NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2017

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 19 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 of the questions in this paper must be answered.

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 of 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 own 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 representing the answer that you consider to be the most correct.

1.1 The chemical formula for aluminium hydrogen sulphate is:

A $A\ell(HSO_4)_3$
B $A\ell_3H_2SO_4$
C $A\ell_2(HSO_4)_3$
D $A\ell_2H_2(SO_4)_3$

1.2 Which one of the following gives the number of methane molecules in 12 g of $CH_4(g)$?

A $\frac{16 \times 6,02 \times 10^{23}}{12}$

B $\frac{12}{16 \times 6,02 \times 10^{23}}$

C $\frac{16}{12 \times 6,02 \times 10^{23}}$

D $\frac{12 \times 6,02 \times 10^{23}}{16}$

1.3 A violet coloured solution is prepared by dissolving cobalt chloride crystals in a mixture of ethanol and water. This violet colour is due to two different coloured cobalt (II) complex ions existing together in equilibrium in the solution as shown in the balanced chemical equation:

$$\underset{\text{BLUE}}{\mathbf{CoC\ell_4^{2-}}} + \mathbf{6H_2O} \rightleftharpoons \underset{\text{PINK}}{\mathbf{Co(H_2O)_6^{2+}}} + \mathbf{4C\ell^-} \qquad \mathbf{\Delta H < 0}$$

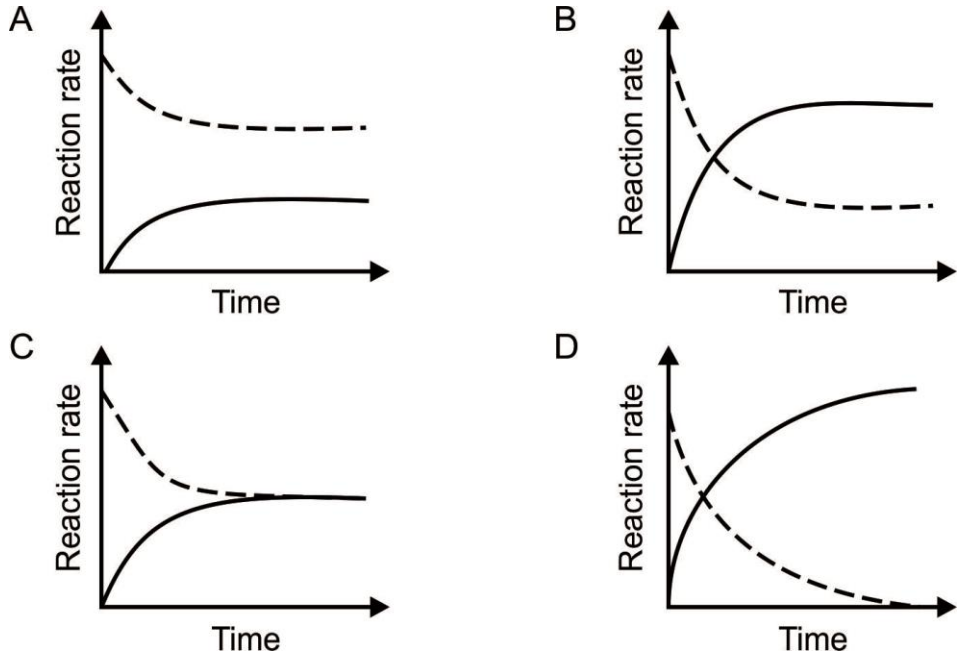
What colour change will be observed when a few drops of concentrated $HC\ell$ are added to 1 cm^3 of the violet solution?

A The solution turns colourless
B The solution turns blue
C The solution turns pink
D No colour change

1.4 Hydrogen gas and iodine gas are introduced into a flask, which is then sealed and allowed to reach dynamic chemical equilibrium. The balanced chemical equation for the reaction is:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

Which one of the following graphs shows how the rates of the forward and reverse reactions change with time?



1.5 Which one of the following gives the approximate pH of an aqueous solution of ammonium chloride and the relevant hydrolysis equation?

	pH	**Hydrolysis equation**
A	Greater than 7	$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$
B	Less than 7	$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$
C	Greater than 7	$C\ell^- + H_2O \rightleftharpoons HC\ell + OH^-$
D	Less than 7	$C\ell^- + H_2O \rightleftharpoons HC\ell + OH^-$

1.6 A table of acid-base indicators and the pH ranges over which they change colour is shown below. Which one of these indicators is most suitable for use in the titration of hydrochloric acid with sodium hydroxide?

