NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2018

# PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

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**PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY**

1. This question paper consists of 18 pages, a yellow ANSWER SHEET of 2 pages (i–ii) and a green DATA SHEET of 3 pages (i–iii). Please check that your question paper is complete.

2. Remove the DATA SHEET and ANSWER SHEET from the middle of this question paper. **Write your examination number on the yellow ANSWER SHEET.**

3. Read the questions carefully.

4. Answer ALL the questions.

5. Question 1 consists of 10 multiple-choice questions. There is only one correct answer to each question. The questions are to be answered on the answer sheet provided on the inside cover on your answer book. The letter that corresponds with your choice of the correct answer must be marked with a cross as shown in the example below.

| A | B | C | D |
|---|---|---|---|

Here the answer C has been marked.

6. **START EACH QUESTION ON A NEW PAGE.**

7. Please ensure that you number your answers as the questions are numbered.

8. Unless instructed otherwise it is NOT necessary to give state symbols (phase indicators) when asked to write a balanced chemical equation.

9. Use the data and formulae whenever necessary.

10. Show all the necessary steps in calculations.

11. Where appropriate, take your answers to 2 decimal places.

12. It is in your interest to write legibly and to present your work neatly.

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## QUESTION 1 MULTIPLE CHOICE

**Answer these questions on the multiple-choice answer sheet on the inside front cover of your Answer Book. Make a cross (X) in the box corresponding to the letter that you consider to be most correct.**

1.1 The chemical formula for dinitrogen tetroxide is:

A $NO$
B $N_2O_4$
C $N_4O_2$
D $N_2O_5$

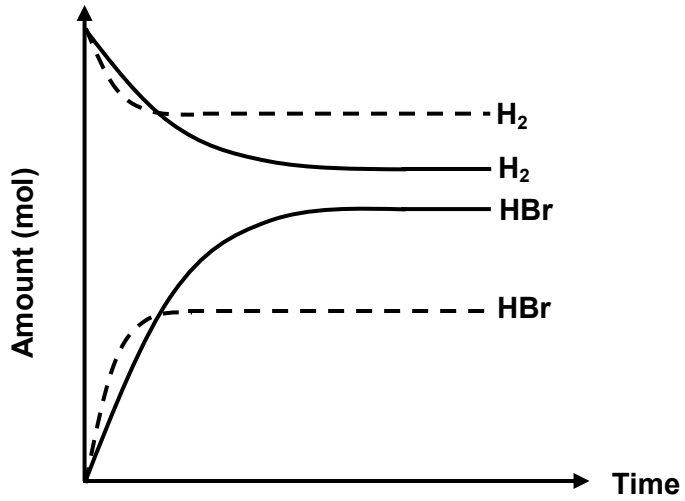
1.2 An exothermic reaction is one in which:

A there is an increase in temperature of the reaction mixture.
B there is a conversion from thermal energy into potential energy.
C there is a low activation energy.
D there is a high number of effective collisions per second.

1.3 A container is filled with $H_2$ and $Br_2$ gases and sealed at a particular temperature. The gases react as shown in the following balanced chemical equation:

$$\mathbf{H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g) \qquad \Delta H < 0}$$

The changes in the amounts of $H_2$ and HBr are shown by the solid lines in the graph below.




The reaction is then repeated under different conditions. Which one of the following changes to the **original** conditions would result in the dashed lines (- - - -) shown on the graph?

A A higher pressure
B A higher temperature
C A higher concentration of $Br_2$
D Addition of a suitable catalyst

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1.4 The **average rate of formation of $CO_2$** in the following reaction is 0,5 mol·min$^{-1}$.

$$CaCO_3(s) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + CO_2(g) + H_2O(\ell)$$

The **average rate of consumption (disappearance) of HCℓ** for this same reaction is:

A 0,25 mol·min$^{-1}$
B 0,5 mol·min$^{-1}$
C 1 mol·min$^{-1}$
D 2 mol·min$^{-1}$

1.5 Which one of the following will behave as a weak, **polyprotic** acid when dissolved in water?

A $NH_3$
B $HNO_2$
C $H_2SO_3$
D $(NH_4)_2SO_4$

1.6 Water is added to a 0,01 mol·dm$^{-3}$ solution of nitric acid. Which one of the following describes the change in concentration of hydronium ions and pH in this solution as water is added?

| | **$[H_3O^+]$** | **pH** |
|---|---|---|
| A | Remains the same | Remains the same |
| B | Increases | Decreases |
| C | Increases | Increases |
| D | Decreases | Increases |

1.7 A small amount of a salt with the formula **XZ** is dissolved in distilled water at 25 °C. The $K_b$ value for **XOH** is $3,2 \times 10^6$ at 25 °C and the $K_a$ value for **HZ** is $1,6 \times 10^{-5}$ at 25 °C. What is the approximate pH of the solution of **XZ** at 25 °C?

