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TOTAL
MARKS

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INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
NOVEMBER 2023

PHYSICAL SCIENCES: PAPER II

EXAMINATION NUMBER

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Time: 3 hours

200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 30 pages and a Data Sheet of 3 pages (i–iii). Please check that your question paper is complete.
2. Read the questions carefully.
3. **Answer ALL the questions on the question paper and hand this in at the end of the examination. Remember to write your examination number in the space above.**
4. Use the data and formulae whenever necessary.
5. Show your working in all calculations.
6. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
7. Answers must be expressed in decimal format, not left as proper fractions.
8. Where appropriate, express answers to TWO decimal places.
9. It is in your own interest to write legibly and to present your work neatly.
10. TWO blank pages (page 29 and 30) are included at the end of the paper. If you run out of space for an answer, use these pages. Clearly indicate the number of your answer should you use this extra space.

FOR MARKERS' USE ONLY

Question	1	2	3	4	5	6	7	8	9	Total
Marks	20	19	17	27	27	28	22	24	16	200
Marked										
Moderated										

QUESTION 1 MULTIPLE-CHOICE QUESTIONS

Answer these multiple-choice questions on the grid below. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct. Every question has only one correct answer.

A	B	C	D
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Here the option C has been marked as an example.

1.1	A	B	C	D	(2)
1.2	A	B	C	D	(2)
1.3	A	B	C	D	(2)
1.4	A	B	C	D	(2)
1.5	A	B	C	D	(2)
1.6	A	B	C	D	(2)
1.7	A	B	C	D	(2)
1.8	A	B	C	D	(2)
1.9	A	B	C	D	(2)
1.10	A	B	C	D	(2)

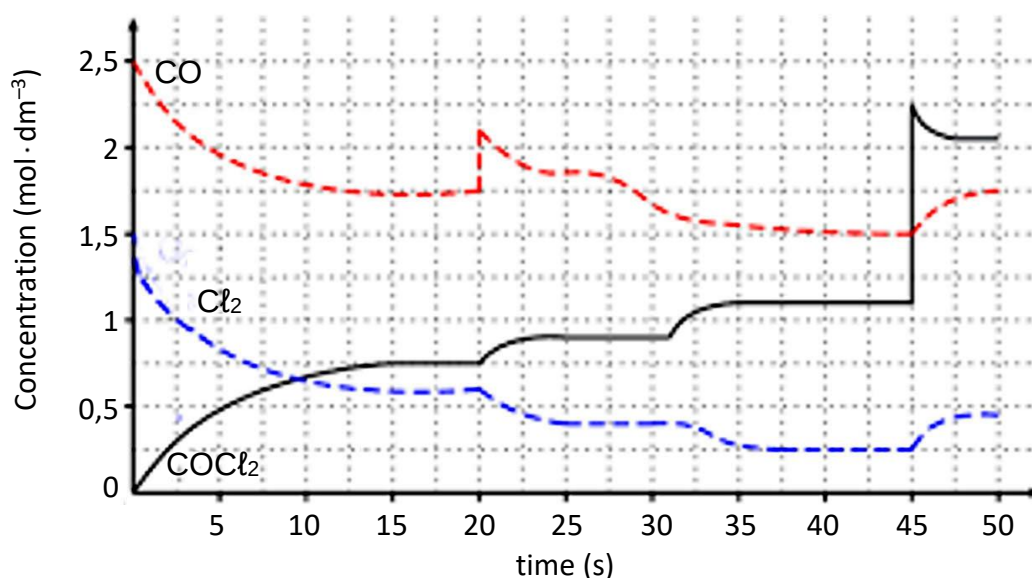
1.1 The oxidation number of the sulphur in H_2SO_3 will be ...

- A -4
- B +4
- C -2
- D +2

1.2 The balanced equation below represents a reaction that occurs in a sealed container:



Various changes were made to the reaction conditions at various times as shown by the graphs below:



[Source: <<http://www.dynamicscience.com.au/tester/solutions1/chemistry/equilibrium/Lesson%203-%20changes%20to%20an%20equilibrium.pdf>>)]

Which of the following statements regarding the changes made to the equilibrium mixture are true?

- (i) at 20 s the concentration of carbon monoxide gas was increased
- (ii) at 32,5 s the pressure of the system was increased
- (iii) at 32,5 s the temperature was decreased suddenly

- A i, ii and iii
- B i only
- C i and iii only
- D ii and iii only

1.3 Which of the following is true for a standard solution? In a standard solution the ...

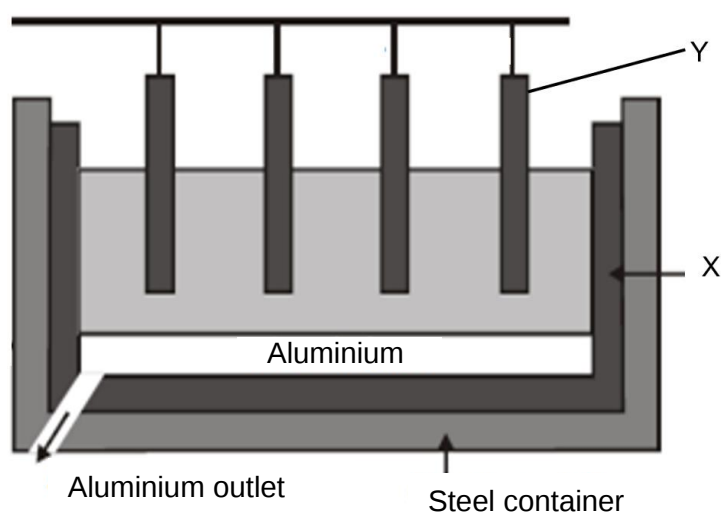
- A concentration is always known.
- B concentration is always $1 \text{ mol} \cdot \text{dm}^{-3}$.
- C temperature is always 275 K.
- D pH is always 7.

