was heated in a Bunsen flame to constant mass, a colourless gas that turned lime water milky was evolved. The remaining solid was cooled and then added to aqueous hydrochloric acid. Vigorous effervescence was seen.

What was the mineral?

**A** aragonite, $CaCO_3$

**B** artinite, $MgCO_3.Mg(OH)_2.3H_2O$

**C** barytocalcite, $BaCO_3.CaCO_3$

**D** dolomite, $CaCO_3.MgCO_3$



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**16 9701/01/O/N/05/Q18**

Lime, CaO, is used to reduce the acidity of soil, and ammonium sulphate is a nitrogenous fertiliser.

Why can they **not** be used in a mixed form?

**A** The dry mixture is explosive.

**B** $CaSO_4$, formed on mixing, causes hard water.

**C** When dampened, ammonia is given off.

**D** Sulphuric acid will form.

**17 9701/01/O/N/06/Q13**

Steam is passed over heated magnesium to give compound **X** and hydrogen.

What is **not** a property of compound **X**?

**A** It has a high melting point.
**B** It is a basic oxide.
**C** It is a white solid.
**D** It is very soluble in water.

**18 9701/01/O/N/06/Q14**

A 5.00 g sample of an anhydrous Group II metal nitrate loses 3.29 g in mass on strong heating.

Which metal is present?

**A** magnesium **B** calcium **C** strontium **D** barium

**19 9701/01/M/J/07/Q14**

Slaked lime, $Ca(OH)_2$, may be made from limestone, $CaCO_3$.

On heating in a lime kiln at 1000 °C, limestone decomposes as follows.

reaction 1 $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Water is then reacted with calcium oxide, CaO, as follows.

reaction 2 $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

What are the enthalpy changes of these reactions?

| | reaction 1 | reaction 2 |
|---|---|---|
| **A** | endothermic | endothermic |
| **B** | endothermic | exothermic |
| **C** | exothermic | endothermic |
| **D** | exothermic | exothermic |



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**20 9701/01/O/N/07/Q15**

The chemical properties of an element at the top of a group in the Periodic Table are often different from those of the rest of the elements in the group.

Of the following properties of beryllium and its compounds, which property **is** typical of the elements below it in Group II?

**A** Be does not react with hot water.

**B** $BeCl_2$ is covalent.

**C** $Be(NO_3)_2$ produces BeO on thermal decomposition.

**D** BeO dissolves in alkalis.

**21 9701/01/M/J/08/Q19**

Total elimination of the pollutant sulphur dioxide, $SO_2$, is difficult, both for economic and technical reasons. Its emission can be reduced in furnace chimneys using desulphurisation plants, where the gases are scrubbed (washed) with calcium hydroxide to remove the $SO_2$.

What is the main product formed initially?

**A** CaO **B** $Ca(OH)_2$ **C** $CaSO_3$ **D** $CaSO_4$

**22 9701/01/M/J/09/Q13**

River water in a chalky agricultural area may contain $Ca^{2+}$, $Mg^{2+}$, $CO_3^{2-}$, $HCO_3^-$, $Cl^-$ and $NO_3^-$ ions. In a waterworks, such water is treated by adding a calculated quantity of calcium hydroxide.

What will be precipitated following the addition of calcium hydroxide?

**A** $CaCl_2$ **B** $CaCO_3$ **C** $Ca(NO_3)_2$ **D** $Mg(NO_3)_2$

**23 9701/12/M/J/10/Q8**

*Use of the Data Booklet is relevant to this question.*

2.920 g of a Group II metal, **X**, reacts with an excess of chlorine to form 5.287 g of a compound with formula **X**$Cl_2$. What is metal **X**?

**A** barium **B** calcium **C** magnesium **D** strontium

**24 9701/12/M/J/10/Q19**

Which property of Group II elements (beryllium to barium) decreases with increasing atomic number?

**A** reactivity with water

**B** second ionisation energy

**C** solubility of hydroxides

**D** stability of the carbonates

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**25 9701/12/O/N/10/Q12**

Equimolar quantities of magnesium carbonate and strontium carbonate are separately heated to bring about complete thermal decomposition. The minimum temperature for this to occur is called $T_d$.

The cold residues are separately added to equal volumes of water and the change in pH is measured. The change in pH is called ΔpH.

Which metal has the higher value of $T_d$, and the greater value of ΔpH?

| | $T_d$ | ΔpH |
|---|---|---|
| **A** | Mg | Mg |
| **B** | Mg | Sr |
| **C** | Sr | Mg |
| **D** | Sr | Sr |

**26 9701/12/O/N/10/Q14**

*Use of the Data Booklet is relevant to this question.*

Which mass of solid residue can be obtained from the thermal decomposition of 4.10 g of anhydrous calcium nitrate?

**A** 0.70 g **B** 1.00 g **C** 1.40 g **D** 2.25 g

**27 9701/12/O/N/10/Q15**

Which statement explains the observation that magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride?

**A** The ionic radius of the $NH_4^+$ ion is similar to that of $Mg^{2+}$ but not that of $Na^+$.

**B** $NH_4Cl$ dissociates less fully than NaCl.

**C** The $Na^+$ and $Mg^{2+}$ ions are isoelectronic (have the same number of electrons).

**D** The $NH_4^+$ ion can donate a proton.

**28 9701/12/O/N/11/Q18**

Lime mortar is made from quicklime, water and sand. Over a period of time, lime mortar changes into a much harder form. Both fresh and old lime mortar react with aqueous hydrochloric acid but only the old lime mortar effervesces during the reaction.

Which equation describes the change from fresh to old lime mortar?

**A** $CaO + CO_2 \rightarrow CaCO_3$

**B** $CaO + H_2O \rightarrow Ca(OH)_2$

**C** $Ca(OH)_2 \rightarrow CaO + H_2O$

**D** $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

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**29** **9701/13/O/N/12/Q14**

*Use of the Data Booklet is relevant to this question.*

When 3.00 g of an anhydrous nitrate of a Group II metal is decomposed, 1.53 g of gas is produced.

What is the nitrate compound?

**A** beryllium nitrate **B** calcium nitrate **C** magnesium nitrate **D** strontium nitrate

**30** **9701/12/O/N/12/Q14**

What are the trends in the stated properties as Group II is descended from magnesium to barium?

| | decomposition temperature of the carbonate | first ionisation energy |
|---|---|---|
| **A** | decreases | decreases |
| **B** | decreases | increases |
| **C** | increases | decreases |
| **D** | increases | increases |

**31** **9701/12/O/N/12/Q15**

*Use of the Data Booklet is relevant to this question.*

The nitrates of beryllium, calcium, magnesium, and strontium all decompose in the same way when heated. When 2.00 g of one of these anhydrous nitrates is decomposed, 1.32 g of gas is produced. What is the nitrate?

**A** beryllium nitrate **B** calcium nitrate **C** magnesium nitrate **D** strontium nitrate

**32** **9701/12/M/J/13/Q14**

In which row of the table are all statements comparing the compounds of calcium and barium correct?

| | solubility of calcium hydroxide | solubility of barium hydroxide | thermal stability of calcium carbonate | thermal stability of barium carbonate |
|---|---|---|---|---|
| **A** | higher | lower | higher | lower |
| **B** | higher | lower | lower | higher |
| **C** | lower | higher | higher | lower |
| **D** | lower | higher | lower | higher |

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**33** **9701/12/O/N/13/Q14**

Which property **increases** in value going down Group II?

**A** electronegativity **C** maximum oxidation number

**B** ionic radius **D** second ionisation energy

**34** **9701/12/O/N/13/Q15**

Which row correctly identifies the uses of some of the compounds of Group II metals?

| | used as a refractory lining in kilns | used in agriculture to increase the pH of a soil |
|---|---|---|
| **A** | CaO | $Ca(OH)_2$ |
| **B** | CaO | $Mg(OH)_2$ |
| **C** | MgO | $Ca(OH)_2$ |
| **D** | MgO | $Mg(OH)_2$ |

**35** **9701/12/M/J/14/Q12**

When barium is burnt in oxygen, what colour is the flame?

**A** green **B** orange **C** red **D** white

**36** **9701/12/O/N/14/Q18**

Total removal of the pollutant sulfur dioxide, $SO_2$, is difficult. The quantities emitted from furnace chimneys can be lowered by using desulfurisation plants. The gases are reacted with calcium hydroxide to remove the $SO_2$.

What is the main product formed **initially**?

**A** $Ca(HSO_4)_2$ **B** CaS **C** $CaSO_3$ **D** $CaSO_4$

**37** **9701/12/M/J/15/Q12**

*Use of the Data Booklet is relevant to this question.*

When 3.00 g of an anhydrous nitrate of a Group II metal is decomposed, 1.53 g of gas is produced.

What is the nitrate compound?

**A** beryllium nitrate **C** magnesium nitrate

**B** calcium nitrate **D** strontium nitrate



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**38 9701/12/M/J/15/Q13**

What happens when a piece of magnesium ribbon is placed in cold water?

**A** A vigorous effervescence occurs.

**B** Bubbles of gas form slowly on the magnesium.

**C** The magnesium floats on the surface of the water and reacts quickly.

**D** The magnesium glows and a white solid is produced.

**39 9701/12/M/J/15/Q14**

Compound **X** releases carbon dioxide gas and forms a white solid, **Y**, when it is heated. Neither **X** nor **Y** are soluble in water. Compound **Y** is used as a refractory kiln lining.

What is compound **X**?

**A** $CaCO_3$ **B** CaO **C** $MgCO_3$ **D** MgO

**40 9701/11/M/J/15/Q13**

The three minerals below are obtained from mines around the world. Each one behaves as a mixture of two carbonate compounds. They can be used as fire retardants because they decompose in the heat, producing $CO_2$. This gas smothers the fire.

| | |
|---|---|
| barytocite | $BaCa(CO_3)_2$ |
| dolomite | $CaMg(CO_3)_2$ |
| huntite | $Mg_3Ca(CO_3)_4$ |

What is the order of effectiveness as fire retardant, from best to worst?

| | best → worst | | |
|---|---|---|---|
| **A** | dolomite | barytocite | huntite |
| **B** | dolomite | huntite | barytocite |
| **C** | huntite | barytocite | dolomite |
| **D** | huntite | dolomite | barytocite |



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**41 9701/11/M/J/16/Q14**

X and Y are both Group 2 metals.

X and Y both form hydroxide compounds, but $X(OH)_2$ is more soluble in water than $Y(OH)_2$.

If a piece of metal Y is put into cold water a very slow reaction occurs, and only a very few, small hydrogen bubbles can be seen.

What could be the identities of X and Y?

| | X | Y |
|---|---|---|
| **A** | barium | magnesium |
| **B** | barium | strontium |
| **C** | calcium | strontium |
| **D** | magnesium | calcium |

**42 9701/13/M/J/16/Q15**

Anhydrous magnesium nitrate, $Mg(NO_3)_2$ , will decompose when heated, giving a white solid and a mixture of two gases X and Y.

Y is oxygen.

What is the ratio $\frac{\text{mass of X released}}{\text{mass of Y released}}$ ?

**A** $\frac{1}{0.174}$ **B** $\frac{1}{0.267}$ **C** $\frac{1}{0.348}$ **D** $\frac{1}{3.43}$

**43 9701/12/F/M/16/Q18**

River water in a chalky agricultural area contains $Ca^{2+}$, $Mg^{2+}$, $CO_3^{2-}$, $HCO_3^-$, $Cl^-$ and $NO_3^-$ ions. In a water treatment plant, such water is treated by adding a calculated quantity of calcium hydroxide.

What will be precipitated from the river water following the addition of calcium hydroxide?

**A** $CaCl_2$ **B** $CaCO_3$ **C** $Ca(NO_3)_2$ **D** $Mg(NO_3)_2$

**44 9701/11/M/J/16/Q16**

In some areas lime, $Ca(OH)_2$, is added to soil to improve crop growth.

Which statement correctly describes a reason why lime improves crop growth?

**A** Lime acts as a catalyst which speeds up the release of nitrates into the soil.

**B** Lime is an effective pesticide and protects the plants from damage.

**C** Lime is used to reduce the acidity of the soil.

**D** Lime lowers the pH of the soil.

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**45 9701/12/M/J/16/Q16**

A solid, **T**, was placed in an excess of the liquid **U**.

A colourless gas was given off and a white precipitate was seen. The precipitate was not **T**.

What could be the identities of **T** and **U**?

| | T | U |
|---|---|---|
| **A** | $BaCO_3$ | $H_2O$ |
| **B** | Ca | dilute $H_2SO_4$ |
| **C** | Mg | dilute $H_2SO_4$ |
| **D** | $SrCO_3$ | dilute HC*l* |

**46 9701/13/M/J/16/Q14**

Solutions of $Mg(NO_3)_2$ and $Ba(NO_3)_2$ separately undergo a series of reactions.

$$Mg(NO_3)_2(aq) \xrightarrow{\text{sodium carbonate solution}} M \xrightarrow{\text{excess HC}l\text{(aq)}} N \xrightarrow{\text{excess NaOH(aq)}} P$$

$$Ba(NO_3)_2(aq) \xrightarrow{\text{sodium carbonate solution}} Q \xrightarrow{\text{excess HC}l\text{(aq)}} R \xrightarrow{\text{excess NaOH(aq)}} S$$

M, N and P are magnesium compounds.

Q, R and S are barium compounds.

How many of M, N, P, Q, R and S are white precipitates?

**A** 2 **B** 3 **C** 4 **D** 5

**47 9701/13/M/J/16/Q16**

Steam is passed over heated magnesium to give compound J and hydrogen.

**9701/12/F/M/17/Q18**

What is **not** a property of compound J?

**A** It has an $M_r$ of 40.3.

**B** It is basic.

**C** It is a white solid.

**D** It is very soluble in water.



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**48 9701/12/F/M/17/Q18**

**Z** is an anhydrous compound of a Group 2 element. When it is heated, **Z** undergoes thermal decomposition to produce two different gases. **Z** has relatively low thermal stability compared to other Group 2 compounds containing the same anion as **Z**.

What is compound **Z**?

**A** barium carbonate

**B** barium nitrate

**C** magnesium carbonate

**D** magnesium nitrate

**49 9701/11/M/J/17/Q14**

An excess of MgO is shaken with water. The resulting mixture is filtered into test-tube X.

An excess of BaO is shaken with water. The resulting mixture is filtered into test-tube Y.

Which oxide reacts more readily with water and which filtrate has the **lower** pH?

| | oxide reacts more readily with water | test-tube with filtrate of **lower** pH |
|---|---|---|
| **A** | barium oxide | X |
| **B** | barium oxide | Y |
| **C** | magnesium oxide | X |
| **D** | magnesium oxide | Y |

**50 9701/11/M/J/17/Q15**

Samples of magnesium carbonate, $MgCO_3$, are placed in crucibles R and S. The sample in crucible R is heated until there is no further loss in mass, and then allowed to cool. The sample in crucible S is left unheated.

Dilute hydrochloric acid is then added to both crucibles.

On adding the dilute hydrochloric acid, which observations are correct?

| | R | S |
|---|---|---|
| **A** | gas produced | gas produced |
| **B** | gas produced | no gas produced |
| **C** | no gas produced | gas produced |
| **D** | no gas produced | no gas produced |

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**51 9701/12/M/J/17/Q14**

Trends are seen in the physical and chemical properties of the elements of Group 2 and their compounds.

Which property shows a **decrease** from magnesium to barium?

**A** the rate of the reaction between the element and dilute hydrochloric acid

**B** the solubility of the hydroxides

**C** the solubility of the sulfates

**D** the temperature of decomposition of the carbonates

**52 9701/12/M/J/17/Q15**

Calcium oxide is added to water and the resulting mixture is filtered.

This filtrate is X.

When carbon dioxide is bubbled through filtrate X, a white precipitate is formed.

Which equation for this reaction of filtrate X with carbon dioxide is correct?

**A** $CaO + CO_2 \rightarrow CaCO_3$

**B** $Ca(OH)_2 + CO_2 \rightarrow CaO + H_2CO_3$

**C** $2CaO + H_2O + CO_2 \rightarrow CaCO_3 + Ca(OH)_2$

**D** $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

**53 9701/13/M/J/17/Q14**

The table gives information about calcium carbonate and calcium hydroxide.

Which row is correct?

| | calcium carbonate is more soluble than calcium hydroxide | calcium hydroxide can be manufactured using calcium carbonate as a starting material |
|---|---|---|
| **A** | no | no |
| **B** | no | yes |
| **C** | yes | no |
| **D** | yes | yes |



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**54 9701/13/M/J/17/Q15**

Which row correctly describes the reactions of calcium and strontium with water?

| | substance reduced | substance oxidised | more vigorous reaction |
|---|---|---|---|
| **A** | calcium or strontium | water | calcium + water |
| **B** | calcium or strontium | water | strontium + water |
| **C** | water | calcium or strontium | calcium + water |

**55 9701/11/O/N/18/Q4**

5.0 g samples of the carbonates of barium, copper, lithium and magnesium are decomposed to the metal oxides and carbon dioxide.

For which compound is there the greatest loss in mass?

**A** barium carbonate

**B** copper(II) carbonate

**C** lithium carbonate

**D** magnesium carbonate

**56 9701/11/O/N/18/Q15**

A sample of anhydrous calcium nitrate is placed in a test-tube and heated in a roaring Bunsen flame until it decomposes. The description of the gas in the test-tube is then noted. A glowing splint is then put into the test-tube and any changes are noted.

Which observations are correct?

| | description of the gas in the test-tube | result of glowing splint test |
|---|---|---|
| **A** | brown | the splint goes out |
| **B** | brown | the splint relights |
| **C** | colourless | the splint goes out |
| **D** | colourless | the splint relights |

**57 9701/12/O/N/18/Q6**

Exactly 1.00 g of a metallic element reacts completely with 300 $cm^3$ of oxygen at 298 K and 1 atm pressure to form an oxide which contains $O^{2-}$ ions.

The volume of one mole of gas at this temperature and pressure is 24.0 $dm^3$.

What could be the identity of the metal?

**A** calcium **B** magnesium **C** potassium **D** sodium



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**58 9701/12/O/N/18/Q14**

A 4.00 g sample of an anhydrous Group 2 metal nitrate is heated strongly until there is no further change. A solid residue of mass 1.37 g is formed.

Which metal is present?

**A** barium **B** calcium **C** magnesium **D** strontium

**59 9701/12/O/N/18/Q15**

In which row are all statements comparing magnesium and barium correct?

| | fourth ionisation energy | | reaction with water | |
|---|---|---|---|---|
| | magnesium | barium | magnesium | barium |
| **A** | higher | lower | faster | slower |
| **B** | higher | lower | slower | faster |
| **C** | lower | higher | faster | slower |
| **D** | lower | higher | slower | faster |

**60 9701/12/F/M/19/Q2**

A 3.7 g sample of copper(II) carbonate is added to 25 $cm_3$ of 2.0 mol $dm_{-3}$ hydrochloric acid.

Which volume of gas is produced under room conditions?

**A** 0.60 $dm^3$ **B** 0.72 $dm^3$ **C** 1.20 $dm^3$ **D** 2.40 $dm^3$

**61 9701/12/F/M/19/Q14**

Metal T reacts with water to produce a colourless solution. A white precipitate is produced when this colourless solution is mixed with aqueous sulfuric acid.

What is metal T?

**A** barium **C** potassium

**B** magnesium **D** sodium

**62 9701/12/F/M/19/Q15**

When calcium nitrate thermally decomposes, oxygen is one of the products.

Which volume of oxygen is produced under room conditions when 0.50 mol of calcium nitrate thermally decomposes?

**A** 6.0 $dm^3$ **B** 12.0 $dm^3$ **C** 18.0 $dm^3$ **D** 30.0 $dm^3$



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**63**

L, M and N are Group 2 metals. L reacts more vigorously with dilute hydrochloric acid than N does. $M(OH)_2$ is more soluble than $N(OH)_2$.

What could be the identities of L, M and N?

| | L | M | N |
|---|---|---|---|
| **A** | Ba | Ca | Sr |
| **B** | Ba | Sr | Ca |
| **C** | Ca | Ba | Sr |
| **D** | Sr | Ca | Ba |

**64** **9701/11/M/J/19/Q12**

1.15 g of a metallic element needs 300 $cm^3$ of oxygen for complete reaction, under room conditions, to form an oxide which contains $O^{2-}$ ions.

What could be the identity of this metallic element?

**A** calcium **B** magnesium **C** potassium **D** sodium

**65** **9701/11/M/J/19/Q14**

Substance X reacts with water. A gas is given off and the pH of the solution increases. The solution is then reacted with sulfuric acid and a white precipitate forms.

What could be substance X?

**A** barium **B** barium oxide **C** magnesium **D** magnesium oxide

**66** **9701/11/M/J/19/Q15**

Solutions of 0.1 mol $dm^{-3}$ $Mg(NO_3)_2$ and 0.1 mol $dm^{-3}$ $Ba(NO_3)_2$ separately undergo a series of reactions using pure reagents.

$$Mg(NO_3)_2(aq) \xrightarrow{\text{sodium carbonate solution}} M \xrightarrow{\text{excess HCl(aq) then boil}} N \xrightarrow{\text{excess NaOH(aq)}} P$$

$$Ba(NO_3)_2(aq) \xrightarrow{\text{sodium carbonate solution}} Q \xrightarrow{\text{excess HCl(aq) then boil}} R \xrightarrow{\text{excess NaOH(aq)}} S$$

M, N and P are magnesium compounds.

Q, R and S are barium compounds.

How many of M, N, P, Q, R and S are white precipitates?

**A** 2 **B** 3 **C** 4 **D** 5



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**67** **9701/12/M/J/19/Q16**

A white solid, Z, is soluble in water. A sample of Z is heated with a Bunsen burner until there is no further change. When the residue is shaken with water a solution is formed with no solid remaining.

What could Z be?

**A** $MgCO_3$ **B** $Mg(NO_3)_2$ **C** $BaCO_3$ **D** $Ba(NO_3)_2$

**68** **9701/11/O/N/19/Q14**

A 5.00 g sample of an anhydrous Group 2 metal nitrate loses 3.29 g in mass when heated strongly.

Which metal is present?

**A** magnesium **C** strontium

**B** calcium **D** barium

**69** **9701/11/O/N/19/Q15**

Solutions P and Q each contain a different Group 2 ion at the same concentration. One contains $Mg^{2+}$, the other contains $Ba^{2+}$. Tests are carried out on separate 5 $cm^3$ samples of P and Q.

test 1: add 1 $cm^3$ of 0.1 mol $dm^{-3}$ $Na_2SO_4(aq)$

test 2: add 1 $cm^3$ of 0.1 mol $dm^{-3}$ NaOH(aq)

What are the results of these tests?

| | results in test 1 | results in test 2 |
|---|---|---|
| **A** | more precipitate with $Ba^{2+}$ | more precipitate with $Ba^{2+}$ |
| **B** | more precipitate with $Ba^{2+}$ | more precipitate with $Mg^{2+}$ |
| **C** | more precipitate with $Mg^{2+}$ | more precipitate with $Ba^{2+}$ |
| **D** | more precipitate with $Mg^{2+}$ | more precipitate with $Mg^{2+}$ |



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**70 9701/12/O/N/19/Q8**

$(NH_4)_2Cr_2O_7$ decomposes when heated.

$$(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$$

Which element is oxidised and which element is reduced?

| | oxidised | reduced |
|---|---|---|
| **A** | chromium | nitrogen |
| **B** | hydrogen | chromium |
| **C** | nitrogen | chromium |
| **D** | nitrogen | hydrogen |

**71 9701/12/O/N/19/Q14**

When equal volumes of saturated solutions of barium hydroxide and calcium hydroxide are mixed, a white precipitate, Y, forms. The mixture is filtered and carbon dioxide is bubbled through the filtrate, producing a second white precipitate, Z.

What are Y and Z?

| | Y | Z |
|---|---|---|
| **A** | $Ba(OH)_2$ | $Ca(OH)_2$ |
| **B** | $Ba(OH)_2$ | $CaCO_3$ |
| **C** | $Ca(OH)_2$ | $BaCO_3$ |
| **D** | $Ca(OH)_2$ | $Ba(OH)_2$ |

**72 9701/12/F/M/20/Q13**

Compound Z is insoluble in water but soluble at low pH.

What could be compound Z?

**A** barium carbonate

**B** barium chloride

**C** barium hydroxide

**D** barium sulfate

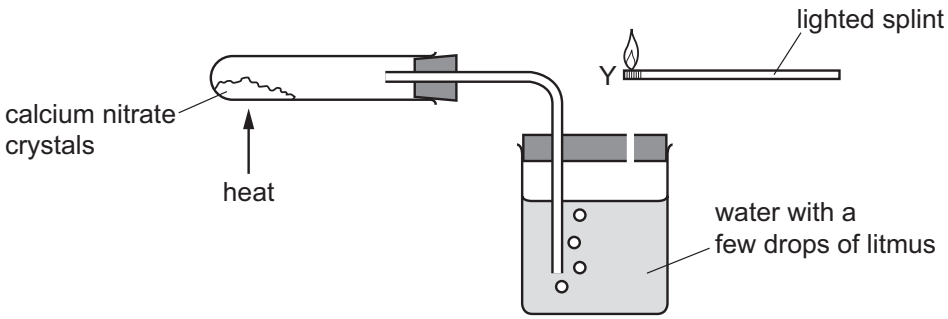


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**73 9701/12/F/M/20/Q17**

A student investigates calcium nitrate crystals by heating them in the apparatus shown.

A colourless gas leaves the apparatus at Y. A flame is held to this gas.




Which observations would the student make?

| | litmus solution | flame at Y |
|---|---|---|
| **A** | changes to blue | flame burns more brightly |
| **B** | changes to blue | flame goes out |
| **C** | changes to red | flame burns more brightly |
| **D** | changes to red | flame goes out |

**74 9701/11/M/J/20/Q14**

An excess of MgO is shaken with water. The resulting mixture is filtered into test-tube P.

An excess of BaO is shaken with water. The resulting mixture is filtered into test-tube Q.

Which oxide reacts more readily with water and which filtrate has the **lower** pH?

| | oxide reacts more readily with water | test-tube with filtrate of **lower** pH |
|---|---|---|
| **A** | BaO | P |
| **B** | BaO | Q |
| **C** | MgO | P |
| **D** | MgO | Q |



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**75 9701/12/M/J/20/Q13**

Magnesium nitrate, $Mg(NO_3)_2$, decomposes when heated to give a white solid and a mixture of gases. One of the gases released is an oxide of nitrogen, X.

7.4 g of anhydrous magnesium nitrate is heated until no further reaction takes place.

What mass of X is produced?

**A** 1.5 g **B** 2.3 g **C** 3.0 g **D** 4.6 g

**76 9701/11/M/J/20/Q17**

0.25 g of anhydrous magnesium nitrate is heated strongly until it completely decomposes.

What is the total volume of gas produced, measured under room conditions?

**A** 40 $cm^3$ **B** 81 $cm^3$ **C** 101 $cm^3$ **D** 202 $cm^3$

**77 9701/12/M/J/20/Q17**

Which property shows an **increase** from magnesium to barium?

**A** the first ionisation energy of the elements
**B** the oxidising power of the metals
**C** the solubility of the hydroxides
**D** the solubility of the sulfates

**78 9701/13/M/J/20/Q12**

Compound T is a white crystalline solid.

When a sample of compound T is mixed with aqueous sodium hydroxide and heated, a gas is produced which turns damp red litmus paper blue.

Further testing of a solution of compound T with aqueous barium chloride produces a dense white precipitate which does not dissolve when dilute hydrochloric acid is added to the mixture.

What is the identity of compound T?

**A** ammonium carbonate
**B** ammonium sulfate
**C** sodium carbonate
**D** sodium sulfate

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**79 9701/13/M/J/20/Q14**

The statements apply to the elements in Group 2.

Which statement is correct?

**A** As atomic number increases, ionic radius increases.

**B** As atomic number increases, reducing ability decreases.

**C** As atomic number increases, first ionisation energy increases.

**D** As atomic radius increases, first ionisation energy increases.

**80 9701/13/M/J/20/Q17**

The addition of aqueous silver nitrate to aqueous barium chloride produces a white precipitate which dissolves in an excess of dilute aqueous ammonia to form a colourless solution.

The addition of an excess of dilute nitric acid to the colourless solution produces a white precipitate, Z.

What is Z?

**A** AgC$l$ **B** BaC$l_2$ **C** $Ba(NO_3)_2$ **D** $NH_4NO_3$

**81 9701/13/M/J/20/Q18**

Which property shows an **increase** from calcium to barium going down Group 2?

**A** the ease of decomposition of the carbonates

**B** the solubility of the hydroxides

**C** the solubility of the sulfates

**D** the volume of hydrogen given off when 1 g of the metal reacts with water



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# Inorganic Chemistry

11 TOPIC

# Group 17



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**1 9701/1/O/N/02/Q17**

The standard enthalpy changes of formation of HC*l* and HI are –92 kJ mol$^{-1}$ and +26 kJ mol$^{-1}$ respectively.

Which statement is **most** important in explaining this difference?

**A** Chlorine is more electronegative than iodine.

**B** The activation energy for the $H_2/Cl_2$ reaction is much less than that for the $H_2/I_2$ reaction.

**C** The bond energy of HI is smaller than the bond energy of HC*l*.

**D** The bond energy of $I_2$ is smaller than the bond energy of $Cl_2$.

**2 9701/1/M/J/03/Q16**

The halogens exist as diatomic molecules, $X_2$.

The boiling points of the Group VII elements increase as the group is descended from chlorine to iodine.

Which statement helps to explain this increase in boiling point as Group VII is descended?

**A** The electronegativity of X decreases as the group is descended.

**B** The number of electrons in each $X_2$ molecule increases as the group is descended.

**C** The size of the permanent dipole in the $X_2$ molecule increases as the group is descended.

**D** The X–X bond strength increases as the group is descended.

**3 9701/1/M/J/03/Q16**

Chlorine compounds show oxidation states ranging from –1 to +7.

What are the reagent(s) and conditions necessary for the oxidation of elemental chlorine into a compound containing chlorine in the +5 oxidation state?

**A** $AgNO_3$(aq) followed by $NH_3$(aq) at room temperature

**B** concentrated $H_2SO_4$ at room temperature

**C** cold dilute NaOH(aq)

**D** hot concentrated NaOH(aq)

**4 9701/1/M/J/03/Q17**

Which gaseous hydride most readily decomposes into its elements on contact with a hot glass rod?

**A** ammonia

**B** hydrogen chloride

**C** hydrogen iodide

**D** steam

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**5 9701/1/O/N/03/Q16**

In black and white photographic film, light converts silver chloride into metallic silver. After the film has been developed, the unreacted silver chloride is removed by reaction with sodium thiosulfate to produce a 'fixed' negative.

$$AgCl + 2Na_2S_2O_3 \rightarrow 4Na^+ + Cl^- + [Ag(S_2O_3)_2]^{3-}$$

What is the function of the thiosulfate ion?

**A** to make the silver ions soluble
**B** to oxidise the silver ions
**C** to oxidise the silver metal
**D** to reduce the silver ions

**6 9701/01/M/J/04/Q17**

Which statement is most likely to be true for astatine, which is below iodine in Group VII of the Periodic Table?

**A** Astatine and aqueous potassium chloride react to form aqueous potassium astatide and chlorine.

**B** Potassium astatide and hot dilute sulphuric acid react to form white fumes of only hydrogen astatide.

**C** Silver astatide reacts with dilute aqueous ammonia in excess to form a solution of a soluble complex.

**D** Sodium astatide and hot concentrated sulphuric acid react to form astatine.

**7 9701/01/M/J/04/Q17**

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**D** Sodium astatide and hot concentrated sulfuric acid react to form astatine.

**8 9701/01/O/N/04/Q16**

A weedkiller can be prepared by heating a bleach solution.

$$\underset{\text{bleach}}{3NaClO} \xrightarrow{\text{heat}} 2NaCl + \underset{\text{weedkiller}}{NaClO_3}$$

What are the oxidation states of chlorine in these three compounds?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **A** | –1 | –1 | +5 | **C** | +1 | –1 | +7 |
| **B** | +1 | –1 | +5 | **D** | +2 | +1 | +7 |

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**9 9701/01/O/N/04/Q17**

The following report appeared in a newspaper.

Drums of bromine broke open after a vehicle crash on the motorway. Traffic was diverted as purple gaseous bromine drifted over the road (it is denser than air), causing irritation to drivers' eyes. Firemen sprayed water over the scene of the accident, dissolving the bromine and washing it away.

What is **wrong** with the report?

**A** Bromine does not dissolve in water.

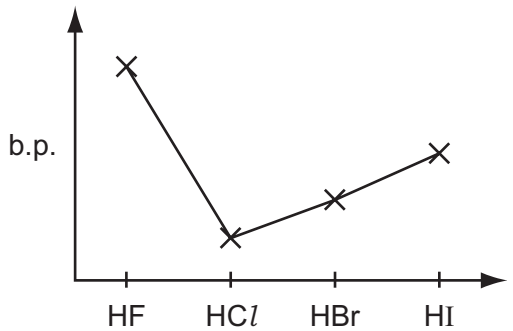
**B** Bromine does not vapourise readily.

**C** Bromine is less dense than air.

**D** Bromine is not purple.

**10 9701/01/M/J/05/Q5**

The diagram shows the variation of the boiling points of the hydrogen halides.




What explains the higher boiling point of hydrogen fluoride?

**A** The bond energy of HF molecules is greater than in other hydrogen halides.

**B** The effect of nuclear shielding is much reduced in fluorine which polarises the HF molecule.

**C** The electronegativity of fluorine is much higher than for other elements in the group.

**D** There is hydrogen bonding between HF molecules.

**11 9701/01/M/J/05/Q15**

Concentrated sulphuric acid is added to separate solid samples of sodium chloride, sodium bromide or sodium iodide.

With which sample(s) does sulphuric acid act as an oxidising agent?

**A** sodium chloride only

**B** sodium chloride and sodium bromide

**C** sodium bromide and sodium iodide

**D** sodium iodide only

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**12 9701/01/O/N/05/Q9**

Chlorine dioxide is produced on a large scale as it is used for bleaching paper pulp. It is made by the following reaction.

$$2ClO_3^-(aq) + SO_2(g) \rightarrow 2ClO_2(g) + SO_4^{2-}(aq)$$

How do the oxidation numbers of chlorine and sulphur change in this reaction?

| | chlorine | sulphur |
|---|---|---|
| **A** | decreases by 1 | increases by 1 |
| **B** | decreases by 1 | increases by 2 |
| **C** | decreases by 3 | increases by 1 |
| **D** | decreases by 3 | increases by 2 |

**13 9701/01/M/J/06/Q14**

The oxide and chloride of an element **X** are separately mixed with water. The two resulting solutions have the same effect on litmus.

What is element **X**?

**A** sodium **B** magnesium **C** aluminium **D** phosphorus

**14 9701/01/M/J/06/Q17**

What happens when chlorine is bubbled through aqueous potassium iodide?

**A** Chlorine is oxidised to chloride ions.

**B** Hydrochloric acid is formed.

**C** Iodide ions are oxidised to iodine.

**D** Potassium iodide is reduced to iodine.

**15 9701/01/O/N/06/Q15**

Which of the following is **not** a correct statement about iodine?

**A** A crystal of iodine contains covalent bonds and van der Waals' forces.

**B** Iodine vapour is purple.

**C** The first ionisation energy of iodine is less than that of bromine.

**D** The hydride of iodine is of greater thermal stability than that of bromine.

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**16 9701/01/O/N/06/Q16**

Mixing aqueous silver nitrate and aqueous sodium chloride produces a precipitate.

Addition of which reagent to the mixture gives a colourless solution?

**A** aqueous ammonia

**B** aqueous potassium iodide

**C** dilute hydrochloric acid

**D** dilute nitric acid

**17 9701/01/O/N/06/Q17**

Which is the complete list of all the products from the reaction of concentrated sulphuric acid with potassium bromide?

**A** potassium hydrogensulphate and hydrogen bromide

**B** potassium hydrogensulphate, hydrogen bromide and bromine

**C** potassium hydrogensulphate, hydrogen bromide, bromine and water

**D** potassium hydrogensulphate, hydrogen bromide, bromine, water and sulphur dioxide

**18 9701/01/M/J/07/Q15**

In the treatment of domestic water supplies, chlorine is added to the water to form chloric(I) acid, HC*l*O.

$$Cl_2(aq) + H_2O(l) \rightarrow H^+(aq) + Cl^-(aq) + HClO(aq)$$

This reacts further to give the chlorate(I) ion.

$$HClO(aq) + H_2O(l) \rightarrow H_3O^+(aq) + ClO^-(aq)$$

Both HC*l*O and C*l*O$^-$ kill bacteria by oxidation.

What is the change in oxidation number of chlorine in forming the chlorate(I) ion from the aqueous chlorine?

**A** –1 **B** 0 **C** +1 **D** +2

**19 9701/01/M/J/08/Q16**

Properties of chlorine, iodine and their compounds are compared.

Property **Q** for chlorine is smaller than for iodine.

What is property **Q**?

**A** oxidising ability of the element

**B** solubility of the silver halide in $NH_3(aq)$

**C** strength of van der Waals' forces between the molecules of the element

**D** thermal stability of the hydrogen halide



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**20 9701/01/O/N/08/Q17**

A student observed the reactions when sodium chloride and sodium iodide were each reacted separately with concentrated sulphuric acid and concentrated phosphoric acid. The observations are recorded in the table.

| | sodium chloride | sodium iodide |
|---|---|---|
| conc. $H_2SO_4$ | colourless acidic gas formed | purple vapour formed |
| conc. $H_3PO_4$ | colourless acidic gas formed | colourless acidic gas formed |

Which deduction can be made from these observations?

**A** Concentrated phosphoric acid is a stronger oxidising agent than concentrated sulphuric acid.

**B** Concentrated phosphoric acid is a stronger oxidising agent than iodine.

**C** Concentrated sulphuric acid is a stronger oxidising agent than chlorine.

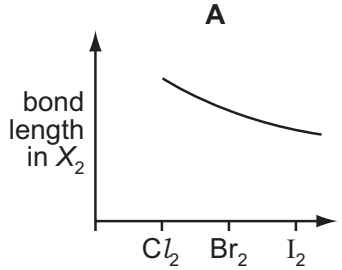
**D** Concentrated sulphuric acid is a stronger oxidising agent than iodine.

**21 9701/12/O/N/09/Q14**

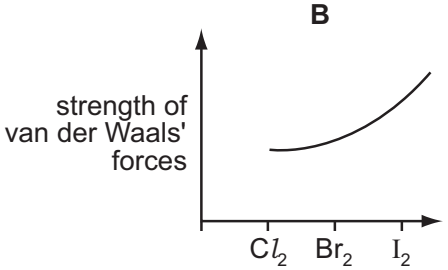
Which graph correctly describes a trend found in the halogen group?

*X* represents a halogen atom.]

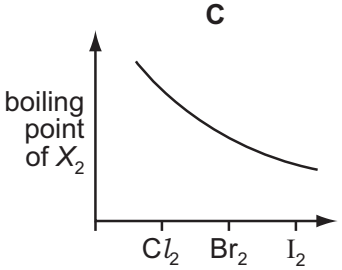
**A**



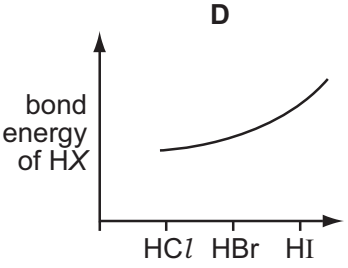

**B**




**C**




**D**






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**22 9701/01/M/J/09/Q14**

Over half a million tonnes of bromine are manufactured annually and are mainly used for making other compounds. One important use is for agricultural chemicals.

What is another important use for bromine?

**A** antiseptic agents

**B** bleaches for textiles and the paper industry

**C** flame-retardants and fire extinguishers

**D** water purification

**23 9701/12/M/J/10/Q13**

$Na_2S_2O_3$ reacts with dilute HC*l* to give a pale yellow precipitate. If 1 $cm^3$ of 0.1 mol $dm^{-3}$ HC*l* is added to 10 $cm^3$ of 0.02 mol $dm^{-3}$ $Na_2S_2O_3$ the precipitate forms slowly.

If the experiment is repeated with 1 $cm^3$ of 0.1 mol $dm^{-3}$ HC*l* and 10 $cm^3$ of 0.05 mol $dm^{-3}$ $Na_2S_2O_3$ the precipitate forms more quickly.

Why is this?

**A** The activation energy of the reaction is lower when 0.05 mol $dm^{-3}$ $Na_2S_2O_3$ is used.

**B** The reaction proceeds by a different pathway when 0.05 mol $dm^{-3}$ $Na_2S_2O_3$ is used.

**C** The collisions between reactant particles are more violent when 0.05 mol $dm^{-3}$ $Na_2S_2O_3$ is used.

**D** The reactant particles collide more frequently when 0.05 mol $dm^{-3}$ $Na_2S_2O_3$ is used.

**24 9701/12/M/J/10/Q14**

How does concentrated sulfuric acid behave when it reacts with sodium chloride?

**A** as an acid only

**B** as an acid and oxidising agent

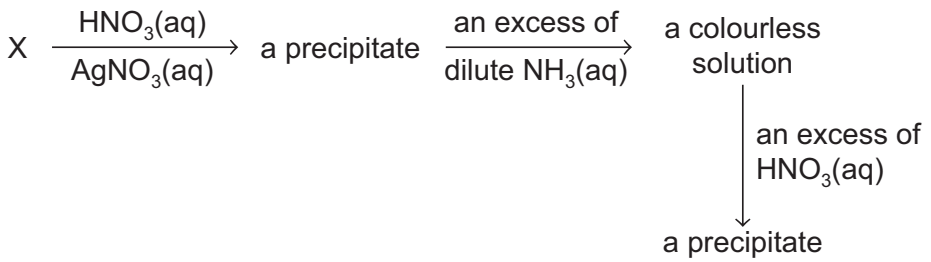
**C** as an oxidising agent only

**D** as a reducing agent only

**25 9701/12/M/J/10/Q15**

X is a salt of one of the halogens chlorine, bromine, iodine, or astatine (proton number 85).

The reaction scheme shows a series of reactions using a solution of X as the starting reagent.




What could X be?

**A** sodium chloride **B** sodium bromide **C** potassium iodide **D** potassium astatide

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**26 9701/12/O/N/10/Q13**

In aqueous solution, the acid HIO disproportionates according to the following equation where **m**, **n**, **p** and **q** are simple whole numbers in their lowest ratios.

$$\mathbf{m}HIO \rightarrow \mathbf{n}I_2 + \mathbf{p}HIO_3 + \mathbf{q}H_2O$$

This equation can be balanced using oxidation numbers.

What are the values for **n** and **p**?

| | **n** | **p** |
|---|---|---|
| **A** | 1 | 2 |
| **B** | 2 | 1 |
| **C** | 4 | 1 |
| **D** | 4 | 2 |

**27 9701/12/O/N/10/Q16**

What happens when chlorine is bubbled through aqueous potassium iodide?

**A** Chlorine is oxidised to chlorate(V) ions.

**B** Chlorine is oxidised to chloride ions.

**C** Iodide ions are oxidised to iodine.

**D** There is no observable reaction.

**28 9701/12/O/N/10/Q19**

Concentrated sulfuric acid reacts with both solid sodium chloride at room temperature and with solid sodium iodide at room temperature.

Which row correctly describes how concentrated sulfuric acid behaves in each of these reactions?

| | with sodium chloride | with sodium iodide |
|---|---|---|
| **A** | as an oxidising agent only | as an oxidising agent only |
| **B** | as a strong acid and as an oxidising agent | as a strong acid only |
| **C** | as a strong acid only | as a strong acid and as an oxidising agent |
| **D** | as a strong acid only | as a strong acid only |

**29 9701/12/M/J/11/Q17**

Concentrated sulfuric acid can behave **both** as a strong acid **and** as an oxidising agent.

With which compound does concentrated sulfuric acid react in this way?

**A** ethanol **B** magnesium carbonate **C** propanenitrile **D** sodium bromide

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**30 9701/12/O/N/11/Q15**

Chlorine can be manufactured from brine in a diaphragm cell.

Which row represents the correct electrodes?

| | nature of anode | nature of cathode |
|---|---|---|
| **A** | graphite | titanium |
| **B** | steel | titanium |
| **C** | titanium | graphite |
| **D** | titanium | steel |

**31 9701/12/O/N/11/Q16**

Sodium iodide reacts with concentrated sulfuric acid. The equation which represents one of the reactions that takes place is shown.

$$8NaI + 9H_2SO_4 \rightarrow 8NaHSO_4 + 4I_2 + H_2S + 4H_2O$$

Which species has been oxidised in this reaction?

**A** $H^+$ **B** $I^-$ **C** $Na^+$ **D** $SO_4^{2-}$

**32 9701/12/M/J/12/Q11**

In which substance does nitrogen exhibit the highest oxidation state?

**A** NO **B** $NO_2$ **C** $N_2O_4$ **D** $NaNO_2$

**33 9701/12/M/J/12/Q16**

Chlorine shows oxidation states ranging from –1 to +7 in its compounds.

What are the reagent(s) and conditions necessary for the oxidation of elemental chlorine into a compound containing chlorine in the +5 oxidation state?

**A** $AgNO_3(aq)$ followed by $NH_3(aq)$ at room temperature

**B** concentrated $H_2SO_4$ at room temperature

**C** cold dilute NaOH(aq)

**D** hot concentrated NaOH(aq)



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**34 9701/12/M/J/13/Q15**

Many modern cars are fitted with halogen lamps. When such lamps are first switched on, a distinct purple colour can be seen.

Which species is responsible for this purple colour?

**A** $I_2(s)$ **B** $I_2(l)$ **C** $I_2(g)$ **D** $I(g)$

**35 9701/12/M/J/13/Q18**

What happens when bromine solution is added to a solution of sodium iodide?

**A** A reaction occurs without changes in oxidation state.

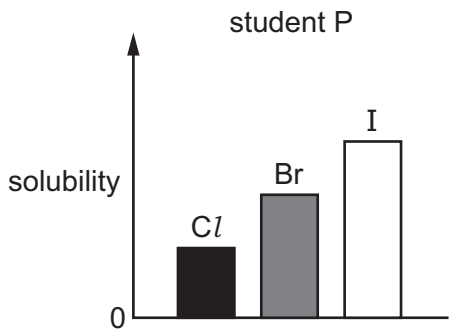
**B** Bromine atoms are oxidised, iodide ions are reduced.

**C** Bromine atoms are reduced, iodide ions are oxidised.

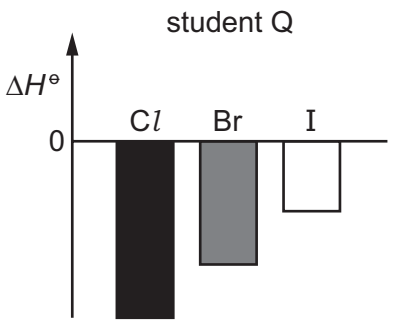
**D** No reaction occurs.

**36 9701/13/M/J/13/Q14**

Two students, P and Q, were asked to draw bar charts to represent how some properties of the halogens and their compounds differ in magnitude. Their diagrams are shown. The bar charts show trends only and not actual values.




solubility of AgX(s) in $NH_3(aq)$




$\Delta H^{\ominus}$ for $H_2(g) + X_2(g) \rightarrow 2HX(g)$

Which of the students have drawn bar charts which show the trends correctly?

**A** both P and Q **B** P only **C** Q only **D** neither P nor Q



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**37 9701/12/M/J/14/Q18**

A test-tube of HBr(g) and a test-tube of HI(g) are heated to the same temperature.
Which combination of observations is possible?

| | tube of HBr(g) | tube of HI(g) |
|---|---|---|
| **A** | a brown vapour appears | no change is apparent |
| **B** | a purple vapour appears | no change is apparent |
| **D** | no change is apparent | a purple vapour appears |

**38 9701/12/M/J/14/Q17**

When solid sodium iodide reacts with concentrated sulfuric acid, the products include $NaHSO_4$, $H_2S$, $SO_2$ and S.

In the formation of which product has the oxidation state of sulfur changed by a value of 8?

**A** $H_2S$ **B** $NaHSO_4$ **C** S **D** $SO_2$

**39 9701/11/M/J/15/Q17**

Astatine, At, is below iodine in Group VII of the Periodic Table.

Which statement is most likely to be correct?

**A** AgAt(s) reacts with excess dilute aqueous ammonia to form a solution of a soluble complex.

**B** Astatine and KC$l$(aq) react to form KAt(aq) and chlorine.

**C** KAt(aq) and dilute sulfuric acid react to form white fumes of HAt(g).

**D** NaAt(s) and concentrated sulfuric acid react to form astatine.

**40 9701/11/M/J/15/Q16**

Chlorine is widely used in water treatment plants.
Which reaction takes place when chlorine dissolves in water?

**A** $Cl_2 + H_2O \rightarrow HCl + HClO$

**B** $2Cl_2 + 2H_2O \rightarrow 3HCl + HClO_2$

**C** $3Cl_2 + 3H_2O \rightarrow 5HCl + HClO_3$

**D** $4Cl_2 + 4H_2O \rightarrow 7HCl + HClO_4$

**41 9701/13/O/N/15/Q17**

Which statement about bromine is correct?

**A** Bromine is insoluble in non-polar solvents.

**B** Bromine vapour is more dense than air.

**C** Bromine will not vapourise significantly under normal conditions.

**D** Gaseous bromine is purple.



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**42 9701/12/F/M/16/Q14**

Chlorine gas is widely used to treat contaminated water.

Which species present in water when chlorine gas has been added is responsible for killing bacteria?

**A** $ClO_2^-$ **B** $Cl^-$ **C** $HCl$ **D** $OCl^-$

**43 9701/12/F/M/16/Q16**

Hydrogen chloride gas and hydrogen iodide gas have different thermal stabilities. The difference is due to a difference in the energies of some of the covalent bonds that are involved in the decomposition.

Which row identifies the more stable of the two compounds, and gives the correct explanation?

| | identity of the more thermally stable compound | explanation for the difference in stability |
|---|---|---|
| **A** | hydrogen chloride | the Cl–Cl bond is stronger than the I–I bond |
| **B** | hydrogen chloride | the H–Cl bond is stronger than the H–I bond |
| **C** | hydrogen iodide | the Cl–Cl bond is stronger than the I–I bond |
| **D** | hydrogen iodide | the H–Cl bond is stronger than the H–I bond |

**44 9701/12/F/M/16/Q19**

After black and white photographic film has been developed, unreacted silver bromide is removed by reaction with sodium thiosulfate.

$$AgBr + 2Na_2S_2O_3 \rightarrow 4Na^+ + Br^- + [Ag(S_2O_3)_2]^{3-}$$

What is the function of the thiosulfate ion?