	Indicator	**pH range**
A	Bromophenol blue	3,0–4,6
B	Litmus	4,5–8,3
C	Bromothymol blue	6,0–7,6
D	Cresolphthalein	8,2–9,8

1.7 Which one of the following redox reactions is NON-SPONTANEOUS under standard conditions?

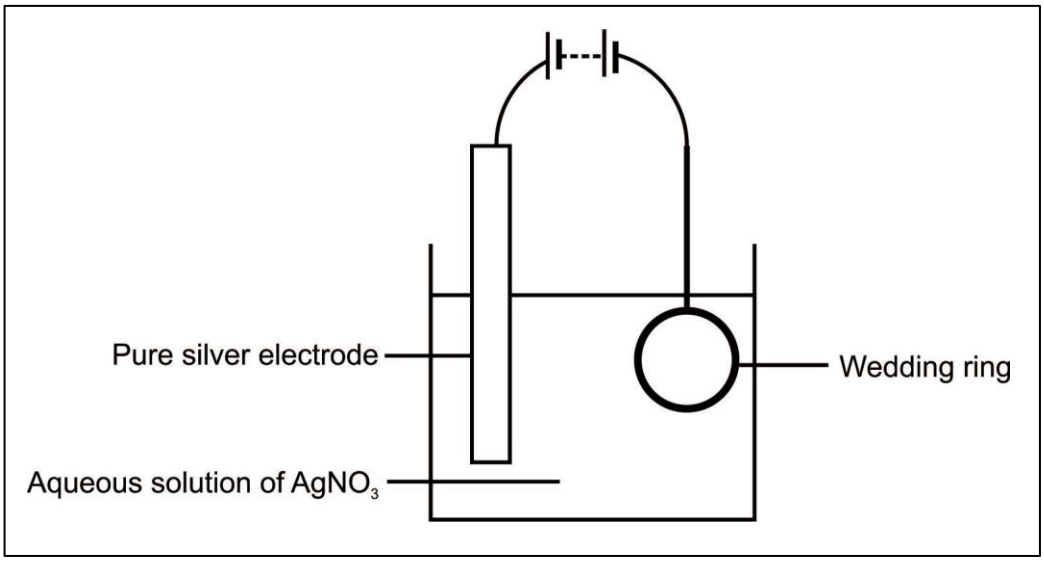
A $2I^-(aq) + 2Ag^+(aq) \longrightarrow I_2(s) + 2Ag(s)$

B $Pb^{2+}(aq) + Cu(aq) \longrightarrow Cu^{2+}(aq) + Pb(s)$

C $Pb^{2+}(aq) + Ni(s) \longrightarrow Pb(s) + Ni^{2+}(aq)$

D $2Ag(s) + C\ell_2(g) \longrightarrow 2C\ell^-(aq) + 2Ag^+(aq)$

1.8 The diagram below represents a cell used in the electroplating of a wedding ring with silver metal.



How does the mass of the pure silver electrode and the concentration of the $AgNO_3$ electrolyte change during electrolysis?

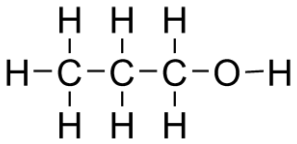
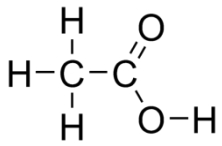
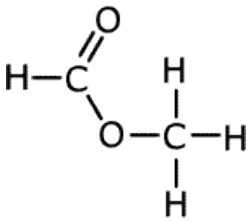
	Mass of silver electrode	**Concentration of $AgNO_3$ electrolyte**
A	Decreases	Increases
B	Increases	No change
C	Decreases	No change
D	Increases	Decreases

1.9 Which of the following statements would apply to organic compounds that belong to the same homologous series?

I They have the same boiling points.
II They have the same functional group.
III They have the same molecular formula.

A II only
B I and II only
C II and III only
D I, II and III

1.10 The organic compounds shown in the table below all have the same molar mass (60 g·mol^{-1}).

	Structural formula of compound	**Boiling point (^{o}C)**
X		97
Y		?
Z		32

Which one of the following is most likely to be the boiling point (in °C) of compound **Y**?

A 24
B 40
C 90
D 118

[20]

QUESTION 2 CHEMICAL BONDING

2.1 Define a *covalent bond.* (2)

2.2 State the difference between a non-polar covalent bond and a polar covalent bond. (2)

2.3 The following table contains eight substances.

graphite	**hydrogen fluoride**	**aluminium oxide**	**argon**
chlorine	**hydrogen chloride**	**magnesium**	**hydrogen**

Select substances from this table when answering each of the following questions.

