Please paste the barcoded label here

TOTAL MARKS

NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2022

PHYSICAL SCIENCES: PAPER II

EXAMINATION NUMBER

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 32 pages as well as a green 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, take your answers to two decimal places.
8. It is in your interest to write legibly and to present your work neatly.
9. One blank page (page 32) is included at the end of the exam paper. If you run out of space for an answer, use this page. If you use this extra space, make sure that you indicate this clearly at the question to ensure that your answer is marked in full.

FOR OFFICE USE ONLY: MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total
Mark										
Marker Initial										
Moderated Mark										
Moderator Initial										
Question Total	**20**	**18**	**24**	**23**	**28**	**23**	**27**	**12**	**25**	**200**
Re-mark										
Initial										
Code										

QUESTION 1 MULTIPLE CHOICE

Answer these questions on the multiple-choice answer 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 An unknown metal M forms the compound $M(SO_4)_2$. Which formula represents another compound where M has the same valency?

A $M(NO_3)_2$
B M_3PO_4
C M_2O
D M_3N_4

1.2 Which one of the following contains $6{,}02 \times 10^{23}$ atoms?

A 18 g of Ar gas
B 5,6 dm^3 of NH_3 gas at STP
C 32 g of O_2 gas
D 22,4 dm^3 of CO gas at STP

1.3 A solution of sodium sulphate (Na_2SO_4) contains $1,5 \times 10^{22}$ sodium ions dissolved in 500 cm^3 of distilled water. The concentration of the sodium sulphate solution is:

A $\frac{1}{2} \times \frac{1,5\times10^{22}}{6,02\times10^{23} \times 0,5}$

B $\frac{1}{2} \times \frac{6,02\times10^{23} \times 0,5}{1,5\times10^{22}}$

C $2 \times \frac{1,5\times10^{22}}{6,02\times10^{23} \times 0,5}$

D $2 \times \frac{6,02\times10^{23} \times 0,5}{1,5\times10^{22}}$

1.4 Which one of the following molecules has polar covalent bonds, but only has London intermolecular forces?

A PH_3
B $CH_3C\ell$
C $CC\ell_4$
D CI_4

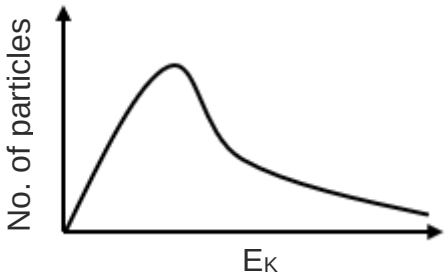
1.5 The catalysed formation of ammonia by the Haber process can be represented by the equation shown.

$$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g) \qquad \Delta H = -92 \text{ kJ.mol}^{-1}$$

Which change in reaction conditions will **increase both** the rate of formation and the equilibrium yield of ammonia?

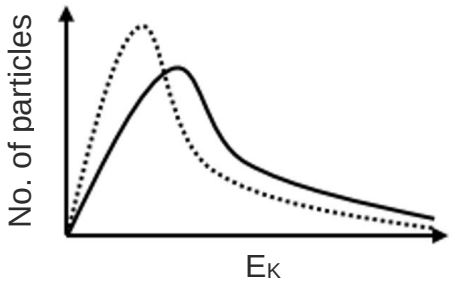
A A decrease in the temperature.
B An increase in the temperature.
C An increase in the pressure at constant temperature.
D An increase in the surface area of the catalyst.

1.6 The Maxwell-Boltzmann distribution curve for a reaction mixture is shown below.

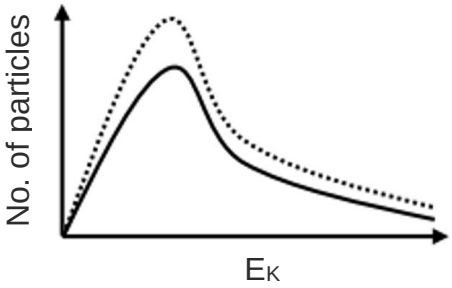


The CONCENTRATION of the reaction mixture is now INCREASED. Which one of the following shows the new distribution curve as a dotted line?

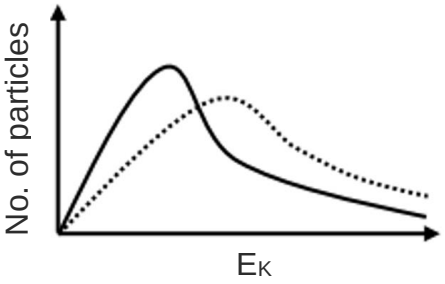
A



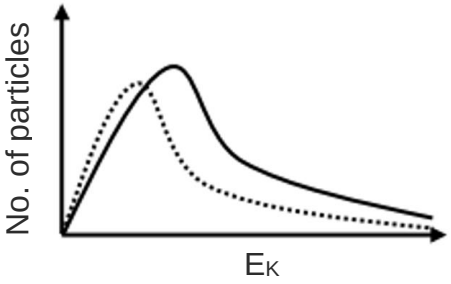
B



C



D



1.7 Consider the following reaction:

$$H_2(g) + I_2(g) \rightleftarrows 2HI\ (g) \qquad K_c = \boldsymbol{x}$$

What will be the K_c value for the REVERSE reaction when the volume of the container is halved at the same constant temperature?