**A** to make the silver ions soluble **C** to reduce the bromine

**B** to oxidise the silver ions **D** to reduce the silver ions



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**45 9701/11/M/J/16/Q15**

The solids sodium chloride and sodium iodide both react with concentrated sulfuric acid at room temperature.

With NaC$l$, the products are $NaHSO_4$ and HC$l$.
With NaI, the products are $NaHSO_4$, HI, $I_2$, $SO_2$, $H_2O$, S and $H_2S$.

What is the best explanation for this difference in products?

**A** Chloride ions will displace iodine from solution.

**B** Hydrogen chloride is more volatile than hydrogen iodide.

**C** Iodide ions are better reducing agents than chloride ions.

**D** Sulfuric acid is able to act as a dehydrating agent with NaI.

**46 9701/12/M/J/16/Q18**

An excess of chlorine gas, C$l_2$, is passed through 60 $cm^3$ of cold aqueous 0.1 mol $dm^{-3}$ sodium hydroxide. In a separate experiment an excess of chlorine gas is passed through 60 $cm^3$ of hot aqueous 0.1 mol $dm^{-3}$ sodium hydroxide until no further reaction takes place.

How much **more** sodium chloride will be produced by the reaction with hot NaOH than with cold NaOH?

**A** 0.002 moles **B** 0.003 moles **C** 0.005 moles **D** 0.006 moles

**47 9701/12/M/J/16/Q19**

Fluorine and iodine are Group 17 elements. Their melting points are different due to differing strengths of van der Waals' forces between molecules.

Which row is correct?

| | melting point | strength of van der Waals' forces between molecules |
|---|---|---|
| **A** | $F_2 > I_2$ | $F_2 > I_2$ |
| **B** | $F_2 > I_2$ | $F_2 < I_2$ |
| **C** | $F_2 < I_2$ | $F_2 < I_2$ |
| **D** | $F_2 < I_2$ | $F_2 > I_2$ |



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**48 9701/13/M/J/16/Q18**

In a series of nine experiments to test the reactivity of the halogens, an aqueous solution of each halogen was added to an equal volume of an aqueous solution containing halide ions as shown in the table below.

| solution | sodium chloride (aq) | sodium bromide (aq) | sodium iodide (aq) |
|---|---|---|---|
| chlorine (aq) | experiment 1 | experiment 2 | experiment 3 |
| bromine (aq) | experiment 4 | experiment 5 | experiment 6 |
| iodine (aq) | experiment 7 | experiment 8 | experiment 9 |

The nine resulting mixtures were then shaken with hexane. The nine tubes were corked and left to stand so that the aqueous and organic solvents could separate into layers.

How many test-tubes contained a purple upper layer?

**A** 1 **B** 2 **C** 3 **D** 5

**49 9701/12/F/M/17/Q16**

Some uses of chlorine and bromine are given.

Which is a use of bromine?

**A** making bleaches for textiles and the paper industry

**B** making CFCs

**C** making flame retardants and fire extinguishers

**D** making the polymer PVC

**50 9701/12/F/M/17/Q17**

In an experiment, 0.600 mol of chlorine gas, $Cl_2$, is reacted with an excess of hot aqueous sodium hydroxide. One of the products is $NaClO_3$.

Which mass of $NaClO_3$ is formed?

**A** 21.3 g **B** 44.7 g **C** 63.9 g **D** 128 g

**51 9701/11/M/J/17/Q18**

A solution of sodium hydroxide reacts with 3 mol of chlorine under certain conditions. The reaction produces 5 mol of sodium chloride and 1 mol of **X**, the only other chlorine-containing product.

What is the formula of compound **X**?

**A** $NaClO$ **B** $NaClO_2$ **C** $NaClO_3$ **D** $NaClO_4$

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**52 9701/11/M/J/17/Q19**

Redox reactions are common in the chemistry of Group 17.

Which statement is correct?

**A** $Br^-$ ions will reduce $Cl_2$ but not $I_2$.

**B** $Cl_2$ will oxidise $Br^-$ ions but not $I^-$ ions.

**C** $F_2$ is the weakest oxidising agent out of $F_2$, $Cl_2$, $Br_2$ and $I_2$.

**D** $I^-$ ions are the weakest reducing agent out of $F^-$, $Cl^-$, $Br^-$ and $I^-$.

**53 9701/12/M/J/17/Q16**

Element X reacts with cold, dilute, aqueous sodium hydroxide to form two different chlorine-containing products, Y and Z.

What are the oxidation states of chlorine in Y and Z?

| | Y | Z |
|---|---|---|
| **A** | 0 | +1 |
| **B** | 0 | +5 |
| **C** | –1 | +1 |
| **D** | –1 | +5 |

**54 9701/12/M/J/17/Q17**

A powder is known to be either a single sodium halide or a mixture of two sodium halides. A sample of the powder was dissolved in water.

Aqueous silver nitrate was added, and a pale yellow precipitate was formed. When concentrated aqueous ammonia was then added, this precipitate partly dissolved leaving a darker yellow precipitate.

What might the powder be?

**A** sodium bromide only

**B** sodium iodide only

**C** a mixture of sodium chloride and sodium bromide

**D** a mixture of sodium chloride and sodium iodide



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**55 9701/13/M/J/17/Q16**

Chlorine gas is added to cold, aqueous sodium hydroxide.

In a separate experiment, chlorine gas is added to hot, aqueous sodium hydroxide.

Which oxidation states of chlorine are found in the reactants and products of the two reactions that take place?

**A** 0, –1, +1 and +5

**B** 0, –1 and +1 only

**C** 0, –1 and +5 only

**D** 0, +1 and +5 only

**56 9701/13/M/J/17/Q17**

A test-tube of HBr(g) and a separate test-tube of HI(g) are heated to the same temperature.

Which combination of observations is possible?

| | test-tube of HBr(g) | test-tube of HI(g) |
|---|---|---|
| **A** | a brown vapour appears | no change |
| **B** | a purple vapour appears | no change |
| **C** | no change | a brown vapour appears |
| **D** | no change | a purple vapour appears |

**57 9701/11/O/N/18/Q16**

Which row correctly describes the properties of the halogens as Group 17 is descended from chlorine to iodine?

| | volatility | strength as oxidising agent |
|---|---|---|
| **A** | decreases | decreases |
| **B** | decreases | increases |
| **C** | increases | decreases |
| **D** | increases | increases |



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**58 9701/11/O/N/18/Q17**

Reaction 1: chlorine reacts with cold aqueous sodium hydroxide to form solution Z.

Reaction 2: solution Z is heated and forms $ClO_3^-$(aq) and $Cl^-$(aq).

Which equations represent reaction 1 and reaction 2?

**A** reaction 1 $2Cl_2 + 4OH^- \rightarrow ClO_2^- + 3Cl^- + 2H_2O$
reaction 2 $3ClO_2^- \rightarrow 2ClO_3^- + Cl^-$

**B** reaction 1 $2Cl_2 + 4OH^- \rightarrow ClO_2^- + 3Cl^- + 2H_2O$
reaction 2 $3ClO^- \rightarrow ClO_3^- + 2Cl^-$

**C** reaction 1 $Cl_2 + 2OH^- \rightarrow ClO^- + Cl^- + H_2O$
reaction 2 $2ClO^- + 2OH^- \rightarrow ClO_3^- + Cl^- + H_2O$

**D** reaction 1 $Cl_2 + 2OH^- \rightarrow ClO^- + Cl^- + H_2O$
reaction 2 $3ClO^- \rightarrow ClO_3^- + 2Cl^-$

**59 9701/12/O/N/18/Q16**

Which statement about the halogens is correct?

**A** Iodine cannot behave as an oxidising agent.

**B** The volatility of the elements increases from chlorine to iodine because of the increase in molecular size down the group.

**C** When an equimolar mixture of chlorine and hydrogen is exploded, only one product is formed.

**D** When concentrated sulfuric acid is added to solid sodium bromide, hydrogen sulfide is one of the products.

**60 9701/12/O/N/18/Q17**

Chlorine reacts with both hot and cold sodium hydroxide to form products containing chlorine.

Cold sodium hydroxide forms sodium chlorate(X) and hot sodium hydroxide forms sodium chlorate(Y). X and Y are oxidation numbers.

Which equation is correct?

**A** Y = X – 6 **B** Y = X – 4 **C** Y = X + 4 **D** Y = X + 6

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**61 9701/12/F/M/19/Q17**

The table shows some reactions of a white compound, G.

| test | observation |
|---|---|
| silver nitrate is added to a solution of G followed by aqueous ammonia | a precipitate is formed which does not dissolve when the ammonia is added |
| solid G is warmed with concentrated sulfuric acid | a mixture of gases is formed including hydrogen sulfide |

What could be the identity of G?

**A** caesium chloride

**B** lithium bromide

**C** potassium sulfate

**D** sodium iodide

**62 9701/12/F/M/19/Q18**

Under standard conditions, which statement is correct?

**A** $Cl_2$(aq) can oxidise $Br^-$(aq).

**B** $Cl_2$(aq) can reduce $Br^-$(aq).

**C** $Cl^-$(aq) can oxidise $Br_2$(aq).

**D** $Cl^-$(aq) can reduce $Br_2$(aq).

**63 9701/11/M/J/19/Q16**

Concentrated sulfuric acid is added to separate solid samples of sodium chloride, sodium bromide and sodium iodide.

With which samples does sulfuric acid act as an oxidising agent?

**A** sodium chloride only

**B** sodium chloride and sodium bromide

**C** sodium bromide and sodium iodide

**D** sodium iodide only

**64 9701/11/M/J/19/Q17**

The reaction of bromine with warm NaOH(aq) produces products with the same oxidation numbers, in the same ratios, as the reaction of chlorine with hot NaOH(aq).

In one reaction between bromine and warm NaOH(aq), 30.2 g of a product containing sodium, bromine and oxygen is produced.

Which mass of NaOH has reacted?

**A** 8.00 g **B** 10.2 g **C** 20.3 g **D** 48.0 g



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**65 9701/12/M/J/19/Q9**

X is either chlorine or an oxide of chlorine.

X reacts with water, under suitable conditions, to form the two acids HC$l$ and HC$l$O$_3$ in the mole ratio of 1 (HC$l$) : 5 (HC$l$O$_3$).

What could be X?

**A** C$l_2$ **B** C$l_2$O **C** C$l$O$_2$ **D** C$l_2$O$_7$

**66 9701/12/M/J/19/Q17**

An excess of chlorine was bubbled into 100 cm$^3$ of hot 6.0 mol dm$^{-3}$ sodium hydroxide.

How many moles of sodium chloride would be produced in the reaction?

**A** 0.3 **B** 0.5 **C** 0.6 **D** 1.2

**67 9701/12/M/J/19/Q18**

Ammonium sulfate, $(NH_4)_2SO_4$, and ammonium nitrate, $NH_4NO_3$, are used as fertilisers.

These salts have different percentages by mass of nitrogen. They have the same effect as each other on the pH of wet neutral soil.

Which row is correct?

| | higher percentage of nitrogen by mass | effect on pH of soil |
|---|---|---|
| **A** | ammonium nitrate | decrease |
| **B** | ammonium nitrate | increase |
| **C** | ammonium sulfate | decrease |
| **D** | ammonium sulfate | increase |

**68 9701/12/M/J/19/Q19**

Which reaction gives a product that is an atmospheric pollutant causing acid rain?

**A** $3Mg(s) + SO_2(g) \rightarrow MgS(s) + 2MgO(s)$

**B** $(NH_4)_2SO_4(s) + Ca(OH)_2(s) \rightarrow 2NH_3(g) + CaSO_4(s) + 2H_2O(l)$

**C** $2MnO_4^-(aq) + 5SO_2(g) + 2H_2O(l) \rightarrow 2Mn^{2+}(aq) + 4H^+(aq) + 5SO_4^{2-}(aq)$

**D** $2FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$

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**69 9701/11/O/N/19/Q16**

Chlorine and bromine have different volatilities.

Which row identifies the more volatile of the two elements, and gives the correct explanation?

| | identity of the more volatile element | explanation for the difference in volatility |
|---|---|---|
| **A** | bromine | instantaneous dipole-induced dipole forces are greater in bromine than they are in chlorine |
| **B** | bromine | instantaneous dipole-induced dipole forces are greater in chlorine than they are in bromine |
| **C** | chlorine | instantaneous dipole-induced dipole forces are greater in bromine than they are in chlorine |
| **D** | chlorine | instantaneous dipole-induced dipole forces are greater in chlorine than they are in bromine |

**70 9701/11/O/N/19/Q17**

Sodium azide, $NaN_3$, is dissolved in water. Acidified silver nitrate is added to the solution and a white precipitate forms. Aqueous ammonia is then added to the white precipitate.

The azide ion, $N_3^-$, has similar chemical properties to the $Cl^-$ ion.

Which row of the table can be predicted from this information?

| | formula of white precipitate | observation on adding aqueous ammonia |
|---|---|---|
| **A** | $AgN_3$ | colourless solution formed |
| **B** | $AgN_3$ | precipitate remains |
| **C** | $Ag_3N$ | colourless solution formed |
| **D** | $Ag_3N$ | precipitate remains |



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**71** **9701/12/O/N/19/Q15**

Chlorate(V) ions, $ClO_3^-$, are produced in the redox reaction between chlorine and hot aqueous sodium hydroxide. Oxidation numbers can be used to help balance the equation for this reaction.

$$vCl_2(g) + wOH^-(aq) \rightarrow xCl^-(aq) + yClO_3^-(aq) + zH_2O(l)$$

What are the values of v, x and y in the balanced equation?

| | v | x | y |
|---|---|---|---|
| **A** | 2 | 3 | 1 |
| **B** | 3 | 4 | 2 |
| **C** | 3 | 5 | 1 |
| **D** | 7 | 12 | 2 |

**72** **9701/12/O/N/19/Q16**

The properties of chlorine, bromine and their compounds are compared.

Which property is **smaller** for chlorine than for bromine?

**A** bond strength of the hydrogen-halide bond

**B** first ionisation energy

**C** solubility of the silver halide in $NH_3(aq)$

**D** strength of the van der Waals' forces between molecules of the element

**73** **9701/12/O/N/19/Q17**

Solid sodium iodide reacts with concentrated sulfuric acid to form more than one product that contains sulfur.

What is the lowest oxidation number of sulfur in these products?

**A** –2 **B** 0 **C** +4 **D** +6



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**74 9701/12/F/M/20/Q14**

Hot aqueous sodium hydroxide reacts with chlorine.

$$6NaOH(aq) + 3Cl_2(g) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$$

Which statement is correct?

**A** The oxidation numbers of chlorine and hydrogen both change in the reaction.

**B** The oxidation numbers of chlorine in the products are –1 and +1.

**C** If the aqueous sodium hydroxide is cold the reaction produces NaClO instead of $NaClO_3$.

**D** Sodium undergoes disproportionation in this reaction.

**75 9701/12/F/M/20/Q18**

How does concentrated sulfuric acid behave when it reacts with sodium chloride?

**A** as an acid only

**B** as an acid and oxidising agent

**C** as an oxidising agent only

**D** as a reducing agent only

**76 9701/12/F/M/20/Q19**

Which statement about nitrogen or its compounds is correct?

**A** In the Haber process the temperature is kept high to give a good equilibrium yield of ammonia.

**B** Nitrogen gas is unreactive because of the strong nitrogen–nitrogen double bond.

**C** Nitrogen monoxide will react with carbon monoxide under suitable conditions.

**D** The formula of ammonium sulfate is $NH_4SO_4$.



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**77 9701/11/M/J/20/Q12**

A white powder is a mixture of sodium chloride and sodium iodide. It is dissolved in water in a test-tube. An excess of aqueous silver nitrate is added to the test-tube. A precipitate, X, is observed.

An excess of concentrated ammonia is then added to the test-tube containing X. After the test-tube has been shaken, a precipitate, Y, is observed.

Which statement about X or Y is correct?

**A** X is a pure white colour.

**B** X is pure silver iodide.

**C** Y is pure silver chloride.

**D** Y is yellow.

**78 9701/11/M/J/20/Q18**

Astatine, At, is below iodine in Group 17 of the Periodic Table.

Which statement is most likely to be correct?

**A** AgAt(s) reacts with an excess of dilute aqueous ammonia to form a solution of a soluble complex.

**B** Astatine and KC$l$(aq) react to form KAt(aq) and chlorine.

**C** KAt(aq) and dilute sulfuric acid react to form HAt(g).

**D** NaAt(s) and concentrated sulfuric acid react to form astatine.

**79 9701/12/M/J/20/Q14**

Which statement explains why iodine is less volatile than chlorine?

**A** Chlorine is more electronegative than iodine and so has more repulsion between its molecules.

**B** The greater number of electrons in iodine leads to larger temporary dipole-induced dipole forces.

**C** The I–I bond energy is smaller than the C$l$–C$l$ bond energy.

**D** The iodine molecules have stronger permanent dipole-permanent dipole forces.



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**80 9701/12/M/J/20/Q18**

| | | |
|---|---|---|
| **A** | a brown vapour appears | no change |
| **B** | a purple vapour appears | no change |
| **C** | no change | a brown vapour appears |
| **D** | no change | a purple vapour appears |

**81 9701/13/M/J/20/Q13**

Which property explains the trend in volatility of the elements going down Group 17?

**A** decreasing covalent bond strength

**B** decreasing van der Waals' forces

**C** increasing covalent bond strength

**D** increasing van der Waals' forces



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Inorganic Chemistry

12 TOPIC

# Nitrogen and Sulfur

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**1 9701/1/M/J/02/Q18**

Sulphur dioxide is an important food preservative.

What property makes sulphur dioxide useful in this role?

**A** It is a gas.

**B** It is a reducing agent.

**C** It reacts with oxygen to form sulphur trioxide.

**D** It reacts with water to form an acidic solution.

**2 9701/1/O/N/02/Q19**

Which gas is present in the exhaust fumes of a car engine in a much greater amount than any other gas?

**A** carbon dioxide **B** carbon monoxide **C** nitrogen **D** water vapour

**3 9701/1/M/J/03/Q18**

Which reagent, when mixed and heated with ammonium sulphate, liberates ammonia?

**A** aqueous bromine

**B** dilute hydrochloric acid

**C** limewater

**D** acidified potassium dichromate(VI)

**4 9701/01/M/J/04/Q13**

Which of these equations represents the reaction of sulphur dioxide with an excess of aqueous sodium hydroxide?

**A** $SO_2 + NaOH \rightarrow NaHSO_3$

**B** $SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$

**C** $SO_2 + 2NaOH \rightarrow Na_2SO_4 + H_2O$

**D** $SO_2 + 2NaOH \rightarrow Na_2SO_4 + H_2$

**5 9701/01/M/J/04/Q19**

Nitrogen dioxide and sulphur dioxide have some properties in common.

Which property is shown by **one** of these compounds, but **not** by the other?

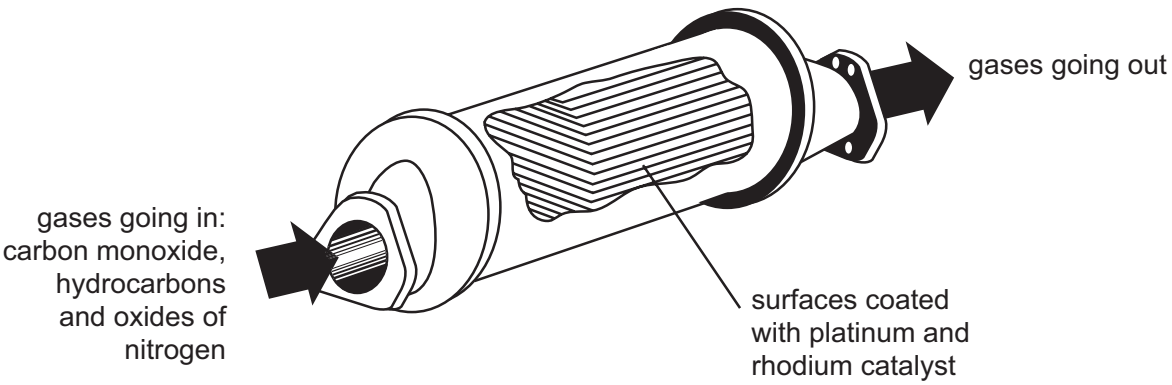
**A** forms 'acid-rain' **C** is insoluble in water

**B** is a reducing agent **D** is used as a food-preservative



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**6 9701/01/M/J/04/Q25**




These equations are qualitative and unbalanced.
[HC = unburnt hydrocarbons; $NO_x$ = oxides of nitrogen]

**A** $HC + NO_x \rightarrow H_2O + CO + N_2$

**B** $CO + NO_x \rightarrow CO_2 + N_2$

**C** $HC + NO_x \rightarrow H_2O + CO_2 + N_2$

**D** $CO + O_2 \rightarrow CO_2$

**7 9701/01/O/N/04/Q18**

Which reaction of ammonia does **not** involve the non-bonding pair of electrons on the nitrogen atom?

**A** $NH_3(g) + CH_3I(g) \rightarrow CH_3NH_3^+I^-(s)$

**B** $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

**C** $2NH_3(l) + 2Na(s) \rightarrow 2NaNH_2(s) + H_2(g)$

**D** $2NH_3(aq) + Ag^+(aq) \rightarrow [Ag(NH_3)_2]^+(aq)$

**8 9701/01/M/J/05/Q18**

In an historically famous experiment Wöhler heated “inorganic” ammonium cyanate in the absence of air. The only product of the reaction was “organic” urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

**A** $CNO^-$ **B** $CNO^{2-}$ **C** $CO^-$ **D** $NO^-$



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**9 9701/01/O/N/05/Q17**

How does ammonia behave when its aqueous solution is used to dissolve silver chloride, AgC$l$?

**A** as a base

**B** as a ligand with the $Ag^+$ ion

**C** as a ligand with the $Cl^-$ ion

**D** as a reducing agent

**10 9701/01/M/J/06/Q18**

The emissions from a power station contain about 14 tonnes of $SO_2$ per hour from the oxidation of $FeS_2$ contained in the coal.

What is the most practical way of preventing the $SO_2$ from being released into the atmosphere?

**A** Cool the gases and the $SO_2$ will liquefy and can be removed.

**B** Dissolve the ionic $FeS_2$ in hexane.

**C** Pass the emissions through a bed of calcium oxide.

**D** Pass the gases through concentrated sulphuric acid to dissolve the $SO_2$.

**11 9701/01/M/J/06/Q19**

The gaseous oxides of nitrogen have positive enthalpy changes of formation.

Which factor is likely to make the most significant contribution to these enthalpy changes?

**A** the high bond energy of the nitrogen molecule, $N_2$

**B** the high electron affinity of nitrogen atoms

**C** the high electron affinity of oxygen atoms

**D** the similarity of the electronegativities of oxygen and nitrogen

**12 9701/01/O/N/06/Q18**

Sulphur dioxide is an important food preservative.

Which property makes sulphur dioxide useful in this role?

**A** It is a gas.

**B** It is a reducing agent.

**C** It reacts with oxygen to form sulphur trioxide.

**D** It reacts with water to form an acidic solution.



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**13 9701/01/O/N/06/Q19**

In the Contact process for the production of sulphuric acid, sulphur dioxide is mixed with air and passed over a vanadium(V) oxide catalyst at about 450 °C and a pressure slightly above atmospheric pressure.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 \; ; \; \Delta H \text{ negative}$$

What affects the choice of conditions for this reaction?

**A** A lower temperature would not raise the concentration of $SO_3$ at equilibrium.

**B** At a lower temperature of 300 °C the $V_2O_5$ catalyst would not be effective.

**C** At 450 °C nitrogen and oxygen from the air combine to form nitrogen oxides which are needed as additional catalysts.

**D** The heat generated by the reaction raises the temperature of the catalyst bed to 600 °C at which temperature the reaction begins to take place.

**14 9701/01/M/J/07/Q17**

Methyl mercaptan, $CH_3SH$, is one of the substances responsible for bad breath and is often used to impart a smell to natural gas in a pipeline.

What will be formed when $CH_3SH$ is burned in an excess of air?

**A** CO $CO_2$ $H_2S$ **C** $CO_2$ $H_2O$ $SO_2$

**B** CO $H_2O$ $SO_3$ **D** $CO_2$ $H_2O$ $SO_3$

**15 9701/01/M/J/07/Q18**

A solid nitrate fertiliser reacts with an alkali to produce a gas which turns damp pH paper blue.

What is the empirical formula of this fertiliser?

**A** $NO_3$ **B** $NHO_3$ **C** $NH_2O$ **D** $N_2H_4O_3$

**16 9701/01/O/N/07/Q3**

The first stage in the manufacture of nitric acid is the oxidation of ammonia by oxygen.

$$\mathbf{w}NH_3(g) + \mathbf{x}O_2(g) \rightarrow \mathbf{y}NO(g) + \mathbf{z}H_2O(g)$$

Which values for **w**, **x**, **y** and **z** are needed to balance the equation?

| | w | x | y | z |
|---|---|---|---|---|
| **A** | 4 | 5 | 4 | 6 |
| **B** | 4 | 6 | 4 | 5 |
| **C** | 5 | 6 | 5 | 4 |
| **D** | 6 | 5 | 6 | 4 |



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**17 9701/01/O/N/07/Q17**

There are three stages in the Contact process for the production of sulphuric acid.

1 $S + O_2 \rightarrow SO_2$

2 $SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$

3 $SO_3 + H_2O \rightarrow H_2SO_4$

Which statement about this process is correct?

**A** In the first stage a large excess of air under high pressure is used to improve the yield.

**B** Two of the three stages are equilibria.

**C** All three stages are exothermic.

**D** In the final stage $SO_3$ is absorbed by water droplets.

**18 9701/01/O/N/07/Q18**

Gaseous nitrogen is less reactive than gaseous fluorine.

What is the reason for this difference in reactivity?

**A** The boiling point of nitrogen is lower than that of fluorine.

**B** The relative molecular mass of nitrogen is lower than that of fluorine.

**C** The atomic radius of nitrogen is greater than that of fluorine.

**D** The bond strength in the molecule is greater in nitrogen than in fluorine.

**19 9701/01/M/J/08/Q15**

*Use of the Data Booklet is relevant to this question.*

The combustion of fossil fuels is a major source of increasing atmospheric carbon dioxide, with a consequential rise in global warming. Another significant contribution to carbon dioxide levels comes from the thermal decomposition of limestone, in the manufacture of cement and of lime for agricultural purposes.

Cement works roast 1000 million tonnes of limestone per year and a further 200 million tonnes is roasted in kilns to make lime.

What is the total annual mass output of carbon dioxide (in million tonnes) from these two processes?

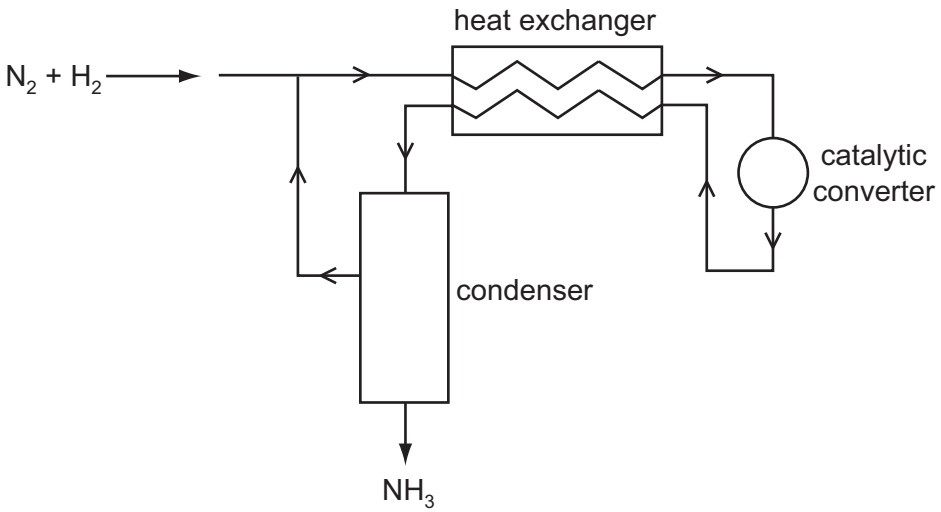
**A** 440 **B** 527 **C** 660 **D** 880



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**20 9701/01/M/J/08/Q18**

The diagram represents the Haber process for the manufacture of ammonia from nitrogen and hydrogen.




What is the purpose of the heat exchanger?

**A** to cool the incoming gas mixture to avoid overheating the catalyst
**B** to cool the reaction products and separate the $NH_3$ from unused $N_2$ and $H_2$
**C** to warm the incoming gas mixture and shift the equilibrium to give more $NH_3$
**D** to warm the incoming gas mixture and speed up the reaction

**21 9701/01/O/N/08/Q14**

Which salt is produced by adding aqueous ammonia to aqueous sulphur dioxide until just alkaline?

**A** $NH_4SO_3$ **B** $NH_4SO_4$ **C** $(NH_4)_2SO_3$ **D** $(NH_4)_2SO_4$

**22 9701/01/M/J/09/Q17**

Deposits of ammonium compounds have been discovered in areas of high atmospheric pollution.

They are believed to arise from the following reaction.

$$SO_3 + H_2O + 2NH_3 \rightarrow (NH_4)_2SO_4$$

What does **not** occur in this reaction?

**A** acid / base neutralisation
**B** dative bond formation
**C** ionic bond formation
**D** oxidation / reduction



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**23 9701/01/M/J/09/Q18**

Mohr's salt is a pale green crystalline solid which is soluble in water. It is a 'double sulfate' which contains two cations, one of which is $Fe^{2+}$.

The identity of the second cation was determined by heating solid Mohr's salt with solid sodium hydroxide and a colourless gas was evolved. The gas readily dissolved in water giving an alkaline solution. A grey-green solid residue was also formed which was insoluble in water.

What are the identities of the gas and the solid residue?

| | gas | residue |
|---|---|---|
| **A** | $H_2$ | $FeSO_4$ |
| **B** | $NH_3$ | $Na_2SO_4$ |
| **C** | $NH_3$ | $Fe(OH)_2$ |
| **D** | $SO_2$ | $Fe(OH)_2$ |

**24 9701/12/O/N/09/Q17**

Most modern cars are fitted with three-way catalytic converters in the exhaust system.

Which three gases are removed by such a catalytic converter?

**A** carbon monoxide, hydrocarbons, nitrogen oxides

**B** carbon monoxide, carbon dioxide, nitrogen oxides

**C** carbon monoxide, nitrogen oxides, sulfur dioxide

**D** hydrocarbons, nitrogen oxides, sulfur dioxide

**25 9701/12/O/N/09/Q18**

In an historically famous experiment Wöhler heated 'inorganic' ammonium cyanate in the absence of air. The only product of the reaction was 'organic' urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

**A** $CNO^-$ **B** $CNO^{2-}$ **C** $CO^-$ **D** $NO^-$

**26 9701/12/O/N/11/Q8**

Which pollutant, present in the exhaust fumes of an internal combustion engine, has an element in the +2 oxidation state and an odd number of electrons in one molecule of the pollutant?

**A** CO **B** $H_2S$ **C** NO **D** $NO_2$

STUDENT'S RESOURCE



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**27 9701/12/O/N/11/Q14**

Nitrogenous fertilisers are used extensively in modern farming. If rainwater washes excess fertiliser into a nearby lake, a process called eutrophication may occur.

Three of the stages of eutrophication are described below.

P Water plants growing on the lake bed die due to lack of sunlight.

Q An excessive growth of algae occurs.

R Excessive bacterial activity causes a reduction in oxygen levels.

In which order do these three stages occur?

**A** $P \rightarrow Q \rightarrow R$ **B** $P \rightarrow R \rightarrow Q$ **C** $Q \rightarrow P \rightarrow R$ **D** $Q \rightarrow R \rightarrow P$

**28 9701/11/M/J/12/Q19**

Carbon monoxide, CO, nitrogen dioxide, $NO_2$, and sulfur dioxide, $SO_2$, are all atmospheric pollutants.

Which reaction concerning these compounds occurs in the atmosphere?

**A** CO is spontaneously oxidised to $CO_2$

**B** $NO_2$ is reduced to NO by CO

**C** $NO_2$ is reduced to NO by $SO_2$

**D** $SO_2$ is oxidised to $SO_3$ by $CO_2$

**29 9701/12/O/N/12/Q16**

In a car engine, non-metallic element *X* forms a pollutant oxide *Y*. *Y* can be further oxidised to *Z*. Two students made the following statements.

Student P The molecule of *Y* contains lone pairs of electrons.

Student Q The oxidation number of *X* increases by 1 from *Y* to *Z*.

*X* could be carbon or nitrogen or sulfur.

Which student could be correct if *X* were any of these elements?

**A** P only **B** Q only **C** both P and Q **D** neither P nor Q

**30 9701/12/M/J/12/Q13**

Which gas is present in the exhaust fumes of a car engine in a much greater amount than any other gas?

**A** carbon dioxide

**B** carbon monoxide

**C** nitrogen

**D** water vapour



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**31 9701/11/M/J/15/Q18**

Mohr's salt is a pale green crystalline solid which is soluble in water. It contains two cations, one of which is $Fe^{2+}$, and one anion which is $SO_4^{2-}$.

The identity of the second cation was determined by heating Mohr's salt with aqueous sodium hydroxide. A colourless gas was evolved which readily dissolved in water giving an alkaline solution.

A green precipitate was also formed.

What are the identities of the gas and the precipitate?

| | gas | precipitate |
|---|---|---|
| **A** | $NH_3$ | $Fe(OH)_2$ |
| **B** | $NH_3$ | $Na_2SO_4$ |
| **C** | $SO_2$ | $Fe(OH)_2$ |
| **D** | $SO_2$ | $Na_2SO_4$ |

**32 9701/12/F/M/16/Q17**

Ammonium sulfate, $(NH_4)_2SO_4$, and ammonium nitrate, $NH_4NO_3$, are used as fertilisers.

These salts have different percentages by mass of nitrogen. They have the same effect as each other on the pH of neutral soil.

Which row is correct?

| | higher percentage of nitrogen by mass | effect on pH of soil |
|---|---|---|
| **A** | ammonium nitrate | decrease |
| **B** | ammonium nitrate | increase |
| **C** | ammonium sulfate | decrease |
| **D** | ammonium sulfate | increase |

**33 9701/11/M/J/16/Q18**

Which statement about the ammonia molecule and/or the ammonium ion is correct?

**A** Ammonia molecules are basic because they can donate $H^+$ ions.

**B** Ammonium ions are basic because they can accept $H^+$ ions.

**C** If ammonium ions are heated with NaOH(aq), ammonia molecules are formed.

**D** The bond angle in $NH_4^+$ is 2.5° less than the bond angle in $NH_3$.

STUDENTS RESOURCE



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**34 9701/11/M/J/16/Q19**

Which reaction **does not** contribute to the problem of acid rain?

**A** the combustion of fossil fuels

**B** the oxidation of sulfur dioxide to sulfur trioxide catalysed by nitrogen dioxide

**C** the reaction between nitrogen monoxide and carbon monoxide in a catalytic converter

**D** the reaction of sulfur trioxide with water

**35 9701/12/M/J/16/Q15**

Ammonia gas, $NH_3$, and hydrogen sulfide gas, $H_2S$, react together to form the salt ammonium sulfide, $(NH_4)_2S$. Ammonium sulfide dissolves in water to produce an orange alkaline solution.

$$(NH_4)_2S(aq) \rightleftharpoons NH_3(aq) + NH_4SH(aq)$$

The addition of NaOH(aq) to this solution produces a gas, **X**.
The addition of HC$l$(aq) to a separate portion of this solution produces a gas, **Y**.

What are the identities of **X** and **Y**?

| | X | Y |
|---|---|---|
| **A** | $H_2S$ | $H_2S$ |
| **B** | $H_2S$ | $NH_3$ |
| **C** | $NH_3$ | $H_2S$ |
| **D** | $NH_3$ | $NH_3$ |

**36 9701/12/M/J/16/Q17**

Nitrogen(II) oxide, NO, nitrogen(IV) oxide, $NO_2$, carbon monoxide, CO, and unburnt hydrocarbons are present in the exhaust gases of internal combustion engines. When catalytic converters are used to remove these compounds from the exhaust gases, redox reactions occur.

What happens to each compound in the catalytic converter?

| | NO | $NO_2$ | CO | hydrocarbons |
|---|---|---|---|---|
| **A** | oxidised | oxidised | reduced | oxidised |
| **B** | oxidised | oxidised | oxidised | oxidised |
| **C** | reduced | reduced | oxidised | oxidised |
| **D** | reduced | reduced | reduced | reduced |



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**37 9701/13/M/J/16/Q19**

Which statement does **not** describe an effect of acid rain on the environment?

**A** Acid rain causes erosion of stone buildings.

**B** Acid rain causes ozone depletion.

**C** Acid rain increases the corrosion of some metals.

**D** Acid rain increases the leaching away of essential nutrients and minerals from soils.

**38 9701/12/F/M/17/Q19**

Methylamine, $CH_3NH_2$, has very similar chemical properties to ammonia, $NH_3$.

Methylamine reacts with hydrogen chloride to form a white crystalline salt, methylammonium chloride.

$$CH_3NH_2 + HCl \rightarrow CH_3NH_3^+Cl^-$$

A sample of methylammonium chloride is heated with aqueous sodium hydroxide.

What are the products?

**A** ammonia, sodium chloride and water

**B** ammonia, sodium hydrogencarbonate and sodium chloride

**C** methylamine, hydrogen chloride and water

**D** methylamine, sodium chloride and water

**39 9701/11/M/J/17/Q16**

Which statement about nitrogen or its compounds is correct?

**A** In the Haber process the temperature is kept high to give a good equilibrium yield of ammonia.

**B** Nitrogen gas is unreactive because of the strong nitrogen-nitrogen double bond.

**C** Nitrogen monoxide will react with carbon monoxide under suitable conditions.

**D** The formula of ammonium sulfate is $NH_4SO_4$.

**40 9701/11/M/J/17/Q17**

When concentrated sulfuric acid reacts with sodium iodide the products include sulfur, iodine, hydrogen sulfide and sulfur dioxide.

Which statement is correct?

**A** Hydrogen sulfide is the product of a reduction reaction.

**B** Iodide ions are stronger oxidising agents than sulfate ions.

**C** Sulfur atoms from the sulfuric acid are both oxidised and reduced.

**D** Sulfur atoms from the sulfuric acid are oxidised to make sulfur dioxide.

STUDENTS RESOURCE



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**41 9701/12/M/J/17/Q8**

A reaction sequence is shown.

$$SO_2 \xrightarrow{1} SO_3 \xrightarrow{2} H_2SO_4 \xrightarrow{3} H_2S \xrightarrow{4} SO_2$$

In each stage of this sequence the sulfur is oxidised, reduced or neither oxidised nor reduced.

Which row is correct?

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **A** | neither | oxidised | reduced | reduced |
| **B** | oxidised | neither | reduced | reduced |
| **C** | oxidised | neither | reduced | oxidised |
| **D** | oxidised | oxidised | reduced | oxidised |

**42 9701/12/M/J/17/Q18**

The ammonium ion is formed by the following reaction. $NH_3 + H_+ \rightarrow NH_{4+}$

Which statement about the species involved in this reaction is correct?

**A** The ammonia molecule contains a dative covalent bond.

**B** The ammonium ion is a Brønsted-Lowry base as it has accepted a proton.

**C** The H–N–H bond angle changes from 107° in ammonia to 90° in the ammonium ion.

**D** The number of electrons surrounding each nitrogen atom does not change.

**43 9701/12/M/J/17/Q19**

A chemist took 2.00 $dm^3$ of nitrogen gas, measured under room conditions, and reacted it with a large volume of hydrogen gas to produce ammonia. Only 15.0% of the nitrogen gas reacted to produce ammonia.

Which mass of ammonia was formed?

**A** 0.213 g

**B** 0.425 g

**C** 1.42 g

**D** 2.83 g



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**44 9701/13/O/N/13/Q15**

Ammonia exists as simple covalent molecules, $NH_3$. Ammonia can react with suitable reagents to form products containing ammonium ions, $NH_4^+$. Ammonia can also react with suitable reagents to form products containing amide ions, $NH_2^-$.

Which of these nitrogen-containing species are present in an aqueous solution of ammonia?

**A** ammonia molecules and amide ions only

**B** ammonia molecules and ammonium ions only

**C** ammonia molecules only

**D** ammonium ions only

**45 9701/13/M/J/17/Q19**

What would be produced when 60 g of nitrogen monoxide react with an excess of carbon monoxide in a catalytic converter?

**A** 12 g of carbon and 92 g of nitrogen dioxide

**B** 24 g of carbon and 92 g of nitrogen dioxide

**C** 88 g of carbon dioxide and 28 g of nitrogen

**D** 88 g of carbon dioxide and 56 g of nitrogen

**46 9701/11/O/N/18/Q7**

Nitric acid is known to take part in the oxidation of atmospheric sulfur dioxide. One possible reaction is shown.

$$SO_2 + HNO_3 \rightarrow NO^+ + HSO_4^-$$

Which row shows the correct changes in oxidation numbers of nitrogen and sulfur?

| | nitrogen | sulfur |
|---|---|---|
| **A** | –3 | +3 |
| **B** | –2 | +2 |
| **C** | –2 | +3 |
| **D** | –1 | +2 |



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**47 9701/11/O/N/18/Q11**

Two reactions are shown.

reaction 1 $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

reaction 2 $2O_3(g) \rightleftharpoons 3O_2(g)$

In reaction 1, a finely powdered iron catalyst is used.

In reaction 2, a vaporised tetrachloromethane catalyst in ultraviolet light is used.

Which statement about the catalysts used is correct?

**A** Both reaction 1 and reaction 2 use a heterogeneous catalyst.

**B** Both reaction 1 and reaction 2 use a homogeneous catalyst.

**C** Reaction 1 uses a heterogeneous catalyst and reaction 2 uses a homogeneous catalyst.

**D** Reaction 1 uses a homogeneous catalyst and reaction 2 uses a heterogeneous catalyst.

**48 9701/11/O/N/18/Q12**

Sodium and sulfur are burned separately in oxygen.

Each reaction has a distinctive coloured flame.

Which row is correct?

| | $Na + O_2$ | $S + O_2$ |
|---|---|---|
| **A** | white | blue |
| **B** | white | yellow |
| **C** | yellow | blue |
| **D** | yellow | yellow |

**49 9701/12/O/N/18/Q18**

The product of the Contact process is Z.

Which reaction or process leads to the formation of a gas that can neutralise an aqueous solution of Z?

**A** atmospheric lightning

**B** combustion of fuel in an internal combustion engine

**C** the Haber process

**D** thermal decomposition of Group 2 nitrates



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**50 9701/12/O/N/18/Q11**

Nitrogen and hydrogen can react together to form ammonia.

The formation of ammonia is exothermic.

The rate and yield of the reaction can be altered by changing the conditions under which the reaction is carried out.

Which row shows the effects of adding iron to the mixture **and** increasing the temperature?

| | adding iron | increasing the temperature |
|---|---|---|
| **A** | has no effect on the equilibrium yield | reduces the equilibrium yield |
| **B** | increases the equilibrium yield | increases the equilibrium yield |
| **C** | increases the equilibrium yield | increases the rate |
| **D** | increases the rate | has no effect on the equilibrium yield |

**51 9701/12/O/N/18/Q19**

If ammonium cyanate is heated in the absence of air, the only product of the reaction is urea, $CO(NH_2)_2$. No other products are formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

**A** $CON_2^-$ **B** $CON_2^{2-}$ **C** $OCN^-$ **D** $OCN^{2-}$

**52 9701/11/M/J/19/Q18**

At 550 °C nitrogen dioxide reacts with unburnt hydrocarbon fragments such as $CH_3$ in the catalytic converter of a motor vehicle.

$$4CH_3 + 7NO_2 \rightarrow 3\tfrac{1}{2}N_2 + 4CO_2 + 6H_2O$$

Which row gives the energy change for this reaction and a possible reason for it?

| | energy change of reaction | reason why the reaction is endothermic or exothermic |
|---|---|---|
| **A** | endothermic | chemical energy is converted to heat energy |
| **B** | endothermic | the N≡N bond energy is very high |
| **C** | exothermic | $CO_2$ and $H_2O$ have negative $\Delta H_f^\ominus$ values |
| **D** | exothermic | double bonds are broken in $NO_2$ |



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**53 9701/12/F/M/19/Q19**

Ammonia, $NH_3$, and hydrazine, $NH_2NH_2$, are two compounds of nitrogen, $N_2$.

Which statement is correct?

**A** The N–N bond in $NH_2NH_2$ is polar.

**B** $NH_3$ and $NH_2NH_2$ have lone pairs of electrons but $N_2$ does not.

**C** The oxidation number of each nitrogen in $NH_2NH_2$ is +2.

**D** The reaction of nitrogen with hydrogen has a high activation energy.

**54 9701/11/M/J/19/Q19**

Which statement is correct?

**A** Ammonia reacts with alkalis to form the ammonium ion.

**B** Ammonium chloride contains ionic, covalent and co-ordinate bonds.

**C** The ammonium ion reacts with acids to produce ammonia.

**D** The bond angle in the ammonium ion is approximately 107°.

**55 9701/12/M/J/19/Q15**

How many of the solutions shown, when added to separate portions of magnesium sulfate solution, produce a white precipitate?

$HCl(aq)$ $NH_3(aq)$ $(NH_4)_2CO_3(aq)$ $Ba(NO_3)_2(aq)$

**A** 0 **B** 1 **C** 2 **D** 3

**56 9701/11/O/N/19/Q18**

Which type of reaction occurs when solid ammonium sulfate is heated with an excess of sodium hydroxide solution?

**A** acid-base

**B** precipitation

**C** redox

**D** thermal decomposition



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**57 9701/12/O/N/19/Q2**

In this question it should be assumed that $(NH_4)_2CO_3.H_2O(s)$ dissolves in water without causing an increase in volume.

Which mass of $(NH_4)_2CO_3.H_2O(s)$ should be added to 800 $cm^3$ of water to form a 0.100 $mol\,dm^{-3}$ solution of $NH_4^+$ ions?

**A** 4.56 g **B** 7.13 g **C** 9.12 g **D** 14.3 g

**58 9701/12/O/N/19/Q19**

Ammonia, carbon dioxide and water react together to form ammonium carbonate.

Which statement about this reaction is correct?

**A** It is a redox reaction.

**B** It is an acid-base reaction.

**C** The H–N–H bond angle decreases as a consequence of this reaction.

**D** The three substances react in a 1 : 1 : 1 ratio in this reaction.

**59 9701/12/F/M/20/Q7**

Sodium azide, $NaN_3$, decomposes as shown.

$$2NaN_3 \rightarrow 2Na + 3N_2$$

Which volume of nitrogen, measured at room temperature and pressure, will be produced by the decomposition of 150 g of sodium azide?

**A** 166 $dm^3$ **B** 83 $dm^3$ **C** 55 $dm^3$ **D** 37 $dm^3$

**60 9701/12/F/M/20/Q15**

Solid ammonium nitrate is put into a test-tube and solution X is added to it. The resulting mixture is warmed and the gas given off is tested with damp red litmus paper. The litmus paper changes colour from red to blue.

What could be the identity of X and its role in the reaction?

| | identity of X | role of X |
|---|---|---|
| **A** | NaOH(aq) | proton donor |
| **B** | NaOH(aq) | proton acceptor |
| **C** | HC*l*(aq) | proton donor |
| **D** | HC*l*(aq) | proton acceptor |



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**61 9701/11/M/J/20/Q13**

6.90 g of an ammonium salt is heated with an excess of aqueous sodium hydroxide. The volume of ammonia produced, measured under room conditions, is 2.51 $dm^3$.

Which ammonium salt is used?

**A** ammonium carbonate ($M_r$ = 96.0)

**B** ammonium chloride ($M_r$ = 53.5)

**C** ammonium nitrate ($M_r$ = 80.0)

**D** ammonium sulfate ($M_r$ = 132.1)

**62 9701/12/M/J/20/Q19**

Most modern cars are fitted with catalytic converters in the exhaust system.

Which three gases are removed by a catalytic converter?

**A** carbon monoxide, hydrocarbons, nitrogen oxides

**B** carbon monoxide, carbon dioxide, nitrogen oxides

**C** carbon monoxide, nitrogen oxides, sulfur dioxide

**D** hydrocarbons, nitrogen oxides, sulfur dioxide

**63 9701/13/M/J/20/Q5**

Nitrogen reacts with oxygen to form nitrogen monoxide, NO, and nitrogen dioxide, $NO_2$. Nitrogen dioxide reacts with water and with hydroxide ions.

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

$$2NO_2(g) + H_2O(l) \rightarrow HNO_2(aq) + H^+(aq) + NO_3^-(aq)$$

$$2NO_2(g) + 2OH^-(aq) \rightarrow NO_2^-(aq) + NO_3^-(aq) + H_2O(l)$$

What can be deduced using **only** the information from these equations?

**A** $HNO_2$ is a strong acid.

**B** $HNO_3$ is a weak acid.

**C** $NO_2$ is a neutral gas.

**D** NO is a reducing agent.



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**64** **9701/13/M/J/20/Q16**

Nitrogen oxides are removed from the exhaust gases of internal combustion engines by the action of a catalyst in a catalytic converter.

Which row is correct?

| | change in oxidation number of nitrogen | type of catalyst |
|---|---|---|
| **A** | decrease | heterogeneous |
| **B** | decrease | homogeneous |
| **C** | increase | heterogeneous |
| **D** | increase | homogeneous |



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# Organic Chemistry And Analysis

13
TOPIC

# An Introduction to Organic Chemistry

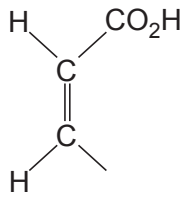
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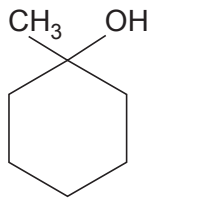
**1 9701/1/O/N/02/Q29**

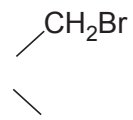
Which compound is both chiral and acidic?

