Please paste the barcoded label here	TOTAL MARKS

NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2023

PHYSICAL SCIENCES: PAPER II

EXAMINATION NUMBER													

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 31 pages as well as a DATA SHEET of 3 pages (i–iii). Please make sure that your question paper is complete.
2. Read the questions carefully.
3. **Answer ALL the questions on the question paper and hand it in at the end of the examination. Remember to write your examination number in the space provided.**
4. Unless instructed otherwise, you do NOT have to give state symbols (phase indicators) when asked to write a balanced chemical equation.
5. Use the data and formulae whenever necessary.
6. Show all the necessary steps in calculations.
7. Where appropriate, give your answers to two decimal places.
8. It is in your interest to write legibly and to present your work neatly.
9. TWO blank pages (pages 29 and 30) and extra graph paper (page 31) are included at the end of the examination 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 OFFICE USE ONLY: MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total
Mark										
Marker's Initials										
Moderated Mark										
Moderator's Initials										
Question Total	**20**	**14**	**24**	**22**	**28**	**22**	**22**	**32**	**16**	**200**
Re-mark										
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QUESTION 1 MULTIPLE-CHOICE QUESTIONS

Answer the 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

Here the option C has been marked as an example.

1.1	**A**	**B**	**C**	**D**
1.2	**A**	**B**	**C**	**D**
1.3	**A**	**B**	**C**	**D**
1.4	**A**	**B**	**C**	**D**
1.5	**A**	**B**	**C**	**D**
1.6	**A**	**B**	**C**	**D**
1.7	**A**	**B**	**C**	**D**
1.8	**A**	**B**	**C**	**D**
1.9	**A**	**B**	**C**	**D**
1.10	**A**	**B**	**C**	**D**

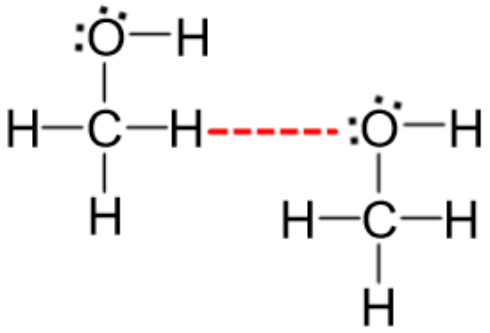
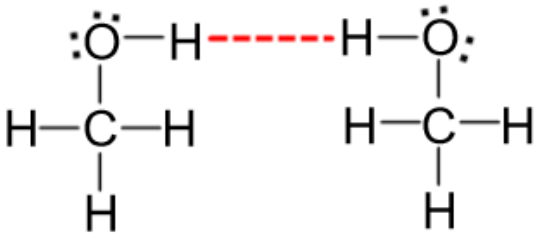
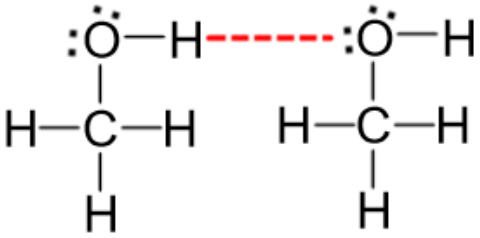
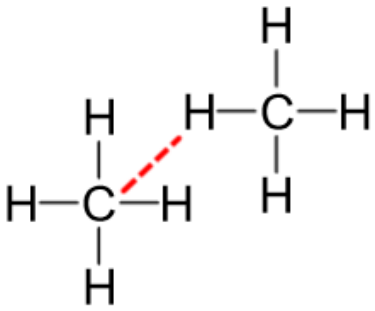
1.1 Which one of the following name and formula combinations is correct?

	Name	Formula
A	potassium dichromate	K_2CrO_7
B	lead(IV) oxide	Pb_2O_4
C	aluminium sulfide	$A\ell_2(SO_3)_3$
D	chromium(III) phosphate	$CrPO_4$

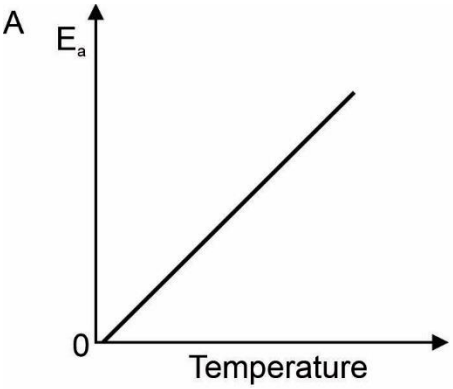
1.2 For which one of the following pairs of compounds will **X** have a higher boiling point than **Y**?

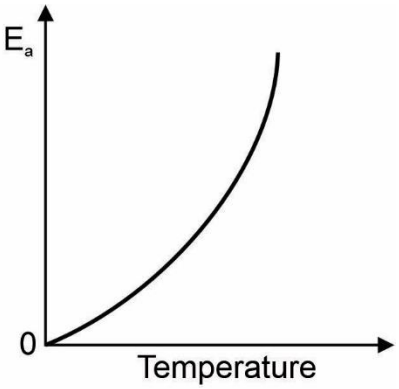
	X	Y
A	H_2O	H_2S
B	C_2H_6	C_3H_8
C	CH_3CH_2OH	CH_2OHCH_2OH
D	F_2	$C\ell_2$

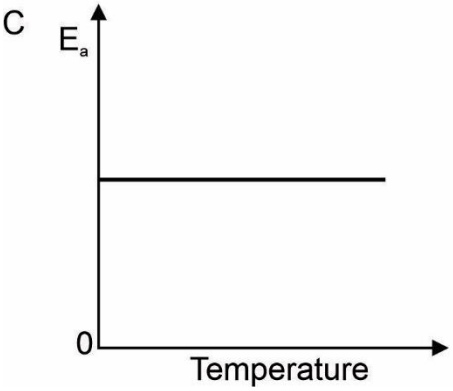
1.3 In which one of the following diagrams does the red dashed line correctly show the formation of a hydrogen bond between two molecules?

