NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2020

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 16 pages, a yellow ANSWER SHEET of 2 pages (i–ii) and a green DATA SHEET of 3 pages (i–iii). Please make sure 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. ALL the questions must be answered.

5. Question 1 consists of 10 multiple-choice questions that must be answered on the Answer Sheet on the inside cover of your Answer Book.

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, you do NOT have 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 two decimal places.

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

QUESTION 1 MULTIPLE CHOICE

Answer these questions on the Answer Sheet on the inside of the front cover of your Answer Book. Make a cross (X) in the box corresponding to the letter of the option that you consider to be correct. Every question has only one correct answer.

A	B	C	D

Here the answer C has been marked.

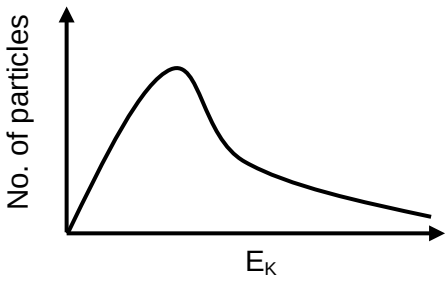
1.1 Identify the predominant intermolecular force in pure, solid $CaC\ell_2$.

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

1.2 Which one of the following contains non-polar covalent bonds?

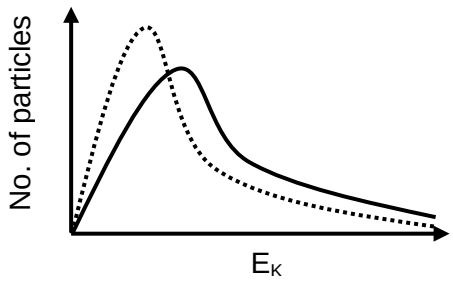
A HBr
B CH_4
C SI_2
D SO_2

1.3 The Maxwell–Boltzmann distribution curve for a reaction mixture is shown below.



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

A



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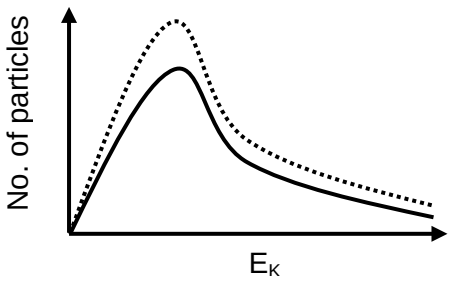

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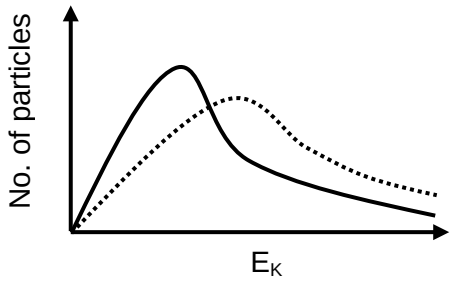

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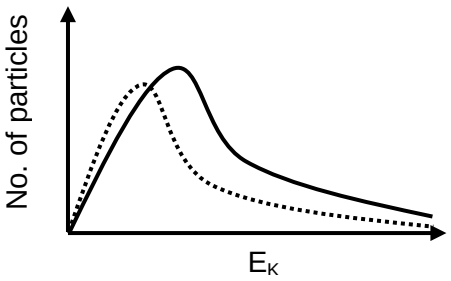


