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## 0620/41

May/June 2022

**1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.

This document has **16** pages. Any blank pages are indicated.

1 A list of substances is shown.

|                 |                 |           |          |         |
|-----------------|-----------------|-----------|----------|---------|
| aluminium oxide | carbon dioxide  | chlorine  | diamond  | ethanol |
| glucose         | iron(III) oxide | limestone | nitrogen | oxygen  |

Answer the questions using the list of substances.

Each substance may be used once, more than once or not at all.

State which of the substances:

(a) is a reactant in photosynthesis

..... [1]

(b) is the main constituent of bauxite

..... [1]

(c) are **two** products of fermentation

..... and ..... [2]

(d) is used as a fuel

..... [1]

(e) is a gas used to convert iron into steel

..... [1]

(f) is a greenhouse gas

..... [1]

(g) is a gas that is approximately 78% of clean, dry air

..... [1]

(h) is a form of carbon.

..... [1]

[Total: 9]

- 2 (a) Atoms are made of protons, neutrons and electrons. Atoms of the same element are known as isotopes.

(i) Complete the table.

| particle | relative charge | relative mass    |
|----------|-----------------|------------------|
| electron |                 | $\frac{1}{1840}$ |
| neutron  |                 |                  |
| proton   | +1              |                  |

[2]

- (ii)  $^{24}_{12}\text{Mg}$  and  $^{25}_{12}\text{Mg}$  are isotopes of magnesium.

Complete the table to show the numbers of electrons, neutrons and protons in these isotopes of magnesium.

| isotope               | number of electrons | number of neutrons | number of protons |
|-----------------------|---------------------|--------------------|-------------------|
| $^{24}_{12}\text{Mg}$ |                     |                    |                   |
| $^{25}_{12}\text{Mg}$ |                     |                    |                   |

[2]

- (iii) Explain why magnesium ions have a charge of 2+.

.....  
 ..... [1]

- (b)  $\text{Mg}^{2+}$  ions have the electronic structure 2,8.

Give the formula of the following particles which have the same electronic structure as  $\text{Mg}^{2+}$  ions.

- a cation (positive ion)

.....

- an anion (negative ion)

.....

- an atom

.....

[3]

[Total: 8]

3 This question is about sodium and compounds of sodium.

(a) (i) Describe the bonding in a metallic element such as sodium.

You may include a diagram as part of your answer.

.....  
.....  
..... [3]

(ii) Describe how solid sodium conducts electricity.

..... [1]

(b) Some properties of sodium chloride are shown:

- melting point of  $801^{\circ}\text{C}$
- non-conductor of electricity when solid
- conductor of electricity when molten
- soluble in water.

(i) Name the type of bonding in sodium chloride.

..... [1]

(ii) Explain why sodium chloride conducts electricity when molten.

.....  
..... [1]

- (c) A student determines the concentration of a solution of dilute sulfuric acid,  $\text{H}_2\text{SO}_4$ , by titration with aqueous sodium hydroxide,  $\text{NaOH}$ .

**step 1**  $25.0 \text{ cm}^3$  of  $0.200 \text{ mol/dm}^3$   $\text{NaOH}$  is transferred into a conical flask.

**step 2** Three drops of methyl orange indicator are added to the conical flask.

**step 3** A burette is filled with  $\text{H}_2\text{SO}_4$ .

**step 4** The acid in the burette is added to the conical flask until the indicator changes colour. The volume of acid is recorded. This process is known as titration.

**step 5** The titration is repeated several times until a suitable number of results is obtained.

- (i) Name the piece of apparatus used to measure exactly  $25.0 \text{ cm}^3$  of  $0.200 \text{ mol/dm}^3$   $\text{NaOH}$  in **step 1**.

..... [1]

- (ii) State the colour change of the methyl orange indicator in **step 4**.

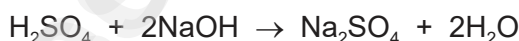
from ..... to ..... [1]

- (iii) State how the student decides that a suitable number of results have been obtained.

.....  
..... [1]

- (iv)  $20.0 \text{ cm}^3$  of  $\text{H}_2\text{SO}_4$  reacts with  $25.0 \text{ cm}^3$  of  $0.200 \text{ mol/dm}^3$   $\text{NaOH}$ .

The equation for the reaction is shown.



Calculate the concentration of  $\text{H}_2\text{SO}_4$  using the following steps.

- Calculate the number of moles in  $25.0 \text{ cm}^3$  of  $0.200 \text{ mol/dm}^3$   $\text{NaOH}$ .

..... mol

- Determine the number of moles of  $\text{H}_2\text{SO}_4$  that react with the  $\text{NaOH}$ .

..... mol

- Calculate the concentration of  $\text{H}_2\text{SO}_4$ .