- 1.4 Sacrificial anodes are used to protect other metals that oxidise easily. Which one of the following metals would protect the anchor of a ship from oxidation? The anchor is made of iron(II).

- A Fe(III)
 B Ni
 C Sn
 D Mg

Questions 1.5 and 1.6 refer to the diagram below:

The schematic diagram below represents a cell used to extract aluminium from bauxite.



[Source: <<https://www.ontexclasses.com/2014/03/in-extraction-of-aluminium.html>>]

- 1.5 Which option gives the names and charges of electrodes X and Y correctly?

	Electrode X	Charge of Electrode X	Electrode Y	Charge of electrode Y
A	cathode	positive	anode	negative
B	anode	negative	cathode	positive
C	cathode	negative	anode	positive
D	anode	positive	cathode	negative

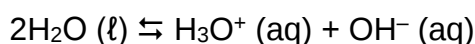
- 1.6 Which option gives the oxidation and reduction half reactions taking place in this cell correctly?

	Reduction	Oxidation
A	$\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$	$2\text{O}^{2-} + 2\text{e}^- \rightarrow \text{O}_2$
B	$\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$	$2\text{O}^{2-} \rightarrow \text{O}_2 + 2\text{e}^-$
C	$\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$	$2\text{O}^{2-} \rightarrow \text{O}_2 + 2\text{e}^-$
D	$\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$	$2\text{O}^{2-} + 2\text{e}^- \rightarrow \text{O}_2$

1.7 Consider the salt MgSO_4 and write down the letter that will explain the pH of the salt solution correctly.

- A **Basic:** $\text{Mg}(\text{OH})_2$ is a strong base. Amount of OH^- more than H_3O^+ as strong base ionises completely but weak acid, H_2SO_4 , ionises partially.
- B **Neutral:** $\text{Mg}(\text{OH})_2$ is a strong base. Amount of OH^- is equal to H_3O^+ as strong base ionises completely and strong acid, H_2SO_4 , fully ionises.
- C **Acidic:** $\text{Mg}(\text{OH})_2$ is a weak base. Amount of OH^- less than H_3O^+ as weak base partially ionised but strong acid, H_2SO_4 , fully ionises.
- D **Acidic:** $\text{Mg}(\text{OH})_2$ is a weak base. Amount of H_3O^+ less than OH^- as weak base partially ionised but strong acid, H_2SO_4 , fully ionises.

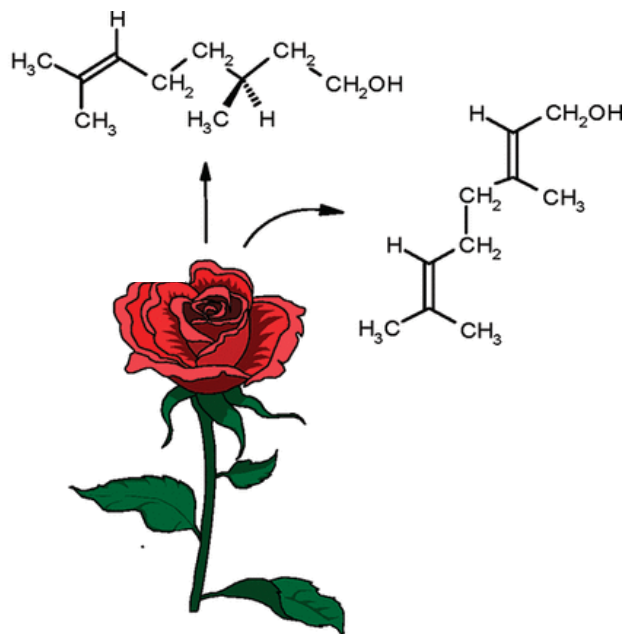
1.8 Water undergoes auto-protolysis and sets up the following equilibrium:



Which of the following statements is **incorrect**:

- A Both the forward and reverse reactions proceed at the same rate.
- B Most of the water molecules do not ionise.
- C The product of the concentrations of the hydronium and hydroxide ions always remains constant at a given temperature.
- D The equilibrium constant will be $K_w = 1 \times 10^7$ as water is not acidic nor basic.

- 1.9 The scent of a red rose consists of a few different molecules represented by the structural formulae given below.



[Source: <<https://pubs.acs.org/doi/abs/10.1021/ed100629v>>]

The structural formulae above are examples of the following homologous series:

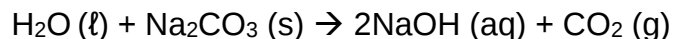
- A haloalkane, ester
 - B alcohol, alkene
 - C carboxylic acids
 - D alcohol, alkane
- 1.10 Which of the following statements regarding carbon is **false**:
- A Carbon has a valency of four in a tetrahedral arrangement.
 - B Carbon atoms can form single, double, triple, or quadruple bonds.
 - C Carbon atoms occur in all organic molecules.
 - D Carbon forms strong covalent bonds with itself and many other elements.