1.4 Which one of the options below is the best description of *reaction rate* for the following reaction?

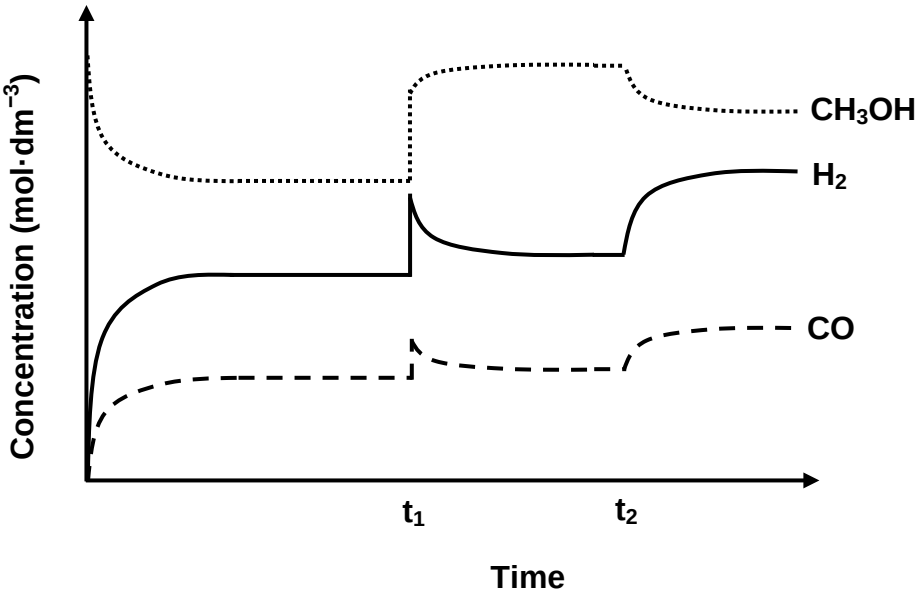
$$Zn(s) + 2HC\ell(aq) \rightarrow ZnC\ell_2(aq) + H_2(g)$$

The reaction rate is …

A the time it takes to use up all of the reactants.
B the decrease in concentration of the Zn per unit time.
C the time it takes for one of the reactants to be used up.
D the increase in concentration of the $ZnC\ell_2$ per unit time.

1.5 Consider the following concentration versus time graph for the reaction shown below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H > 0$$

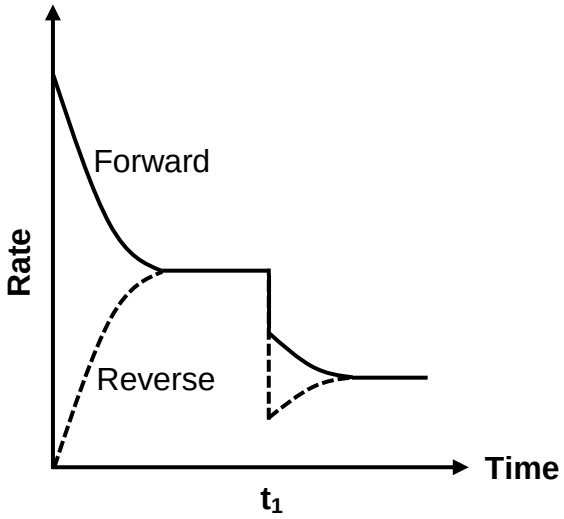


Which one of the following combinations correctly identifies the changes made at times $\mathbf{t_1}$ and $\mathbf{t_2}$?

	Time t_1	**Time t_2**
A	Increase in pressure	Decrease in temperature
B	Increase in pressure	Increase in temperature
C	Addition of CH_3OH	Increase in temperature
D	Addition of CH_3OH	Decrease in temperature

1.6 Consider the reaction rate versus time graph for the following reaction.

$$H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$$



At t_1 there was a TEMPERATURE change. Which one of the following combinations is true for the FORWARD reaction and the pH change that occurs after time t_1?

	FORWARD reaction	**pH change after time t_1**
A	Exothermic	Increases
B	Exothermic	Decreases
C	Endothermic	Increases
D	Endothermic	Decreases

1.7 Which one of the following is true for an ACIDIC solution at 25 °C?

A $[H_3O^+] > [OH^-]$
B $[OH^-]$ = zero
C $K_w < 10^{-14}$
D pH > 7

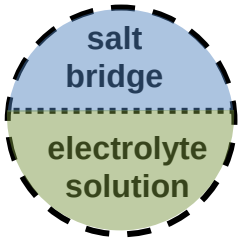
1.8 In the chlor-alkali industry, in which one of the following cells is a sodium amalgam produced?

