NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2015

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).

2. Please make sure that your question paper is complete.

3. Remove the Data Booklet and Answer Sheet from the middle of this question paper. **Write your examination number on the yellow Answer Sheet.**

4. Read the questions carefully.

5. ALL of the questions in this paper must be answered.

6. Question 1 consists of 10 multiple-choice questions. There is only one correct answer to each question. The questions are answered on the Answer Sheet provided on the inside cover of your Answer Book. The letter that corresponds with your choice for 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 as correct.

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

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

9. Use the data and formulae whenever necessary.

10. Show all of the necessary steps in calculations.

11. Where appropriate, take your final answers to 2 decimal places, unless instructed otherwise.

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

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 which you consider to be correct.

1.1 The correct chemical formula for magnesium phosphate is:

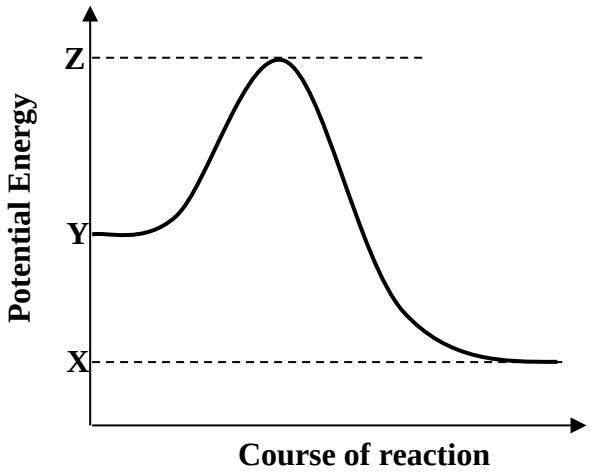
A $Mg(PO_4)_2$
B $Mg_2(PO_4)_3$
C $MgPO_4$
D $Mg_3(PO_4)_2$

1.2 Which one of the following statements represents the best explanation for the term 'electronegativity'?

A A measure of the tendency of an atom to attract a bonding pair of electrons.
B A measure of the tendency of an atom to attract an electron.
C A measure of the strength of a covalent bond.
D A measure of the strength of an ionic bond.

1.3 Consider the following energy profile graph. Potential energy values X, Y and Z are indicated on the graph. The activation energy for the forward reaction is given by:

A Z
B Z – Y
C Z – X
D X – Y



1.4 A base is defined as:

A a proton donor
B an electron donor
C a proton acceptor
D an electron acceptor

1.5 Which one of the following indicators is most suitable for use in the titration of sodium hydroxide with ethanoic acid?

	INDICATOR	pH RANGE OF INDICATOR
A	cresol blue	1,2 – 1,8
B	methyl orange	3,1 – 4,4
C	bromothymol blue	6,0 – 7,6
D	phenolphthalein	8,4 – 10,0

1.6 1 mole of $N_2O_4(g)$ was placed in an empty 1 dm^3 container and allowed to decompose at a certain temperature to form $NO_2(g)$. The container was then sealed. The reaction reached equilibrium according to the following balanced chemical equation:

$$\mathbf{N_2O_4(g) \rightleftharpoons 2NO_2(g)}$$

At equilibrium, x mole of $N_2O_4(g)$ had decomposed. What is the value of the equilibrium constant, K_c, assuming that the temperature remained constant?

A $\dfrac{2x}{(1-x)}$

B $\dfrac{2x}{(1-x)^2}$

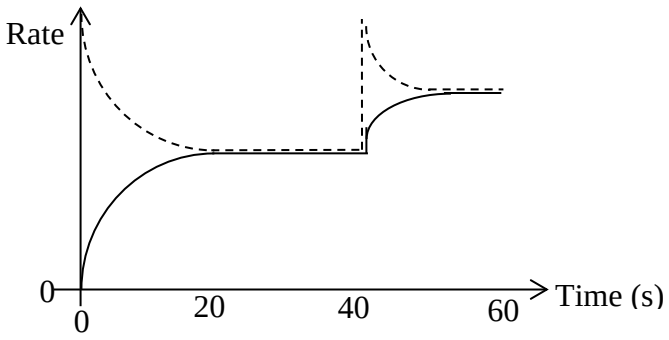
C $\dfrac{4x^2}{(1-x)^2}$

D $\dfrac{4x^2}{(1-x)}$

1.7 Nitrogen and hydrogen gas are introduced into a container, which is then sealed, and then allowed to reach equilibrium. The balanced chemical equation for the reaction is:

$$\mathbf{N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)} \qquad \mathbf{\Delta H < 0}$$