A 5
B 7
C 9
D 14

1.8 A galvanic cell is constructed under standard conditions. The spontaneous reaction that occurs is represented by the following balanced chemical equation:

$$2A\ell + 3Co^{2+} \rightarrow 2A\ell^{3+} + 3Co$$

Which one of the following is the standard potential for this cell?

A +1,38 V
B −1,38 V
C +2,48 V
D −2,48 V

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1.9 The process used to deposit a metal onto a conductive object is called:

A Electrolysis
B Electrorefining
C Electroextraction
D Electroplating

1.10 Which one of the following is NOT a property of carbon that enables it to be the building block of organic chemistry?

A It forms strong covalent bonds to other atoms.
B It forms weak induced dipole forces with other atoms.
C It has a valency of four in a tetrahedral arrangement.
D It can form bonds to itself.

**[20]**

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## QUESTION 2

Chromium metal reacts with hydrochloric acid to produce a **green** solution of chromium(III) chloride and hydrogen gas, as shown in the following balanced chemical equation.

$$\mathbf{2Cr(s) + 6HC\ell(aq) \rightarrow 2CrC\ell_3(aq) + 3H_2(g) \qquad \Delta H < 0}$$

2.1 A partially drawn potential energy profile for this reaction is provided on your ANSWER SHEET.

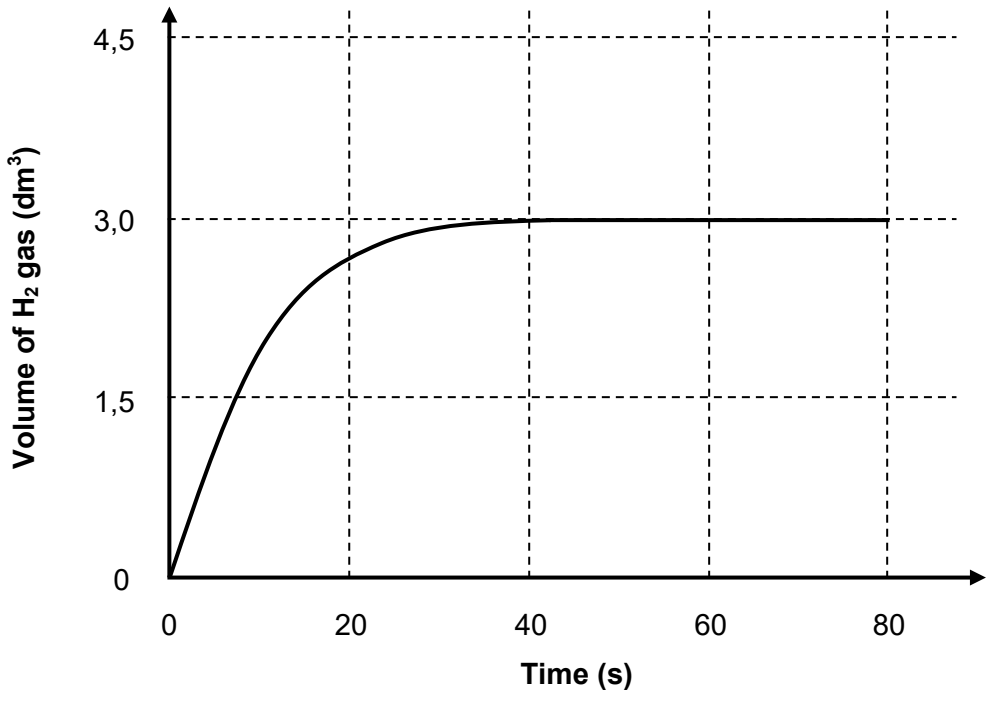
2.1.1 Complete this energy profile. (1)

2.1.2 Write the relevant labels in the boxes provided. (3)

Dana performs a series of experiments to test the effect of certain factors on the average rate of reaction between chromium metal and hydrochloric acid. In each of the experiments, Dana ensures that **chromium is the limiting reagent** and is always completely covered by the **same volume** of hydrochloric acid of the **same concentration**. The reaction conditions for each of the experiments are tabulated below.

| Experiment | State of chromium | Mass of chromium (g) | Temperature (°C) |
|---|---|---|---|
| 1 | Single lump | 6,0 | 25 |
| 2 | Single lump | 6,0 | 15 |
| 3 | Fine powder | 4,5 | 25 |

Dana observes that in all three experiments, all of the chromium fully reacts in less than 80 s. Dana collects the hydrogen gas produced at STP at set time intervals. Dana's results for **experiment 1** are shown on the graph below.