[20]

QUESTION 2 STOICHIOMETRIC CALCULATIONS

Over half of all soda ash (Na_2CO_3) production is used in glass manufacturing, but it is also used in a wide range of other products, such as powdered detergents and soaps and rechargeable batteries, as well as being used extensively in metallurgical processes, and across the food, cosmetic and pharmaceutical industries.

The balanced chemical reaction that occurs when soda ash and water react is as follows:



- 2.1 Give the chemical name of soda ash. (2)

- 2.2 One teaspoon of soda ash is equivalent to 3 g. Calculate the number of moles of soda ash in one teaspoon. Give your answer to **four** decimal places. (3)

- 2.3 Soda ash is a white solid that is dissolvable in water. When 3 g soda ash is dissolved in 200 ml water, calculate the limiting reactant ($1 \text{ dm}^3 \text{ water} = 1 \text{ kg}$). (5)

- 2.4 Use your knowledge regarding intermolecular forces and explain why oil is not soluble in water. (3)

- 2.5 The CO_2 gas was collected to determine the carbon footprint of the reaction. Calculate the expected volume in cm^3 , at room temperature, once the reaction has reached completion. (3)

The actual volume of CO_2 was measured to be $57,33 \text{ cm}^3$.

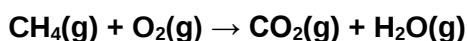
- 2.6 Calculate the percentage yield of the carbon dioxide gas produced in this reaction. (3)

[19]

QUESTION 3 ENERGY CHANGE AND REACTION RATE

The largest and most powerful rocket ever built has blasted off from Texas but blew up within minutes in a test flight that its makers, Space X, hoped will be the first step in the journey to Mars. After a cancelled launch because of a pressurisation issue, the 120-metre Starship rocket system took off, but as it gathered speed, it started to spin at an altitude of 39 kilometres before exploding about four minutes after leaving the ground (*The Guardian*, 20 April 2023).

The explosion reaction that takes place is represented by the chemical equation shown below.



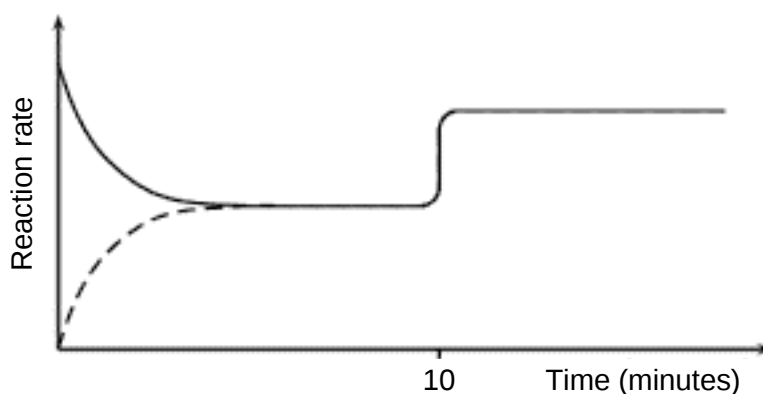
- 3.1 Define an exothermic reaction. (2)

- 3.2 On the following axes, sketch a labelled potential energy graph of the reaction above. (5)



- 3.3 Elon Musk stated that the explosion was intentional. The engineers initiated the reaction between the methane and oxygen gas. Use the collision theory and explain how increasing the oxygen gas in the chamber will affect the reaction rate. (4)

3.4 The following reaction rate–time graph was obtained from the reaction.

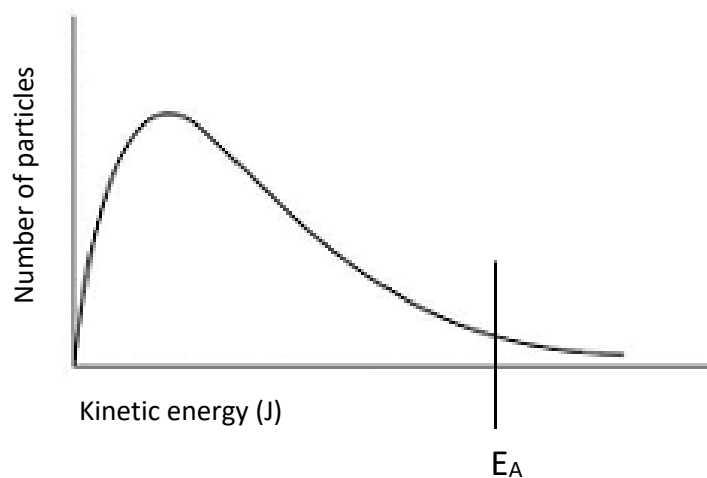


[Source: <<https://www.siyavula.com/read/za/physical-sciences/grade-12/chemical-equilibrium/08-chemical-equilibrium-03>>]

3.4.1 Identify the change in the reaction at 10 min to obtain this graph if atmospheric pressure remained the same. (1)

3.4.2 Explain your answer given in Question 3.4.1. Also write whether the amount of product formed will INCREASE, DECREASE or REMAIN THE SAME. (3)

3.4.3 The following graph is a Maxwell–Boltzmann distribution graph. On this graph, indicate the effect that the change, as identified in Question 3.4.1, will have.



