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Physical Science Preliminary Paper 2: Chemistry
17th September 2020

Examiner: Mrs Govender
Moderator: Ms Van Schoor

Marks: 200
Time: 3 hours

Examination Number

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PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of **16** pages and a separate answer sheet (page 17). Ensure that your paper is complete.
2. Answer all questions on the folio paper and answer sheet provided.
3. Read the questions carefully.
4. Use the data and formulae sheet whenever necessary.
5. **START EACH QUESTION ON A NEW PAGE.**
6. Please ensure that you number your answers as the questions are numbered
7. Unless instructed otherwise, it is NOT necessary to give state symbols (phase indicators) when asked to write a balanced chemical equation.
8. Show all necessary steps in calculations.
9. Where appropriate, express final answers correct to TWO decimal places.
10. It is in your own interest to write legibly and to present your work neatly.

Acknowledgments:
IEB, Kearsney College, Michael House

Question 1: Multiple Choice

[20]

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Indicate your choice by placing a cross on the letter in the cover of the **answer book** provided.

1.1 The correct chemical formula for aluminium sulphite is:

- A. AlSO_3
- B. $\text{Al}(\text{SO}_3)_3$
- C. $\text{Al}_2(\text{SO}_3)_3$
- D. Al_2SO_3

1.2 Identify the predominant intermolecular forces in pure liquid ammonia.

- A. Hydrogen bonds
- B. Dipole-dipole interactions
- C. London forces
- D. Ionic bonds

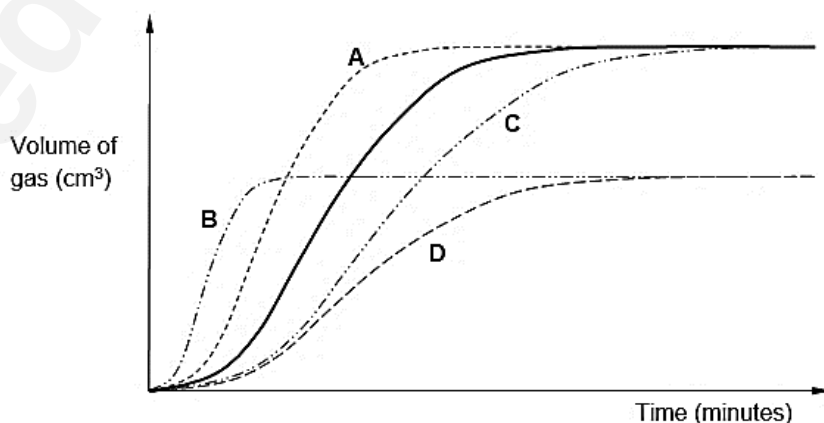
1.3 Carbon monoxide reacts with steam in the following reaction equation:



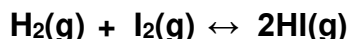
Which change will favour the forward reaction?

- A. Decrease in pressure
- B. Increase in pressure
- C. Increase in temperature
- D. Decrease in temperature

1.4 In an experiment a 3 g lump of zinc and 1,5 g of powdered, zinc are added separately to equal volumes of dilute sulphuric acid. The **solid line** in the graph shows the volume of gas given off when the 3 g lump of zinc is used. Which dotted line is obtained when 1,5 g of powdered zinc is used?



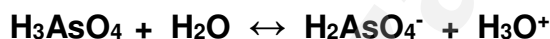
- 1.5 Consider the reaction represented by the following balanced chemical equation. The system is initially at equilibrium.



The pressure is increased by decreasing the volume of the container at constant temperature. How will the **amount** of HI and the **concentration** of HI change due to this increase in pressure?

	Amount of HI	Concentration of HI
A.	Remains the same	Decrease
B.	Remains the same	Increase
C.	Increase	Increase
D.	Decrease	Decrease

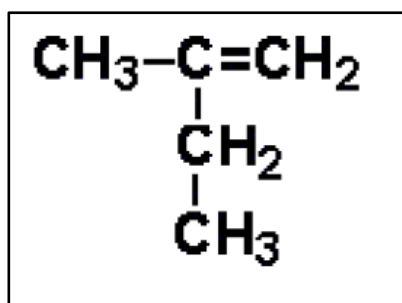
- 1.6 Arsenic acid (H_3AsO_4) reacts with water as follows:



The conjugate base of arsenic acid in this reaction is:

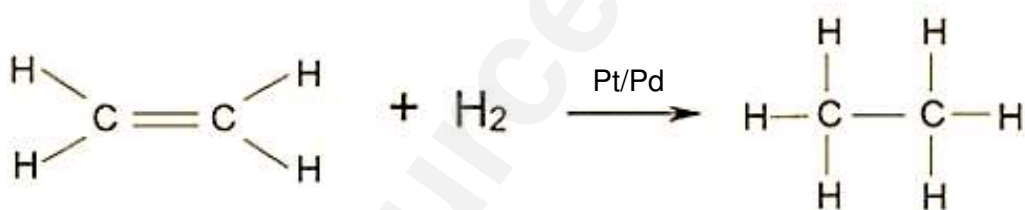
- A. H_3O^+
 B. H_2AsO_4^-
 C. H_2O
 D. OH^-
- 1.7 Which of the following pairs will react spontaneously with each other?
- A. $\text{Ag}^+(\text{aq}) + \text{Pb}(\text{s})$
 B. $\text{Mg}^{2+}(\text{aq}) + \text{Cu}(\text{s})$
 C. $\text{Mg}^{2+}(\text{aq}) + \text{Zn}(\text{s})$
 D. $\text{Cu}^{2+}(\text{aq}) + \text{Ag}(\text{s})$
- 1.8 Which one of the statements about the extraction of aluminium from alumina is **false**?
- A. Aluminium is formed at the negative electrode through the process of reduction.
 B. Carbon dioxide is a by-product of the extraction process.
 C. Oxide ions are reduced at the graphite electrodes.
 D. Alumina dissolves in molten cryolite reducing the energy cost of running the smelter.

1.9 The correct IUPAC name for the following:



- A. pentene
- B. 3-methyl- 2-but-2-ene
- C. 2-methylbut-1-ene
- D. 2-ethylprop-1-ene

1.10 Consider the following organic reaction.



Which one of the following is the correct SPECIFIC type and GENERAL type of reaction shown above?

	SPECIFIC TYPE	GENERAL TYPE
A.	hydrogenation	addition
B.	hydrogenation	substitution
C.	halogenation	addition
D.	halogenation	substitution

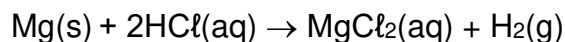
Question 2

[21]

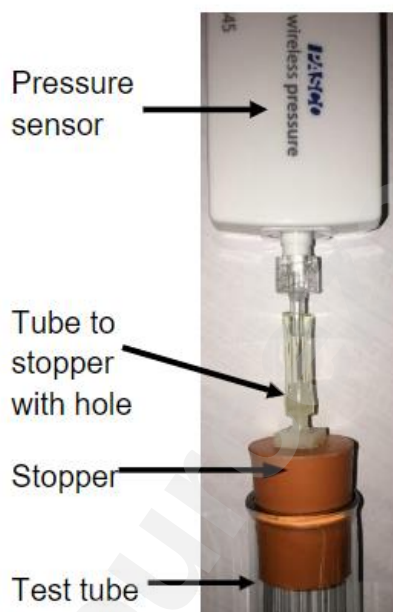
- 2.1 Define *electronegativity*. (2)
- 2.2 Use the electronegativity difference to explain the difference in the **type** of covalent bonds present in SiCl_2 and CS_2 . (4)
- 2.3 Molybdenum (Mo) is a metal that is often used to make an alloy with iron. Like iron, it is extracted from its oxide. Unlike iron, it occurs mainly as its sulphide. Molybdenum sulphide is converted into molybdenum oxide by heating in air. The balanced equation for the reaction is:
- $$2 \text{MoS}_2 + 7 \text{O}_2 \rightarrow 2 \text{MoO}_3 + 4 \text{SO}_2 \quad \Delta H < 0$$
- 2.3.1 Name the type of intramolecular bonds present in solid molybdenum. (1)
- 2.3.2 Explain the origin of the type of intramolecular bonds mentioned in 2.3.1 (2)
- 2.3.3 Define *exothermic reaction*. (2)
- 2.3.4 Is the reaction between molybdenum sulphide and oxygen exothermic or endothermic? Explain your answer by referring to the energies absorbed and released. (3)
- 2.4 4 g of molybdenum sulphide reacts with 28 000 cm^3 of oxygen gas at S.T.P.
- 2.4.1 Determine the number of moles of molybdenum sulphide present at the beginning of the reaction. (3)
- 2.4.2 Use suitable calculations to calculate the mass of oxygen gas that is in excess. (4)

Question 3 Practical day at OWLAG**[23]**

At OWLAG we investigated the rate of the reaction between magnesium metal ribbon and hydrochloric acid. The chemical equation for this reaction is given below:

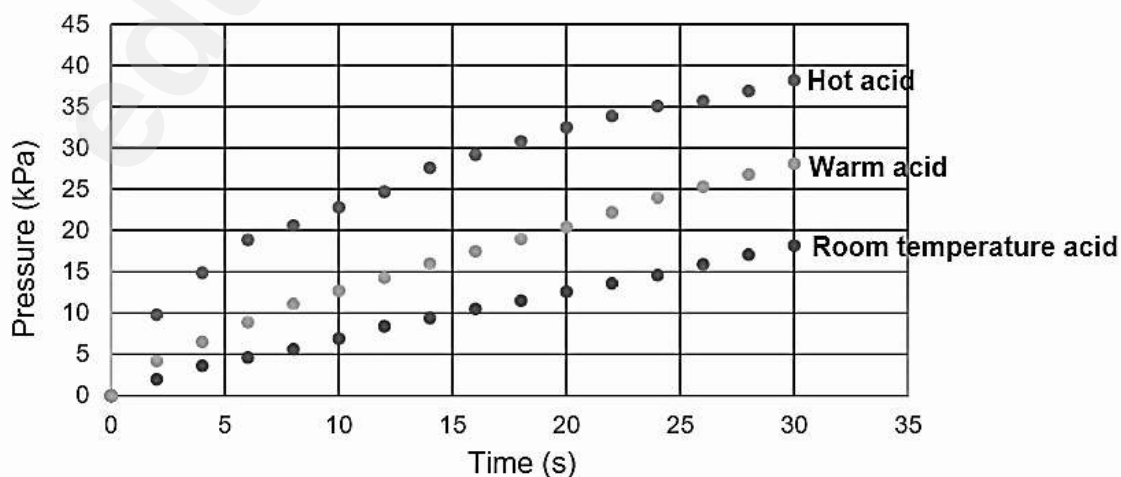


We recorded the pressure within a test tube as the reaction proceeded using the set-up and apparatus below.



- 3.1 Adrian and Bonga tested the effect of temperature on the reaction rate. They produced the following interesting pressure versus time graphs, by adding 0,05 g of magnesium ribbon to 5 ml of 1,0 mol.dm⁻³ HCl, at different temperatures. They stopped the recording of results after 30 seconds.

Graph showing pressure vs time



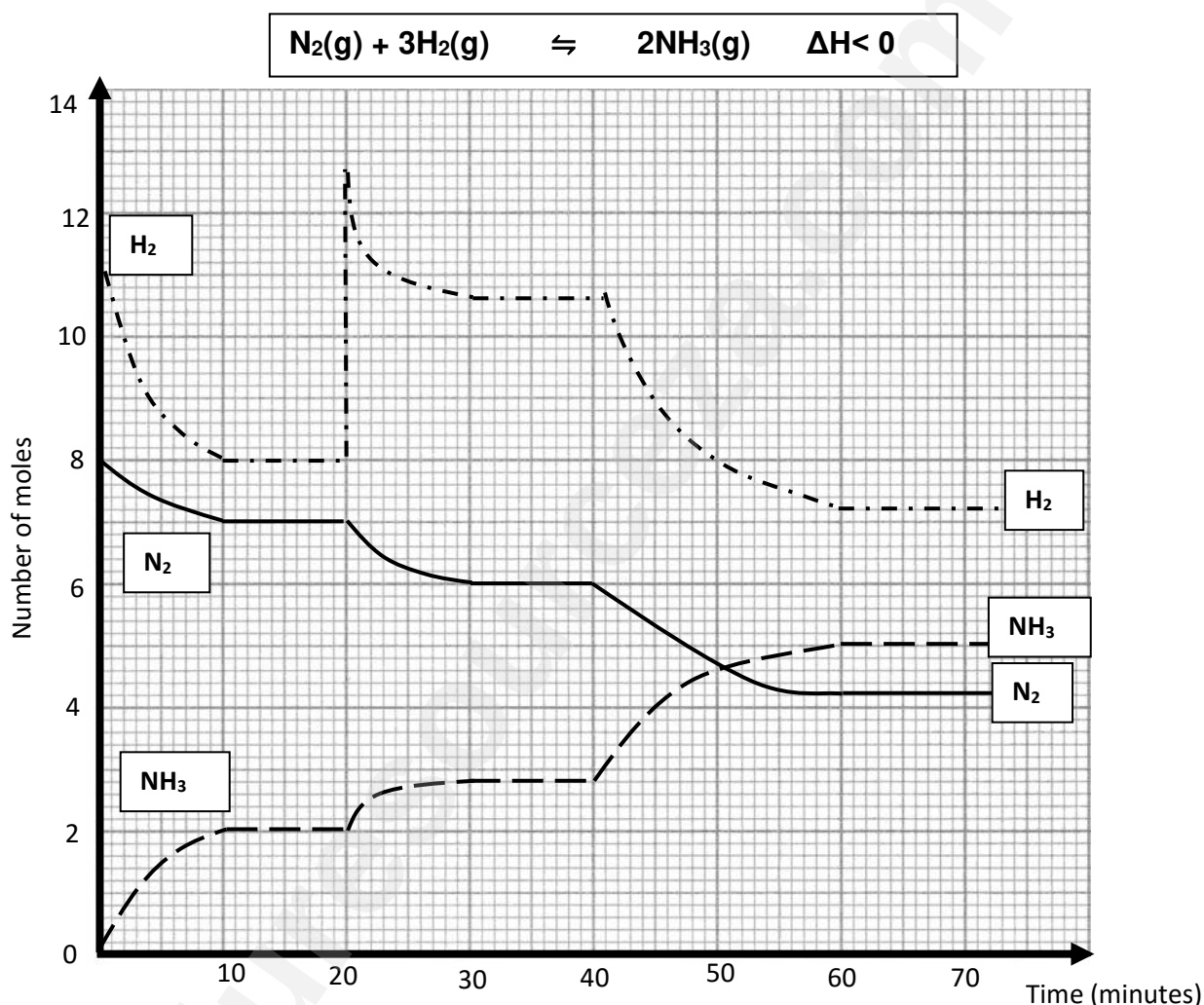
- 3.1.1 Define *reaction rate*. (2)
- 3.1.2 Please answer this question on your **ANSWER SHEET**. Draw in a best fit curve for each graph. (2)
- 3.1.3 What physical quantity does the gradient of these curves represent? (1)
- 3.1.4 Describe the trend that can be seen between temperature and average reaction rate in this investigation. (2)
- 3.1.5 Use the collision theory to explain the trend described in 3.1.4. (3)
- 3.2 Bonga wonders how much hydrogen gas would have been produced if the reaction between 5 ml of 1 mol.dm⁻³ HCl and 0,05 g of magnesium ribbon was run **to completion**.
- 3.2.1 Calculate the maximum number of moles of hydrogen gas that could be produced. (5)
- 3.2.2 What observation could Bonga use to confirm that the reaction is complete? (2)
- 3.3 What mass of impure magnesium metal with a percentage purity of 89,5% is required to produce 0,04 moles of hydrogen gas?
(Use the equation from page 6). (6)