A The membrane cell
B The diaphragm cell
C The mercury cell
D The Hall–Héroult cell

1.9 Consider the galvanic cell represented in the cell notation below:

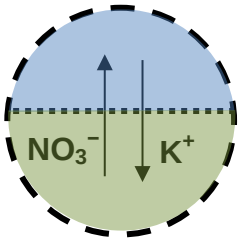
$$Ni(s) \mid Ni(NO_3)_2(aq) \parallel AgNO_3(aq) \mid Ag(s)$$

The salt bridge contains a solution of potassium nitrate. The diagram below shows a representation of one end of the salt bridge in the electrolyte solution.

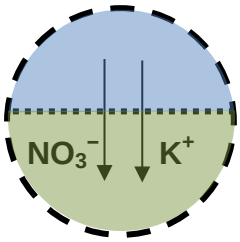


Which one of the following diagrams correctly represents the movement of ions between the salt bridge and electrolyte solution in the OXIDATION half-cell?

A



B



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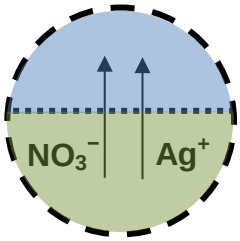
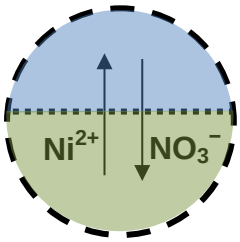


D



1.10 Which one of the following combinations of reactants is most likely to produce ethyl propanoate?

	Reactant 1	Reactant 2
A	ethanol	propane
B	propanol	ethene
C	ethanol	propanoic acid
D	propanol	ethanoic acid

[20]

QUESTION 2

Vitesh works at a chemical company and has been asked to design an industrial process to produce sulfuric acid.

2.1 One of the reactions in the production of sulfuric acid is the roasting (heating in oxygen) of a metal ore that contains lead(II) sulfide:

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$

Vitesh does a test experiment in which 36,8 g of O_2 gas completely reacts with 800 g of the metal ore. All of the PbS in the ore reacts, and ONLY the PbS in the ore reacts with the oxygen.

2.1.1 Define *molar mass*. (2)

2.1.2 Calculate the amount (in moles) of O_2 that reacted. (3)

2.1.3 Calculate the mass of pure PbS in the metal ore. (3)

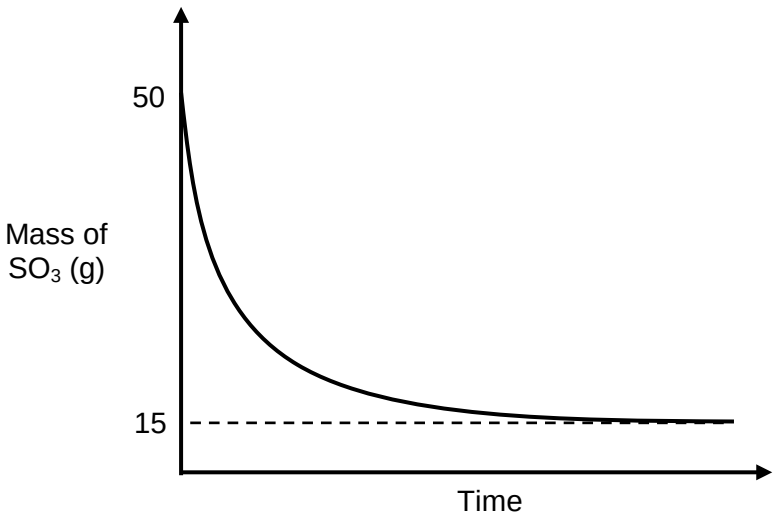
2.1.4 Hence, calculate the mass percentage of the PbS in the metal ore. (2)

2.2 In another test experiment, Vitesh reacts 50 g of sulfur trioxide with water:

$$SO_3(g) + H_2O(\ell) \rightarrow H_2SO_4(\ell)$$

The amount of sulfur trioxide present in the container is monitored over time until the reaction is complete.

He plots the following graph:



Mandy says that Vitesh cannot use the SO_3 to determine the amount of sulfuric acid produced because the SO_3 is not the limiting reagent.