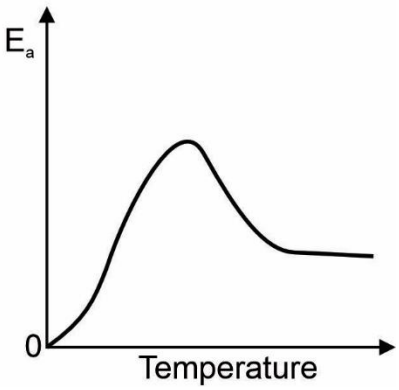
A	B
	
C	**D**
	

1.4 Which one of the following graphs shows the relationship between the activation energy (E_a) for a reaction and temperature?

A


B


C


D


1.5 A certain amount of $IC\ell(g)$ is sealed in an empty flask at a fixed temperature. The equation for the reaction that takes place is:

$$2IC\ell(g) \rightleftharpoons I_2(g) + C\ell_2(g)$$

Which of the following statements describe(s) the change(s) that occur(s) as the system proceeds towards equilibrium?

(i) The rate of the reverse reaction increases.
(ii) The concentrations of $IC\ell$, I_2 and $C\ell_2$ change at the same rate.
(iii) The concentration of $C\ell_2$ increases.

A (i) only
B (ii) only
C (i) and (iii) only
D (ii) and (iii) only

1.6 The K_b values of two hypothetical bases are tabulated below:

Base	**K_b at 25 °C**
$X(OH)_2$	$4{,}4 \times 10^{-4}$
$Y(OH)_2$	$5{,}6 \times 10^{-4}$

Aqueous solutions of the bases and their chloride salts are compared. All four solutions have the same concentration. Which base solution will have the higher pH and which chloride salt solution will have the higher pH?

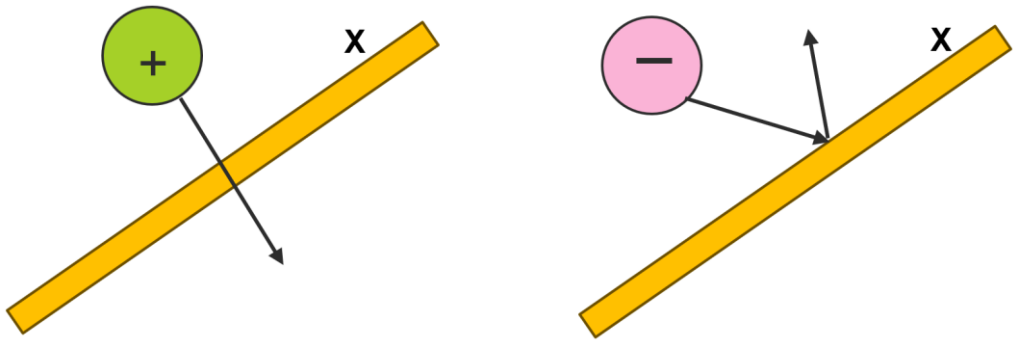
	Base solution with the higher pH	**Chloride salt solution with the higher pH**
A	$X(OH)_2$	$XC\ell_2$
B	$X(OH)_2$	$YC\ell_2$
C	$Y(OH)_2$	$XC\ell_2$
D	$Y(OH)_2$	$YC\ell_2$

1.7 An impure copper electrode, which contains small amounts of gold and zinc, is purified by electrolysis. During this process a sludge forms beneath the anode.

Why is gold the only metal found in the sludge?

A Copper and zinc are oxidised, but gold is not.
B Gold ions are more easily reduced than copper ions.
C Gold reacts with the electrolyte to form an insoluble salt.
D The amount of gold in the electrode is too low, so it does not react.

1.8 Cations can pass through component **X**, while anions cannot.



Which of the following might component **X** represent?

A The diaphragm of an electrolytic cell used in the chlor-alkali process
B The membrane of an electrolytic cell used in the chlor-alkali process
C The wire in a galvanic cell
D The salt bridge in a galvanic cell

1.9 The alcohols form a homologous series. Which statement is correct?

Alcohols have …

A similar physical properties.
B similar chemical properties.
C the same molecular formula.
D the same structural formula.

1.10 When red-brown bromine water is added to a hydrocarbon, the colour disappears **immediately**. From this it can be concluded that:

A The general formula of the hydrocarbon is C_nH_{2n+2}.
B The hydrocarbon undergoes a hydration reaction with bromine.
C The red-brown colour fades immediately in the presence of any hydrocarbon.
D The hydrocarbon undergoes an addition reaction with bromine.

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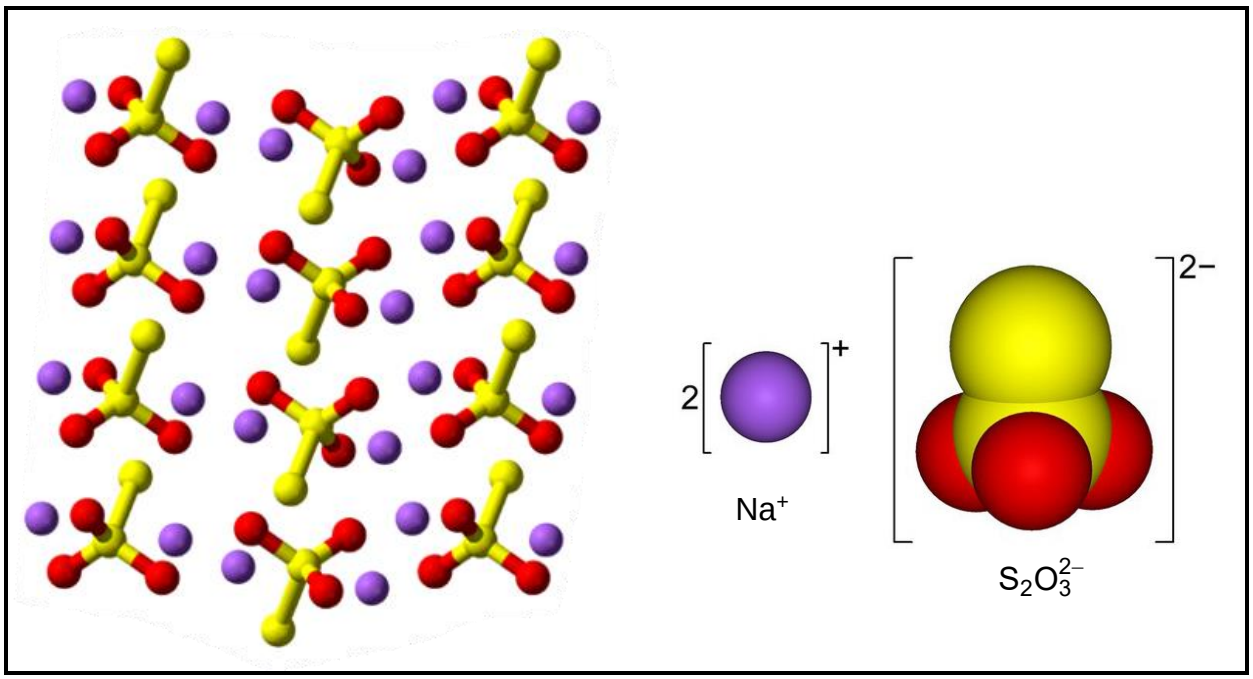
QUESTION 2