A $\boldsymbol{x}$

B $\frac{\boldsymbol{x}}{2}$

C $\frac{2}{\boldsymbol{x}}$

D $\frac{1}{\boldsymbol{x}}$

1.8 How many straight-chain esters are there with molecular formula $C_4H_8O_2$?

A 2
B 3
C 4
D 5

1.9 Which one of the following organic compounds does not contain oxygen?

A 1,1-dibromooctane
B pentan-2-ol
C butyl propanoate
D methanoic acid

1.10 Which option correctly shows a positional isomer and a chain isomer of the compound **pent-1-ene**?

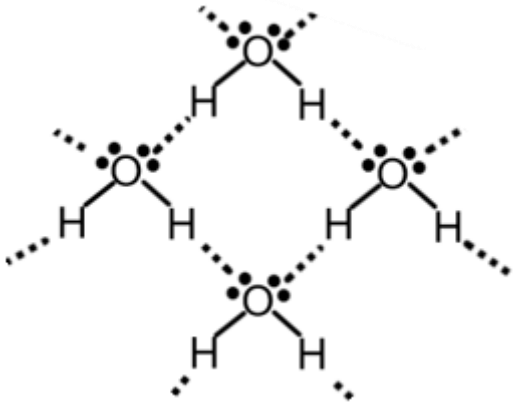
	Positional isomer	**Chain isomer**
A	2-methylbut-1-ene	methylpropene
B	pent-2-ene	but-1-ene
C	2-methylbut-1-ene	pent-2-ene
D	pent-2-ene	3-methylbut-1-ene

[20]

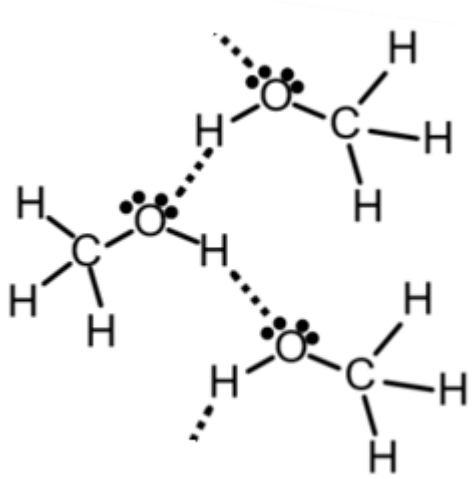
QUESTION 2

In the diagrams below, the intramolecular bonds are represented by solid lines, while the intermolecular forces are represented by dotted lines. (Note that this is a 2-D (flat) representation of a 3-D reality.) Study the diagrams and answer the questions set.

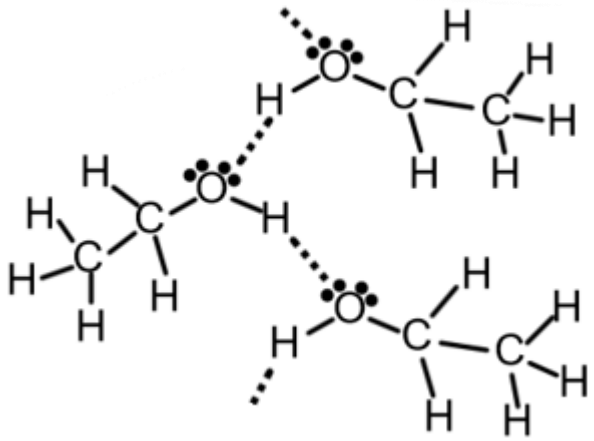
A: Water, boiling point 100 °C



B: Methanol, b.p. 64,7 °C



C: Ethanol, b.p. 78,4 °C



2.1 The solid lines represent covalent bonds.

2.1.1 Define *polar covalent bond*. (2)

2.1.2 Between which two atoms is the **polar** covalent bond the **least** polar? (1)

2.1.3 Give a reason for your answer to Question 2.1.2. (1)

2.2 The dotted lines represent hydrogen bonds.

2.2.1 State THREE requirements for the formation of a hydrogen bond. (3)

2.2.2 Why are hydrogen bonds stronger than dipole-dipole forces? (2)

2.3 Circle the CORRECT words from within brackets in the statement below: (2)

Boiling is a (PHYSICAL / CHEMICAL) process in which (INTRAMOLECULAR BONDS ARE BROKEN / INTERMOLECULAR FORCES ARE OVERCOME.)

2.4 Explain fully why water has a higher boiling point than the other two compounds. Make specific reference to the diagrams. (4)

2.5 Ethanol has a higher boiling point than methanol.

2.5.1 Which type of intermolecular forces are predominantly responsible for this? (1)

2.5.2 Explain why the intermolecular forces are stronger in ethanol than methanol. (2)

[18]

THIS PAGE IS INTENTIONALLY LEFT BLANK.

QUESTION 3

Nitrogen monoxide gas may be prepared by adding copper metal to dilute nitric acid. The balanced equation for the redox reaction is given below:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(\ell)$$

BLUE

Three different experiments were conducted in which various reaction conditions were changed. The data is tabulated below.

