NATIONAL SENIOR CERTIFICATE EXAMINATION
SUPPLEMENTARY EXAMINATION – MARCH 2018

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of 16 pages and a green Data Sheet of 3 pages (i–iii). Please make sure that your question paper is complete.

2. Remove the Data Sheet from the middle of this question paper.

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 must 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 of 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 set your work out neatly.

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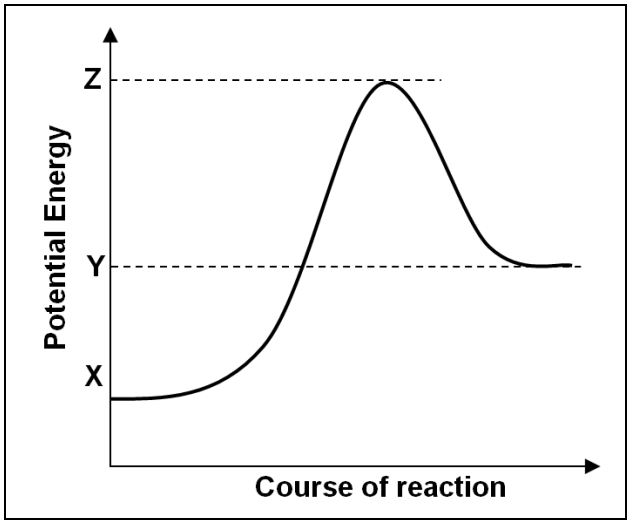
QUESTION 1 MULTIPLE CHOICE

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 which you consider to be the most correct.

1.1 The chemical formula for magnesium sulphite is:

A $Mg(SO_3)_2$
B $MgSO_4$
C Mg_3SO_2
D $MgSO_3$

1.2 Consider the following energy profile graph. Potential energy values X, Y and Z are indicated on the graph.



The heat of reaction (ΔH) for the forward reaction is given by:

A Y – X
B Z – X
C Z – Y
D X – Y

1.3 Consider the balanced chemical equation for the following reaction in equilibrium.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

The equilibrium constant, K_c, for this reaction is 6×10^{-3} at 25 °C.

What is the equilibrium constant, K_c, for the reverse reaction?

A $\sqrt{6 \times 10^{-3}}$
B $\dfrac{6 \times 10^{-3}}{2}$
C $\dfrac{1}{6 \times 10^{-3}}$
D $(6 \times 10^{-3})^2$

1.4 In an experiment, 0,1 mole of $SO_2(g)$ and 0,1 mole of $O_2(g)$ are added to an empty 1 dm^3 flask which is then sealed. The resulting reaction reaches equilibrium as shown in the following balanced chemical equation:

$$\mathbf{2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)}$$

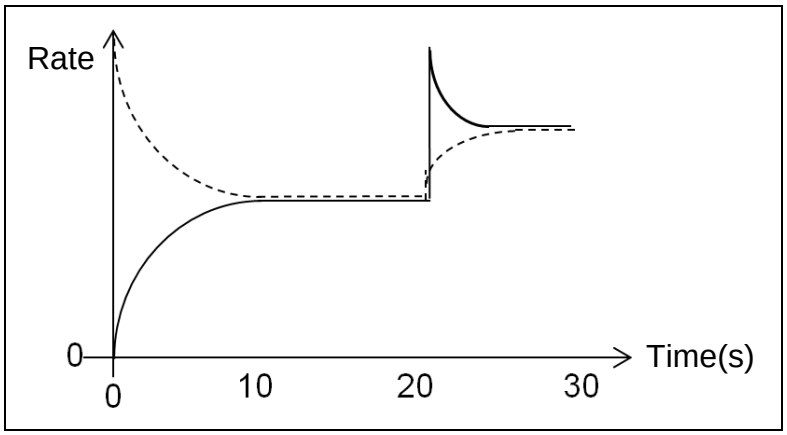
Which one of the following must ALWAYS be true at equilibrium?