(2)
[17]

QUESTION 4 CHEMICAL EQUILIBRIUM

- 4.1 Chlorine gas is used as a disinfectant, microbicide and algicide in food processing systems, pulp and paper mill systems, and commercial and industrial water-cooling systems. The following balanced chemical reaction indicates the formation of chlorine gas and carbon monoxide from carbonyl dichloride.

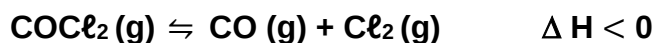
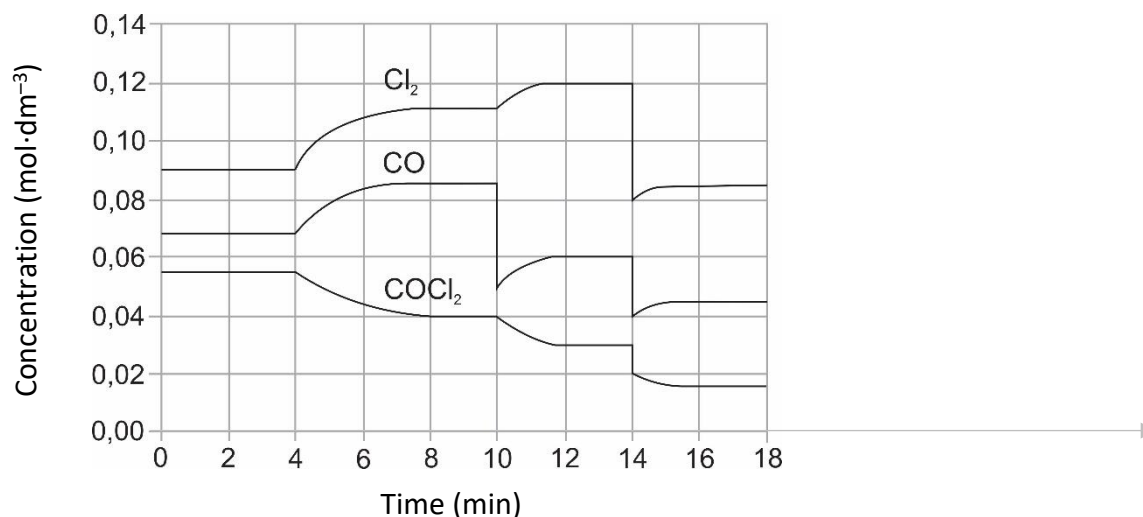


Figure 1: Concentration–time graph of the formation of chlorine gas

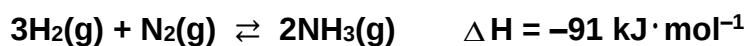


- 4.1.1 State Le Chatelier's principle. (2)

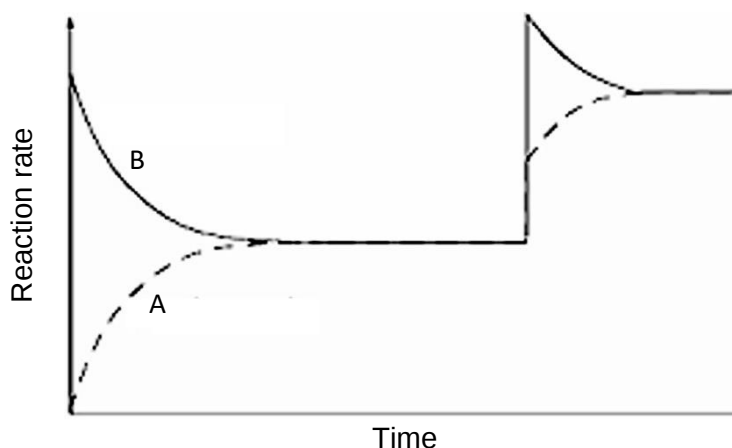
- 4.1.2 Use Le Chatelier's principle to explain the disturbance at 14 minutes. (4)

4.1.3 At 18 minutes, a student added CO. On Figure 1 on page 11, draw the effect the disturbance will have on the reaction. Your graph must show the effect until the reaction reached equilibrium again. (3)

4.2 The following balanced equation represents the Haber process that took place in a sealed reaction flask.



The graph below represents the rate of the forward and reverse reactions over time. Study the graph and answer the questions below.