At t = 40 s, a change is made to the reaction in equilibrium. The graph below shows the changes in the **rates** of the forward and reverse reactions with time.



Which one of the following best describes the change made at t = 40 s?

A Increase in temperature
B Increase in pressure
C Decrease in temperature
D Decrease in pressure

1.8 Four tin (Sn) cans are each filled with a different solution as shown by the labels on the cans in the diagrams below. Each solution has a concentration of 1 mol·dm^{-3} at 25 °C. Which one of the tin cans will undergo oxidation?

A B C D

1.9 Which one of the following organic compounds will rapidly decolourise bromine water?

A CH_3CH_2COOH
B $CH_3CH_2CH_3$
C CH_2CHCH_3
D CH_3COOCH_3

1.10 The reaction of ethane with chlorine in the presence of ultra-violet light is given by the balanced chemical equation:

$$C_2H_6 + C\ell_2 \longrightarrow C_2H_5C\ell + HC\ell$$

Which one of the following describes the type of chemical reaction taking place?

A substitution
B addition
C elimination
D combustion

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QUESTION 2 CHEMICAL BONDING

2.1 Use only substances from the list below when answering Question 2.1.1 to 2.1.6. The state symbols (phase indicators) represent the physical state of each of the substances at room temperature.

SiO_2(s) HCℓ(g) H_2O(ℓ) PH_3(g) Mg(s) He(g) KF(s)

Select one substance from the list that has:
(Only write down the question number and the formula of the substance next to it.)

2.1.1 Pure covalent intramolecular bonds. (1)

2.1.2 A high melting point due to the strong electrostatic attraction between the cations and anions in the crystal lattice. (1)

2.1.3 Hydrogen bonding intermolecular forces. (1)

2.1.4 A very high melting point due to its giant covalent network structure. (1)

2.1.5 Delocalised valence electrons. (1)

2.1.6 Dipole – dipole intermolecular forces. (1)

2.2 Consider the table below, which shows the boiling point of the halogens.

Halogens	F_2	$C\ell_2$	Br_2	I_2
Boiling point (^oC)	-188	-35	59	184

2.2.1 Name the **specific** type of intramolecular bond that occurs between the atoms in a fluorine molecule. (2)

2.2.2 The table shows that the boiling point of the halogens increases from F_2 to I_2. Explain this trend by making reference to the relevant intermolecular force between the halogen molecules and the factor influencing its strength. (4)

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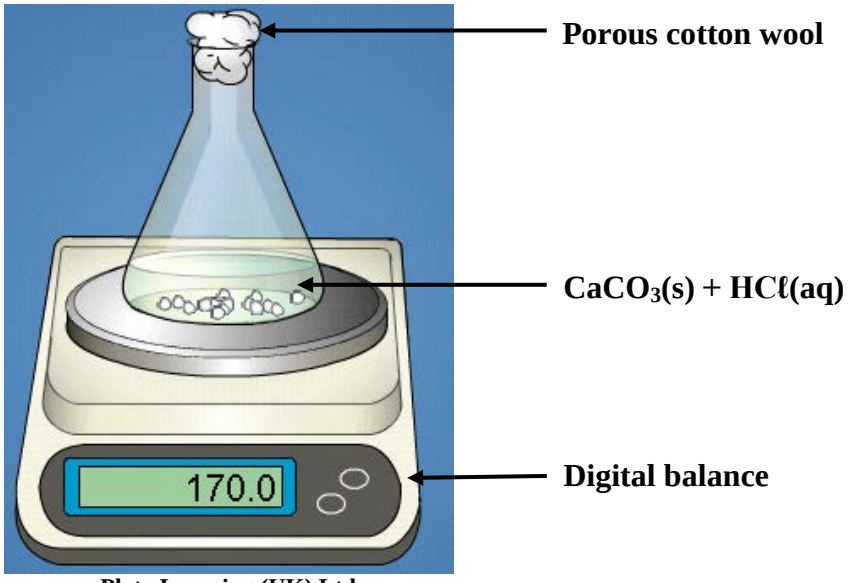
QUESTION 3 ENERGY CHANGE AND REACTION RATES

