NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2016

# 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 15 pages, a 1 page, yellow Answer Sheet and a green Data Sheet of 3 pages (i–iii).

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

3. Remove the Data Sheet 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. Answer ALL the questions.

6. Question 1 consists of 10 multiple-choice questions. There is only one correct answer to each question. The questions are answered on the multiple-choice 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.

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. You may use an approved, non-programmable and non-graphical calculator, unless otherwise stated.

11. Show all necessary steps in calculations.

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

13. 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 that you consider to be correct.

1.1 The correct chemical formula for ammonium dichromate is:

A $NH_4Cr_2O_7$
B $(NH_4)_3Cr_2O_7$
C $NH_4(Cr_2O_7)_2$
D $(NH_4)_2Cr_2O_7$

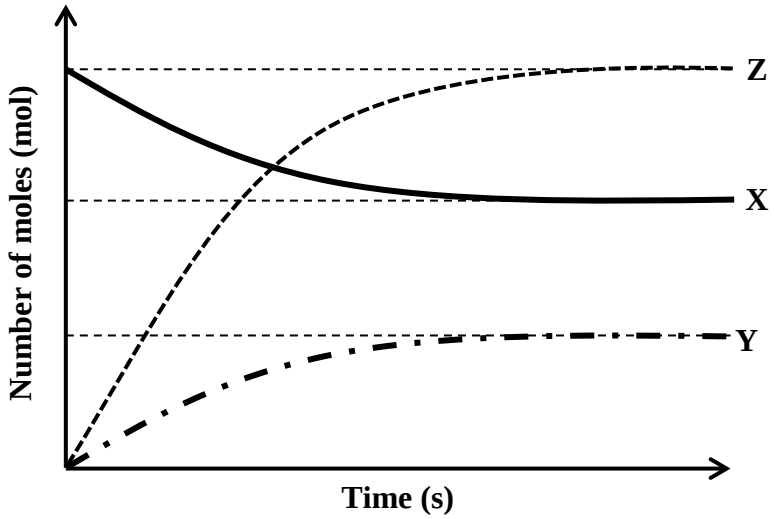
1.2 A catalyst is a substance that increases the rate of a chemical reaction by …

A increasing the activation energy for the reaction.
B decreasing the activation energy for the reaction.
C increasing the average kinetic energy of the reacting particles.
D decreasing the average kinetic energy of the reacting particles.

1.3 Which one of the following statements is true for a reaction in a state of dynamic chemical equilibrium?

A The limiting reagent has been used up.
B The forward and reverse reactions have stopped.
C The rates of the forward and reverse reactions are equal.
D The concentration of products equals the concentration of reactants.

1.4 Gas X is placed in a flask, which is then sealed. Gas X decomposes to produce gas Y and gas Z. The reaction reaches dynamic chemical equilibrium after a certain period of time as shown in the graph below.




Which one of the following balanced chemical equations represents the decomposition of gas X as shown in the above graph?

A $X(g) \rightleftharpoons Y(g) + 2Z(g)$
B $2X(g) \rightleftharpoons 2Y(g) + Z(g)$
C $2X(g) \rightleftharpoons Y(g) + Z(g)$
D $X(g) \rightleftharpoons Y(g) + 3Z(g)$

1.5 A Lowry-Bronsted acid is defined as a substance that …

A is sour.
B is a proton donor.
C neutralises a base.
D has a pH of less than 7.

1.6 Which one of the following substances will not react with hydrochloric acid to produce copper II chloride ($CuC\ell_2$)?