[Source: <<http://www.dynamicscience.com.au/tester/solutions1/chemistry/equilibrium/Lesson%203-%20equilibriumgraphs.pdf>>]

4.2.1 Which symbol, A or B, represents the reverse reaction? (2)

4.2.2 Explain your answer to Question 4.2.1. (4)

4.2.3 Write down the expression for the equilibrium constant (K_c) for the reverse reaction. (2)

4.2.4 Initially only 3 moles of NH_3 are sealed in the 750 cm^3 reaction flask. When equilibrium is established, 0,75 moles of N_2 is present in the container. Calculate the K_c value for this reaction. (6)

4.2.5 What does a low K_c value indicate?

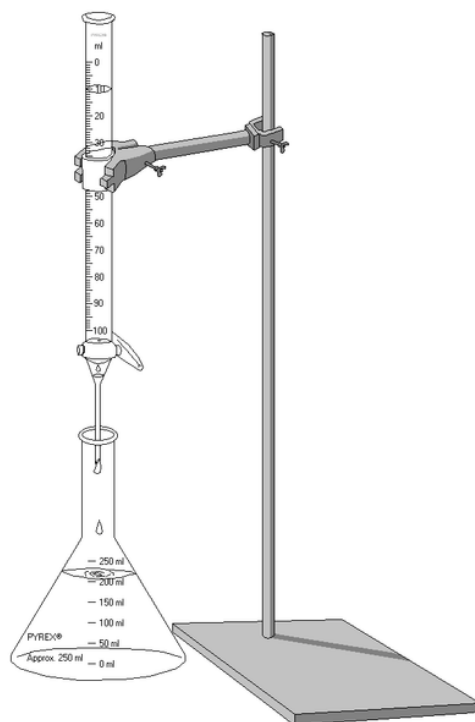
(2)

4.2.6 During the reaction, NH_3 is added. What effect will the increase in concentration of NH_3 have on the equilibrium constant? Explain briefly. (2)

[27]

QUESTION 5 ACIDS AND BASES

A student titrated a solution of sodium hydroxide with a standard solution of hydrochloric acid. The apparatus used during the experiment is shown below.



[Source: <https://commons.wikimedia.org/wiki/File:Titration_Apparatus.png>]

The following table of indicators might be useful in the questions that follow.

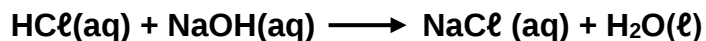
Indicator	Acidic Colour	pH Range of Colour Change	Basic Colour
Phenolphthalein	Colourless	8,3–10,0	Pink
Bromothymol blue	Yellow	6,0–7,6	Blue
Phenol red	Yellow	6,8–8,0	Red
Methyl orange	Red	3,2–4,4	Yellow

[Source: <<https://scienceready.com.au/pages/ph-indicators>>]

5.1 Give the aim of the titration. (2)

5.2 Explain why hydrochloric acid can be classified as a strong acid. (2)

During the titration, a standard solution of hydrochloric acid reacts with a sodium hydroxide solution with a concentration of $0,2 \text{ mol}\cdot\text{dm}^{-3}$. The chemical equation representing this titration is given below:

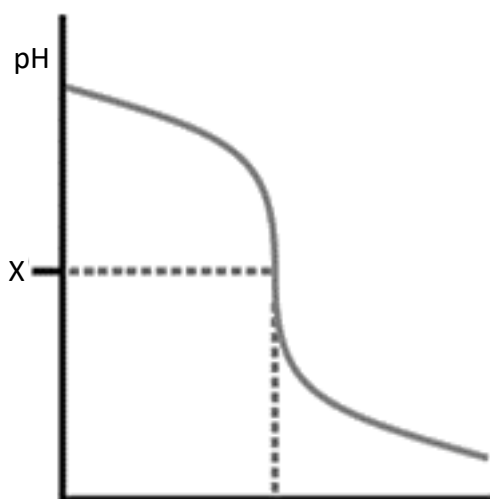


- 5.3 Assuming that the sodium hydroxide fully dissociates in the solution, calculate the concentration of **hydronium** ions in the standard solution of hydrochloric acid. (4)

- 5.4 Is hydrochloric acid a monoprotic, diprotic or polyprotic acid? Give a reason for your answer. (2)

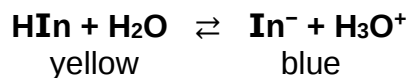
The curve below shows the change in pH observed in the Erlenmeyer flask during the above titration.

Titration curve for sodium hydroxide and hydrochloric acid.



- 5.5 Identify point X on the graph above. Give a possible value for point X for this specific titration. (2)

Bromothymol blue solution is used for this titration. When bromothymol blue indicator is added to water to make up a solution, the following equation represents the equilibrium reaction.



- 5.6 Use Le Chatelier's principle and refer to the above equation to explain what colour change will be observed during the titration of sodium hydroxide and hydrochloric acid. Your explanation must include the initial colour, the neutralised colour and the over-titrated colour. (6)