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2.2 Dana's graph has been reproduced on your ANSWER SHEET. On the axes provided, redraw the graph that would result for:

2.2.1 **Experiment 2** (2)

2.2.2 **Experiment 3** (3)

2.3 Other than measuring the volume of collected hydrogen gas produced over time, briefly describe ONE alternative method that could have been used to measure the rate of this reaction. In your answer, specify what equipment should be used and what measurements should be made. (3)

2.4 Consider the reaction conditions and the graph given for **Experiment 1**.

2.4.1 Determine the total amount (in moles) of hydrogen gas collected at STP. Round your answer to **3 decimal places**. (3)

2.4.2 Considering that the chromium metal is the limiting reagent, calculate the percentage yield of hydrogen gas in this reaction. (5)

2.4.3 Calculate the average rate of formation of $H_2$ (during the first 40 s) in units of $dm^3 \cdot s^{-1}$. Round your answer to **3 decimal places**. (2)

2.5 According to the collision theory, when reacting particles collide, not all of these collisions result in a reaction occurring, i.e. not all of these collisions are **effective**. State TWO conditions necessary for an effective collision. (2)

2.6 Explain fully, in terms of the collision theory, how the reaction rate would be affected if a higher concentration of HCℓ were used. (4)

2.7 Consider **pure** hydrogen chloride, HCℓ(g).

2.7.1 Define *covalent bond*. (2)

2.7.2 Define *electronegativity*. (2)

2.7.3 With reference to the difference in electronegativity between hydrogen and chlorine, explain why the covalent bond in hydrogen chloride is considered to be polar. (3)

**[35]**

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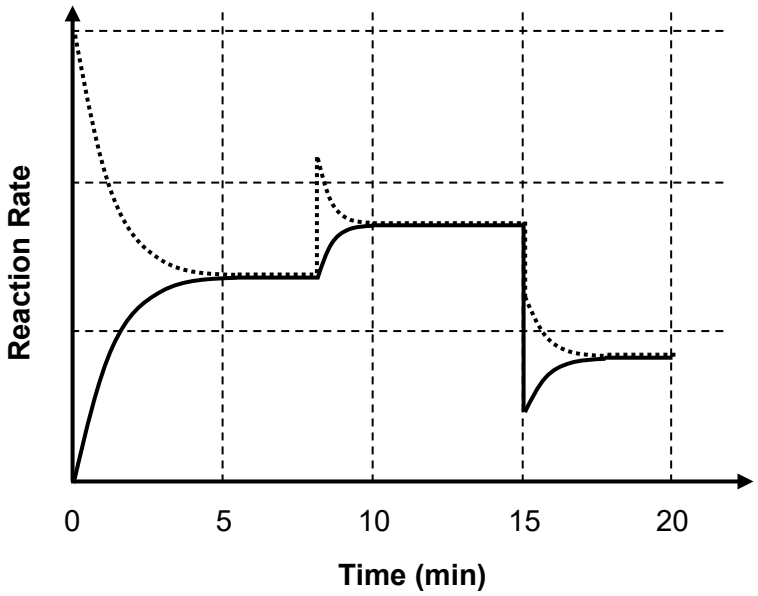
## QUESTION 3

The reaction represented by the following balanced chemical equation is important in the Contact Process for the industrial production of sulfuric acid:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Dikeledi adds some sulfur dioxide and oxygen to a container and then seals the container. He monitors the rates of the forward and reverse reactions over time and the following graph is obtained:




3.1 After what time was dynamic equilibrium reached for the first time? (1)

3.2 Write down the equation for the reaction represented by the solid line. (2)

3.3 State *Le Châtelier's principle*. (2)

3.4 At 8 minutes, more oxygen gas was added to the container whilst maintaining a constant temperature and volume of container. With reference to Le Châtelier's principle, fully explain how the amount of sulfur dioxide was affected when the equilibrium was re-established. (3)

3.5 At 15 minutes, the temperature of the reaction mixture was suddenly decreased.

3.5.1 From the graph, determine and write down which reaction (FORWARD or REVERSE) was initially favoured. (1)

3.5.2 Is the forward reaction EXOTHERMIC or ENDOTHERMIC? No explanation is necessary. (2)

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3.6 The following equations may be used to represent the rates of the forward and the reverse reaction:

$$\textbf{Rate of forward reaction} = k_1[SO_2]^2[O_2]$$
$$\textbf{Rate of reverse reaction} = k_2[SO_3]^2$$

where $k_1$ and $k_2$ are constants.