A Copper metal
B Copper II oxide
C Copper II carbonate
D Copper II hydroxide

1.7 Which one of the following is a weak polyprotic acid?

A $H_2SO_4$
B $HNO_3$
C $H_2SO_3$
D $CH_3COOH$

1.8 Chlorine gas is bubbled through a solution of $Fe^{2+}$ ions. Consider the balanced chemical equation for the reaction given below.

$$\mathbf{2Fe^{2+}(aq) + C\ell_2(g) \longrightarrow 2Fe^{3+}(aq) + 2C\ell^-(aq)}$$

The symbol of the reducing agent in this reaction is:

A $Fe^{2+}$
B $C\ell_2$
C $Fe^{3+}$
D $C\ell^-$

1.9 Which one of the following correctly describes the process taking place at the cathode of an electrochemical cell and the electron transfer involved?

| | Process | Electron transfer |
|---|---|---|
| A | Oxidation | Loss of electrons |
| B | Reduction | Loss of electrons |
| C | Oxidation | Gain of electrons |
| D | Reduction | Gain of electrons |

1.10 Which one of the following arranges the chain isomers methylbutane, dimethylpropane and pentane in order of **increasing** boiling point?

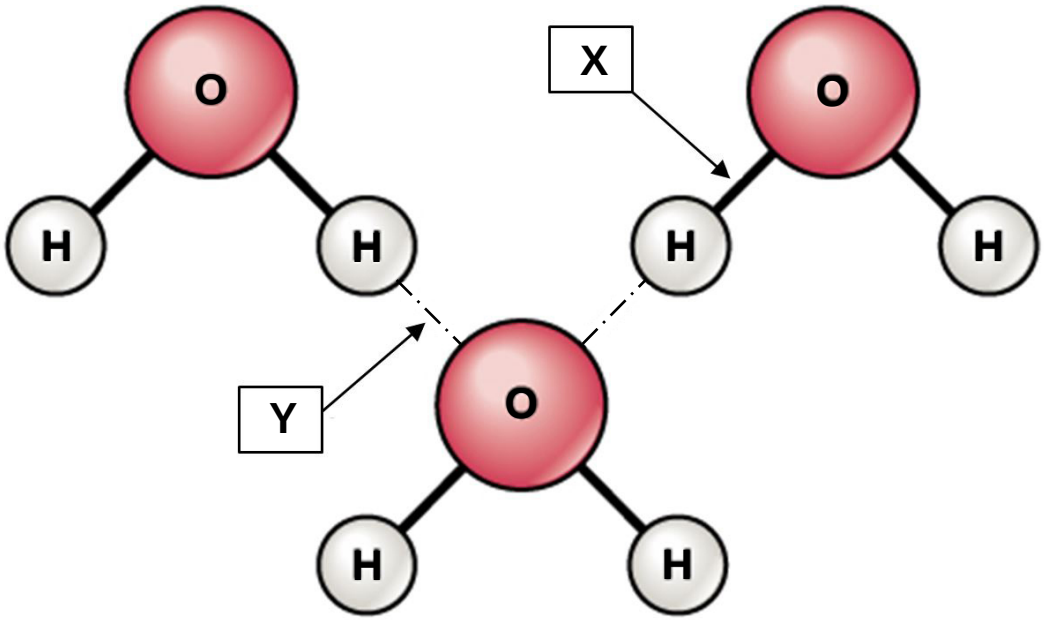
A methylbutane, dimethylpropane, pentane
B dimethylpropane, methylbutane, pentane
C pentane, methylbutane, dimethylpropane
D pentane, dimethylpropane, methylbutane