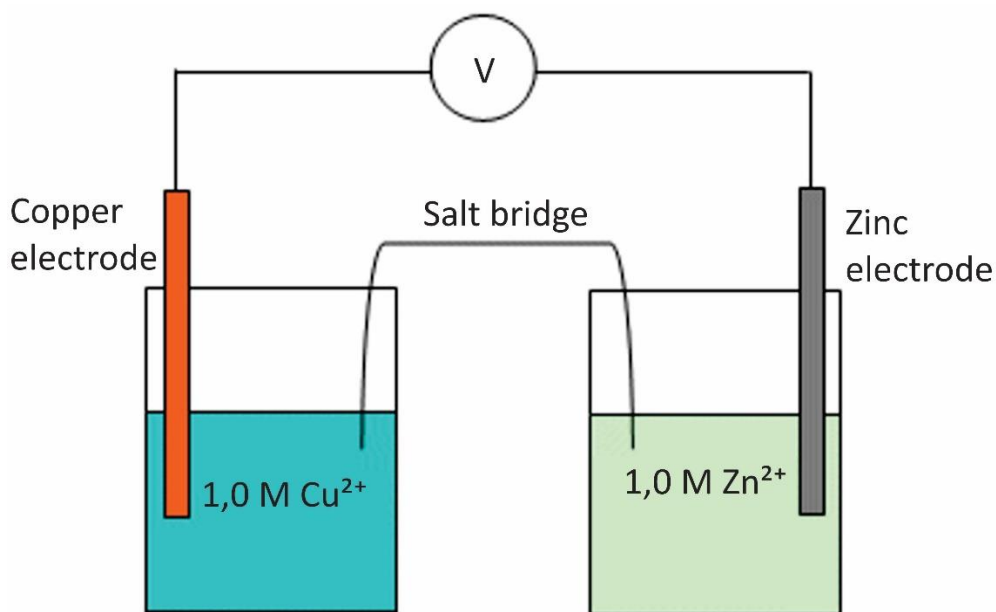
- 5.7 In another experiment it takes 54 ml of $0,1 \text{ mol} \cdot \text{dm}^{-3}$ of HCl solution to neutralise 75 ml NaOH solution. Calculate the concentration of NaOH. Write your answer to **three** decimal places. (5)

- 5.8 Give the autoionisation reaction equation of water and indicate the acid-base pairs. (4)

[27]

QUESTION 6 ELECTROCHEMICAL CELLS

An electrochemical cell is constructed as shown. Study the diagram drawn below and answer the questions that follow.



[Source: <<http://www.4college.co.uk/a/ss/cell.php>>]

6.1 Consider the aqueous copper nitrate solution.

6.1.1 Give the formula of the solute that was used to make the copper(II)nitrate solution. (2)

6.1.2 Name the solvent that was used to make the electrolyte. (1)

6.1.3 Explain why the solute will be soluble in the solvent. (3)

6.2 The zinc rod is now replaced by an iron rod, and the zinc solution is replaced with an iron(II)nitrate solution.

6.2.1 Name the reducing agent in this reaction. (1)

6.2.2 Give the equations for the oxidation and reduction half reactions. Label the reactions. (4)

6.2.3 Write the cell notation for this cell. (Standard conditions and phases need not be shown.) (2)

6.2.4 State which electrode, Cu or Fe, would decrease in mass as the reaction proceeds. Explain your answer. (3)

6.2.5 Give the name of component X and give **two** functions of this component. (3)

6.2.6 Component X is replaced by one that is narrower and longer than the one shown in the diagram. State how each of the following will be affected by this change: (answer only **increase**, **decrease** or **no effect**.)

(a) The internal resistance (1)

(b) The emf (1)

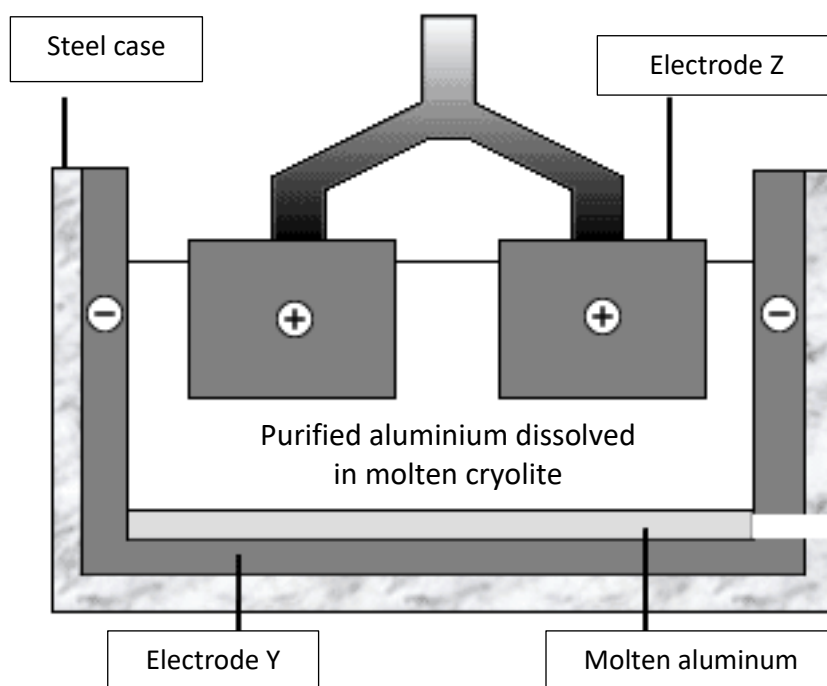
6.2.7 Would a potassium chloride solution be a suitable chemical to use in component X? Explain your answer by mentioning the movement of the different ions. (4)

6.2.8 Calculate the emf generated by this cell under standard conditions. (3)

[28]

QUESTION 7 ELECTROCHEMISTRY

Aluminium is extracted from bauxite through the Bayer process, which converts bauxite to sodium aluminate. The sodium aluminate solution is then subjected to the Hall–Hérout process, where aluminium ions are reduced at the cathode, forming liquid aluminium metal. The liquid aluminium is collected, purified, and used in various industries. Study the diagram and then answer the questions that follow.