**A**




**B**

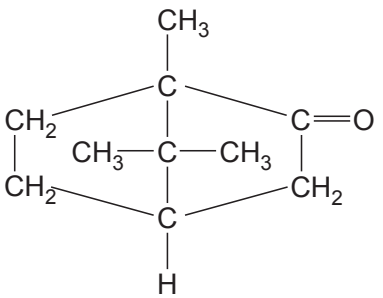





**2 9701/1/O/N/02/Q21**

Camphor is used for medical purposes, the diagram shows its structure.




How many chiral centres are present in one molecule of camphor?

**A** 0 **B** 1 **C** 2 **D** 3



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**3 9701/1/M/J/03/Q19**

Which pollutant is formed in the internal combustion engine and, if not removed by the catalytic converter, may become involved in the formation of acid rain?

**A** C **B** $C_8H_{18}$ **C** CO **D** NO

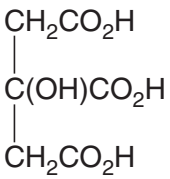
**4 9701/1/M/J/03/Q20**

How many structural and *cis-trans* isomers are there for dichloropropene, $C_3H_4Cl_2$?

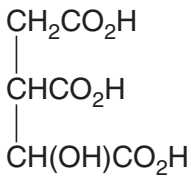
**A** 3 **B** 5 **C** 6 **D** 7

**5 9701/1/M/J/03/Q21**

The isomers, citric acid and isocitric acid, are intermediates in the Krebs cycle of the oxidation of glucose in living cells.



citric acid



isocitric acid

How many chiral centres does each acid possess?

| | citric acid | isocitric acid |
|---|---|---|
| **A** | 0 | 1 |
| **B** | 0 | 2 |
| **C** | 1 | 1 |
| **D** | 1 | 2 |

**6 9701/01/M/J/04/Q21**

Which of these always applies to a nucleophile?

**A** It attacks a double bond.

**B** It has a lone pair of electrons.

**C** It is a single atom.

**D** It is negatively charged.



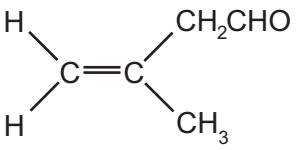
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**7 9701/01/M/J/04/Q22**

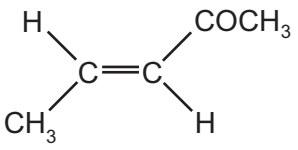
Compound **P** displays *cis-trans* isomerism and gives a red-brown precipitate with Fehling's solution.

What is **P**?

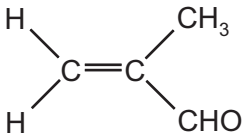
**A**



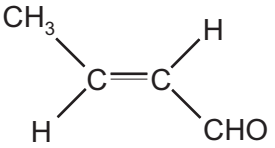
**B**



**C**



**D**



**8 9701/01/O/N/04/Q9**

Which of these compounds, on complete combustion of one mole, will release the greatest amount of energy?

**A** $CH_3CH_2CH_2OH$ **B** $CH_3CH_2CH_3$ **C** $CH_3CH_2CO_2H$ **D** $CH_3COCH_3$

**9 9701/01/O/N/04/Q20**

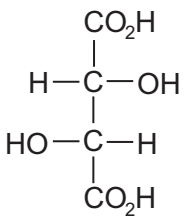
What can behave as an electrophilic reagent?

**A** $Br_2$ **B** Na **C** $NH_3$ **D** $CN^-$

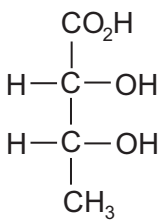
**10 9701/01/O/N/04/Q21**

Which molecule does not have a chiral centre?

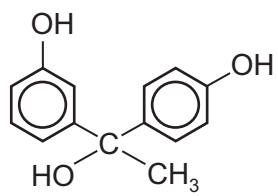
**A**



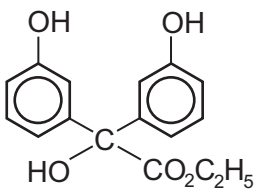
**B**



**C**



**D**

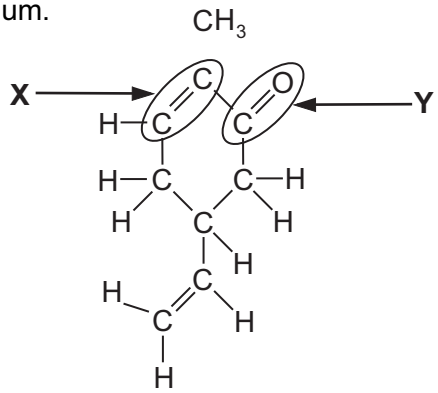




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**11 9701/01/O/N/04/Q24**

This molecule is responsible for the flavour of spearmint chewing gum.




What is a true statement about the functional groups **X** or **Y**?

**A** **X** will undergo nucleophilic addition.

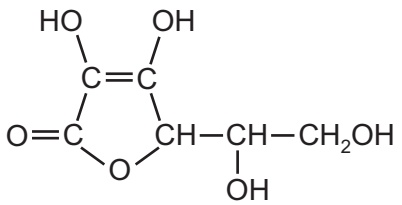
**B** **Y** will undergo nucleophilic addition.

**C** **X** will undergo electrophilic substitution.

**D** **Y** will undergo electrophilic substitution.

**12 9701/01/O/N/05/Q19**

The diagram shows the structure of vitamin C.




How many chiral centres are there in one molecule?

**A** 1 **B** 2 **C** 3 **D** 4

**13 9701/01/O/N/05/Q20**

What is the number of isomers of $C_2H_2Cl_2$ including *cis-trans* isomers?

**A** 2 **B** 3 **C** 4 **D** 5

**14 9701/01/O/N/06/Q20**

In which class of compound, in its general formula, is the ratio of hydrogen atoms to carbon atoms the highest?

**A** alcohols **B** aldehydes **C** carboxylic acids **D** halogenoalkanes

**15 9701/01/O/N/06/Q21**

What is the total number of different chloroethanes, formula $C_2H_{6-n}Cl_n$, where $n$ can be any integer from 1 to 4?

**A** 4 **B** 6 **C** 7 **D** 8

**16 9701/01/O/N/06/Q24**

When gaseous chemicals are transported by road or by rail they are classified as follows.

flammable non-flammable poisonous

Which commonly transported gas is non-flammable?

**A** butane **B** hydrogen **C** oxygen **D** propene

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**17** **9701/01/O/N/06/Q23**

Which alkene could exist in *cis* and *trans* forms?

**A** $CH_3CH_2CH_2CH{=}CH_2$

**B** $CH_3CH_2CH{=}CHCH_3$

**C** $CH_3CH_2C(CH_3){=}CH_2$

**D** $CH_3CH{=}C(CH_3)CH_3$

**18** **9701/01/O/N/07/Q12**

When dangerous chemicals are transported by road, vehicles must carry signs that indicate what measures should be taken in the event of a spillage of the chemical carried.

Which material must be used if there were a spillage of metallic sodium?

**A** ethanol **B** jets of water **C** sand **D** water spray

**19** **9701/01/O/N/07/Q19**

Which molecules, each with a linear carbon chain, can have an optically active isomer?

| I | II | III | IV |
|---|---|---|---|
| $C_3H_6BrI$ | $C_3H_4BrI$ | $C_3H_6I_2$ | $C_3H_4Br_2$ |

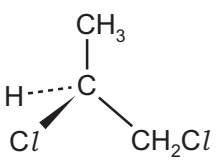
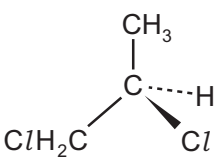
**A** I and II only **B** I, II and III only **C** II and III only **D** I, II and IV only

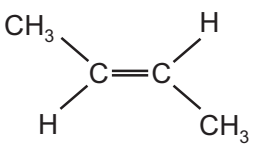
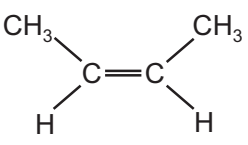
**20** **9701/01/O/N/07/Q20**

In which pair do the isomers have identical boiling points?

**A** $CH_3CH_2CH_2CH_2OH$ and $(CH_3)_2CHCH_2OH$

**B** $CH_3(CH_2)_4CH_3$ and $(CH_3)_2CHCH(CH_3)_2$

**C**  and 

**D**  and 

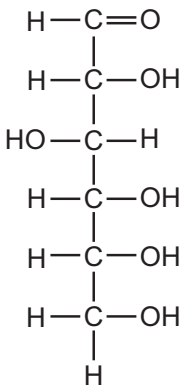


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**21 9701/01/M/J/07/Q19**

Glucose, $C_6H_{12}O_6$, is a product of photosynthesis.

It has the following structure.



How many *chiral* centres does the molecule have?

**A** 1 **B** 2 **C** 4 **D** 6

**22 9701/01/M/J/08/Q20**

Which pair of reaction types is illustrated by the reaction sequence below?

$$CH_3CH{=}CHCH_3 \xrightarrow{HI \text{ in } CH_3CO_2H} CH_3CH_2CHICH_3 \xrightarrow{NaOH(aq)} CH_3CH_2CH(OH)CH_3$$

**A** electrophilic addition and electrophilic substitution

**B** electrophilic addition and nucleophilic substitution

**C** nucleophilic addition and electrophilic substitution

**D** nucleophilic addition and nucleophilic substitution

**23 9701/12/M/J/10/Q28**

Which compound exhibits both *cis-trans* and optical isomerism?

**A** $CH_3CH{=}CHCH_2CH_3$ **C** $CH_3CBr{=}CBrCH_3$

**B** $CH\ CHBrCH{=}CH_2$ **D** $CH\ CH\ CHBrCH{=}CHBr$

**24 9701/12/O/N/10/Q20**

How many structural isomers are there of trichloropropane, $C_3H_5Cl_3$?

**A** 3 **B** 4 **C** 5 **D** 6

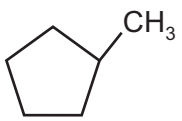


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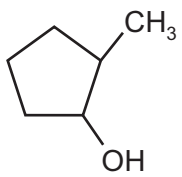
**25 9701/12/O/N/10/Q30**

Which of the compounds shown have chiral carbon atoms?

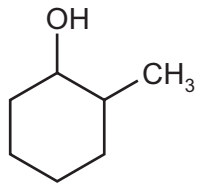
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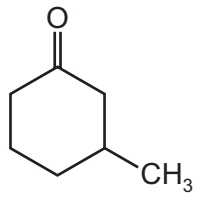

2




3




4




**A** 1, 2, 3 and 4 **B** 1 and 4 only **C** 2 and 3 only **D** 2, 3 and 4 only

**26 9701/12/M/J/11/Q24**

Which compound does **not** show cis-trans isomerism?

**A** 2-methylpent-2-ene

**B** 3-methylpent-2-ene

**C** 3,4-dimethylhex-3-ene

**D** pent-2-ene

**27 9701/12/M/J/11/Q25**

Which formulae show propanone and propanal as different compounds?

**A** empirical, molecular, structural **and** displayed formulae

**B** molecular, structural and displayed formulae **only**

**C** structural and displayed formulae **only**

**D** displayed formulae **only**

**28 9701/12/O/N/11/Q20**

Bromine and propene undergo an addition reaction.

Which is a property of the product?

**A** It exists in *cis-trans* isomers.

**B** It is more volatile than propene.

**C** It possesses a chiral centre.

**D** It possesses hydrogen bonding.

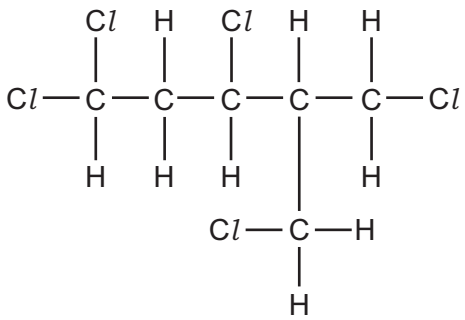
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**29 9701/12/O/N/11/Q27**

The molecule shown is optically active.

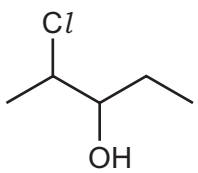


How many chiral carbon atoms are present in this molecule?

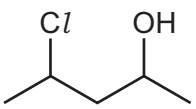
**A** 1 **B** 2 **C** 3 **D** 4

**30 9701/12/M/J/12/Q21**

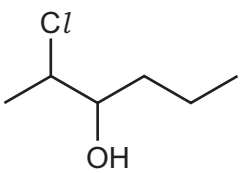
**A**



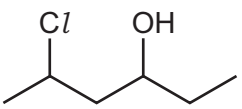
**B**



**C**

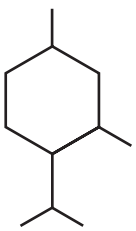


**D**



**31 9701/12/O/N/12/Q22**

Menthol is an important compound extracted from the peppermint plant.

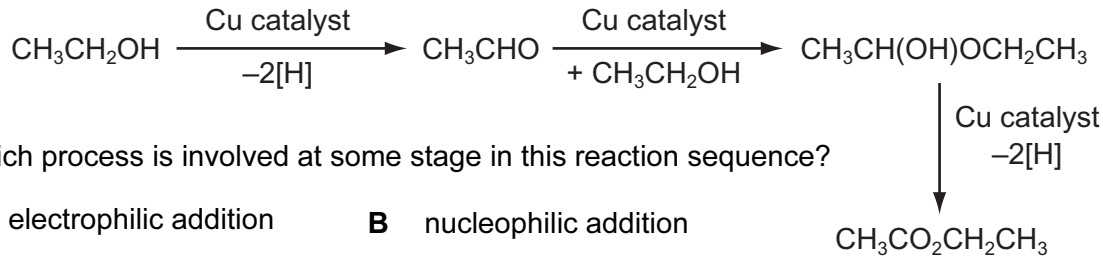




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**32 9701/12/O/N/13/Q20**

A new industrial preparation of ethyl ethanoate has been developed using cheap sources of ethanol.




Which process is involved at some stage in this reaction sequence?

**A** electrophilic addition **B** nucleophilic addition

**C** nucleophilic substitution **D** reduction

**33 9701/12/O/N/13/Q23**

Which compound exhibits stereoisomerism?

**A** $CH_3CHClCH_3$ **B** $CH_3CHClCH_2Cl$ **C** $CH_3CCl_2CH_3$ **D** $CH_2ClCH_2CH_2Cl$

**34 9701/12/M/J/13/Q17**

Which statement about ammonia is completely correct?

**A** Ammonia acts as a nucleophile by accepting a pair of electrons when it reacts with bromoethane.

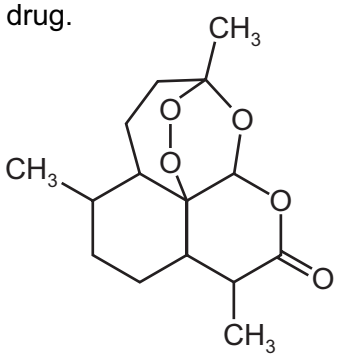
**B** Ammonia can form a co-ordinate bond with a hydrogen ion to form an ammonium ion.

**C** Ammonia is a base and accepts hydroxide ions.

**D** The shape of the ammonia molecule is pyramidal with bond angles of 109.5°.

**35 9701/12/M/J/14/Q30**

Artemisinin is a powerful anti-malarial drug.




artemisinin

How many chiral centres are there in each molecule of artemisinin?

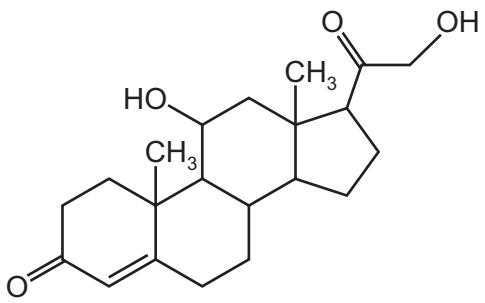
**A** 4 **B** 6 **C** 7 **D** 8



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**36 9701/12/O/N/14/Q26**

Corticosterone is a hormone involved in the metabolism of carbohydrates and proteins.




corticosterone

How many chiral centres are there in one molecule of corticosterone?

**A** 5 **B** 6 **C** 7 **D** 8

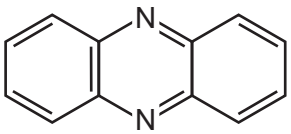
**37 9701/12/M/J/14/Q20**

The diagram shows the skeletal formula of phenazine.

What is the empirical formula of phenazine?

**A** $C_6H_4N$ **B** $C_6H_6N$

**C** $C_{12}H_8N_2$ **D** $C_{12}H_{12}N_2$




phenazine

**38 9701/12/O/N/14/Q29**

Which equation correctly represents the balanced equation for the complete combustion of a hydrocarbon with the formula $C_xH_y$?

**A** $C_xH_y + (x + \frac{y}{2})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$

**B** $C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + yH_2O$

**C** $C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{4}H_2O$

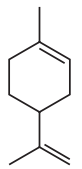
**D** $C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$



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**39 9701/11/M/J/15/Q29**

The citrus flavour of lemons is due to the compound limonene, present in both the peel and the juice.



limonene

What is the mole ratio of carbon dioxide to water produced when limonene is completely burnt in oxygen?

| | number of moles carbon dioxide | number of moles water |
|---|---|---|
| **A** | 4 | 3 |
| **B** | 5 | 4 |
| **C** | 5 | 8 |
| **D** | 9 | 7 |

**40 9701/12/M/J/15/Q25**

Terpinen-4-ol is one of the active ingredients in tea tree oil.

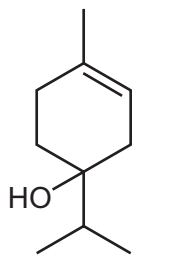
What is the molecular formula of terpinen-4-ol?

**A** $C_7H_{11}O$

**B** $C_{10}H_{16}O$

**C** $C_{10}H_{17}O$

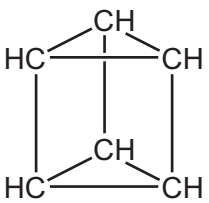
**D** $C_{10}H_{18}O$




terpinen-4-ol

**41 9701/11/M/J/15/Q28**

In 1869 Ladenburg suggested a structure for benzene, $C_6H_6$, in which one hydrogen atom is attached to each carbon atom.




Ladenburg structure

A compound $C_6H_4Cl_2$ could be formed with **the same** carbon skeleton as the Ladenburg structure.

How many **structural** isomers would this compound have?

**A** 3 **B** 4 **C** 5 **D** 6

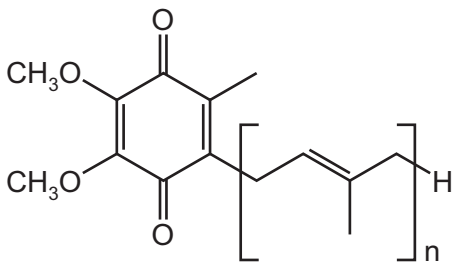


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**42 9701/12/F/M/16/Q20**

People who take statin drugs to control their blood cholesterol may also take 'coenzyme $Q_{10}$'.

The diagram shows a simplified structure of one form of this coenzyme.



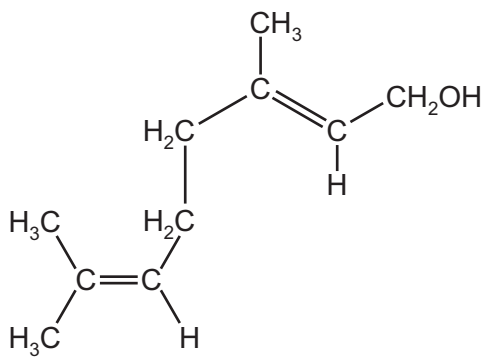
coenzyme $Q_{10}$

Which row describes this structure correctly?

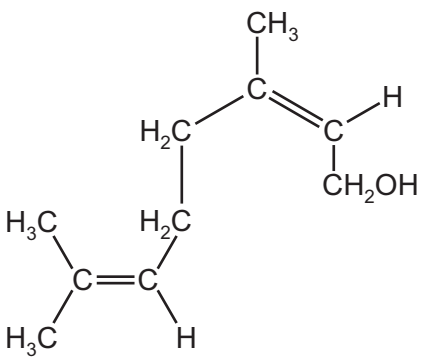
| | the coenzyme is | number of π bonds in one molecule |
|---|---|---|
| **A** | an aldehyde | *n* + 2 |
| **B** | an aldehyde | *n* + 4 |
| **C** | a ketone | *n* + 2 |
| **D** | a ketone | *n* + 4 |

**43 9701/12/F/M/16/Q21**

Geraniol and nerol are compounds found in some flower fragrances. They are isomers of each other.



geraniol



nerol

Which type of isomerism is shown here?

**A** chain **B** geometrical (cis-trans) **C** optical **D** positional

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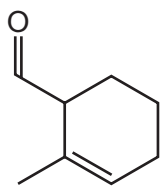
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**44 9701/11/M/J/16/Q20**

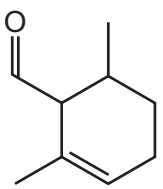
The diagrams show two different compounds.

What is
- the total number of structural isomers, including compound 2, that could be formed by adding a second methyl group to the ring of compound 1,
- the number of π electrons in each compound?

| | number of isomers | number of π electrons |
|---|---|---|
| **A** | 3 | 2 |
| **B** | 3 | 4 |
| **C** | 5 | 2 |
| **D** | 5 | 4 |




1




2

**45 9701/11/M/J/16/Q22**

Which pair of reagents will take part in a redox reaction?

**A** $CH_3CHCH_2$ + $Br_2$

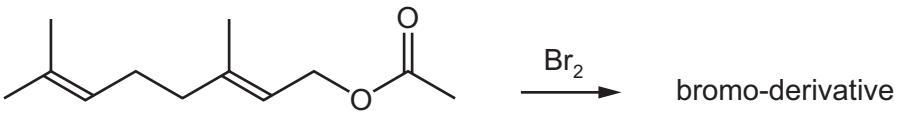
**B** $CH_3CH_2CH_2OH$ + concentrated $H_3PO_4$

**C** $CH_3COCH_3$ + HCN

**D** $HCO_2C_2H_5$ + dilute $H_2SO_4$

**46 9701/11/M/J/16/Q30**

Geranyl ethanoate is present in ginger and cocoa, and is used in shampoos and soaps as a perfume. It reacts with an excess of bromine in an organic solvent to give X, a bromo-derivative.




geranyl ethanoate

Including geranyl ethanoate, how many cis-trans isomers are there of geranyl ethanoate, and how many chiral centres are there in X?

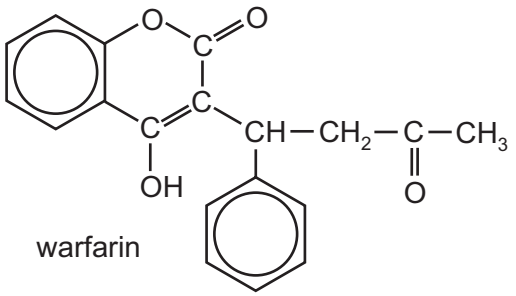
| | cis-trans isomers | chiral centres in X |
|---|---|---|
| **A** | 2 | 3 |
| **B** | 2 | 4 |
| **C** | 4 | 3 |
| **D** | 4 | 4 |



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**47** **9701/01/M/J/06/Q21**

Warfarin is used as a rat poison.




warfarin

How many chiral centres are present in the warfarin molecule?

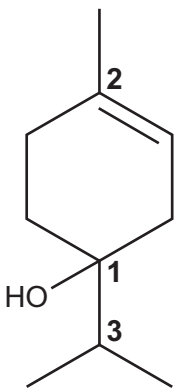
**A** 0 **B** 1 **C** 2 **D** 3

**48** **9701/12/M/J/16/Q38**

One of the active ingredients in tea-tree oil is terpinen-4-ol.

In the diagram of the skeletal formula of terpinen-4-ol, three of the carbon atoms are labelled **1**, **2** and **3**.

Which of the labelled carbon atoms are chiral?




terpinen-4-ol

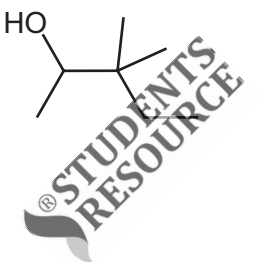
The responses **A** to **D** should be selected on the basis of

| A | B | C | D |
|---|---|---|---|
| **1**, **2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

No other combination of statements is used as a correct response.

**49** **9701/13/M/J/16/Q20**

What is the correct name of the molecule with the skeletal formula shown?




**A** 1,2,2-trimethylbutan-3-ol **C** 3,3-dimethylpentan-2-ol

**B** 2-ethyl-2-methylbutan-2-ol **D** 4-hydroxy-3,3-dimethylpentane

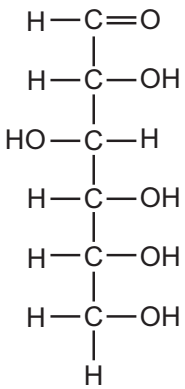


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**50** **9701/01/M/J/07/Q19**

Glucose, $C_6H_{12}O_6$, is a product of photosynthesis.

It has the following structure.



How many *chiral* centres does the molecule have?

**A** 1 **B** 2 **C** 4 **D** 6

**51** **9701/12/F/M/17/Q20**

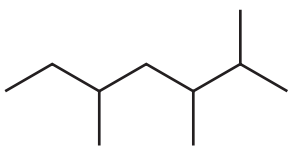
Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomers with the formula $C_4H_8$ have structures that contain a $\pi$ bond?

**A** 1 **B** 2 **C** 3 **D** 4

**52** **9701/12/F/M/17/Q21**

Kerosene is used as an aircraft fuel. Q is one of the molecules in kerosene and has the skeletal formula shown.

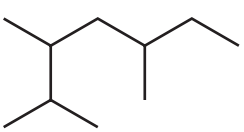


Q

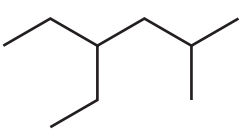
Other structural isomers of this molecule are also found in kerosene.

Which structure is a structural isomer of Q?

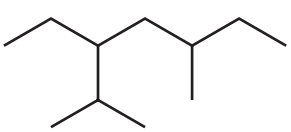
**A**



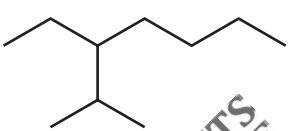
**B**



**C**



**D**



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**53** **9701/12/F/M/17/Q22**

Which radical is most likely to form by the homolytic fission of one covalent bond in bromochloromethane, $CH_2BrCl$?

**A** $\bullet CH_2Cl$ **B** $\bullet CH_2Br$ **C** $\bullet CHBrCl$ **D** $\bullet CH_2BrCl$

**54** **9701/11/M/J/17/Q20**

Structural isomerism and stereoisomerism should be considered when answering this question.

Each of the following carbonyl compounds is reacted with $NaBH_4$. The product of each reaction is heated with $Al_2O_3$ at 600 °C, generating one product or a mixture of isomers.

Which carbonyl compound will produce the most isomers?

**A** butanal

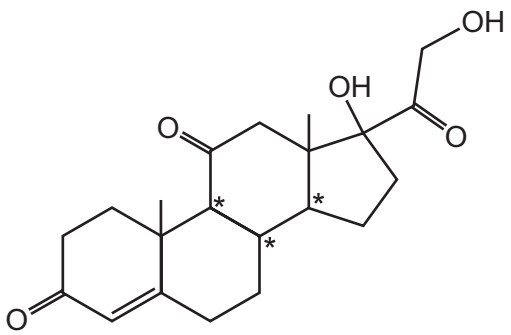
**B** butanone

**C** pentan-3-one

**D** propanone

**55** **9701/11/M/J/17/Q21**

The drug cortisone has the formula shown.




In addition to those chiral centres marked by an asterisk (*), how many **other** chiral centres are present in the cortisone molecule?

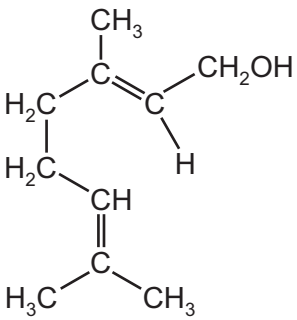
**A** 0 **B** 1 **C** 2 **D** 3



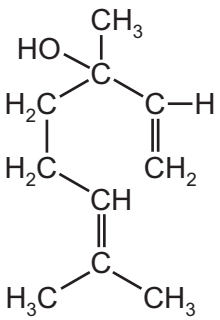
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**56 9701/12/M/J/17/21**

Geraniol and linalool are compounds found in some flower fragrances.



geraniol



linalool

Which statement is correct?

**A** They are chain isomers of each other.

**B** They are geometrical isomers of each other.

**C** They are optical isomers of each other.

**D** They are positional isomers of each other.

**57 9701/12/M/J/17/Q22**

Which equation represents the initiation step of the substitution reaction between methane and chlorine?

**A** $CH_4 \rightarrow CH_3\bullet + H\bullet$

**B** $CH_4 \rightarrow CH_3^- + H^+$

**C** $Cl_2 \rightarrow 2Cl\bullet$

**D** $Cl_2 \rightarrow Cl^+ + Cl^-$

**58 9701/13/M/J/17/Q20**

Structural isomerism and stereoisomerism should be considered when answering this question.

Which formula identifies a **single** substance?

**A** $CH_3CHClCH_2CHO$

**B** $CH_3CHCHCH_3$

**C** $CH_2ClCH_2CHCl_2$

**D** $C_4H_{10}$

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**59 9701/13/M/J/17/Q21**

Structural isomerism and stereoisomerism should be considered when answering this question.

If a molecule contains two non-identical chiral carbon atoms, four optical isomers exist.

How many isomers are there with

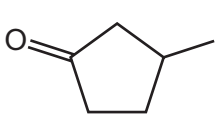
- molecular formula $C_7H_{14}O$ **and**
- a five-membered ring **and**
- a tertiary alcohol group?

**A** 4 **B** 5 **C** 9 **D** 13

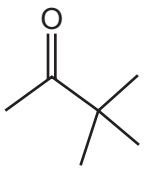
**60 9701/11/M/J/19/Q21**

Which compound has the molecular formula $C_6H_{10}O$?

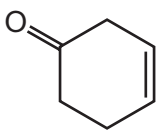
**A**



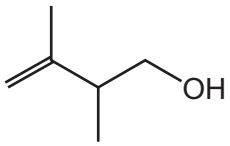

**B**




**C**




**D**




**61 9701/11/M/J/19/Q30**

Which compound is chiral?

**A** 1-chloro-3-methylbutane

**B** 2-chloro-2-methylbutane

**C** 2-chloro-3-methylbutane

**D** 3-chloropentane

**62 9701/12/O/N/19/Q20**

Structural isomerism and stereoisomerism should be considered when answering this question.

How many isomers with the formula $C_5H_{10}$ have structures that involve $\pi$ bonding?

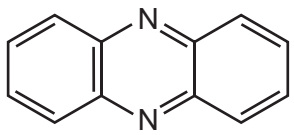
**A** 3 **B** 4 **C** 5 **D** 6



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**63** **9701/12/O/N/19/Q21**

The diagram shows the skeletal formula of phenazine.



phenazine

What is the empirical formula of phenazine?

**A** $C_6H_4N$ **B** $C_6H_6N$ **C** $C_{12}H_8N_2$ **D** $C_{12}H_{12}N_2$

**64** **9701/12/F/M/20/Q20**

Which pair of compounds are functional group isomers of each other?

**A** butan-1-ol and butanal

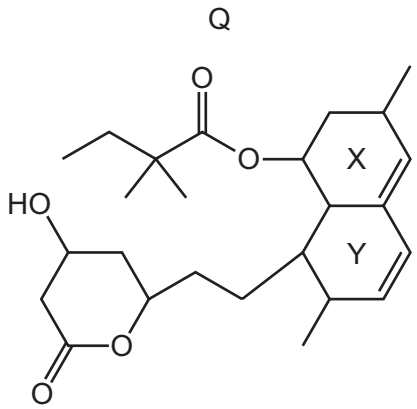
**B** ethylpropanoate and pentanoic acid

**C** hex-1-ene and hex-2-ene

**D** propylamine and propanenitrile

**65** **9701/12/F/M/20/Q30**

The diagram shows the structure of compound Q.




Two of the rings, X and Y, contain a C=C bond.

Which row is correct?

| | number of ester groups in one molecule of Q | description of rings X and Y |
|---|---|---|
| **A** | 1 | both are planar |
| **B** | 1 | neither is planar |
| **C** | 2 | both are planar |
| **D** | 2 | neither is planar |



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**66 9701/12/F/M/20/Q25**

Structural isomerism and stereoisomerism should be considered when answering this question.

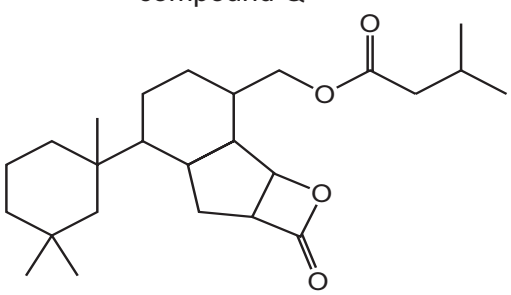
How many non-cyclic isomers have the molecular formula $C_5H_{10}$?

**A** 3 **B** 4 **C** 5 **D** 6

**67 9701/11/M/J/20/Q28**

The structure of compound Q is shown.

compound Q



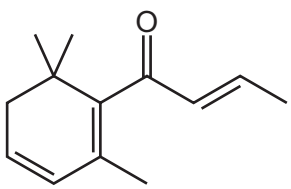
How many chiral centres are present in a molecule of Q?

**A** 4 **B** 5 **C** 6 **D** 7

**68 9701/12/M/J/20/Q26**

The structure of damascenone is shown.

damascenone



Including damascenone, how many stereoisomers exist with this structural formula?

**A** 1 **B** 2 **C** 4 **D** 8

**69 9701/12/M/J/20/Q27**

How many isomeric esters have the molecular formula $C_4H_8O_2$?

**A** 2 **B** 3 **C** 4 **D** 5

**70 9701/13/M/J/20/Q20**

Structural and stereoisomerism should be considered when answering this question.

When *trans*-pent-2-ene reacts with HBr, how many different products can form?

**A** 1 **B** 2 **C** 3 **D** 4



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# Organic Chemistry And Analysis

14
TOPIC

# Hydrocarbons



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**1 9701/1/M/J/02/Q21**

What is the total number of different chloroethanes (formula $C_2H_{6-n}Cl_n$, where $n$ can be any integer from 1 to 6)?

**A** 6 **B** 8 **C** 9 **D** 10

**2 9701/1/M/J/02/Q22**

Polymerisation of chloroethene gives pvc.

How does the carbon-carbon bond in pvc compare with that in chloroethene?

| | | | | | |
|---|---|---|---|---|---|
| **A** | longer | stronger | **C** | shorter | stronger |
| **B** | longer | weaker | **D** | shorter | weaker |

**3 9701/1/M/J/02/Q24**

Which substance in a vehicle exhaust results from incomplete combustion of a hydrocarbon fuel?

**A** CO **B** $H_2O$ **C** $N_2$ **D** NO

**4 9701/1/O/N/02/Q26**

Oxidation of an alkene **Y** gives a diol; further oxidation gives a diketone.

What could be **Y**?

**A** $CH_3CH{=}C(CH_3)_2$

**B** $(CH_3)_2CHCH{=}CH_2$

**C** $C_6H_5CH{=}CHC_6H_5$

**D** $(C_6H_5)_2C{=}CHCH_3$

**5 9701/1/M/J/03/Q22**

The compound hex-3-en-1-ol, **P**, has a strong 'leafy' smell of newly cut grass and is used in perfumery.

$CH_3CH_2CH{=}CHCH_2CH_2OH$

**P**

What is produced when **P** is treated with an excess of hot concentrated acidic $KMnO_4$?

**A** $CH_3CH_2CH(OH)CH(OH)CH_2CH_2OH$

**B** $CH_3CH_2CH{=}CHCH_2CO_2H$

**C** $CH_3CH_2CHO$ and $OCHCH_2CH_2OH$

**D** $CH_3CH_2CO_2H$ and $HO_2CCH_2CO_2H$

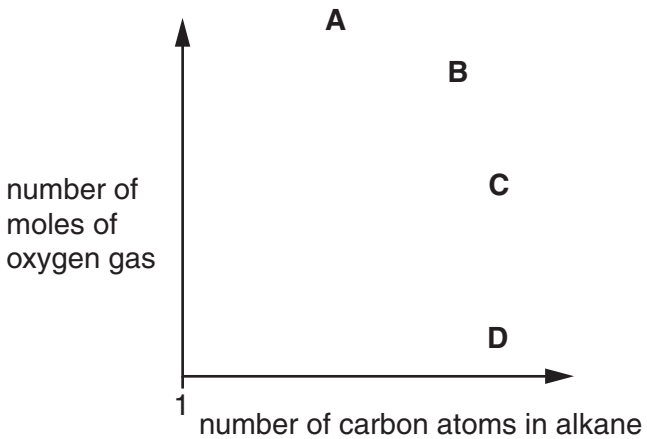


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**6 9701/1/M/J/03/Q23**

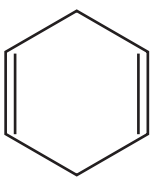
The complete combustion of alkanes to produce carbon dioxide and water is an important exothermic reaction.

Which line on the graph shows the relationship between the number of carbon atoms in the alkane and the number of moles of oxygen gas needed for complete combustion of the alkane?



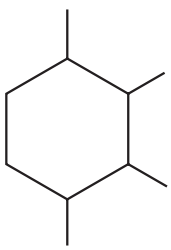

**7 9701/1/M/J/03/Q24**

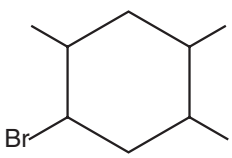
Cyclohexa-1,4–diene is treated with a solution of bromine in tetrachloromethane.

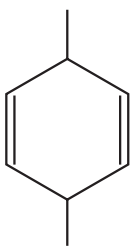


cyclohexa-1,4-diene

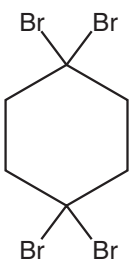
Which product is formed?





D






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**8 9701/1/M/J/03/Q25**

Which reaction is **not** an electrophilic addition?

**A** $CH_2{=}CH_2 + HI \longrightarrow CH_3CH_2I$

**B** $CH_3CH{=}CH_2 + Br_2 \longrightarrow CH_3CHBrCH_2Br$

**C** $CH_3CH{=}CH_2 + H_2O \xrightarrow{\text{conc } H_2SO_4} CH_3CH(OH)CH_3$

**D** $CH_3CHO + HCN \longrightarrow CH_3CH(OH)CN$

**9 9701/1/M/J/04/Q23**

Which compound could **not** be obtained from cracking a sample of nonane, $CH_3(CH_2)_7CH_3$?

**A** $CH_3CH{=}CHCH{=}CHCH_2CH_2CH_2CH_3$

**B** $CH_3CH_2CH_2CH_2CH_3$

**C** $CH_3CH_2CH_2CH_2CH_2CH{=}CH_2$

**D** $(CH_3CH_2CH_2)_3CH$

**10 9701/01/M/J/04/Q24**

In which way are ethene and propane similar?

| $CH_2{=}CH_2$ | $CH_3CH_2CH_3$ |
|---|---|
| ethene | propane |

**A** They are both obtained by the dehydration of alcohols.

**B** They are both neutral to an indicator solution.

**C** They can both be hydrogenated using a suitable catalyst.

**D** They can both undergo polymerisation under suitable conditions.

**11 9701/01/M/J/04/Q25**

Which reaction occurs with saturated hydrocarbons?

**A** catalytic hydrogenation

**B** ready decolourisation of aqueous bromine

**C** polymerisation

**D** thermal cracking

**12 9701/01/O/N/04/Q26**

The reaction of chlorine with methane is carried out in the presence of light.

What is the function of the light?

**A** to break the C – H bonds in methane

**B** to break up the chlorine molecules into atoms

**C** to break up the chlorine molecules into ions

**D** to heat up the mixture

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**13** **9701/01/M/J/05/Q22**

When bromine reacts with propene in an organic solvent at room temperature, what is the mechanism by which the bromine attacks the propene?

**A** electrophilic addition

**B** electrophilic substitution

**C** nucleophilic addition

**D** nucleophilic substitution

**14** **9701/01/M/J/05/Q30**

In many countries plastic waste is collected separately and sorted. Some of this is incinerated to provide heat for power stations.

Why is pvc, polyvinylchloride, removed from any waste that is to be incinerated?

**A** It can be melted down and re-used.

**B** Its combustion products are harmful.

**C** It destroys the ozone layer.

**D** It does not burn easily.

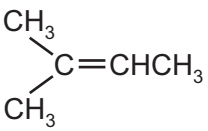
**15** **9701/01/M/J/05/Q21**

Which hydrocarbon, on treatment with hot acidified potassium manganate(VII), would give ethanoic acid **only**?

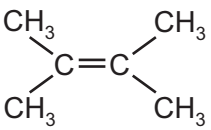
**A** $CH_3CH=CH_2$

**B** $CH_3CH=CHCH_3$

**C**



**D**





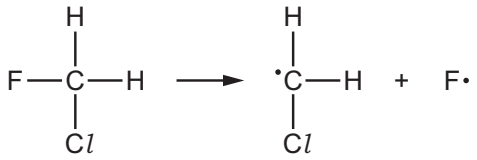
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**16 9701/12/M/J/16/Q20**

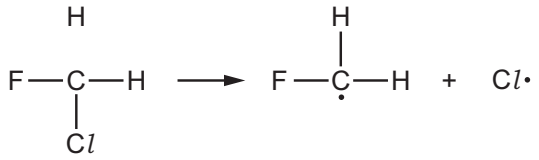
Chlorofluorocarbons damage the ozone layer by undergoing reactions with a free radical mechanism. The first stage of this is initiation.

Which equation is most likely to be the initiation stage when chlorofluoromethane is involved in such a reaction?

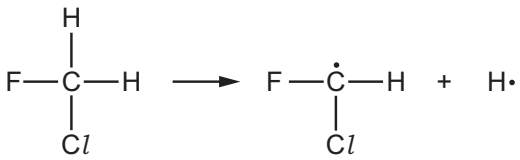
**A**



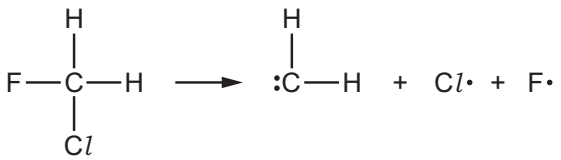
**B**



**C**



**D**



**17 9701/01/M/J/06/Q24**

Light initiates the following reaction.

alkane + chlorine → chloroalkane + hydrogen chloride

What happens to chlorine in this photochemical reaction?

**A** heterolytic fission to give an electrophile

**B** homolytic fission to give an electrophile

**C** heterolytic fission to give a free radical

**D** homolytic fission to give a free radical

**18 9701/01/O/N/06/Q24**

When gaseous chemicals are transported by road or by rail they are classified as follows.

flammable non-flammable poisonous

Which gas is non-flammable?

**A** butane **B** hydrogen **C** oxygen **D** propene

**19 9701/01/O/N/06/Q25**

Which equation or statement describes what happens when poly(propene) is burned in an excess of air?

**A** $(C_3H_6)_n + 1\frac{1}{2}\,nO_2 \rightarrow 3nC + 3nH_2O$

**B** $(C_3H_6)_n + 4\frac{1}{2}\,nO_2 \rightarrow 3nCO_2 + 3nH_2O$

**C** $(C_3H_6)_n + 6nO_2 \rightarrow 3nCO_2 + 3nH_2O$

**D** Poly(propene) does not burn.

STUDENTS RESOURCE

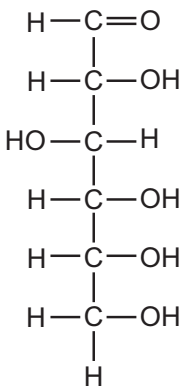


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**20** **9701/01/M/J/07/Q19**

Glucose, $C_6H_{12}O_6$, is a product of photosynthesis.

It has the following structure.



How many *chiral* centres does the molecule have?

**A** 1 **B** 2 **C** 4 **D** 6

**21** **9701/01/M/J/07/Q21**

Which reagent could be used to convert $CH_3CO_2CH_3$ into $C\mathit{l}CH_2CO_2CH_3$?

**A** concentrated hydrochloric acid at 100 °C

**B** phosphorus pentachloride at room temperature

**C** sulphur dichloride oxide (thionyl chloride, $SOC\mathit{l}_2$) at 50 °C

**D** chlorine in bright sunlight at 100 °C

**22** **9701/01/M/J/07/Q22**

In which reaction is a carbocation (carbonium ion) an intermediate?

**A** $CH_2{=}CH_2 + Br_2 \longrightarrow CH_2BrCH_2Br$

**B** $CH_3CH_2Br + NaOH \longrightarrow CH_3CH_2OH + NaBr$

**C** $CH_3CH_3 + C\mathit{l}_2 \longrightarrow CH_3CH_2C\mathit{l} + HC\mathit{l}$

**D** $CH_3CHO + HCN \xrightarrow{CN^-} CH_3CH(OH)CN$

**23** **9701/01/O/N/07/Q21**

Tetramethyl-lead(IV), $(CH_3)_4Pb$, increases the rate of the reaction of methane with chlorine.

$$CH_4(g) + C\mathit{l}_2(g) \rightarrow CH_3C\mathit{l}(g) + HC\mathit{l}(g)$$

Why can tetramethyl-lead(IV) behave in this way?

**A** It is a source of methyl radicals.

**B** It releases $CH_3^+(g)$.

**C** It reacts with chloromethane and prevents equilibrium being established.

**D** Metal ions catalyse the reaction.

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**24 9701/01/O/N/07/Q22**

Which reaction occurs when ethane and chlorine are mixed in diffused sunlight?

**A** a free-radical substitution with hydrogen given off

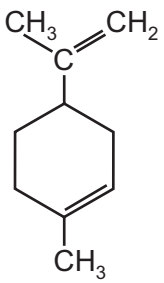
**B** a free-radical substitution with hydrogen chloride given off

**C** a free-radical substitution with no gas given off

**D** a nucleophilic substitution with hydrogen chloride given off

**25 9701/01/O/N/07/Q23**

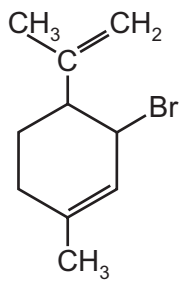
Limonene is an oil formed in the peel of citrus fruits.



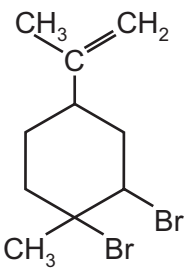
limonene

Which product is formed when molecular bromine reacts with limonene at room temperature in the dark?

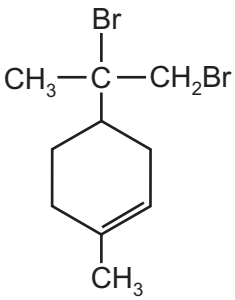
**A**



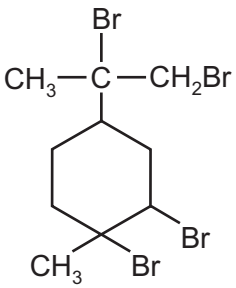
**B**



**C**

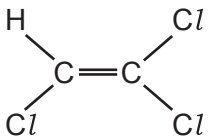


**D**



**26 9701/01/M/J/08/Q21**

Trichloroethene is widely used as a dry-cleaning agent.



With which of the following does trichloroethene react to give a chiral product?

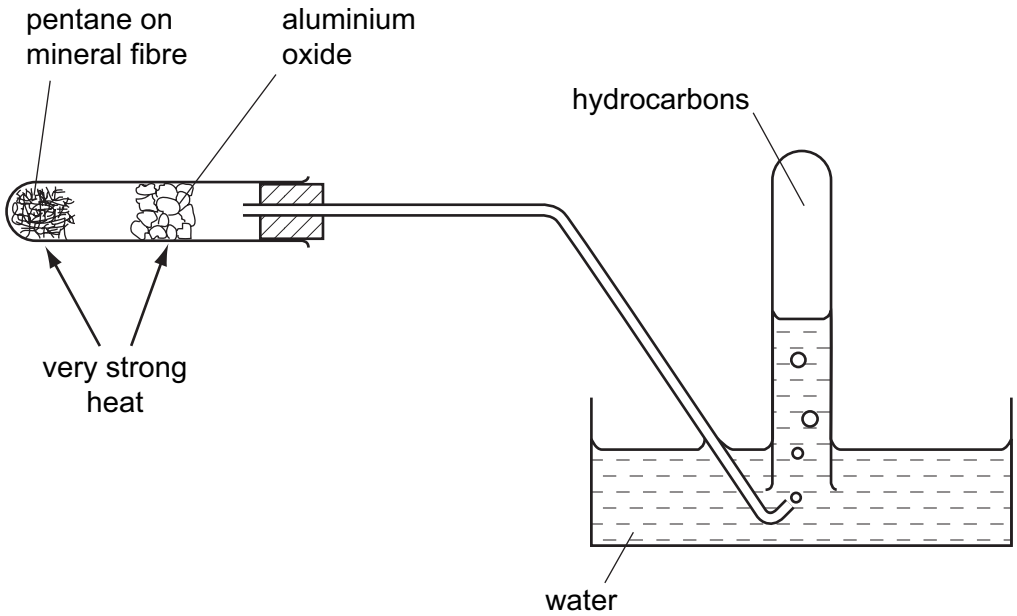
**A** $Br_2$ **B** $HCl$ **C** NaCN(aq) **D** NaOH(aq)



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**27 9701/01/M/J/08/Q23**

Which hydrocarbon would **not** be collected in the inverted tube by heating pentane, $CH_3(CH_2)_3CH_3$, in the apparatus shown?




**A** $CH_4$

**B** $CH_3CH_3$

**C** $CH_3CH_2CH{=}CH_2$

**D** $CH_3(CH_2)_8CH_3$

**28 9701/12/M/J/16/Q11**

Which stage in the free radical substitution of ethane by chlorine has the lowest activation energy?

**A** $Cl_2 \rightarrow 2Cl\bullet$

**B** $Cl\bullet + C_2H_6 \rightarrow C_2H_5\bullet + HCl$

**C** $C_2H_5\bullet + Cl_2 \rightarrow C_2H_5Cl + Cl\bullet$

**D** $Cl\bullet + C_2H_5\bullet \rightarrow C_2H_5Cl$

**29 9701/01/O/N/08Q22**

Which hydrocarbon can form a monochloro-substitution derivative which shows **both** chirality **and** *cis-trans* isomerism?