A $[SO_2] = [O_2] = [SO_3]$
B $[O_2] < [SO_3]$
C $[SO_2] = [SO_3]$
D $[SO_2] < [O_2]$

1.5 Gas X_2Y is introduced into a container, which is then sealed. The gas decomposes and the reaction reaches equilibrium. The balanced chemical equation for the reaction is:

$$\mathbf{2X_2Y(g) \rightleftharpoons 2X_2(g) + Y_2(g) \qquad \Delta H > 0}$$

At t = 20 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 gives the change made at t = 20 s?

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

1.6 A strong base is defined as one which …

A neutralises a strong acid
B dissociates almost completely in an aqueous solution
C is a metal hydroxide
D has a pH between 8 and 10

1.7 Which one of the following gives the approximate pH of an aqueous solution of sodium carbonate and the relevant hydrolysis equation?

	pH	**Hydrolysis equation**
A	Less than 7	$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$
B	Less than 7	$Na^+ + H_2O \rightleftharpoons NaOH + H^+$
C	Greater than 7	$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$
D	Greater than 7	$Na^+ + H_2O \rightleftharpoons NaOH + H^+$

1.8 The equation for the half-reaction taking place at the anode during the electrolysis of molten aluminium oxide is:

A $A\ell^{3+} + 3e^- \longrightarrow A\ell$
B $2O^{2-} \longrightarrow O_2 + 4e^-$
C $O_2 + 4e^- \longrightarrow 2O^{2-}$
D $A\ell \longrightarrow A\ell^{3+} + 3e^-$

1.9 Which of the following statements ALWAYS apply to compounds that are structural isomers of one another?

I They belong to the same homologous series
II They have the same structural formula
III They have the same molecular formula

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

1.10 Ethanol is least likely to undergo …

A addition reactions
B substitution reactions
C combustion reactions
D esterification reactions

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QUESTION 2 CHEMICAL BONDING

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

2.2 Give the name or chemical formula/symbol of a substance which exhibits ionic bonding. (1)

2.3 Name the **specific** type of **intramolecular** bonds found in:

2.3.1 Hydrogen fluoride. (2)

2.3.2 Fluorine. (2)

2.4 Name the **specific** type of **intermolecular** forces found between molecules of:

2.4.1 Hydrogen fluoride. (2)

2.4.2 Fluorine. (2)

2.5 Explain why the boiling point of hydrogen fluoride (19,5 °C) is higher than the boiling point of fluorine (–188 °C). (2)

2.6 Silicon dioxide has a very high melting point of 1 610 °C. With reference to the structure and relevant bonds, explain why silicon dioxide has such a high melting point. (4)

2.7 A student is required to make 250 cm^3 of a standard aqueous solution of 0,2 $mol \cdot dm^{-3}$ sodium sulphate, Na_2SO_4.

2.7.1 Calculate the mass of Na_2SO_4 required. (4)

2.7.2 Describe in point form how a standard solution is prepared. (5)

2.7.3 Name the intermolecular forces between the solute and the solvent in the solution. (2)

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QUESTION 3 ENERGY CHANGE AND REACTION RATES

3.1 Define the following terms:

3.1.1 *Heat of reaction.* (2)

3.1.2 *Activated complex.* (2)

3.2 According to the collision theory, in order for a chemical reaction to occur reactant particles must collide. State TWO requirements for an **effective** collision. (4)