**[20]**

## QUESTION 2 CHEMICAL BONDING

2.1 Consider the diagram below, showing an arrangement of water molecules in the liquid phase.




2.1.1 What is an intramolecular bond? (1)

2.1.2 Name the specific type of intramolecular bond represented by the letter **X** in the diagram. (2)

2.1.3 Define the term *intermolecular force.* (2)

2.1.4 Name the specific type of intermolecular force represented by the letter **Y** in the diagram. (1)

2.1.5 State two properties of the oxygen atom that make this type of intermolecular force (**Y**) possible. (2)

2.1.6 What is the partial charge ($\delta^+$ or $\delta^-$) on the hydrogen atom in a water molecule? (1)

2.2 Diagrams 1 and 2 below show the crystal lattice structure of the giant ionic solid sodium chloride.

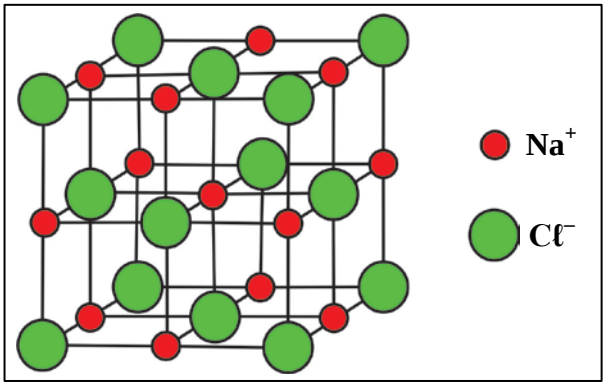



**Diagram 1**

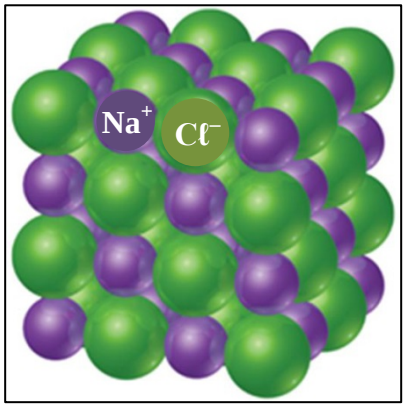



**Diagram 2**

2.2.1 Define the term *ionic bond.* (2)

2.2.2 With reference to the crystal lattice structure, explain why sodium chloride has a very high melting point (801 °C). (3)

Sodium chloride dissolves in water. The ions are surrounded by water molecules as shown in Diagram 3 below.

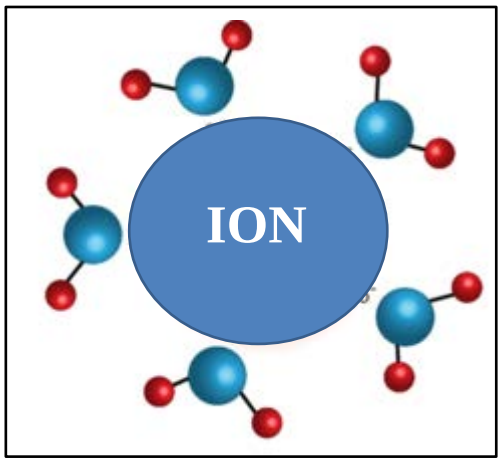



**Diagram 3**

2.2.3 Name the **specific type** of force between the ion and the water molecules. (1)

2.2.4 Is the ion shown in the above diagram a sodium ion ($Na^+$) or a chloride ion ($C\ell^-$)? Explain. (2)

2.2.5 A relatively large amount of water is needed to dissolve a small amount of sodium chloride. Explain why this is so by referring to the structure of sodium chloride and the strengths of the forces involved. (3)