The structure of solid sodium thiosulfate, $Na_2S_2O_3$, is shown in the diagram.



[Source:<https://en.wikipedia.org/wiki/Sodium_thiosulfate>]

2.1 Define *electronegativity*. (2)

2.2 Describe a covalent bond. (2)

2.3 Which two atoms in this compound are held together by polar covalent bonds? Explain the answer. (3)

2.4 An aqueous solution of sodium thiosulfate is prepared.

2.4.1 What is meant by the term *solution* in the above statement? (2)

2.4.2 Identify the solvent in this solution. (1)

2.4.3 Name the bonds/forces in sodium thiosulfate that are broken/overcome when the compound dissolves. (1)

2.4.4 Define *electrolyte*. (2)

2.4.5 Is this solution an electrolyte? Answer either YES or NO. (1)

[14]

QUESTION 3

Solutions of sodium thiosulfate and hydrochloric acid react as follows:

$$Na_2S_2O_3(aq) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + SO_2(g) + S(s) + H_2O(\ell)$$

3.1 Define *reaction rate*. (2)

The effect of the concentration of sodium thiosulfate on the rate of the reaction was investigated.

In each experiment, 5 cm^3 of 0,15 $mol \cdot dm^{-3}$ $HC\ell$ was added to 25 cm^3 of the $Na_2S_2O_3$ solution in the flask.

The results are tabulated below.

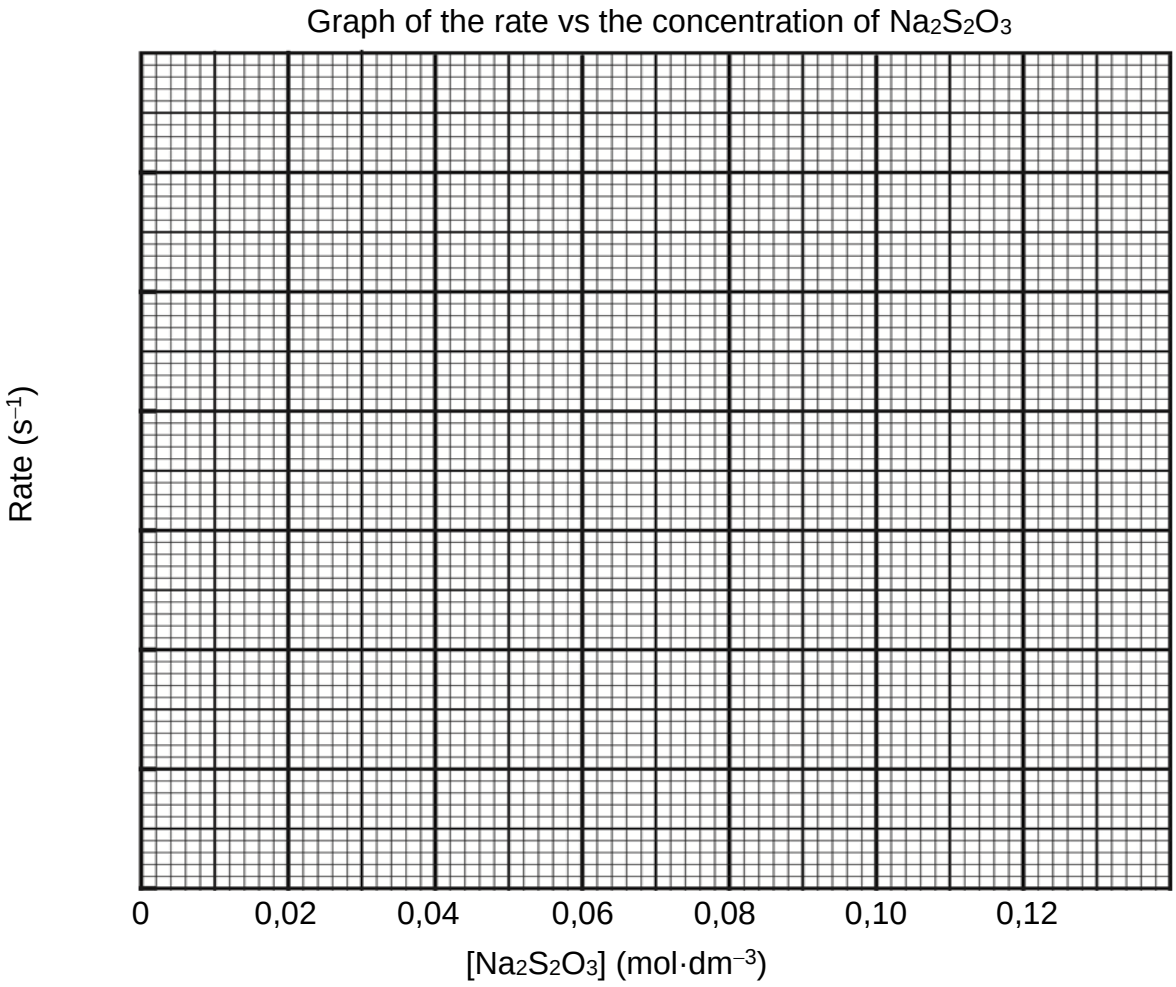
EXPERIMENT	**1**	**2**	**3**	**4**	**5**
$[Na_2S_2O_3]$ $(mol \cdot dm^{-3})$	0,01	0,02	0,04	0,08	0,10
Rate (s^{-1})	0,005	0,009	0,022	0,042	0,050

