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**TRIALS EXAMINATION
6 September 2021
GRADE 12**

**PHYSICAL SCIENCE
PAPER II**



CLIFTON
Scholarship
Leadership
Sportsmanship
Community

**TIME: 3 HOURS
MARKS: 200**

**EXAMINER: K. Garrett
MODERATOR: T. Doyle**

INSTRUCTIONS TO CANDIDATES

Please read the following instructions carefully.

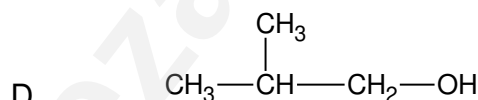
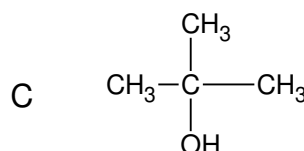
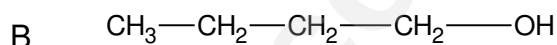
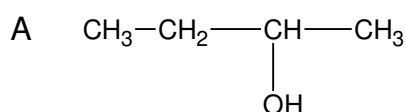
PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 18 pages and a Data Sheet of 3 pages (19, 20 and 21). Please make sure that your question paper is complete.
2. Answer ALL the questions.
3. Read the questions carefully.
4. Use the data and formulae whenever necessary.
5. Start each question on a new page.
6. Show your working in all calculations.
7. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
8. Answers must be expressed in decimal format, not left as proper fractions.
9. Where appropriate express answers to TWO decimal places.
10. It is in your own interest to write legibly and to present your work neatly.

QUESTION 1

For Questions 1.1 to 1.10, choose the most correct answer from the options presented and record the answer on the answer grid provided on the *FRONT* inside cover of your answer booklet.

1.1 Which one of the following is the correct formula for 2-methylpropan-2-ol?



(2)

1.2 Between the molecules of which of the given substances would the intermolecular forces be the strongest?



(2)

1.3 The following cell has an EMF of +0.46 V.



Which statement is correct about the operation of the cell?

A Metallic copper is oxidised by Ag^+ ions.

B The silver electrode has a negative polarity.

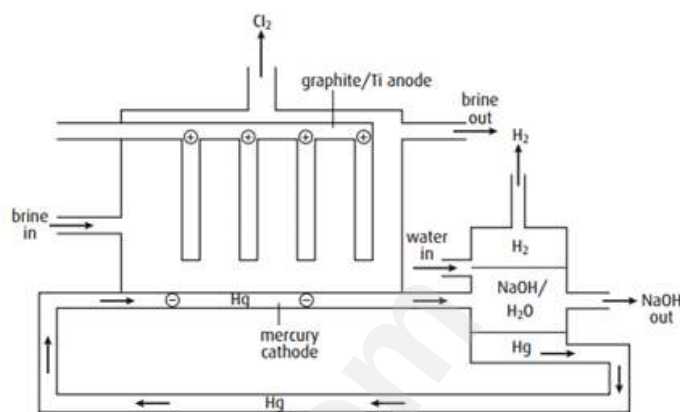
C The silver electrode gradually dissolves to form Ag^+ ion.

D Electrons flow from the silver electrode to the copper electrode through the external circuit.

(2)

- 1.4 The image alongside shows a flow diagram of the mercury cell used in the chlor-alkali industry.

The process uses a brine solution to produce three industrially important chemicals.

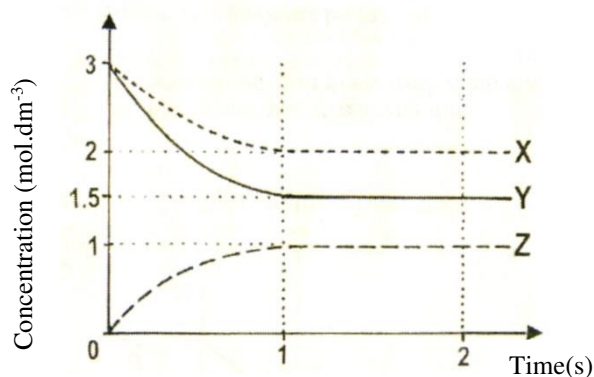


Which statement below **does not explain** why is it possible that the Na(Hg) amalgam is able to be formed at the cathode when a solution of brine is used?