Experiment	Mass of Cu (g)	Volume of HNO_3 (dm^3)	[HNO_3] ($mol.dm^{-3}$)	State of Cu(s)
A	2,54	0,10	0,8	Small pellets
B	2,54	0,05	0,8	Large chunks
C	5,08	0,05	1,6	Small pellets

3.1 Using the data from EXPERIMENT **A**:

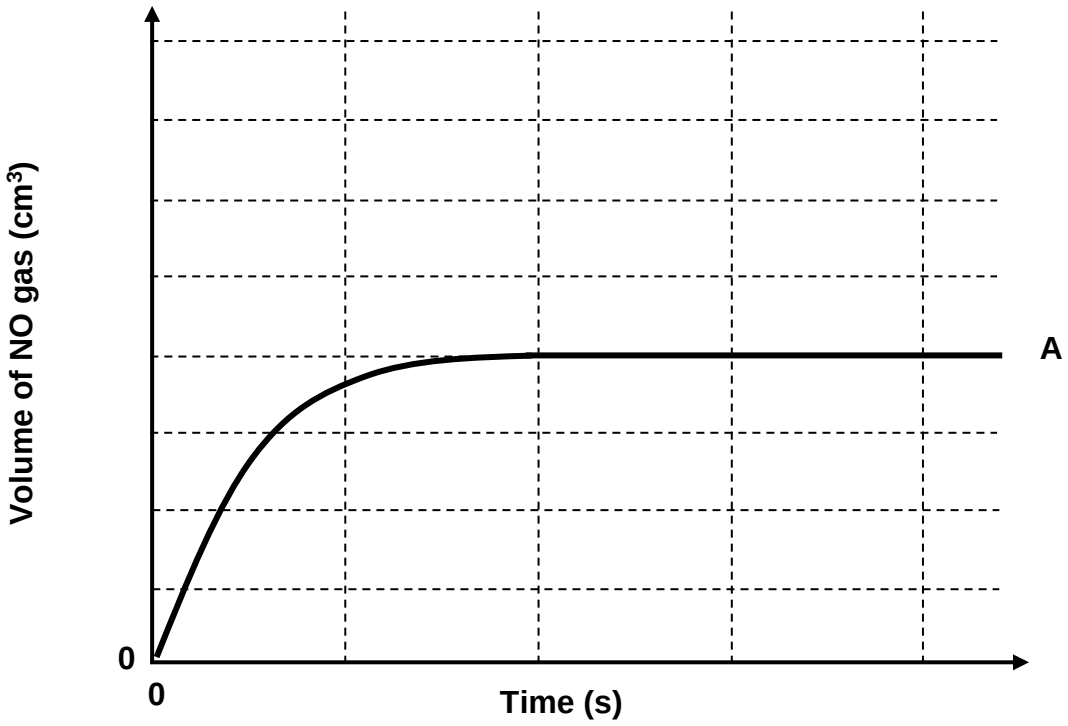
3.1.1 Calculate the number of moles of Cu. (2)

3.1.2 Calculate the number of moles of HNO_3. (2)

3.1.3 Hence, show that copper is in excess. (1)

3.1.4 Assuming that the reaction proceeds to completion, calculate the volume of NO(g) that would be produced at STP. (3)

The NO gas was collected in a gas syringe. The volume of NO gas produced in EXPERIMENT **A** is plotted against time, as shown in the graph below:



3.2 Draw the curves that will be obtained for experiments **B** and **C** on the above axes. **LABEL** the **two** new curves clearly. (4)

3.3 Explain how an increase in concentration affects the rate of a reaction in terms of the Collision Theory. (4)

The reaction equation is re-written below:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(\ell)$$

BLUE

3.4 Some alternative methods of measuring the rate of this reaction are:

- Measure the pH of the reaction mixture vs time.
- Shine light through the solution and measure the % transmission of the light vs time.

3.4.1 State whether the pH of the reaction mixture would INCREASE, DECREASE or STAY THE SAME as the reaction proceeds. Give a reason for your answer. (2)

3.4.2 State whether the % transmission of light through the reaction mixture would INCREASE, DECREASE or STAY THE SAME as the reaction proceeds. Give a reason for your answer. (2)

3.5 The reaction equation is re-written below:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(\ell)$$

3.5.1 Define *redox reaction*. (1)

3.5.2 Identify the reducing agent in this reaction. (1)

3.5.3 Identify and write down the ionic equation for the reduction half-reaction. Refer to the table of standard electrode potentials (Table 4). (2)