Question 4 Chemical Equilibrium

[25]

In the Haber process reaction to make ammonia, 8 mol of N_2 gas and 11 mol of H_2 gas are placed into a $5\,000\text{ cm}^3$ container at a temperature of $450\text{ }^\circ\text{C}$. The container is sealed immediately after the gases are added. The graph below represents the change in the number of **moles** of gases in the reaction vessel over a period of 70 minutes. **Pressure remains constant throughout.**



- 4.1 Write the **equilibrium constant expression**, K_c , for the Haber process reaction. (2)
- 4.2 Use your graph to determine the equilibrium concentrations of H_2 , N_2 and NH_3 at a time of 15 minutes. (4)
- 4.3 Calculate the equilibrium constant, K_c at $450\text{ }^\circ\text{C}$, for this reaction at 15 minutes. (3)
- 4.4 Evaluate the significance of the K_c value at $450\text{ }^\circ\text{C}$ in terms of the expected yield of products in this reaction (2)
- 4.5 What change was made to the equilibrium mixture at a time of 20 minutes? (2)
- 4.6 State *Le Chatelier's Principle*. (2)

- 4.7 Use Le Chatelier's Principle to explain the change in the number of moles of **each gas** as a result of the change that occurred at a time of 20 minutes. (4)
- 4.8 State the cause of the change occurring at $t = 40$ min. (2)
- 4.9 Sketch a reaction rate versus time graph for the period of 70 minutes on your **ANSWER SHEET**. (4)

Use the following **key** to show the forward and the reverse reactions:

Forward reaction _____ Reverse reaction - - - - -

Question 5 Acids and Bases

[30]

Consider a **strong** hypothetical base $X(OH)_2$.