- A Due to the nature of the mercury cathode, the reduction potential of Na^+ ion is adjusted.
- B Due to the nature of the mercury cathode, the Na^+ ion is made to be a stronger oxidizing agent than H_2O .
- C The electrode potential of water is higher than that of the Na^+ ion.
- D The Na^+ ion is preferentially reduced at the mercury cathode. (2)

- 1.5 The accompanying graph shows the changes in the amounts of X, Y and Z with time during a reaction. The equation for the reaction once dynamic equilibrium has been reached can be represented as follows:

- A $\text{X} + 1,5\text{Y} \rightleftharpoons \text{Z}$
- B $5\text{X} + 3\text{Y} \rightleftharpoons 2\text{Z}$
- C $3\text{X} + 3\text{Y} \rightleftharpoons \text{Z}$
- D $4\text{X} + 3\text{Y} \rightleftharpoons 2\text{Z}$



(2)

1.6 The average mass of a crystal of NaCl is 3,2 mg. The total number of ions in a crystal of sodium chloride is....

A
$$\frac{0,0032 \times 2}{58,5 \times 6,02 \times 10^{23}}$$

(2)

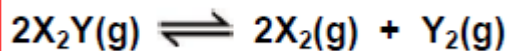
B
$$\frac{0,0032 \times 6,02 \times 10^{23}}{58,5}$$

C
$$\frac{0,0032 \times 6,02 \times 10^{23}}{58,5 \times 2}$$

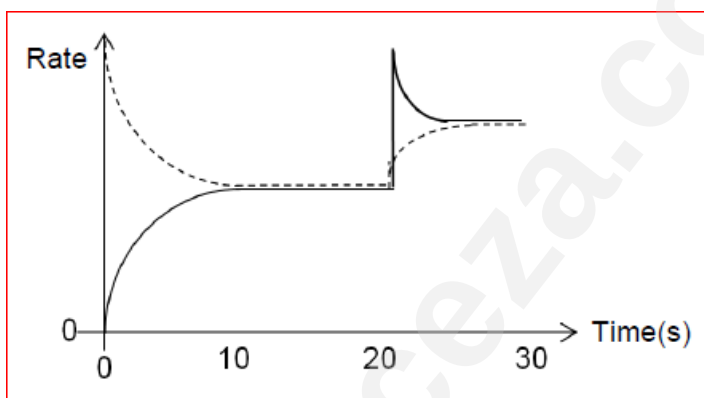
D
$$\frac{0,0032 \times 6,02 \times 10^{23} \times 2}{58,5}$$

(2)

- 1.7 Gas X_2Y is introduced into the container, which is then sealed. The gas decomposes and the reaction reaches equilibrium. The balanced chemical equation for the reaction is:



At $t = 20$ s, a change is made to the reaction in equilibrium. The graph below shows the changes in the **rates** of the forward and reverse reactions with time.



Which of the following gives the change made at $t = 20$ s?

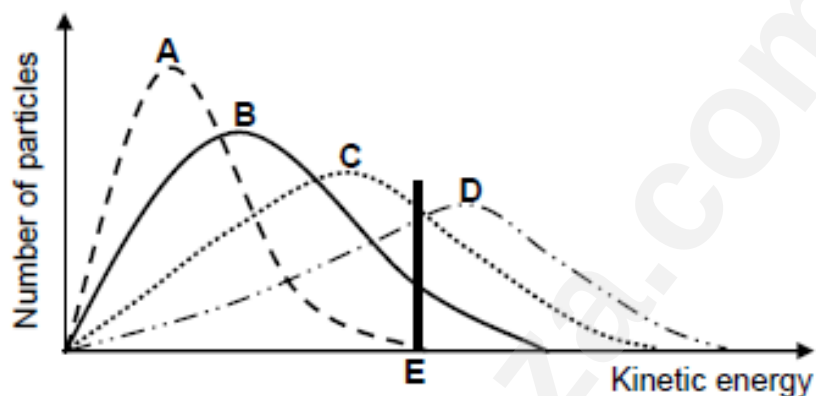
- A Using a catalyst
- B Increase in pressure
- C Decrease in temperature
- D Decrease in pressure. (2)

- 1.8 $1,0 \text{ mol.dm}^{-3}$ solutions of H_2SO_4 , HCl and CH_3COOH are prepared. When comparing the three solutions, which one of the following statements is correct?