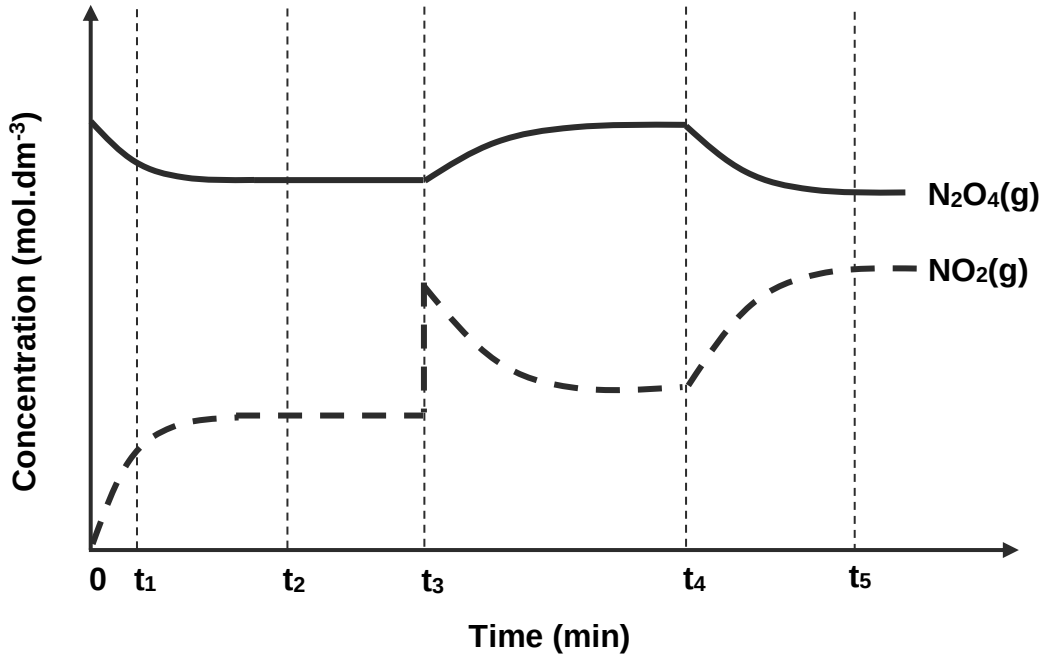
[24]

QUESTION 4

A sample of N_2O_4 gas is sealed in a container and heated. The N_2O_4 gas decomposes to NO_2 gas. The reaction reaches equilibrium according to the following balanced equation:

$$N_2O_4(g) \rightleftarrows 2NO_2(g) \qquad \Delta H > 0$$

The graph below shows how the concentrations of the two gases change as a result of changes made to the reaction conditions.



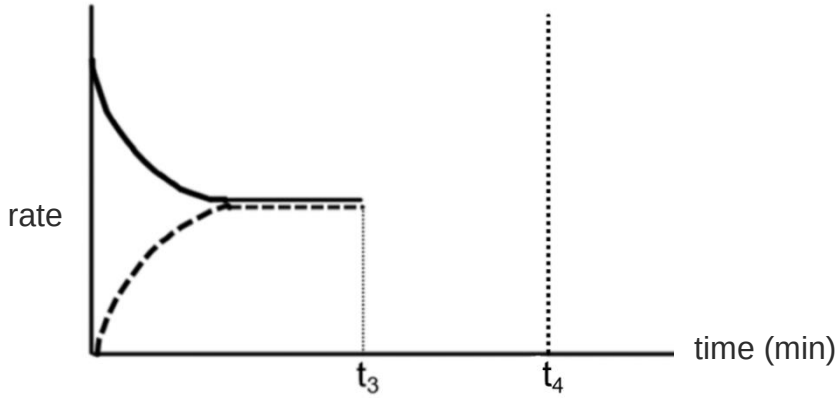
4.1 How does the rate of the forward reaction compare to the rate of the reverse reaction at the following times?
(Choose from: HIGHER THAN, LOWER THAN or EQUAL TO)

4.1.1 **t_1** (1)

4.1.2 **t_2** (1)

4.2 As the reaction starts, the concentration of $NO_2(g)$ increases faster than the concentration of $N_2O_4(g)$ decreases. Explain this observation. (2)

4.3 At **t_3**, some NO_2 gas was added to the container. Complete the graph below from **t_3** to **t_4** to show the effect of this change on the rates of the forward and reverse reactions. (3)



4.4 Shariq **incorrectly** says that the change at **t_4** was an increase in the volume of the container.

4.4.1 State (do not redraw the graph) how the graph of **concentration vs time** (page 14) would differ if the volume of the container had been increased at **t_4**. (2)

4.4.2 Explain your answer to Question 4.4.1 with reference to a suitable formula from the Data Sheet. (2)

4.5 The actual change at **t_4** was an increase in the temperature of the equilibrium mixture. Make use of Le Chatelier's Principle to explain the observations on the graph (page 14) at **t_4**. (3)

4.6 At t_5, a catalyst was added to the reaction mixture. State and explain the effect of this on the equilibrium concentrations of NO_2 and N_2O_4. (2)

4.7 N_2O_4 gas was pumped into a container until the concentration was 0,46 mol.dm^{-3}. The container was then sealed and heated to 100°C. At equilibrium, 20,7% of the N_2O_4 gas had decomposed to NO_2 gas. The reaction equation is re-written below.

$$N_2O_4(g) \rightleftarrows 2NO_2(g)$$

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

4.7.2 Calculate the equilibrium constant for this reaction at 100 °C. (5)

[23]

QUESTION 5

5.1 Consider three acid solutions:

- Solution **A** = 0,4 mol.dm^{-3} H_2SO_3(aq)
- Solution **B** = 0,4 mol.dm^{-3} H_2SO_4(aq)
- Solution **C** = 4 mol.dm^{-3} H_2SO_3(aq)