If the **pressure** of the system is decreased by increasing the volume of the container, both the forward and reverse reaction rates will decrease, but the forward rate will decrease more than the reverse.

3.6.1 Consider the rate equations provided and state why a decrease in pressure causes both reaction rates to decrease. (1)

3.6.2 With reference to the rate equations provided, explain why a decrease in pressure causes the forward reaction rate to decrease more than the reverse. (2)

**[14]**

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## QUESTION 4

The balanced chemical equation below shows a hydrated copper(II) ion, which is **blue** in colour, reacting with chloride ions to form the complex copper tetrachloride ion, which is **green** in colour.

An aqueous equilibrium mixture is prepared in order to obtain a mixture that is initially **blue-green** in colour at 25 °C.

$$\underset{\text{BLUE}}{Cu(H_2O)_6^{2+}(aq)} + 4C\ell^-(aq) \rightleftharpoons \underset{\text{GREEN}}{CuC\ell_4^{2-}(aq)} + 6H_2O(\ell) \qquad \Delta H > 0$$

4.1 What would happen to the **equilibrium** concentration of $C\ell^-$ ions if the reaction mixture were cooled? State only INCREASES, DECREASES or REMAINS THE SAME. (2)

4.2 Which reaction will be favoured by the addition of $CuC\ell_4^{2-}$ ions to the reaction mixture? State only FORWARD or REVERSE. (2)

4.3 What would happen to the **colour** of the mixture if crystals of sodium chloride were dissolved in the reaction mixture? State only TURNS BLUE, TURNS GREEN or REMAINS THE SAME. (2)

4.4 A new solution is prepared by dissolving 4 mol of $CuC\ell_4^{2-}$ completely in water to make up a solution of volume 2 $dm^3$. When equilibrium is established, there are 2,2 mol of $Cu(H_2O)_6^{2+}$ ions present at 25 °C.

$$Cu(H_2O)_6^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CuC\ell_4^{2-}(aq) + 6H_2O(\ell)$$

4.4.1 Write an expression for the equilibrium constant for this reaction. (2)

4.4.2 Determine the value of the equilibrium constant, $K_c$, for this reaction at 25 °C. (6)

**[14]**

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## QUESTION 5

Consider sodium hydroxide (NaOH), a strong base, and butanoic acid, a weak organic acid with the molecular formula $C_4H_8O_2$.

5.1 Define a *base* in terms of the Lowry-Brønsted model. (1)

5.2 Why is NaOH considered to be a strong base? (2)

5.3 Write down the formula of another strong base. (1)

5.4 Write a reaction equation for the dissociation of NaOH in water. (2)

5.5 Consider aqueous solutions of NaOH and butanoic acid of equal concentrations. Which solution will have a greater conductivity? FULLY explain the answer. (4)