.....  $\text{mol/dm}^3$   
[3]

[Total: 12]

4 This question is about compounds of sulfur.

(a) Sulfuric acid,  $\text{H}_2\text{SO}_4$ , is manufactured using the Contact process. This manufacture involves four stages.

**stage 1** Molten sulfur burns in air to produce sulfur dioxide.

**stage 2** Sulfur dioxide reacts with oxygen to form sulfur trioxide.

**stage 3** Sulfur trioxide combines with concentrated sulfuric acid to form oleum,  $\text{H}_2\text{S}_2\text{O}_7$ .

**stage 4** Oleum reacts to form concentrated sulfuric acid.

(i) Write a chemical equation for the reaction occurring in **stage 1**.

..... [1]

(ii) State the essential conditions that are necessary for **stage 2**. Write an equation for the chemical reaction that occurs.

.....  
 .....  
 .....  
 ..... [4]

(iii) Write a chemical equation for the reaction occurring in **stage 3**.

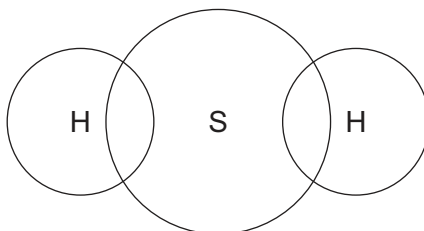
..... [1]

(iv) Name the substance that reacts with oleum in **stage 4**.

..... [1]

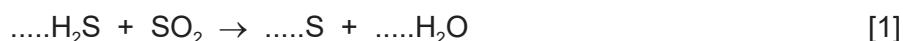
(b) Hydrogen sulfide has the formula  $\text{H}_2\text{S}$ .

(i) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of hydrogen sulfide. Show outer shell electrons only.



[2]

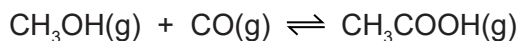
(ii) Balance the chemical equation for the reaction of hydrogen sulfide with sulfur dioxide shown.



[Total: 10]

- 5 Ethanoic acid is manufactured by the reaction of methanol with carbon monoxide.

An equilibrium mixture is produced.



- (a) State **two** characteristics of an equilibrium.

1 .....

2 ..... [2]

- (b) The purpose of the industrial process is to produce a high yield of ethanoic acid at a high rate of reaction.

The manufacture is carried out at a temperature of 300 °C.

The forward reaction is exothermic.

Use this information to state why the manufacture is **not** carried out at temperatures:

- **below** 300 °C

.....

- **above** 300 °C.

..... [2]

- (c) Complete the table using only the words *increases*, *decreases* or *no change*.

|                         | effect on the rate of the forward reaction | effect on the equilibrium yield of CH <sub>3</sub> COOH(g) |
|-------------------------|--------------------------------------------|------------------------------------------------------------|
| adding a catalyst       |                                            | no change                                                  |
| decreasing the pressure |                                            |                                                            |

[3]

- (d) Suggest which of the following metals is a suitable catalyst for the reaction. Give a reason for your answer.

**aluminium**

**calcium**

**cobalt**

**magnesium**

**potassium**

suitable catalyst .....

reason .....

[2]

- (e) Ethanoic acid is a member of the homologous series of carboxylic acids.

State the general formula of this homologous series.

..... [1]

- (f) Draw the structure of the carboxylic acid containing three carbon atoms. Show all of the atoms and all of the bonds.

[2]

- (g) When carboxylic acids react with alcohols, esters are produced.

The formula of ester **X** is  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOCH}_3$ .

- (i) Name ester **X**.

..... [1]

- (ii) Give the name of the carboxylic acid and the alcohol that react together to produce ester **X**.

carboxylic acid .....

alcohol .....

[2]

- (h) Ester **Y** has the following composition by mass:

C, 48.65%; H, 8.11%; O, 43.24%.

Calculate the empirical formula of ester **Y**.

empirical formula = ..... [3]

- (i) Ester **Z** has the empirical formula  $\text{C}_2\text{H}_4\text{O}$  and a relative molecular mass of 88.

Determine the molecular formula of ester **Z**.

molecular formula = ..... [1]

[Total: 19]

6 This question is about zinc and its compounds.

(a) Zinc is extracted from its ore which is mainly zinc sulfide, ZnS.

The steps for this extraction are shown.

**step 1** Zinc sulfide is converted into zinc oxide.

**step 2** The zinc oxide is then reduced to zinc in a furnace. The zinc formed becomes a gas.

**step 3** The zinc gas is cooled to form molten zinc.

(i) Name the ore of zinc, which is mainly zinc sulfide.

..... [1]

(ii) Describe how zinc sulfide is converted into zinc oxide in **step 1**.

.....  
..... [1]

(iii) Name the reducing agent used in **step 2**.