[Source: <<https://www.tes.com/teaching-resource/c6-extraction-of-aluminium-11678811>>]

7.1 Define the term *electrolyte*. (2)

7.2 Explain why the ore is dissolved in molten cryolite before undergoing electrolysis. (3)

7.3 Write down the half reactions of each electrode and derive the overall molecular net cell reaction. Show your working. (3)

7.4 Calculate the current (in kA) required to produce 250 mol of Al in 5 minutes. (6)

- 7.5 The anode and cathode of this cell are made of graphite, which is an allotrope of carbon. By referring to the structure of graphite, explain why it is a suitable substance to use in this cell in terms of the following properties:

7.5.1 Melting point (3)

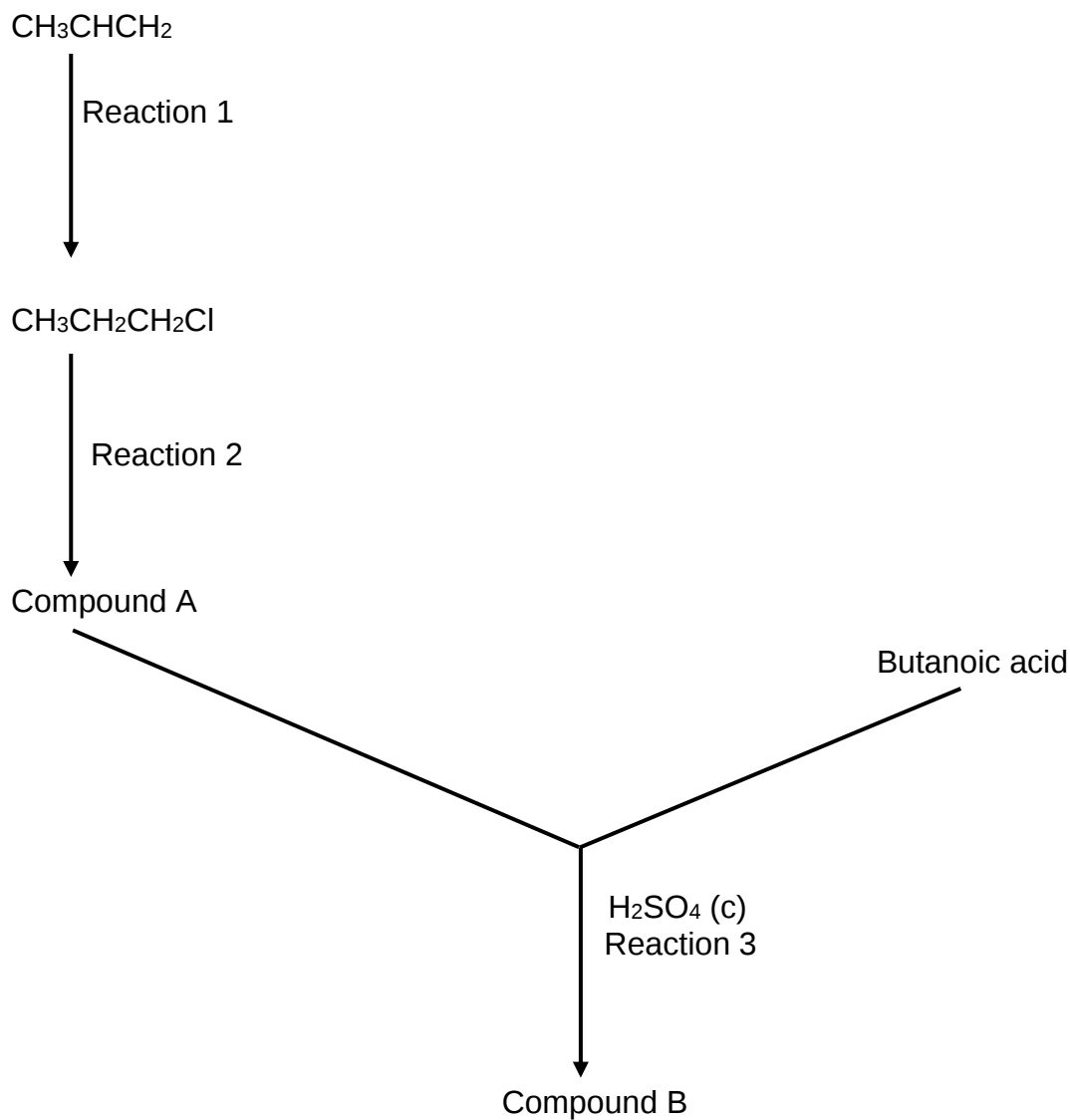
7.5.2 Conductivity (2)

- 7.6 During the reaction, the mass of the carbon electrodes decreases. Write down a reaction equation to confirm this and explain the effect of the reaction on the environment. (3)

[22]

QUESTION 8 ORGANIC CHEMISTRY

Use the diagram to answer the following questions.