Evaluate Mandy's statement. (3)

[13]

QUESTION 3

The reaction of nickel metal with hydrochloric acid is represented below.

$$Ni(s) + 2HC\ell(aq) \rightarrow NiC\ell_2(aq) + H_2(g)$$

3.1 Which TWO conditions have to be met for an effective collision to occur between colliding reactant particles? (2)

3.2 Use the collision theory to explain how an increase in the concentration of $HC\ell$ would affect the rate of this reaction. (4)

3.3 A catalyst is now added to the reaction mixture.

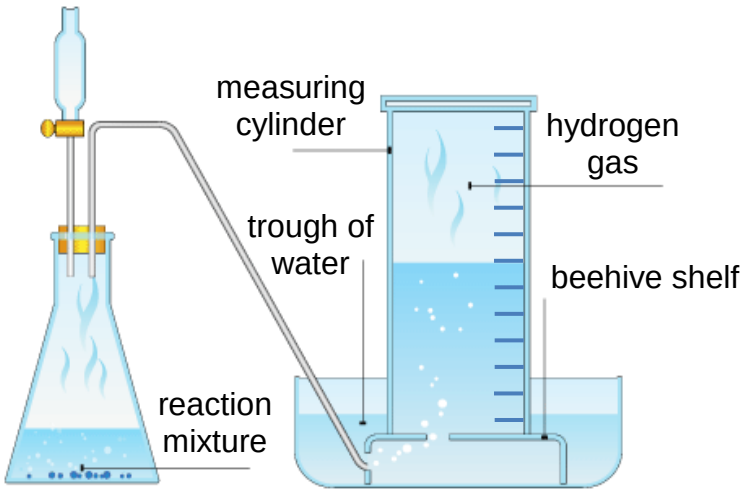
3.3.1 Define *activated complex*. (2)

3.3.2 How is the **stability** of the activated complex affected by the catalyst? (1)

3.3.3 An unlabelled energy profile for the uncatalysed reaction has been provided on your ANSWER SHEET. Complete the graph by adding the following:

- the *x*-axis label
- the *y*-axis label
- a dotted line to show the reaction profile for the catalysed reaction. (3)

In an experiment, Kristen collects the hydrogen gas by the downward displacement of water. The setup is shown below.



Kristen measures the volume of gas produced over time in two experiments, **Experiment 1** and **Experiment 2**.

In both experiments, Kristen uses the same mass and state of nickel; **the acid is the limiting reagent** and the nickel is completely covered by the acid solution.

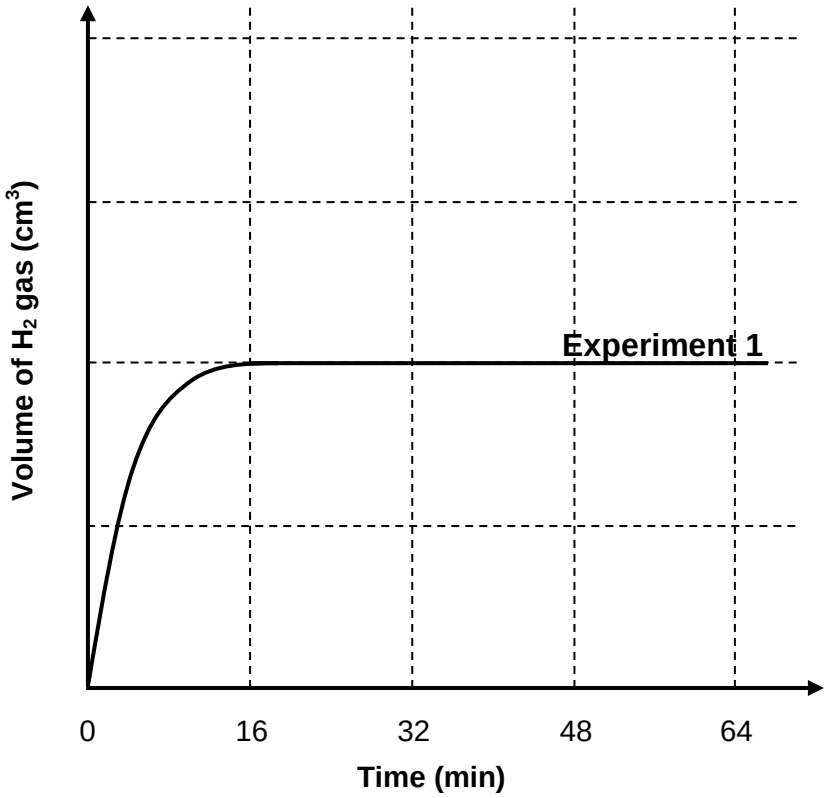
The reaction conditions for each experiment are tabulated below.