**[20]**

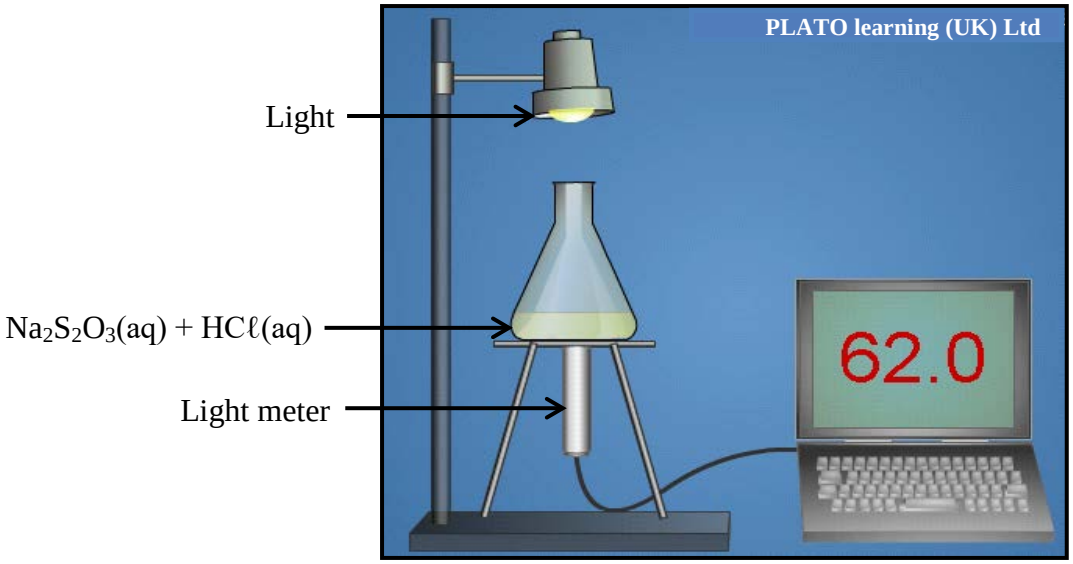
 

## QUESTION 3 ENERGY CHANGE AND REACTION RATES

Consider the reaction of sodium thiosulphate solution with dilute hydrochloric acid as given by the balanced chemical equation below.

$$Na_2S_2O_3(aq) + 2HC\ell(aq) \longrightarrow 2NaC\ell(aq) + SO_2(g) + S(s) + H_2O(\ell)$$

The rate of reaction between the sodium thiosulphate solution and hydrochloric acid can be monitored using a light meter, which measures the decrease in the intensity of light passing through the solution as the reaction proceeds. The apparatus is set up as shown in the diagram below.




Luke uses the apparatus shown in the diagram to conduct a series of experiments to determine the relationship between the concentration of the sodium thiosulphate solution and the time taken for the light meter to show a reading of 62 lumens. (Lumens = unit for light intensity.)

Luke follows the method outlined below and obtains the results shown in the table.

### Method

1. Pour 100 $cm^3$ of sodium thiosulphate solution of concentration 0,2 $mol \cdot dm^{-3}$ into a conical flask and place the conical flask on the gauze on top of the tripod as shown in the diagram.
2. Add 10 $cm^3$ of dilute hydrochloric acid to the flask, swirl once to mix and start the stopwatch.
3. Stop the watch when the light meter reads 62 lumens.
4. Repeat steps 1 to 3 for samples of sodium thiosulphate with concentrations of 0,4 $mol \cdot dm^{-3}$; 0,6 $mol \cdot dm^{-3}$; 0,8 $mol \cdot dm^{-3}$; 1,0 $mol \cdot dm^{-3}$ and 1,2 $mol \cdot dm^{-3}$.

### Results

| | Concentration of $Na_2S_2O_3(aq)$ ($mol \cdot dm^{-3}$) | Time (s) |
|---|---|---|
| Experiment 1 | 0,2 | 180 |
| Experiment 2 | 0,4 | 90 |
| Experiment 3 | 0,6 | 60 |
| Experiment 4 | 0,8 | 45 |
| Experiment 5 | 1,0 | 36 |
| Experiment 6 | 1,2 | 30 |

3.1 Why will there be a decrease in the intensity of the light passing through the solution as the reaction proceeds? (2)

3.2 Luke plotted a graph to show the relationship between the concentration of the $Na_2S_2O_3(aq)$ and the time taken for the light meter to show a reading of 62 lumens. The **incomplete** graph is provided on your yellow ANSWER SHEET. Complete the graph by providing the information requested below.

3.2.1 Write down a suitable label for the x-axis in the empty block provided on your ANSWER SHEET. (2)

3.2.2 Determine the scale used on the y-axis and fill in the numbers in the empty blocks provided on your ANSWER SHEET. (1)

3.2.3 Plot the points for experiments 2 and 5 on your ANSWER SHEET. (2)

3.2.4 Draw a best-fit line through the points on your ANSWER SHEET. (1)

3.3 State a reason why Luke plotted time on the y-axis rather than on the x-axis. (1)

3.4 Luke correctly states the following conclusion from his experiments:

"*The time taken for the light meter to show a reading of 62 lumens is inversely proportional to the concentration of the $Na_2S_2O_3(aq)$.*"

Luke now plots a new graph. He plots the inverse of concentration on the x-axis and time on the y-axis.