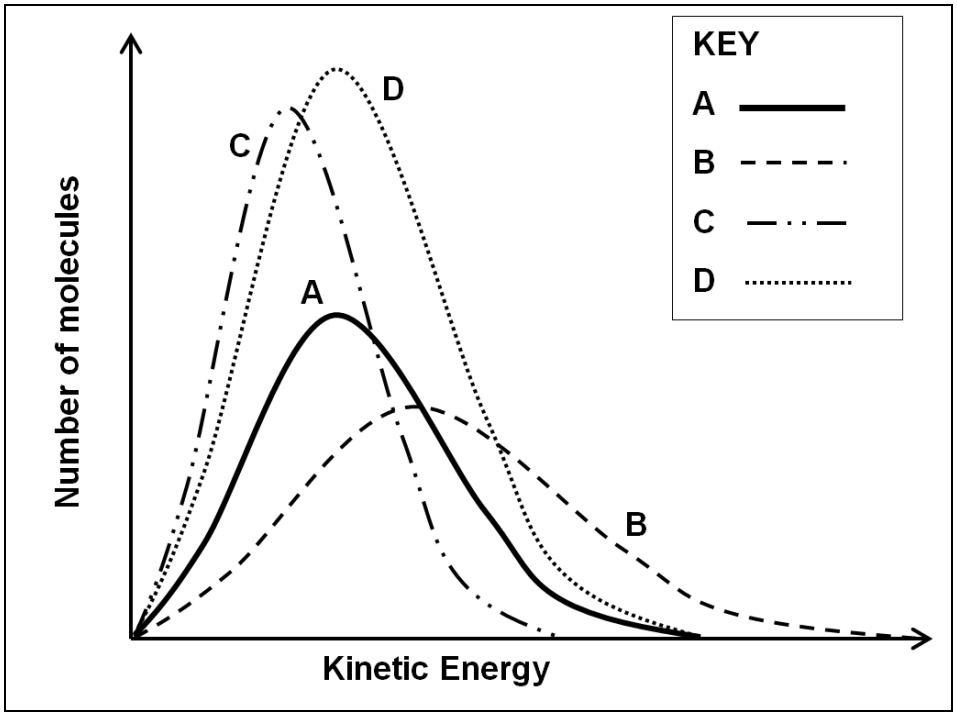
3.3 Excess dilute hydrochloric acid is added to a single large piece of zinc metal in an open test-tube.

3.3.1 Write a balanced chemical equation for the reaction which takes place in the test-tube. (3)

3.3.2 Other than using a suitable catalyst, state THREE different ways of increasing the rate of this particular reaction. (6)

3.3.3 Explain in simple terms how a catalyst increases the rate of a chemical reaction. (2)

3.4 The Maxwell-Boltzmann curve labelled **A** shows the distribution of molecular energies in **0,5 mol** of ozone gas (O_3) at STP.



3.4.1 Which of curves **B, C** or **D** represents 0,5 mol of ozone gas at a **lower** temperature? (1)

3.4.2 Which of curves **B, C** or **D** represents **1,0 mol** of ozone gas at STP? (1)

[21]

QUESTION 4 CHEMICAL EQUILIBRIUM

Iron (III) oxide reacts with carbon monoxide in a closed system to produce iron and carbon dioxide. Dynamic chemical equilibrium is established as shown by the following balanced chemical equation:

$$Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g) \qquad \Delta H<0$$

4.1 State what is meant by each of the following:

4.1.1 Closed system. (2)

4.1.2 Dynamic chemical equilibrium. (2)

4.2 State how each of the following changes will affect the yield of iron at equilibrium. Choose from: INCREASES, DECREASES or NO EFFECT.

4.2.1 An increase in pressure (by decreasing the volume of the reaction container). (1)

4.2.2 Adding more $Fe_2O_3(s)$ and re-sealing the reaction container. (1)

4.3 Using Le Chatelier's principle, explain how an increase in temperature will affect the yield of iron at equilibrium. (4)

4.4 Initially 800 g of Fe_2O_3 is placed in a 10 dm^3 container with 18 moles of CO. The container is then sealed at a particular temperature and the reaction reaches equilibrium. The volume of CO_2 (at STP) produced at equilibrium is 215,04 dm^3.