5.6 Draw the structural formula of butanoic acid. (2)

5.7 Give the IUPAC name of a FUNCTIONAL isomer of butanoic acid. (2)

**[14]**

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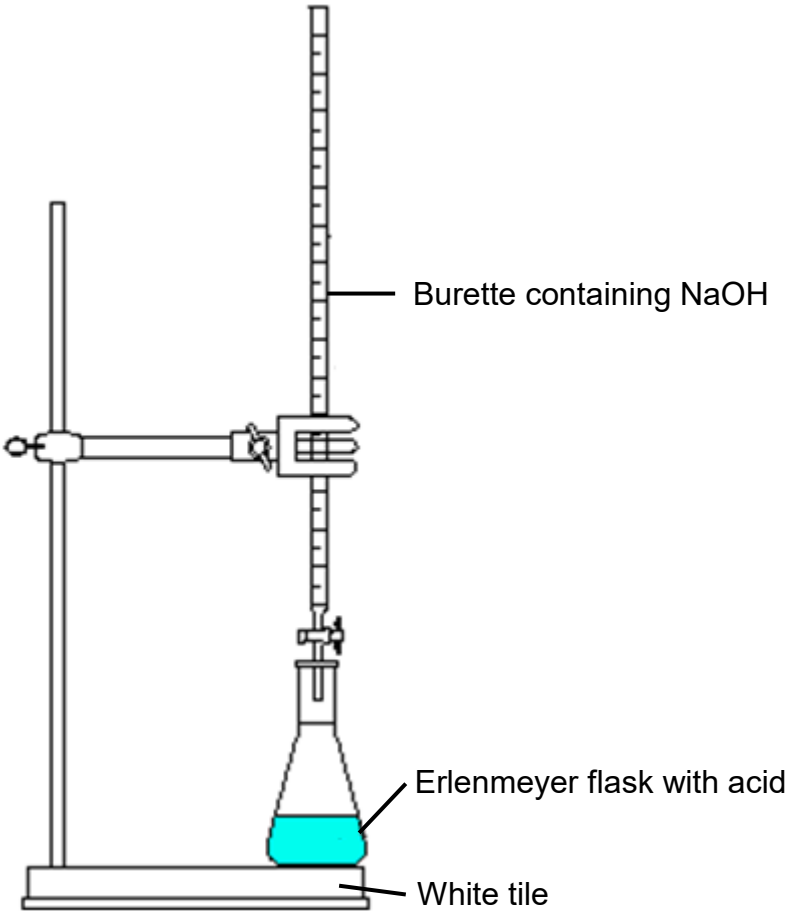
## QUESTION 6

Latif performs a titration by slowly adding a dilute standard solution of NaOH by burette to an **unknown volume** of a standard solution of butanoic acid that has been placed in an Erlenmeyer flask. A simplified diagram of this experimental setup is shown below.




Latif monitors the concentration of hydronium ions as the base is added to the flask, and he arrives at the table of selected results below:

| **$[H_3O^+]$ in flask ($mol \cdot dm^{-3}$)** | **Volume of NaOH added ($cm^3$)** |
|---|---|
| $1 \times 10^{-3}$ | 0 |
| $6{,}31 \times 10^{-5}$ | 10 |
| $3{,}16 \times 10^{-9}$ | 30 |
| $1 \times 10^{-12}$ | 50 |

6.1 How does the **pH** of the solution in the flask change on addition of NaOH? State only INCREASES, DECREASES, or REMAINS THE SAME. (1)

6.2 Calculate the concentration of hydroxide ions in the solution after the addition of 10 $cm^3$ of NaOH at 25 °C. (4)

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6.3 The concentration of the butanoic acid solution used was 0,21 $mol \cdot dm^{-3}$, and the neutralisation point was reached after the addition of 0,0165 mol of NaOH. The neutralisation reaction is represented by the balanced chemical equation below.

$$\mathbf{NaOH(aq) + C_3H_7COOH(aq) \rightarrow C_3H_7COONa(aq) + H_2O(\ell)}$$

6.3.1 Define the term *neutralisation* or *equivalence point*. (2)

6.3.2 Determine the number of moles of butanoic acid that was neutralised. Use **4 decimal places** in your answer. (1)

6.3.3 Calculate the original volume (in $cm^3$) of the butanoic acid solution that was placed in the flask. (4)

6.4 At the neutralisation point, the solution in the flask is basic. This is due to the following hydrolysis reaction:

$$\mathbf{C_3H_7COO^-(aq) + H_2O(\ell) \rightleftharpoons C_3H_7COOH(aq) + OH^-(aq)}$$