3.2 Consider **EXPERIMENT 5**, in which the concentration of the sodium thiosulfate solution is 0,10 $mol \cdot dm^{-3}$.

3.2.1 Prove by calculation that hydrochloric acid is the limiting reagent. Do not round your answers. (4)

3.2.2 Calculate the number of sulphur atoms in the precipitate produced when the reaction goes to completion. (3)

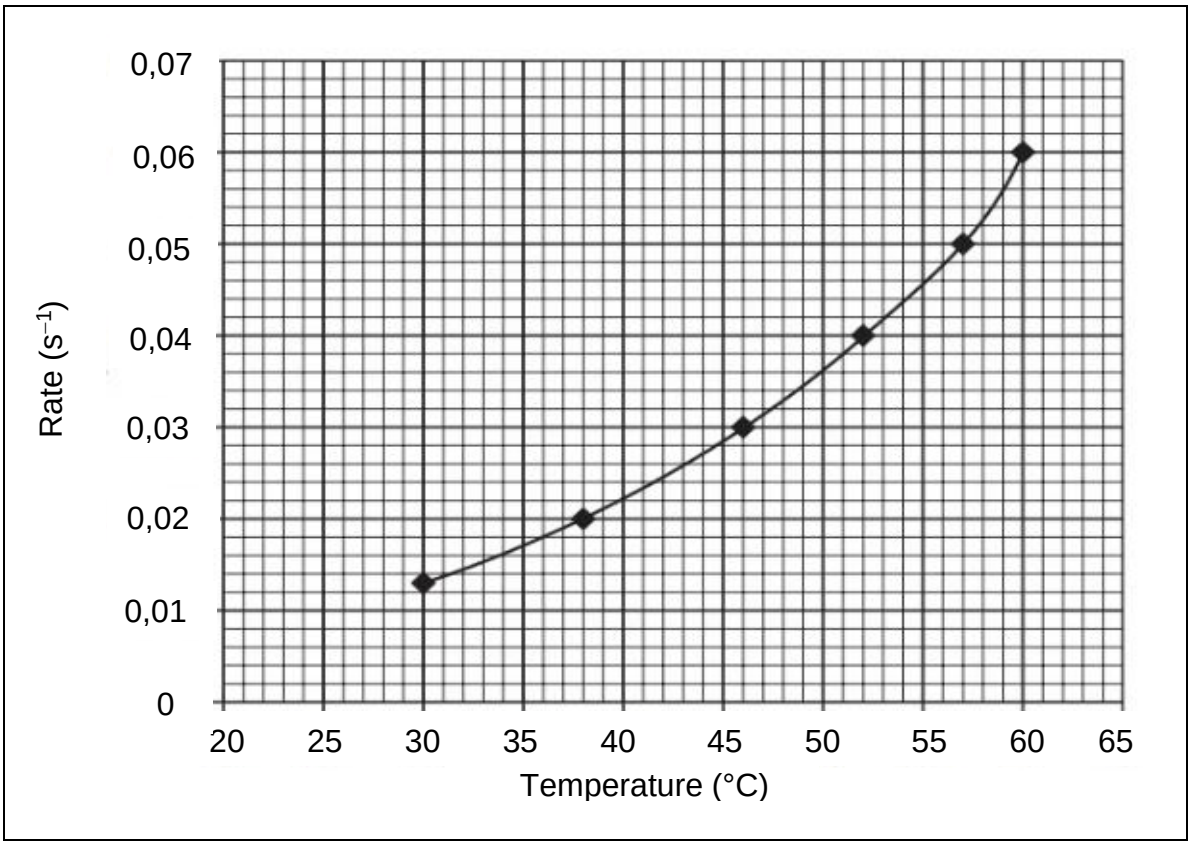
3.3 Plot a graph of reaction rate versus concentration. Draw the line of best fit. *(An extra copy of the graph paper is provided on page 31, should you need it.)* (4)



3.4 Determine how long (in seconds) it would take for a sodium thiosulfate solution of concentration 0,03 mol·dm^{-3} to react in this experiment. (3)

3.5 State in words the relationship between the concentration of the sodium thiosulfate and the rate of the reaction. (2)

3.6 When the effect of temperature on the rate of the same reaction was investigated, the graph below was obtained.



[Source: <https://blogs.glowscotland.org.uk/gc/hchemextra/>]

3.6.1 Use values from the graph to determine the temperature rise required to double the rate of this reaction. Show your working. (2)

3.6.2 Explain the effect of increasing temperature on the rate of reaction in terms of the collision theory. (4)

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QUESTION 4

Consider the equation below, which represents a hypothetical equilibrium reaction:

$$3A(s) + 2B(g) \rightleftharpoons A_3B_2(g) \qquad \Delta H < 0 \quad \text{and} \quad K_c = 1{,}65 \text{ at } 40\ ^\circ C$$

4.1 Why is the temperature of 40 °C specified? (1)

4.2 Write the expression for the equilibrium constant (K_c) of this reaction. (2)

4.3 **0,3 mol** of B was added to a **2 dm^3** reaction vessel containing some of A. The container was sealed and allowed to reach equilibrium at 40 °C. At equilibrium, there were ***x*** moles of A_3B_2 in the container.