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

4.4.2 Calculate the value of K_c for this reaction at the particular temperature. (10)

4.5 State the effect of the following on the value of K_c. Choose from: INCREASES, DECREASES or NO EFFECT.

4.5.1 Addition of a catalyst. (1)

4.5.2 Cooling the reaction container. (1)

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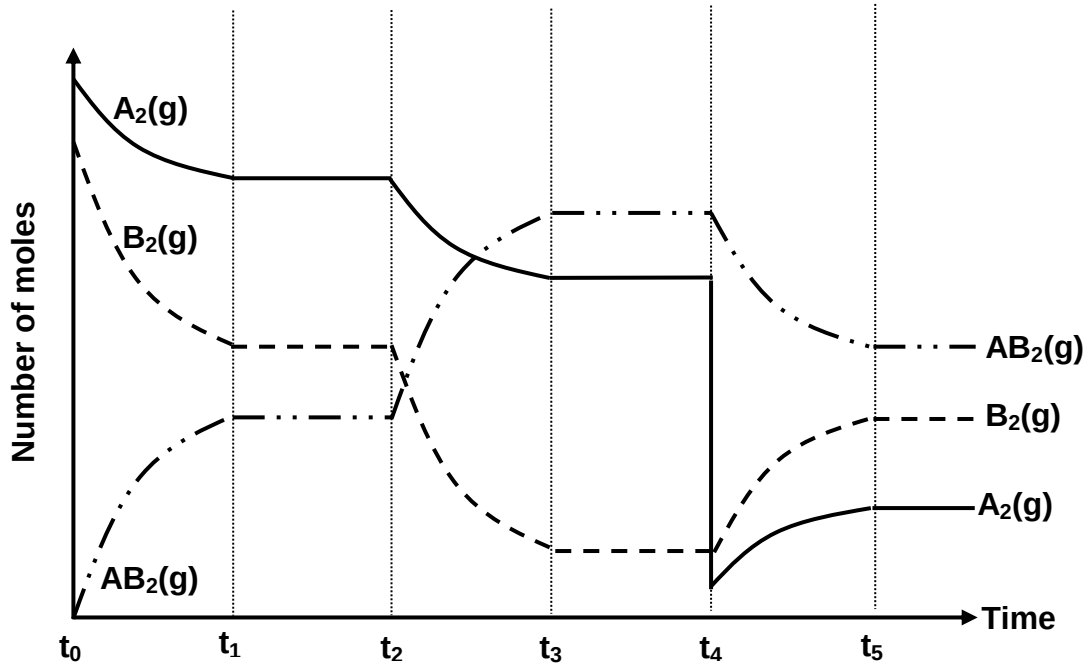
QUESTION 5 EQUILIBRIUM GRAPH

Two gases, $\mathbf{A_2}$ and $\mathbf{B_2}$, are introduced into a flask which is then sealed. They react and reach dynamic chemical equilibrium. The balanced chemical equation for the reaction is:

$$\mathbf{A_2(g) + 2B_2(g) \rightleftharpoons 2AB_2(g)}$$

The following graph shows the changes in the number of moles of each of the gases as the reaction proceeds.



5.1 How do the rates of the forward and reverse reactions compare in the time interval:

5.1.1 t_1 to t_2? (1)

5.1.2 t_2 to t_3? (1)

5.2 Suggest what change was made to the equilibrium system at time t_2. Assume that the temperature remained constant. (1)

5.3 Suggest what change was made to the equilibrium system at time t_4 and hence explain the changes in the graph between times t_4 and t_5. (3)

5.4 State how the graph would change between times t_0 and t_1 if a catalyst had been added to the flask at time t_0. (2)

[8]

QUESTION 6 TITRATION

Sulphuric acid of concentration 0,04 mol·dm^{-3} is added, drop by drop, to 0,05 dm^3 of an aqueous solution of potassium hydroxide, which is constantly stirred using a magnetic stirrer as shown in diagram 1 below. The balanced chemical equation for the reaction taking place in the beaker is:

$$H_2SO_4(aq) + 2KOH(aq) \rightleftharpoons K_2SO_4(aq) + 2H_2O(\ell)$$

The pH of the solution is continuously monitored using a pH electrode. The graph (titration curve) showing how the pH changes with the volume of H_2SO_4 added is shown in diagram 2.