Mandy and Siya conduct a series of experiments to investigate the effect of changing temperature, concentration and surface area on the rate of reaction between hydrochloric acid and calcium carbonate. The balanced chemical equation for the reaction taking place is:

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

They carry out each experiment in a conical flask, which is placed on top of a sensitive digital balance as shown in the diagram below. They monitor the decrease in mass of the conical flask and its contents over a period of time.



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3.1 Mandy makes the following statement: *'The reason why the mass of the conical flask and its contents decreases over a period of time is because the reactants are being used up.'* Do you agree with Mandy? Explain your answer. (2)

Mandy and Siya carry out FOUR different experiments using the conditions indicated in the table below.

Experiment	**Temperature (^oC)**	**Concentration of HCℓ ($mol \cdot dm^{-3}$)**	**State of $CaCO_3$**
1	20	0,1	Large pieces
2	15	0,1	Large pieces
3	20	0,1	Powder
4	20	0,2	Large pieces

In each of their four experiments Mandy and Siya did the following:

- They used the same volume of hydrochloric acid.
- They used the same mass of calcium carbonate.
- They ensured the calcium carbonate was always in excess.
- They ensured the calcium carbonate was always fully covered by the acid.

The results of EXPERIMENT 1 were used to sketch the graph shown on your ANSWER SHEET.

3.2 On the same set of axes used to sketch the graph for Experiment 1, on your ANSWER SHEET, draw sketch graphs to represent the results of Experiments 2, 3 and 4. Use of a SHARP, DARK pencil for each graph is recommended. CLEARLY LABEL EACH GRAPH using the key indicated below.

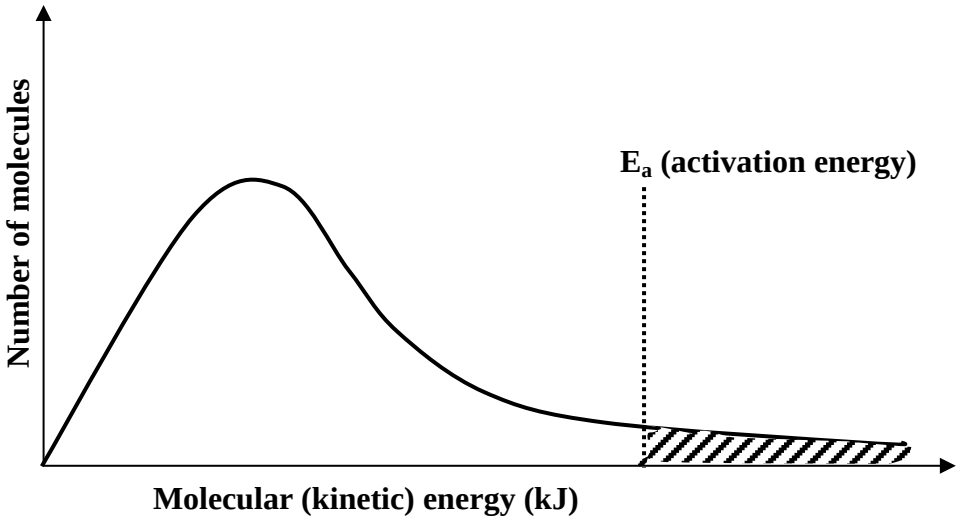
Experiment 2	Dashed line	- - - - - -
Experiment 3	Solid line	———
Experiment 4	Dash-dot line	- · - · - · -

(6)

3.3 Siya makes the following statement: *'At time X, the reaction taking place in the flask in Experiment 1 reaches dynamic chemical equilibrium, which explains why the graph levels out after time X.'*

Do you agree with Siya? Fully explain your answer and correct any error which you think Siya may have made. (3)

3.4 The Maxwell-Boltzmann curve below shows the distribution of molecular energies of reacting molecules in a chemical reaction at low temperature.