Identify:

2.3.1 a molecular substance with non-polar covalent bonds. (1)

2.3.2 a molecular substance with polar covalent bonds. (1)

2.3.3 a substance with ionic bonding. (1)

2.3.4 a substance which has hydrogen bonding intermolecular forces. (1)

2.3.5 a different substance to that given in Question 2.3.4 which has dipole-dipole intermolecular forces. (1)

2.3.6 a substance which has London forces between its atoms. (1)

2.3.7 a substance which consists of positive atomic kernels surrounded by a sea of delocalised electrons. (1)

2.3.8 a substance which has a giant network structure in which the atoms are held together by covalent bonds. (1)

[12]

QUESTION 3 ENERGY CHANGE

Ammonia is prepared in industry by means of the Haber process. The balanced chemical equation for the reaction is given below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92{,}4\ kJ{\cdot}mol^{-1}$$

The activation energy for this reaction is 242,6 $kJ{\cdot}mol^{-1}$.

3.1 Define the following terms:

3.1.1 *Activation energy.* (2)

3.1.2 *Catalyst.* (2)

3.2 Calculate the activation energy for the **REVERSE** reaction. (2)

3.3 A learner incorrectly states:

"A catalyst lowers the activation energy which results in more collisions taking place per second."

Explain why this statement is incorrect. (2)

3.4 The following table shows two catalysts that can be used for this reaction and their corresponding activation energies.

Catalyst	**Activation energy ($kJ{\cdot}mol^{-1}$)**
Platinum catalyst	70,6
Osmium catalyst	104,6

Which catalyst, platinum or osmium, will be most effective for this reaction? Explain. (4)

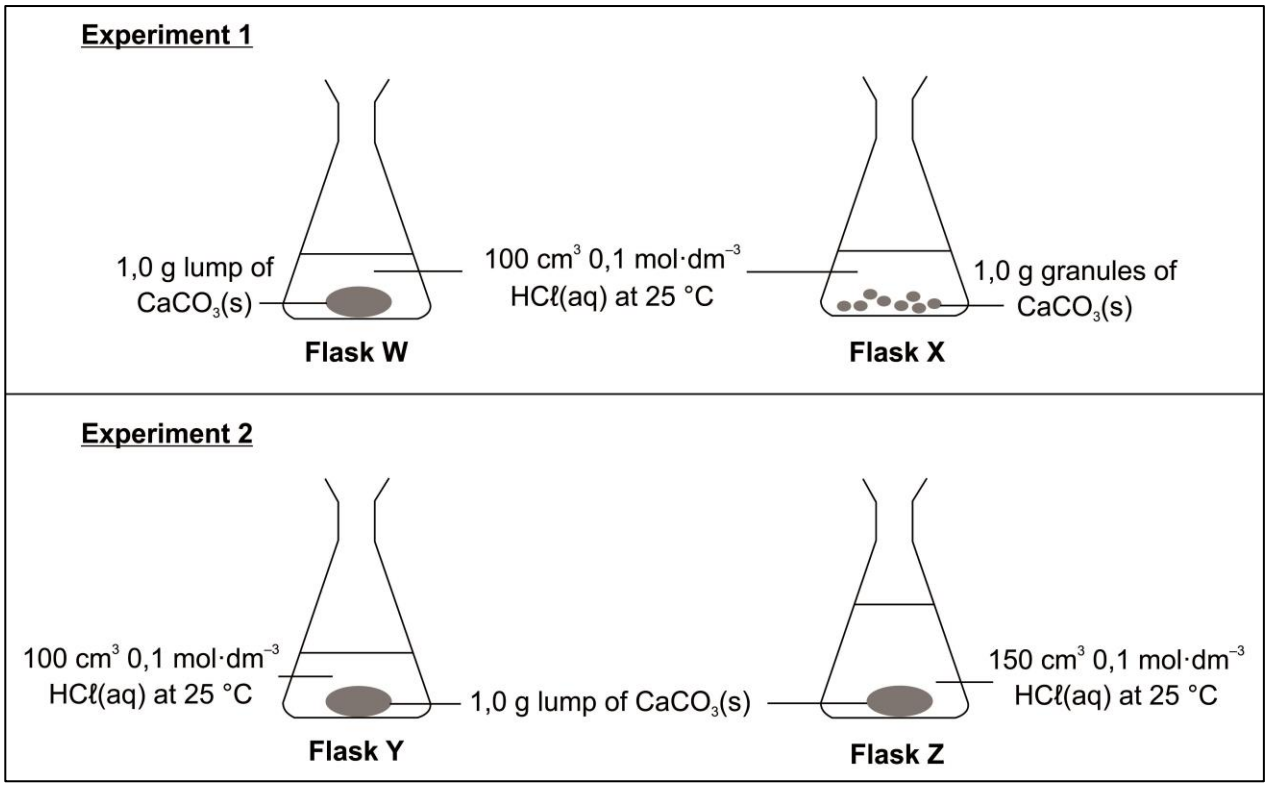
[12]