**A** $CH_3CH{=}CH_2$

**B** $(CH_3)_2C{=}CH_2$

**C** $CH_3CH{=}C(CH_3)_2$

**D** $CH_3CH{=}CHCH_2CH_3$

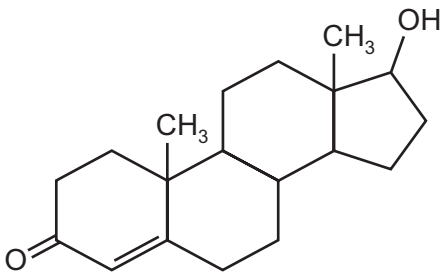
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**30** **9701/01/M/J/09/Q19**

In recent years a number of athletes have been banned from sports because of their illegal use of synthetic testosterone, a naturally occurring hormone in the body.




testosterone

How many chiral centres are present in a testosterone molecule?

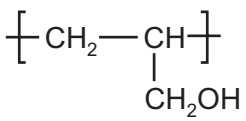
**A** 1 **B** 2 **C** 3 **D** 6

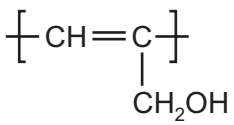
**31** **9701/12/M/J/16/Q21**

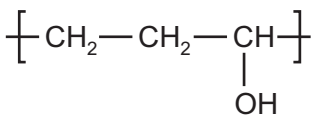
Synthetic resins can be made by polymerisation of a variety of monomers including prop-2-en-1-ol, $CH_2=CHCH_2OH$.

Which structure represents the repeat unit in poly(prop-2-en-1-ol)?

**A** 

**B** 

**C** 

**D** 



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**32** **9701/01/M/J/09/Q20**

The compound known as 'gamma-linolenic acid' is found in significant amounts in the seeds of the Evening Primrose plant. There is evidence that the compound may help patients with diabetes.

$CH_3(CH_2)_4CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_4CO_2H$

gamma-linolenic acid

How many *cis-trans* isomers does gamma-linolenic acid have?

**A** 3 **B** 6 **C** 8 **D** 12

**33** **9701/01/M/J/09/Q21**

What always applies to a nucleophile?

**A** It attacks a double bond.
**B** It has a lone pair of electrons.
**C** It is a single atom.
**D** It is negatively charged.

**34** **9701/01/M/J/02/Q22**

Polymerisation of chloroethene gives PVC.

How does the carbon-carbon bond in PVC compare with that in chloroethene?

**A** longer and stronger
**B** longer and weaker
**C** shorter and stronger
**D** shorter and weaker

**35** **9701/01/M/J/09/Q29**

2-Methylbuta-1,3-diene, $CH_2=C(CH_3)–CH=CH_2$, is used as a monomer in the manufacture of synthetic rubbers.

Which compound would **not** produce this monomer on treatment with concentrated sulfuric acid at 170 °C?

**A** $(CH_3)_2C(OH)CH(OH)CH_3$
**B** $HOCH_2CH(CH_3)CH_2CH_2OH$
**C** $HOCH_2CH(CH_3)CH(OH)CH_3$
**D** $HOCH_2C(CH_3)(OH)CH_2CH_3$

**36** **9701/01/M/J/09/Q30**

A compound **Y** has the following properties.

- It is a liquid at room temperature and atmospheric pressure.
- It does not mix completely with water.
- It does not decolourise acidified potassium manganate(VII).

What could **Y** be?

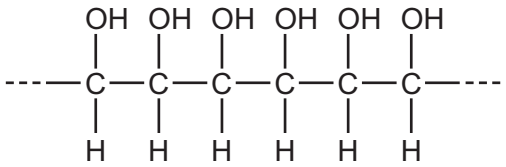
**A** ethane
**B** ethanoic acid
**C** ethanol
**D** ethyl ethanoate



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**37 9701/11/O/N/09/Q23**

The following diagram represents the structure of a possible polymer.



By which method might this polymer be made?

**A** polymerise ethene followed by hydration

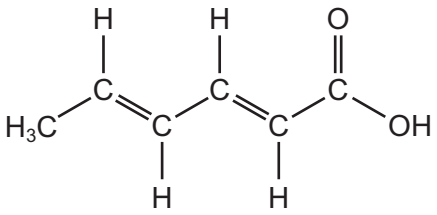
**B** polymerise ethene followed by oxidation with cold acidified $KMnO_4$

**C** polymerise 1,2-dichloroethene followed by hydrolysis

**D** polymerise 1,2-dichloroethene followed by oxidation with cold acidified $KMnO_4$

**38 9701/12/O/N/09/Q23**

Sorbic acid is used as a food preservative because it kills fungi and moulds.



sorbic acid

Sorbic acid will react with

- hydrogen in the presence of a nickel catalyst,
- bromine in an organic solvent.

How many moles of hydrogen and of bromine will be incorporated into one mole of sorbic acid by these reactions?

| | moles of hydrogen | moles of bromine |
|---|---|---|
| **A** | 2 | 2 |
| **B** | 2 | $2\frac{1}{2}$ |
| **C** | 3 | 2 |
| **D** | 3 | $2\frac{1}{2}$ |

**39 9701/12/O/N/09/Q24**

Bromine reacts with ethene to form 1,2-dibromoethane.

What is the correct description of the organic intermediate in this reaction?

**A** It has a negative charge.

**B** It is a free radical.

**C** It is a nucleophile.

**D** It is an electrophile.



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**40 9701/12/O/N/09/Q25**

Which equation represents a valid propagation step in the free radical reaction between ethane and chlorine?

**A** $C_2H_6 + Cl^{\bullet} \rightarrow C_2H_5Cl + H^{\bullet}$

**B** $C_2H_5Cl + Cl^{\bullet} \rightarrow C_2H_4Cl^{\bullet} + HCl$

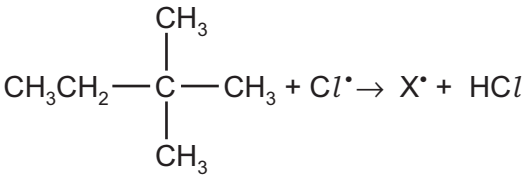
**C** $C_2H_6 + H^{\bullet} \rightarrow C_2H_5^{\bullet} + HCl$

**D** $C_2H_5^{\bullet} + Cl^{\bullet} \rightarrow C_2H_5Cl$

**41 9701/12/M/J/10/Q25**

When heated with chlorine, the hydrocarbon 2,2-dimethylbutane undergoes free radical substitution.

In a propagation step the free radical $X^{\bullet}$ is formed.



How many different forms of $X^{\bullet}$ are possible?

**A** 1 **B** 2 **C** 3 **D** 4

**42 9701/12/M/J/10/Q29**

In many countries plastic waste is collected separately and sorted. Some of this is incinerated to provide heat for power stations.

Why is pvc, polyvinylchloride, removed from any waste that is to be incinerated?

**A** It destroys the ozone layer.

**B** It does not burn easily.

**C** It is easily biodegradable.

**D** Its combustion products are harmful.

**43 9701/12/M/J/10/Q30**

Polymerisation of 1,1-dichloroethene produces a dense, high melting point substance that does not allow gases to pass through. It is used as cling wrapping.

Which sequence appears in a short length of the polymer chain?

**A** $\dagger CH_2CCl_2CH_2CCl_2CH_2CCl_2\dagger$

**B** $\dagger CHClCHClCHClCHClCHClCHCl\dagger$

**C** $\dagger CCl_2CCl_2CCl_2CCl_2CCl_2CCl_2\dagger$

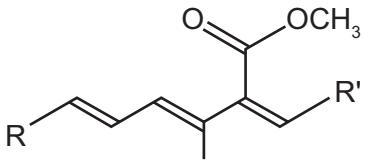
**D** $\dagger CH_2CCl_2CHClCHClCH_2CCl_2\dagger$



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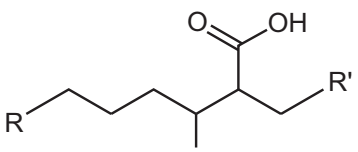
**44** **9701/12/O/N/10/Q27**

Part of the structure of strobilurin, a fungicide, is shown. R and R' are inert groups.

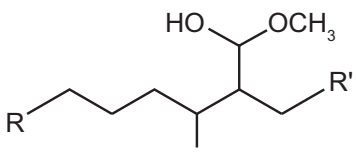



If strobilurin is first warmed with aqueous sulfuric acid, and its product then treated with hydrogen in the presence of a palladium catalyst, what could be the structure of the final product?

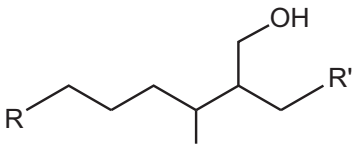
**A**



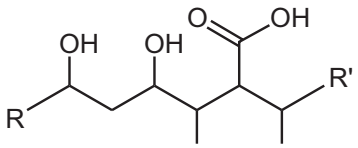

**B**




**C**



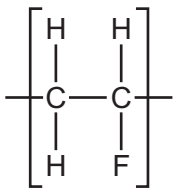

**D**




**45** **9701/12/O/N/10/Q28**

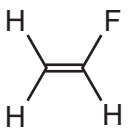
Fluoroalkenes are used to make polymers such as poly(vinyl)fluoride (PVF).

PVF is used to make non-flammable interiors for aircraft. The diagram shows the repeat unit of the polymer PVF.




What is the skeletal formula of the monomer of PVF?

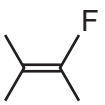
**A**



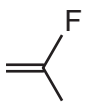

**B**




**C**




**D**




**46** **9701/12/M/J/11/Q23**

The products obtained by cracking an alkane, **X**, are methane, ethene and propene.

The mole fraction of ethene in the products is 0.5. What is the identity of **X**?

**A** $C_6H_{14}$ **B** $C_8H_{18}$ **C** $C_9H_{20}$ **D** $C_{11}H_{24}$

**47** **9701/12/M/J/11/Q26**

How many isomers with the formula $C_5H_{10}$ have structures that involve $\pi$ bonding?

**A** 3 **B** 4 **C** 5 **D** 6

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**48 9701/12/O/N/11/Q13**

Methyl mercaptan, $CH_3SH$, has a foul smell and is often used to impart a smell to natural gas.
What will be formed when $CH_3SH$ is burned in an excess of air?

**A** CO $H_2O$ $SO_2$ **C** $CO_2$ $H_2O$ $SO_2$

**B** $CO_2$ $H_2O$ $H_2S$ **D** $CO_2$ $H_2O$ $SO_3$

**49 9701/12/O/N/11/Q28**

Which reagent could best be used to distinguish between cyclohexene and cyclohexanol?

**A** $Ag(NH_3)_2^+$ in $H_2O$ **B** $Br_2$ in $CCl_4$

**C** 2,4-dinitrophenylhydrazine in $CH_3OH$ **D** $NaBH_4$ in $CH_3OH$

**50 9701/12/O/N/11/Q29**

Compound X, molecular formula $C_4H_8$, undergoes the following reactions.

$$\underset{\textbf{X}}{C_4H_8} \xrightarrow{Br_2} \underset{\textbf{Y}}{C_4H_8Br_2} \xrightarrow{\text{aq.NaOH / heat}} \underset{\textbf{Z}}{C_4H_{10}O_2}$$

$$\underset{\textbf{X}}{C_4H_8} \xrightarrow{H_2/Ni} \text{methylpropane}$$

What is the formula of compound Z?

**A** $CH_3CH_2CH(OH)CH_2OH$ **C** $CH_3CH(CH_2OH)CH_2OH$

**B** $CH_3CH(OH)CH(OH)CH_3$ **D** $(CH_3)_2C(OH)CH_2OH$

**51 9701/12/M/J/12/Q19**

Which substance does **not** produce a poisonous gas, when burnt in a limited amount of air?

**A** hydrogen **B** methane **C** propene **D** sulfur

**52 9701/12/M/J/12/Q24**

Oct-1-ene, $CH_3(CH_2)_5CH=CH_2$, is subjected to thermal cracking.

Which combination of compounds W, X, Y and Z can be obtained?

| $CH_2=CH_2$ | $CH_3CH=CH_2$ | $CH_3CH_2CH_3$ | $CH_2=CHCH=CH_2$ |
|---|---|---|---|
| W | X | Y | Z |

**A** W, X, Y and Z **B** W, X and Y only **C** W, X and Z only **D** W and X only

**53 9701/12/O/N/12/Q21**

An alkene has the formula $CH_3CH=CRCH_2CH_3$ and does **not** possess *cis-trans* isomers. What is *R*?

**A** H **B** Cl **C** $CH_3$ **D** $C_2H_5$

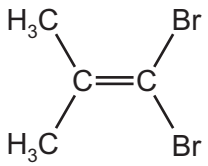
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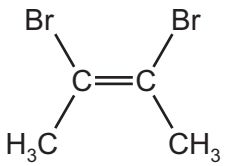
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**54** **9701/12/M/J/12/Q23**

Isomers **X** and **Y** both react with HBr.



**X**



**Y**

A mixture of **X** and **Y** is reacted with HBr.

Which three structures represent three **different** possible products of this reaction?

| | | | |
|---|---|---|---|
| **A** | $(CH_3)_2CHCBr_3$ | $(CH_3)_2CBrCHBr_2$ | $CH_3CHBrCHBrCH_3$ |
| **B** | $(CH_3)_2CHCBr_3$ | $(CH_3)_2CBrCHBr_2$ | $CH_3CBr_2CHBrCH_3$ |
| **C** | $(CH_3)_2CBrCBr_3$ | $(CH_3)_2CHCBr_3$ | $CH_3CBr_2CHBrCH_3$ |
| **D** | $(CH_3)_2CBrCHBr_2$ | $CHBr_2CBr(CH_3)CH_3$ | $CH_3CHBrCBr_2CH_3$ |

**55** **9701/12/O/N/12/Q23**

The cracking of a single hydrocarbon molecule, $C_nH_{2n+2}$, produces two hydrocarbon molecules only. Each hydrocarbon product contains the same number of carbon atoms in one molecule.
Each hydrocarbon product has non-cyclic structural isomers.

What is the value of n?

**A** 4 **B** 6 **C** 8 **D** 9

**56** **9701/12/O/N/12/Q25**

One of the reactions taking place in a catalytic converter in a car exhaust system is between nitrogen oxide and octane (unburned petrol). The products of this reaction are non-toxic.
Which is the correct equation for the reaction?

**A** $C_8H_{16} + 16NO \rightarrow 8CO + 8N_2 + 8H_2O$

**B** $C_8H_{16} + 24NO \rightarrow 8CO_2 + 12N_2 + 8H_2O$

**C** $C_8H_{18} + 17NO \rightarrow 8CO + 8\frac{1}{2}N_2 + 9H_2O$

**D** $C_8H_{18} + 25NO \rightarrow 8CO_2 + 12\frac{?}{1}N_2 + 9H_2O$

**57** **9701/12/O/N/13/Q22**

The compound ‘leaf alcohol’ is partly responsible for the smell of new-mown grass.

$CH_3CH_2CH{=}CHCH_2CH_2OH$

leaf alcohol

Which two compounds will be formed when ‘leaf alcohol’ is oxidised using hot, concentrated manganate(VII) ions?

**A** $CH_3CO_2H$ and $HOCH_2CH_2CH_2CO_2H$

**B** $CH_3CO_2H$ and $HO_2CCH_2CH_2CO_2H$

**C** $CH_3CH_2CO_2H$ and $HO_2CCH_2CO_2H$

**D** $CH_3CH_2CO_2H$ and $HOCH_2CH_2CO_2H$

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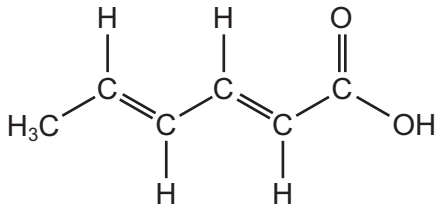
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**58 9701/12/M/J/13/Q21**

Sorbic acid is used as a food preservative because it kills fungi and moulds.

Sorbic acid will react with

- hydrogen in the presence of a nickel catalyst,
- bromine in an organic solvent.



sorbic acid

How many moles of hydrogen and of bromine will be incorporated into one mole of sorbic acid by these reactions?

| | moles of hydrogen | moles of bromine |
|---|---|---|
| **A** | 2 | 2 |
| **B** | 2 | $2\frac{1}{2}$ |
| **C** | 3 | 2 |
| **D** | 3 | $2\frac{1}{2}$ |

**59 9701/12/M/J/13/Q30**

Polymerisation of ethene gives poly(ethene).

How does the carbon-carbon bond in poly(ethene) compare with that in ethene?

**A** The carbon-carbon bond is longer and stronger in poly(ethene).

**B** The carbon-carbon bond is longer and weaker in poly(ethene).

**C** The carbon-carbon bond is shorter and stronger in poly(ethene).

**D** The carbon-carbon bond is shorter and weaker in poly(ethene).

**60 9701/12/M/J/14/Q24**

Ethene reacts with aqueous bromine to give two products, $CH_2BrCH_2Br$ and $CH_2BrCH_2OH$.

Which statement about these products is correct?

**A** Both products are obtained in this reaction by electrophilic substitution.

**B** Both products are obtained in this reaction by nucleophilic addition.

**C** Both products can be hydrolysed to form the same organic compound.

**D** Both products can form hydrogen bonds with water.

**61 9701/12/M/J/14/Q25**

Which statement does **not** correctly describe a problem related to the disposal of PVC?

**A** PVC is slowly degraded in the environment by bacteria and fungi.

**B** PVC is slowly degraded in the environment by sunlight.

**C** When PVC is burnt, a significant amount of ethene gas is present in the products.

**D** When PVC is burnt, a significant amount of HC*l* gas is present in the products.

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**62 9701/12/O/N/14/Q20**

Which row correctly describes the reaction between propene and bromine, $Br_2(l)$?

| | reaction mechanism | organic product |
|---|---|---|
| **A** | electrophilic addition | $CH_3CHBrCH_2Br$ |
| **B** | electrophilic addition | $CH_3CH_2CH_2Br$ |
| **C** | nucleophilic substitution | $CH_3CH_2CH_2Br$ |
| **D** | nucleophilic substitution | $CH_3CHBrCH_2Br$ |

**63 9701/12/O/N/14/Q21**

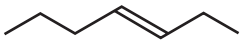
*Use of the Data Booklet is relevant to this question.*

Which compound has an $M_r$ of 84 and will react with HBr to give a product with an $M_r$ of 164.9?

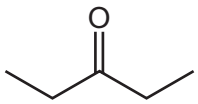
**A**



**B**



**C**




**D**



**64 9701/11/M/J/15/Q22**

Cottonseed oil contains large amounts of polyunsaturated carboxylic acids. When this oil is used to make margarine, the C=C double bonds in the unsaturated carboxylic acids are hydrogenated.

What reagents and conditions would be suitable to bring about this hydrogenation reaction?

**A** $H_2$ gas, nickel catalyst, 400 °C

**B** $LiAlH_4$ in dry ether

**C** $NaBH_4$, aqueous solution

**D** steam, concentrated $H_2SO_4$, 300 °C and 60 atm pressure

**65 9701/12/M/J/15/Q22**

Four students, W, X, Y and Z, made the following statements about alkanes and alkenes.

W 'Bromine reacts with alkanes by electrophilic substitution.'

X 'Bromine reacts with alkenes by a free-radical addition mechanism.'

Y 'Alkenes can be oxidised by acidified manganate(VII) ions.'

Z 'Alkenes are formed from alkanes by cracking.'

Which two students are correct?

**A** W and X **B** W and Z **C** X and Y **D** Y and Z

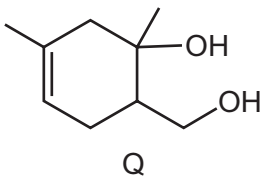
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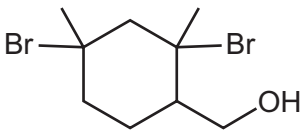
**66** **9701/12/M/J/15/Q21**

What is the major product formed when compound Q is warmed with excess HBr?

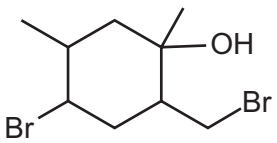



Q

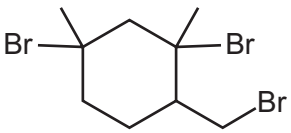
**A**



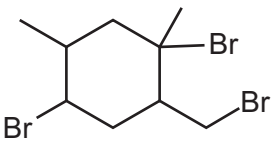

**B**




**C**




**D**




**67** **9701/12/M/J/15/Q24**

Which reaction would **not** give propene?

**A** adding excess hot concentrated sulfuric acid to propan-1-ol

**B** adding warm aqueous sodium hydroxide to 2-bromopropane

**C** adding warm ethanolic sodium hydroxide to 1-bromopropane

**D** passing propan-2-ol vapour over heated aluminium oxide

**68** **9701/11/M/J/15/Q23**

Which intermediate ion forms in the greatest amount during the addition of HBr to propene?

**A** $CH_3CH^+CH_3$

**B** $CH_3CH_2CH_2^+$

**C** $CH_3CH^-CH_2Br$

**D** $CH_3CHBrCH_2^-$

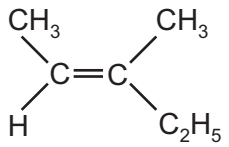


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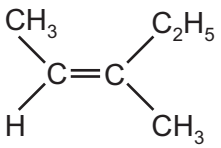
**69 9701/01/M/J/06/Q22**

The structures below show isomers of $C_6H_{12}$.

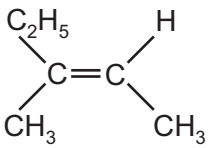
1



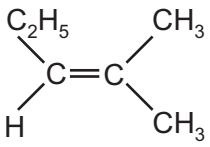
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3



4

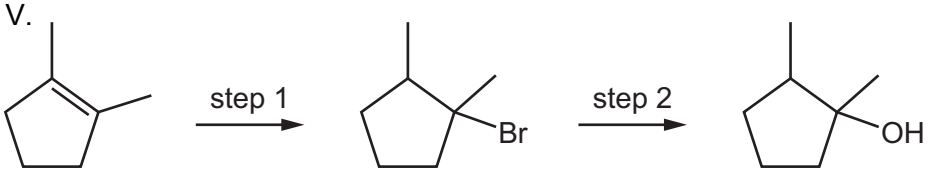


In which pair are the members *cis-trans* isomers of each other?

**A** 1 and 2 **B** 1 and 3 **C** 1 and 4 **D** 2 and 4

**70 9701/12/F/M/16/Q24**

Hydrogen bromide can be added to T to give compound U. Compound U can be hydrolysed to compound V.




T U V

Four students, W, X, Y and Z, made the following statements.

W All the atoms in a molecule of compound T lie in the same plane.

X Compound V contains only one chiral centre.

Y Step 1 is an electrophilic addition reaction.

Z Step 2 is a nucleophilic substitution reaction.

Which two students are correct?

**A** W and Y **B** W and Z **C** X and Y **D** Y and Z

**71 9701/12/F/M/16/Q29**

Which statement about poly(chloroethene) is correct?

**A** The polymer can be cracked to produce chlorinated alkenes.

**B** The polymer has harmless combustion products.

**C** The polymer is readily biodegradable when buried.

**D** The repeat unit of the polymer has an $M_r$ of 97.

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**72 9701/11/M/J/16/Q23**

The **first** propagation step in the reaction between methane and chlorine is shown.

$$CH_4 + Cl\bullet \rightarrow CH_3\bullet + HCl$$

How many different **first** propagation steps are possible in the reaction between pentane and chlorine?

**A** 2 **B** 3 **C** 4 **D** 5

**73 9701/12/M/J/16/Q22**

Oct-1-ene, $CH_3(CH_2)_5CH=CH_2$, can be thermally cracked.

Which combination of compounds W, X, Y and Z can be obtained by thermally cracking oct-1-ene?

| $CH_2=CH_2$ | $CH_3CH=CH_2$ | $CH_3CH_2CH_3$ | $CH_2=CHCH=CH_2$ |
|---|---|---|---|
| W | X | Y | Z |

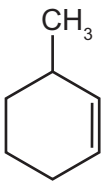
**A** W, X, Y and Z **B** W, X and Y only **C** W, X and Z only **D** W and X only

**74 9701/12/M/J/16/Q23**

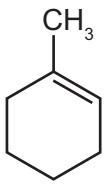
A cycloalkene with the molecular formula $C_7H_{12}$ was oxidised by hot concentrated acidified $MnO_4^-$. The only organic product was 2-methylhexane-1,6-dioic acid.

What is the identity of the cycloalkene?

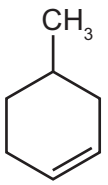
**A**



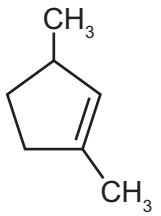

**B**




**C**




**D**




**75 9701/13/M/J/13/Q05**

Crotonaldehyde, $CH_3CH=CHCHO$, can be obtained by oxidising butadiene, $CH_2=CHCH=CH_2$, using air or oxygen. One method is to pass a mixture of butadiene and oxygen through a hot aqueous solution of palladium(II) ions, $Pd^{2+}(aq)$, which catalyse the reaction.

Which statement is **not** correct about the action of the $Pd^{2+}(aq)$ ions?

**A** Changing the concentration of the $Pd^{2+}(aq)$ will have an effect on the rate of the reaction.

**B** $Pd^{2+}(aq)$ increases the energy of the reacting molecules.

**C** $Pd^{2+}(aq)$ lowers the activation energy for the reaction.

**D** When $Pd^{2+}(aq)$ is used, the reaction proceeds by a different route.

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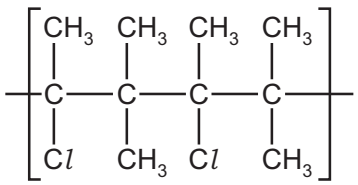
**76 9701/13/M/J/16/Q26**

Which volume of oxygen, at room temperature and pressure, is needed for complete combustion of 1.0 mol of methylpropan-1-ol?

**A** 108 $dm^3$ **B** 144 $dm^3$ **C** 156 $dm^3$ **D** 288 $dm^3$

**77 9701/12/F/M/16/Q22**

A section showing two repeat units of an addition polymer is shown.



What is the identity of the monomer that produced this polymer?

**A** 2-chloro-3-methylbutane
**B** 2-chloro-3-methylbut-2-ene
**C** 2-chloropent-2-ene
**D** 2,4-dichloro-3,3,4,5-tetramethylhexane

**78 9701/12/F/M/16/Q23**

But-2-ene-1,4-diol is converted in two steps through an intermediate **X** into oxobutanedioic acid.

$HOCH_2CH{=}CHCH_2OH \xrightarrow{\text{step 1}} \mathbf{X} \xrightarrow[\text{hot, acidified } KMnO_4]{\text{step 2}} HO_2CCOCH_2CO_2H$

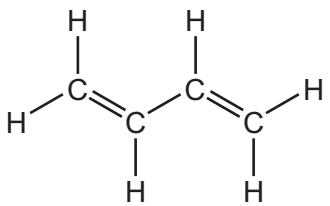
but-2-ene-1,4-diol — oxobutanedioic acid

What could be the reagent for step 1 and what is the intermediate **X**?

| | reagent for step 1 | **X** |
|---|---|---|
| **A** | cold, acidified $KMnO_4$ | $HOCH_2CH_2CH(OH)CH_2OH$ |
| **B** | hot, acidified $K_2Cr_2O_7$ | $HO_2CCH{=}CHCO_2H$ |
| **C** | steam and concentrated $H_2SO_4$ | $HOCH_2CH(OH)CH_2CH_2OH$ |
| **D** | warm, acidified $K_2Cr_2O_7$ | $OHCCH(OH)CH_2CHO$ |

**79 9701/13/M/J/16/Q21**

The diagram shows the structure of 1,3-butadiene.



1,3-butadiene

The addition reaction between 1,3-butadiene and two molecules of hydrogen bromide can produce three structurally isomeric products.

How many of these products have at least one chiral centre?

**A** 0 **B** 1 **C** 2 **D** 3

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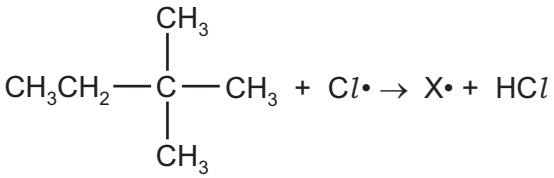


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**80 9701/13/M/J/16/Q23**

When heated with chlorine, the hydrocarbon 2,2-dimethylbutane undergoes free radical substitution.

In a propagation step a free radical X• is formed.

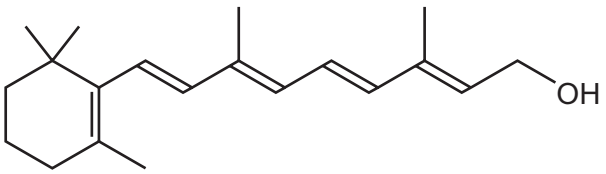


How many different structures of X• are possible?

**A** 2 **B** 3 **C** 4 **D** 5

**81 9701/13/M/J/16/Q24**

Vitamin A contains retinol.



retinol

Under appropriate conditions, acidified $KMnO_4(aq)$ can be used to break apart C=C bonds.

After these bonds have been broken, further oxidation of the fragments may occur.

Under which conditions is the acidified $KMnO_4(aq)$ used and what do the final oxidation products include?

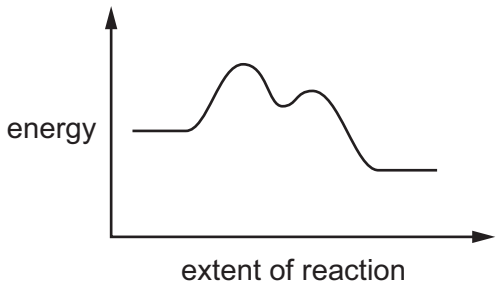
| | conditions | final oxidation products |
|---|---|---|
| **A** | cold, dilute | aldehydes and carboxylic acids |
| **B** | cold, dilute | ketones and carboxylic acids |
| **C** | hot, concentrated | aldehydes and carboxylic acids |
| **D** | hot, concentrated | ketones and carboxylic acids |



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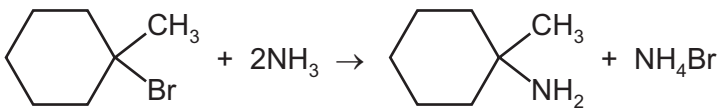
**82 9701/13/M/J/16/Q25**

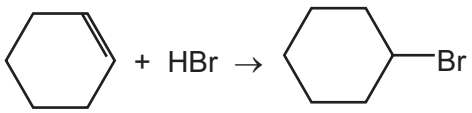
A reaction pathway diagram is shown.

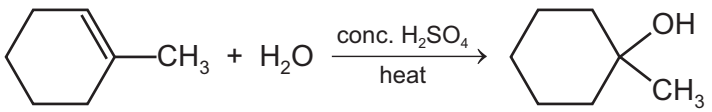



The four reactions that follow are all exothermic.
Which reaction would **not** have such a pathway?

**A** $CH_3I + NaCN \rightarrow CH_3CN + NaI$

**B** 


**C** 


**D** 


**83 9701/13/M/J/16/Q26**

Which volume of oxygen, at room temperature and pressure, is needed for complete combustion of 1.0 mol of methylpropan-1-ol?

**A** 108 $dm^3$ **B** 144 $dm^3$ **C** 156 $dm^3$ **D** 288 $dm^3$

**84 9701/12/F/M/17/Q23**

Propene undergoes a variety of reactions.
Which row is correct?

| | reagent added to propene | products include |
|---|---|---|
| **A** | $Br_2(aq)$ | 1-bromopropane |
| **B** | cold, dilute, acidified $KMnO_4(aq)$ | propanoic acid |
| **C** | HBr(g) | 2-bromopropane |
| **D** | hot, concentrated, acidified $KMnO_4(aq)$ | propanoic acid |

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**85 9701/12/F/M/17/Q24**

Polymerisation of ethene gives poly(ethene).

How does the bonding between carbon atoms in poly(ethene) compare with that in ethene?

**A** longer and stronger in poly(ethene)

**B** longer and weaker in poly(ethene)

**C** shorter and stronger in poly(ethene)

**D** shorter and weaker in poly(ethene)

**86 9701/12/F/M/17/Q25**

Diols in which both hydroxy groups are bonded to the same carbon can spontaneously eliminate a molecule of water to produce a carbonyl compound.

Which compound, after complete hydrolysis, gives a positive reaction with Tollens' reagent?

**A** 1,1-dibromobutane

**B** 1,2-dibromobutane

**C** 1,3-dibromobutane

**D** 2,2-dibromobutane

**87 9701/11/M/J/17/Q22**

An alkene is reacted with acidified manganate(VII) ions, $MnO_4^-$. The desired organic product has a relative molecular mass greater than that of the alkene by 34.

What conditions should be used?

**A** cold, concentrated $MnO_4^-$

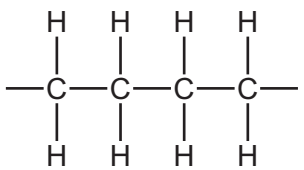
**B** cold, dilute $MnO_4^-$

**C** hot, concentrated $MnO_4^-$

**D** hot, dilute $MnO_4^-$

**88 9701/11/M/J/17/Q23**

The diagram shows a short length of an addition polymer chain.



The polymer has a relative molecular mass of approximately 10 000.

Approximately how many monomer units are joined together in each polymer molecule?

**A** 180 **B** 360 **C** 625 **D** 710



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**89** **9701/13/M/J/17/Q3**

Which equation correctly describes the complete combustion of an alkene, $C_nH_{2n}$?

**A** $C_nH_{2n} + \frac{3}{2}nO_2 \rightarrow nCO_2 + 2nH_2O$

**B** $C_nH_{2n} + \frac{3}{2}nO_2 \rightarrow nCO_2 + nH_2O$

**C** $C_nH_{2n} + 2nO_2 \rightarrow nCO_2 + nH_2O$

**D** $C_nH_{2n} + 2nO_2 \rightarrow nCO_2 + 2nH_2O$

**90** **9701/13/M/J/17/Q22**

The formulae of three compounds are shown.

$C_3H_7CHO$ $C_2H_5COCH_3$ $CH_2CHCH_2CH_2OH$

Only one of these compounds will decolourise bromine water. Only one of these compounds will produce a silver mirror with Tollens' reagent.

Which row shows the correct results?

| | decolourises bromine water | forms a silver mirror with Tollens' reagent |
|---|---|---|
| **A** | $C_3H_7CHO$ | $C_2H_5COCH_3$ |
| **B** | $C_2H_5COCH_3$ | $C_3H_7CHO$ |
| **C** | $CH_2CHCH_2CH_2OH$ | $C_2H_5COCH_3$ |
| **D** | $CH_2CHCH_2CH_2OH$ | $C_3H_7CHO$ |

**91** **9701/13/M/J/17/Q25**

Bromine reacts with ethene in the dark.

Which description of the organic intermediate in this reaction is correct?

**A** It has a negative charge.

**B** It is a free radical.

**C** It is a nucleophile.

**D** It is an electrophile.

**92** **9701/11/O/N/18/Q20**

What is true of **every** nucleophile?

**A** It attacks a double bond.

**B** It donates a lone pair of electrons.

**C** It is a single atom.

**D** It is negatively charged.



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**93** **9701/11/O/N/18/Q21**

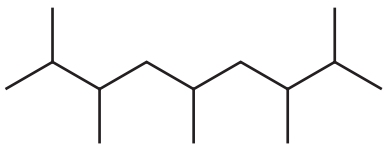
X has the molecular formula $C_5H_{12}O$. X has a branched carbon skeleton and a secondary alcohol functional group.

How many **structural** isomers fit this description of X?

**A** 1 **B** 2 **C** 3 **D** 4

**94** **9701/11/O/N/18/Q22**

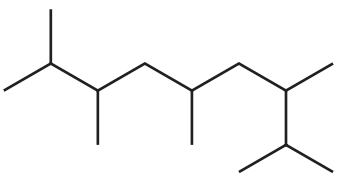
A new jet fuel has been produced that is a mixture of different structural isomers of compound Q.



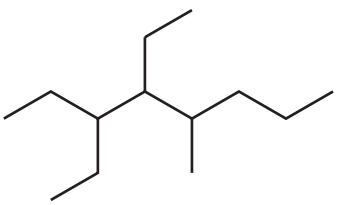
Q

Which skeletal formula represents a **structural isomer** of Q?

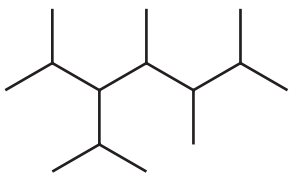
**A**



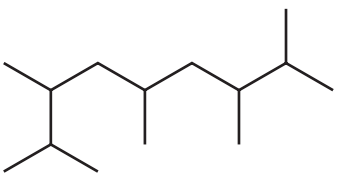
**B**



**C**



**D**



**95** **9701/11/O/N/18/Q24**

An organic molecule W contains 3 carbon atoms. It requires 4.5 molecules of oxygen for complete combustion.

What could W be?

**A** propane **C** propanone

**B** propanoic acid **D** propan-1-ol

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**96 9701/11/O/N/18/Q23**

The conversion of propene to propan-2-ol can be carried out in two stages represented by the equations shown.

reaction 1 $CH_3CH{=}CH_2(g) + HI(g) \rightarrow CH_3CHICH_3(l)$

reaction 2 $CH_3CHICH_3(l) + KOH(aq) \rightarrow CH_3CH(OH)CH_3(aq) + K^+(aq) + I^-(aq)$

How can these two reactions be described?

| | reaction 1 | reaction 2 |
|---|---|---|
| **A** | addition | elimination |
| **B** | addition | substitution |
| **C** | elimination | substitution |
| **D** | substitution | elimination |

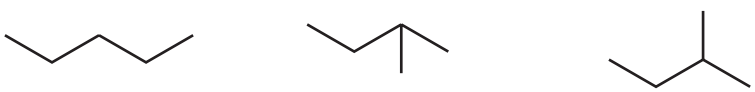
**97 9701/12/O/N/18/Q20**

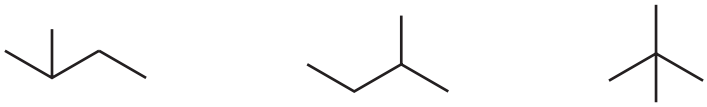
There are three structural isomers with the formula $C_5H_{12}$.

Which formulae correctly represent these three structural isomers?

**A** $CH_3CH_2CH_2CH_2CH_3$ $CH_3CH(CH_3)CH_2CH_3$ $C(CH_3)_4$

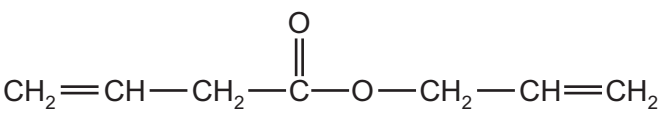
**B** $CH_3CH_2CH_2CH_2CH_3$ $CH_3CH(CH_3)CH_2CH_3$ $CH_3CH_2CH(CH_3)CH_3$

**C** 

**D** 

**98 9701/12/O/N/18/Q21**

The diagram shows a molecule that has σ bonds and π bonds.



How many σ bonds are present in this molecule?

**A** 15 **B** 17 **C** 18 **D** 21

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**99 9701/12/O/N/18/Q22**

Polyethene is made by the polymerisation of ethene.

Which statement is correct?

**A** The monomer and the polymer have different empirical formulae.

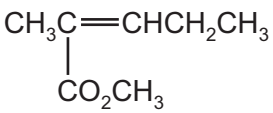
**B** The monomer can be oxidised without heat whereas the polymer cannot.

**C** The monomer can be used as a fuel whereas the polymer cannot.

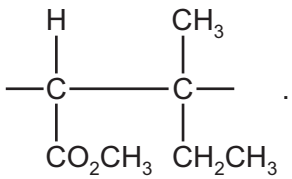
**D** The monomer has greater van der Waals' forces than the polymer.

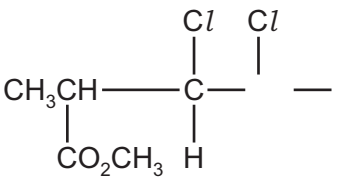
**100 9701/12/O/N/18/Q24**

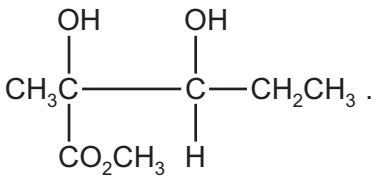
Which statement about compound Q is correct?

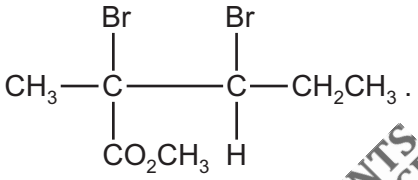


Q

**A** It could be polymerised to give a polymer with the repeat unit  .

**B** It reacts with chlorine by a free radical mechanism to give  .

**C** It reacts with cold, dilute acidified manganate(VII) to give  .

**D** It reacts with bromine via a free radical mechanism to give  .

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**101 9701/12/F/M/19/Q20**

How many structural isomers are there of trichloropropane, $C_3H_5Cl_3$?

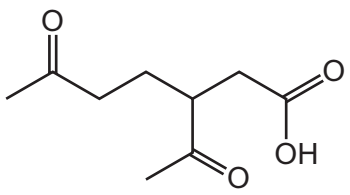
**A** 3 **B** 4 **C** 5 **D** 6

**102 9701/12/F/M/19/Q21**

Compound L has the molecular formula $C_{10}H_{16}$.

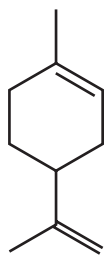
A sample of L reacted with an excess of hot, concentrated, acidified potassium manganate(VII). Compound M is produced.

M

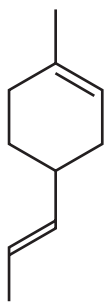



What could be the structure of compound L?

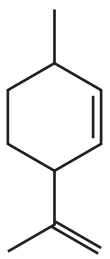
**A**



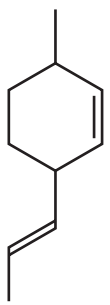
**B**



**C**



**D**



**103 9701/12/F/M/19/Q22**

Many reactions take place in the engine and catalytic converter of a car.

Which pair of substances is produced **both** by the reactions in a car engine and in a catalytic converter?

**A** carbon dioxide and unburnt hydrocarbons

**B** carbon dioxide and water

**C** carbon monoxide and nitrogen

**D** carbon monoxide and unburnt hydrocarbons

**104 9701/12/F/M/19/Q23**

Structural isomerism and stereoisomerism should be considered when answering this question.

2-bromopentane is heated with an excess of ethanolic sodium hydroxide.

How many different hydrocarbons are produced?

**A** 1 **B** 2 **C** 3 **D** 4

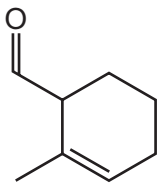
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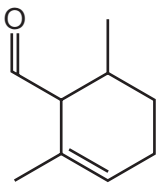
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**105 9701/11/M/J/19/Q20**

The diagrams show two different compounds.



1



2

What is

- the total number of structural isomers, including compound 2, that could be formed by adding a second methyl group to the ring of compound 1,
- the number of π electrons in each compound?

| | number of isomers | number of π electrons |
|---|---|---|
| **A** | 3 | 2 |
| **B** | 3 | 4 |
| **C** | 5 | 2 |
| **D** | 5 | 4 |

**106 9701/11/M/J/19/Q22**

What is the structural formula of the major product when hydrogen bromide reacts with 2-methylbut-2-ene?

**A** $CH_2BrCH(CH_3)CH_2CH_3$

**B** $(CH_3)_2CBrCH_2CH_3$

**C** $(CH_3)_2CHCHBrCH_3$

**D** $(CH_3)_2CHCH_2CH_2Br$

**107 9701/11/M/J/19/Q29**

Which reagent may be used to distinguish between propanone and ethanol?

**A** 2,4-dinitrophenylhydrazine

**B** bromine water

**C** Fehling's reagent

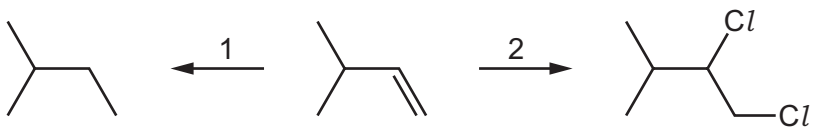
**D** Tollens' reagent



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**108 9701/12/M/J/19/Q20**

3-methylbut-1-ene can undergo different types of reaction.




Which row correctly identifies the reaction types?

| | reaction 1 | reaction 2 |
|---|---|---|
| **A** | oxidation | electrophilic addition |
| **B** | oxidation | nucleophilic addition |
| **C** | reduction | electrophilic addition |
| **D** | reduction | nucleophilic addition |

**109 9701/12/M/J/19/Q21**

Compound X does **not** show cis-trans isomerism.

What could be the identity of compound X?

**A** 1,1,2-trichloropropene

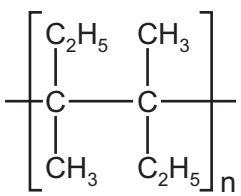
**B** 1,2,3-trichloropropene

**C** 1-chlorobut-1-ene

**D** 1-chlorobut-2-ene

**110 9701/12/M/J/19/Q22**

The diagram shows the repeat unit of an addition polymer.




What is the correct name for the monomer that would form this polymer?

**A** cis-1,2-diethyl-1,2-dimethylethene

**B** cis-2-ethyl-3-methylpent-2-ene

**C** trans-2-ethyl-3-methylpent-2-ene

**D** trans-3,4-dimethylhex-3-ene

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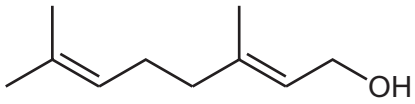


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**111 9701/12/M/J/19/Q23**

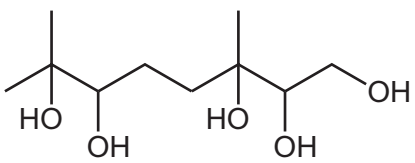
A molecule of geraniol is shown.

geraniol

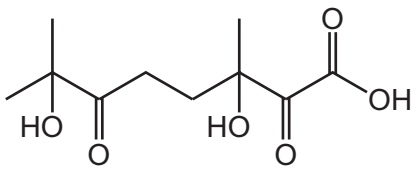



What is formed when geraniol is reacted with an excess of cold, dilute, acidified manganate(VII) ions?

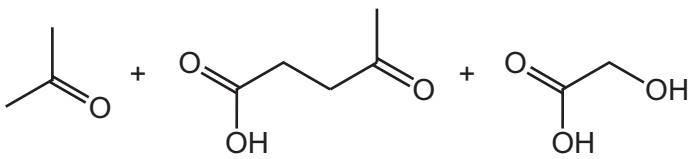
**A**



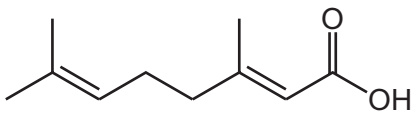

**B**




**C**




**D**




**112 9701/12/M/J/19/Q26**

Propene, bromine and hydrogen bromide are mixed in the dark.

A number of products are formed, some in very small quantities.

Which substance will **not** be present in the mixture of products?

**A** 1-bromopropane

**B** 2-bromopropane

**C** 1,1-dibromopropane

**D** 1,2-dibromopropane



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**113 9701/11/O/N/19/Q19**

Catalytic converters are fitted in the exhaust systems of many cars.

Which gas:

- causes acid rain if it is released into the air
- is removed from car exhaust fumes by a catalytic converter?

**A** carbon dioxide **B** carbon monoxide **C** hydrocarbon vapour **D** nitrogen dioxide

**114 9701/11/O/N/19/Q20**

Which substance reacts with trichloroethene to give a chiral product?

**A** $Br_2$ **B** $HCl$ **C** NaCN **D** NaOH

**115 9701/11/O/N/19/Q21**

Alkanes are saturated hydrocarbons.

Which type of reaction are alkanes most likely to undergo?

**A** electrophilic addition

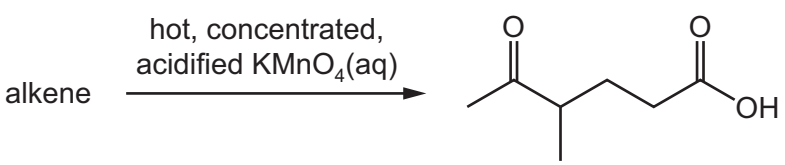
**B** electrophilic substitution

**C** free radical substitution

**D** nucleophilic addition

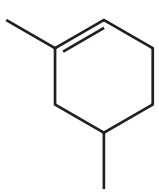
**116 9701/11/O/N/19/Q22**

An alkene reacts with hot, concentrated, acidified potassium manganate(VII) to produce a single organic product as shown.

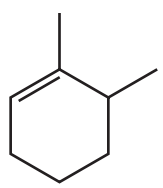



What is the structure of the alkene?

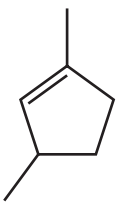
**A**



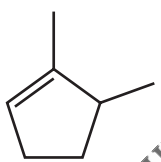
**B**



**C**



**D**



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**117 9701/12/O/N/19/Q18**

Which emission from an internal combustion engine contributes to the erosion of marble statues?

**A** carbon monoxide

**B** nitrogen

**C** nitrogen dioxide

**D** unburnt hydrocarbons

**118 9701/12/O/N/19/Q22**

An organic compound X reacts with hot, concentrated acidified potassium manganate(VII) solution to give a single carbon-containing product.

What could be X?

**A** $CH_2C(CH_3)_2$

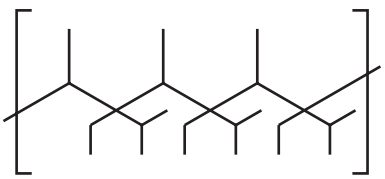
**B** $CH_3CHCHCH_3$

**C** $CH_2CHCH_2CH_3$

**D** $CH_3CH_2CH_2CH_3$

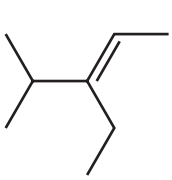
**119 9701/12/F/M/20/Q24**

A section of a polymer chain is shown.

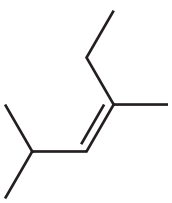


What is the correct monomer?