4.3.1 Use the K_c expression to set up a mathematical equation that can be used to solve for ***x***. **It is not necessary to simplify or solve the equation.** (5)

The equation for the equilibrium reaction is rewritten here:

$$3A(s) + 2B(g) \rightleftharpoons A_3B_2(g)$$

4.3.2 Simplifying and solving the mathematical equation obtained in Question 4.3.1 gives two answers for ***x***, the number of moles of A_3B_2 at equilibrium:

x = 0,56 mol OR x = 0,04 mol.

(a) Explain why the value of ***x*** = 0,56 mol is impossible if the container originally contained 0,3 mol of B. (2)

(b) Calculate the equilibrium concentration of B in the reaction vessel. (2)

4.4 The reaction is repeated using a catalyst; with all other conditions remaining the same.

4.4.1 Circle the correct option between the brackets.

(a) The value of K_c

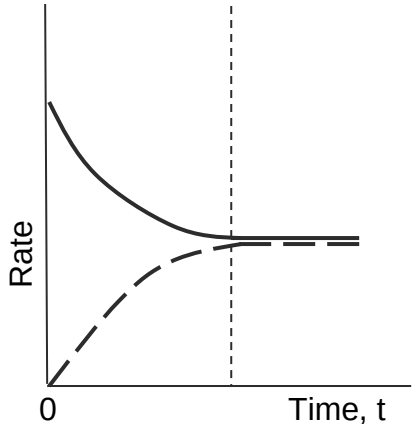
will (INCREASE / DECREASE / REMAIN THE SAME). (1)

(b) The value of ΔH

will (INCREASE / DECREASE / REMAIN THE SAME). (1)

4.4.2 The graph of the original reaction rate vs time is given below. On the same set of axes, draw the graph to show the effect of using a catalyst **from time t = 0**.

(3)



4.5 The reaction (rewritten below) is carried out at a LOWER temperature.

$$3A(s) + 2B(g) \rightleftharpoons A_3B_2(g) \qquad \Delta H < 0 \quad \text{and } K_c = 1{,}65 \text{ at } 40\ ^\circ C$$

Circle the correct option between the brackets where appropriate.

4.5.1 The yield

will (INCREASE / DECREASE / REMAIN THE SAME). (1)

4.5.2 Explain the answer to Question 4.5.1 by applying Le Châtelier's principle.

(3)

4.5.3 The value of K_c

will (INCREASE / DECREASE / REMAIN THE SAME). (1)

[22]

QUESTION 5

Solutions of a hypothetical weak acid H_3A and sodium hydroxide react according to the equation below:

$$H_3A(aq) + 3NaOH(aq) \rightarrow Na_3A(aq) + 3H_2O(\ell)$$

5.1 Classify the acid in terms of the specific number of protons donated. (1)

The acid is _____PROTIC.

5.2 Consider the ionisation reaction of the weak acid H_3A represented by the equation shown below:

$$H_3A(aq) + H_2O(\ell) \rightleftharpoons H_2A^-(aq) + H_3O^+(aq)$$

5.2.1 Two K_a values are shown. Circle the value that is most likely for H_3A. (1)

$$K_a = 7{,}1 \times 10^{-4} \quad \text{OR} \quad K_a = 6{,}5 \times 10^{2}$$

5.2.2 H_2A^- is amphoteric.

(a) Circle the correct option between the brackets: (1)

In the ionisation reaction shown above,

H_2A^- is acting as (an ACID / a BASE).

(b) Write an equation for the hydrolysis reaction of H_2A^- when it acts as an ACID. (3)

_____

5.3 The salt Na_3A dissociates completely in water.

5.3.1 Define *dissociation*. (2)

_____

_____

5.3.2 Complete and balance the equation for the dissociation of Na_3A in water. (2)

$Na_3A(s) \xrightarrow{H_2O}$ _____

5.3.3 Circle the correct answer between the brackets: (1)

Na_3A is (an ACIDIC / a BASIC) salt.

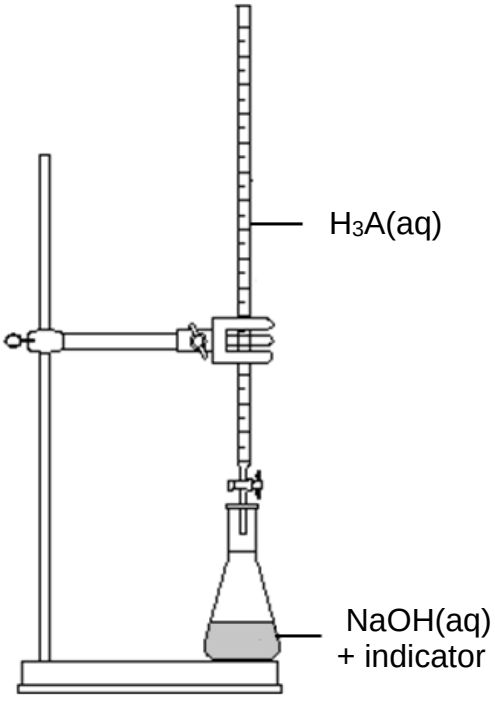
The Grade 12 learners were required to standardise a sodium hydroxide solution by titration with $H_3A(aq)$.

Zandi prepared a standard solution of $H_3A(aq)$ of concentration $3{,}81 \times 10^{-2}$ mol·dm^{-3} in a 200 cm^3 volumetric flask. After filling the flask to the mark on the neck, she put the stopper on and mixed the solution well to ensure it was homogeneous.