QUESTION 4 RATES OF REACTION

Two experiments were conducted to investigate the rate of reaction between **EXCESS** calcium carbonate and dilute hydrochloric acid. The balanced chemical equation for the reaction is given below.

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

The diagrams show the reaction conditions used in each experiment.



4.1 Suggest a suitable method of measuring the rates of the reactions in these experiments. Additional apparatus besides that shown in the diagrams may be used. State what apparatus is required and what reading(s) would need to be taken. (3)

4.2 Identify the independent variable in **Experiment 1**. (1)

4.3 In **Experiment 1**, in which flask, **W** or **X**, will the reaction rate be faster? Explain fully. (4)

4.4 Calculate the volume of $CO_2(g)$ produced at STP in flask **W**. (5)

4.5 Consider the reaction conditions given for **Experiment 2**.

4.5.1 How will the rate of reaction in flask **Z** compare to that in flask **Y**? Choose from **GREATER THAN Y**, **LESS THAN Y or EQUAL TO Y**. (1)

4.5.2 It is observed that the total volume of gas produced in flask **Z** is greater than that produced in flask **Y**. Account for this observation. (2)

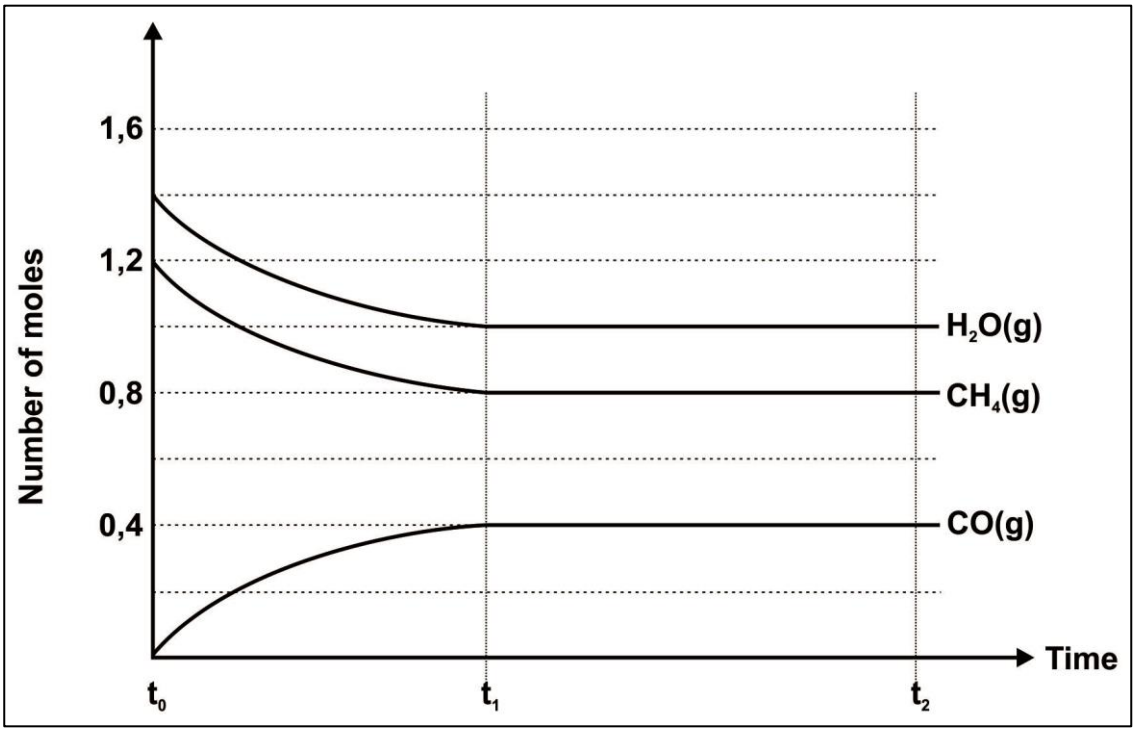
[16]

QUESTION 5 CHEMICAL EQUILIBRIUM

The hydrogen gas used in the Haber process is prepared by the reaction of methane and steam as shown in the following balanced chemical equation.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206\ kJ$$

Initially 1,2 moles of methane and 1,4 moles of steam are placed in a closed container. They react and then dynamic chemical equilibrium is reached at a fixed temperature. The following graph shows the changes in the number of moles of methane, steam and carbon monoxide as the reaction proceeds.