Experiment	Volume of HCℓ (dm^3)	Concentration of HCℓ ($mol \cdot dm^{-3}$)	Temperature (°C)
1	0,4	0,04	50
2	0,6	0,04	40

The balanced chemical equation for the reaction of nickel with hydrochloric acid is repeated here:

$$Ni(s) + 2HC\ell(aq) \rightarrow NiC\ell_2(aq) + H_2(g)$$

Kristen plots a graph of volume of hydrogen gas produced versus time for **Experiment 1**, which is shown below.



3.4 The average rate of formation of H_2, as shown on the graph for **Experiment 1**, is 12 $cm^3 \cdot min^{-1}$.

3.4.1 Determine the TOTAL volume of hydrogen gas collected. (3)

3.4.2 Determine the percentage yield of hydrogen for **Experiment 1**. Take the molar volume of the gas at 50 °C to be 26 490 $cm^3 \cdot mol^{-1}$. (7)

3.4.3 The graph for **Experiment 1** is provided on your ANSWER SHEET. On these same axes, draw the graph for **Experiment 2**. Assume this reaction goes to completion within the 64 minutes shown. (2)

[24]

QUESTION 4

4.1 Nitrosyl chloride is a yellow gas that decomposes into colourless nitrogen monoxide gas and green chlorine gas at temperatures above 100 °C.

$$2NOC\ell(g) \rightleftharpoons 2NO(g) + C\ell_2(g)$$

Consider an equilibrium mixture of $NOC\ell$, NO, and $C\ell_2$, which is initially yellow–green, in a sealed container.

4.1.1 Define *closed system*. (2)

4.1.2 NO(g) is added to the container at constant volume.

(a) What colour change will be observed in the container after some time? (1)

(b) Explain this effect of adding NO(g) with reference to the RELATIVE RATES of the forward and reverse reactions. (4)

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

4.1.4 When the pressure in the container is changed, the colour becomes green. Use Le Châtelier's principle to explain whether the pressure was increased or decreased. (4)

4.1.5 Nitrogen monoxide has dipole-dipole interactions. Explain the origin of these dipole-dipole interactions. (3)

4.2 Graphite reacts with carbon dioxide to form carbon monoxide in the Boudouard reaction:

$$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$$

36 g of graphite were mixed with 66 g of carbon dioxide in a 400 cm^3 container and the container was then sealed at a particular temperature. At equilibrium, it was noted that 2 mol of graphite remained.

Determine the equilibrium constant at this temperature. (8)

4.3 CO_2 has a boiling point of −78 °C, whereas $C\ell_2$ has a boiling point of −34 °C. Given that both CO_2 and $C\ell_2$ are nonpolar molecules with the same type of intermolecular forces, fully account for this difference in boiling point. (5)

[29]

QUESTION 5

5.1 Tendai prepares 0,6 dm^3 of a 0,25 $mol \cdot dm^{-3}$ standard solution of potassium hydroxide to titrate against a solution of hydrofluoric acid of unknown concentration. The reaction is represented by the following:

$$HF(aq) + KOH(aq) \rightarrow KF(aq) + H_2O(\ell)$$

5.1.1 Define *standard solution*. (1)

5.1.2 Calculate the mass of pure potassium hydroxide needed to prepare the standard solution. (4)

5.1.3 Solid KOH is hygroscopic, meaning it absorbs water from the atmosphere. How will this affect the ACTUAL concentration of the potassium hydroxide if the mass that you calculated in Question 5.1.2 is used? State only INCREASE, DECREASE, or REMAIN THE SAME. (2)

5.1.4 At some stage during the titration, the concentration of KOH in the flask was found to be $6,5 \times 10^{-3}$ $mol \cdot dm^{-3}$. Calculate the concentration of hydronium ions at this stage, if the temperature was 25 °C. (3)