3.4.1 Define *activation energy.* (2)

3.4.2 State what is represented by the shaded area shown on the above graph. (2)

3.4.3 On the same set of axes used to draw the Maxwell-Boltzmann curve in Question 3.4, on your ANSWER SHEET, draw a new curve indicating the distribution of molecular energies at a **higher temperature**. Use of a SHARP, DARK pencil is recommended. (2)

3.4.4 Use the graph you have drawn in Question 3.4.3 to EXPLAIN the effect of an increase in temperature on reaction rate. (3)

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QUESTION 4 CHEMICAL EQUILIBRIUM

4.1 Nitric acid is prepared in industry by means of the Ostwald Process. The first step of this process involves the catalytic oxidation of ammonia as given by the balanced chemical equation below.

$$\mathbf{4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)}$$

In an experiment, a mixture of $NH_3(g)$, $O_2(g)$, NO(g) and $H_2O(g)$ is allowed to reach **dynamic chemical equilibrium** in a cylinder fitted with a movable piston.

4.1.1 State Le Chatelier's principle. (3)

4.1.2 State what is meant by **dynamic chemical equilibrium**. (2)

4.1.3 Whilst keeping the temperature constant, the pressure is increased by decreasing the volume of the cylinder. State the effect of this change on each of the following:
(Answer only INCREASES, DECREASES or NO EFFECT.)

(a) the rate of the forward reaction. (1)

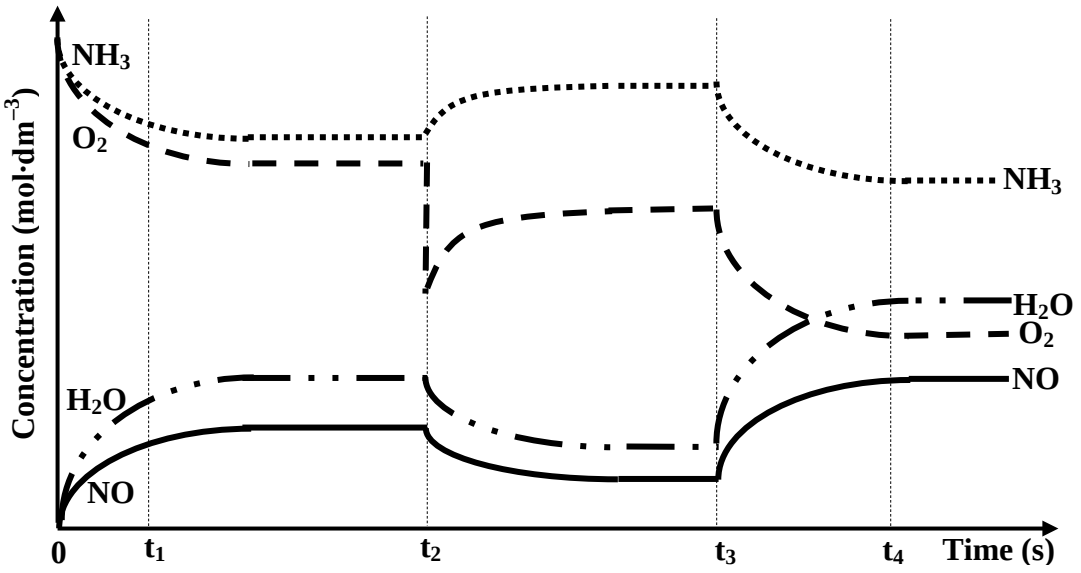
(b) the yield of NO(g) (1)

4.1.4 Apply Le Chatelier's principle to explain your answer to Question 4.1.3 (b). (3)

4.2 In a new experiment, ammonia gas and oxygen gas are introduced into a container at a certain temperature, which is then sealed and the reaction taking place reaches dynamic chemical equilibrium, according to the following balanced chemical equation:

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

The graph below shows the changes in the concentration of $NH_3(g)$, $O_2(g)$, NO(g) and $H_2O(g)$ with time.