8.1 Give the definition of a homologous series. (2)

8.2 Give the definition of a positional isomer. (2)

8.3 Draw the structural formula of the positional isomer of $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ and give the IUPAC name for the isomer. (4)

8.4 Write, by making use of **molecular formulae**, an equation for the complete chemical reaction to produce compound A. (2)

8.5 Identify the type of reaction in Reaction 1. (2)

8.6 Use **structural formulae** and write the complete reaction equation for the formation of Compound B. Name the reactants and products. Also name the type of reaction. (5)

- 8.7 Identify the catalyst needed for the reaction in Question 8.6. What property does the catalyst have? (3)

- 8.8 Propane experiences complete combustion. Use **molecular formulas** and give the balanced chemical reaction. (4)

[24]

QUESTION 9 ORGANIC CHEMISTRY

Use the following table to answer the following questions.

A	$ \begin{array}{c} \text{CH}_3 \quad \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C} = \text{C} \\ \diagup \quad \diagdown \\ \text{CH}_3 \quad \quad \text{CH}_3 \end{array} $	B	$ \begin{array}{c} \text{H} \quad \quad \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C} \equiv \text{C}-\text{C}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \quad \quad \text{CH}_3 \end{array} $
C	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	D	2,2 dimethylpropane
E	$ \begin{array}{ccccccc} & \text{H} & & \text{O} & & \text{H} & \text{H} \\ & & & & & & \\ \text{H}- & \text{C} & -\text{O}- & \text{C} & - & \text{C} & - & \text{C} & -\text{H} \\ & & & & & & \\ & \text{H} & & & & \text{H} & \text{H} \end{array} $	F	$\text{CH}_3\text{CHC}(\text{CH}_3)_2$

[Source: <<https://megatude.co.za/wp-content/uploads/2018/08/Physical-Science-Grade-12-Definitions-Paper-2-Free-State.pdf>>]

9.1 Give the definition for intermolecular force. (2)

9.2 Identify the LETTER that represents the following: (2)

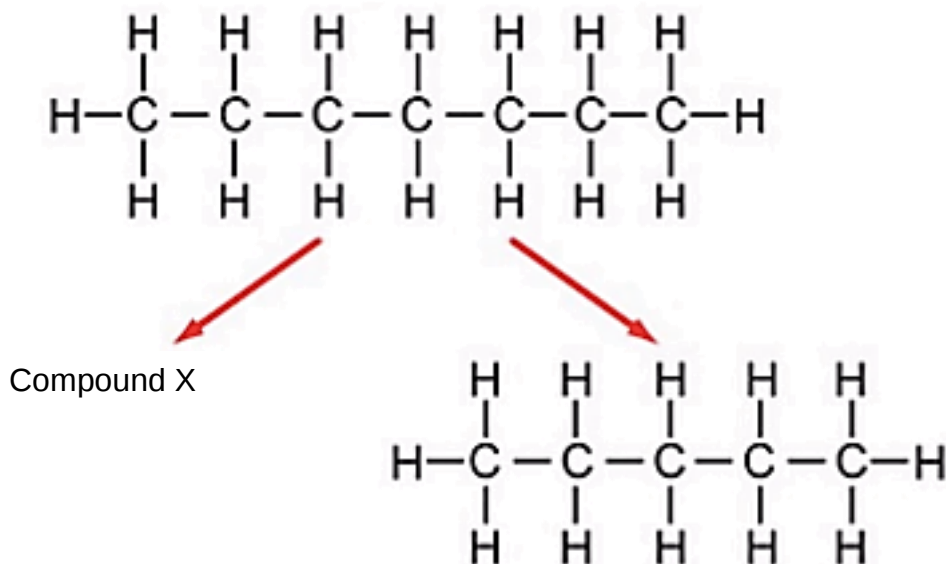
9.2.1 Alkyne: _____

9.2.2 Alcohol: _____

9.3 Which one of the compounds, **Compound C** or **Compound E**, has the **highest** boiling point? Explain your answer in terms of the type of intermolecular forces, relative strength of the forces and energy. (4)

9.4 Give the IUPAC name of Compound B. (2)

9.5 The following reaction illustrates the cracking of an organic compound.



[Source: <[https://www.google.com/search?q=cracking+reaction+structural&rlz=1C5CHFA_enZA905ZA906&sxsrf=APwXEdd59EBPQhUQ3wgfGrY4vCKqdJHdA:1685899907650&source=lnms&tbn=isch&sa=X&ved=2ahUKEwiBm_nlkqr_AhUBg1wKHQC8D9cQ_AUoAXoECAEQAw&biw=1440&bih=789&dpr=1#imgsrc=li3UylcL1V-lsM](https://www.google.com/search?q=cracking+reaction+structural&rlz=1C5CHFA_enZA905ZA906&sxsrf=APwXEdd59EBPQhUQ3wgfGrY4vCKqdJHdA:1685899907650&source=lnms&tbn=isch&sa=X&ved=2ahUKEwiBm_nlkqr_AhUBg1wKHQC8D9cQ_AUoAXoECAEQAw&biw=1440&bih=789&dpr=1#imgsrc=li3UylcL1V-lsM>)>]

9.5.1 Explain the reaction of cracking. (2)

9.5.2 Name an advantage and a disadvantage of thermal cracking. (2)

9.5.3 Give the IUPAC name of Compound X. (2)

[16]

Total: 200 marks

ADDITIONAL SPACE (ALL QUESTIONS)

REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED THE ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.