5.1.5 Tendai chose phenolphthalein as the indicator for this titration. Phenolphthalein changes colour at a pH of approximately 9. Write the equation for the hydrolysis of the F^- ion, and briefly explain why this choice of indicator was suitable. (3)

5.2 Consider the following bases, together with their K_b values.

Ammonia, NH_3 $K_b = 1,8 \times 10^{-5}$
Pyridine, C_5H_5N $K_b = 1,8 \times 10^{-9}$
Carbonate, CO_3^{2-} $K_b = 2,1 \times 10^{-4}$

5.2.1 Of the three bases listed, which one is the strongest? (1)

5.2.2 Define a *base* in terms of the Lowry–Brønsted model. (1)

5.2.3 Define a *weak base*. (2)

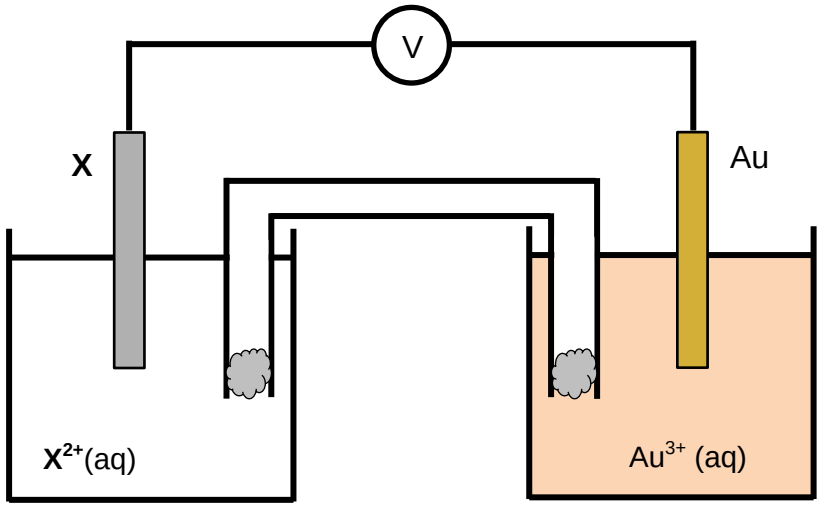
5.2.4 Write a balanced chemical equation for the ionisation of ammonia in water. (3)

[20]

QUESTION 6

Ufezile sets up the galvanic cell shown below, using a gold half-cell and a half-cell of unknown identity, **X**, under standard conditions.

Ufezile notes that solid **gold metal deposits on the gold electrode**.



6.1 Define *electrolyte*. (2)

6.2 Write the FORMULA of a suitable electrolyte that could be used in the Au half-cell solution. (2)

6.3 Which electrode, X or Au, is the anode? (1)

6.4 Write an equation for the reduction half-reaction. (2)

6.5 The initial reading of the voltmeter is 1,82 V.

6.5.1 Perform a calculation to determine the identity of **X**. (4)

6.5.2 Despite the large emf, it is not profitable to produce this cell for use in a commercial battery. Suggest ONE reason for this. (1)

6.6 Ufezile wants to use a standard hydrogen electrode to determine the standard electrode potential of the Au | Au^{3+} half-cell.