5.1.1 Define *acid*. (1)

5.1.2 Name the acid H_2SO_3. (1)

5.1.3 Define *weak acid*. (2)

5.1.4 What specific property of a solution does the pH measure? (2)

5.1.5 Which solution, **A, B** or **C**, will have the **highest** pH? (2)

5.1.6 Maya says: *'**C** is the strongest acid solution.'* Correct Maya's statement. (1)

5.2 The polyatomic ions $H_2PO_4^-$ and HCO_3^- can act as either acids or bases.

5.2.1 What is the term used to describe a substance that can act as either an acid or a base? (1)

5.2.2 Study the reaction below: Label each substance as either an acid or a base in the boxes provided. Then link the conjugate acid-base pairs.

$$H_2PO_4^- + HCO_3^- \rightleftarrows H_3PO_4 + CO_3^{2-}$$

(2)

5.3 Ammonium fluoride, NH_4F, is a salt. When ammonium fluoride is dissolved in water, it dissociates into ammonium ions and fluoride ions. These ions both undergo hydrolysis reactions.

5.3.1 Write down the hydrolysis reaction for $\mathbf{NH_4^+}$. (2)

5.3.2 Write down the hydrolysis reaction for $\mathbf{F^-}$. (2)

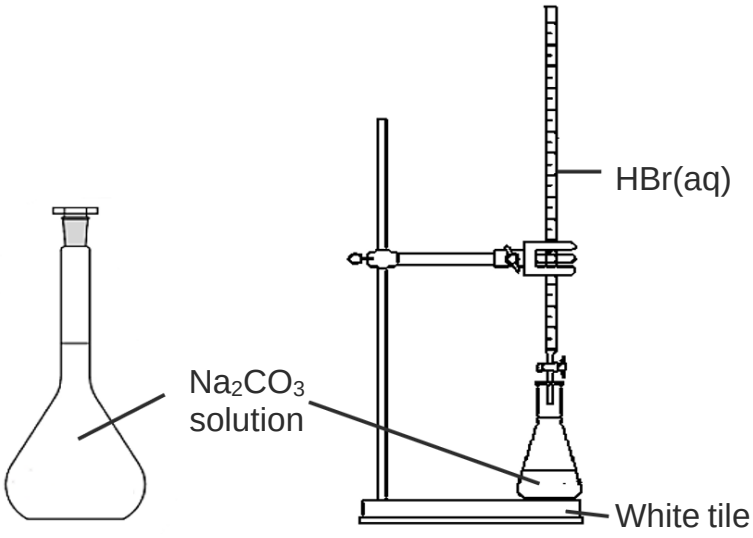
5.3.3 At 25 °C, K_a for HF = $6{,}8 \times 10^{-4}$ and K_b for NH_3 = $1{,}8 \times 10^{-5}$.

(a) Make use of this information to predict whether an ammonium fluoride solution will be ACIDIC, BASIC or NEUTRAL at 25 °C. (1)

(b) Which of K_a for NH_4^+ OR K_b for F^- will be the larger value at 25 °C? (1)

(c) Explain the answer to Question 5.3.3(a). Refer to the relative extent of ionisation in the two hydrolysis reactions. (2)

5.4 A standard solution of sodium carbonate of concentration 0,120 mol.dm^{-3} was prepared in a volumetric flask. 0,0200 dm^3 of this solution was transferred into a conical flask. The concentration of a HBr solution was then determined by titration.



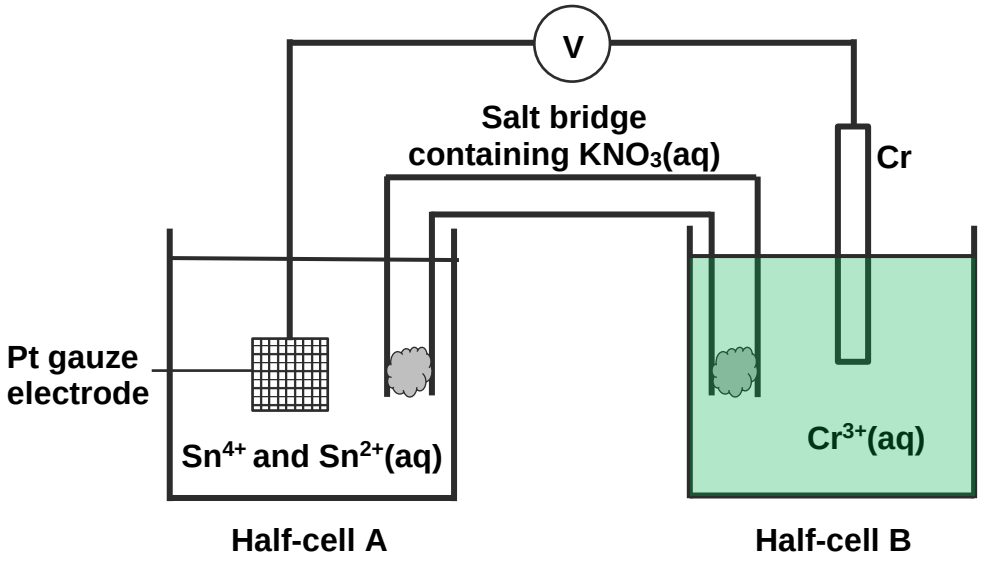
5.4.1 Write a balanced chemical equation for the reaction of Na_2CO_3 with HBr. State symbols are not required. (3)

5.4.2 The Na_2CO_3 solution in the conical flask was neutralised by 0,0152 dm^3 of the HBr solution. Calculate the concentration of the HBr solution. Work to four decimal places at each step of the calculation. (5)

[28]

QUESTION 6

A standard voltaic cell is set up as shown below.