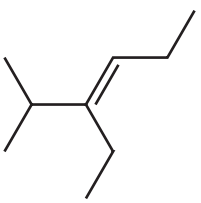
**A**



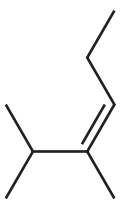
**B**



**C**



**D**

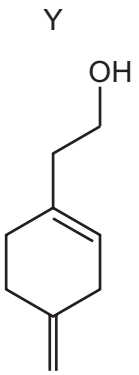




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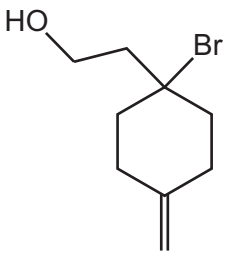
**120 9701/12/F/M/20/Q26**

An excess of dry HBr is warmed with compound Y.

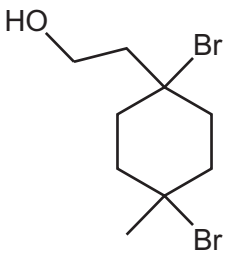



What is the major product of the reaction?

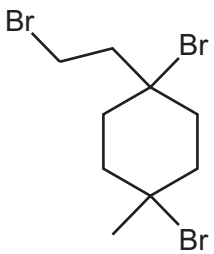
**A**



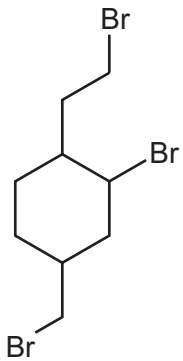

**B**




**C**




**D**




**121 9701/12/F/M/20/Q27**

Which reaction would produce propanoic acid as one of its products?

**A** heating $(CH_3)_2C{=}CHCH_2CH_3$ with concentrated, acidified $KMnO_4$

**B** heating $CH_3CH_2CO_2CH_2CH_2CH_3$ with NaOH(aq)

**C** heating $CH_3CH_2OH$ with acidified $K_2Cr_2O_7$ under reflux

**D** reacting $CH_3CHO$ with HCN then heating the organic product with $H_2SO_4$(aq)



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**122 9701/11/M/J/20/Q22**

But-1-ene and but-2-ene are treated separately with cold, dilute acidified manganate(VII) ions.

Four students, W, X, Y and Z, make statements about these alkenes and the diols formed from them.

W One diol contains two primary alcohol groups.

X One diol contains a primary and a secondary alcohol group.

Y One diol contains two secondary alcohol groups.

Z Both alkenes exhibit *cis-trans* isomerism.

Which two students are correct?

**A** W and Y **B** W and Z **C** X and Y **D** X and Z

**123 9701/11/M/J/20/Q24**

Poly(propene) is an addition polymer.

What are the C–C–C bond angles along its polymer chain?

**A** They are all 109°.

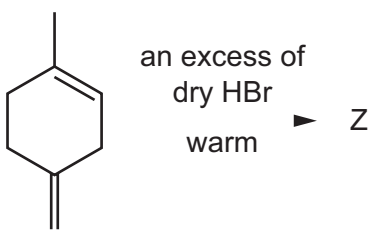
**B** Half of them are 109° and half are 120°.

**C** Half of them are 90° and half are 180°.

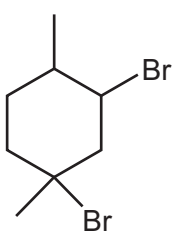
**D** They are all 120°.

**124 9701/11/M/J/20/Q27**

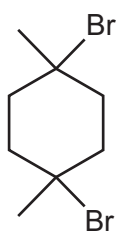
What is the major product Z of the following reaction?



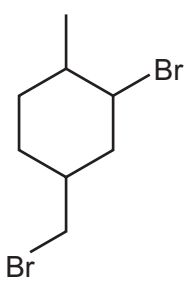

**A**



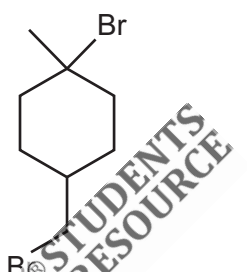

**B**




**C**




**D**




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**125 9701/12/M/J/20/Q6**

In this question you should assume air contains 21% oxygen.

What is the minimum volume of air required to ensure complete combustion of 10 $cm^3$ of butane gas, under room conditions?

**A** 14 $cm^3$ **B** 27 $cm^3$ **C** 65 $cm^3$ **D** 310 $cm^3$

**126 9701/12/M/J/20/Q7**

When aqueous bromine is shaken with cyclohexane and allowed to stand, two layers form. The top cyclohexane layer is coloured and the bottom aqueous layer is almost colourless.

What is the most likely explanation for this observation?

**A** Bromine is reduced to bromide ions in the bottom layer.

**B** Bromine molecules are non-polar.

**C** Bromine reacts with water but cannot react with cyclohexane.

**D** The product of the reaction between bromine and cyclohexane is coloured.

**127 9701/12/M/J/20/Q25**

Which substance forms propanoic acid as one of the products when it reacts with hot concentrated acidified potassium manganate(VII)?

**A** but-1-ene **C** 2-methylpropene

**B** but-2-ene **D** 2-methylbut-1-ene

**128 9701/12/M/J/20/Q28**

Ethene reacts with aqueous bromine to give two products, $CH_2BrCH_2Br$ and $CH_2BrCH_2OH$.

Which statement about these products is correct?

**A** Both products are obtained in this reaction by nucleophilic substitution.

**B** Both products are obtained in this reaction by nucleophilic addition.

**C** Both products can be hydrolysed to form the same organic compound.

**D** Both products can form hydrogen bonds with water.



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**129 9701/12/M/J/20/Q29**

PVC is used as a packaging material.

What holds the different polymer strands together in a piece of solid PVC?

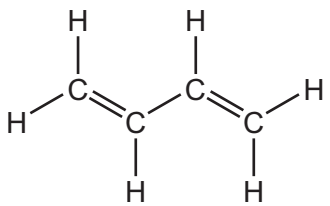
**A** covalent bonds **C** ionic bonds

**B** hydrogen bonds **D** van der Waals' forces

**130 9701/12/M/J/20/Q30**

The diagram shows the structure of buta-1,3-diene.

buta-1,3-diene



The addition reaction between buta-1,3-diene and two molecules of hydrogen bromide can produce three structurally isomeric products.

How many of these products have at least one chiral centre?

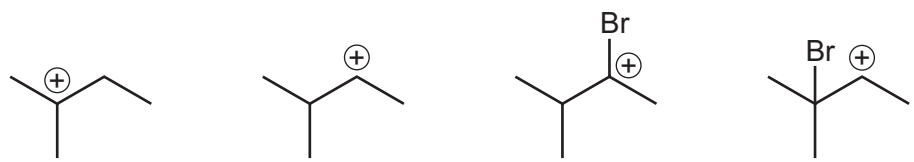
**A** 0 **B** 1 **C** 2 **D** 3

**131 9701/13/M/J/20/Q28**

2-methylbut-2-ene reacts with HBr(g) to form two isomeric products. During the reaction two positively charged intermediates can be made.

Which diagram shows the more stable of the two positively charged intermediates?

**A** **B** **C** **D**






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# Organic Chemistry And Analysis

15
TOPIC

# Halogen Compounds

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**1 9701/1/M/J/02/Q23**

2-Bromopropane, $(CH_3)_2CHBr$, may be used as the starting point for making $(CH_3)_2CHCO_2H$.

Which of the following sequences would be most suitable?

**A** $(CH_3)_2CHBr \rightarrow (CH_3)_2CHOH \rightarrow (CH_3)_2CHCO_2H$

**B** $(CH_3)_2CHBr \rightarrow (CH_3)_2CHCN \rightarrow (CH_3)_2CHCO_2H$

**C** $(CH_3)_2CHBr \rightarrow (CH_3)_2CHOH \rightarrow (CH_3)_2CHCN \rightarrow (CH_3)_2CHCO_2H$

**D** $(CH_3)_2CHBr \rightarrow (CH_3)_2CHCN \rightarrow (CH_3)_2CHOH \rightarrow (CH_3)_2CHCO_2H$

**2 9701/1/O/N/02/Q22**

Chloroethane is used as a starting material for the production of 'time-release capsules' in pharmaceutical products. One way of preparing chloroethane is to react chlorine and ethane in the presence of ultraviolet light.

Which statement is correct about the **first** stage of the mechanism of this reaction?

**A** The C*l* – C*l* bond is split homolytically.

**B** The C*l* – C*l* bond is split heterolytically.

**C** The C – H bond is split homolytically.

**D** The C – H bond is split heterolytically.

**3 9701/1/O/N/02/Q24**

Compound **X** undergoes the following reactions.

$$\underset{\textbf{X}}{C_4H_9Br} \xrightarrow{NaOH(aq)\ /\ heat} C_4H_{10}O \xrightarrow{Cr_2O_7^{2-},\ H^+(aq)\ /\ heat} C_4H_8O \text{ only}$$

What is **X**?

**A** 1-bromobutane

**B** 2-bromobutane

**C** 1-bromo-2-methylpropane

**D** 2-bromo-2-methylpropane

**4 9701/1/O/N/02/Q25**

Chlorofluorocarbons (CFCs) have been widely used in aerosol sprays, refrigerators and in making foamed plastics, but are now known to destroy ozone in the upper atmosphere.

Which of the following will not destroy ozone, and therefore can be used safely as a replacement for CFCs?

**A** $CHBr_3$ **B** $CCl_3CBr_3$ **C** $CHClFCClF_2$ **D** $CH_3CH_2CH_2OH$

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**5 9701/1/M/J/03/Q26**

The reaction scheme outlines the production of one of the monomers of nylon 66 from compound **X**.

$$\text{compound } \mathbf{X} \xrightarrow[\text{in ethanol}]{\text{KCN}} NCCH_2CH_2CH_2CH_2CN \xrightarrow{\text{reduction}} H_2N(CH_2)_6NH_2$$

Which compound could be **X**?

**A** $BrCH_2CH_2CH_2CH_2Br$

**B** $CH_2{=}CHCH{=}CH_2$

**C** $HOCH_2CH_2CH_2CH_2OH$

**D** $HO_2CCH_2CH_2CH_2CH_2CO_2H$

**6 9701/1/M/J/03/Q27**

Chlorofluoroalkanes, commonly known as CFCs, undergo homolytic fission by ultraviolet irradiation in the stratosphere.

Which radical could result from this irradiation of $CHFCl CF_2Cl$?

**A** $CHFCl\dot{C}FCl$ **B** $\dot{C}HCl CF_2Cl$ **C** $\dot{C}HFCF_2Cl$ **D** $\dot{C}FCl CF_2Cl$

**7 9701/01/M/J/04/Q27**

Ethene reacts with aqueous bromine to give two products, $CH_2BrCH_2Br$ and $CH_2BrCH_2OH$.

Which statement is correct for these products?

**A** Both products are obtained in this reaction by electrophilic substitution.

**B** Both products are obtained in this reaction by nucleophilic addition.

**C** Both products can be hydrolysed to form the same diol.

**D** Both products can form hydrogen bonds with water.

**8 9701/01/O/N/04/Q23**

How many different substitution products are possible, in principle, when a mixture of bromine and ethane is allowed to react?

**A** 3 **B** 5 **C** 7 **D** 9

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**9 9701/01/M/J/05/Q19**

Bromomethane, $CH_3Br$, is used as a fumigant to destroy insect pests in grain that is to be stored. It can be made by reacting methanol with hydrogen bromide.

$$CH_3OH + HBr \rightarrow CH_3Br + H_2O$$

What type of reaction is this?

**A** condensation
**B** electrophilic substitution
**C** free radical substitution
**D** nucleophilic substitution

**10 9701/01/M/J/05/Q21**

Under the Montreal Protocol the use of chlorofluorocarbons is to be phased out. Fluorocarbons are often used to replace them. One chlorofluorocarbon which was widely used as a solvent is $CCl_2FCClF_2$ and large stocks of it remain. One process to use up these stocks is to convert it into the fluorocarbon $CH_2FCF_3$ by the following route.

$$CCl_2FCClF_2 \xrightarrow{\text{step 1}} CCl_3CF_3 \xrightarrow{\text{step 2}} CCl_2FCF_3 \xrightarrow{\text{step 3}} CH_2FCF_3$$

**11 9701/01/M/J/05/Q23**

**12 9701/01/M/J/05/Q24**



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**13 9701/01/O/N/05/Q22**

In the upper atmosphere chlorofluoroalkanes (CFCs) are broken down to give chlorine radicals but not fluorine radicals.

What is the best explanation for this?

**A** Fluorine is more electronegative than chlorine.
**B** Fluorine radicals are less stable than chlorine radicals.
**C** The C–F bond is stronger than the C–C*l* bond.
**D** The chlorine atom is larger than the fluorine atom.

**14 9701/01/O/N/05/Q23**

An amine is produced in the following reaction. $C_2H_5I + 2NH_3 \rightarrow C_2H_5NH_2 + NH_4I$

What is the mechanism?

**A** electrophilic addition
**B** electrophilic substitution
**C** nucleophilic addition
**D** nucleophilic substitution

**15 9701/01/M/J/06/Q23**

*Use of the Data Booklet is relevant to this question.*

In which reaction is the relative molecular mass of the organic product the largest?

**A** bromoethane + aqueous sodium hydroxide
**B** bromoethane + alcoholic sodium hydroxide
**C** ethane + bromine
**D** ethanol + phosphorus pentachloride

**16 9701/01/M/J/06/Q25**

High-energy irradiation in the stratosphere produces radicals from chlorofluoroalkanes, commonly known as CFCs.

Which radical could result from this irradiation of $CHFCl CF_2Cl$?

**A** $CHFCl\dot{C}FCl$
**B** $\dot{C}HCl CF_2Cl$
**C** $\dot{C}HFCF_2Cl$
**D** $\dot{C}FCl CF_2Cl$

**17 9701/01/O/N/06/Q22**

Which reaction is an example of nucleophilic substitution?

**A** $CH_3CH_2Br \rightarrow CH_2{=}CH_2 + HBr$
**B** $CH_2{=}CH_2 + HBr \rightarrow CH_3CH_2Br$
**C** $C_3H_7Br + H_2O \rightarrow C_3H_7OH + HBr$
**D** $C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$

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**18 9701/01/O/N/06/Q26**

When (chloromethyl)benzene, $C_6H_5CH_2Cl$, is treated in succession with two reagents **X** and **Y**, it gives phenylethanoic acid, $C_6H_5CH_2CO_2H$.

What are reagents **X** and **Y**?

| | X | Y |
|---|---|---|
| **A** | NaOH(aq) | $K_2Cr_2O_7$(aq) |
| **B** | $Cl_2$(aq) | NaOH(aq) |
| **C** | NaCN (in aqueous ethanol) | dilute $H_2SO_4$ |
| **D** | NaOH(aq) | $CO_2$ |

**19 9701/01/O/N/06/Q31**

The chlorine oxide free radical, $ClO^{\bullet}$, is formed during the depletion of the ozone layer by chlorofluoroalkanes (CFCs).

$$Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$$

Which features are present in the chlorine oxide free radical?

**1** an odd number of electrons
**2** a single covalent bond
**3** a dative covalent bond from oxygen to chlorine

**20 9701/01/M/J/07/Q20**

Under the Montreal Protocol, the manufacture of chlorofluorocarbons has been phased out, and they are being replaced by fluorocarbons.

One chlorofluorocarbon which was widely used as a solvent is $CCl_2FCClF_2$. Large stocks of it remain. One process to use up these stocks is to convert it into the fluorocarbon $CH_2FCF_3$ by the following route.

$$CCl_2FCClF_2 \xrightarrow{\text{step 1}} CCl_3CF_3 \xrightarrow{\text{step 2}} CCl_2FCF_3 \xrightarrow{\text{step 3}} CH_2FCF_3$$

What type of reaction is step 2?

**A** electrophilic substitution
**B** free radical reduction
**C** isomerisation
**D** nucleophilic substitution



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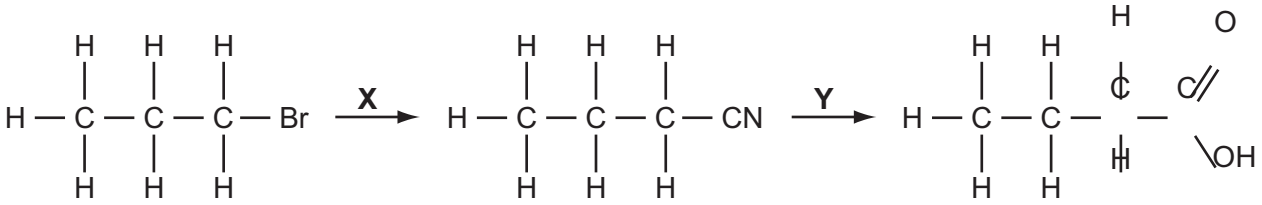
**21 9701/01/M/J/07/Q24**

Which term describes the action of NaOH(aq) on a bromoalkane?

**A** acid-base reaction
**B** electrophilic substitution
**C** elimination of HBr
**D** nucleophilic substitution

**22 9701/01/M/J/07/Q25**

**X** and **Y** are the reagents required to convert 1-bromopropane into butanoic acid.




What are the correct identities of **X** and **Y**?

| | X | Y |
|---|---|---|
| **A** | $NH_3$ | HC*l*(aq) |
| **B** | KCN in $C_2H_5OH$ | NaOH(aq) |
| **C** | KCN in $C_2H_5OH$ | HC*l*(aq) |
| **D** | HCN | NaOH(aq) |

**23 9701/01/M/J/02/Q19**

The anaesthetic *halothane,* $CF_3CHBrCl$, is made industrially as shown below.

$$CCl_2{=}CHCl \xrightarrow[\text{stage 1}]{HF} CF_3CH_2Cl \xrightarrow[\text{stage 2}]{Br_2} CF_3CHBrCl$$

What type of reaction is occurring in stage 2?

**A** electrophilic addition
**B** electrophilic substitution
**C** free radical substitution
**D** nucleophilic addition

**24 9701/01/O/N/07/Q16**

Compound **X** on refluxing with aqueous sodium hydroxide gave mixture **Y** which on distillation with acidified potassium dichromate(VI) produced propanone. Mixing **Y** with dilute nitric acid and aqueous silver nitrate gave a cream precipitate.

What could compound **X** be?

**A** $CH_3CHBrCH_3$ **B** $CH_3CHICH_3$ **C** $CH_3CH_2CH_2Br$ **D** $CH_3CH_2CH_2I$

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**25 9701/01/O/N/07/Q24**

The anaesthetic *halothane,* $CF_3CHBrCl$, is made industrially as shown below.

$$CCl_2{=}CHCl \xrightarrow[\text{stage 1}]{HF} CF_3CH_2Cl \xrightarrow[\text{stage 2}]{Br_2} CF_3CHBrCl$$

Which type of reaction is occurring in stage 2?

**A** electrophilic addition
**B** electrophilic substitution
**C** free radical substitution
**D** nucleophilic addition

**26 9701/01/O/N/07/Q25**

Chlorofluoroalkanes, CFCs, can be used as refrigerants, aerosol propellants and fire extinguishers.

CFCs such as $CCl_3F$ and $CCl_2F_2$ are more stable than chloroalkanes such as $CCl_4$.

What is the reason for their greater stability?

**A** Fluorine has a higher first ionisation energy than chlorine.

**B** Fluorine radicals are more stable than chlorine radicals.

**C** The C–F bond energy is larger than the C–Cl bond energy.

**D** The C–F bond is more polar than the C–Cl bond.

**27 9701/01/M/J/08/Q25**

Halogenoalkanes are important molecules in organic synthetic reactions. In particular they undergo a range of nucleophilic reactions.

Which reaction proceeds **only** by an $S_N1$ mechanism?

**A** $CH_3CH_2Br + NH_3$
**B** $CH_3CH_2CH_2I + OH^-$
**C** $CH_3CHBrCH_3 + NH_3$
**D** $(CH_3)_3CI + OH^-$

**28 9701/01/O/N/08/Q23**

Four drops of 1-chlorobutane, 1-bromobutane and 1-iodobutane were put separately into three test-tubes containing 1.0 $cm^3$ of aqueous silver nitrate at 60 °C.

A hydrolysis reaction occurred. (R represents the butane chain $C_4H_9$– and *X* the halogen atom.)

$$H_2O(l) + R{-}X(l) + Ag^+(aq) \rightarrow R{-}OH(aq) + AgX(s) + H^+(aq)$$

The rate of formation of cloudiness in the tubes was in the order RCl < RBr < RI.

Why is this?

**A** The R–*X* bond polarity decreases from RCl to RI.
**B** The solubility of Ag*X*(s) decreases from AgCl to AgI.
**C** The ionisation energy of the halogen decreases from Cl to I.
**D** The bond energy of R–*X* decreases from RCl to RI.



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**29 9701/12/M/J/10/Q26**

When an isomer Y of molecular formula $C_4H_9Br$ undergoes hydrolysis in aqueous alkali to form an alcohol $C_4H_9OH$, the rate of reaction is found to be unaffected by changes in the concentration of $OH^-$ ions present.

Which is the most likely molecular structure of Y?

**A** $CH_3CH_2CH_2CH_2Br$ **B** $CH_3CH_2CHBrCH_3$ **C** $(CH_3)_2CHCH_2Br$ **D** $(CH_3)_3CBr$

**30 9701/12/O/N/10/Q21**

Nine compounds have molecular formula $C_4H_8Br_2$.

Which compound may be synthesised from an alkene by an addition reaction?

**A** 1,1-dibromobutane

**B** 1,2-dibromobutane

**C** 1,3-dibromobutane

**D** 1,3-dibromomethylpropane

**31 9701/12/O/N/10/Q25**

Many, but not all, organic reactions need to be heated before reaction occurs.

Which reaction occurs at a good rate at room temperature (20 °C)?

**A** $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$

**B** $CH_3CH_2CH_2Br + NH_3 \rightarrow CH_3CH_2CH_2NH_2 + HBr$

**C** $CH_3CH_2OH + KBr \rightarrow CH_3CH_2Br + KOH$

**D** $(CH_3)_2CO + H_2NNHC_6H_3(NO_2)_2 \rightarrow (CH_3)_2C{=}NNHC_6H_3(NO_2)_2 + H_2O$

**32 9701/12/M/J/11/Q21**

Which halogenoalkane will undergo an $S_N1$ reaction and produce a yellow precipitate when $AgNO_3(aq)$ is added to it?

**A** 1-chlorobutane

**B** 1-iodobutane

**C** 2-chloro-2-methylpropane

**D** 2-iodo-2-methylpropane



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**33 9701/12/M/J/11/Q22**

Which reaction will give 2-chloropropane in the best yield?

**A** propane gas with chlorine gas in the presence of ultraviolet light

**B** propan-2-ol with dilute NaC$l$(aq)

**C** propan-2-ol with SOC$l_2$

**D** propene with dilute HC$l$(aq)

**34 9701/12/M/J/11/Q27**

1,1-dichloropropane reacts with aqueous sodium hydroxide in a series of steps to give propanal.

$$CH_3CH_2CHCl_2 \xrightarrow{NaOH(aq)} CH_3CH_2CHO$$

Which term describes the first step of this reaction?

**A** electrophilic addition

**B** elimination

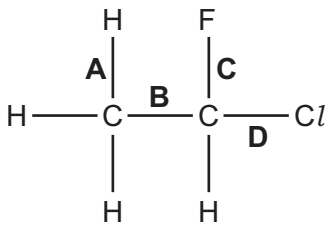
**C** nucleophilic substitution

**D** oxidation

**35 9701/12/O/N/11/Q22**

*Use of the Data Booklet is relevant to this question.*

Which bond in the structure below has the lowest bond energy?




**36 9701/12/O/N/11/Q25**

What is involved in the mechanism of the reaction between aqueous sodium hydroxide and 2-bromo-2-methylbutane?

**A** heterolytic bond fission, attack by an electrophile on a carbanion

**B** heterolytic bond fission, attack by a nucleophile on a carbocation

**C** homolytic bond fission, attack by an electrophile on a carbanion

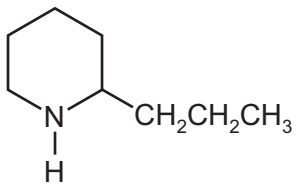
**D** homolytic bond fission, attack by a nucleophile on a carbocation



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**37 9701/12/M/J/12/Q28**

Coniine is the major constituent of the poison 'oil of hemlock'.




coniine

Coniine can be synthesised by reacting ammonia with a dibromo compound, **X**.

$$NH_3 + C_8H_{16}Br_2 \rightarrow \text{coniine} + 2HBr$$

**X**

What is the name of compound **X**?

**A** 1,1-dibromo-2-propylcyclopentane

**B** 1,2-dibromo-2-propylcyclopentane

**C** 1,4-dibromooctane

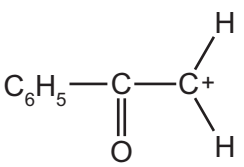
**D** 1,5-dibromooctane

**38 9701/12/M/J/12/Q25**

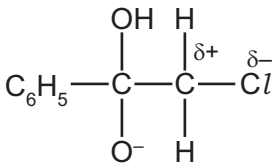
When phenacyl chloride, $C_6H_5COCH_2Cl$, is reacted with aqueous NaOH, the substitution reaction follows an $S_N2$ mechanism.

Which structure represents a species formed during the reaction?

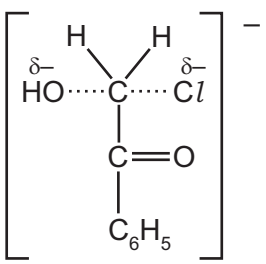
**A**



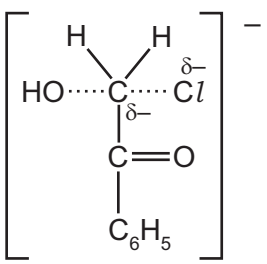

**B**




**C**




**D**






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**39 9701/12/M/J/12/Q22**

When 1-bromopropane is treated in succession with two reagents, X and Y, it produces propanoic acid.

What are reagents X and Y?

| | X | Y |
|---|---|---|
| **A** | NaOH(aq) | $H^+ / Cr_2O_7^{2-}$(aq) |
| **B** | NaOH(aq) | $CO_2$ |
| **C** | KCN in ethanol | HCl(aq) |
| **D** | KCN in ethanol | NaOH(aq) |

**40 9701/12/O/N/12/Q26**

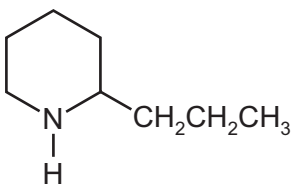
High-energy radiation in the stratosphere produces free-radicals from chlorofluoroalkanes, commonly known as CFCs.

Which free-radical is most likely to result from the irradiation of $CHFClCF_2Cl$?

**A** $CHFCl\dot{C}FCl$ **B** $\dot{C}HClCF_2Cl$ **C** $\dot{C}HFCF_2Cl$ **D** $\dot{C}FClCF_2Cl$

**41 9701/12/M/J/12/Q28**

Coniine is the major constituent of the poison 'oil of hemlock'.




coniine

Coniine can be synthesised by reacting ammonia with a dibromo compound, **X**.

$$NH_3 + C_8H_{16}Br_2 \rightarrow \text{coniine} + 2HBr$$

**X**

What is the name of compound **X**?

**A** 1,1-dibromo-2-propylcyclopentane

**B** 1,2-dibromo-2-propylcyclopentane

**C** 1,4-dibromooctane

**D** 1,5-dibromooctane



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**42 9701/12/M/J/13/Q23**

Aqueous sodium hydroxide reacts with 2-bromo-2-methylpropane to give 2-methylpropan-2-ol.

The reaction proceeds by an $S_N1$ mechanism.

How should the first step in the mechanism be described?

**A** by a curly arrow from a lone pair on the $OH^-$ ion to the $C^{\delta+}$ atom of 2-bromopropane

**B** by a curly arrow from the C–Br bond to the Br atom

**C** by a curly arrow from the C–Br bond to the C atom

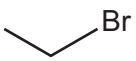
**D** by the homolytic fission of the C–Br bond

**43 9701/12/M/J/13/Q24**

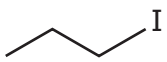
Compound **Y** can be hydrolysed by warm aqueous silver nitrate to form a precipitate that is soluble in dilute aqueous ammonia. Compound **Y** can undergo an elimination reaction to form an alkene.

What could be the skeletal formula of compound **Y**?

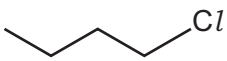
**A**



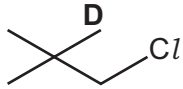

**B**




**C**




**D**




**44 9701/12/O/N/13/Q21**

Which reaction will give the best yield of 1-chloropropane?

**A** chlorine gas with propene gas in the dark

**B** propan-1-ol with dilute NaCl(aq)

**C** propan-1-ol with $PCl_5$

**D** propene with dilute HCl(aq)

**45 9701/12/O/N/13/Q24**

A carbanion is an organic ion in which a carbon atom has a negative charge. A carbocation is an organic ion in which a carbon atom has a positive charge.

The reaction between aqueous sodium hydroxide and 1-bromobutane proceeds by an $S_N2$ mechanism.

How should the first step in the mechanism be described?

**A** attack by a nucleophile on a carbon atom with a partial positive charge

**B** heterolytic bond fission followed by an attack by an electrophile on a carbanion

**C** heterolytic bond fission followed by an attack by a nucleophile on a carbocation

**D** homolytic bond fission followed by an attack by a nucleophile on a carbocation

STUDENTS RESOURCE



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**46** **9701/12/O/N/14/Q25**

In the hydrolysis of bromoethane by aqueous sodium hydroxide, what is the nature of the attacking group and of the leaving group?

| | attacking group | leaving group |
|---|---|---|
| **A** | electrophile | electrophile |
| **B** | electrophile | nucleophile |
| **C** | nucleophile | electrophile |
| **D** | nucleophile | nucleophile |

**47** **9701/12/M/J/14/Q21**

Halogenoalkanes undergo a range of nucleophilic substitution reactions.

Which reaction proceeds **only** by an $S_N1$ mechanism?

**A** $CH_3CH_2Br + NH_3$ **C** $CH_3CHBrCH_3 + NH_3$

**B** $CH_3CH_2CH_2I + OH^-$ **D** $(CH_3)_3CI + OH^-$

**48** **9701/12/M/J/14/Q27**

Dichlorodifluoromethane, $CCl_2F_2$, has been used in aerosol propellants and as a refrigerant.

Which statement helps to explain why dichlorodifluoromethane is chemically inert?

**A** All fluorine compounds are non-flammable. **C** The carbon-fluorine bond energy is large.

**B** Fluorine is highly electronegative. **D** The carbon-fluorine bond has a low polarity.

**49** **9701/12/M/J/14/Q29**

When heated with KOH dissolved in ethanol, halogenoalkanes can undergo an elimination reaction to form alkenes.

What are the possible elimination products when 2-bromobutane is heated with KOH dissolved in ethanol?

**A** $CH_3CH{=}CHCH_3$ only **C** $CH_3CH{=}CHCH_3$ and $CH_3CH_2CH{=}CH_2$

**B** $CH_3CH_2CH{=}CH_2$ only **D** $CH_3CH{=}CHCH_3$ and $CH_2{=}CHCH{=}CH_2$

**50** **9701/12/O/N/14/Q22**

1,1-dichloropropane reacts with aqueous sodium hydroxide in a series of steps to give propanal.

$$CH_3CH_2CHCl_2 \xrightarrow{NaOH(aq)} CH_3CH_2CHO$$

Which term describes the first step of this reaction?

**A** addition **B** elimination **C** oxidation **D** substitution



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**51 9701/11/M/J/15/Q25**

2-bromopropane reacts with a hot concentrated solution of sodium hydroxide in ethanol.

Which substance is the major product of this reaction?

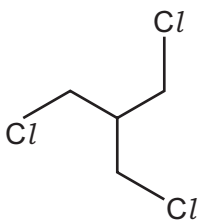
**A** propan-1-ol **B** propan-2-ol **C** 2-hydroxypropene **D** propene

**52 9701/11/M/J/15/Q26**

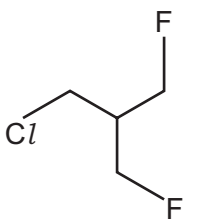
The presence of a halogen in an organic compound may be detected by warming the organic compound with aqueous silver nitrate.

Which compound would be the quickest to produce a precipitate?

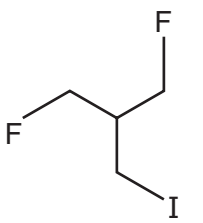
**A**



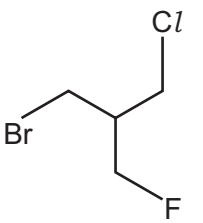

**B**




**C**




**D**




**53 9701/11/M/J/15/Q30**

What is the organic product when ethanamide, $CH_3CONH_2$, is boiled with excess aqueous sodium hydroxide?

**A** $CH_3CN$ **B** $CH_3CO_2^-NH_4^+$ **C** $CH_3CONH^-Na^+$ **D** $CH_3CO_2^-Na^+$

**54 9701/12/M/J/15/Q23**

Butanedioic acid may be synthesised in two steps from 1,2-dibromoethane.

$$BrCH_2CH_2Br \xrightarrow{\text{step 1}} X \xrightarrow{\text{step 2}} HO_2CCH_2CH_2CO_2H$$

Which reagents could be used for this synthesis?

| | step 1 | step 2 |
|---|---|---|
| **A** | HCN(g) | HCl(aq) |
| **B** | $HCO_2Na$(aq) | HCl(aq) |
| **C** | KCN(alcoholic) | $H_2SO_4$(aq) |
| **D** | NaOH(aq) | $K_2Cr_2O_7$ / $H_2SO_4$(aq) |



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**54 9701/12/F/M/16/Q25**

Structural isomerism and stereoisomerism should be considered in answering this question.

Compound J is reacted with KOH dissolved in ethanol. Three isomeric alkenes with molecular formula $C_4H_8$ are formed.

What is J?

**A** $CH_3—CH_2—CH_2—CH_2—Br$

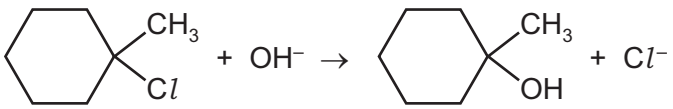
**B** $CH_3—CH(Br)—CH_2—CH_3$

**C** $CH_3—CH(CH_3)—CH_2—Br$

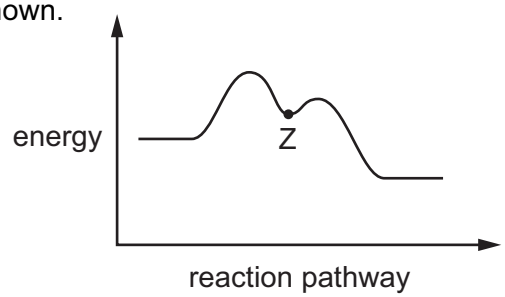
**D** $CH_3—C(CH_3)_2—Br$

**56 9701/12/M/J/16/Q24**

1-chloro-1-methylcyclohexane is hydrolysed by heating with NaOH(aq).




The reaction pathway is shown.




One carbon atom in 1-chloro-1-methylcyclohexane is bonded to three other carbon atoms.

What is the charge on this carbon atom at point Z?

**A** δ+ **B** + **C** δ– **D** –

**57 9701/12/M/J/17/Q06**

Which reaction involves a decrease in the bond angle at a carbon atom?

**A** bromoethane refluxed with ethanolic sodium hydroxide

**B** complete combustion of methane in air

**C** ethanol heated with conc. $H_2SO_4$

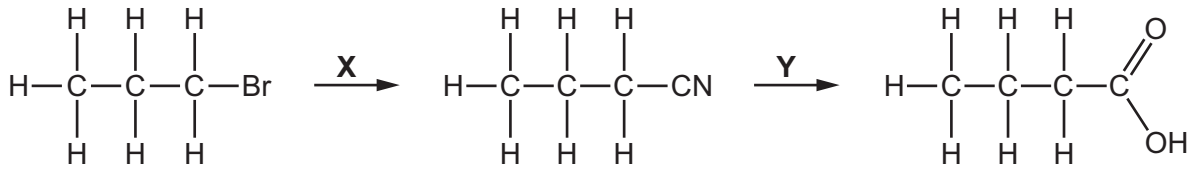
**D** polymerisation of ethene



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**58 9701/11/M/J/17/Q26**

**X** and **Y** are the reagents required to convert 1-bromopropane into butanoic acid.



What are the correct identities of **X** and **Y**?

| | X | Y |
|---|---|---|
| **A** | $NH_3$ | HC*l*(aq) |
| **B** | KCN in $C_2H_5OH$ | NaOH(aq) |
| **C** | KCN in $C_2H_5OH$ | HC*l*(aq) |
| **D** | HCN | NaOH(aq) |

**59 9701/12/M/J/17/Q23**

Aqueous sodium hydroxide reacts with 1-bromopropane to give propan-1-ol.

What should be included in a diagram of the first step in the mechanism?

**A** a curly arrow from a lone pair on the $OH^-$ ion to the $C^{\delta+}$ atom of 1-bromopropane

**B** a curly arrow from the $C^{\delta+}$ atom of 1-bromopropane to the $OH^-$ ion

**C** a curly arrow from the C–Br bond to the C atom

**D** the homolytic fission of the C–Br bond

**60 9701/12/M/J/17/Q26**

2-bromo-2-methylpropane undergoes nucleophilic substitution when heated under reflux with an aqueous solution of sodium hydroxide.

Which row is correct?

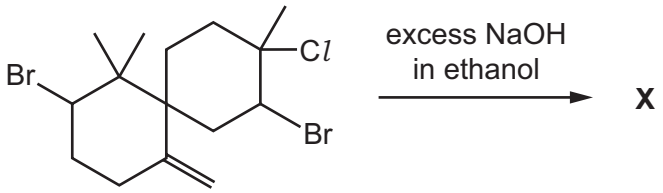
| | mechanism for this reaction | reason |
|---|---|---|
| **A** | $S_N1$ | the hydroxide ion is helped in its approach to the central carbon atom by the methyl groups |
| **B** | $S_N1$ | the intermediate carbocation is stabilised by the inductive effect of the methyl groups |
| **C** | $S_N2$ | the hydroxide ion is hindered in its approach to the central carbon atom by the methyl groups |
| **D** | $S_N2$ | the intermediate carbocation is destabilised by the inductive effect of the methyl groups |



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**61 9701/11/O/N/18/Q25**

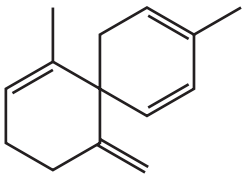
Compound J, $C_{15}H_{23}Br_2Cl$, is reacted with an excess of a hot concentrated solution of sodium hydroxide in ethanol. One of the products is **X**.



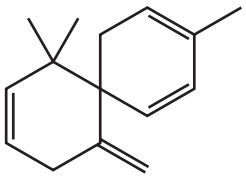

compound J

What could be the skeletal formula of **X**?

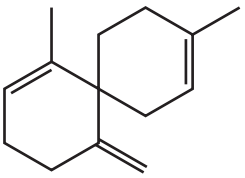
**A**



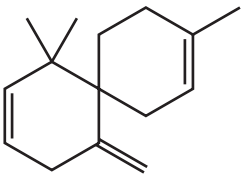
**B**



**C**



**D**



**62 9701/12/O/N/18/Q23**

Compound P reacts separately with KOH(aq) and HBr.

$CH_2CHCH_2CH_2Cl$

compound P

What are the mechanisms of these two reactions?

| | KOH (aq) | HBr |
|---|---|---|
| **A** | nucleophilic addition | electrophilic addition |
| **B** | nucleophilic addition | free radical substitution |
| **C** | nucleophilic substitution | electrophilic addition |
| **D** | nucleophilic substitution | free radical substitution |



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**63 9701/12/O/N/18/Q25**

A halogenoalkane has the molecular formula $C_5H_{11}Br$. The halogenoalkane does **not** form an alkene when treated with ethanolic sodium hydroxide.

What could be the halogenoalkane?

**A** 1-bromo-2-methylbutane

**B** 2-bromo-2-methylbutane

**C** 3-bromopentane

**D** bromodimethylpropane

**64 9701/12/F/M/19/Q25**

Which product is formed when 3-methylpentane-1,3,4-triol is heated under reflux with an excess of acidified potassium dichromate(VI)?

**A** $HO_2CCH_2C(CH_3)(OH)COCH_3$

**B** $HO_2CCH_2COC(OH)(CH_3)_2$

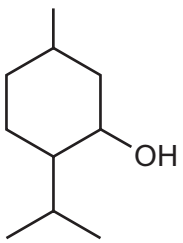
**C** $OHCCH_2C(CH_3)(OH)COCH_3$

**D** $HO_2CCH_2CO(CH_3)COCH_3$

**65 9701/12/F/M/19/Q26**

Menthol is a naturally occurring alcohol.

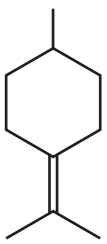
menthol



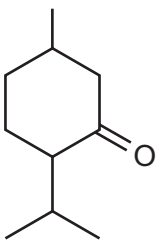

When menthol is heated with concentrated sulfuric acid it reacts. The products formed include compound T.

What could be the structure of compound T?

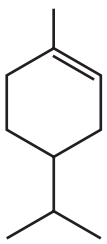
**A**



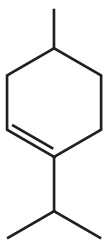
**B**




**C**



**D**





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**66 9701/12/F/M/19/Q24**

Bromopropane reacts with water as shown.

$$CH_3CH_2CH_2Br + H_2O \rightarrow CH_3CH_2CH_2OH + HBr$$

Which statement is correct?

**A** This is an elimination reaction.

**B** This is a hydrolysis reaction.

**C** This is a redox reaction.

**D** This reaction tends to proceed via the $S_N1$ mechanism.

**67 9701/12/F/M/19/Q27**

Structural isomerism only should be considered when answering this question.

All the isomeric alcohols with the molecular formula $C_5H_{12}O$ are added separately to warm alkaline aqueous iodine.

How many of the isomers give a yellow precipitate?

**A** 0 **B** 1 **C** 2 **D** 3

**68 9701/11/M/J/19/Q23**

Which reaction is most likely to involve the formation of a positively charged intermediate?

**A** 1-bromopentane and warm dilute NaOH(aq)

**B** 1-bromo-2,2-dimethylpropane and warm dilute NaOH(aq)

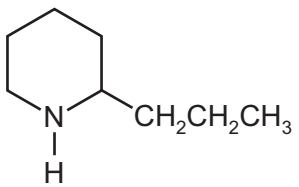
**C** 1-bromo-3-methylbutane and warm dilute NaOH(aq)

**D** 2-bromo-2-methylbutane and warm dilute NaOH(aq)

**69 9701/11/M/J/19/Q25**

The structure of coniine is shown.

coniine




Coniine can be synthesised by reacting ammonia with a dibromo compound, X.

$$NH_3 + C_8H_{16}Br_2 \rightarrow \text{coniine} + 2HBr$$

X

What is the name of compound X?

**A** 1,1-dibromo-2-propylcyclopentane

**B** 1,2-dibromo-2-propylcyclopentane

**C** 1,4-dibromooctane

**D** 1,5-dibromooctane



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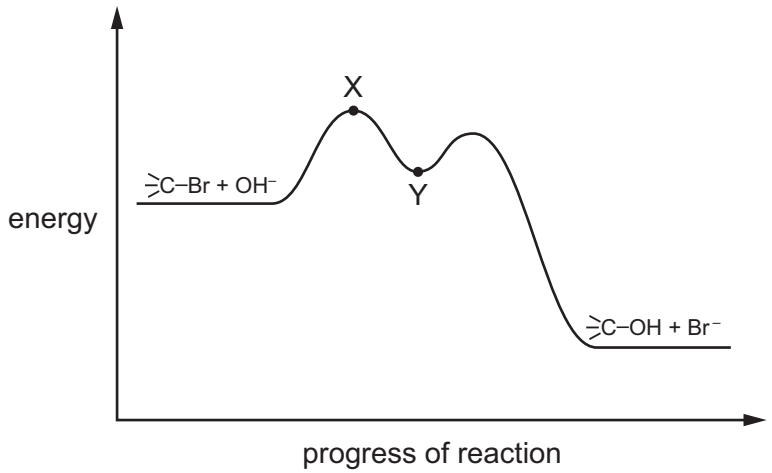
**70 9701/12/M/J/19/Q25**

Which product can be made from bromoethane by an elimination reaction?

**A** ethanol **B** ethene **C** ethylamine **D** propanenitrile

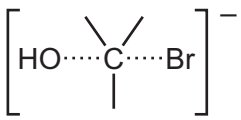
**71 9701/11/O/N/19/Q23**

A tertiary bromoalkane, indicated here by $\geq$C–Br, reacts with aqueous NaOH. The mechanism has the reaction pathway shown.

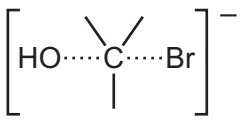



Which point in the diagram is correctly identified?

**A** X is $\geq$C+

**B** X is 


**C** Y is $\geq$C+

**D** Y is 




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**72 9701/11/O/N/19/Q24**

Bromoethane and chloroethane are added separately to water. Hydrolysis reactions occur.

Which compound hydrolyses more rapidly and what is the mechanism?

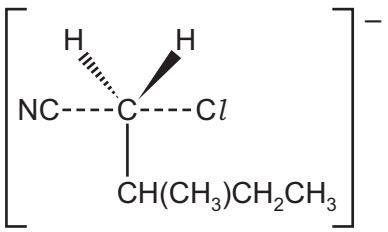
| | compound that hydrolyses more rapidly | mechanism |
|---|---|---|
| **A** | bromoethane | electrophilic substitution |
| **B** | bromoethane | nucleophilic substitution |
| **C** | chloroethane | electrophilic substitution |
| **D** | chloroethane | nucleophilic substitution |

**73 9701/12/O/N/19/Q23**

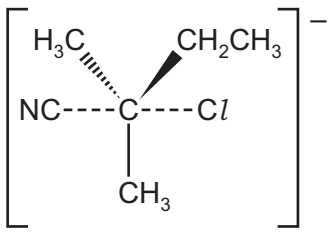
1-chloro-2-methylbutane reacts with sodium cyanide in ethanol in a nucleophilic substitution reaction.

What is the most likely intermediate or transition state in this reaction?

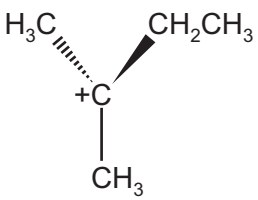
**A**



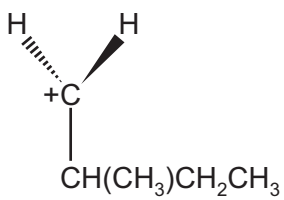

**B**




**C**




**D**






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**74 9701/12/F/M/20/Q21**

Which row identifies a suitable starting material and reagent that can be used to produce butanenitrile?

| | starting material | reagent |
|---|---|---|
| **A** | $CH_3CH_2CH_2Br$ | HCN |
| **B** | $CH_3CH_2CH_2Br$ | NaCN |
| **C** | $CH_3CH_2CH_2CH_2Br$ | HCN |
| **D** | $CH_3CH_2CH_2CH_2Br$ | NaCN |

**75 9701/11/M/J/20/Q23**

2-bromo-2-methylpentane is a tertiary halogenoalkane.

Which organic products are formed when 2-bromo-2-methylpentane reacts with a hot concentrated ethanolic solution of sodium hydroxide?

**A** 2-methylpent-1-ene only

**B** 2-methylpent-1-ene and 2-methylpent-2-ene

**C** 2-methylpent-2-ene only

**D** 2-methylpent-2-ene and 4-methylpent-2-ene

**76 9701/13/M/J/20/Q27**

1,2-dibromopropane can be made from 1-bromopropane in two steps.

Which row is correct?

| | step 1 | step 2 |
|---|---|---|
| **A** | addition | substitution |
| **B** | elimination | addition |
| **C** | hydrolysis | elimination |
| **D** | substitution | hydrolysis |



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# Organic Chemistry And Analysis

16 TOPIC

# Hydroxy Compounds

NIAZ AHMED AWAN 347 Airport Road | Bahria Town | Johar Town

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**1 9701/1/M/J/02/Q20**

Which set of alcohols correctly shows a primary, a secondary and a tertiary alcohol?

| | *primary* | *secondary* | *tertiary* |
|---|---|---|---|
| **A** | $CH_2OH$<br>\|<br>$CH_2$<br>\|<br>$CH_3$ | $CH_2OH$<br>\|<br>$CHOH$<br>\|<br>$CH_3$ | $CH_2OH$<br>\|<br>$CHOH$<br>\|<br>$CH_2OH$ |
| **B** | $CH_2OH$<br>\|<br>$CH_3—C—H$<br>\|<br>$CH_3$ | $CH_3$<br>\|<br>$CH_3—C—OH$<br>\|<br>$CH_3$ | $CH_3$<br>\|<br>$CH_3—C—H$<br>\|<br>$CH_2OH$ |
| **C** | $CH_2OH$<br>\|<br>$CH_3—C—H$<br>\|<br>$H$ | $CH_2OH$<br>\|<br>$CH_3—C—CH_2OH$<br>\|<br>$H$ | $CH_2OH$<br>\|<br>$CH_3—C—CH_2OH$<br>\|<br>$CH_2OH$ |
| **D** | $H$<br>\|<br>$CH_3—C—OH$<br>\|<br>$H$ | $CH_3$<br>\|<br>$CH_3—C—OH$<br>\|<br>$H$ | $CH_3$<br>\|<br>$CH_3—C—OH$<br>\|<br>$CH_3$ |

**2 9701/1/O/N/02/Q20**

The Russian composer Borodin was also a research chemist who discovered a reaction in which two ethanal molecules combine to form a compound commonly known as aldol (reaction I). Aldol forms another compound on heating (reaction II).

I $2CH_3CHO \rightarrow CH_3CH(OH)CH_2CHO$

II $CH_3CH(OH)CH_2CHO \rightarrow CH_3CH{=}CHCHO + H_2O$

Which of the following best describes reactions I and II?

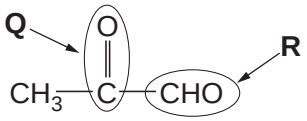
| | I | II |
|---|---|---|
| **A** | addition | elimination |
| **B** | addition | reduction |
| **C** | elimination | reduction |
| **D** | substitution | elimination |



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**3 9701/1/O/N/02/Q27**

Burnt sugar has a characteristic smell caused partly by the following compound. It has two functional groups indicated by **Q** and **R**.