Describe the shape of his new graph. (2)

3.5 Explain, by referring to the collision theory, how an increase in the concentration of $Na_2S_2O_3(aq)$ affects the rate of the reaction with $HC\ell(aq)$. (3)

3.6 Suggest an alternative method of monitoring the rate of this reaction if a light meter is not available. Clearly explain what reading(s) would need to be taken. (2)

3.7 In a NEW experiment Luke reacts 100 $cm^3$ of 0,2 $mol \cdot dm^{-3}$ $HC\ell(aq)$ with excess $Na_2S_2O_3(aq)$. He filters the solution and collects 0,18 g of sulphur.

3.7.1 Calculate the number of moles of $HC\ell$ that reacted. (2)

3.7.2 Calculate the percentage yield of sulphur in Luke's reaction. (5)

**[23]**

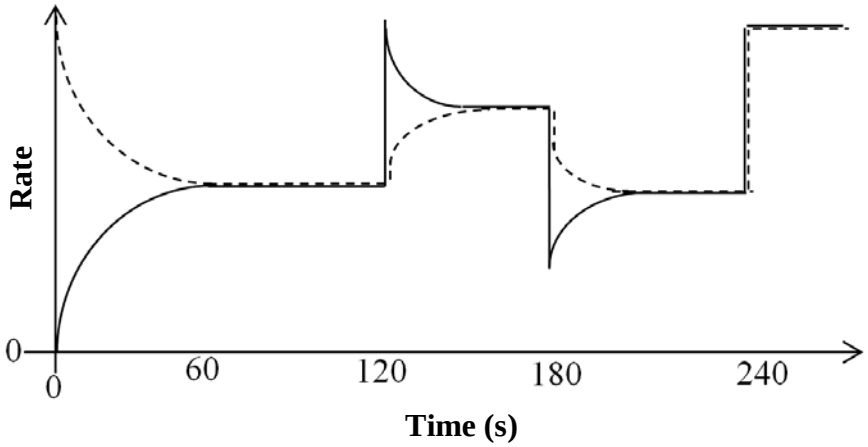
 

## QUESTION 4 CHEMICAL EQUILIBRIUM

Gas $A_2B$ is introduced into a flask, which is then sealed, and then allowed to reach dynamic chemical equilibrium at a certain temperature. The balanced chemical equation for the reaction is:

$$\mathbf{2A_2B(g) \rightleftharpoons 2A_2(g) + B_2(g)}$$

The graph below shows the changes in the rates of the forward and reverse reactions with time. The **solid** line represents the **reverse** reaction.




4.1 Explain why the rate of the reverse reaction increases (as shown on the graph) during the first 60 s. (2)

4.2 At t = 120 s the volume of the container is decreased, which leads to an increase in pressure.

4.2.1 The graph shows that at t = 120 s, both the forward and reverse reactions initially immediately increase at the same rate. Why is this so? (2)

4.2.2 Which reaction is favoured between t = 120 s and t = 150 s (FORWARD OR REVERSE)? (1)

4.2.3 Explain your answer to Question 4.2.2 above by applying Le Chatelier's Principle. (2)

4.3 At t = 180 s the temperature in the container is decreased. Is the forward reaction EXOTHERMIC or ENDOTHERMIC? Explain by applying Le Chatelier's Principle. (3)

4.4 Suggest what change is made at t = 240 s. (1)

4.5 How does the concentration of $A_2B$ change between t = 230 s and t = 250 s? Explain. (3)

4.6 How is the equilibrium constant ($K_c$) for this reaction affected by each of the following changes? (Answer: INCREASES, DECREASES or NO EFFECT.)

4.6.1 The increase in pressure at t = 120 s (1)

4.6.2 The decrease in temperature at t = 180 s (1)

4.7 Initially 5,1 moles of gas $A_2B$ are introduced into a reaction flask. The flask is then sealed and kept at a constant temperature. The gas $A_2B$ decomposes as shown in the balanced chemical equation below:

$$\mathbf{2A_2B(g) \rightleftharpoons 2A_2(g) + B_2(g)}$$

When dynamic chemical equilibrium is established, there is 3,6 mol of gas $A_2$ in the flask. The concentration of gas $A_2$ in the flask at equilibrium is 1,2 $mol \cdot dm^{-3}$.