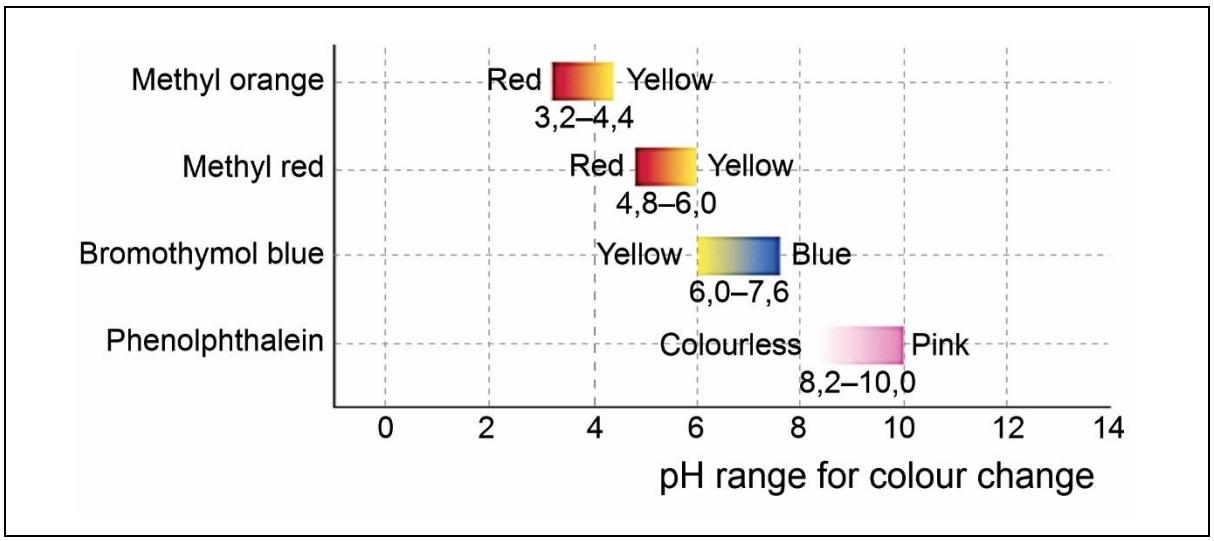
5.4 Calculate the mass of H_3A crystals ($M = 192$ g·mol^{-1}) that Zandi used. (4)

5.5 Why is it especially important that the standard solution be homogeneous when doing titrations? (2)

Zandi pipetted 25,0 cm^3 of the NaOH solution into a conical flask. She added a few drops of indicator solution and titrated with the standard H_3A solution. She repeated this procedure several times and obtained an average titration volume (titre) of 32,6 cm^3 of $H_3A(aq)$.



5.6 Consider the selection of available indicators shown below.



[Source: <https://www.coursehero.com/sg/general-chemistry/acid-base-titrations>]

5.6.1 Which one of these indicators would be suitable for this titration? (1)

5.6.2 State the colour change that would be observed at the end point in this particular titration. (1)

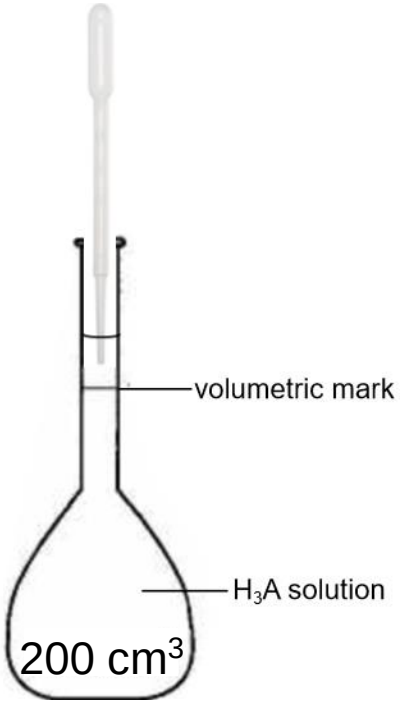
The equation for the titration reaction is repeated below:

$$H_3A(aq) + 3NaOH(aq) \rightarrow Na_3A(aq) + 3H_2O(\ell)$$

5.7 Calculate the concentration of the sodium hydroxide solution that Zandi would obtain. Write the answer correct to three decimal places. (4)

Mike also used a 200 cm^3 volumetric flask to make his $H_3A(aq)$ standard solution.

- He recorded the mass of H_3A crystals that he transferred into the flask.
- He dissolved the crystals in distilled water, then added more distilled water to above the mark on the neck of the flask.
- He carefully removed some of the solution with a dropper until the bottom of the meniscus was on the mark on the neck of the volumetric flask.
- Then he placed the stopper on the flask and mixed the solution well.
- He calculated the concentration of his H_3A solution using the recorded mass and the volume of 200 cm^3.



5.8 Consider Mike's method of preparing his standard solution. Circle the correct option between the brackets and **explain** the answer. (2)

The ACTUAL concentration of Mike's H_3A solution is

(GREATER THAN / LESS THAN / EQUAL TO) the value calculated, because:

5.9 Consider Mike's calculated sodium hydroxide concentration after his titration.

5.9.1 Circle the correct option between the brackets:

Mike's calculated NaOH concentration would be

(EQUAL TO / HIGHER THAN / LOWER THAN) the actual value. (1)

5.9.2 Briefly explain the answer to Question 5.9.1. (2)

[28]

QUESTION 6

Sam wrote the following cell notation to represent a galvanic cell:

$$Fe(s)\,|\,Fe^{3+}(aq)\,||\,C\ell_2(g)\,|\,C\ell^-(aq)$$

6.1 **Complete the above cell notation** to include the one important component that Sam left out. Standard conditions were not required. (2)

6.2 Define *anode*. (2)

6.3 Identify the anode in this cell. (1)

6.4 Write down the net ionic equation for the reaction that takes place when this cell operates. (3)

6.5 For this cell to operate at standard conditions, standard solutions of Fe^{3+} and $C\ell^-$ need to be prepared.

6.5.1 Define *standard solution*. (2)

6.5.2 The standard solutions are prepared using the ionic salts $Fe(NO_3)_3$ and $CaC\ell_2$. What should the concentrations of these solutions be? (3)

$Fe(NO_3)_3$ _____

$CaC\ell_2$ _____

6.6 Sam states: 'For this cell to be operating at standard conditions, the atmospheric pressure must be $1{,}01 \times 10^5$ Pa.'