When this compound is tested in a laboratory with 2,4-dinitrophenylhydrazine and Fehling's reagent, which functional groups are responsible for positive tests?

| | 2,4-dinitrophenylhydazine | Fehling's reagent |
|---|---|---|
| **A** | **Q** and **R** | **Q** and **R** |
| **B** | **R** only | **Q** and **R** |
| **C** | **Q** and **R** | **R** only |
| **D** | **Q** only | **R** only |

**4 9701/1/O/N/02/Q28**

Ethanal may be converted into a three-carbon acid in a two-step process.

Which compound is the intermediate?

**A** $CH_3CO_2H$ **B** $CH_3CN$ **C** $CH_3CH_2CN$ **D** $CH_3CH(OH)CN$

**5 9701/1/M/J/03/Q29**

In a preparation of ethene, ethanol is added a drop at a time to a heated reagent **Y**. To purify the ethene it is bubbled through a solution **Z** and then collected.

What could reagent **Y** and solution **Z** be?

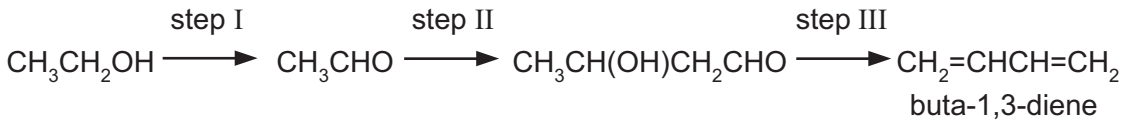
| | reagent **Y** | solution **Z** |
|---|---|---|
| **A** | acidified $K_2Cr_2O_7$ | dilute NaOH |
| **B** | concentrated $H_2SO_4$ | dilute $H_2SO_4$ |
| **C** | concentrated $H_2SO_4$ | dilute NaOH |
| **D** | ethanolic NaOH | concentrated $H_2SO_4$ |



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**6 9701/01/O/N/04/Q22**

Instead of obtaining buta-1,3-diene from fossil fuel sources, it is proposed to obtain it from ethanol, which can be obtained from non–food agricultural crops. The sequence of reactions is as follows.

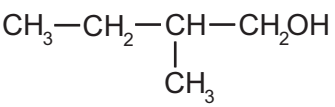


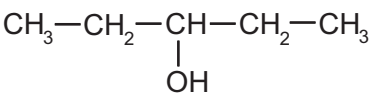

Which term could be used to describe step I?

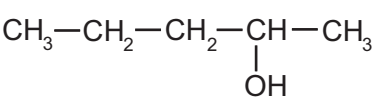
**A** condensation **B** dehydration **C** dehydrogenation **D** hydrogenation

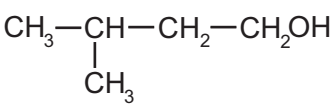
**7 9701/01/O/N/04/Q28**

Which isomer of $C_5H_{11}OH$ gives, on dehydration, the greatest number of different alkenes?

**A** 

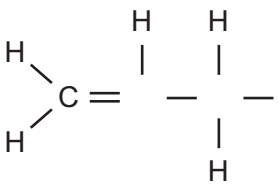
**C** 

**B** 

**D** 

**8 9701/01/M/J/05/Q20**

Prop-2-en-1-ol (allyl alcohol) has the following structure.



Which reagent would react with prop-2-en-1-ol to form a product that could exist as optical isomers?

**A** bromine

**B** hydrogen and nickel

**C** phosphorus pentachloride

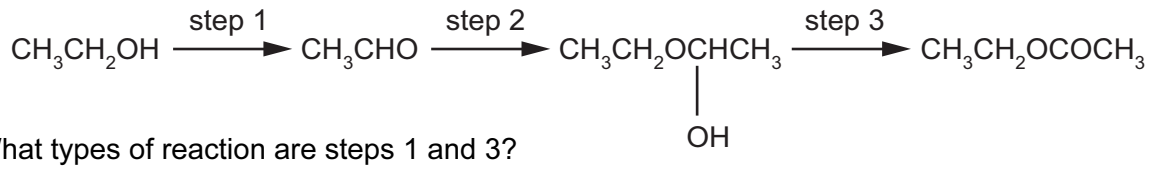
**D** sodium



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**9 9701/01/M/J/05/Q25**

Ethyl ethanoate is a very important solvent in industry. Currently, researchers are investigating ways of producing the ester from cheap, low grade ethanol by the following process.




What types of reaction are steps 1 and 3?

| | step 1 | step 3 |
|---|---|---|
| **A** | elimination | esterification |
| **B** | elimination | isomerisation |
| **C** | oxidation | esterification |
| **D** | oxidation | oxidation |

**10 9701/01/O/N/05/Q25**

Compounds *X*, *Y* and *Z* all react with $PCl_5$ to release hydrogen chloride, but only one of them reacts with 2,4-dinitrophenylhydrazine reagent.
Which one of the following combinations could be *X*, *Y* and *Z*?

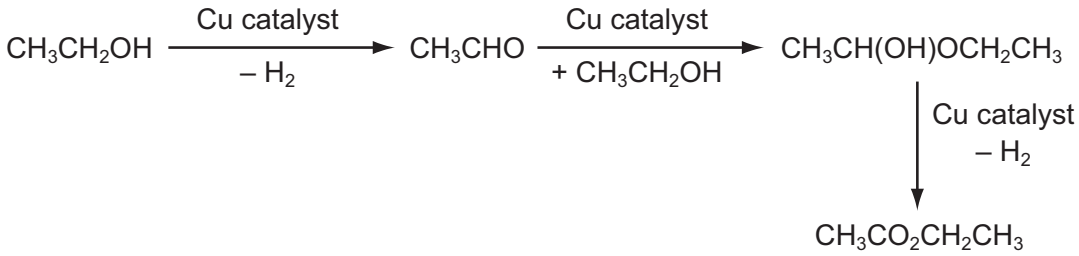
| | *X* | *Y* | *Z* |
|---|---|---|---|
| **A** | $CH_2OH$<br>\|<br>$CH_2OH$ | CHO<br>\|<br>CHO | $CO_2H$<br>\|<br>$CO_2H$ |
| **B** | $CH_2OH$<br>\|<br>$CH_2OH$ | $CH_2OH$<br>\|<br>CHO | CHO<br>\|<br>$CO_2H$ |
| **C** | $CH_2OH$<br>\|<br>CHO | $CH_2OH$<br>\|<br>$CO_2H$ | CHO<br>\|<br>$CO_2H$ |
| **D** | $CH_2OH$<br>\|<br>$CO_2H$ | CHO<br>\|<br>$CO_2H$ | $CO_2H$<br>\|<br>$CO_2H$ |



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**11 9701/01/M/J/06/Q20**

A new industrial preparation of ethyl ethanoate has been developed using cheap sources of ethanol.




Which process is involved at some stage in this reaction sequence?

**A** disproportionation **B** electrophilic addition **C** nucleophilic addition **D** reduction

**12 9701/01/M/J/06/Q26**

Which reagent could detect the presence of alcohol in a petrol consisting mainly of a mixture of alkanes and alkenes?

**A** Na **C** $KMnO_4(aq)$

**B** $Br_2$ (in $CCl_4$) **D** 2,4-dinitrophenylhydrazine

**13 9701/01/M/J/06/Q27**

Which alcohol may be oxidised to a product which reacts with 2,4-dinitrophenylhydrazine reagent but not with Fehling's reagent?

**A** butan-1-ol **C** 2-methylpropan-1-ol

**B** butan-2-ol **D** 2-methylpropan-2-ol

**14 9701/01/O/N/06/Q27**

Which compound
- is unaffected by hot alkaline potassium manganate(VII);
- gives hydrogen when treated with sodium?

**A** $(CH_3)_2CHCOCH_3$ **B** $(CH_3)_3COH$ **C** $CH_3CH_2CH(OH)CH_3$ **D** $CH_3CO_2CH(CH_3)_2$

**15 9701/01/M/J/07/Q26**

An alcohol with molecular formula $C_nH_{2n+1}OH$ has a chiral carbon atom but does not react with $MnO_4^- / H^+$.

What is the least number of carbon atoms such an alcohol could possess?

**A** 5 **B** 6 **C** 7 **D** 8



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**16 9701/01/O/N/07/Q27**

Which reaction will distinguish between a primary and a secondary alcohol?

**A** warming with $H^+ / MnO_4^-$

**B** warming with $H^+ / Cr_2O_7^{2-}$

**C** dehydration, followed by reaction with $Br_2(aq)$

**D** oxidation, followed by reaction with Fehling's (or Tollens') reagent

**17 9701/01/M/J/08/Q26**

An alcohol of molecular formula $C_4H_{10}O_2$ contains two OH groups and has an unbranched carbon atom chain.

On reaction with an excess of hot $MnO_4^- / H^+$ this alcohol is converted into a compound of molecular formula $C_4H_6O_4$.

To which two carbon atoms in the chain of the alcohol are the two OH groups attached?

**A** 1st and 2nd

**B** 1st and 3rd

**C** 1st and 4th

**D** 2nd and 3rd

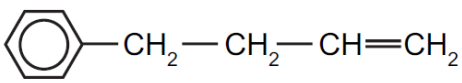
**18 9701/01/M/J/08/Q27 9701/01/M/J/08/Q27**

Compound **X**

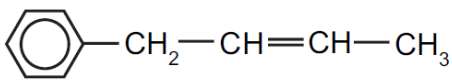
- has the molecular formula $C_{10}H_{14}O$;
- is unreactive towards mild oxidising agents.

What is the structure of the compound formed by dehydration of **X**?

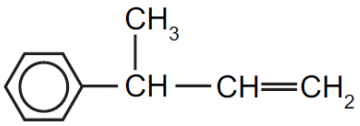
**A**



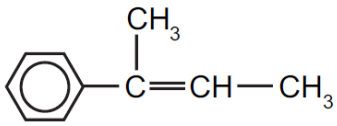
**B**



**C**



**D**





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**19 9701/01/O/N/08/Q25**

The functional group in a primary alcohol is $–CH_2OH$.

Which reagent reacts with a primary alcohol, under suitable conditions, to give an organic product with the same number of oxygen atoms as the alcohol?

**A** $Al_2O_3$ **B** $CH_3CO_2H$ **C** HBr **D** Na

**20 9701/01/O/N/08Q/30**

*Use of the Data Booklet is relevant to this question.*

Ethyl ethanoate can be obtained from ethanoic acid and ethanol by the following reaction.

$$CH_3CH_2OH + CH_3CO_2H \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

Ethanol (30 g) and ethanoic acid (30 g) are heated under reflux together, and 22 g of ethyl ethanoate are obtained.

What is the yield of the ester?

**A** 25 % **B** 38 % **C** 50 % **D** 77 %

**21 9701/01/M/J/09/Q25**

reaction would **not** give propene as one product?

**A** adding an excess of concentrated sulfuric acid to propan-1-ol

**B** adding warm aqueous sodium hydroxide to 2-bromopropane

**C** adding warm ethanolic sodium hydroxide to 1-bromopropane

**D** passing propan-2-ol vapour over heated aluminium oxide

**22 9701/01/M/J/09/Q26**

Glycol, used in anti-freeze, has the formula $HOCH_2CH_2OH$. It can be oxidised to give a number of products.

What is the molecular formula of an oxidation product of glycol that will **not** react with sodium?

**A** $C_2H_2O_2$ **B** $C_2H_2O_3$ **C** $C_2H_2O_4$ **D** $C_2H_4O_2$

**23 9701/13/O/N/10/Q26**

Lactic acid occurs naturally, for example in sour milk.

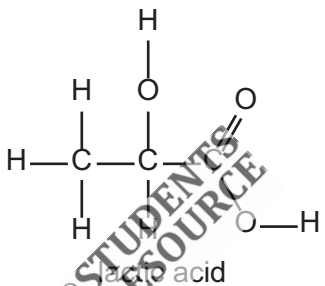
What is a property of lactic acid?

**A** It decolourises aqueous bromine rapidly.

**B** It is insoluble in water.

**C** It reduces Fehling's reagent.

**D** Two molecules react with each other in the presence of a strong acid.



Lactic acid

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**24 9701/12/M/J/10/Q21**

What will react differently with the two isomeric alcohols, $(CH_3)_3CCH_2OH$ and $(CH_3)_2CHCH_2CH_2OH$?

**A** acidified aqueous potassium manganate(VII)

**B** concentrated sulfuric acid

**C** phosphorus pentachloride

**D** sodium

**25 9701/12/M/J/10/Q27**

Which isomer of $C_4H_{10}O$ forms three alkenes on dehydration?

**A** butan-1-ol

**B** butan-2-ol

**C** 2-methylpropan-1-ol

**D** 2-methylpropan-2-ol

**26 9701/12/O/N/10/Q23**

Which sequence of reagents may be used in the laboratory to convert propan-1-ol into 2-bromopropane?

**A** concentrated sulfuric acid, followed by bromine

**B** concentrated sulfuric acid, followed by hydrogen bromide

**C** ethanolic sodium hydroxide, followed by bromine

**D** ethanolic sodium hydroxide, followed by hydrogen bromide

**27 9701/12/O/N/11/Q9**

The use of sucrose in food processing depends in part on osmotic pressure, symbol $\Pi$.

In dilute solution, $\Pi$ varies with concentration in a similar way to gas behaviour. The equation $\Pi V = nRT$ can be used, where $n$ is the number of moles of solute molecules contained in volume $V$ at temperature $T$. The number of moles of solvent molecules should be ignored.

Under aqueous acidic conditions sucrose is hydrolysed.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \rightarrow \underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} + \underset{\text{fructose}}{CH_2OH(CHOH)_3COCH_2OH}$$

What can be deduced from this hydrolysis equation?

| | the osmotic pressure | glucose and fructose are |
|---|---|---|
| **A** | decreases | optical isomers |
| **B** | decreases | structural isomers |
| **C** | increases | optical isomers |
| **D** | increases | structural isomers |



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**28 9701/12/O/N/11/Q26**

*Use of the Data Booklet is relevant to this question.*

2.30 g of ethanol were mixed with aqueous acidified potassium dichromate(VI). The desired product was collected by immediate distillation under gentle warming.

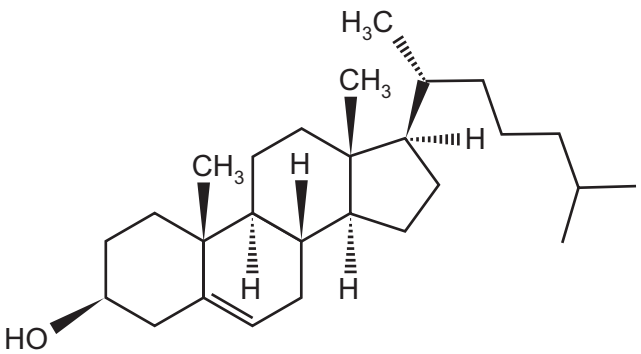
The yield of product was 70.0 %. What mass of product was collected?

**A** 1.54 g **B** 1.61 g **C** 2.10 g **D** 3.14 g

**29 9701/12/M/J/11/Q29**

This question should be answered by considering the reactions of $KMnO_4$ with different functional groups under the stated conditions.

The diagram shows the structure of the naturally-occurring molecule cholesterol.




cholesterol

Cholesterol is separately treated with

- cold, dilute acidified $KMnO_4$,
- hot, concentrated acidified $KMnO_4$.

What is the change in the **number** of chiral carbon atoms in the molecule during each reaction?

| | cold, dilute acidified $KMnO_4$ | hot, concentrated acidified $KMnO_4$ |
|---|---|---|
| **A** | +1 | 0 |
| **B** | +1 | –1 |
| **C** | +2 | 0 |
| **D** | +2 | –1 |



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**30 9701/12/M/J/12/Q30**

An organic compound will decolorise dilute acidified aqueous potassium manganate(VII) on warming, but will not decolorise bromine water.

What could the organic compound be?

**A** butane **B** ethanol **C** ethene **D** ethanoic acid

**31 9701/12/M/J/12/Q30**

An organic compound will decolorise dilute acidified aqueous potassium manganate(VII) on warming, but will not decolorise bromine water.

What could the organic compound be?

**A** butane **B** ethanol **C** ethene **D** ethanoic acid

**32 9701/11/M/J/12/Q16**

In the treatment of domestic water supplies, chlorine is added to the water to form HC O. $^{l}$

$$Cl_2(aq) + H_2O(l) \rightarrow H^+(aq) + Cl^-(aq) + HClO(aq)$$

The HC$l$O reacts further to give C$l$O$^-$ ions.

$$HClO(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + ClO^-(aq)$$

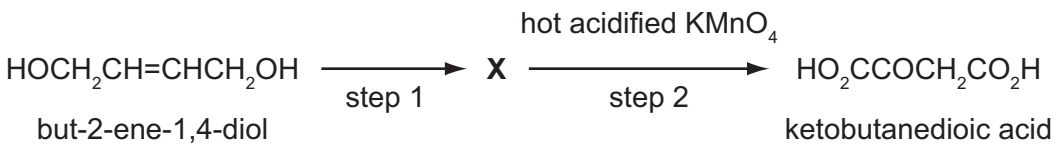
Both HC$l$O and C$l$O$^-$ kill bacteria by oxidation.

What is the change in oxidation number of chlorine when forming the C$l$O$^-$ ion from aqueous chlorine?

**A** –1 **B** 0 **C** +1 **D** +2

**33 9701/12/O/N/12/Q24**

But-2-ene-1,4-diol is converted in two steps through an intermediate **X** into ketobutanedioic acid.




What could be the reagent for step 1 and the intermediate **X**?

| | reagent for step 1 | **X** |
|---|---|---|
| **A** | cold acidified $KMnO_4$ | $HOCH_2CH_2CH(OH)CH_2OH$ |
| **B** | hot acidified $KMnO_4$ | $OHCCH(OH)CH_2CHO$ |
| **C** | steam and concentrated $H_2SO_4$ | $HOCH_2CH(OH)CH_2CH_2OH$ |
| **D** | warm acidified $K_2Cr_2O_7$ | $HO_2CCH=CHCO_2H$ |

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**34 9701/12/O/N/12/Q29**

Many, but not all, organic reactions need to be heated before reaction occurs.

Which reaction occurs at a good rate at **room** temperature (20 °C)?

**A** $CH_3OH + PCl_5 \rightarrow CH_3Cl + POCl_3 + HCl$

**B** $CH_3CH_2Br + KCN \rightarrow CH_3CH_2CN + KBr$

**C** $CH_3CH_2OH \rightarrow C_2H_4 + H_2O$

**D** $CH_3CH_2CN + 2H_2O \rightarrow CH_3CH_2CO_2H + NH_3$

**35 9701/12/O/N/12/Q30**

Compound **X**, $C_6H_{12}O$, is oxidised by acidified sodium dichromate(VI) to compound **Y**.

Compound **Y** reacts with ethanol in the presence of a little concentrated sulfuric acid to give liquid **Z**.

What is the formula of **Z**?

**A** $CH_3(CH_2)_4COCH_2CH_3$

**B** $CH_3(CH_2)_4CO_2CH_2CH_3$

**C** $CH_3CH_2CO_2(CH_2)_4CH_3$

**D** $CH_3CO_2(CH_2)_5CH_3$

**36 9701/13/M/J/13/Q25**

What is involved in the mechanism of the reaction between aqueous sodium hydroxide and 2-bromo-2-methylbutane?

**A** heterolytic bond fission, attack by an electrophile on a carbanion

**B** heterolytic bond fission, attack by a nucleophile on a carbocation

**C** homolytic bond fission, attack by an electrophile on a carbanion

**D** homolytic bond fission, attack by a nucleophile on a carbocation

**37 9701/12/M/J/13/Q20**

The compound hex-3-en-1-ol, **P**, has a strong 'leafy' smell of newly cut grass and is used in perfumery.

$CH_3CH_2CH{=}CHCH_2CH_2OH$

**P**

What is produced when **P** is treated with an excess of hot concentrated acidified $KMnO_4$?

**A** $CH_3CH_2CH(OH)CH(OH)CH_2CH_2OH$

**B** $CH_3CH_2CH{=}CHCH_2CO_2H$

**C** $CH_3CH_2CHO$ and $OCHCH_2CH_2OH$

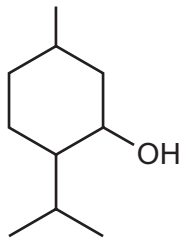
**D** $CH_3CH_2CO_2H$ and $HO_2CCH_2CO_2H$



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**38 9701/12/M/J/13/Q25**

The compound shown is menthol, a naturally-occurring alcohol found in peppermint oil.

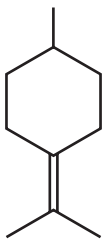



menthol

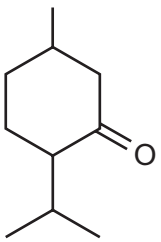
When menthol is heated with concentrated sulfuric acid it reacts. The products that form include compound **T**.

What could be the structure of compound **T**?

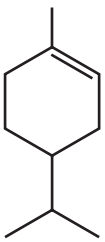
**A**



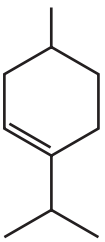
**B**




**C**



**D**



**39 9701/12/O/N/13/Q22**

The compound 'leaf alcohol' is partly responsible for the smell of new-mown grass.

$CH_3CH_2CH{=}CHCH_2CH_2OH$

leaf alcohol

What will be formed when 'leaf alcohol' is oxidised using an excess of hot, acidified $K_2Cr_2O_7$(aq)?

**A** $CH_3CH_2CH(OH)CH(OH)CH_2CO_2H$

**B** $CH_3CH_2COCOCH_2CO_2H$

**C** $CH_3CH_2CH{=}CHCH_2CO_2H$

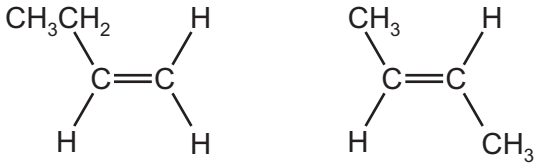
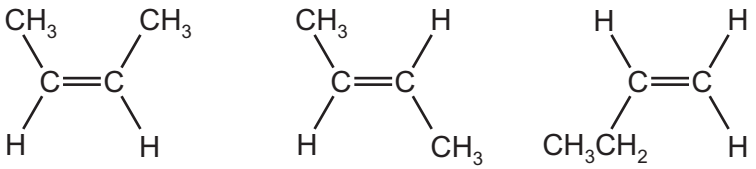
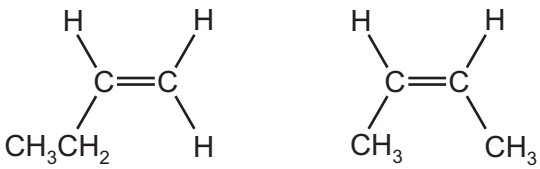
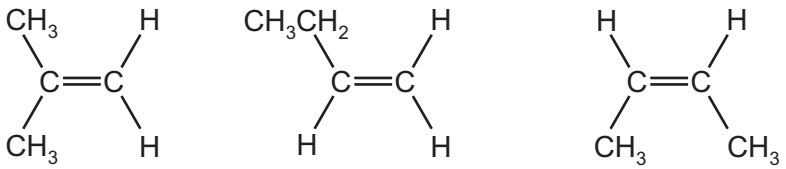
**D** $CH_3CH_2CO_2H$ and $HO_2CCH_2CO_2H$



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**40 9701/12/O/N/13/Q25**

What are the only structures formed when butan-2-ol is heated with concentrated $H_2SO_4$?

| | |
|---|---|
| **A** |  |
| **B** |  |
| **C** |  |
| **D** |  |

**41 9701/12/M/J/14/Q22**

Which alcohol has a chiral centre **and** can be oxidised to a ketone?

**A** pentan-2-ol

**B** pentan-3-ol

**C** 3-methylhexan-1-ol

**D** 3-methylhexan-3-ol



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**42 9701/12/O/N/13/Q27**

Primary alcohols can be oxidised to aldehydes using either acidified potassium dichromate(VI) or acidified potassium manganate(VII). Both these oxidising agents change colour as they are reduced.

What is the colour of each oxidising agent before and after it has reacted?

| | acidified potassium dichromate(VI) | | acidified potassium manganate(VII) | |
|---|---|---|---|---|
| | before | after | before | after |
| **A** | green | orange | purple | colourless |
| **B** | orange | green | colourless | purple |
| **C** | orange | green | purple | colourless |
| **D** | purple | colourless | orange | green |

**43 9701/12/O/N/14/Q9**

Methylpropan-1-ol and butan-1-ol are structural isomers. Methylpropan-1-ol has a lower boiling point.

Which statement explains why the boiling point of methylpropan-1-ol is lower than that of butan-1-ol?

**A** Methylpropan-1-ol cannot form hydrogen bonds.

**B** Methylpropan-1-ol has weaker covalent bonds than butan-1-ol.

**C** Methylpropan-1-ol has weaker van der Waals' forces than butan-1-ol.

**D** Methylpropan-1-ol molecules have more surface area than butan-1-ol molecules.

**44 9701/12/O/N/14/Q23**

Considering **only** structural isomers, what is the number of alcohols of each type with the formula $C_5H_{12}O$?

| | primary | secondary | tertiary |
|---|---|---|---|
| **A** | 3 | 3 | 2 |
| **B** | 4 | 2 | 2 |
| **C** | 4 | 3 | 1 |
| **D** | 5 | 2 | 1 |



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**45** **9701/12/M/J/15/Q20**

Which alcohol will react with an acidified solution of potassium dichromate(VI) to produce a ketone containing six carbon atoms?

**A** 2,2-dimethylbutan-1-ol

**B** 2-methylpentan-3-ol

**C** 3,3-dimethylpentan-2-ol

**D** 3-methylpentan-3-ol

**46** **9701/12/M/J/15/Q26**

*Use of the Data Booklet is relevant to this question.*

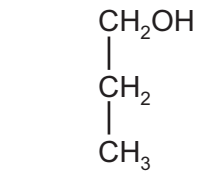
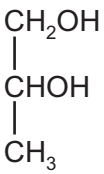
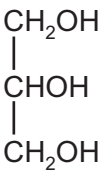
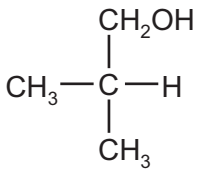
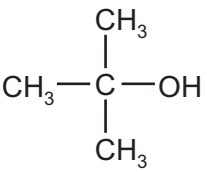
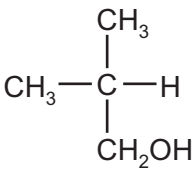
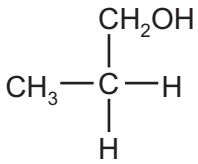
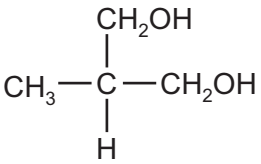
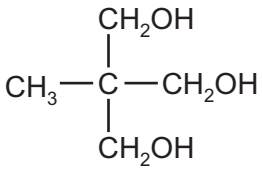
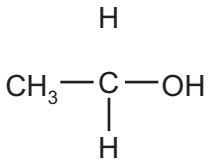
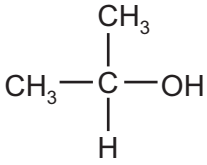
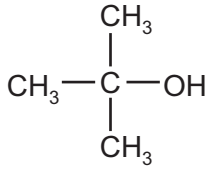
2.40 g of propan-2-ol were mixed with excess acidified potassium dichromate(VI). The reaction mixture was then boiled under reflux for twenty minutes. The organic product was then collected by distillation. The yield of product was 75.0%.

What mass of product was collected?

**A** 1.74 g **B** 1.80 g **C** 2.22 g **D** 2.32 g

**47** **9701/12/F/M/16/Q26**

Which row correctly shows a primary, a secondary and a tertiary alcohol?

| | primary | secondary | tertiary |
|---|---|---|---|
| **A** |  |  |  |
| **B** |  |  |  |
| **C** |  |  |  |
| **D** |  |  |  |



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**48 9701/11/M/J/16/Q24**

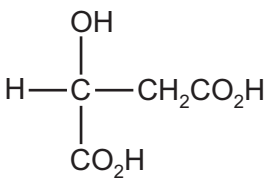
Alcohol Y gives product Z after mild oxidation. Z gives a positive result with Tollens' reagent and with 2,4-dinitrophenylhydrazine reagent.

What could be the identity of alcohol Y?

**A** butan-1-ol
**B** butan-2-ol
**C** butan-2,3-diol
**D** 2-methylbutan-2-ol

**49 9701/11/M/J/16/Q26**

Malic acid is found in apples.



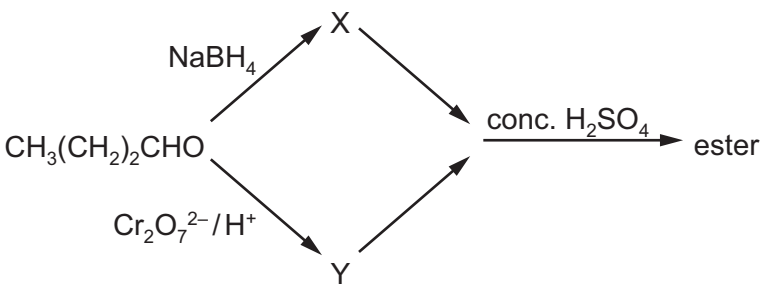
malic acid

Which reagent will react with all three –OH groups present in the malic acid molecule?

**A** ethanol in the presence of concentrated sulfuric acid
**B** potassium hydroxide
**C** sodium
**D** sodium carbonate

**50 9701/13/M/J/16/Q22**

An ester with an aroma of pineapples can be synthesised in the laboratory from butanal using this reaction scheme.




What is the structural formula of the **ester**?

**A** $CH_3(CH_2)_2CO_2(CH_2)_2CH_3$
**B** $CH_3(CH_2)_2CO_2(CH_2)_3CH_3$
**C** $CH_3(CH_2)_3CO_2(CH_2)_2CH_3$
**D** $CH_3(CH_2)_3CO_2(CH_2)_3CH_3$



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**51 9701/11/M/J/16/Q25**

A student prepares pentan-1-ol by the alkaline hydrolysis of 1-iodopentane. She gently warms the reaction mixture for 20 minutes.

$$CH_3CH_2CH_2CH_2CH_2I + OH^- \rightarrow CH_3CH_2CH_2CH_2CH_2OH + I^-$$

When the student uses 1-chloropentane to prepare the same alcohol she has to change the condition of the reaction.

Which change in condition should she use and what is the correct reason for its use?

| | change in condition | reason |
|---|---|---|
| **A** | heat under reflux | C–C*l* bond is more polar than the C–I bond |
| **B** | heat under reflux | C–C*l* bond is stronger than the C–I bond |
| **C** | room temperature | C–C*l* bond is more polar than the C–I bond |
| **D** | room temperature | C–C*l* bond is shorter than the C–I bond |

**52 9701/12/F/M/17/Q26**

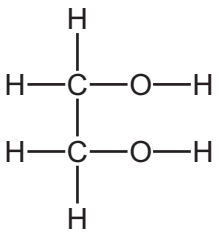
Propan-2-ol undergoes many reactions.

Which row is correct?

| | reagent added to propan-2-ol | product |
|---|---|---|
| **A** | acidified $KMnO_4$ | $CH_3CH_2CHO$ |
| **B** | $Cl_2$ | $CH_3CHClCH_3$ |
| **C** | conc. $H_2SO_4$ | $CH_3CHCH_2$ |
| **D** | methanoic acid | $HCO_2CH_2CH_2CH_3$ |

**53 69701/12/F/M/17/Q27**

Ethane-1,2-diol has the following structure.



Without breaking the C–C bond, there are five possible oxidation products.

What is the **total** number of aldehyde groups and carboxylic acid groups in these five products?

| | –CHO | –COOH |
|---|---|---|
| **A** | 3 | 3 |
| **B** | 3 | 4 |
| **C** | 4 | 3 |
| **D** | 4 | 4 |



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**54 9701/11/M/J/17/Q27**

**Q** is a compound with the molecular formula $C_4H_{10}O$. **Q** can be oxidised with acidified potassium dichromate(VI). **Q cannot** be made by reducing a carboxylic acid with $LiAlH_4$.

What is the structure of **Q**?

**A** $CH_3CH(OH)CH_2CH_3$

**B** $CH_3CH_2CH_2CH_2OH$

**C** $(CH_3)_3COH$

**D** $(CH_3)_2CHCH_2OH$

**55 9701/11/M/J/17/Q28**

A sample of 2.30 g of ethanol was mixed with an excess of aqueous acidified potassium dichromate(VI). The reaction mixture was then boiled under reflux for one hour. The required organic product was then collected by distillation. The yield of product was 60.0%.

Which mass of product was collected?

**A** 1.32 g **B** 1.38 g **C** 1.80 g **D** 3.00 g

**56 9701/12/M/J/17/Q24**

A sample of 2.76 g of ethanol was mixed with an excess of aqueous acidified potassium dichromate(VI). The reaction mixture was then boiled under reflux for one hour. The required organic product was then collected by distillation.

The yield of product was 75.0%.

Which mass of product was collected?

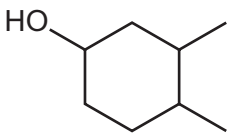
**A** 1.26 g **B** 1.98 g **C** 2.07 g **D** 2.70 g

**57 9701/12/M/J/17/Q25**

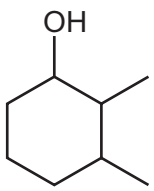
Compound X is a single, pure, optical isomer. X is heated with an excess of concentrated $H_2SO_4$. Only one organic product is formed.

What could X be?

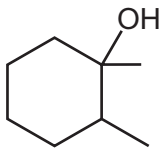
**A**



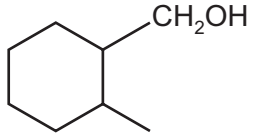

**B**




**C**




**D**




**58 9701/12/M/J/17/Q30**

Which compound, when hydrolysed, gives propanoic acid and propan-2-ol?

**A** $CH_3CH_2CO_2CH_2CH(CH_3)CH_3$

**B** $(CH_3)_2CHCO_2CH_2CH_3$

**C** $CH_3CH_2CO_2CH(CH_3)CH_3$

**D** $CH_3CH_2CH_2CO_2CH(CH_3)CH_3$

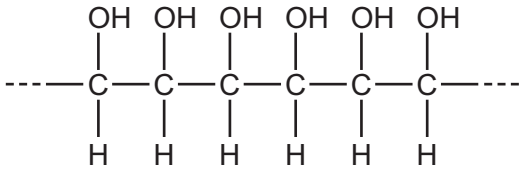
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**59 9701/13/M/J/17/Q24**

The diagram represents the structure of a polymer.



By which method might this polymer be made?

**A** polymerise ethene followed by hydration

**B** polymerise ethene followed by oxidation with cold, acidified $KMnO_4$

**C** polymerise 1,2-dichloroethene followed by hydrolysis

**D** polymerise 1,2-dichloroethene followed by oxidation with cold, acidified $KMnO_4$

**60 9701/13/M/J/17/Q26**

Which statement about butan-1-ol, butan-2-ol, and 2-methylbutan-2-ol is **not** correct?

**A** They all react with methanoic acid to form an ester.

**B** They all react with sodium.

**C** They can all be dehydrated to form an alkene.

**D** They can all be oxidised to a carbonyl compound.

**61 9701/13/M/J/17/Q27**

Which compound will react with acidified potassium dichromate(VI) **and** with alkaline aqueous iodine?

**A** $CH_3COCH_2CH_3$

**B** $CH_3CH(OH)CH_2CH_3$

**C** $CH_3CH_2CH_2CHO$

**D** $CH_3CH_2CH_2CH_2OH$

**62 9701/11/O/N/18/Q26**

Sodium reacts with 1 mol of compound Y to produce 1 mol of $H_2(g)$.

Which compound could Y be?

**A** $CH_3CH_2CH_2CH_2OH$

**B** $(CH_3)_3COH$

**C** $CH_3CH_2CH_2CO_2H$

**D** $CH_3CH(OH)CO_2H$



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**63 9701/12/O/N/18/Q26**

The reactions of four organic compounds are given in the table.

Which compound could be propan-2-ol?

| | reagent / observations | |
|---|---|---|
| | when oxidised with $Cr_2O_7^{2-}/H^+$, gives an organic product with a boiling point greater than the original compound | when added to ethanoic acid, and a few drops of conc. $H_2SO_4$, gives a sweet-smelling compound |
| **A** | no | no |
| **B** | no | yes |
| **C** | yes | no |
| **D** | yes | yes |

**64 9701/12/O/N/18/Q28**

Compound **Y** gives methanol and sodium ethanoate on treatment with aqueous sodium hydroxide.

What is the structure of **Y**?

**A** $CH_3CO_2CH_3$ **C** $HO_2CCH_2CHO$

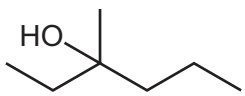
**B** $HCO_2C_2H_5$ **D** $HOCH_2CH_2COOH$

**65 9701/11/M/J/19/Q26**

Structural isomerism and stereoisomerism should be considered when answering this question.

3-methylhexan-3-ol reacts with hot, concentrated sulfuric acid to form several isomeric compounds with the molecular formula $C_7H_{14}$.

3-methylhexan-3-ol




How many isomeric compounds could be formed in this reaction?

**A** 3 **B** 4 **C** 5 **D** 6



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**66** **9701/11/M/J/19/Q27**

An organic compound T undergoes the following reactions.

- T is oxidised by hot, acidified potassium manganate(VII).
- T reacts with sodium to give hydrogen.

What could be compound T?

**A** $CH_3CH_2CH(OH)CH_3$ **C** $(CH_3)_3COH$

**B** $CH_3CH_2CH_2CHO$ **D** $CH_3CH_2COCH_3$

**67** **9701/12/M/J/19/Q24**

Alcohol W **cannot** be made by reducing a carboxylic acid with $LiAlH_4$. Alcohol W gives only one product when dehydrated with concentrated sulfuric acid.

What could be the identity of W?

**A** butan-1-ol **B** butan-2-ol **C** propan-1-ol **D** propan-2-ol

**68** **9701/11/O/N/19/Q25**

Alcohol X is oxidised to form compound Y.

The composition of Y is 54.54% carbon, 36.36% oxygen and 9.10% hydrogen. The $M_r$ of Y is 88.0.

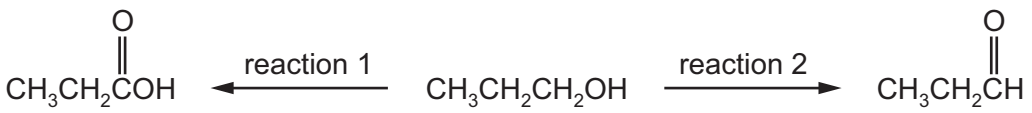
What could be the structure of alcohol X?

**A** $CH_3CH_2CH(OH)CH_3$ **C** $CH_3CH_2CH_2CH_2OH$

**B** $CH_3CH_2CH_2CH_2CH_2OH$ **D** $CH_3CH_2CH(OH)CH_2CH_3$

**69** **9701/12/O/N/19/Q24**

Propan-1-ol can be reacted with acidified potassium dichromate(VI) to form propanoic acid, reaction 1, or propanal, reaction 2.




propan-1-ol

How can the reaction be carried out to ensure that reaction 2 occurs rather than reaction 1?

**A** An excess of acidified potassium dichromate(VI) is used.

**B** An excess of concentrated sulfuric acid is added.

**C** The reaction mixture is distilled immediately after mixing.

**D** The reaction mixture is heated under reflux.



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**70** **9701/12/O/N/19/Q25**

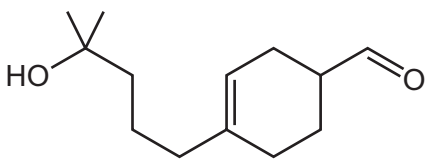
What is the smallest amount of oxygen molecules needed for the complete combustion of 40.0 g of methanol?

**A** 1.88 moles **B** 2.50 moles **C** 3.75 moles **D** 5.00 moles

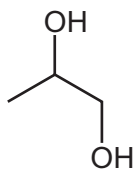
**71** **9701/12/F/M/20/Q38**

Which compounds will produce a yellow precipitate with alkaline aqueous iodine?

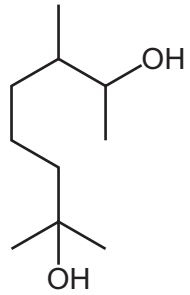
**1**




**2**




**3**




**72** **9701/11/M/J/20/Q21**

Which statement is correct?

**A** 2,2-dimethylpropanoic acid is an isomer of propyl methanoate.

**B** 2-methylbutan-2-ol is an isomer of hexan-3-ol.

**C** 3-methylbutan-2-one is an isomer of pentanal.

**D** 3,3-dimethylbutan-2-one is an isomer of pentan-3-one.

**73** **9701/11/M/J/20/Q25**

An alcohol has the molecular formula $C_5H_{12}O$. It has several isomers.

Which isomer forms a yellow precipitate with alkaline aqueous iodine?

**A** 2,2-dimethylpropan-1-ol **C** 3-methylbutan-2-ol

**B** 2-methylbutan-2-ol **D** pentan-3-ol

**74** **9701/12/M/J/20/Q24**

Which reagent could be used to distinguish between propane-1,2-diol and ethane-1,2-diol?

**A** alkaline aqueous iodine **C** ethanol and a few drops of concentrated sulfuric acid

**B** aqueous acidified dichromate(VI) **D** sodium metal

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**75 9701/13/M/J/20/Q22**

There are many non-cyclic alcohols that cannot be oxidised by warm acidified $MnO_4^-$ ions. Alcohol X is the member of this set of alcohols with the **lowest** molecular mass.

How many moles of oxygen are required for the complete combustion of 1.0 mol of alcohol X?

**A** 3.5 mol **B** 4.5 mol **C** 6.0 mol **D** 6.5 mol

**76 9701/13/M/J/20/Q26**

Which reagent reacts with **both** of the –OH groups in lactic acid, $CH_3CH(OH)CO_2H$?

**A** acidified potassium dichromate(VI)

**B** ethanol

**C** sodium

**D** sodium hydroxide



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# Organic Chemistry And Analysis

17 TOPIC

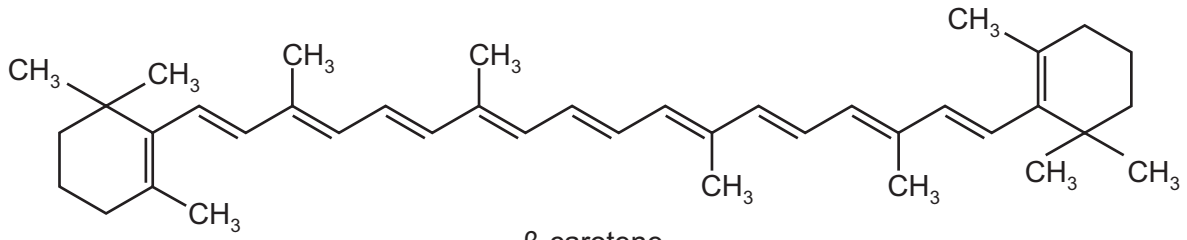
# Carbonyl Compounds



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**1 9701/12/O/N/14/Q30**

β-carotene is responsible for the orange colour of carrots.



β-carotene

β-carotene is oxidised by hot, concentrated, acidified $KMnO_4$.

When an individual molecule of β-carotene is oxidised in this way, many product molecules are formed.

How many of these product molecules contain a ketone functional group?

**A** 4 **B** 6 **C** 9 **D** 11

**2 9701/1/M/J/02/Q25**

Which compound on reaction with hydrogen cyanide produces a compound with a chiral centre?

**A** $CH_3CHO$

**B** $CH_3CH_2COCH_2CH_3$

**C** $CH_3CO_2CH_3$

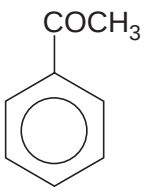
**D** HCHO

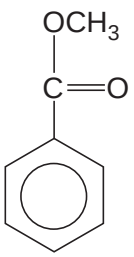
**3 9701/1/M/J/02/Q28**

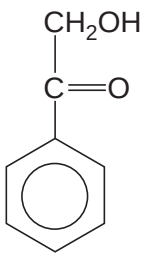
A compound **R** has all of the following properties:

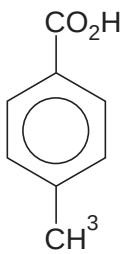
it is neutral;
it gives an orange precipitate with 2,4-dinitrophenylhydrazine;
it evolves hydrogen chloride when treated with $PCl_5$ in the cold.

What could **R** be?

**A** 

**B** 

**C** 

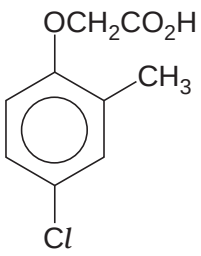
**D** 



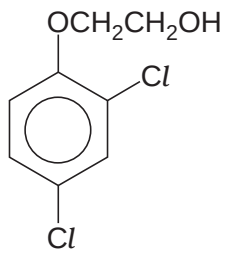
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**4 9701/1/M/J/02/Q29**

MCPA and 2,4-D are two widely-used selective weedkillers.




MCPA




2,4-D

Which reagent will distinguish MCPA from 2,4-D?

**A** acidified $AgNO_3(aq)$

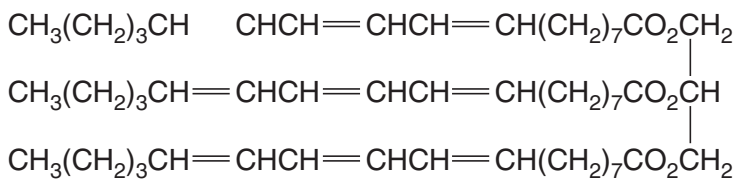
**B** Fehling's solution

**C** Na

**D** $Na_2CO_3(aq)$

**5 9701/1/M/J/03/Q2**

In the preparation of soft margarine, glyceryl trieleostearate




is suitably hydrogenated so that, on average, one of its side-chains is converted into the $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7CO_2$ residue and two side-chains are converted into the $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2$ residue.

How many moles of hydrogen are required to convert one mole of glyceryl trieleostearate into the soft margarine?

**A** 4 **B** 5 **C** 6 **D** 9

**6 9701/01/M/J/03/Q30**

The product of the reaction between propanone and hydrogen cyanide is hydrolysed under acidic conditions.

What is the formula of the final product?

**A** $CH_3CH(OH)CO_2H$

**B** $CH_3CH_2CH_2CO_2H$

**C** $(CH_3)_2CHCONH_2$

**D** $(CH_3)_2C(OH)CO_2H$



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**7 9701/01/M/J/04/Q29**

For which pair of compounds can the members be distinguished by means of Tollens' test (the use of a solution containing $Ag(NH_3)_2^+$)?

**A** $CH_3CHO$ and $CH_3COCH_3$

**B** $CH_3COCH_3$ and $C_2H_5COCH_3$

**C** $CH_3COCH_3$ and $CH_3CO_2CH_3$

**D** $CH_3CO_2H$ and $CH_3CO_2CH_3$

**8 9701/01/M/J/04/Q30**

Compound **X** changes the colour of acidified sodium dichromate(VI) from orange to green. 1 mol of **X** reacts with 2 mol of HCN(g).

What could **X** be?

**A** $CH_3COCH_2COCH_3$

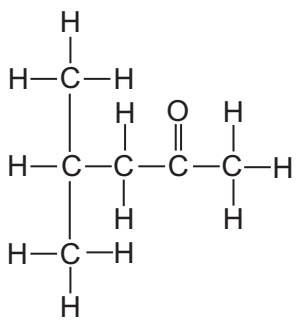
**B** $CH_3CH_2CH_2CHO$

**C** $H_2C{=}CHCH_2CHO$

**D** $OHCCH_2CH_2CHO$

**9 9701/01/O/N/04/Q29**

The solvent methylisobutylketone, MIBK, can be made from propanone.



Which reagent could distinguish this compound from an aldehyde?

**A** $Br_2(aq)$

**B** 2,4-dinitrophenylhydrazine

**C** $NaBH_4$

**D** Tollens' reagent

**10 9701/01/M/J/05/Q27**

Which compound reacts with its own oxidation product (an oxidation which involves no loss of carbon) to give a sweet-smelling liquid?

**A** propanal

**B** propanoic acid

**C** propanone

**D** propan–1–ol



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**11 9701/01/O/N/05/Q26**

In 1903 Arthur Lapworth became the first chemist to investigate a reaction mechanism. The reaction he investigated was that of hydrogen cyanide with propanone.

What do we now call the mechanism of this reaction?

**A** electrophilic addition
**B** electrophilic substitution
**C** nucleophilic addition
**D** nucleophilic substitution

**12 9701/01/M/J/05/Q27**

What is formed when propanone is refluxed with an anhydrous solution of $NaBH_4$?

**A** propanal **B** propan-1-ol **C** propan-2-ol **D** propane

**13 01/01/M/J/06/Q29**

Aldehydes and ketones are carbonyl compounds.

Which of them react both with $NaBH_4$ and with Tollens' reagent?

**A** both aldehydes and ketones
**B** aldehydes only
**C** ketones only
**D** neither aldehydes nor ketones

**14 9701/01/O/N/06/Q28**

A common industrial solvent is a mixture of propanone, $CH_3COCH_3$, and pentyl ethanoate $CH_3CO_2(CH_2)_4CH_3$.

Which reagent would have no effect on this solvent?

**A** Na(s) **B** $NaBH_4$ **C** NaOH(aq) **D** 2,4-dinitrophenylhydrazine reagent

**15 9701/01/O/N/06/Q29**

Apples, the fruit of trees of the genus *Malus*, are rich in malic acid. Malic acid may be synthesised in the laboratory in two steps.

$$NCCH_2CHO \xrightarrow{\text{step 1}} X \longrightarrow HO_2CCH_2CH(OH)CO_2H$$

| | | |
|---|---|---|
| **A** | HC*l*(aq) | HCN(g) |
| **B** | HCN, NaCN(aq/alcoholic) | $H_2SO_4$(aq) |
| **C** | $H_2SO_4$(aq) | $K_2Cr_2O_7$ / $H_2SO_4$(aq) |
| **D** | KCN(aq/alcoholic) | HC*l*(aq) |



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**16** **9701/01/M/J/07/Q27**

Which reagent gives the same visible result with propanal and with propan-2-ol?

**A** 2,4-dinitrophenylhydrazine reagent
**B** acidified potassium dichromate(VI)
**C** sodium
**D** Tollens' reagent

**17** **9701/01/M/J/07/Q28**

Compound **X** will decolourise a warm acidified solution of manganate(VII) ions and forms orange crystals on reaction with 2,4-dinitrophenylhydrazine.