6.4.1 Define the term *hydrolysis*. (2)

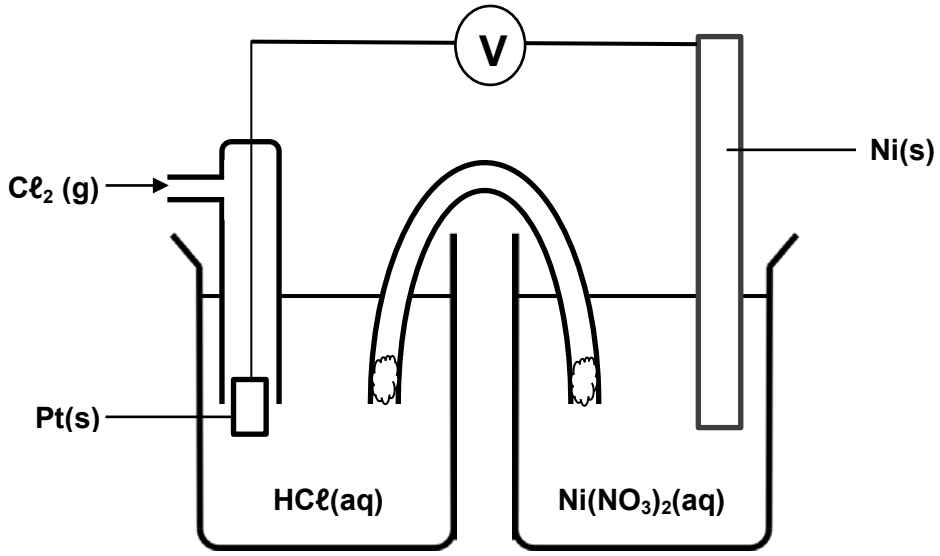
6.4.2 With reference to this hydrolysis equation, explain why the solution in the flask is basic at the neutralisation point. (2)

6.5 Latif states: "*Because NaOH is a strong base, a solution of NaOH will* ***ALWAYS*** *have a higher pH than a solution of a weak base such as* $NH_3$*.*"

Evaluate Latif's statement. (3)
**[19]**

## QUESTION 7

A galvanic cell is constructed using a standard $C\ell_2|C\ell^-$ half-cell and a standard $Ni|Ni^{2+}$ half-cell, as shown in the diagram below. The solution in the nickel half-cell is initially **pale green**.




7.1 The reduction half-reaction that occurs in this cell is shown below:

$$C\ell_2 + 2e^- \rightarrow 2C\ell^-$$

7.1.1 Define *oxidising agent*. (1)

7.1.2 With reference to the strengths of oxidising agents, explain why $C\ell_2$ is reduced instead of $Ni^{2+}$. (2)

7.2 7.2.1 Define *anode*. (2)

7.2.2 Identify the anode in this cell. (1)

7.3 Identify the positive electrode in this cell. (1)

7.4 Write the cell notation for this cell, including relevant conditions. State symbols need not be shown. (5)

7.5 The voltmeter is now replaced with a light bulb so that current flows.

7.5.1 Write down the half-reaction that occurs in the nickel half-cell. (2)

7.5.2 Hence, state TWO changes that will be **observed** in the nickel half-cell after a significant amount of time has passed. (2)

7.5.3 One of the functions of the salt bridge is to maintain electrical neutrality. State ONE other function of the salt bridge. (1)

7.5.4 Explain how the salt bridge maintains electrical neutrality with reference to the changing ionic conditions in the **nickel half-cell**. (2)

7.6 Lerusha accidentally drops some concentrated $AgNO_3$ solution into the chlorine half-cell, causing a white precipitate of $AgC\ell$ to form.

How would this affect the initial cell emf? State only INCREASES, DECREASES or REMAINS THE SAME. (2)

**[21]**

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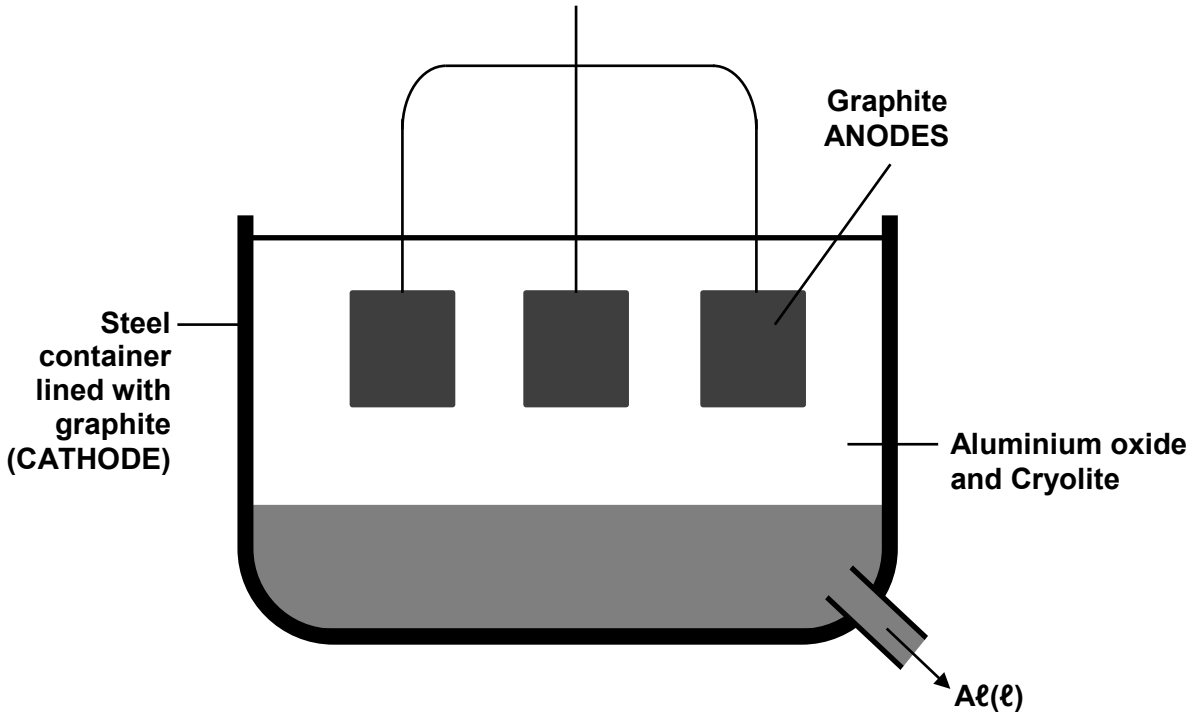
## QUESTION 8