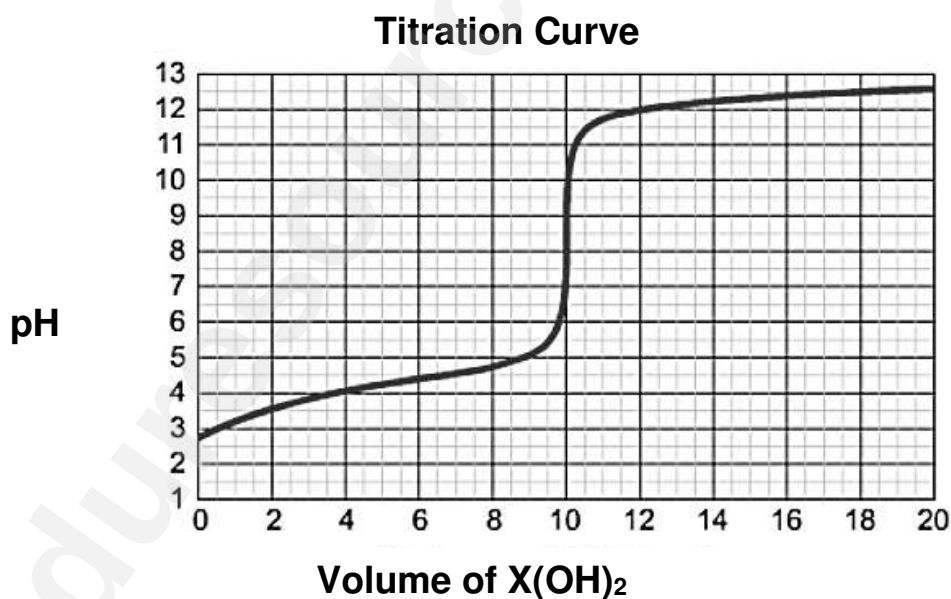
$0,5 \text{ dm}^3$ of a $0,22 \text{ mol} \cdot \text{dm}^{-3}$ solution of this base is prepared at 30°C .

- 5.1 Define a *standard solution*. (2)
- 5.2 Determine the number of moles of $X(OH)_2$ needed to prepare the solution. (3)
- 5.3 Write down a balanced chemical equation to show the dissociation of $X(OH)_2$ in water. Include state symbols in your answer. (3)
- 5.4 K_w of water at 30°C is $1,219 \times 10^{-14}$. Calculate the concentration of the hydronium ions in the $X(OH)_2$ solution at 30°C . (3)

The standard $X(OH)_2$ solution prepared is used to find the concentration of either aqueous **oxalic acid** ($H_2C_2O_4$)/(COOH) $_2$ or **hydrochloric acid** by means of a titration.

- 5.5 The K_a value at 25°C for HCl is $1,3 \times 10^6$ and for $H_2C_2O_4$ is $6,6 \times 10^{-5}$. Which of the two acids will have a higher electrical conductivity. Explain. (3)

The pH of the reaction between $X(OH)_2$ and **one** of the acids was recorded with a pH sensor as the reaction took place. The curve obtained is shown below.



- 5.6 Define *equivalence point*. (2)
- 5.7 Use the graph to establish which one of the two acids was used in this titration. (1)
- 5.8 Explain your choice in 5.7. (2)

- 5.9 The table below shows two possible unbalanced salt hydrolysis equations of the aqueous salt XC_2O_4 that forms when X(OH)_2 reacts with $\text{H}_2\text{C}_2\text{O}_4$.

A	$\text{C}_2\text{O}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{C}_2\text{O}_4 + \text{OH}^-$
B	$\text{X}^{2+} + \text{H}_2\text{O} \rightleftharpoons \text{X(OH)}_2 + \text{H}_3\text{O}^+$

Choose the correct equation by writing down the corresponding letter.
Only write A or B.

(1)

- 5.10 Explain your choice in 5.9.

(3)

The table below lists the indicators that are most commonly used in the school laboratory and their pH ranges.

Indicator	pH range
Bromothymol blue	6,0 - 7,6
Methyl orange	3,1 - 4,4
Phenolphthalein	8,3 - 10,0

- 5.11 Which indicator would be best suited for the titration of X(OH)_2 against the hydrochloric acid solution?

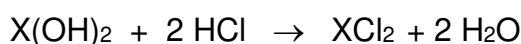
(1)

- 5.12 Chloe dissolves X(OH)_2 in water to make a standard solution of 250 ml.

The steps below indicate the method followed to make the standard solution.

A	Add pure water to dissolve the salt completely and stir.
B	Rinse the sides of the beaker to ensure salt crystals on the side of the beaker are dissolved.
C	Place empty beaker on the scale and note the reading.
D	Transfer the solution in the beaker to a 250 ml volumetric flask using funnel to prevent spillage.
E	Fill the volumetric flask so that the meniscus is on the calibration mark.
F	Use a spatula to add the correct mass of X(OH)_2 to the beaker.
G	Rinse all solution remaining in the beaker into the flask, seal and shake.

- a) Determine the correct order for the steps shown above and write the **letters** in the correct sequence from start to finish. (2)
- b) Chloe used 3,4 g of solid to make the 250 ml solution of X(OH)_2 . In a titration she uses 25,0 ml of this solution and titrates it with dilute hydrochloric acid according to the following balanced equation.