6.6.1 Describe the **standard hydrogen electrode** and briefly explain its role as the reference electrode. (4)

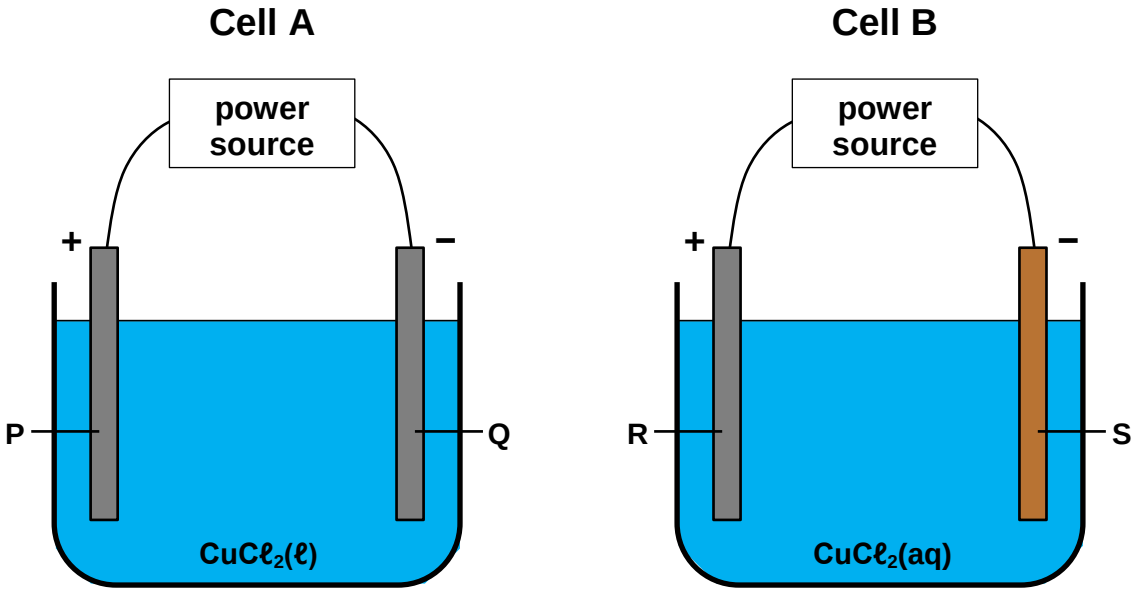
6.6.2 Write the cell notation for the cell that Ufezile would use to determine the standard electrode potential for the gold half-cell. Include phase indicators. (4)

[20]

QUESTION 7

Consider the two electrolytic cells, **Cell A** and **Cell B**, shown in the diagrams below. Electrodes **P**, **Q**, and **R** are made of graphite, and electrode **S** is made of copper.

The electrolyte in **Cell A** is MOLTEN copper(II) chloride, and the electrolyte in **Cell B** is **concentrated** AQUEOUS copper(II) chloride solution. The $CuC\ell_2$ solution is **BLUE**.



7.1 One of the reasons graphite is a suitable material for the electrodes in **Cell A** is that it has a very high melting point.

7.1.1 Why is it important for graphite to have a high melting point in **Cell A**? (1)

7.1.2 Provide TWO other reasons why graphite is a suitable material for the electrodes in **Cell A**. (2)

7.2 What energy conversion occurs in an electrolytic cell? (2)

7.3 Briefly explain why the copper(II) chloride must be in either molten or aqueous state. (2)

7.4 Consider **Cell A**.

7.4.1 Identify the cathode in **Cell A**. Write down only **P** or **Q**. (1)

7.4.2 Write an equation for the half-reaction occurring at electrode **P**. (2)

7.4.3 Write an equation for the half-reaction occurring at electrode **Q**. (2)

7.4.4 Identify the reducing agent in **Cell A**. (1)

7.5 What observation(s) will be made in the **electrolyte** solution around electrode **S** during the operation of **Cell B** after a significant amount of time has passed? Give a half-reaction to support your answer. (3)

7.6 At which electrodes will a gain in mass be observed? (2)

7.7 Andrew suggests a little concentrated sulfuric acid be added to the electrolyte solution in **Cell B** to improve conductivity.

7.7.1 What effect would a higher conductivity have in **Cell B**? (1)

7.7.2 Define *ionisation*. (2)

7.7.3 Explain why this addition of sulfuric acid would improve the conductivity of the solution. (2)

7.7.4 If too much sulfuric acid is added, HCℓ gas will be produced and escape from the solution:

$$H_2SO_4 + C\ell^- \rightarrow HSO_4^- + HC\ell(g)$$

How would this affect the likelihood of water being oxidised at electrode **R**? State only INCREASE, DECREASE, or NO EFFECT. (2)

[25]

QUESTION 8

In order to investigate the relationship between the molecular mass of various fluoroalkanes and their boiling point, Jerome collects the data shown in the table below.