- A The H_2SO_4 solution has the highest $[H_3O^+]$.
- B The CH_3COOH solution has the lowest pH.
- C The HCl solution has the lowest $[OH^-]$.
- D CH_3COOH has the highest K_a value (ionisation constant). (2)

- 1.9 The Maxwell-Boltzmann energy distribution curves below show the number of particles as a function of their kinetic energy for a reaction at four different temperatures. The activation energy for the reaction is represented by E.

Which one of these curves (A to D) represents a reaction which will NOT take place?



(2)

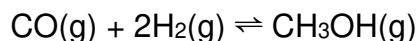
- 1.10 Why is it necessary to dissolve aluminium oxide in molten cryolite during the extraction of aluminium from crushed bauxite?

- A The cryolite reduces the melting point of the aluminium oxide.
 - B The cryolite acts as a catalyst for the production of aluminium.
 - C The cryolite reacts with aluminium oxide to form aluminium.
 - D Aluminium oxide can only conduct electricity when mixed with cryolite.
- (2)

[20]

QUESTION 2

The reaction below between carbon monoxide and hydrogen can be used industrially to make methanol. The process is carried out at 250°C and between 5000 kPa and 10 000 kPa.

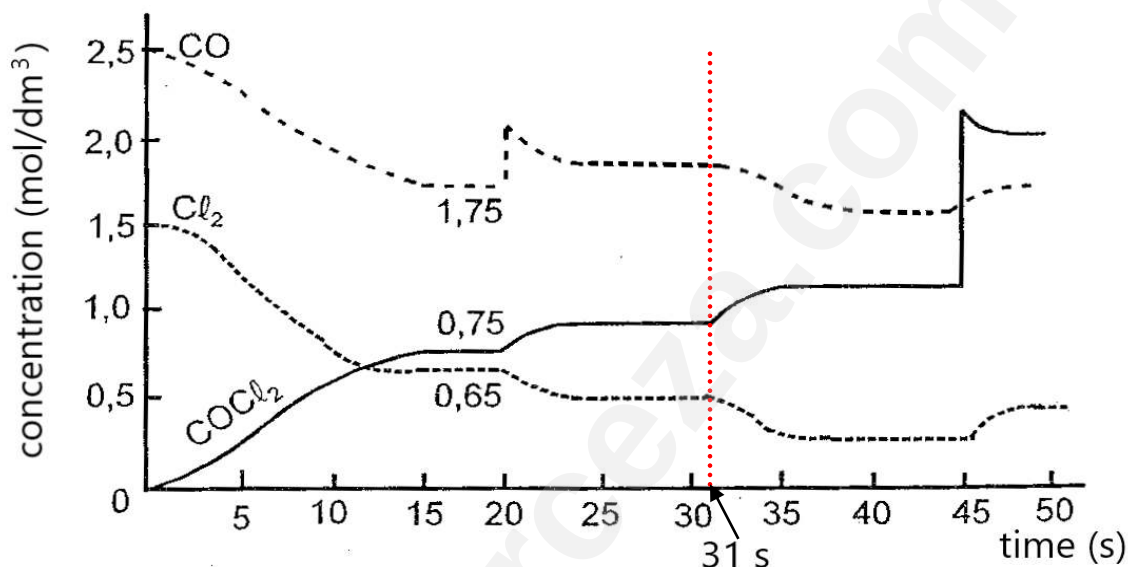


- 2.1 Explain in terms of the *collision theory* why increasing the pressure increases the yield of methanol. (4)
- 2.2 Define the term *reaction rate*. (2)
- 2.3 The reaction gives a greater equilibrium yield at 100°C than at 250°C. Is the forward reaction in this process exothermic or endothermic? Explain. (3)
- 2.4 Explain why the reaction needs to be carried out at 250°C. (1)
- 2.5 Draw a reaction rate vs time graph to illustrate the reaction between carbon monoxide and hydrogen from when the reactants were initially placed into the reaction vessel, until equilibrium was reached five minutes later and the catalyst, Al_2O_3 , is added to the system five minute after equilibrium had been reached. (5)
- 2.6 Aluminium oxide is a catalyst in this process. Draw and label an energy profile diagram of E_p versus course of reaction, to clearly show how a catalyst affects the activation energy required for this reaction. (4)
- 2.7 If 100 dm³ carbon monoxide and 120 dm³ hydrogen are placed in a container at STP and allowed to react completely, which gas would be in excess and by how many moles? (6)
- 2.8 Calculate the volume of methanol gas that would be produced in 2.7 should the reaction run to completion with the quantities given in 2.7. (3)