5.1 State why there is no change in the number of moles of each of the gases between times t_1 and t_2. (2)

5.2 The above graph has been reproduced on your ANSWER SHEET.
On the graph on your ANSWER SHEET:

5.2.1 Draw a line to show the change in the number of moles of hydrogen gas between t_0 and t_2. **Label this line $H_2(g)$**. (3)

5.2.2 Draw a **dashed line** (- - -) to show how the number of moles of methane gas would change with time if a catalyst had been added to the container at time t_0. (2)

5.3 Calculate the value of the equilibrium constant, K_c, at the fixed temperature used in this reaction. The volume of the container is 2 dm^3. (6)

5.4 What does the K_c value indicate about the yield of products? (1)

5.5 State *Le Chatelier's principle*. (2)

5.6 How will an increase in pressure affect the yield of hydrogen? Explain. (3)

5.7 How will an increase in pressure affect the equilibrium constant, K_c, for this reaction?

Choose from **INCREASES**, **DECREASES or NO CHANGE**. (1)

5.8 This reaction is carried out in industry at a temperature of 1 000 °C. State TWO reasons why high temperatures are an advantage. No explanations are required. (2)

[22]

QUESTION 6 EXPERIMENTAL SKILLS AND THE AUTO-IONISATION OF WATER

The balanced chemical equation for the auto-ionisation (autoprotolysis) of water is given below.

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

The table below gives the variation of the equilibrium constant of water, K_w, and the concentration of hydronium ions, $[H_3O^+]$, with temperature (**T**).

T (^oC)	K_w ($\times 10^{-14}$)	$[H_3O^+]$ ($\times 10^{-7}$) (mol·dm^{-3})
0	0,114	0,34
10	0,293	0,54
20	0,681	0,83
30	1,47	1,21
40		1,71
50	5,48	2,34

6.1 Calculate the value of K_w at 40 ^oC. (2)

6.2 Is the auto-ionisation (autoprotolysis) of water EXOTHERMIC or ENDOTHERMIC? Explain. (3)

6.3 Use the GRAPH PAPER PROVIDED ON YOUR ANSWER SHEET to plot a graph of concentration of hydronium ions versus temperature. Draw the line of best fit. (6)

6.4 Use your graph to determine the concentration of hydronium ions, $[H_3O^+]$ at a temperature of 45 ^oC. (Indicate clearly on your graph how you achieved your answer.) (2)

6.5 A learner draws the following conclusion from the graph:

"The concentration of hydronium ions, $[H_3O^+]$ is directly proportional to the temperature of the water."

Give TWO features of the graph which do NOT support this relationship. (2)

6.6 A small amount of NaOH is now added to the water at 25 °C.
How will this affect the:

6.6.1 K_w? (1)

6.6.2 $[H_3O^+]$? (1)

Choose from **INCREASES**, **DECREASES or REMAINS THE SAME**.

6.7 How will the pH of pure water be affected by increasing the temperature of the water?

Choose from **INCREASES**, **DECREASES or NO CHANGE**. (1)

[18]

QUESTION 7 ACIDS & BASES

7.1 Define an *acid*. (1)

7.2 State the difference between a concentrated acid and a strong acid. (2)

7.3 0,1 mol·dm^{-3} aqueous solutions of the following compounds are prepared.

HNO_3 **H_2SO_4** **KCℓ** **$NaHCO_3$**

H_3PO_4 **LiOH** **HCOOH**

Choose from this list a:

7.3.1 Strong base. (1)

7.3.2 Weak polyprotic acid. (1)

7.3.3 Strong monoprotic acid. (1)

7.3.4 Weak monoprotic acid. (1)

7.3.5 Solution with a pH of approximately 8,5. (1)

7.4 Write a balanced chemical equation to show the ionisation of sulphuric acid in water. (3)

7.5 Katie is given the task of determining the percentage of magnesium oxide in a health tablet. She dissolves the tablet in 0,05 dm^3 of 0,8 mol·dm^{-3} hydrochloric acid.