She finds that she needs 24,9 ml of 0,22 mol.dm⁻³ hydrochloric acid to fully neutralise the base.

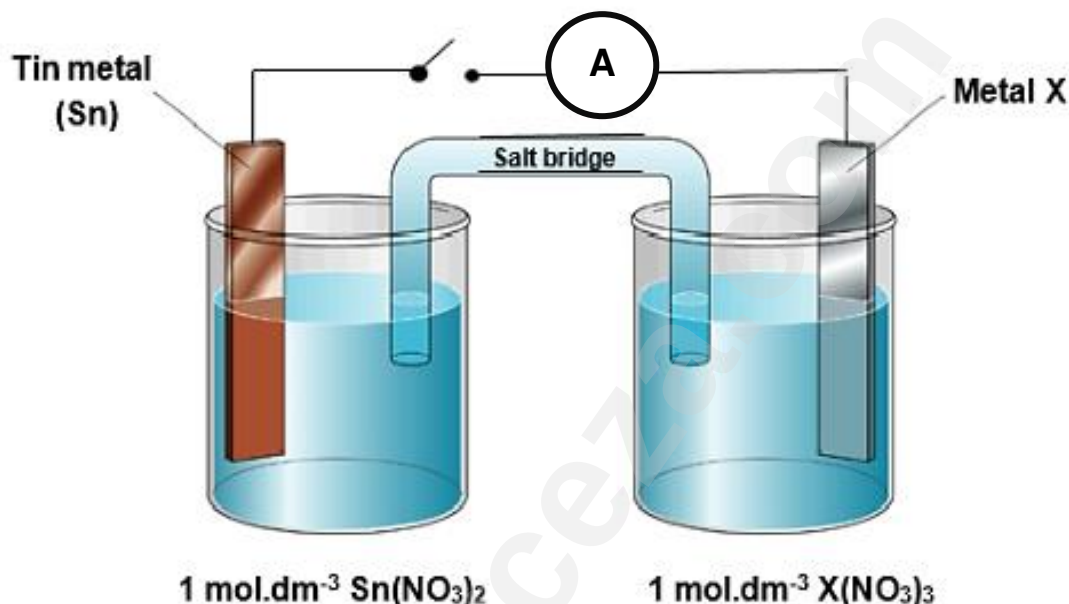
Calculate the number of moles of X(OH)_2 in the original solution.

(4)

Question 6 Electrochemistry

[23]

An electrochemical cell is constructed with an open switch, as shown in the diagram. A strip of tin (Sn) and a strip of unknown metal, X are used as electrodes. When the switch is closed, the mass of the Sn electrode increases.



The half reactions involved in this cell are as follows:



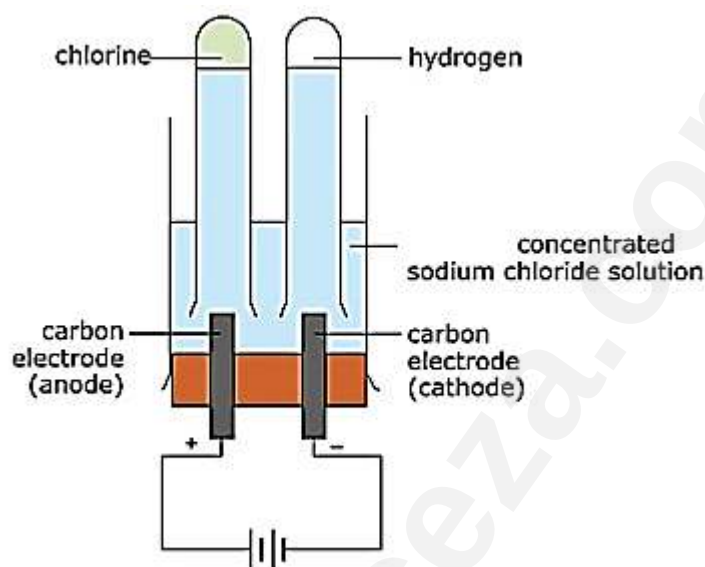
- 6.1. Name the energy conversion that takes place in this cell. (2)
- 6.2. Which electrode (Sn or X) is the cathode? Justify your answer. (2)
- 6.3. Define the term *anode*. (2)
- 6.4. State the direction of electron flow in the external circuit when the switch is closed. State only from **X to Sn** or from **Sn to X**. (1)
- 6.5. If the standard cell potential for this cell is +0,60 V, calculate the standard electrode potential for the half cell labelled X. (3)
- 6.6. Identify metal X. (1)
- 6.7. Write down the cell notation with standard conditions for this cell. (4)
- 6.8. Write down the balanced net-ionic equation for the overall chemical reaction occurring in this cell. (2)
- 6.9. Explain how the salt bridge maintains neutrality at the **cathode**. (3)