What is **X**?

**A** $CH_3CH=CHCH_2OH$
**B** $CH_3COCH_2CH_3$
**C** $CH_3CH_2CH_2CHO$
**D** $CH_3CH(OH)CH_2CO_2H$

**18** **9701/01/M/J/07/Q29**

Which compound would undergo nucleophilic addition?

**A** ethene, $C_2H_4$
**B** bromoethane, $C_2H_5Br$
**C** ethanal, $CH_3CHO$
**D** ethane, $C_2H_6$

**19** **9701/01/O/N/07/Q28**

Hept-4-enal is present in cow's milk.

$$CH_3CH_2CH=CHCH_2CH_2CHO$$

hept-4-enal

What is formed when hept-4-enal is reduced with **either** hydrogen and a nickel catalyst **or** sodium borohydride?

**A** with $H_2$ / Ni $CH_3(CH_2)_5CH_2OH$
**B** with $H_2$ / Ni $CH_3(CH_2)_5CH_3$
**C** with $NaBH_4$ $CH_3(CH_2)_5CH_2OH$
**D** with $NaBH_4$ $CH_3(CH_2)_5CHO$

**20** **9701/01/O/N/07/Q29**

Which of these reactions is shown by butanone, $CH_3COCH_2CH_3$?

**A** On warming with acidified potassium dichromate(VI) the solution turns green.
**B** On heating with Fehling's reagent a red precipitate is formed.
**C** With 2,4-dinitrophenylhydrazine reagent an orange precipitate is formed.
**D** With hydrogen cyanide an aldehyde is formed.



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**21 9701/01/O/N/06/Q28**

A common industrial solvent is a mixture of propanone, $CH_3COCH_3$, and pentyl ethanoate $CH_3CO_2(CH_2)_4CH_3$.

Which reagent would have **no** reaction with this industrial solvent?

**A** HC*l*(aq) **B** HCN(aq) with a little KCN **C** Na(s) **D** $NaBH_4$

**22 9701/01/O/N/07/Q30**

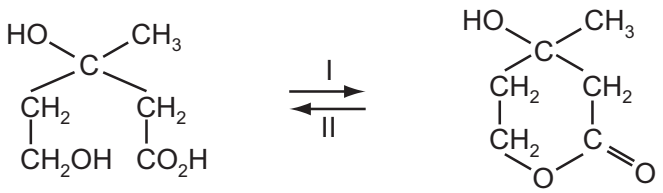
The ester $CH_3CH_2CH_2CO_2CH_3$ is responsible for the aroma of apples.

When this ester is hydrolysed by acid in the stomach, what is the empirical formula of the organic acid produced?

**A** $CH_4O$ **B** $C_2H_4O$ **C** $C_2H_4O_2$ **D** $C_3H_7O_2$

**23 9701/01/M/J/08/Q24**

Mevalonic acid, 3,5-dihydroxy-3-methylpentanoic acid, is involved in cholesterol formation in the body. It is an oil that occurs as a mixture of the two interchanging molecules shown in the diagram.




What names are used to describe the pair of interchanging reactions I and II?

**A** condensation and addition

**B** dehydrogenation and hydrogenation

**C** esterification and hydrolysis

**D** neutralisation and acidification

**24 9701/01/M/J/08/Q28**

Ethanal, $CH_3CHO$, can be reduced using an aqueous methanolic solution of $NaBH_4$ as the reducing agent.

This is a nucleophilic addition reaction.

What could be the first step of this mechanism?

**A** attack of an $H^+$ ion at the carbon atom of the carbonyl group

**B** attack of an $H^+$ ion at the oxygen atom of the carbonyl group

**C** attack of an $H^-$ ion at the carbon atom of the carbonyl group

**D** attack of an $H^-$ ion at the oxygen atom of the carbonyl group

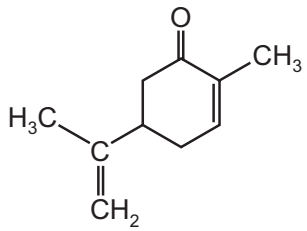
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**25 9701/01/M/J/09/Q28**

Carvone gives the characteristic flavour to caraway and spearmint.



carvone

Prolonged heating of carvone with hot concentrated acidified potassium manganate(VII) produces carbon dioxide and a compound **X**.

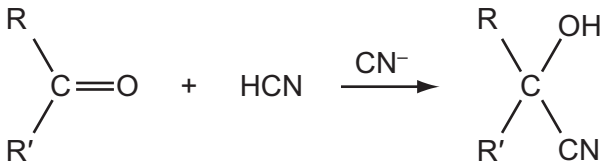
**X** contains nine carbon atoms and reacts with 2,4-dinitrophenylhydrazine reagent.

What is the maximum number of molecules of 2,4-dinitrophenylhydrazine that will react with one molecule of **X**?

**A** 1 **B** 2 **C** 3 **D** 4

**26 9701/12/O/N/09/Q27**

Cyanohydrins can be made from carbonyl compounds by generating CN ions from HCN in the presence of a weak base.




In a similar reaction, $^{-}CH_2CO_2CH_3$ ions are generated from $CH_3CO_2CH_3$ by strong bases.

Which compound can be made from an aldehyde and $CH_3CO_2CH_3$ in the presence of a strong base?

**A** $CH_3CH(OH)CO_2CH_3$

**B** $CH_3CO_2CH_2CH(OH)CH_3$

**C** $CH_3CH_2CH(OH)CH_2CO_2CH_3$

**D** $(CH_3)_2C(OH)CH_2CO_2CH_3$

**27 9701/12/M/J/10/Q22**

Which reagent will give similar results with both butanone and butanal?

**A** acidified aqueous potassium dichromate(VI)

**B** an alkaline solution containing complexed $Cu^{2+}$ ions (Fehling's solution)

**C** an aqueous solution containing $[Ag(NH_3)_2]^+$ (Tollens' reagent)

**D** 2,4-dinitrophenylhydrazine reagent

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**28** **9701/12/M/J/10/Q23**

What is formed when propanone is refluxed with a solution of $NaBH_4$?

**A** propanal **B** propan-1-ol **C** propan-2-ol **D** propane

**29** **9701/12/O/N/10/Q22**

When ethanal, $CH_3CHO$, reacts with HCN and the organic product is hydrolysed by aqueous acid, organic compound Y is formed.

When propanal, $C_2H_5CHO$, is heated under reflux with acidified potassium dichromate(VI), organic compound Z is formed.

What is the difference in relative molecular mass of compounds Y and Z?

**A** 12 **B** 14 **C** 16 **D** 17

**30** **9701/12/O/N/10/Q26**

Which pair of reagents will take part in a redox reaction?

**A** $CH_3CH_2OH$ + concentrated $H_2SO_4$

**B** $CH_3CHO$ + Tollens' reagent

**C** $CH_3CO_2C_2H_5$ + dilute $H_2SO_4$

**D** $CH_3COCH_3$ + Fehling's solution

**31** **9701/12/O/N/10/Q29**

$CH_3CH_2COCH_2CH_3$ reacts with hydrogen cyanide to form a cyanohydrin.

Which feature applies to the product?

**A** It has one chiral centre.

**B** It is formed by electrophilic addition.

**C** It is formed via a C–OH intermediate.

**D** Its formation requires the use of cyanide ions as a catalyst.

**32** **9701/01/O/N/06/Q30**

Which pair of compounds is formed when the ester $C_2H_5CO_2CH_3$ is boiled with aqueous sodium hydroxide?

**A** $C_2H_5CO_2H$ $CH_3OH$

**B** $C_2H_5CO_2Na$ $CH_3ONa$

**C** $C_2H_5CO_2Na$ $CH_3OH$

**D** $C_2H_5OH$ $CH_3CO_2Na$

**33** **9701/12/M/J/11/Q20**

Which reagent gives the same visible result with propanal and with propan-2-ol?

**A** 2,4-dinitrophenylhydrazine reagent

**B** acidified potassium dichromate(VI)

**C** sodium

**D** Tollens' reagent



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**34** **9701/12/O/N/12/Q28**

In 1903 Arthur Lapworth became the first chemist to investigate a reaction mechanism. The reaction he investigated was that of hydrogen cyanide with propanone.

What do we now call the mechanism of this reaction?

**A** electrophilic addition
**B** electrophilic substitution
**C** nucleophilic addition
**D** nucleophilic substitution

**35** **9701/12/O/N/11/Q23**

Ethanal, $CH_3CHO$, can be reduced using $NaBH_4$ in aqueous ethanol.

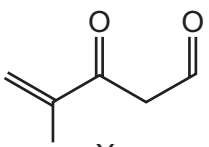
This is a nucleophilic addition reaction.

What could be the first step of this mechanism?

**A** attack of an $H^-$ ion at the carbon atom of the carbonyl group
**B** attack of an $H^-$ ion at the oxygen atom of the carbonyl group
**C** attack of an $H^+$ ion at the carbon atom of the carbonyl group
**D** attack of an $H^+$ ion at the oxygen atom of the carbonyl group

**36** **9701/12/M/J/15/Q27**

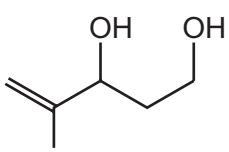
The diagram shows the structure of compound X.



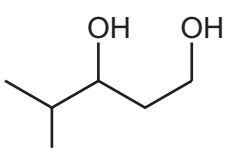

X

What is the product of the reaction between compound X and an excess of $NaBH_4$?

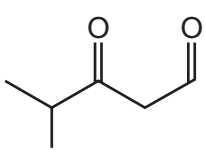
**A**



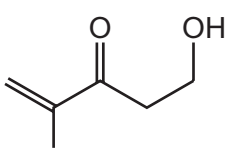

**B**




**C**




**D**




**37** **9701/01/M/J/05/Q28**

Which reagent could be used to distinguish between

$CH_3CH(OH)CH_2CHO$ and $CH_3COCH_2CH_2OH$ ?

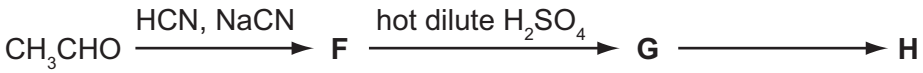
**A** acidified potassium dichromate(VI)
**B** dilute sulphuric acid
**C** 2,4–dinitrophenylhydrazine
**D** Fehling's reagent

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In a sequence of reactions, ethanal is converted into a compound **H**.




**41 9701/12/M/J/14/Q26**

**42 9701/12/M/J/11/Q30**

Which reaction would **not** give ethanoic acid as a product?

**A** heating ethanenitrile under reflux with dilute sodium hydroxide

**B** heating ethanenitrile under reflux with dilute sulfuric acid

**C** heating ethanal under reflux with acidified sodium dichromate(VI)

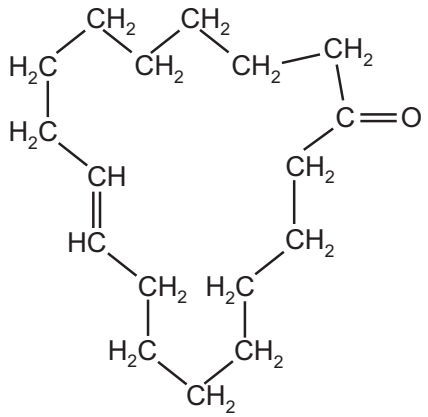
**D** heating ethanol under reflux with acidified sodium dichromate(VI)



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**43** **9701/13/M/J/15/Q24**

The naturally-occurring molecule civetone is found in a gland of the African civet cat and has been used in perfumery.



civetone

With which reagent will civetone **not** react?

**A** 2,4-dinitrophenylhydrazine reagent

**C** hydrogen bromide

**B** Fehling's reagent

**D** sodium tetrahydridoborate(III) (sodium borohydride)

**44** **9701/11/M/J/16/Q28**

Which reagent **cannot** be used to distinguish between ethanal and propanone?

**A** acidified sodium dichromate(VI) solution

**B** alkaline aqueous iodine

**C** cold acidified potassium manganate(VII) solution

**D** Fehling's reagent

**45** **9701/12/M/J/16/Q26**

Which organic compound would **not** give **either** a yellow precipitate when treated with alkaline aqueous iodine **or** an orange precipitate when treated with 2,4-dinitrophenylhydrazine reagent?

**A** propanal **B** propan-1-ol **C** propan-2-ol **D** propanone

**46** **9701/12/M/J/16/Q27**

In which reaction is the organic compound oxidised?

**A** $CH_3CH_2CH_2CHO$ + Tollens' reagent

**B** $CH_3CH_2CH_2CHO$ + $LiAlH_4$

**C** $CH_3CH_2CH_2OH$ + concentrated $H_3PO_4$

**D** $CH_3CO_2C_2H_5$ + dilute $H_2SO_4$



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**47 9701/13/M/J/16/Q27**

An unknown organic compound reacts with sodium to give a combustible gas as one product but does **not** give a yellow precipitate with alkaline aqueous iodine.

What is a possible identity of the unknown organic compound?

**A** propanal

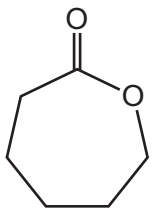
**B** propan-1-ol

**C** propan-2-ol

**D** propanone

**48 9701/13/M/J/16/Q30**

Caprolactone is a cyclic ester. It is being used increasingly for the manufacture of specialist polymers.



caprolactone

From which compound could caprolactone be made by a single reaction?

**A** $OHCCH_2CH_2CH_2CH_2CHO$

**B** $HOCH_2CH_2CH_2CH_2CH_2CH_2OH$

**C** $HOCH_2CH_2CH_2CH_2CH_2CO_2H$

**D** $HO_2CCH_2CH_2CH_2CH_2CO_2H$

**49 9701/12/F/M/17/Q28**

$CH_3CH_2COCH_2CH_3$ reacts with hydrogen cyanide to form an organic product called a cyanohydrin.

Which statement is correct?

**A** The cyanohydrin product has one chiral centre.

**B** The cyanohydrin product is formed by electrophilic addition.

**C** The cyanohydrin product is formed via an intermediate which contains a C–OH group.

**D** The formation of the cyanohydrin product requires the use of cyanide ions as a catalyst.

**50 9701/12/F/M/17/Q29**

Compound X, $CH_3CH(OH)CH(CHO)CH_3$, is heated under reflux with an excess of acidified $K_2Cr_2O_7$ to form compound Y.

Both X and Y are separately warmed with Fehling's solution and the observations noted.

What are the observations?

**A** Both X and Y give a red precipitate.

**B** Only X gives a red precipitate.

**C** Only Y gives a red precipitate.

**D** Neither X nor Y gives a red precipitate.

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**51 9701/11/M/J/17/Q25**

Diols in which both hydroxy groups are bonded to the same carbon atom spontaneously eliminate a molecule of water to produce a carbonyl compound.

Which compound is hydrolysed to form a product that gives a positive reaction with 2,4-dinitrophenylhydrazine but **not** with Fehling's reagent?

**A** 1,1-dibromopropane
**B** 1,2-dibromopropane
**C** 1,3-dibromopropane
**D** 2,2-dibromopropane

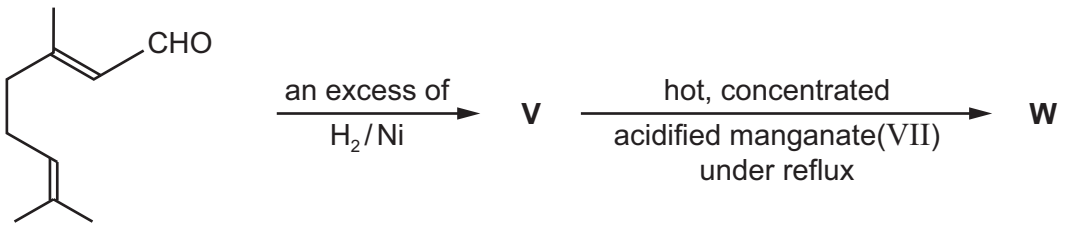
**52 9701/11/M/J/17/Q29**

Which compound gives a positive test with alkaline aqueous iodine and does **not** show optical isomerism?

**A** $CH_3COCH_2CH_2OH$
**B** $CH_3CH_2CH(OH)CHO$
**C** $CH_3COCH(OH)CH_3$
**D** $(CH_3)_2C(OH)CHO$

**53 9701/11/M/J/17/Q30**

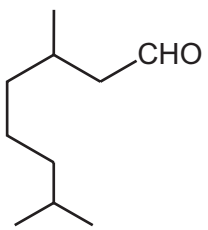
Citral is found in lemongrass oil. It can react to give compound **W**.



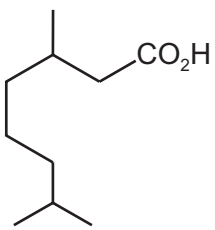

citral

What could compound **W** be?

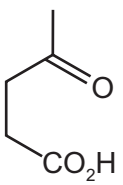
**A**



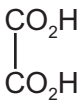

**B**




**C**




**D**




**54 9701/12/M/J/17/Q20**

A carbonyl compound **X** will react with HCN in the presence of NaCN to make a compound with $M_r$ 85. Compound **X** does **not** react with Fehling's reagent.

What is **X**?

**A** butanal **B** butanone **C** propanal **D** propanone

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**55 9701/12/M/J/17/Q27**

$H_2NNHC_6H_3(NO_2)_2$ is the structural formula of 2,4-DNPH.

Many, but not all, organic reactions need to be heated before reaction occurs.

Which reaction occurs at a good rate at room temperature (20 °C)?

**A** $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$

**B** $CH_3CH_2CH_2Br + NH_3 \rightarrow CH_3CH_2CH_2NH_2 + HBr$

**C** $CH_3CH_2OH + KBr \rightarrow CH_3CH_2Br + KOH$

**D** $(CH_3)_2CO + H_2NNHC_6H_3(NO_2)_2 \rightarrow (CH_3)_2C{=}NNHC_6H_3(NO_2)_2 + H_2O$

**56 9701/11/O/N/18/Q27**

Which compound shows optical isomerism and gives a positive test with alkaline aqueous iodine?

**A** $CH_3COCH(OH)CH_3$

**B** $CH_3COCH_2CH_2OH$

**C** $HOCH_2CH(CH_3)CHO$

**D** $(CH_3)_2C(OH)CHO$

**57 9701/11/O/N/18/Q28**

Ethanedioic acid, $HO_2CCO_2H$, is reduced using an excess of lithium aluminium hydride, $LiAlH_4$.

What is the organic product of the reaction?

**A** ethanol **B** ethane-1,2-diol **C** ethanedial, OHCCHO **D** methane

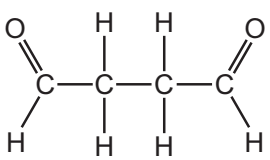
**58 9701/12/O/N/18/Q27**

Compound X has the empirical formula $C_2H_3O$.

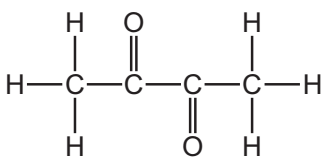
Compound X reacts with 2,4-dinitrophenylhydrazine reagent to give an orange precipitate and also decolourises warmed acidified potassium manganate(VII) solution.

What could be the identity of X?

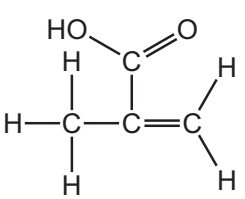
**A**



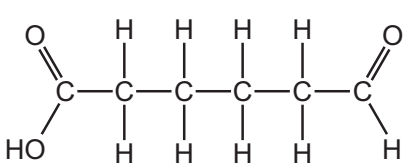
**B**



**C**



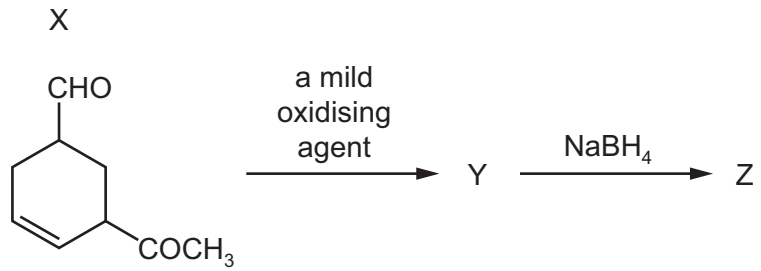
**D**





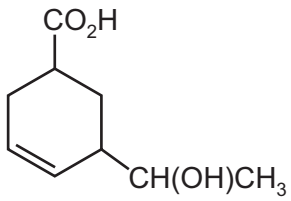
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Compound X is treated with two reagents successively, forming compound Z.

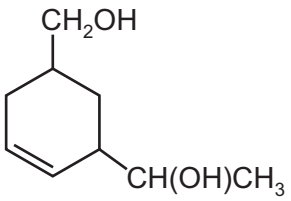



What could be Z?

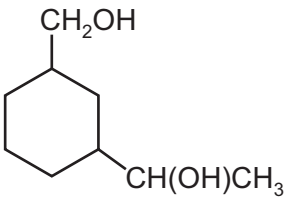
**A**

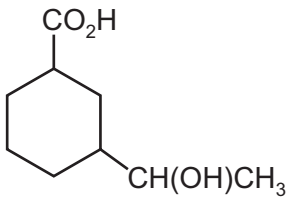



**B**



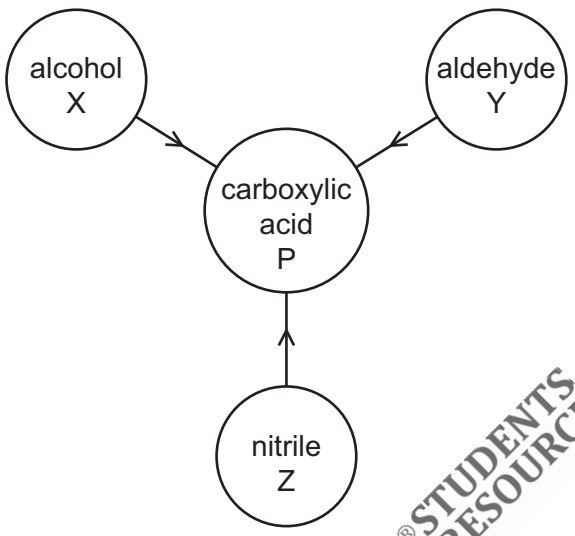

**C**




**60 9701/12/M/J/19/Q27**

**61 9701/12/M/J/19/Q28**




Which row is correct?

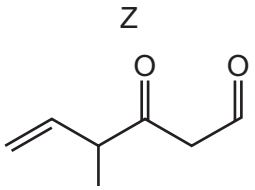
| | alcohol X is | the change in $M_r$ is greatest for |
|---|---|---|
| **A** | primary | Y to P |
| **B** | primary | Z to P |
| **C** | secondary | Y to P |
| **D** | secondary | Z to P |



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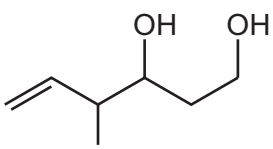
**62 9701/11/O/N/19/Q26**

The diagram shows the structure of compound Z.

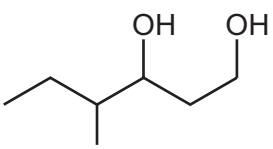



What is the product of the reaction between compound Z and an excess of $NaBH_4$?

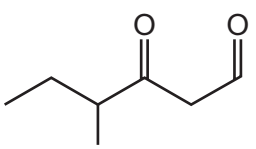
**A**



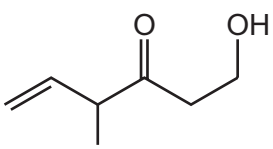

**B**




**C**




**D**




**63 9701/13/O/N/19/Q27**

Compound Q shows the following reactions.

- It gives an orange precipitate with 2,4-dinitrophenylhydrazine.
- It gives a red-brown precipitate with Fehling's reagent.
- It gives a pale yellow precipitate with alkaline aqueous iodine.

What could be the identity of Q?

**A** ethanal

**B** propan-2-ol

**C** propanal

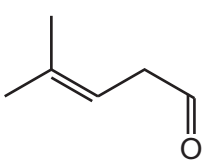
**D** propanone

**64 9701/12/O/N/19/Q26**

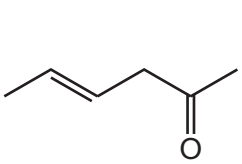
Compound X has stereoisomers and forms a precipitate when warmed with Fehling's reagent.

What could be the structure of compound X?

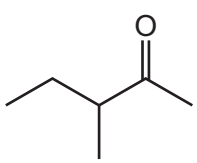
**A**



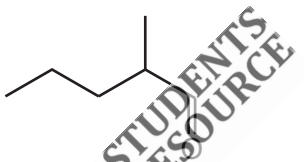

**B**




**C**




**D**



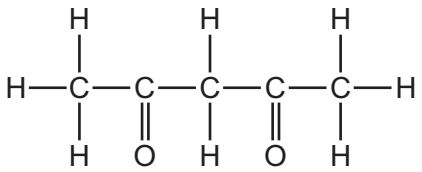
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**65 9701/12/O/N/19/Q27**

The diagram shows the structure of Y.



Two suggestions are made about Y.

1 Y can be oxidised by hot, acidified dichromate(VI) ions.

2 One mole of Y gives one mole of tri-iodomethane when it reacts with an excess of alkaline aqueous iodine.

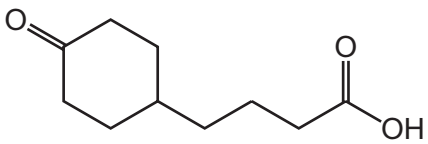
Which suggestions are correct?

**A** both 1 and 2 **B** 1 only **C** 2 only **D** neither 1 nor 2

**66 9701/12/F/M/20/Q28**

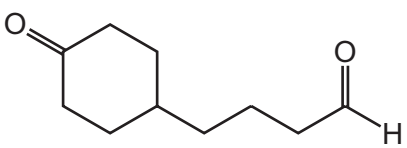
Compound X is treated with an excess of lithium aluminium hydride. The reaction is allowed to go to completion.

X

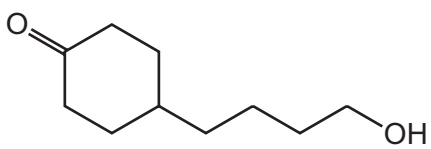


What is the structure of the organic product?

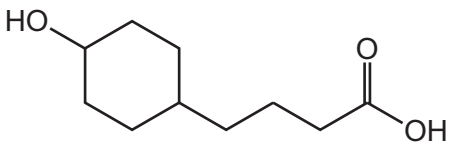
**A**



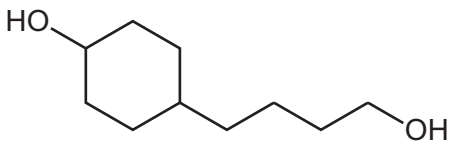
**B**



**C**



**D**



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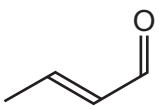


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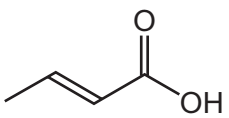
**67 9701/12/F/M/20/Q29**

What is the skeletal formula of the compound formed when $CH_3CH{=}CHCH_2OH$ is heated, under reflux, with $K_2Cr_2O_7 / H^+$?

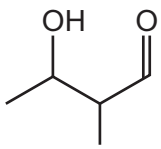
**A**



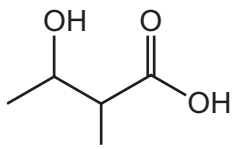

**B**




**C**

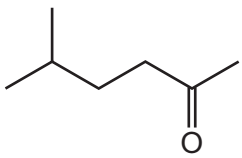



**D**




**68 9701/11/M/J/20/Q20**

The skeletal formula of compound X is shown.




Which row is correct?

| | molecular formula of X | observation on addition of X to Fehling's reagent |
|---|---|---|
| **A** | $C_7H_{14}O$ | no change |
| **B** | $C_7H_{14}O$ | red precipitate forms |
| **C** | $C_7H_{16}O$ | no change |
| **D** | $C_7H_{16}O$ | red precipitate forms |

**69 9701/11/M/J/20/Q30**

Which reaction produces an organic anion with a good yield?

**A** heating ethanenitrile under reflux with dilute sodium hydroxide

**B** heating ethanenitrile under reflux with dilute sulfuric acid

**C** heating ethane with sodium metal

**D** heating ethanol under reflux with dilute sodium hydroxide

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**70 9701/12/M/J/20/Q21**

The table shows the molecular formulae of three molecules P, Q and R. None of the molecules are cyclic.

| molecule | molecular formula |
|---|---|
| P | $CH_4O$ |
| Q | $CH_2O_2$ |
| R | $CH_2O$ |

Which molecules show a strong absorption between 1610 $cm^{-1}$ and 1750 $cm^{-1}$ in their infra-red spectra?

**A** Q only **B** R only **C** Q and R only **D** P, Q and R

**71 9701/12/M/J/20/Q22**

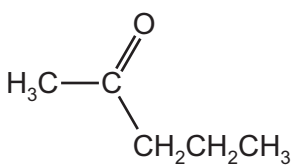
Which row correctly shows the type of mechanism of each of the two reactions?

| | $C_2H_5Br$ + KCN | $CH_3COCH_3$ + HCN |
|---|---|---|
| **A** | electrophilic substitution | electrophilic addition |
| **B** | electrophilic substitution | nucleophilic addition |
| **C** | nucleophilic substitution | electrophilic addition |
| **D** | nucleophilic substitution | nucleophilic addition |

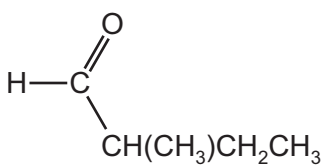
**72 9701/13/M/J/20/Q24**

Which statement about compound T and compound U is correct?

compound T




compound U




**A** T and U are stereoisomers.

**B** T can be distinguished from U by the use of alkaline aqueous iodine.

**C** T can be reduced by $LiAlH_4$ but not by $NaBH_4$.

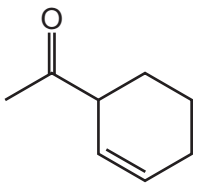
**D** U can be formed by the oxidation of 3-methylbutan-1-ol.



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**73 9701/13/M/J/20/Q30**

compound X




Which type of carbonyl group is present and how many chiral centres are there in one molecule of X?

| | carbonyl group | chiral centres |
|---|---|---|
| **A** | aldehyde | 0 |
| **B** | aldehyde | 1 |
| **C** | ketone | 0 |
| **D** | ketone | 1 |



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Organic Chemistry
And Analysis

18
TOPIC

# Carboxylic Acids and Derivatives

NIAZ AHMED AWAN 393 Airport Road | Bahria Town | Johar Town

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**1 9701/1/M/J/02/Q27**

A compound **X** has all of the following properties:

it is a liquid at room temperature and atmospheric pressure;

it does not mix completely with water;

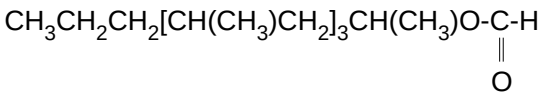
it does not decolorise acidified potassium manganate(VII).

What could **X** be?

**A** ethane **B** ethanoic acid **C** ethanol **D** ethyl ethanoate

**2 9701/1/M/J/02/Q30**

The acarid mite releases *lardolure* to attract other mites to a host: this chemical can be destroyed by hydrolysis with acid.



A simplified formula for *lardolure* may be written as $RCH(CH_3)O\text{-}\overset{\overset{O}{\|}}{C}\text{-}H$.

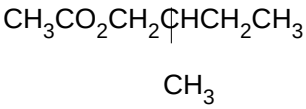
What are the products of its hydrolysis?

**A** $RCH(CH_3)CO_2H + CH_3OH$ **C** $RCH(CH_3)OH + CO_2$

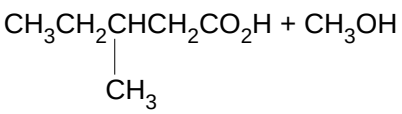
**B** $RCH(CH_3)CO_2H + HCO_2H$ **D** $RCH(CH_3)OH + HCO_2H$

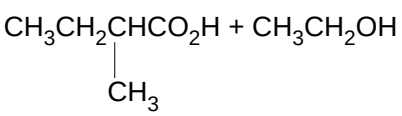
**3 9701/1/O/N/02/Q30**

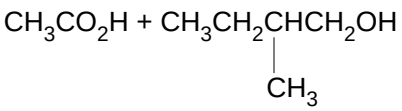
An ester with an odour of banana has the following formula.

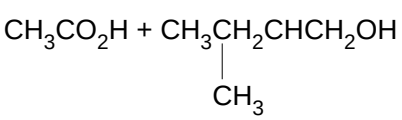


In which of the following do the substances react together, under suitable conditions, to produce this ester?

**A** 

**B** 

**C** 

**D** 



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**4 9701/1/M/J/03/Q28**

In its reaction with sodium, 1 mol of a compound **X** gives 1 mol of $H_2(g)$.

Which compound might **X** be?

**A** $CH_3CH_2CH_2CH_2OH$

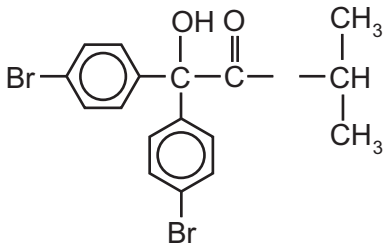
**B** $(CH_3)_3COH$

**C** $CH_3CH_2CH_2CO_2H$

**D** $CH_3CH(OH)CO_2H$

**5 9701/01/O/N/04/Q30**

*Acarol* is sold as an insecticide for use on fruit and vegetables.



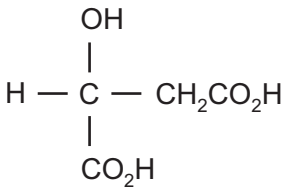

*Acarol*

The final stage of its manufacture is an esterification.
Which alcohol is used to form the ester?

**A** di(4-bromophenyl)methanol **B** methanol **C** propan-1-ol **D** propan-2-ol

**6 9701/01/M/J/05/Q26**

Malic acid occurs in apples.




malic acid

Which substance will react with all three –OH groups present in the malic acid molecule?

**A** ethanol in the presence of concentrated sulphuric acid

**B** potassium hydroxide

**C** sodium

**D** sodium carbonate

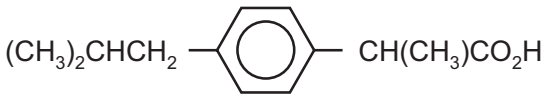
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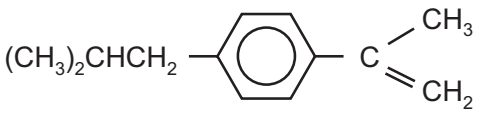
**7 9701/01/M/J/05/Q29**

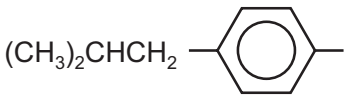
Ibuprofen is an anti-inflammatory drug.

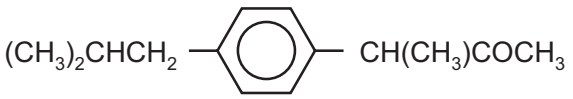


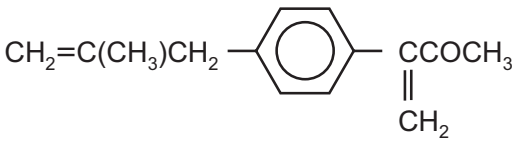

ibuprofen

What reaction would lead to its formation?

**A**  + hot concentrated $KMnO_4$

**B**  + warm acidified $K_2Cr_2O_7$

**C**  + warm $H_2SO_4(aq)$

**D**  + $H_2$ / Pt catalyst

**8 9701/01/O/N/06/Q30**

Which pair of compounds is formed when the ester $C_2H_5CO_2CH_3$ is boiled with aqueous sodium hydroxide?

| | | | | | |
|---|---|---|---|---|---|
| **A** | $C_2H_5CO_2H$ | $CH_3OH$ | **C** | $C_2H_5CO_2Na$ | $CH_3OH$ |
| **B** | $C_2H_5CO_2Na$ | $CH_3ONa$ | **D** | $C_2H_5OH$ | $CH_3CO_2Na$ |

**9 9701/01/M/J/07/Q30**

Which formula represents the organic compound formed by the reaction of propanoic acid with methanol in the presence of concentrated sulphuric acid as a catalyst?

**A** $CH_3CH_2COCH_3$

**B** $CH_3CH_2CO_2CH_3$

**C** $CH_3CO_2CH_2CH_3$

**D** $CH_3CH_2CH_2CO_2CH_3$

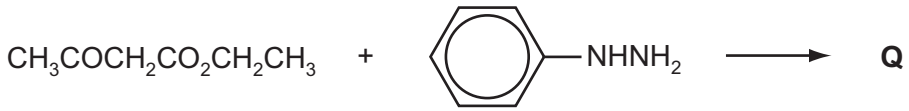
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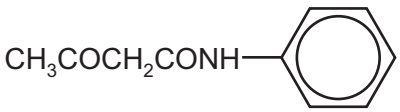
**10 9701/01/M/J/06/Q28**

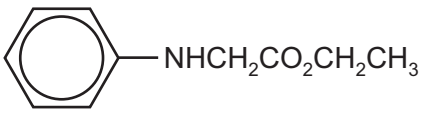
The first stage in the synthesis of antipyrine, a drug used in reducing fever, is the reaction between compound **P** and phenylhydrazine.

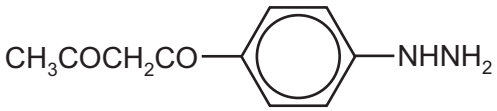


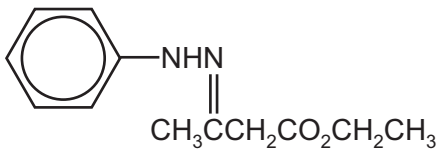

**P** phenylhydrazine

What is the product **Q** of this first stage?

**A** 

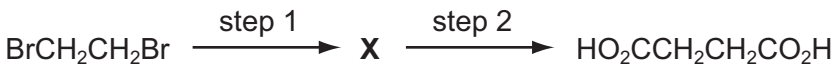

**B** 


**C** 


**D** 


**11 9701/01/O/N/07/Q26**

Butanedioic acid occurs in amber, algae, lichens, sugar cane and beets. It may be synthesised in two steps from 1,2-dibromoethane.




Which reagents could be used for this synthesis?

| | step 1 | step 2 |
|---|---|---|
| **A** | HCN(g) | HC*l*(aq) |
| **B** | $HCO_2Na$(aq) | HC*l*(aq) |
| **C** | KCN(aq/alcoholic) | $H_2SO_4$(aq) |
| **D** | NaOH(aq) | $K_2Cr_2O_7$ / $H_2SO_4$(aq) |



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**12 9701/01/O/N/08/Q26**

Ethyl phenylethanoate, $C_6H_5CH_2CO_2C_2H_5$, gives a characteristic flowery aroma to honey.

Which sequence of reagents, with heating in each case, leads to the preparation of $C_6H_5CH_2CO_2C_2H_5$ from $C_6H_5CH_2Br$?

**A** $C_6H_5CH_2Br \xrightarrow{NaOH(aq)} \underline{\quad C_2H_5COCl \quad}$

**B** $C_6H_5CH_2Br \xrightarrow{NaOH(aq)} \xrightarrow{C_2H_5CO_2H,\ conc.\ H_2SO_4}$

**C** $C_6H_5CH_2Br \xrightarrow{NaCN(alcoholic)} \xrightarrow{H^+(aq)} \xrightarrow{C_2H_5OH,\ conc.\ H_2SO_4}$

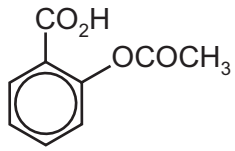
**D** $C_6H_5CH_2Br \xrightarrow{NaOH(aq)} \xrightarrow{conc.\ MnO_4,\ H_+(aq)} \xrightarrow{C_2H_5OH,\ conc.\ H_2SO_4}$

**13 9701/01/O/N/08/Q27**

The stomach wall can become sensitive to acidic compounds.

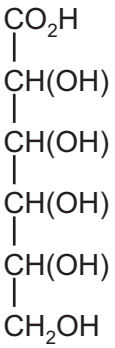
Which is the most acidic compound?

**A**



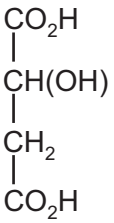
aspirin

**B**



gluconic acid

**C**



malic acid

**D**

$CH_3CH(OH)CO_2H$

lactic acid

**14 9701/01/O/N/08/Q28**

Bees use 2-methylbutyl ethanoate as an 'alarm' pheromone. When disturbed, individual bees on guard will raise their abdomen and emit the alarm pheromone, fanning their wings to aid its dispersal. This alerts other bees to a danger and makes them ready to sting when required.

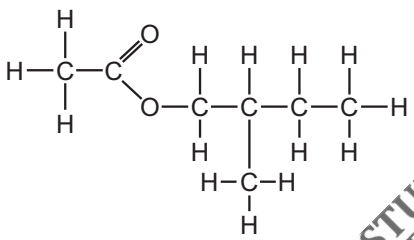
Which starting materials would be required to synthesise 2-methylbutyl ethanoate?

**A** $CH_3CH_2OH$ and $CH_3CH_2CH(CH_3)CO_2H$

**B** $CH_3CO_2H$ and $CH_3CH_2CH(CH_3)CH_2OH$

**C** $CH_3CH_2OH$ and $CH_3CH_2CH(CH_3)CH_2CO_2H$

**D** $CH_3CO_2H$ and $CH_3CH_2CH(CH_3)CH_2CO_2H$



2-methylbutyl ethanoate

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**15 9701/01/O/N/08/Q29**

The product of the reaction between propanone and hydrogen cyanide is hydrolysed under acidic conditions.

What is the formula of the final product?

**A** $CH_3CH(OH)CO_2H$ **B** $CH_3CH_2CH_2CO_2H$ **C** $(CH_3)_2CHCONH_2$ **D** $(CH_3)_2C(OH)CO_2H$

**16 9701/01/M/J/09/Q22**

Trichloroethanoic acid, $CCl_3CO_2H$, is used in cosmetic surgery to perform a 'chemical peel' to remove dead skin.

Trichloroethanoic acid can be made by reacting chlorine with ethanoic acid.

What is the mechanism of this reaction?

**A** electrophilic addition
**B** electrophilic substitution
**C** free radical addition
**D** free radical substitution

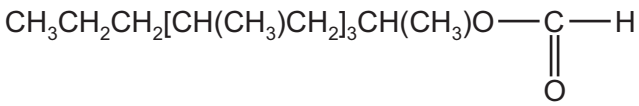
**17 9701/01/M/J/09/Q27**

Which ester is formed when the alcohol $CH_3CH_2OH$ is reacted with $CH_3CH_2CH_2CO_2H$?

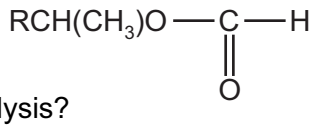
**A** ethyl propanoate
**B** ethyl butanoate
**C** propyl ethanoate
**D** butyl ethanoate

**18 9701/12/O/N/09/Q29**

The acarid mite releases *lardolure* to attract other mites to a host. This chemical can be destroyed by hydrolysis with acid.



A simplified formula for *lardolure* may be written as follows.



What are the products of its hydrolysis?

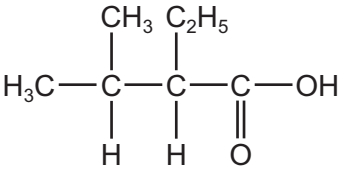
**A** $RCH(CH_3)CO_2H + CH_3OH$
**B** $RCH(CH_3)CO_2H + HCO_2H$
**C** $RCH(CH_3)OH + CO_2$
**D** $RCH(CH_3)OH + HCO_2H$



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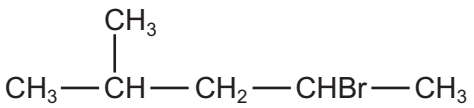
**19 9701/12/O/N/09/Q28**

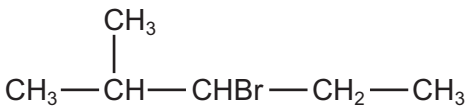
The characteristic odour of rum is attributed to the compound 2-ethyl-3-methylbutanoic acid.

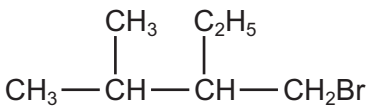


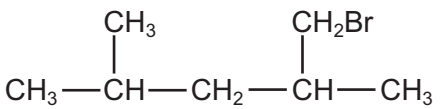
2-ethyl-3-methylbutanoic acid

Which compound will produce 2-ethyl-3-methylbutanoic acid by heating under reflux with alcoholic sodium cyanide and subsequent acid hydrolysis of the reaction product?

**A**


**B**


**C**


**D**


**20 9701/12/M/J/10/Q24**

Which compound is a product of the hydrolysis of $CH_3CO_2C_3H_7$ by boiling aqueous sodium hydroxide?

**A** $CH_3OH$ **B** $C_3H_7OH$ **C** $C_3H_7CO_2H$ **D** $C_3H_7CO_2^-Na^+$

**21 9701/12/M/J/10/Q24**

Which compound is a product of the hydrolysis of $CH_3CO_2C_3H_7$ by boiling aqueous sodium hydroxide?

**A** $CH_3OH$ **B** $C_3H_7OH$ **C** $C_3H_7CO_2H$ **D** $C_3H_7CO_2^-\ Na^+$



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**22 9701/12/O/N/10/Q24**

Esters are frequently used as solvents and as flavouring agents in fruit drinks and confectionery.

An ester $C_8H_{12}Br_2O_4$ can be prepared in low yield by the reaction shown.

$$CH_3C(Br)(CH_2Br)CO_2H + (CH_3)_2C(OH)CO_2H \rightleftharpoons C_8H_{12}Br_2O_4 + H_2O$$

What is the structural formula of the ester $C_8H_{12}Br_2O_4$?

**A** $CH_3C(Br)(CH_2Br)CO_2C(CH_3)_2CO_2H$

**B** $CH_3C(Br)(CH_2Br)CO_2C(OH)(CH_3)CO_2CH_3$

**C** $CH_3C(Br)(CH_3)CO_2C(CH_3)_2CO_2CH_2Br$

**D** $(CH_3)_2C(Br)C(CO_2H)(CH_2Br)CO_2CH_3$

**23 9701/12/M/J/11/Q28**

The ester $CH_3CH_2CH_2CO_2CH_3$ is responsible for the aroma of apples.

When this ester is hydrolysed by acid in the stomach, what is the empirical formula of the organic acid produced?

**A** $CH_2O$ **B** $CH_4O$ **C** $C_2H_4O$ **D** $C_3H_6O_2$

**24 9701/12/M/J/12/Q20**

*Use of the Data Booklet is relevant to this question.*

A sample of propyl ethanoate is hydrolysed by heating under reflux with aqueous sodium hydroxide. The two organic products of the hydrolysis are separated, purified and weighed.

Out of the total mass of products obtained, what is the percentage by mass of each product?

**A** 32.4 % and 67.6 %

**B** 38.3 % and 61.7 %

**C** 42.3 % and 57.7 %

**D** 50.0 % and 50.0 %

**25 9701/12/M/J/12/Q26**

Complete combustion of compound X gives carbon dioxide and water only. A sample of X is mixed with aqueous potassium(V) dichromate and boiled under reflux for one hour. The mixture is then distilled and the only organic substance present is collected.

The organic substance collected reacts with sodium to give hydrogen, but does not react with 2,4-dinitrophenylhydrazine reagent and does not react with ethanol in the presence of concentrated sulfuric acid to give an ester.

What can be deduced from this information?

**A** X is a carboxylic acid. **B** X is a ketone. **C** X is an alcohol. **D** X is an alkane.

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**26 9701/12/M/J/12/Q27**

A compound **Y** has the following properties.

- It is a liquid at room temperature and atmospheric pressure.
- It does not mix completely with water.
- It does not give steamy fumes with $PCl_5$.

What could **Y** be?

**A** ethane **B** ethanoic acid **C** ethanol **D** ethyl ethanoate

**27 9701/12/M/J/13/Q28**

How many of the following compounds produce a carboxylic acid on heating under reflux with hot acidified $K_2Cr_2O_7$?

$CH_3CH_2CHO$

$CH_3COCH_3$

$CH_3CH_2CH_2OH$

$CH_3CHOHCH_3$

**A** 1 **B** 2 **C** 3 **D** 4

**28 9701/12/M/J/13/Q29**

Compound **Y** has $M_r$ of 88. It does not fizz when added to a solution of sodium hydrogencarbonate. It can be hydrolysed by dilute sulfuric acid to produce two organic products with $M_r$ values of 46 and 60.

What is the identity of compound **Y**?

**A** butanoic acid **B** ethyl ethanoate **C** 3-hydroxybutanal **D** butyl methanoate

**29 9701/13/M/J/13/Q29**

How many isomeric esters, including structural isomers and stereoisomers, can be made with the molecular formula $C_5H_{10}O_2$, if methanoic acid is one of the two reactants used?

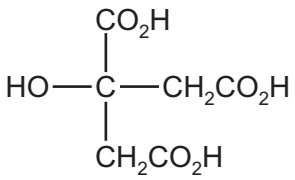
**A** 2 **B** 3 **C** 4 **D** 5



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**30 9701/12/O/N/13/Q26**

How many moles of hydrogen, $H_2$, are evolved when an excess of sodium metal is added to one mole of citric acid?

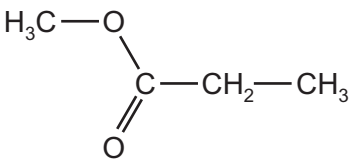


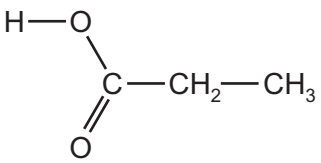
citric acid

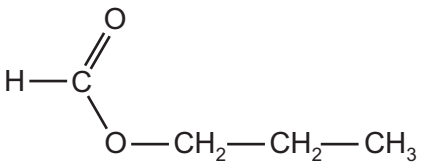
**A** 1 **B** 2 **C** 3 **D** 4

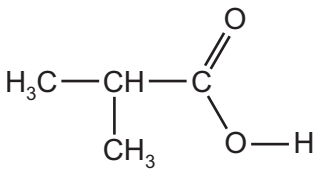
**31 9701/12/O/N/13/Q29**

How many of the compounds shown will react with aqueous sodium hydroxide to form the sodium salt of a carboxylic acid?