6.1 What is the benefit of using platinum gauze rather than just a straight piece of platinum wire? (2)

6.2 Give the symbol of the oxidising agent in this cell. (2)

6.3 Write the cell notation for this cell. The conditions and state symbols are not required. (4)

6.4 Consider the electrolyte solutions in this cell:

- $SnC\ell_2(aq)$ and $SnC\ell_4(aq)$ in half-cell **A**
- $Cr_2(SO_4)_3(aq)$ in half-cell **B**
- $KNO_3(aq)$ in the salt bridge

6.4.1 Name the compound $SnC\ell_4$. (2)

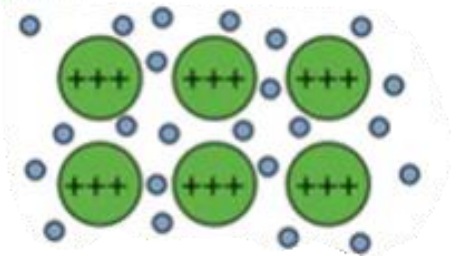
6.4.2 Identify the anion, other than NO_3^-, that will be in higher concentration in the salt bridge after the cell has been operating for some time. (2)

6.4.3 Explain the direction of the movement of the anion identified in Question 6.4.2. (2)

6.5 State TWO changes that could be made to the salt bridge to **decrease** the internal resistance of the cell. (2)

6.6 A soluble $Cr_2(SO_4)_3$ salt is used to prepare the electrolyte for half-cell **B**. Assume that the salt dissociates completely. Calculate the mass of $Cr_2(SO_4)_3$ that should be weighed out in order to prepare 0,25 dm^3 of the 1 $mol.dm^{-3}$ Cr^{3+} electrolyte solution. (4)

6.7 The bonding in solid Cr is represented in the diagram below.



[<ChemistryLearner.com>]

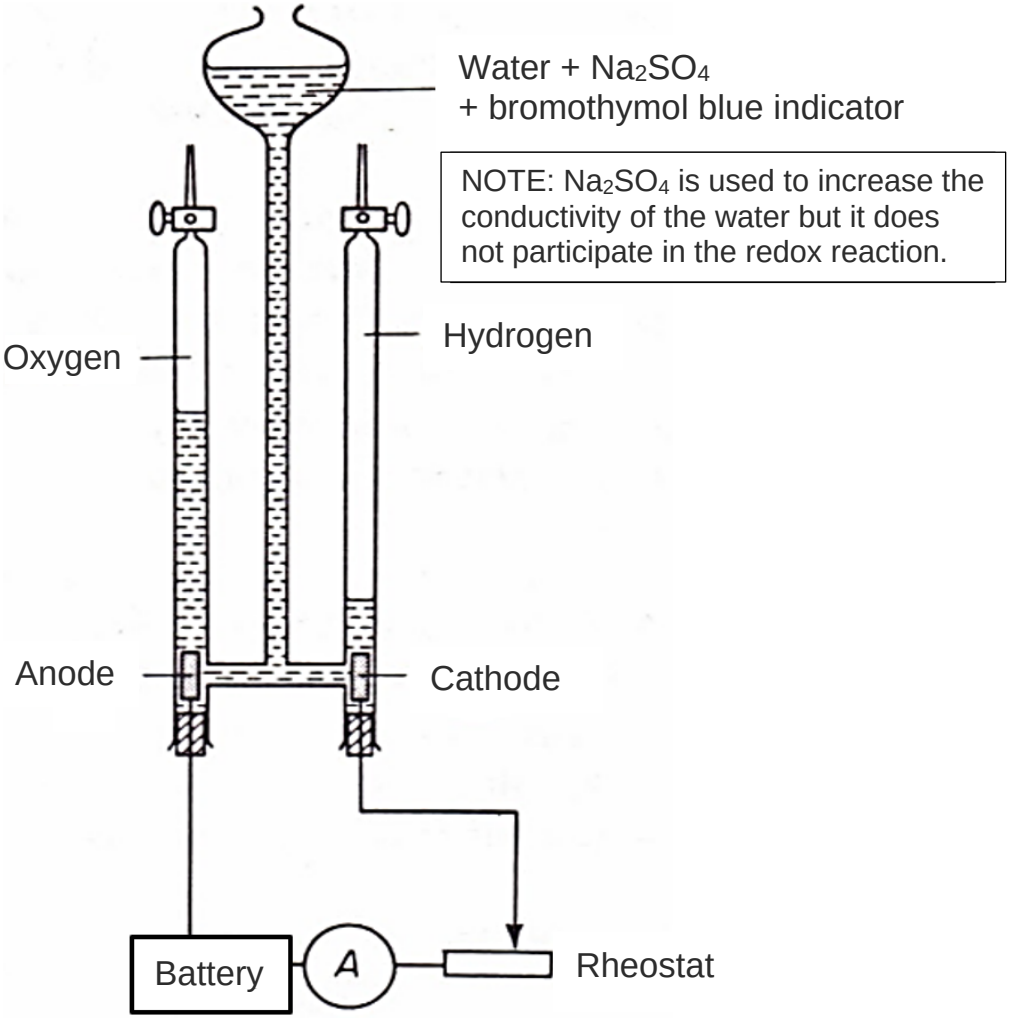
6.7.1 Name this type of bonding. (1)