7.5.1 Calculate the number of moles of acid present in 0,05 dm^3 of 0,8 mol·dm^{-3} hydrochloric acid solution. (3)

All of the magnesium oxide in the tablet reacts with the hydrochloric acid as shown in the balanced chemical equation below.

$$\mathbf{MgO(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)}$$

Not all of the hydrochloric acid reacts. Katie titrates the excess hydrochloric acid with a solution of sodium hydroxide. It takes 0,02 dm^3 of 0,5 mol·dm^{-3} sodium hydroxide to neutralise the excess hydrochloric acid. The hydrochloric acid and sodium hydroxide react as shown in the balanced chemical equation below.

$$\mathbf{NaOH(aq) + HC\ell(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)}$$

7.5.2 The original mass of the tablet is 0,96 g. Calculate the percentage of magnesium oxide in the tablet. (7)

[21]

QUESTION 8 GALVANIC CELLS

Ayanda and Zoe are given three unknown half-cells I, II and III. The half-reaction taking place in each half-cell is given below.

Half-cell I $X^{2+}(aq) + 2e^- \rightleftharpoons X(s)$

Half-cell II $Y^{3+}(aq) + 3e^- \rightleftharpoons Y(s)$

Half-cell III $Z^{+}(aq) + e^- \rightleftharpoons Z(s)$

Ayanda and Zoe connect half-cell I to half-cell II under standard conditions and record the cell potential (E^{o}_{cell}) as well as the metal electrode that acted as the anode. They then connect half-cell I to half-cell III under standard conditions and again record the cell potential (E^{o}_{cell}) as well as the metal electrode that acted as the anode.

The results for the two half-cell combinations are given in the table below.

Cell	Combination	E^{o}_{cell} (V)	Anode
A	Half-cell I + Half-cell II	0,84	X
B	Half-cell I + Half-cell III	0,68	Z

8.1 Define the following terms:

8.1.1 *Anode.* (2)

8.1.2 *Reducing agent.* (1)

8.2 State the energy conversion that takes place in these cells. (1)

8.3 State the standard conditions under which these cells operate. (2)

8.4 Write down the balanced chemical equation for the reaction taking place in **Cell A**. (3)

8.5 Write down the symbol of the oxidising agent in **Cell A**. (1)

8.6 Write down the cell notation for **Cell B**. Standard conditions and state symbols do not need to be shown. (3)

8.7 Give the symbol of the chemical species that is reduced in **Cell B**. (1)

8.8 8.8.1 Which metal, **X**, **Y** or **Z** is the strongest reducing agent? (1)

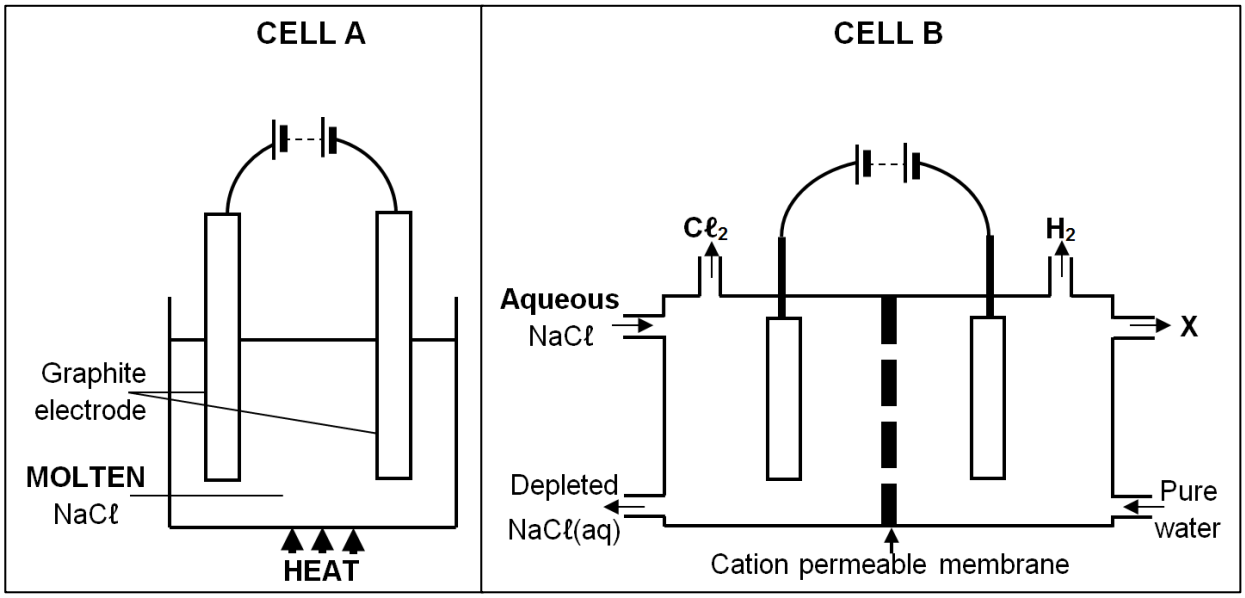
8.8.2 Which metal, **X**, **Y** or **Z** is the weakest reducing agent? (1)