4.2.1 If numerical values were given for concentration on the concentration-axis, would it be possible to calculate the equilibrium constant (K_c) for this reaction at time t_1? Explain your answer. (2)

4.2.2 Identify the change (stress) which was introduced to the reaction at time t_2 and explain the subsequent changes in the concentrations of all substances immediately after time t_2. (4)

4.2.3 At time t_3 the temperature in the container is decreased.

(a) Is the forward reaction exothermic or endothermic? (1)

(b) Consider the changes in concentration shown in the graph between time t_3 and t_4 and apply Le Chatelier's principle to explain your answer to Question 4.2.3 (a). (4)

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QUESTION 5 ACIDS AND BASES

5.1 Use only the compounds from the list below when answering Question 5.1.1 to 5.1.6. All the substances are in the aqueous (aq) phase.

H_3PO_4	**$HC\ell$**	**Li_2SO_4**	**NaOH**
CH_3COOH	**$MgSO_4$**	**K_2SO_3**	**NH_4OH**

Choose from this list a compound which is a:
(Only write down the question number and the formula of the compound next to it.)

5.1.1 Strong acid (1)

5.1.2 Strong base (1)

5.1.3 Weak monoprotic acid (1)

5.1.4 Polyprotic acid (1)

5.1.5 Neutral salt (1)

5.1.6 Basic salt (1)

5.2 Consider the hydrolysis of NH_4NO_3 in water as represented by the balanced chemical equations below:

$$\mathbf{NH_4NO_3(s) \rightleftharpoons NH_4^+(aq) + NO_3^-(aq)}$$

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

With reference to the above equations, explain why an aqueous solution of the salt NH_4NO_3 would be weakly acidic. (4)

5.3 Consider the balanced chemical equations (i) and (ii) and equilibrium constants (K_a) for the ionisation of acid HF and HI in water respectively, at 25 °C, as given below.

(i) $\mathbf{HF(g) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + F^-(aq) \quad K_a = 6{,}6 \times 10^{-4}}$

(ii) $\mathbf{HI(g) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + I^-(aq) \quad K_a = 3{,}2 \times 10^{9}}$

5.3.1 Define a *strong acid.* (2)

5.3.2 Which acid is stronger, HF or HI? Justify your choice. (3)

5.3.3 Which acid would be a better electrical conductor, HF or HI? Explain your answer. Assume the concentration of both acids is the same. (2)

5.3.4 Reaction (ii) reaches equilibrium. A soluble salt containing I^- ions is then added to it. Apply Le Chatelier's principle to deduce how each of the following will be affected:
(Answer only INCREASES, DECREASES or NO EFFECT.)

(a) Concentration of H_3O^+ ions. (1)

(b) pH (1)

(c) Concentration of OH^- ions. (1)

5.3.5 The concentration of hydronium ions (H_3O^+) in a solution of **hydrofluoric acid (HF)** at equilibrium at 25 °C is 0,02 mol·dm^{-3}.