4.7.1 Calculate the volume of the reaction flask. (2)

4.7.2 Write down an expression for the equilibrium constant ($K_c$) for this reaction. (2)

4.7.3 Calculate the value of the equilibrium constant ($K_c$) for this reaction at this constant temperature. (6)

**[26]**

## QUESTION 5 QUANTITATIVE CHEMISTRY AND ACIDS AND BASES

5.1 Amy is instructed to prepare 250 $cm^3$ of a standard solution of sodium carbonate ($Na_2CO_3$) of concentration 0,05 $mol \cdot dm^{-3}$. Amy follows the steps outlined below.

(a) Calculate the mass of sodium carbonate required.
(b) Mass the required amount of sodium carbonate onto a piece of filter paper placed on a digital balance (as shown in the diagram below).
(c) Pour tap water up to the 250 $cm^3$ mark into a beaker (as shown in the diagram below).
(d) Transfer the sodium carbonate from the filter paper into the water in the beaker and stir with a glass rod until dissolved.


[<http://cfnewsads.thomasnet>]

5.1.1 Define the term *standard solution*. (1)

5.1.2 Identify TWO errors made by Amy when making her solution and correct each of them. (4)

5.1.3 Identify the solute used to make this solution. (1)

5.2 Amy titrates her solution of sodium carbonate against a solution of hydrochloric acid (HCℓ). She uses an indicator to determine the neutralisation or equivalence point of her titration. The indicator she uses is a weak acid with the general formula HIn. The balanced chemical equation for the ionisation of the indicator is given below. The colour of the un-ionised indicator, HIn, is orange and the colour of the $In^-$ ions is blue.

$$\underset{\text{Orange}}{HIn} + H_2O \rightleftharpoons H_3O^+ + \underset{\text{Blue}}{In^-}$$

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

5.2.2 State the colour of the indicator in a solution of hydrochloric acid. Explain your answer by applying Le Chatelier's Principle. (5)

5.3 In a separate investigation Amy reacts hydrochloric acid of concentration 0,25 mol·dm$^{-3}$ with excess sodium carbonate powder. The reaction produces a total volume of 0,56 dm$^3$ of carbon dioxide gas at STP. The balanced chemical equation for the reaction is given below.

$$\mathbf{Na_2CO_3(s) + 2HC\ell(aq) \longrightarrow 2NaC\ell(aq) + H_2O(\ell) + CO_2(g)}$$

5.3.1 Calculate the number of moles of $CO_2(g)$ formed in the reaction at STP. (2)

5.3.2 Calculate the volume of hydrochloric acid that reacted with the excess sodium carbonate. (3)

5.4 Amy carries out further investigations using 0,1 mol·dm$^{-3}$ solutions of nitric acid and ethanoic acid. The value of the ionisation constant ($K_a$) of ethanoic acid at 25 °C is given in the table below.

| **Name** | **Formula** | **Concentration (mol·dm$^{-3}$)** | **$K_a$ at 25 °C** |
|---|---|---|---|
| Nitric acid | $HNO_3$ | 0,1 | ? |
| Ethanoic acid | $CH_3COOH$ | 0,1 | $1,8 \times 10^{-5}$ |

5.4.1 Write down a balanced chemical equation for the ionisation of ethanoic acid in water. State symbols (phase indicators) need not be shown. (3)

5.4.2 Will the ionisation constant ($K_a$) of nitric acid be LESS THAN, GREATER THAN or EQUAL TO that of ethanoic acid? Explain. (3)

5.4.3 Which of these acid solutions (if any) will have a higher electrical conductivity? Explain. (2)

5.4.4 Which of these acid solutions (if any) will have a higher concentration of hydroxide ions ($OH^-$)? Explain. (3)

5.5 Amy dissolves the solid salt, sodium ethanoate ($CH_3COONa$), in water. Consider the following balanced chemical equation for the hydrolysis of the ethanoate ion:

$$\mathbf{CH_3COO^-(aq) + H_2O(\ell) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)}$$