8.9 Ayanda and Zoe now connect half-cell II to half-cell III, under standard conditions, to make **Cell C**. Calculate the cell potential (E^{o}_{cell}) of **Cell C**. Show all workings. (3)

[19]

QUESTION 9 ELECTROLYTIC CELL

Kamo sets up TWO different cells for the electrolysis of sodium chloride as shown in the diagrams below.



9.1 Explain why Kamo had to either melt or dissolve the solid sodium chloride in order to electrolyse it in each of the respective cells. (2)

9.2 Give TWO reasons why **graphite** electrodes are suitable in Cell **A**. (2)

9.3 Write down the equation for the half-reaction taking place at the:

9.3.1 Anode in Cell **A**. (2)

9.3.2 Cathode in Cell **A**. (2)

9.3.3 Cathode in Cell **B**. (2)

9.4 Give the symbol of the ions which pass through the membrane in Cell **B**. (1)

9.5 Identify product **X** in Cell **B**. (1)

Kamo carries out an investigation to determine how the concentration of the NaCℓ solution used in Cell **B** affects the purity of the chlorine gas produced at the anode. She records her observations in the table below.

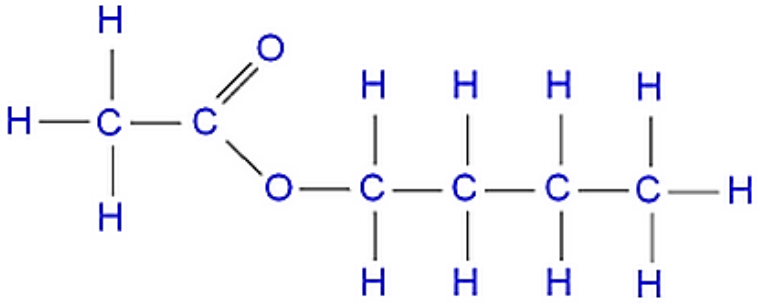
Concentration of NaCℓ(aq)	Purity of chlorine gas
HIGH (saturated solution)	Fairly pure, low contamination with oxygen gas.
LOW (dilute solution)	Impure, high contamination with oxygen gas.

9.6 Explain why the chlorine gas produced from a dilute solution of NaCℓ was highly contaminated with oxygen gas compared to that from the saturated NaCℓ solution. Write down an equation for a suitable half-reaction which supports your answer. (4)

[16]

QUESTION 10 ORGANIC CHEMISTRY (1)

10.1 The structural formula of an organic compound found in pears, raspberries and pineapples is given below.



10.1.1 Name the homologous series to which this compound belongs. (1)

10.1.2 Give the IUPAC name of this compound. (2)

10.1.3 Give the IUPAC name of the organic acid used to make this compound. (2)

10.1.4 Write a balanced chemical equation, using molecular formulae, for the complete combustion of this compound. (3)

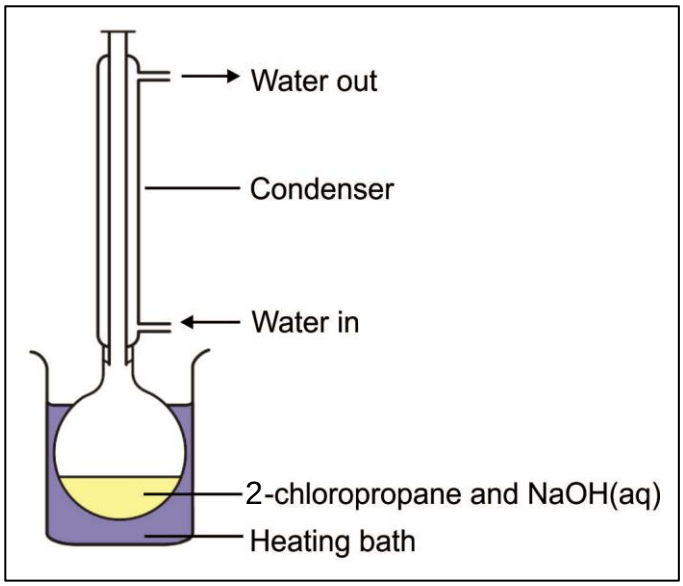
10.1.5 Define the term *isomers.* (2)

10.1.6 Give the IUPAC name of a:

(a) positional isomer of this compound. (2)

(b) functional isomer of this compound. (2)

10.2 2-chloropropane is heated under reflux with an aqueous solution of sodium hydroxide as shown in the diagram.