- 6.10 The salt bridge is replaced by one which is narrower and longer than the one shown in the diagram. With the cell operating under standard conditions, state how each of the following will be affected by this change. Write down: **INCREASES, DECREASES OR REMAINS THE SAME.**

- | | | |
|--------|-------------------------|-----|
| 6.10.1 | The emf | (1) |
| 6.10.2 | The internal resistance | (1) |
| 6.10.3 | The current delivered | (1) |

Question 7 Electrochemistry**[14]**

Sodium chloride can be easily dissolved in water. The diagram below shows the apparatus used to electrolyse a concentrated solution of sodium chloride (brine). Two gases, hydrogen and chlorine, are formed as products.



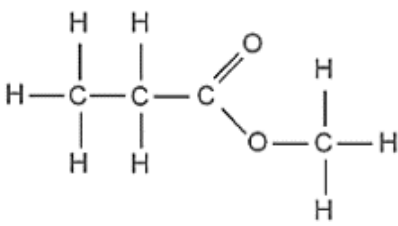
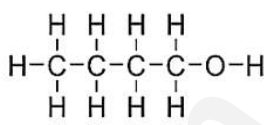
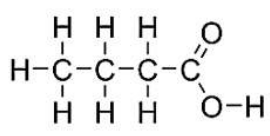
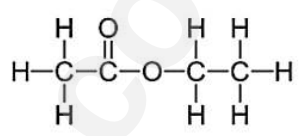
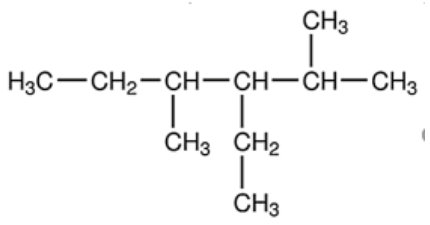
- 7.1 Write down the half-reaction that takes place at the positive electrode. (2)
- 7.2 Why is it important that the chlorine gas and hydrogen gas are collected in two different test tubes as is shown in the diagram above? (2)
- 7.3 Use the relative strengths of the oxidising agents present to explain why sodium metal is not produced at the cathode in the cell above. (3)
- 7.4 A constant current of 4 150 A is passed through a membrane cell for 3,5 minutes .

Calculate the volume of chlorine gas produced, at STP, during this period of time. (7)

Question 8 Organic Chemistry

[22]

Consider the following organic compounds.