5.5.1 Define the term *salt*. (2)

5.5.2 Predict the approximate pH of an aqueous solution of sodium ethanoate. Explain your answer. (3)

5.5.3 The salt, sodium ethanoate, can be prepared from the reaction of ethanoic acid with sodium oxide. Write down a balanced chemical equation for this reaction. (3)

**[37]**

## QUESTION 6 GALVANIC CELLS

Ayanda and Alison are given the task of setting up a galvanic cell (under standard solutions) between copper (Cu) and lead (Pb). They are provided with copper and lead electrodes, beakers containing suitable electrolytes, a salt bridge, a voltmeter and connecting wires.

6.1 Draw a diagram of the cell that they should set up and clearly label the following:

- Cathode (Indicate whether copper or lead.)
- Electrolyte in the anode half-cell (Give a suitable chemical formula or name.)
- Direction of electron flow (Use a labelled arrow.) (6)

6.2 Write down the cell notation for this cell showing standard conditions. (4)

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

6.4 Ayanda and Alison fill their salt bridge with a concentrated aqueous solution of potassium iodide, KI(aq).

6.4.1 State TWO functions of the salt bridge. (2)

6.4.2 With reference to the electrochemical processes occurring in the lead half-cell, explain why iodide ions ($I^-aq$) move from the salt bridge into this half-cell. (3)

A precipitate of insoluble lead II iodide now forms in the lead half-cell.

6.4.3 How will this affect the emf of the cell? (Answer: INCREASES, DECREASES or NO CHANGE.) (1)

6.5 Ayanda and Alison replace their electrodes with new, larger electrodes that have a greater surface area. State how this will affect each of the following: (Answer INCREASES, DECREASES or NO EFFECT.)

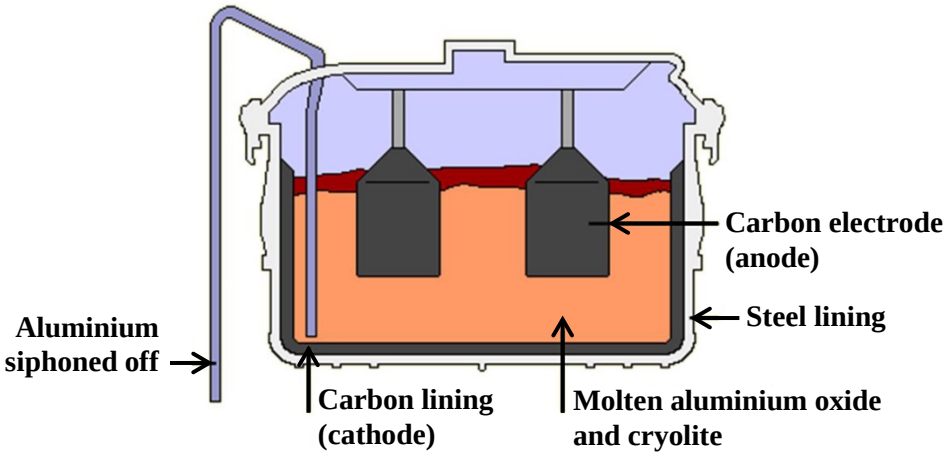
6.5.1 The ability of the cell to deliver current (1)

6.5.2 The emf of the cell (1)

**[20]**

## QUESTION 7 ELECTROLYTIC CELLS

Aluminium is prepared on a large scale in industry by the electrolysis of molten aluminium oxide that is dissolved in molten cryolite at 950 °C. The electrolytic cell used in this process is shown in the diagram below.




[Source: PLATO learning (UK) Ltd]

7.1 State the energy conversion that takes place in this electrolytic cell. (1)

7.2 Write down the equation for the half-reaction that takes place at the cathode. (2)

7.3 Write down the equation for the half-reaction that takes place at the anode. (2)

7.4 The carbon electrodes in this cell constantly corrode and need to be replaced. Explain why they corrode and write down a balanced chemical equation to support your answer. (3)

Cryolite lowers the melting point of aluminium oxide from 2 000 °C to 950 °C.