Correct Sam's statement. (1)

6.7 Calculate the standard cell potential, E^{θ}_{cell} , for this cell. (4)

6.8 Sam adds some $AgNO_3$ solution to the chlorine half-cell, causing solid AgCℓ to precipitate. How will this affect the voltage of the cell?

Circle the correct option between the brackets and explain the answer. (4)

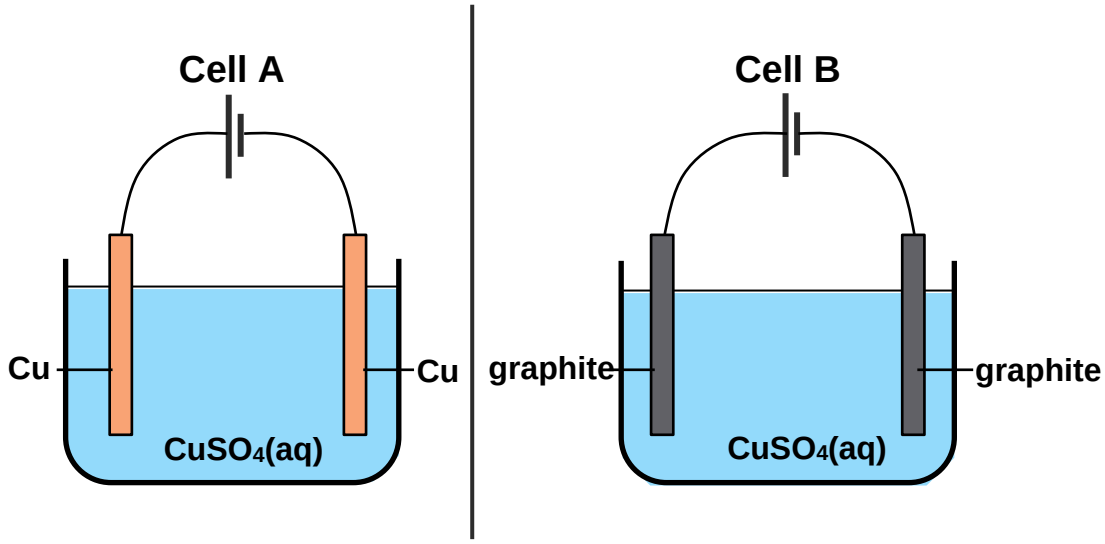
The voltage of the cell will (INCREASE / DECREASE / REMAIN THE SAME)

because

[22]

QUESTION 7

7.1 In both cells shown below, a concentrated aqueous solution of **copper(II) sulfate** is electrolysed using pure electrodes.



7.1.1 In **Cell A**, **copper electrodes** are used.

Circle the correct answer between the brackets.

(a) At the cathode: (Cu / Cu^{2+} / H_2O / SO_4^{2-}) will be reduced. (1)

(b) At the anode: (Cu / Cu^{2+} / H_2O / SO_4^{2-}) will be oxidised. (1)

(c) The concentration of the solution as time passes will:

(INCREASE / DECREASE / REMAIN CONSTANT). (1)

7.1.2 In **Cell B**, **graphite electrodes** are used.

(a) Write the chemical symbol for graphite. (1)

(b) Give a reason why graphite can function as an electrode by referring to the structure of graphite. (1)

(c) Circle the correct answer between the brackets.

(i) At the cathode: (graphite / Cu^{2+} / H_2O / SO_4^{2-}) will be reduced. (1)

(ii) At the anode: (graphite / Cu^{2+} / H_2O / SO_4^{2-}) will be oxidised. (1)

(iii) The concentration of the solution as time passes will:

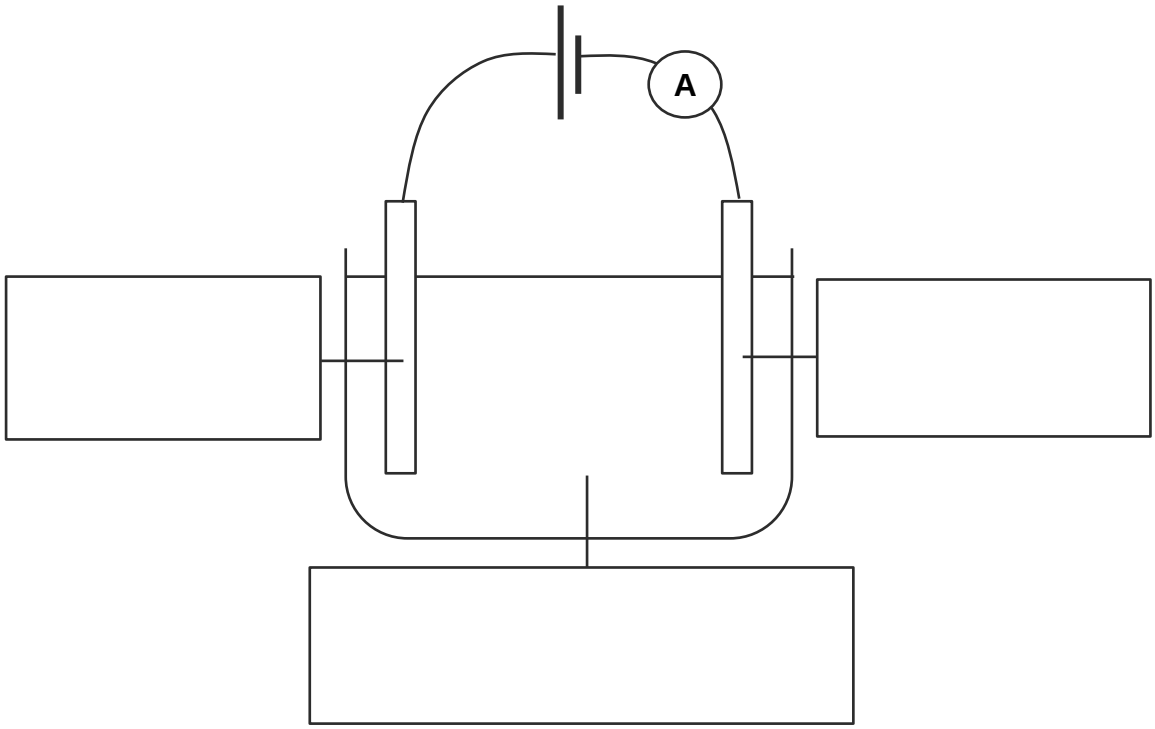
(INCREASE / DECREASE / REMAIN CONSTANT). (1)