..... [1]

(iv) Explain why the zinc forms a gas in **step 2** inside the furnace.

..... [1]

(v) State the name of the physical change occurring when zinc gas is converted into molten zinc.

..... [1]

(b) Zinc sulfate crystals,  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ , are hydrated.

Zinc sulfate crystals are made by reacting zinc carbonate with dilute sulfuric acid.

The equation for the overall process is shown.



**step 1** Large pieces of solid zinc carbonate are added to dilute sulfuric acid until the zinc carbonate is in excess. This forms aqueous zinc sulfate.

**step 2** The excess zinc carbonate is separated from the aqueous zinc sulfate.

**step 3** The aqueous zinc sulfate is heated until a saturated solution is formed.

**step 4** The saturated solution is allowed to cool and crystallise.

**step 5** The crystals are removed and dried.

- (i) In **step 1**, zinc carbonate is in excess when no more zinc carbonate dissolves.

State one **other** observation that indicates the zinc carbonate is in excess in **step 1**.

..... [1]

- (ii) Name a different substance, other than zinc carbonate, that can be added to dilute sulfuric acid to produce aqueous zinc sulfate in **step 1**.

..... [1]

- (iii) **Step 1** is repeated using powdered zinc carbonate instead of large pieces.

All other conditions are kept the same.

The rate of reaction increases.

Give a reason why the rate of reaction increases. Explain your answer in terms of particles.

.....  
.....  
..... [2]

- (iv) Suggest what is observed when the solution is saturated in **step 3**.

.....  
.....  
..... [1]

- (v) The formula of zinc sulfate crystals is  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ .

Give the formula of the solid formed if the crystals are heated to dryness in **step 3**.

..... [1]

[Total: 11]

7 The Periodic Table can be used to classify elements.

(a) Group I elements react with cold water to form alkaline solutions.

(i) Place the Group I elements caesium, lithium, potassium, rubidium and sodium in their order of reactivity with water.

Put the most reactive element first.

most reactive → least reactive

|  |  |  |  |  |
|--|--|--|--|--|
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[1]

(ii) Name the alkaline solution formed when caesium reacts with cold water.

..... [1]

(b) Group I elements have lower melting points than transition elements.

Describe one **other** difference in the **physical** properties of Group I elements and transition elements.

..... [1]

(c) Group VII elements are known as the halogens.

Astatine is below iodine in Group VII.

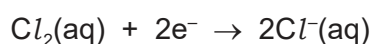
Predict the physical state of astatine at room temperature and pressure.

..... [1]

(d) Some Group VII elements react with aqueous solutions containing halide ions.

When aqueous chlorine is added to aqueous potassium bromide a reaction occurs.

The ionic half-equations for the reaction are shown.



(i) Describe the colour change of the solution.

original colour of potassium bromide solution .....

final colour of reaction mixture .....

[2]

- (ii) Identify the species that is oxidised.

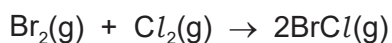
Explain your decision.

species oxidised .....

explanation .....

[2]

- (e) Bromine monochloride,  $\text{BrCl}$ , is made by the reaction between bromine and chlorine. The chemical equation is shown.



| bond  | bond energy in kJ/mol |
|-------|-----------------------|
| Br–Br | 190                   |
| Cl–Cl | 242                   |
| Br–Cl | 218                   |

Calculate the overall energy change for the reaction using bond energies.

Use the following steps.

- Calculate the total amount of energy required to break the bonds in 1 mole of  $\text{Br}_2(\text{g})$  and 1 mole of  $\text{Cl}_2(\text{g})$ .

..... kJ

- Calculate the total amount of energy released when the bonds in 2 moles of  $\text{BrCl}(\text{g})$  are formed.

..... kJ

- Calculate the overall energy change for the reaction.

..... kJ/mol  
[3]

[Total: 11]