[28]

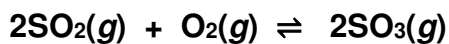
QUESTION 3

- 3.1 $\text{CO}(g)$ reacts with $\text{Cl}_2(g)$ in a closed system and reaches equilibrium, represented by the equation and graph below:



- 3.1.1 How much time passed before the system reached equilibrium for the first time? (1)
- 3.1.2 How do the rates of the forward and reverse reactions compare at the following times: (2)
- 6 s
 - 18 s
- 3.1.3 State *Le Chatelier's principle*. (2)
- 3.1.4 Describe what happened at 20 s. (1)
- 3.1.5 Explain, using *Le Chatelier's principle*, the change in concentration of **each gas** during the time interval of 20 – 25 seconds. (4)
- 3.1.6 Identify the change made at 31 s. Use *Le Chatelier's principle* to explain your answer. (4)
- 3.1.7 How does the equilibrium constant (K_c) at 25 s compare with that at 40 s? State *greater than*, *less than* or *equal to*. (1)

- 3.2 The following equilibrium reaction represents one of the reactions in the preparation of sulphuric acid, at a temperature of 400 °C in the presence of a contact catalyst called vanadium pentoxide:



The following information was obtained at equilibrium:

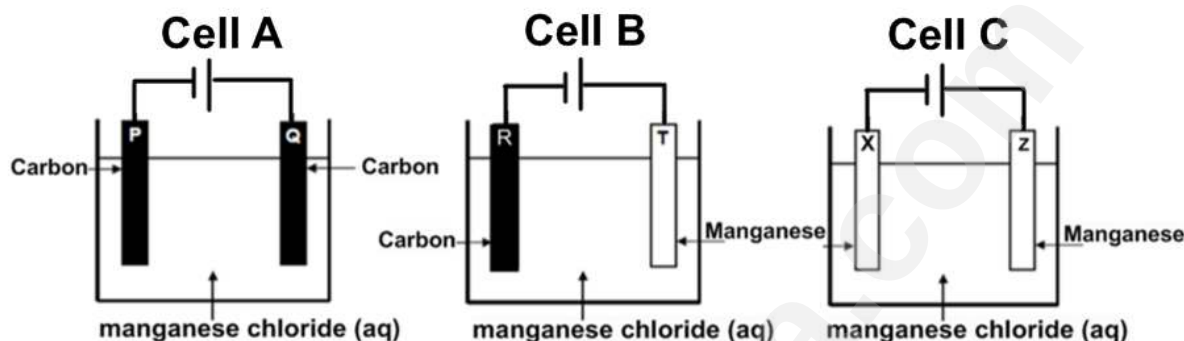
Volume of the container:	200 dm ³
Amount of SO ₂ present:	0,17 mol.dm ⁻³
Amount of SO ₃ present:	0,29 mol.dm ⁻³
K _c at 400 °C:	7,328

- 3.2.1 Write an expression for the equilibrium constant, K_c. (2)
- 3.2.2 Calculate the concentration of oxygen in the equilibrium mixture. (3)
- 3.2.3 Calculate the mass of oxygen that was present in the container at equilibrium. (6)

[26]

QUESTION 4

Consider the following electrolytic cells A, B and C. Cell A has two inert carbon electrodes (P and Q), cell B has an inert carbon electrode (R) and an **active** pure manganese electrode (T) and cell C has two **active** manganese electrodes, one pure (X) and one impure (Z). The electrodes are all dipped into **dilute** solutions of manganese chloride.