(a) Calculate the concentration of hydroxide ions (OH^-) in the solution of hydrofluoric acid (HF) at 25 °C. (3)

(b) Write down the expression for the equilibrium constant (K_a) for reaction (i). (2)

(c) Calculate the concentration of un-ionised hydrofluoric acid (HF) in the solution at 25 °C. (3)

5.4 11,2 g of an impure sample of potassium hydroxide pellets reacts with 600 cm^3 of 0,15 mol.dm^{-3} sulphuric acid. Assume that H_2SO_4 ionises completely. They react according to the balanced chemical equation given below:

$$\mathbf{H_2SO_4(aq) + 2KOH(s) \longrightarrow K_2SO_4(aq) + 2H_2O(\ell)}$$

5.4.1 Calculate the number of moles of sulphuric acid that are available to react. (3)

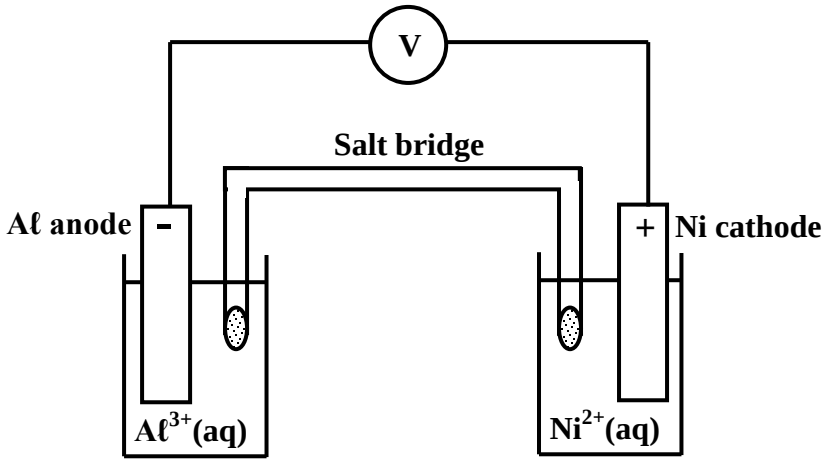
5.4.2 The percentage purity of the potassium hydroxide pellets used is 80%. Calculate the number of moles of pure potassium hydroxide that react with the acid. (4)

5.4.3 Determine which reactant is in excess and hence state whether the final solution is acidic, basic or neutral. (3)

[38]

QUESTION 6 GALVANIC CELL

A galvanic cell is set up under standard conditions using aluminium and nickel electrodes as shown in the diagram below.



Net cell reaction: $2A\ell(s) + 3Ni^{2+}(aq) \longrightarrow 2A\ell^{3+}(aq) + 3Ni(s)$

6.1 State the energy conversion that takes place in this cell. (2)

6.2 Write down the cell notation for this cell. (Standard conditions need not be shown.) (3)

6.3 Define:

6.3.1 *Oxidation.* (1)
6.3.2 *Oxidising agent.* (1)

6.4 Give the symbol of the oxidising agent in this cell. (1)

6.5 Calculate the initial emf of this cell under standard conditions. (2)

6.6 State how each of the following changes affect the emf of this cell:
(Answer only INCREASES, DECREASES or NO EFFECT.)

6.6.1 A soluble salt containing $A\ell^{3+}$ ions is added to the anode half-cell. (1)

6.6.2 The galvanic cell approaches chemical equilibrium. (1)

6.7 The salt bridge is replaced by one which is wider, shorter and more conductive than that shown in the diagram. State how each of the following will be affected by this change:
(Answer only INCREASES, DECREASES or NO EFFECT.)