10.2.1 Name the type of reaction taking place between 2-chloropropane and aqueous sodium hydroxide. (1)

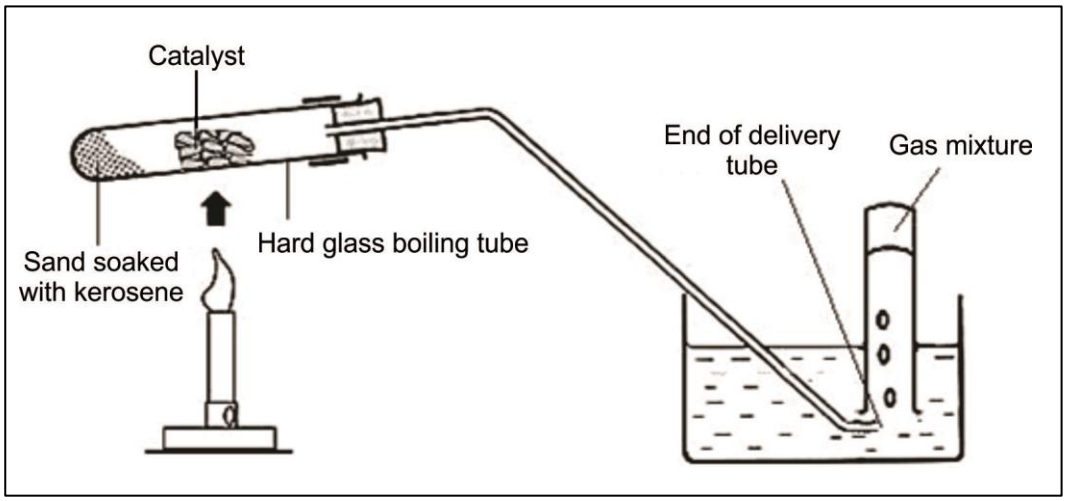
10.2.2 Using condensed structural formulae, write a balanced chemical equation for this reaction. (5)

10.2.3 A second reaction using 2-chloropropane and sodium hydroxide was done. This time the NaOH was dissolved in ethanol and the mixture was heated strongly. Give the structural formula of the organic product of this reaction. (2)

[22]

QUESTION 11 ORGANIC CHEMISTRY (2)

Kerosene is a mixture of a number of long chain saturated hydrocarbons. When kerosene is strongly heated in the presence of a hot catalyst, it decomposes to produce a gaseous mixture of butane, ethene and other short chain hydrocarbons. The gas mixture produced can be collected in the laboratory as shown in the diagram below.



[Source: <http://www.entertainmentbazar.com>]

11.1 What name is given to the type of elimination reaction described above? (1)

11.2 Define *saturated hydrocarbon*. (3)

11.3 Name the homologous series to which the saturated hydrocarbons belong. (1)

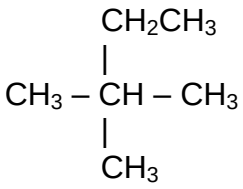
11.4 The gases produced in this process are collected by the downward displacement of water. With reference to the relevant intermolecular forces, explain why these gases are insoluble in water. (3)

11.5 The test tube containing the gas mixture collected in this reaction is shaken with a solution of bromine. The bromine solution rapidly loses its colour.

11.5.1 Which compound (butane or ethene) reacted most to cause the rapid decolourisation of bromine? (1)

11.5.2 Name the type of reaction that has taken place. (1)

11.6 One of the branched chain hydrocarbon products of this reaction is shown below.



Write down the IUPAC name of this compound. (4)

11.7 One of the components of kerosene has the molecular formula $C_{12}H_{26}$. The equation below shows the hydrocarbon products formed when $C_{12}H_{26}$ breaks down.

$$C_{12}H_{26}(\ell) \xrightarrow[\textbf{Catalyst}]{\textbf{Heat}} C_4H_{10}(g) + C_2H_4(g) + 2\,\mathbf{X}(g)$$

11.7.1 Determine the molecular formula of compound **X**. Show all workings. (3)

11.7.2 With reference to the intermolecular forces and the factors influencing their strength, explain why $C_{12}H_{26}$ is a liquid but the hydrocarbon products of this reaction are all gases at room temperature. (5)

[22]

Total: 200 marks