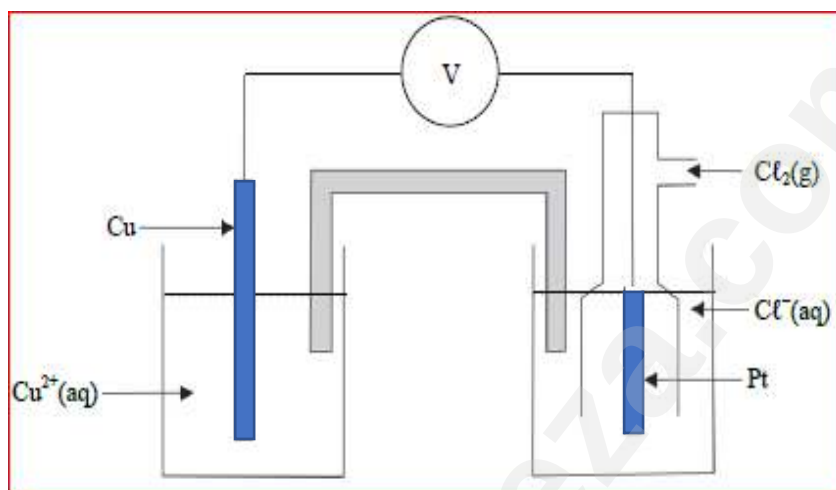


- 4.1 **State** and describe what PROCESS will occur on the carbon electrode labelled **Q** in Cell **A**. (2)
- 4.2 What would you observe at the carbon electrode labelled **Q** in Cell **A**. (2)
- 4.3 Write down the half-reaction that occurs at the electrodes labelled **P**, **R** and **X**. (2)
- 4.4 Write down the half-reaction that occurs at the electrode labelled **T** in Cell **B**. (2)
- 4.5 The loss of mass at the anode in Cell **B** is 3,46 g when the current flows for 40 minutes. Calculate the magnitude of the current flowing in this cell. (7)
- 4.6 The impure manganese electrode labelled **Z** in Cell **C** contains metal impurities, namely magnesium and iron.
 - 4.6.1 Write down the oxidation half reaction/s that will take place during this electroplating process. (3)
 - 4.6.2 Write down the reduction half reaction that will take place during this process. (2)
 - 4.6.3 Explain your answer in 4.6.2. (2)

[22]

QUESTION 5

A galvanic cell is constructed under standard conditions by connecting a copper half-cell and a chlorine half-cell using a salt bridge. In the chlorine half-cell, a platinum electrode is placed in the electrolyte. The diagram below represents this galvanic cell.

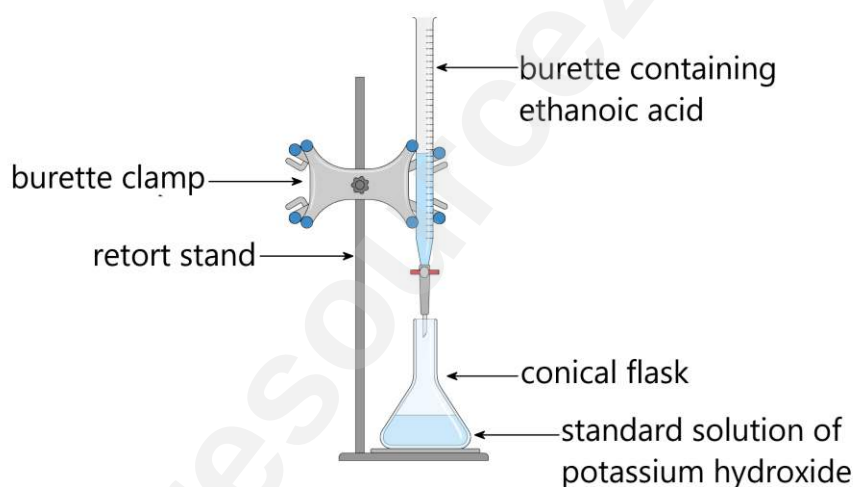


- 5.1 State the standard conditions that are applicable to this galvanic cell. (3)
- 5.2 Write down the chemical formula of a suitable electrolyte that could be used in the copper half-cell. (1)
- 5.3 Write the cell notation for this cell. (2)
- 5.4 Calculate the initial emf of this cell. (3)
- 5.5 In which direction will electrons move in the external circuit? (1)
- 5.6 What effect will a decrease in concentration of $\text{Cu}^{2+}_{(\text{aq})}$ have on the initial emf of the cell? Explain your answer. (3)
- 5.7 Explain how the increase in the concentration of $\text{Cl}^{-}_{(\text{aq})}$ is continually counteracted while the cell is operating. (2)
- 5.8 State two structural changes that could be made to this galvanic cell to increase the maximum current that the cell can deliver. (2)