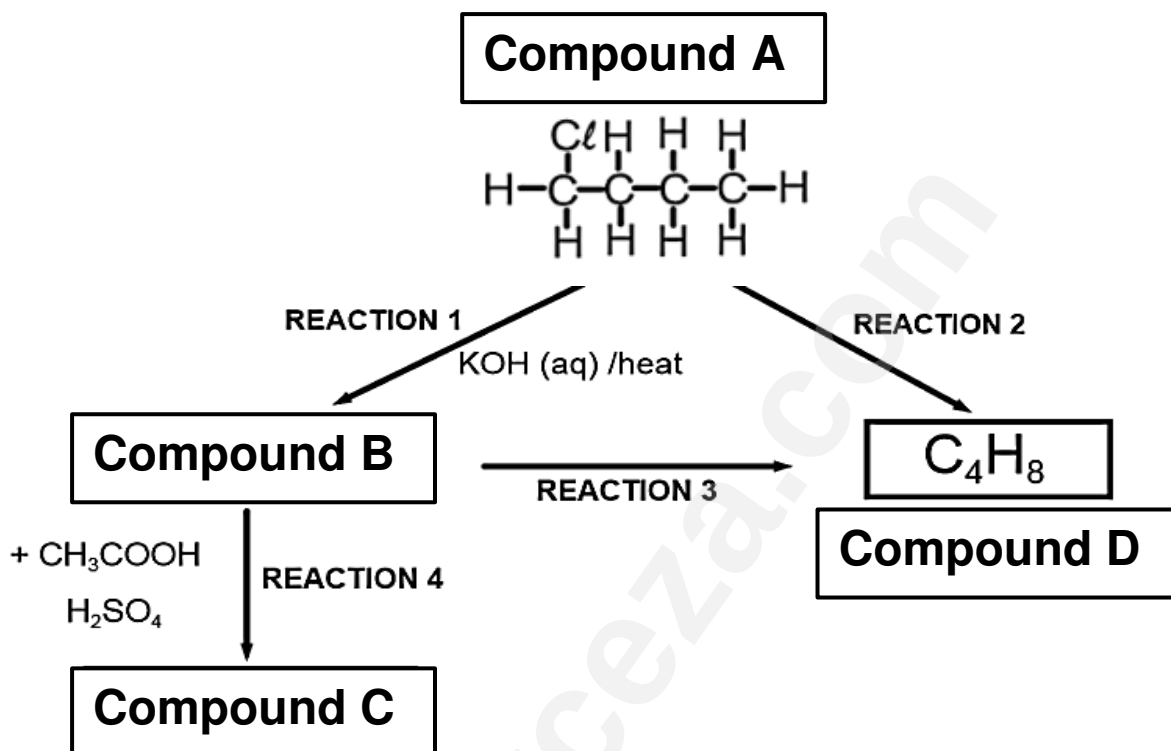
Compound A	Compound B
	
Compound C	Compound D
	
Compound E	
	

- 8.1 Define *functional group*. (2)
- 8.2 Name the functional group in compound C. (1)
- 8.3 Give the IUPAC name for compound A. (2)
- 8.4 Give the condensed structural formula for compound D. (2)
- 8.5 Define the term *structural isomer*. (2)
- 8.6 Why can compound B and C **not** be called isomers? (2)
- 8.7 Provide the name of a compound in the table that is a functional isomer of D. (2)
- 8.8 Define *intermolecular force*. (2)
- 8.9 The boiling point of compound D is 117,7 °C and for compound C is 163,5 °C. Explain the difference in boiling points between the two compounds by referring to the type and strength of their intermolecular forces. (4)
- 8.10 Give the IUPAC name of the compound E. (3)

Question 9 Organic Reactions

[22]

Consider the following sequence of organic reactions.



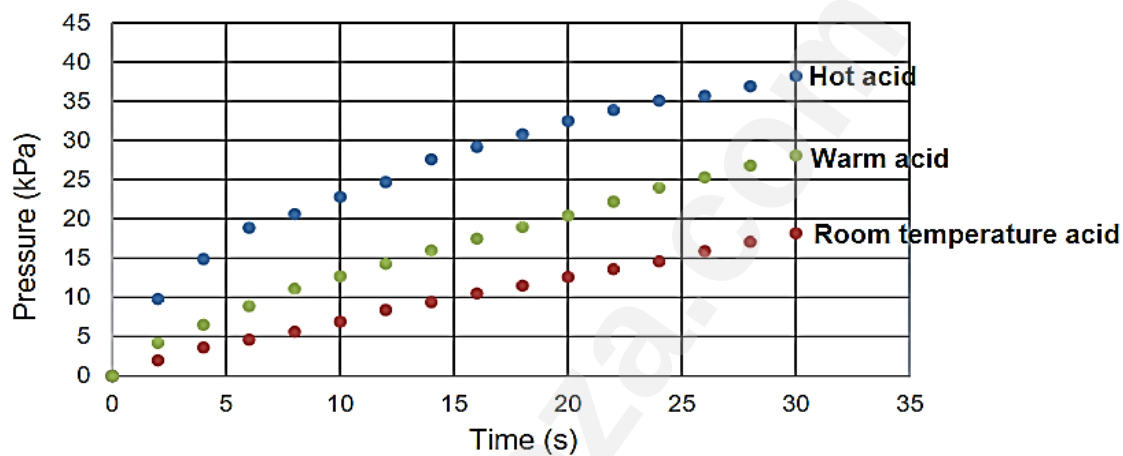
- 9.1 Define *homologous series* (2)
- 9.2 Name the homologous series that compound A belongs to. (1)
- 9.3 Identify and name the **specific** type of reaction occurring in:
- 9.3.1 Reaction 1 (1)
- 9.3.2 Reaction 2 (1)
- 9.4 Draw the structural formula of compound B and **circle** its functional group. (2)
- 9.5 Compound B reacts with ethanoic acid to produce compound C in the presence of concentrated sulphuric acid according to reaction 4.
- 9.5.1 Draw and name the organic molecule of compound C, using a structural formula. (4)
- 9.5.2 Give the chemical formula of the inorganic product that will also be produced in reaction 4. (2)
- 9.5.3 Give one reason why sulphuric acid is used in this reaction. (1)
- 9.6 Compound D (C_4H_8) reacts with excess oxygen.
- 9.6.1 Write a balanced chemical equation for the reaction. (3)
- 9.6.2 When 12,32 g of compound D (C_4H_8) reacted with excess O_2 , 30,03 g of carbon dioxide gas was produced. Calculate the percentage yield of carbon dioxide. (5)

Answer Sheet for Questions 3.1.2 and 4.9

Exam Number

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3.1.2



4.9