Haloalkane	Molecular mass (u)	Boiling point (°C)
CH_3F	34	−78
C_2H_5F	48	−38
C_4H_9F	76	33
$C_5H_{11}F$	90	63

8.1 Identify the predominant intermolecular force in CH_3F. (1)

8.2 Is fluorobutane a GAS or a LIQUID at room temperature (25 °C)? (1)

8.3 Plot a graph of boiling point versus molecular mass for the given data on the axes provided on your ANSWER SHEET. Draw a **straight** line of best fit. (6)

8.4 Jerome wants to use the data he collected to determine the boiling point of C_3H_7F. USE THE GRAPH that you drew in Question 8.3 to determine the boiling point of C_3H_7F. Indicate clearly on your graph how you arrived at your answer. (2)

8.5 Jerome now wants to use the graph from Question 8.3 to predict the boiling point of chloromethane, $CH_3C\ell$.

8.5.1 Can Jerome use this graph (from Question 8.3) to accurately determine the boiling point of chloromethane? (1)

8.5.2 Briefly explain your answer. (2)

8.6 8.6.1 Define *structural isomers*. (2)

8.6.2 Draw the structural formulae for TWO structural isomers of C_3H_7F. (3)

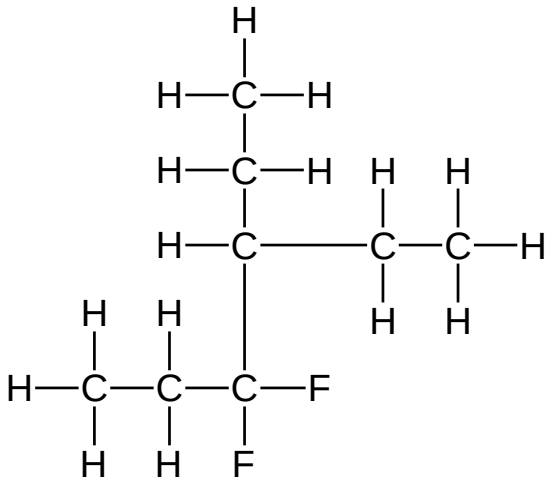
8.6.3 Identify the TYPE of structural isomers you have drawn. (1)

[19]

QUESTION 9

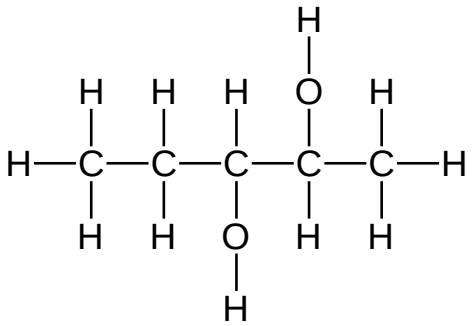
9.1 Write the IUPAC names for the following compounds.

9.1.1



(4)

9.1.2



(3)

9.1.3 $CH_3(CH_2)_4COOCH_3$ (2)

9.2 Use molecular formulae to write a balanced chemical equation for the complete combustion of propene. (4)

9.3 Use condensed-structural formulae to write a balanced chemical equation for the reaction between butane and bromine in the presence of UV light. (4)

PLEASE TURN OVER FOR QUESTION 9.4

9.4 Consider the three organic reactions, **A**, **B** and **C**, shown below:

A: $CH_3CH_2C\ell + KOH \rightarrow$ **X** $+ KC\ell$

B: $CH_2CH_2 + HC\ell \rightarrow$ **Y**

C: $C_{12}H_{26} \rightarrow C_9H_{20} +$ **Z**

9.4.1 Identify the GENERAL TYPE of reaction for **A**. (1)

9.4.2 Write the molecular formula for product **X**. (2)

9.4.3 Identify the SPECIFIC TYPE of reaction for **B**. (1)

9.4.4 Draw the structural formula for product **Y**. (2)

9.4.5 Identify the SPECIFIC TYPE of reaction for **C**. (1)

9.4.6 Define *hydrocarbon*. (2)

9.4.7 Identify the homologous series to which product **Z** belongs. (2)

9.4.8 What is the commercial significance of reaction **C**? Explain briefly. (2)

[30]

Total: 200 marks