[17]

QUESTION 6

- 6.1 To prepare 250 cm^3 of a $0,4\text{ mol}\cdot\text{dm}^{-3}$ standard solution of potassium hydroxide, a student dissolves pure potassium hydroxide pellets in distilled water.
- 6.1.1 Consider the structure of a molecule of potassium hydroxide and state the **two** types of bonding that exist within the molecule. Refer to the atoms between which these bonds exist. (3)
- 6.1.2 Is potassium hydroxide a strong or a weak base? Explain. (3)
- 6.1.3 Define a *standard solution*. (2)
- 6.1.4 Calculate the mass of potassium hydroxide used by the student to make the standard solution. (5)
- 6.2 During a **titration** the student finds that, on average, 20 cm^3 of ethanoic acid is neutralised by 30 cm^3 of the standard potassium hydroxide solution.



- 6.2.1 Write a balanced equation for the protolytic reaction that occurs. (2)
- 6.2.2 Calculate the number of moles of ethanoic acid that is neutralised by the potassium hydroxide solution. (3)
- 6.2.3 Calculate the concentration of the ethanoic acid. (3)
- 6.2.4 Define the term *hydrolysis of a salt*. (2)
- 6.2.5 *Hydrolysis* occurs in the potassium ethanoate solution. **Explain** this process with the use of a **suitable equation** and hence deduce the approximate equivalence point **pH** of the final solution. (4)

6.3 Hydrochloric acid is formed when hydrogen chloride gas is dissolved in water.

6.3.1 Write a suitable equation to show the complete ionisation of hydrogen chloride gas in water. (2)

6.3.2 Hydrochloric acid is present in the stomach. Milk of magnesia is a suspension containing magnesium hydroxide as the active ingredient to relieve "heartburn". Write a balanced chemical equation to show the reaction between hydrochloric acid and magnesium hydroxide. (3)

6.3.3 Rennies, an antacid containing calcium carbonate and magnesium carbonate, results in the release of a gas during the neutralization of excessive stomach acid build up. Name this gas. (1)

[33]

QUESTION 7

The letters **A** to **E** below each refer to a specific organic compound or a series of compounds:

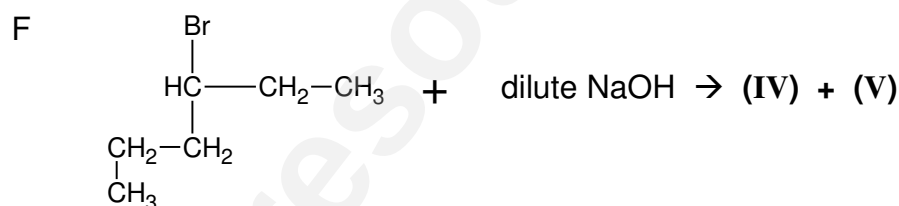
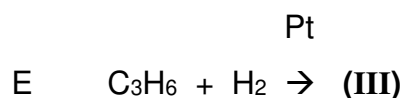
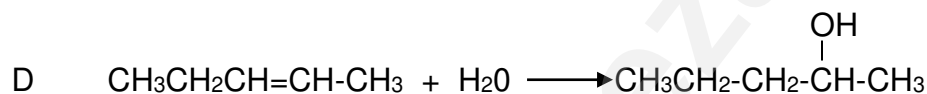
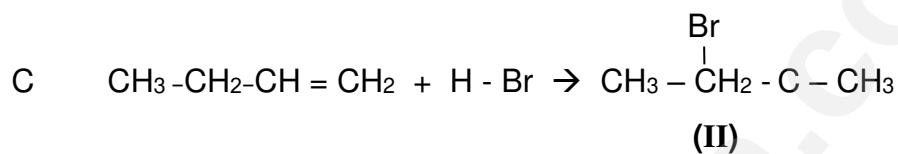
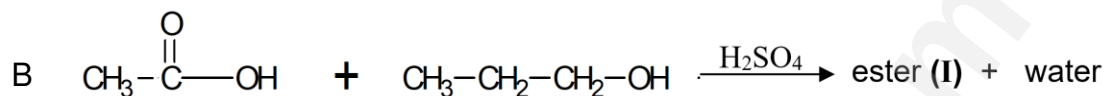
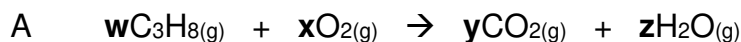
A	C_nH_{2n+2}
B	Butane gas
C	$\begin{array}{c} \text{Cl} \quad \quad \text{Cl} \\ \diagdown \quad \diagup \\ \text{C} = \text{C} \\ \diagup \quad \diagdown \\ \text{Cl} \quad \quad \text{Cl} \end{array}$
D	Ethanoic acid
E	Propanol