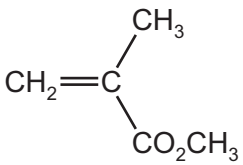
**A** 1 **B** 2 **C** 3 **D** 4

**32 9701/12/O/N/14/Q27**

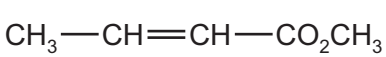
Methyl methylpropenoate is the monomer used to make *Perspex*.

Which diagram correctly shows methyl methylpropenoate?

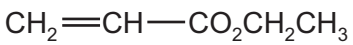
**A**



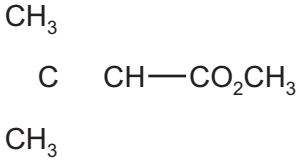
**B**



**C**



**D**



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**33 9701/12/M/J/14/Q23**

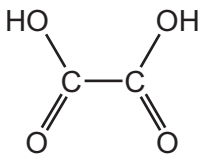
An ester of structural formula $CH_3CO_2CH_3$ is heated with an aqueous solution of sodium hydroxide.

What are the two organic products of this reaction?

**A** ethanoic acid and methanol
**B** methanoic acid and ethanol
**C** sodium ethanoate and methanol
**D** sodium methanoate and ethanol

**34 9701/12/M/J/14/Q28**

The diagram shows the structure of ethanedioic acid.




Ethanedioic acid reacts with ethanol in the presence of a few drops of concentrated sulfuric acid to form a diester. The molecular formula of the diester is $C_6H_{10}O_4$.

What is the structural formula of the diester?

**A** $CH_3CH_2CO_2CO_2CH_2CH_3$
**B** $CH_3CH_2OCOCO_2CH_2CH_3$
**C** $CH_3CH_2O_2CO_2CCH_2CH_3$
**D** $CH_3CO_2CH_2CH_2OCOCH_3$

**35 9701/12/O/N/14/Q24**

Lactic acid, $CH_3CH(OH)CO_2H$, causes pain when it builds up in muscles.

Which reagent reacts with **both** of the –OH groups in lactic acid?

**A** acidified potassium dichromate(VI)
**B** ethanol
**C** sodium
**D** sodium hydroxide

**36 9701/12/O/N/14/Q28**

The ester $CH_3CH_2CH_2CO_2CH_3$ is responsible for the aroma of apples.

When this ester is hydrolysed by acid in the stomach, what is the empirical formula of the organic acid produced?

**A** $CH_2O$ **B** $CH_4O$ **C** $C_2H_4O$ **D** $C_3H_6O_2$

**37 9701/12/M/J/15/Q29**

Citric acid is found in lemon juice.

$HO_2CCH_2C(OH)(CO_2H)CH_2CO_2H$

citric acid

What is the volume of 0.4 mol $dm^{-3}$ sodium hydroxide solution required to neutralise a solution containing 0.005 mol of citric acid?

**A** 12.5 $cm^3$ **B** 25.0 $cm^3$ **C** 37.5 $cm^3$ **D** 50.0 $cm^3$

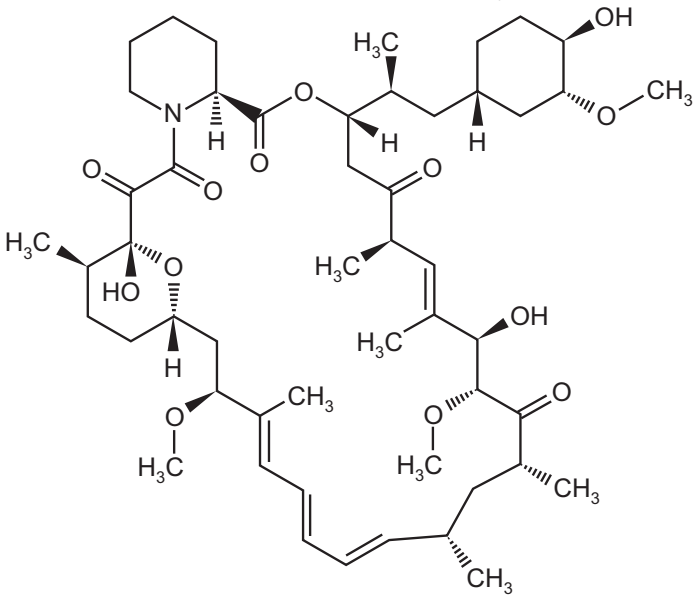
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**38 9701/12/M/J/15/Q30**

The drug *Sirolimus* is used to treat patients after kidney transplants.

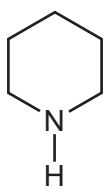


*Sirolimus*

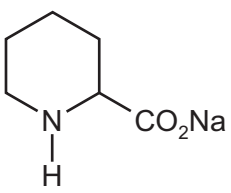
On reaction with hot aqueous sodium hydroxide, *Sirolimus* produces an equimolar mixture of two organic products.

What is the structural formula of the product with the lower relative molecular mass?

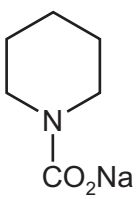
**A**



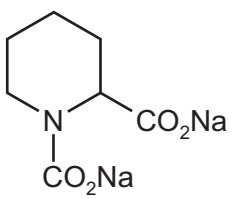
**B**



**C**

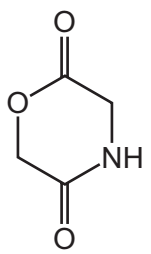


**D**



**39 9701/11/M/J/15/Q21**

The cyclic compound M is heated with dilute hydrochloric acid.



compound M

What are the products of the reaction?

**A** $HOCH_2CO_2H$ and $H_2NCH_2CO_2H$

**B** $HO_2CCH_2OH$ and $HO_2CCH_2NH_3^+$

**C** $H_2NCOCH_2OH$ and $HOCH_2CHO$

**D** $HOCH_2CONH_3^+$ and $HOCH_2CH_2O$

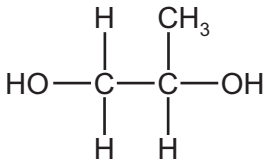
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**40 9701/12/F/M/16/Q27**

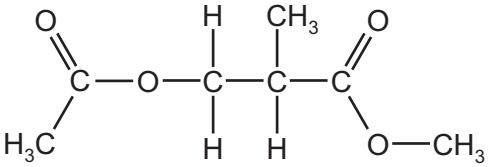
The fragrance compounds of perfumes are often dissolved in solvent **Y**, which has a molecular formula $C_7H_{12}O_4$. It is made by reacting propane-1,2-diol with ethanoic acid in the presence of an acid catalyst.



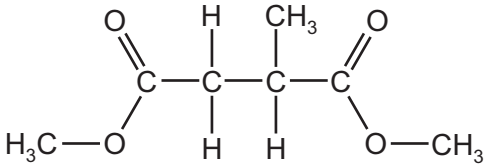
propane-1,2-diol

What is the structure of solvent **Y**?

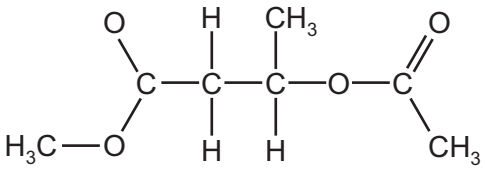
**A**



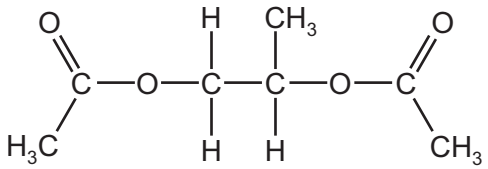
**B**



**C**



**D**



**41 9701/12/F/M/16/Q28**

Which mixture could be used to produce propyl methanoate?

**A** $CH_3CH_2CO_2H$ and $CH_3OH$

**B** $CH_3CH_2CH_2CH_2OH$ and $HCO_2H$

**C** $CH_3CH_2CH_2OH$ and $HCO_2H$

**D** $CH_3CH_2CH_2CO_2H$ and $CH_3OH$

**42 9701/12/F/M/16/Q30**

Which row of the table is correct?

| | increasing number of carbon atoms ⟶ | | | |
|---|---|---|---|---|
| **A** | ethyl methanoate | methyl propanoate | pentyl pentanoate | propyl butanoate |
| **B** | ethyl methanoate | methyl propanoate | propyl butanoate | pentyl pentanoate |
| **C** | methyl propanoate | propyl butanoate | ethyl methanoate | pentyl pentanoate |
| **D** | propyl butanoate | ethyl methanoate | pentyl pentanoate | methyl propanoate |

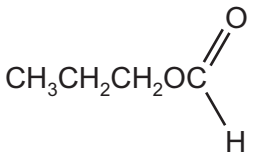
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**43 9701/11/M/J/16/Q21**

The structural formula of compound **X** is shown below.



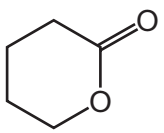
compound **X**

What is the name of compound **X** and how does its boiling point compare with that of butanoic acid?

| | name of **X** | boiling point of **X** |
|---|---|---|
| **A** | methyl propanoate | higher than butanoic acid |
| **B** | methyl propanoate | lower than butanoic acid |
| **C** | propyl methanoate | higher than butanoic acid |
| **D** | propyl methanoate | lower than butanoic acid |

**44 9701/11/M/J/16/Q27**

Cyclic esters are also known as lactones. *Delta* lactone is used as a solvent and in the manufacture of polyesters.



*delta* lactone

From which compound could *delta* lactone be made by a single reaction?

**A** $HOCH_2CH_2CH_2CH_2CHO$

**B** $HOCH_2CH_2CH_2CH_2CO_2H$

**C** $HOCH_2CH_2CH_2CH_2CH_2OH$

**D** $HOCH_2CH_2CH_2CH_2CH_2CO_2H$

**48 9701/11/M/J/16/Q29**

The ester $CH_3CH_2CH_2CO_2CH_2CH(CH_3)_2$ was hydrolysed under acidic conditions.

What are the organic products of this hydrolysis?

**A** butanoic acid and 2-methylpropan-1-ol

**B** butanoic acid and 2-methylpropan-2-ol

**C** butan-1-ol and 2-methylpropanoic acid

**D** propanoic acid and 2-methylpropan-1-ol



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**46 9701/12/M/J/16/Q25**

Malic acid is found in apples.

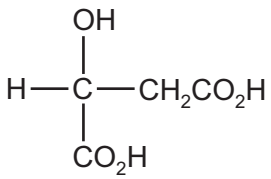
Which reagent will react with only one of the –OH groups in the malic acid molecule?

**A** ethanoic acid in the presence of concentrated sulfuric acid

**B** sodium

**C** sodium hydrogen carbonate

**D** sodium hydroxide




malic acid

**47 9701/12/M/J/16/Q26**

Which organic compound would **not** give **either** a yellow precipitate when treated with alkaline aqueous iodine **or** an orange precipitate when treated with 2,4-dinitrophenylhydrazine reagent?

**A** propanal **B** propan-1-ol **C** propan-2-ol **D** propanone

**48 9701/12/M/J/16/Q28**

How many of the following compounds produce a carboxylic acid on heating under reflux with an excess of hot acidified $K_2Cr_2O_7$?

$CH_3CH_2CHO$ $CH_3CH_2CH_2OH$

$CH_3COCH_3$ $CH_3CH(OH)CH_3$

**A** 1 **B** 2 **C** 3 **D** 4

**49 9701/12/M/J/16/Q30**

Compound X, $C_4H_8O_2$, has an unbranched carbon chain. An aqueous solution of X has an approximate pH of 3.

Compound Y, $C_3H_8O$, is a secondary alcohol.

X and Y are reacted together in the presence of a little concentrated sulfuric acid to form Z as the major organic product. What is the structural formula of Z?

**A** $(CH_3)_2CHCO_2CH_2CH_2CH_3$

**B** $CH_3(CH_2)_2CO_2CH(CH_3)_2$

**C** $CH_3(CH_2)_2CO_2(CH_2)_2CH_3$

**D** $(CH_3)_2CHCO_2CH(CH_3)_2$

**50 9701/13/M/J/16/Q29**

The ester, $CH_3CH_2CO_2CH_3$, is hydrolysed by boiling with aqueous sodium hydroxide.

Which compound is one of the products?

**A** ethanol **B** propan-1-ol **C** sodium methanoate **D** sodium propanoate

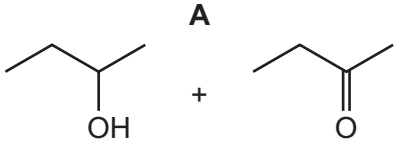
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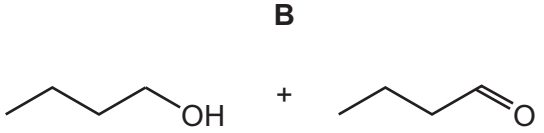
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Which two compounds can react together to produce an ester?

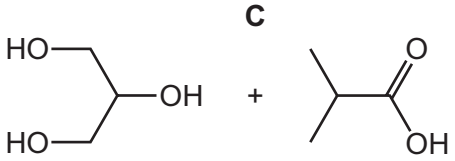
**A**



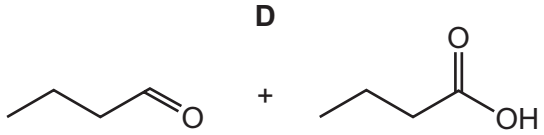
**B**



**C**



**D**



Lactide is an intermediate in the manufacture of a synthetic fibre.

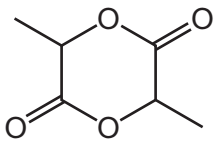
Which compound, on heating with an acid catalyst, can produce lactide?

**A** hydroxyethanoic acid

**B** 2-hydroxybutanoic acid

**C** 2-hydroxypropanoic acid

**D** 3-hydroxypropanoic acid



lactide

A carboxylic acid, P, has no possible chain isomers. It reacts with an alcohol, Q, that has only one positional isomer.

What could be the ester formed from a reaction between P and Q?

**A** butyl propanoate

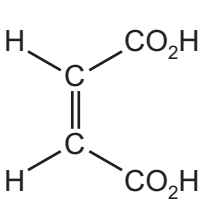
**B** ethyl butanoate

**C** pentyl ethanoate

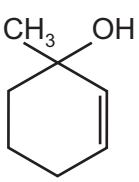
**D** propyl pentanoate

Which compound is chiral and reacts with $Na_2CO_3$ to give $CO_2$?

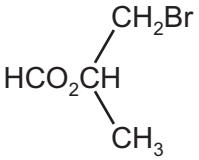
**A**



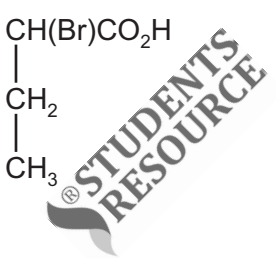
**B**



**C**



**D**





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**55 9701/13/M/J/17/Q23**

Carboxylic acids may be prepared by several different methods.

In which reaction would propanoic acid be formed?

**A** adding ammonium propanoate to dilute sulfuric acid

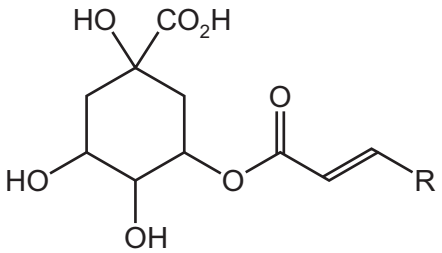
**B** heating ethyl propanoate with aqueous sodium hydroxide

**C** heating propan-2-ol with acidified potassium manganate(VII) under reflux

**D** heating propyl ethanoate with dilute sulfuric acid

**56 9701/13/M/J/17/Q28**

Chlorogenic acid is found in green coffee beans and is used in treatments for weight loss.

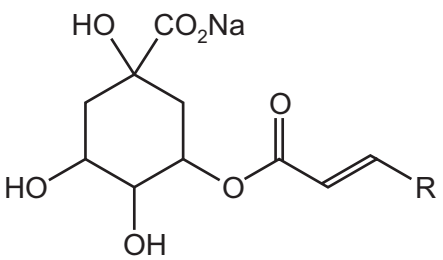



chlorogenic acid

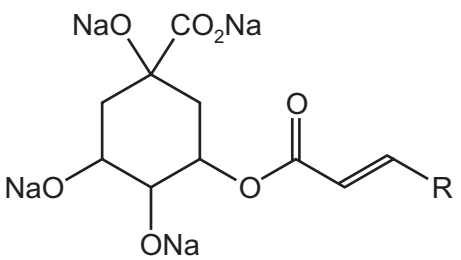
$R = C_6H_5O_2$ and takes no part in the reaction with sodium carbonate.

What is produced in good yield when chlorogenic acid is treated with an excess of sodium carbonate solution at room temperature?

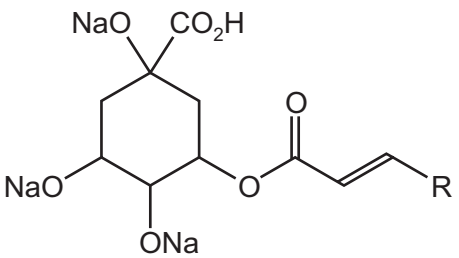
**A**



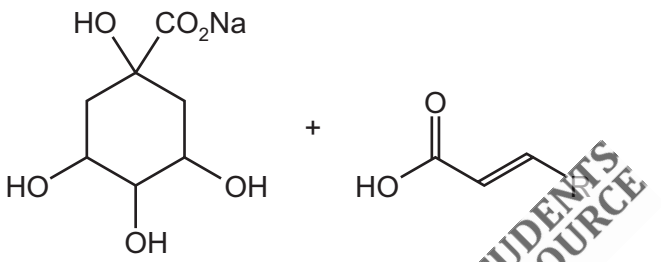

**B**




**C**




**D**






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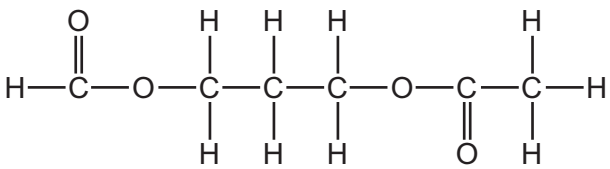
**57 9701/13/M/J/17/Q30**

How many esters with the molecular formula $C_5H_{10}O_2$ can be made by reacting a **primary** alcohol with a carboxylic acid?

**A** 4 **B** 5 **C** 6 **D** 8

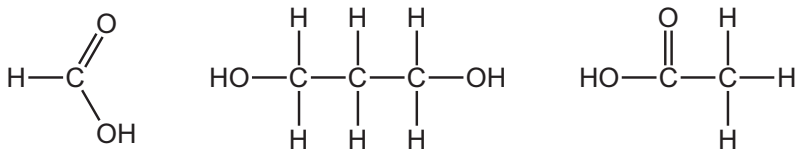
**58 9701/11/O/N/18/Q29**

The diester shown can be hydrolysed by heating with an excess of aqueous sodium hydroxide.

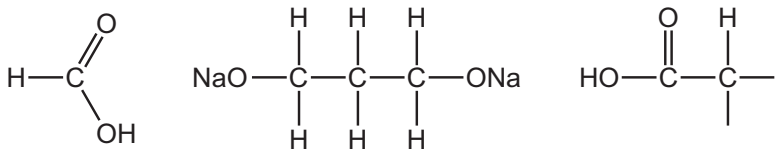


What would the products of this reaction be?

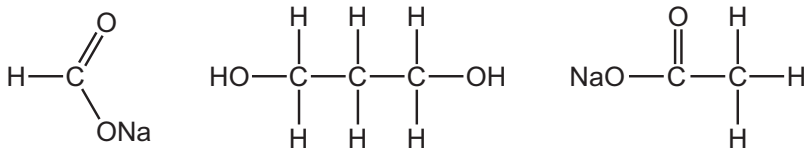
**A**



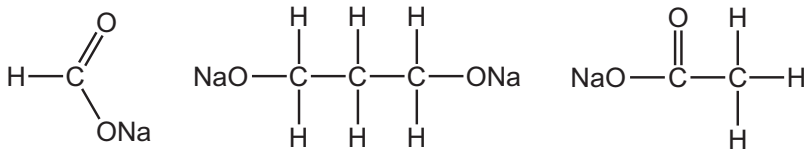
**B**



**C**



**D**



**59 9701/12/O/N/18/Q29**

Which compound can be used to make propanoic acid by treatment with a single reagent?

**A** $CH_2$=$CHCH_2CH_3$ **C** $CH_3CH(OH)CN$

**B** $CH_3CH_2CH_2CN$ **D** $CH_3CH(OH)CH_3$



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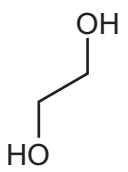
**60 9701/12/F/M/19/Q29**

1 mole of each of the following four compounds is reacted separately with:

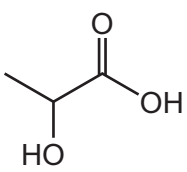
- an excess of sodium
- an excess of sodium carbonate.

Which compound produces the same volume of gas with each of the **two** reagents?

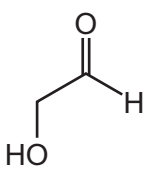
**A**



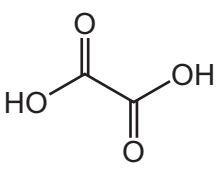

**B**




**C**




**D**




**61 9701/12/F/M/19/Q30**

An infra-red spectrum shows a broad peak at 3000 $cm^{-1}$ and a strong peak at 1710 $cm^{-1}$.

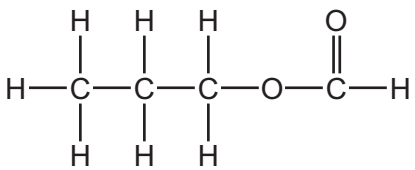
Which substance could have produced this spectrum?

**A** methyl propanoate **B** propan-2-ol **C** propanoic acid **D** propanone

**62 9701/12/M/J/19/Q29**

One molecule of compound R is shown.

compound R




What is the name of compound R and how does its boiling point compare with that of butanoic acid?

| | name of R | boiling point of R |
|---|---|---|
| **A** | methyl propanoate | higher than butanoic acid |
| **B** | methyl propanoate | lower than butanoic acid |
| **C** | propyl methanoate | higher than butanoic acid |
| **D** | propyl methanoate | lower than butanoic acid |

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**63 9701/11/O/N/19/Q28**

Tartaric acid, $HO_2CCH(OH)CH(OH)CO_2H$, is found in many plants.

A sample of tartaric acid reacts with an excess of $LiAlH_4$ to form the organic product J.

What happens when NaOH(aq) is added to separate samples of tartaric acid and J?

**A** Both tartaric acid and J react.

**B** Only tartaric acid reacts.

**C** Only J reacts.

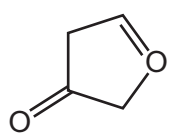
**D** Neither tartaric acid nor J react.

**64 9701/13/O/N/19/Q29**

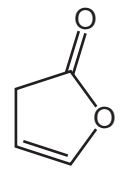
When $CH_2(OH)CH{=}CHCO_2H$ is warmed with a little concentrated sulfuric acid, a cyclic compound is formed.

What is the skeletal formula of the cyclic compound?

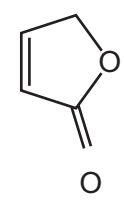
**A**



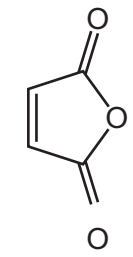
**B**



**C**



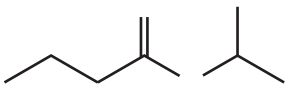
**D**



**65 9701/12/O/N/19/Q28**

Esters can be prepared by the reaction of a carboxylic acid with an alcohol in the presence of concentrated sulfuric acid.

Which row gives the correct names of the reagents that would be suitable to prepare ester Z?



| | alcohol | carboxylic acid |
|---|---|---|
| **A** | butan-1-ol | methyl propanoic acid |
| **B** | propan-1-ol | butanoic acid |
| **C** | propan-2-ol | butanoic acid |
| **D** | propan-2-ol | propanoic acid |

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**66 9701/12/O/N/19/Q29**

Compound Q can be hydrolysed by HC$l$(aq). The two products of this hydrolysis have the same empirical formula.

What could Q be?

**A** $CH_3CO_2CH_2CH_2OH$

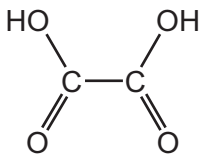
**B** $CH_3CO_2CH_2CH_2CO_2H$

**C** $CH_3CH_2CO_2CH_2CH_2CH_3$

**D** $CH_3CH_2CH(OH)CH(OH)CH_2CH_3$

**67 9701/12/F/M/20/Q22**

The diagram shows the structure of ethanedioic acid.




Ethanedioic acid reacts with ethanol in the presence of a few drops of concentrated sulfuric acid to form a diester. The molecular formula of the diester is $C_6H_{10}O_4$.

What is the structural formula of the diester?

**A** $CH_3CH_2CO_2CO_2CH_2CH_3$

**B** $CH_3CH_2OCOCO_2CH_2CH_3$

**C** $CH_3CH_2O_2CO_2CCH_2CH_3$

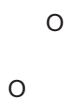
**D** $CH_3CO_2CH_2CH_2OCOCH_3$

**68 9701/11/M/J/20/Q26**

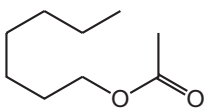
When compound X is heated under reflux with aqueous sodium hydroxide solution two products are formed: sodium ethanoate and hexan-1-ol.

What is compound X?

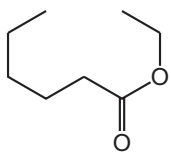
**A**



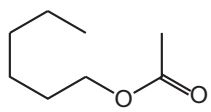

**B**




**C**




**D**




**69 9701/12/M/J/20/Q23**

Ester X is shown.

ester X

$CH_3CO_2(CH_2)_7CH_3$

Ester X is hydrolysed using aqueous sodium hydroxide.

What is the molecular formula of one of the products?

**A** $C_2H_4O_2$ **B** $C_2H_3O_2Na$ **C** $C_8H_{16}O$ **D** $C_8H_{17}O_2Na$

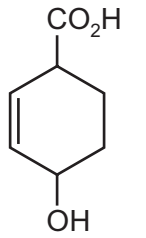


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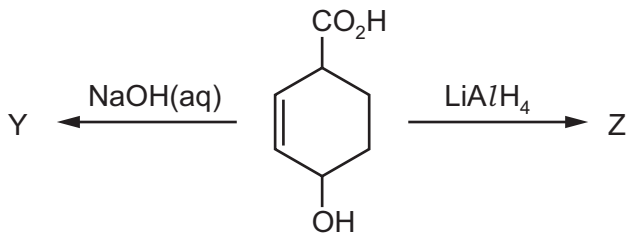
**70 9701/12/M/J/20/Q20**

Compound X is shown.

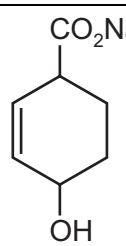
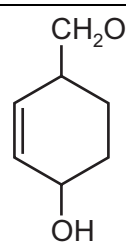
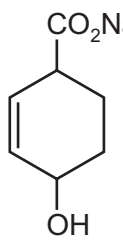
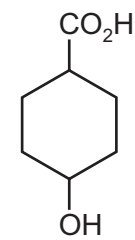
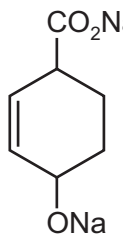
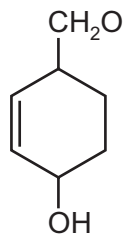
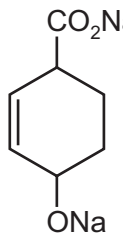
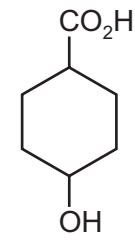
compound X




X is treated separately with NaOH(aq) and LiA$l$H$_4$ to give Y and Z.




What are Y and Z?

| | Y | Z |
|---|---|---|
| **A** |   |   |
| **B** |   |   |
| **C** |   |   |
| **D** |   |   |

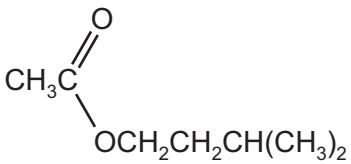


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**71 9701/13/M/J/20/Q21**

Ester P has the following structural formula.

ester P




Which compounds are produced when P is hydrolysed using dilute hydrochloric acid?

**A** $CH_3COCl$ and $(CH_3)_2CHCH_2CH_2OH$

**B** $CH_3CH_2OH$ and $(CH_3)_2CHCH_2CO\ H$

**C** $CH_3CO_2H$ and $(CH_3)_2CHCH_2CO_2H$

**D** $CH_3CO_2H$ and $(CH_3)_2CHCH_2CH_2OH$

**72 9701/13/M/J/20/Q23**

Butanoic acid can be produced from 1-bromopropane in two steps using reagents V and W as shown.

1-bromopropane $\xrightarrow{\text{reagent V}}$ compound Q $\xrightarrow{\text{reagent W}}$ butanoic acid

What could be reagents V and W?

| | V | W |
|---|---|---|
| **A** | KCN in ethanol | $HCl$(aq) |
| **B** | KCN in ethanol | NaOH(aq) |
| **C** | $NH_3$ in ethanol | $HCl$(aq) |
| **D** | NaOH(aq) | $H^+ / Cr_2O_7^{2-}$(aq) |

**73 9701/13/M/J/20/Q29**

The ester ethyl methanoate is prepared in a school laboratory by reacting a carboxylic acid with an alcohol.

During the reaction, only 50.0% of the alcohol is converted into the ester.

Which mass of alcohol is needed to prepare 10.0 g of the ester?

**A** 3.11 g **B** 8.65 g **C** 12.4 g **D** 32.2 g



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## TOPIC 1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | A | 16 | A | 31 | D | 46 | A |
| 2 | B | 17 | D | 32 | D | 47 | D |
| 3 | A | 18 | C | 33 | D | 48 | A |
| 4 | D | 19 | C | 34 | A | 49 | D |
| 5 | C | 20 | D | 35 | C | 50 | D |
| 6 | C | 21 | B | 36 | A | 51 | A |
| 7 | D | 22 | D | 37 | D | 52 | A |
| 8 | B | 23 | C | 38 | A | 53 | A |
| 9 | D | 24 | A | 39 | C | 54 | A |
| 10 | B | 25 | B | 40 | C | 55 | C |
| 11 | C | 26 | D | 41 | A | 56 | B |
| 12 | C | 27 | D | 42 | C | 57 | D |
| 13 | A | 28 | C | 43 | C | | |
| 14 | A | 29 | B | 44 | B | | |
| 15 | C | 30 | B | 45 | A | | |

## TOPIC 2

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 13 | C | 25 | C | 37 | B | 49 | B | 61 | D |
| 2 | C | 14 | C | 26 | D | 38 | A | 50 | B | 62 | C |
| 3 | C | 15 | D | 27 | D | 39 | A | 51 | B | 63 | C |
| 4 | A | 16 | B | 28 | D | 40 | B | 52 | D | | |
| 5 | C | 17 | A | 29 | B | 41 | D | 53 | A | | |
| 6 | C | 18 | D | 30 | C | 42 | B | 54 | A | | |
| 7 | C | 19 | C | 31 | C | 43 | C | 55 | B | | |
| 8 | C | 20 | B | 32 | A | 44 | D | 56 | A | | |
| 9 | B | 21 | A | 33 | D | 45 | B | 57 | D | | |
| 10 | C | 22 | D | 34 | A | 46 | C | 58 | B | | |
| 11 | C | 23 | A | 35 | C | 47 | C | 59 | C | | |
| 12 | B | 24 | A | 36 | B | 48 | D | 60 | C | | |

## TOPIC 3

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 16 | A | 31 | B | 46 | A | 61 | D |
| 2 | A | 17 | C | 32 | C | 47 | A | 62 | C |
| 3 | C | 18 | B | 33 | C | 48 | B | 63 | B |
| 4 | A | 19 | D | 34 | C | 49 | C | 64 | C |
| 5 | D | 20 | A | 35 | B | 50 | C | 65 | C |
| 6 | A | 21 | D | 36 | D | 51 | D | 66 | C |
| 7 | C | 22 | D | 37 | B | 52 | C | 67 | D |
| 8 | C | 23 | C | 38 | D | 53 | C | 68 | B |
| 9 | D | 24 | D | 39 | C | 54 | C | 69 | C |
| 10 | B | 25 | C | 40 | A | 55 | C | 70 | A |
| 11 | D | 26 | C | 41 | C | 56 | C | 71 | C |
| 12 | B | 27 | C | 42 | B | 57 | B | 72 | B |
| 13 | C | 28 | B | 43 | D | 58 | D | 73 | A |
| 14 | C | 29 | A | 44 | D | 59 | B | 74 | A |
| 15 | B | 30 | D | 45 | A | 60 | A | 75 | B |

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## TOPIC 4

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 11 | A | 21 | D | 31 | A | 41 | B |
| 2 | A | 12 | A | 22 | C | 32 | C | 42 | C |
| 3 | A | 13 | D | 23 | A | 33 | C | 43 | B |
| 4 | C | 14 | C | 24 | B | 34 | D | 44 | C |
| 5 | C | 15 | D | 25 | D | 35 | D | 45 | B |
| 6 | D | 16 | B | 26 | A | 36 | C | 46 | D |
| 7 | C | 17 | A | 27 | D | 37 | A | 47 | D |
| 8 | C | 18 | C | 28 | D | 38 | B | 48 | B |
| 9 | D | 19 | D | 29 | D | 39 | B | 49 | A |
| 10 | A | 20 | C | 30 | C | 40 | A | | |

## TOPIC 5

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 16 | B | 31 | D | 46 | B | 61 | B | 76 | C |
| 2 | A | 17 | C | 32 | B | 47 | B | 62 | C | 77 | C |
| 3 | C | 18 | B | 33 | B | 48 | B | 63 | D | 78 | A |
| 4 | A | 19 | C | 34 | A | 49 | B | 64 | B | 79 | D |
| 5 | C | 20 | D | 35 | D | 50 | B | 65 | C | | |
| 6 | D | 21 | D | 36 | D | 51 | A | 66 | D | | |
| 7 | B | 22 | B | 37 | A | 52 | B | 67 | B | | |
| 8 | D | 23 | C | 38 | B | 53 | B | 68 | C | | |
| 9 | C | 24 | B | 39 | C | 54 | B | 69 | D | | |
| 10 | A | 25 | B | 40 | A | 55 | C | 70 | D | | |
| 11 | A | 26 | D | 41 | B | 56 | B | 71 | B | | |
| 12 | B | 27 | C | 42 | B | 57 | B | 72 | A | | |
| 13 | D | 28 | C | 43 | A | 58 | D | 73 | D | | |
| 14 | C | 29 | A | 44 | B | 59 | A | 74 | D | | |
| 15 | C | 30 | A | 45 | A | 60 | B | 75 | B | | |

## TOPIC 6

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | B | 16 | A | 31 | C | 46 | A |
| 2 | B | 17 | B | 32 | D | 47 | D |
| 3 | A | 18 | C | 33 | A | 48 | D |
| 4 | A | 19 | B | 34 | C | 49 | D |
| 5 | A | 20 | D | 35 | A | 50 | C |
| 6 | D | 21 | C | 36 | C | 51 | B |
| 7 | C | 22 | B | 37 | A | 52 | C |
| 8 | B | 23 | D | 38 | B | 53 | D |
| 9 | C | 24 | A | 39 | A | 54 | B |
| 10 | B | 25 | B | 40 | B | 55 | C |
| 11 | A | 26 | D | 41 | C | | |
| 12 | D | 27 | A | 42 | D | | |
| 13 | B | 28 | B | 43 | B | | |
| 14 | D | 29 | C | 44 | B | | |
| 15 | D | 30 | C | 45 | B | | |

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## TOPIC 7

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 13 | C | 25 | A | 37 | A | 49 | C | 61 | A |
| 2 | B | 14 | C | 26 | A | 38 | B | 50 | A | 62 | B |
| 3 | A | 15 | B | 27 | C | 39 | B | 51 | A | 63 | B |
| 4 | B | 16 | A | 28 | B | 40 | A | 52 | B | 64 | A |
| 5 | D | 17 | A | 29 | D | 41 | A | 53 | D | 65 | B |
| 6 | D | 18 | D | 30 | B | 42 | C | 54 | D | 66 | C |
| 7 | D | 19 | A | 31 | C | 43 | B | 55 | C | 67 | D |
| 8 | A | 20 | D | 32 | D | 44 | A | 56 | C | 68 | B |
| 9 | D | 21 | A | 33 | C | 45 | D | 57 | C | 69 | D |
| 10 | D | 22 | D | 34 | D | 46 | D | 58 | C | 70 | C |
| 11 | D | 23 | C | 35 | A | 47 | C | 59 | A | | |
| 12 | A | 24 | A | 36 | C | 48 | A | 60 | C | | |

## TOPIC 8

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | C | 11 | B | 21 | D | 31 | C |
| 2 | D | 12 | D | 22 | C | 32 | B |
| 3 | B | 13 | A | 23 | C | 33 | C |
| 4 | D | 14 | B | 24 | D | 34 | D |
| 5 | C | 15 | C | 25 | C | 35 | D |
| 6 | B | 16 | B | 26 | B | 36 | B |
| 7 | C | 17 | A | 27 | D | 37 | C |
| 8 | C | 18 | B | 28 | B | 38 | C |
| 9 | C | 19 | A | 29 | D | | |
| 10 | B | 20 | C | 30 | D | | |

## TOPIC 9

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 21 | D | 41 | B | 61 | A | 81 | C | 101 | C |
| 2 | B | 22 | B | 42 | B | 62 | D | 82 | A | 102 | D |
| 3 | A | 23 | D | 43 | C | 63 | D | 83 | B | 103 | A |
| 4 | D | 24 | A | 44 | A | 64 | D | 84 | C | 104 | C |
| 5 | B | 25 | A | 45 | B | 65 | B | 85 | B | 105 | C |
| 6 | A | 26 | A | 46 | B | 66 | B | 86 | D | 106 | B |
| 7 | B | 27 | D | 47 | A | 67 | B | 87 | C | 107 | D |
| 8 | C | 28 | A | 48 | A | 68 | D | 88 | B | 108 | D |
| 9 | B | 29 | C | 49 | C | 69 | C | 89 | C | 109 | B |
| 10 | C | 30 | D | 50 | A | 70 | B | 90 | C | 110 | D |
| 11 | C | 31 | C | 51 | A | 71 | A | 91 | B | 111 | A |
| 12 | C | 32 | C | 52 | A | 72 | C | 92 | D | 112 | B |
| 13 | C | 33 | D | 53 | D | 73 | D | 93 | A | 113 | A |
| 14 | D | 34 | D | 54 | D | 74 | D | 94 | D | | |
| 15 | D | 35 | D | 55 | D | 75 | D | 95 | B | | |
| 16 | D | 36 | A | 56 | D | 76 | D | 96 | A | | |
| 17 | D | 37 | C | 57 | D | 77 | A | 97 | B | | |
| 18 | D | 38 | C | 58 | B | 78 | D | 98 | B | | |
| 19 | D | 39 | B | 59 | C | 79 | B | 99 | C | | |
| 20 | A | 40 | A | 60 | D | 80 | C | 100 | D | | |

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## TOPIC 10

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 16 | C | 31 | B | 46 | B | 61 | A | 76 | C |
| 2 | B | 17 | D | 32 | D | 47 | D | 62 | A | 77 | C |
| 3 | D | 18 | B | 33 | B | 48 | D | 63 | B | 78 | B |
| 4 | C | 19 | B | 34 | C | 49 | A | 64 | D | 79 | A |
| 5 | A | 20 | C | 35 | A | 50 | C | 65 | A | 80 | A |
| 6 | A | 21 | C | 36 | C | 51 | C | 66 | B | 81 | B |
| 7 | A | 22 | B | 37 | D | 52 | D | 67 | D | | |
| 8 | B | 23 | D | 38 | B | 53 | B | 68 | B | | |
| 9 | B | 24 | B | 39 | C | 54 | D | 69 | B | | |
| 10 | C | 25 | D | 40 | D | 55 | C | 70 | C | | |
| 11 | B | 26 | C | 41 | A | 56 | B | 71 | C | | |
| 12 | B | 27 | D | 42 | A | 57 | A | 72 | A | | |
| 13 | C | 28 | D | 43 | B | 58 | B | 73 | C | | |
| 14 | D | 29 | D | 44 | C | 59 | B | 74 | A | | |
| 15 | C | 30 | C | 45 | B | 60 | A | 75 | D | | |

## TOPIC 11

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | C | 16 | A | 31 | B | 46 | C | 61 | D | 76 | C |
| 2 | B | 17 | D | 32 | C | 47 | C | 62 | A | 77 | D |
| 3 | D | 18 | C | 33 | D | 48 | D | 63 | C | 78 | D |
| 4 | C | 19 | C | 34 | C | 49 | C | 64 | D | 79 | B |
| 5 | A | 20 | D | 35 | C | 50 | A | 65 | C | 80 | D |
| 6 | D | 21 | B | 36 | C | 51 | C | 66 | B | 81 | D |
| 7 | D | 22 | C | 37 | D | 52 | A | 67 | A | | |
| 8 | B | 23 | D | 38 | A | 53 | C | 68 | D | | |
| 9 | D | 24 | A | 39 | D | 54 | D | 69 | C | | |
| 10 | D | 25 | A | 40 | A | 55 | A | 70 | A | | |
| 11 | C | 26 | B | 41 | B | 56 | D | 71 | C | | |
| 12 | B | 27 | C | 42 | D | 57 | A | 72 | D | | |
| 13 | D | 28 | C | 43 | B | 58 | D | 73 | A | | |
| 14 | C | 29 | D | 44 | A | 59 | C | 74 | C | | |
| 15 | D | 30 | D | 45 | A | 60 | C | 75 | A | | |

## TOPIC 12

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 12 | B | 23 | C | 34 | C | 45 | C | 56 | A |
| 2 | C | 13 | B | 24 | A | 35 | C | 46 | B | 57 | A |
| 3 | C | 14 | C | 25 | A | 36 | C | 47 | C | 58 | B |
| 4 | B | 15 | D | 26 | C | 37 | B | 48 | C | 59 | B |
| 5 | D | 16 | A | 27 | C | 38 | D | 49 | C | 60 | B |
| 6 | A | 17 | D | 28 | C | 39 | C | 50 | A | 61 | D |
| 7 | C | 18 | B | 29 | A | 40 | A | 51 | C | 62 | A |
| 8 | B | 19 | B | 30 | C | 41 | C | 52 | C | 63 | D |
| 9 | C | 20 | D | 31 | A | 42 | D | 53 | D | 64 | A |
| 10 | C | 21 | C | 32 | A | 43 | B | 54 | B | | |
| 11 | A | 22 | D | 33 | C | 44 | B | 55 | D | | |

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## TOPIC 13

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 16 | D | 31 | C | 46 | A | 61 | D |
| 2 | C | 17 | B | 32 | B | 47 | B | 62 | D |
| 3 | D | 18 | C | 33 | B | 48 | D | 63 | A |
| 4 | D | 19 | B | 34 | B | 49 | C | 64 | B |
| 5 | B | 20 | C | 35 | C | 50 | C | 65 | D |
| 6 | B | 21 | C | 36 | C | 51 | D | 66 | D |
| 7 | D | 22 | B | 37 | A | 52 | D | 67 | D |
| 8 | B | 23 | D | 38 | D | 53 | A | 68 | B |
| 9 | A | 24 | C | 39 | B | 54 | B | 69 | C |
| 10 | D | 25 | D | 40 | D | 55 | D | 70 | C |
| 11 | B | 26 | A | 41 | A | 56 | D | | |
| 12 | B | 27 | C | 42 | D | 57 | C | | |
| 13 | B | 28 | C | 43 | B | 58 | C | | |
| 14 | D | 29 | A | 44 | D | 59 | A | | |
| 15 | C | 30 | A | 45 | A | 60 | C | | |

## TOPIC 14

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | C | 26 | A | 51 | A | 76 | B | 101 | C | 126 | B |
| 2 | B | 27 | D | 52 | A | 77 | B | 102 | A | 127 | A |
| 3 | A | 28 | D | 53 | D | 78 | C | 103 | B | 128 | C |
| 4 | C | 29 | D | 54 | B | 79 | C | 104 | C | 129 | D |
| 5 | D | 30 | D | 55 | C | 80 | B | 105 | D | 130 | C |
| 6 | B | 31 | B | 56 | D | 81 | D | 106 | B | 131 | A |
| 7 | B | 32 | C | 57 | C | 82 | A | 107 | A | | |
| 8 | D | 33 | B | 58 | A | 83 | B | 108 | C | | |
| 9 | D | 34 | B | 59 | B | 84 | C | 109 | A | | |
| 10 | B | 35 | D | 60 | C | 85 | B | 110 | D | | |
| 11 | D | 36 | D | 61 | C | 86 | A | 111 | A | | |
| 12 | B | 37 | C | 62 | A | 87 | B | 112 | C | | |
| 13 | A | 38 | A | 63 | D | 88 | B | 113 | D | | |
| 14 | B | 39 | D | 64 | A | 89 | B | 114 | A | | |
| 15 | B | 40 | B | 65 | D | 90 | D | 115 | C | | |
| 16 | B | 41 | C | 66 | C | 91 | D | 116 | D | | |
| 17 | D | 42 | D | 67 | B | 92 | B | 117 | C | | |
| 18 | C | 43 | A | 68 | A | 93 | A | 118 | B | | |
| 19 | B | 44 | A | 69 | A | 94 | C | 119 | A | | |
| 20 | C | 45 | B | 70 | D | 95 | D | 120 | C | | |
| 21 | D | 46 | B | 71 | A | 96 | B | 121 | A | | |
| 23 | A | 48 | C | 73 | A | 98 | C | 123 | A | | |
| 24 | B | 49 | B | 74 | A | 99 | B | 124 | B | | |
| 25 | D | 50 | D | 75 | B | 100 | C | 125 | D | | |

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## TOPIC 15

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 16 | C | 31 | D | 46 | D | 61 | B | 76 | B |
| 2 | A | 17 | C | 32 | D | 47 | D | 62 | C | | |
| 3 | B | 18 | C | 33 | C | 48 | C | 63 | D | | |
| 4 | D | 19 | B | 34 | C | 49 | C | 64 | A | | |
| 5 | A | 20 | D | 35 | D | 50 | D | 65 | D | | |
| 6 | C | 21 | D | 36 | B | 51 | D | 66 | B | | |
| 7 | C | 22 | C | 37 | D | 52 | C | 67 | C | | |
| 8 | D | 23 | C | 38 | C | 53 | D | 68 | D | | |
| 9 | D | 24 | A | 39 | A | 54 | C | 69 | D | | |
| 10 | C | 25 | C | 40 | C | 55 | B | 70 | B | | |
| 11 | A | 26 | C | 41 | D | 56 | B | 71 | C | | |
| 12 | C | 27 | D | 42 | B | 57 | D | 72 | B | | |
| 13 | C | 28 | D | 43 | C | 58 | C | 73 | A | | |
| 14 | D | 29 | D | 44 | C | 59 | A | 74 | B | | |
| 15 | C | 30 | B | 45 | A | 60 | B | 75 | B | | |

## TOPIC 16

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 16 | D | 31 | B | 46 | A | 61 | B | 76 | C |
| 2 | A | 17 | C | 32 | C | 47 | D | 62 | D | | |
| 3 | C | 18 | D | 33 | C | 48 | A | 63 | B | | |
| 4 | D | 19 | D | 34 | A | 49 | C | 64 | A | | |
| 5 | C | 20 | C | 35 | B | 50 | B | 65 | C | | |
| 6 | C | 21 | B | 36 | B | 51 | B | 66 | A | | |
| 7 | B | 22 | A | 37 | D | 52 | C | 67 | D | | |
| 8 | A | 23 | D | 38 | D | 53 | D | 68 | C | | |
| 9 | D | 24 | B | 39 | C | 54 | A | 69 | C | | |
| 10 | D | 25 | B | 40 | B | 55 | C | 70 | A | | |
| 11 | C | 26 | B | 41 | A | 56 | D | 71 | C | | |
| 12 | A | 27 | D | 42 | C | 57 | D | 72 | C | | |
| 13 | B | 28 | A | 43 | C | 58 | C | 73 | C | | |
| 14 | B | 29 | D | 44 | C | 59 | C | 74 | A | | |
| 15 | C | 30 | B | 45 | B | 60 | D | 75 | C | | |

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## TOPIC 17

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 16 | B | 31 | D | 46 | A | 61 | B |
| 2 | A | 17 | C | 32 | C | 47 | B | 62 | A |
| 3 | C | 18 | C | 33 | B | 48 | C | 63 | A |
| 4 | D | 19 | A | 34 | C | 49 | D | 64 | D |
| 5 | B | 20 | C | 35 | A | 50 | B | 65 | D |
| 6 | D | 21 | A | 36 | A | 51 | D | 66 | D |
| 7 | A | 22 | B | 37 | D | 52 | A | 67 | B |
| 8 | D | 23 | C | 38 | B | 53 | B | 68 | A |
| 9 | D | 24 | C | 39 | D | 54 | D | 69 | A |
| 10 | D | 25 | C | 40 | B | 55 | D | 70 | C |
| 11 | C | 26 | C | 41 | A | 56 | A | 71 | D |
| 12 | C | 27 | D | 42 | A | 57 | B | 72 | B |
| 13 | B | 28 | C | 43 | B | 58 | A | 73 | D |
| 14 | A | 29 | C | 44 | B | 59 | A | | |
| 15 | B | 30 | B | 45 | B | 60 | B | | |

## TOPIC 18

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 16 | D | 31 | D | 46 | A | 61 | C |
| 2 | D | 17 | B | 32 | A | 47 | B | 62 | D |
| 3 | C | 18 | D | 33 | C | 48 | B | 63 | B |
| 4 | D | 19 | B | 34 | B | 49 | B | 64 | C |
| 5 | D | 20 | B | 35 | C | 50 | D | 65 | C |
| 6 | C | 21 | B | 36 | C | 51 | C | 66 | B |
| 7 | B | 22 | A | 37 | C | 52 | C | 67 | B |
| 8 | C | 23 | C | 38 | B | 53 | A | 68 | D |
| 9 | B | 24 | C | 39 | B | 54 | D | 69 | B |
| 10 | D | 25 | C | 40 | D | 55 | A | 70 | A |
| 11 | C | 26 | D | 41 | C | 56 | A | 71 | D |
| 12 | C | 27 | B | 42 | B | 57 | C | 72 | A |
| 13 | C | 28 | B | 43 | D | 58 | C | 73 | C |
| 14 | B | 29 | D | 44 | B | 59 | A | | |
| 15 | D | 30 | B | 45 | A | 60 | D | | |



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