Aluminium is produced in modern times through the Hall-Héroult process, whereby a molten aluminium oxide electrolyte is electrolysed between graphite electrodes. A simplified diagram of the cell used in the Hall-Héroult process is shown below.




Although the production of aluminium is expensive, it is worth the cost. Aluminium is light, so it is useful in the manufacture of aircrafts and cars. It protects itself from corrosion by producing a layer of aluminium oxide on its surface, which is very tough and therefore difficult to remove.

8.1 From the information given above, write down ONE **physical** property of aluminium that makes it a useful metal. (1)

8.2 From the information given above, write down ONE **chemical** property of aluminium that makes it a useful metal. (1)

8.3 Identify the positive electrode in the above cell. State only ANODE or CATHODE. (1)

8.4 Write down the ionic equation for the half-reaction that occurs at the cathode. (2)

8.5 Explain briefly how the use of **cryolite** to decrease the melting point of the electrolyte is:

8.5.1 economically beneficial. (2)

8.5.2 environmentally harmful. (2)

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8.6 Explain why the carbon anodes need regular replacing. Give a relevant chemical reaction equation to support your answer. (4)

8.7 One of the reasons aluminium is so difficult to electrolyse is that aluminium oxide has a very high melting point. With reference to the forces holding its particles together, explain why aluminium oxide has such a high melting point. (4)

8.8 Aluminium can also be produced on a small scale by the reduction of aluminium chloride by sodium metal, shown in the UNBALANCED chemical equation below.

$$\mathbf{A\ell C\ell_3 + Na \rightarrow A\ell + NaC\ell}$$

8.8.1 Balance the above equation. (2)

8.8.2 A chemical engineer wants to test what mass of sodium metal is needed to react completely in order to make 7,56 mol of pure aluminium metal, using this reaction. Calculate the mass of sodium metal needed to do this. (3)

**[22]**

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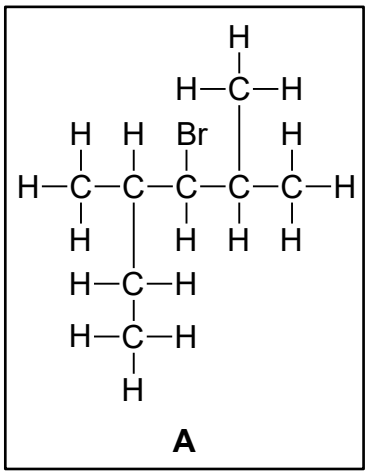
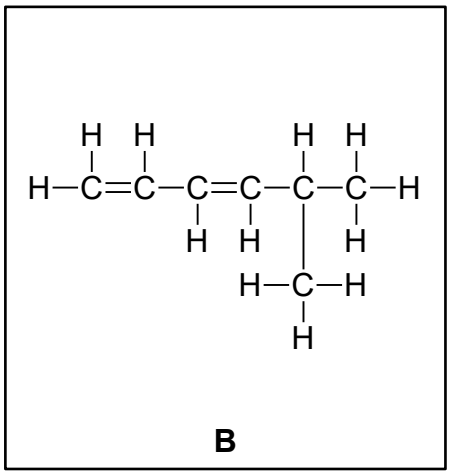
## QUESTION 9

Consider the compounds, labelled **A**, **B**, and **C**, below and answer the questions that follow.