- 7.1 Define the term *homologous series*. (2)
- 7.2 Explain why the homologous series of compounds with the general formula **A** are **insoluble** in water and are comparatively **unreactive**. (2)
- 7.3 Write down the IUPAC **NAME** of compound **C**. (2)
- 7.4 Consider compound **B**.
- 7.4.1 Name the products formed when butane gas is placed in a clear glass container with chlorine gas and placed in direct sunlight. (2)
- 7.4.2 Would this reaction be a fast or slow reaction? (1)
- 7.4.3 How would one test for the presence of the inorganic product? (3)
- 7.5 Write the **structural formula** of the ester which is formed when **D** and **E** react under the correct conditions. (2)
- 7.6 Explain why compound **E** is soluble in water. (3)
- 7.7 Propanol has a boiling point of 97°C and propanoic acid has a boiling point of 141,2°C. Explain why the boiling point of the carboxylic acid is much higher than that of the alcohol. (3)

[20]

QUESTION 8

A selection of organic chemical reactions labelled **A** to **G** are represented below. Look through each reaction carefully and answer the questions that follow.



8.1 Identify the specific type of reaction in:

8.1.1 **F** (1)

8.1.2 **B** (1)

8.2 Balance Reaction **A** and show clearly the values of **w**, **x**, **y** and **z**. (2)

8.3 What process does Reaction **A** represent? (2)

- 8.4 Many chemical reactions will not take place under “normal” conditions unless a catalyst is used to promote the reaction.
- 8.4.1 Which two of the above reactions are acid catalysed? Write down only the letters labelling the reactions. (2)
- 8.4.2 Write down the molecular formulae of the acids that are used. (2)
- 8.5 One of the above reactions uses a contact catalyst. Which is it? Write down only the letter labelling the reaction. (1)
- 8.6 Considering your answer to question 8.5 above, what is the function of the catalyst in this reaction? (2)
- 8.7 Hydrogenation of vegetable oils has been used in the food industry to make the well-known butter substitute, margarine.
- 8.7.1 Use the terms *saturated*, *unsaturated*, *addition*, *double bond* in a short description of what happens to an organic molecule that is hydrogenated. (4)
- 8.7.2 Explain in detail why liquid plant oils (unsaturated fats) become a high melting point (saturated) solid fats when they are hydrogenated. (3)
- 8.7.3 Reaction **E** is a hydrogenation reaction. Write the IUPAC **name** of the product (**III**) if the reactant is completely hydrogenated. (1)
- 8.8 Esters, such as the product in Reaction **B**, are used in the food industry as flavourings. These are not entirely artificial since esters produced by certain plants are often responsible for the plant’s characteristic flavour.
- 8.8.1 Write the IUPAC **name** of the carboxylic acid used in Reaction **B**. (1)
- 8.8.2 Give the condensed structural formula of the ester (**I**) produced in Reaction **B** and give its IUPAC **name**. (3)
- 8.8.3 Would you expect the ester (**I**) produced in Reaction **B** to have a lower or higher boiling point than the alcohol used to produce it? Explain your answer. (4)