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## Group

| Group                      |                             |                                                                |                                 |                             |                              |                             |                              |                              |                                |                               |                               |                             |                             |                               |                              |                               |                            |
|----------------------------|-----------------------------|----------------------------------------------------------------|---------------------------------|-----------------------------|------------------------------|-----------------------------|------------------------------|------------------------------|--------------------------------|-------------------------------|-------------------------------|-----------------------------|-----------------------------|-------------------------------|------------------------------|-------------------------------|----------------------------|
| I                          | II                          | Key                                                            |                                 |                             |                              |                             | III                          | IV                           | V                              | VI                            | VII                           | VIII                        |                             |                               |                              |                               |                            |
|                            |                             | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                                 |                             |                              |                             | 1<br>H<br>hydrogen<br>1      |                              |                                |                               |                               |                             |                             |                               |                              |                               |                            |
| 3<br>Li<br>lithium<br>7    | 4<br>Be<br>beryllium<br>9   |                                                                |                                 |                             |                              |                             |                              |                              |                                |                               |                               |                             | 2<br>He<br>helium<br>4      |                               |                              |                               |                            |
| 11<br>Na<br>sodium<br>23   | 12<br>Mg<br>magnesium<br>24 |                                                                |                                 |                             |                              |                             | 5<br>B<br>boron<br>11        | 6<br>C<br>carbon<br>12       | 7<br>N<br>nitrogen<br>14       | 8<br>O<br>oxygen<br>16        | 9<br>F<br>fluorine<br>19      | 10<br>Ne<br>neon<br>20      |                             |                               |                              |                               |                            |
|                            |                             |                                                                |                                 |                             |                              |                             | 13<br>Al<br>aluminium<br>27  | 14<br>Si<br>silicon<br>28    | 15<br>P<br>phosphorus<br>31    | 16<br>S<br>sulfur<br>32       | 17<br>Cl<br>chlorine<br>35.5  | 18<br>Ar<br>argon<br>40     |                             |                               |                              |                               |                            |
| 19<br>K<br>potassium<br>39 | 20<br>Ca<br>calcium<br>40   | 21<br>Sc<br>scandium<br>45                                     | 22<br>Ti<br>titanium<br>48      | 23<br>V<br>vanadium<br>51   | 24<br>Cr<br>chromium<br>52   | 25<br>Mn<br>manganese<br>55 | 26<br>Fe<br>iron<br>56       | 27<br>Co<br>cobalt<br>59     | 28<br>Ni<br>nickel<br>59       | 29<br>Cu<br>copper<br>64      | 30<br>Zn<br>zinc<br>65        | 31<br>Ga<br>gallium<br>70   | 32<br>Ge<br>germanium<br>73 | 33<br>As<br>arsenic<br>75     | 34<br>Se<br>selenium<br>79   | 35<br>Br<br>bromine<br>80     | 36<br>Kr<br>krypton<br>84  |
| 37<br>Rb<br>rubidium<br>85 | 38<br>Sr<br>strontium<br>88 | 39<br>Y<br>yttrium<br>89                                       | 40<br>Zr<br>zirconium<br>91     | 41<br>Nb<br>niobium<br>93   | 42<br>Mo<br>molybdenum<br>96 | 43<br>Tc<br>technetium<br>— | 44<br>Ru<br>ruthenium<br>101 | 45<br>Rh<br>rhodium<br>103   | 46<br>Pd<br>palladium<br>106   | 47<br>Ag<br>silver<br>108     | 48<br>Cd<br>cadmium<br>112    | 49<br>In<br>indium<br>115   | 50<br>Sn<br>tin<br>119      | 51<br>Sb<br>antimony<br>122   | 52<br>Te<br>tellurium<br>128 | 53<br>I<br>iodine<br>127      | 54<br>Xe<br>xenon<br>131   |
| 55<br>Cs<br>caesium<br>133 | 56<br>Ba<br>barium<br>137   | 57–71<br>lanthanoids                                           | 72<br>Hf<br>hafnium<br>178      | 73<br>Ta<br>tantalum<br>181 | 74<br>W<br>tungsten<br>184   | 75<br>Re<br>rhenium<br>186  | 76<br>Os<br>osmium<br>190    | 77<br>Ir<br>iridium<br>192   | 78<br>Pt<br>platinum<br>195    | 79<br>Au<br>gold<br>197       | 80<br>Hg<br>mercury<br>201    | 81<br>Tl<br>thallium<br>204 | 82<br>Pb<br>lead<br>207     | 83<br>Bi<br>bismuth<br>209    | 84<br>Po<br>polonium<br>—    | 85<br>At<br>astatine<br>—     | 86<br>Rn<br>radon<br>—     |
| 87<br>Fr<br>francium<br>—  | 88<br>Ra<br>radium<br>—     | 89–103<br>actinoids                                            | 104<br>Rf<br>rutherfordium<br>— | 105<br>Db<br>dubnium<br>—   | 106<br>Sg<br>seaborgium<br>— | 107<br>Bh<br>bohrium<br>—   | 108<br>Hs<br>hassium<br>—    | 109<br>Mt<br>meitnerium<br>— | 110<br>Ds<br>darmstadtium<br>— | 111<br>Rg<br>roentgenium<br>— | 112<br>Cn<br>copernicium<br>— | 113<br>Nh<br>nihonium<br>—  | 114<br>Fl<br>flerovium<br>— | 115<br>Lv<br>livermorium<br>— | 116<br>Ts<br>tennessine<br>— | 117<br>Uue<br>unbinetium<br>— | 118<br>Og<br>oganeson<br>— |

lanthanoids

actinoids

The volume of one mole of any gas is  $24\text{ dm}^3$  at room temperature and pressure (r.t.p.).