**A**



**B**

pentan−2−ol

**C**

9.1 9.1.1 Write down the IUPAC name for compound **A**. (4)

9.1.2 Draw the condensed-structural formula for compound **A**. (2)

9.2 9.2.1 NAME the homologous series to which compound **B** belongs. (1)

9.2.2 Draw the structural formula for the unbranched CHAIN isomer of compound **B**. (2)

9.3 9.3.1 NAME the functional group present in compound **C**. (1)

9.3.2 State what is meant by the term *positional isomers*. (2)

9.3.3 Draw the structural formula for a POSITIONAL isomer of compound **C**. (2)

9.4 9.4.1 Define *intermolecular force.* (2)

9.4.2 Compound **C** has a **significantly** higher viscosity than compound **B**. Account for this difference with reference to the relevant intermolecular forces in each of these compounds. (4)

9.5 Using molecular formulae, write a balanced chemical equation for the complete combustion of compound **B**. (4)

**[24]**

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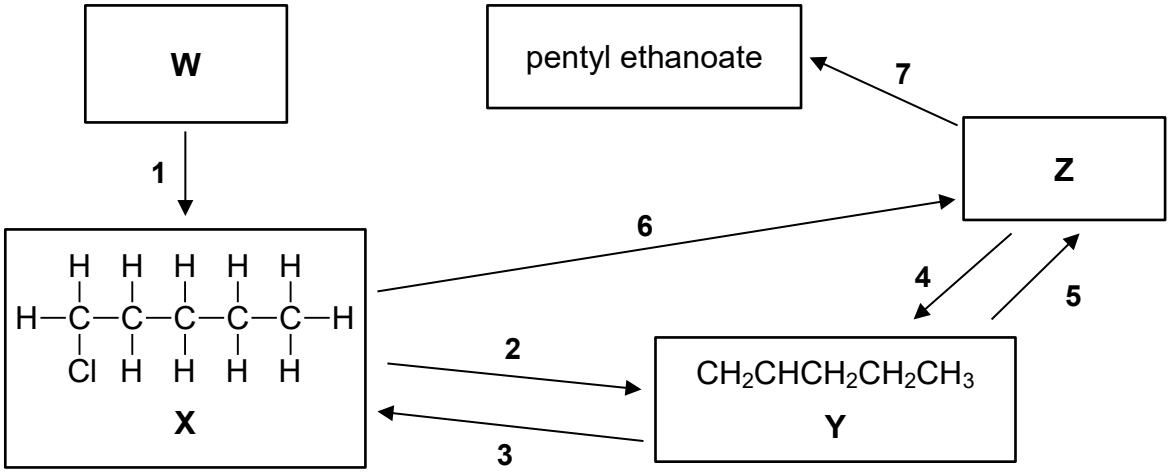
## QUESTION 10

Consider the flow chart below showing the interconversion of organic molecules through organic reactions, and answer the questions that follow. **W** to **Z** are organic compounds, and **1** to **7** are organic reactions.




The conditions for reactions **1**, **5** and **7** are tabulated below.

| Reaction | Conditions |
|---|---|
| 1 | $C\ell_2$ gas is bubbled through compound **W** in the presence of UV light. |
| 5 | Compound **Y** is treated with steam and $H_3PO_4(aq)$. |
| 7 | Compound **Z** is heated gently with a carboxylic acid, together with a few drops of concentrated $H_2SO_4(aq)$. |

10.1 Define *hydrocarbon*. (2)

10.2 Write down the IUPAC name for hydrocarbon **W**. (2)

10.3 Identify the general TYPE of reaction for each of the following:

10.3.1 Reaction **1** (1)

10.3.2 Reaction **5** (1)

10.3.3 Reaction **7** (1)

10.4 NAME the specific type of addition reaction represented by reaction **3**. (1)

10.5 Write down the IUPAC name of compound **Y**. (2)

10.6 Classify compound **Y** as SATURATED or UNSATURATED. (1)

10.7 Consider reactions **5**, **6** and **7** and write down the IUPAC NAME of compound **Z**. (3)

10.8 Draw the structural formula of pentyl ethanoate. (2)

10.9 Write down the NUMBER of the reaction that would take place if the relevant organic compound were heated strongly in the presence of concentrated alcoholic potassium hydroxide. (1)

**[17]**

**Total: 200 marks**

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