7.5 State one way in which the use of cryolite is an advantage to the environment. (1)

7.6 State one way in which the use of cryolite is a potential risk to the environment. (1)

7.7 Despite the use of cryolite, this process still consumes large quantities of electricity in order to achieve the required temperature of 950 °C. Thuli makes the following energy saving suggestion:

"*They should use the electrolysis of a concentrated aqueous solution of aluminium chloride at room temperature rather than molten aluminium oxide at 950 °C.*"

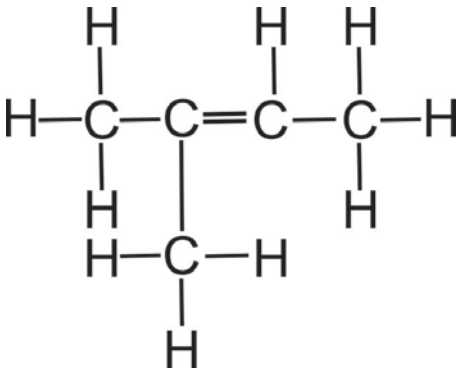
Consider the reaction taking place at the **cathode** in order to explain why Thuli's suggestion will not work. Write down the equation for a suitable half-reaction that supports your answer. (4)

**[14]**

## QUESTION 8 ORGANIC CHEMISTRY

8.1 The structural formula of an unsaturated hydrocarbon is given below.



8.1.1 Define the term *unsaturated hydrocarbon.* (3)

8.1.2 Write down the IUPAC name of the above compound. (4)

8.2 Propanoic acid is a functional isomer of methyl ethanoate.

8.2.1 Define the term *functional group.* (2)

8.2.2 Draw the structural formula of propanoic acid and highlight or draw a circle around the atom(s) in the functional group. (3)

8.2.3 Draw the structural formula of methyl ethanoate. (3)

8.2.4 Explain why propanoic acid and methyl ethanoate are described as functional isomers. (3)

8.2.5 Write down the IUPAC name of the alcohol used to prepare methyl ethanoate. (1)

8.2.6 Write down the IUPAC name of a positional isomer of methyl ethanoate. (1)

8.2.7 Which one of propanoic acid or methyl ethanoate will have the higher boiling point? (1)

8.2.8 Explain your answer to Question 8.2.7 with reference to the relevant intermolecular forces. (4)

8.3 Consider reactions I, II, III, IV and V below.

**Reaction I** $\boxed{\text{Compound P}} + C\ell_2(g) \xrightarrow[\text{light}]{\text{ultraviolet}} CH_3CH_2C\ell(g) + HC\ell(g)$

**Reaction II** $CH_3CH_2C\ell(g) + NaOH(aq) \xrightarrow{\text{heat}} \boxed{\text{Compound Q}} + NaC\ell(aq)$

**Reaction III** $\boxed{\text{Compound Q}} \xrightarrow[H_2SO_4 \text{ catalyst}]{\text{heat}} CH_2CH_2(g) + H_2O(g)$

**Reaction IV** $CH_2CH_2(g) + H_2(g) \xrightarrow[\text{Ni catalyst}]{\text{heat}} \boxed{\text{Compound P}}$

**Reaction V** $CH_2CH_2(g) + 3O_2(g) \xrightarrow{\text{heat}} 2CO_2(g) + 2H_2O(g)$

8.3.1 Write down the condensed structural formula of:

(a) Compound P (2)

(b) Compound Q (2)

8.3.2 Write down the IUPAC name of:

(a) $CH_3CH_2C\ell$ (2)

(b) $CH_2CH_2$ (2)

8.3.3 Name the homologous series to which $CH_3CH_2C\ell$ belongs. (1)

8.3.4 Name the homologous series to which $CH_2CH_2$ belongs. (1)

8.3.5 Name the type of reaction taking place in:

(a) Reaction I (1)

(b) Reaction II (1)

(c) Reaction III (1)

(d) Reaction IV (1)

(e) Reaction V (1)

**[40]**

**Total: 200 marks**