7.2 You are required to plate a lead rod with nickel. You are supplied with a cell, a beaker, an ammeter, connecting wires, and:

- a lead rod
- a nickel rod
- an aqueous solution of lead(II) nitrate
- an aqueous solution of nickel(II) nitrate.

7.2.1 Give the formula of lead(II) nitrate. (1)

7.2.2 Choose from the bulleted list above to label the diagram of the set-up. (3)



7.2.3 After 30 minutes of the plating process, the mass of the lead rod had increased by 1,10 g.

(a) Calculate the number of moles of electrons needed to produce this increase in mass. Write the answer correct to four decimal places. (3)

(b) Hence, calculate the average current that was maintained during this time period. (4)

7.2.4 Explain why it would not be possible, under standard conditions, to plate the lead rod with aluminium metal from an aqueous solution of $A\ell^{3+}$ ions. (3)

[22]

QUESTION 8

8.1 The saturated hydrocarbon C_5H_{12} reacts with $C\ell_2$ as shown below:

$$C_5H_{12} + 2C\ell_2 \xrightarrow{uv\ light} C_5H_{10}C\ell_2 + 2HC\ell$$

8.1.1 State the GENERAL reaction type of the above reaction. (1)

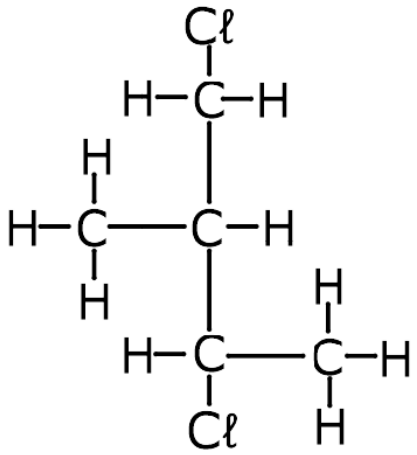
8.1.2 Explain the meaning of the term *saturated hydrocarbon*. (3)

8.1.3 In one experiment, 45 g of C_5H_{12} reacted.

(a) Calculate the volume of chlorine gas (at STP) needed to react with all the C_5H_{12} to form $C_5H_{10}C\ell_2$. (5)

(b) The percentage yield of the reaction was 76%. Calculate the mass of $C_5H_{10}C\ell_2$ that was obtained. (3)

8.1.4 One possible product of the reaction has the structure shown below. Give the IUPAC name of this compound. (3)



8.1.5 Write a balanced equation for the complete combustion of C_5H_{12}. (4)

8.1.6 Structural isomers of C_5H_{12} are possible.

(a) Define *structural isomers*. (2)

(b) Write the condensed structural formula of the isomer of **C_5H_{12}** with the most possible branches (alkyl substituents). (2)

8.2 Consider the compound pent-1-ene.

8.2.1 Define *functional group*. (2)

8.2.2 Draw the structural formula of the **functional group** of pent-1-ene. (1)

8.2.3 Write the condensed structural formula of a **positional isomer** of pent-1-ene. (2)

8.2.4 Answer TRUE or FALSE:

Dimethylpropene is a chain isomer of pent-1-ene. (2)

8.2.5 Methylbut-2-ene is a chain isomer of pent-1-ene. Which of these two compounds will have the higher boiling point? (2)

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QUESTION 9

Ethanol is a very useful compound. It can be produced by several different reactions.

9.1 **Name** the functional group of ethanol. (1)

9.2 One example of a reaction producing ethanol is given below:

$$\underset{\text{glucose}}{C_6H_{12}O_6(s)} \xrightarrow{\textit{yeast fermentation}} 2C_2H_5OH(\ell) + 2CO_2(g)$$

The products of this reaction have a similar molar mass. Explain why ethanol is a liquid at room temperature, while carbon dioxide is a gas. (4)

9.3 Two other reactions by which ethanol may be produced are shown below:

Reaction I ethene + **A** $\xrightarrow{H_3PO_4}$ ethanol

Reaction II **B** + KOH(aq) $\xrightarrow{\text{heat under reflux}}$ ethanol + KCℓ

9.3.1 Identify reactant **A**. (1)

9.3.2 Give the IUPAC name of reactant **B**. (1)

9.3.3 State the SPECIFIC reaction type for:

(a) Reaction **I** (1)

(b) Reaction **II** (1)

9.4 Ethanol can be used to prepare the compound ethyl hexanoate, which has a fruity smell.

ethanol + **X** $\xrightarrow{\text{Catalyst}}$ ethyl hexanoate + **Y**

9.4.1 Name the homologous series to which ethyl hexanoate belongs. (1)

9.4.2 Give the IUPAC **name** of compound **X** in the above equation. (2)

9.4.3 Identify compound **Y** in the above equation. (1)

9.4.4 Identify a suitable catalyst for the reaction. (1)

9.4.5 Give the IUPAC name of a straight chain **functional isomer** of ethyl hexanoate. (2)

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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.

Question 3.3 (extra graph paper)

EXPERIMENT	**1**	**2**	**3**	**4**	**5**
$[Na_2S_2O_3]$ (mol·dm^{-3})	0,01	0,02	0,04	0,08	0,10
Rate (s^{-1})	0,005	0,009	0,022	0,042	0,050

Graph of the rate vs the concentration of $Na_2S_2O_3$