- 8.9 Reaction **C** represents an addition reaction known as “hydrohalogenation”.
- 8.9.1 Give two basic requirements for addition reactions to occur in organic molecules? (2)
- 8.9.2 Give the IUPAC **name** for molecule (**II**) in reaction **C**. (1)
- 8.10 Name the products (**IV**) and (**V**) in Reaction **F**. (2)
- [34]

EXAMINATION TOTAL: 200 marks

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EXAMINATION DATA SHEET FOR THE PHYSICAL SCIENCES
(CHEMISTRY)

TABLE 1 PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Magnitude of charge on electron	e	$1,6 \times 10^{-19} \text{ C}$
Mass of an electron	m_e	$9,1 \times 10^{-31} \text{ kg}$
Standard pressure	p^θ	$1,01 \times 10^5 \text{ Pa}$
Molar gas volume at STP	V_m	$22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
Standard temperature	T^θ	273 K
Avogadro's constant	N_A	$6,02 \times 10^{23} \text{ mol}^{-1}$
Faraday's constant	F	$96\,500 \text{ C} \cdot \text{mol}^{-1}$

TABLE 2 CHEMISTRY FORMULAE

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$	$n = \frac{V}{V_m}$
$c = \frac{n}{V}$ OR $c = \frac{m}{MV}$	$K_w = [H_3O^+] \cdot [OH^-] = 1 \times 10^{-14}$ at 25 °C (298 K)	
$q = It$ $q = nF$	$E_{\text{cell}}^\theta = E_{\text{cathode}}^\theta - E_{\text{anode}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{oxidising agent}}^\theta - E_{\text{reducing agent}}^\theta$	

TABLE 3 PERIODIC TABLE

[illegible]

TABLE 4 STANDARD ELECTRODE POTENTIALS

	Half-reaction	E°/volt
	$\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$	-3,05
	$\text{K}^+ + \text{e}^- \rightleftharpoons \text{K}$	-2,93
	$\text{Cs}^+ + \text{e}^- \rightleftharpoons \text{Cs}$	-2,92
	$\text{Ba}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ba}$	-2,90
	$\text{Sr}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sr}$	-2,89
	$\text{Ca}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ca}$	-2,87
	$\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$	-2,71
	$\text{Mg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mg}$	-2,37
	$\text{Al}^{3+} + 3\text{e}^- \rightleftharpoons \text{Al}$	-1,66
	$\text{Mn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mn}$	-1,18
	$2\text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-$	-0,83
	$\text{Zn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Zn}$	-0,76
	$\text{Cr}^{3+} + 3\text{e}^- \rightleftharpoons \text{Cr}$	-0,74
	$\text{Fe}^{2+} + 2\text{e}^- \rightleftharpoons \text{Fe}$	-0,44
	$\text{Cd}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cd}$	-0,40
	$\text{Co}^{2+} + 2\text{e}^- \rightleftharpoons \text{Co}$	-0,28
	$\text{Ni}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ni}$	-0,25
	$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}$	-0,14
	$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}$	-0,13
	$\text{Fe}^{3+} + 3\text{e}^- \rightleftharpoons \text{Fe}$	-0,04
	$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0,00
	$\text{S} + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$	+0,14
	$\text{Sn}^{4+} + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}$	+0,15
	$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0,17
	$\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$	+0,34
	$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightleftharpoons 4\text{OH}^-$	+0,40
	$\text{SO}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{S} + 2\text{H}_2\text{O}$	+0,45
	$\text{I}_2 + 2\text{e}^- \rightleftharpoons 2\text{I}^-$	+0,54
	$\text{O}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2$	+0,68
	$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0,77
	$\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}$	+0,79
	$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{NO}_2(\text{g}) + \text{H}_2\text{O}$	+0,80
	$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$	+0,80
	$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}$	+0,96
	$\text{Br}_2 + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$	+1,09
	$\text{Pt}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pt}$	+1,20
	$\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1,21
	$\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$	+1,23
	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	+1,33
	$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	+1,36
	$\text{Au}^{3+} + 3\text{e}^- \rightleftharpoons \text{Au}$	+1,42
	$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1,51
	$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$	+1,77
	$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-$	+2,87

Increasing oxidising ability

Increasing reducing ability