6.7.1 The emf. (1)

6.7.2 The internal resistance. (1)

6.7.3 The ability of the cell to deliver current. (1)

6.8 After the cell has been operating for a period of time, the gain in mass at the nickel cathode is 1,77 g.

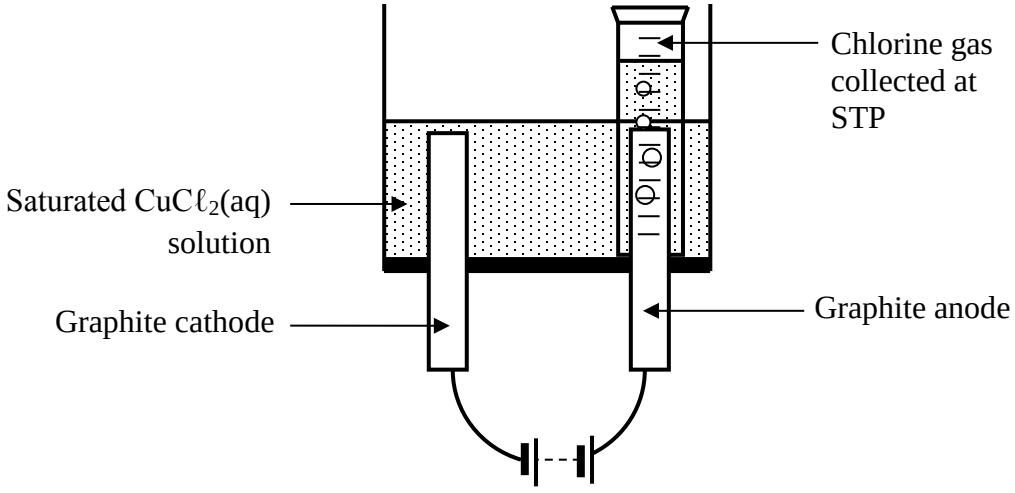
6.8.1 Calculate the number of moles of nickel which have been deposited at the cathode. (2)

6.8.2 Calculate the subsequent loss in mass at the aluminium anode. (3)

[20]

QUESTION 7 ELECTROLYSIS

7.1 Jabulani and Jane conduct a series of small-scale experiments in the laboratory to determine the relationship between the current that passes through a saturated $CuC\ell_2(aq)$ solution and the volume of chlorine gas collected at STP. Each experiment is conducted over the same period of time using the same volume of the same saturated $CuC\ell_2(aq)$ solution. They use the apparatus as shown in the diagram below.



7.1.1 Name the solute that is used to make the saturated $CuC\ell_2(aq)$ solution. (1)

7.1.2 Name the solvent that is used to make the saturated $CuC\ell_2(aq)$ solution. (1)

7.1.3 Name the **specific type** of forces of attraction between the solute and solvent particles in the aqueous solution of copper(II)chloride ($CuC\ell_2$). (2)

7.1.4 Write down an equation to show the half-reaction taking place at the

(a) anode (2)

(b) cathode (2)

The results of the experiments conducted by Jabulani and Jane are tabulated below.

	Current passed through the saturated $CuC\ell_2(aq)$ solution (A)	**Volume of chlorine gas collected at STP (cm^3)**
Experiment 1	0,2	14,0
Experiment 2	0,5	34,8
Experiment 3	0,8	58,0
Experiment 4	1,2	82,8
Experiment 5	1,5	102,0
Experiment 6	2,0	139,3

7.1.5 Plot a best fit line graph on the graph paper provided on your ANSWER SHEET to show the relationship between the current passed through the saturated $CuC\ell_2(aq)$ solution and the volume of chlorine gas collected at STP. (7)