6.7.2 With reference to the diagram, explain why Cr can be used as an electrode in half-cell **B**. (2)

[23]

QUESTION 7

7.1 Water can be electrolysed using a Hofmann Voltameter, illustrated below.



The equations for the half-reactions that take place are as follows:

I $2H_2O + 2e^- \rightarrow 2OH^- + H_2(g)$

II $2H_2O \rightarrow O_2(g) + 4H^+ + 4e^-$

The anode and the cathode are both made of platinum.

7.1.1 What is the benefit of using platinum rather than another metal? (1)

7.1.2 State whether the anode is connected to the POSITIVE or NEGATIVE terminal of the battery. (1)

7.1.3 Classify half-reaction **I** as OXIDATION or REDUCTION. Give a reason for your answer.

$$\textbf{I} \quad 2H_2O + 2e^- \rightarrow 2OH^- + H_2(g) \qquad (2)$$

7.1.4 Calculate the cell potential (E^{θ}_{cell}) for the decomposition of water under standard conditions. (4)

7.1.5 Is the reaction SPONTANEOUS or NON-SPONTANEOUS? Give a reason in terms of the calculated cell potential. (2)

7.1.6 Bromothymol blue is a weak acid indicator that is **yellow** in acidic solution and **blue** in alkaline solution. The indicator can be represented as HIn, and the equilibrium that occurs in solution can be represented as follows:

$$HIn + H_2O \rightleftarrows In^- + H_3O^+$$

(a) What is the colour of In^-, the deprotonated form of the indicator? (2)

(b) What will be the colour of the solution around the cathode? (2)

7.1.7 A constant current of 0,05 A is maintained for 1,5 hours by carefully controlling the rheostat.

(a) Calculate the amount of charge that passes through the solution in this time period. (3)

(b) Hence, calculate the volume of oxygen gas that will be produced at STP in this time period. (4)

$$2H_2O \rightarrow O_2(g) + 4H^+ + 4e^-$$

7.2 The chlor-alkali industry involves the electrolysis of a concentrated aqueous solution of sodium chloride. The three types of cells used are the diaphragm cell, the membrane cell and the mercury cell.

7.2.1 What is a concentrated aqueous solution of sodium chloride commonly known as? (1)

7.2.2 Which one of the three cells produces the purest and most concentrated NaOH(aq) product? State the main reason for this. (2)

Cell:

Reason:

7.2.3 Which one of the three cells produces the least pure NaOH(aq) product? What is the major contaminant? State the reason for this. (3)

Cell:

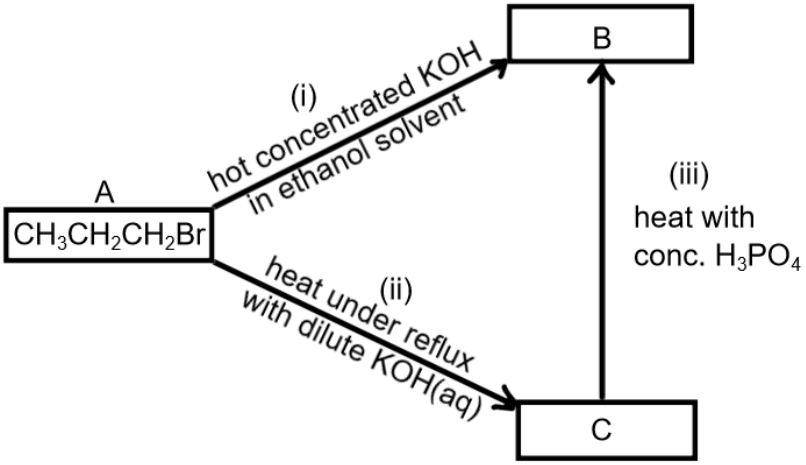
Major contaminant:

Reason:

[27]

QUESTION 8

Study the flowchart below in which **B** and **C** are the organic products of chemical reactions **(i)** to **(iii)**.



8.1 Write the IUPAC name for compound **A**. (2)

8.2 Identify the homologous series to which compound **A** belongs. (1)

8.3 Write the condensed structural formula for:

8.3.1 compound **B**. (2)

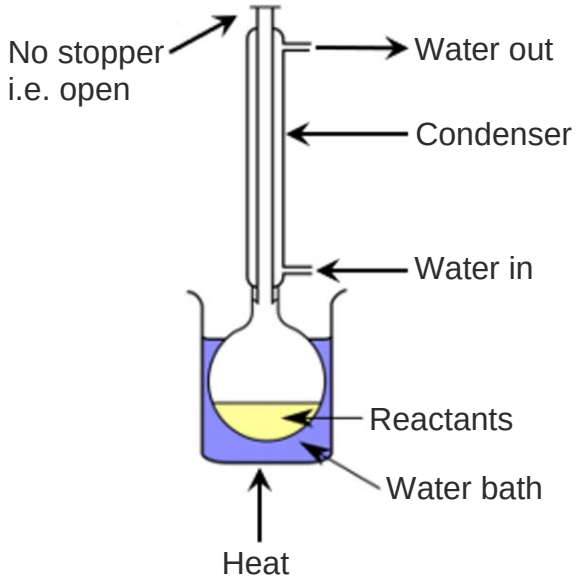
8.3.2 compound **C**. (2)

8.4 For reaction **(i)**, state the GENERAL reaction type. (1)

8.5 For reaction **(ii)**, state the SPECIFIC reaction type. (1)

8.6 For reaction **(iii),** state the SPECIFIC reaction type. (1)

8.7 The diagram illustrates 'heating under reflux' in reaction **(ii)**.



Why is it often necessary to carry out reactions involving organic compounds under reflux? (2)

[12]

QUESTION 9

9.1 Consider the compound **pentyl ethanoate**.

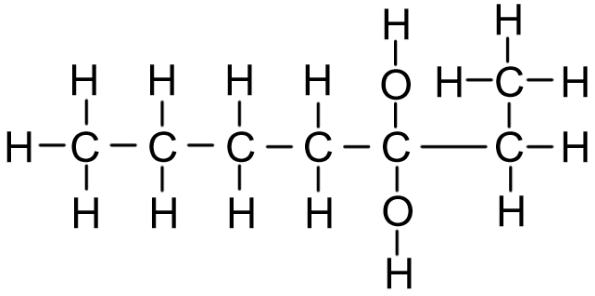
9.1.1 Draw the **structural** formula of this compound. (3)

9.1.2 Circle the functional group of the compound in your formula above. (1)

9.1.3 The reaction to prepare this compound involves two molecules combining to form a single molecule, with the elimination of a water molecule. State the GENERAL term used to describe such reactions. (1)

9.1.4 Give the IUPAC name of the carboxylic acid that would be used to make pentyl ethanoate. (1)

9.2 Give the IUPAC name of the compound below. (3)

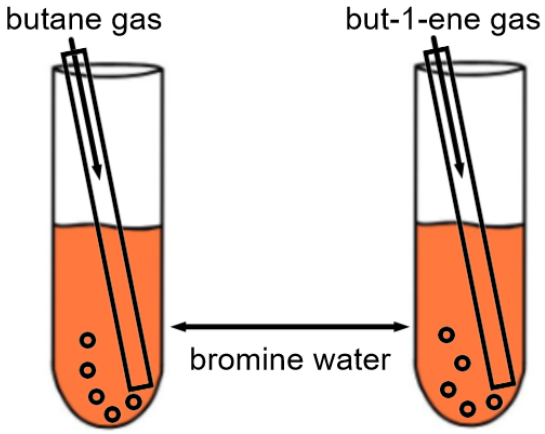


9.3 Consider the reaction equation: $C_{13}H_{28} \xrightarrow{heat}$ heptane + 2**X**

9.3.1 State the SPECIFIC reaction type. (1)

9.3.2 Give the IUPAC name of compound **X**. (3)

9.4 **Butane** and **but-1-ene** are both colourless gases at room temperature. Each gas is bubbled through a separate solution of red-brown bromine (Br_2) water.



9.4.1 Describe by means of observable changes how one can distinguish between butane and but-1-ene. (3)

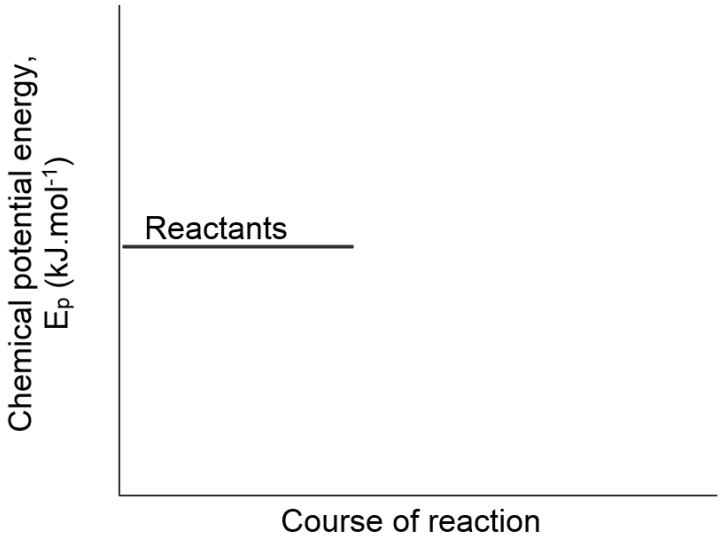
9.4.2 Give the GENERAL name for the type of reaction between **butane** and bromine in the presence of UV light. (1)

9.4.3 Write a balanced chemical equation using condensed structural formulae for the reaction of **but-1-ene** with bromine. (3)

9.4.4 For the reaction in Question 9.4.3, the activation energy, E_a, is 4795 kJ.mol^{-1} and the energy released when the product bonds form, E_{out}, is 4889 kJ.mol^{-1}.

(a) Calculate ΔH for the reaction. (2)

(b) Complete the energy-profile graph for the reaction on the axes provided. (1)



(c) Indicate and label the two energy intervals E_a and ΔH on your graph. It is not necessary to show the numerical values. (2)

[25]

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.