7.1.6 State a suitable conclusion for this experiment. (2)

7.1.7 Calculate the gradient of your graph, including suitable units in your answer. (3)

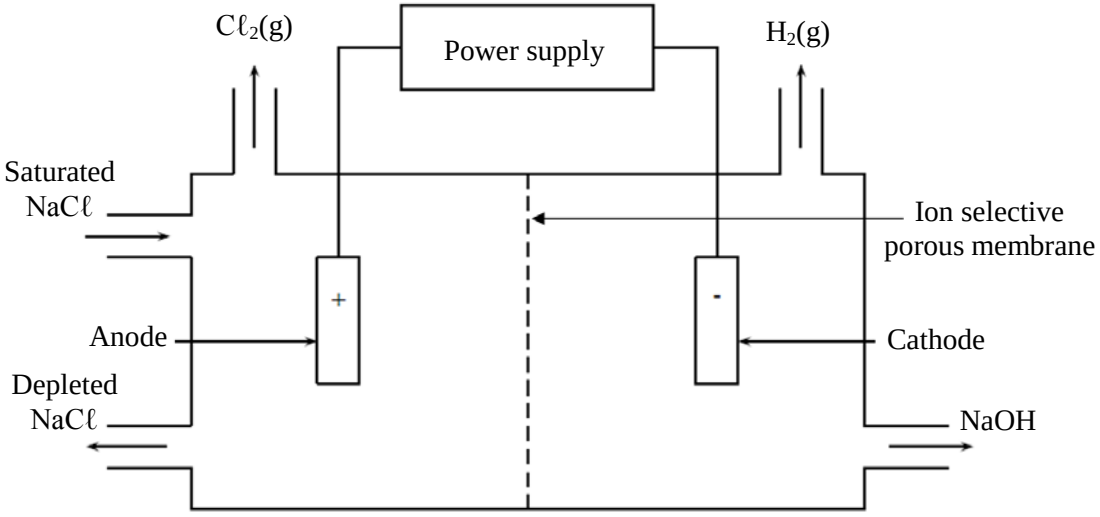
7.1.8 Calculate the volume of chlorine gas collected at STP if a current of 25 A is passed through the same volume of the same saturated $CuC\ell_2(aq)$ solution used in the experiments for the same period of time. (2)

7.1.9 The volume of chlorine gas collected at STP when a current of **2,0 A** was passed through the saturated $CuC\ell_2(aq)$ solution was **139,3 cm^3** as shown in the table.

(a) Calculate the number of moles of chlorine in 139,3 cm^3 of chlorine gas at STP. Round off your answer to 4 decimal places. (2)

(b) Calculate the time taken to collect 139,3 cm^3 of chlorine gas at STP. (5)

7.2 Chlorine gas is produced on a large scale in industry by the electrolysis of a saturated solution of sodium chloride. The diagram below shows the membrane cell used in the chlor-alkali process.



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7.2.1 Write down an equation for the half-reaction taking place at the cathode. (2)

7.2.2 Explain why sodium is not produced at the cathode. (2)

7.2.3 Give ONE reason why it is necessary to separate the products of the reactions taking place at the electrodes. (2)

[35]

QUESTION 8 ORGANIC CHEMISTRY

Consider the information given in the table below before answering the questions that follow.

Compound	Name	Molecular formula	Molar mass ($g \cdot mol^{-1}$)	Boiling point (^oC)
X	2,3-dimethylbutane	C_6H_{14}	86	57,9
Y	Methyl propanoate	$C_4H_8O_2$	88	79,8
Z	Pentan-1-ol	$C_5H_{12}O$	88	138,5

8.1 Define *homologous series.* (3)

8.2 Name the homologous series to which compound **X** belongs. (1)

8.3 Draw the structural formula of compound **Y**. (2)

8.4 Give the IUPAC name of the organic reactants needed to make compound **Y**. (2)

8.5 Identify the functional group of compound **Z**. (1)

8.6 Which one of compounds **X**, **Y** or **Z** can be classified as a saturated hydrocarbon? (1)

8.7 Compound **Z** is dehydrated using heat and an acid catalyst.

8.7.1 Use condensed structural formulae to write a balanced chemical equation for the dehydration of compound **Z**. It is not necessary to show heat and the acid catalyst in your equation. (3)

8.7.2 Give the IUPAC name of the organic product formed in Question 8.7. (2)

8.7.3 State what type of reaction the dehydration of pentan-1-ol is. (1)

8.8 Write a balanced equation, using molecular formulae, for the complete combustion of compound **X**. (4)

8.9 Structural isomers of organic compounds can exist as chain isomers, functional isomers and positional isomers.

8.9.1 Define the term *isomers*. (2)

8.9.2 Give the IUPAC name of a straight **chain** isomer of compound **X**. (2)

8.9.3 Give the IUPAC name of a **functional** isomer of compound **Y**. (2)

8.9.4 DRAW the structural formula of a **positional** isomer of compound **Z**. (2)

8.10 Although compounds **X**, **Y** and **Z** have similar molar masses, they have significantly different boiling points. With reference to the relevant intermolecular forces, explain this difference in boiling points. (6)

[34]

Total: 200 marks