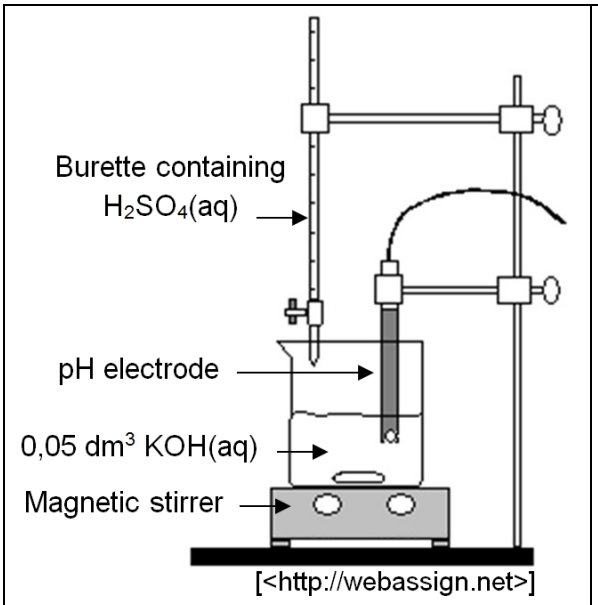


Diagram 1

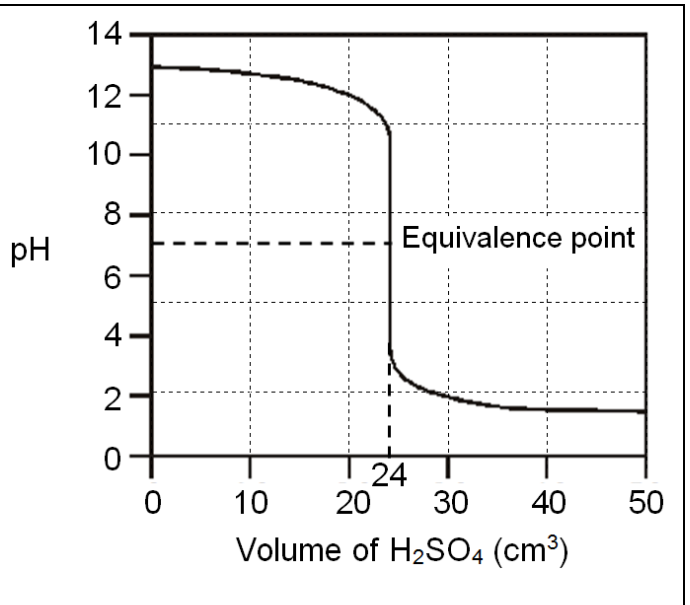


Diagram 2

6.1 State what is meant by the term equivalence (or neutralisation) point. (2)

6.2 Explain why the pH at the equivalence point in this titration is 7, as shown on the graph. (3)

6.3 The volume of H_2SO_4 required to reach the equivalence point is 24,0 cm^3. Calculate the concentration of the KOH solution. Take your answer to 3 decimal places. (5)

6.4 Explain why the pH of the solution dropped rapidly between the addition of 20 cm^3 and 30 cm^3 of H_2SO_4, as shown on the graph. (2)

A table of acid-base indicators and the pH ranges over which they change colour is given below.

Indicator	**pH range**
Methyl red	4,2 – 6,3
Bromothymol blue	6,0 – 7,6
Thymolphthalein	9,3 – 10,5

6.5 Select an indicator (from the table) which would be most suitable to use in this titration. Give a reason for your choice. (2)

[14]

QUESTION 7 ACIDS AND BASES

7.1 The table below shows the ionisation constants of two acids.

Name	**Formula**	**K_a**
Nitrous acid	HNO_2	$4{,}5 \times 10^{-4}$
Hypochlorous acid	$HC\ell O$	$3{,}5 \times 10^{-8}$

7.1.1 Write a balanced chemical equation for the ionisation of nitrous acid in water. (2)

7.1.2 Which of these acids would be a better electrical conductor? Explain. Assume the concentration of both acids is the same. (3)

7.2 Write a balanced chemical equation for the reaction of:

7.2.1 Hydrochloric acid with magnesium carbonate. (3)

7.2.2 Nitric acid with aluminium oxide. (3)

7.3 The salt ammonium chloride dissolves readily in water to form an aqueous solution.

7.3.1 Identify the acid and base required to make the salt ammonium chloride. (2)

7.3.2 Predict the approximate pH of a solution of ammonium chloride. Choose from: GREATER THAN 7, LESS THAN 7 or EQUAL TO 7. (1)

[14]

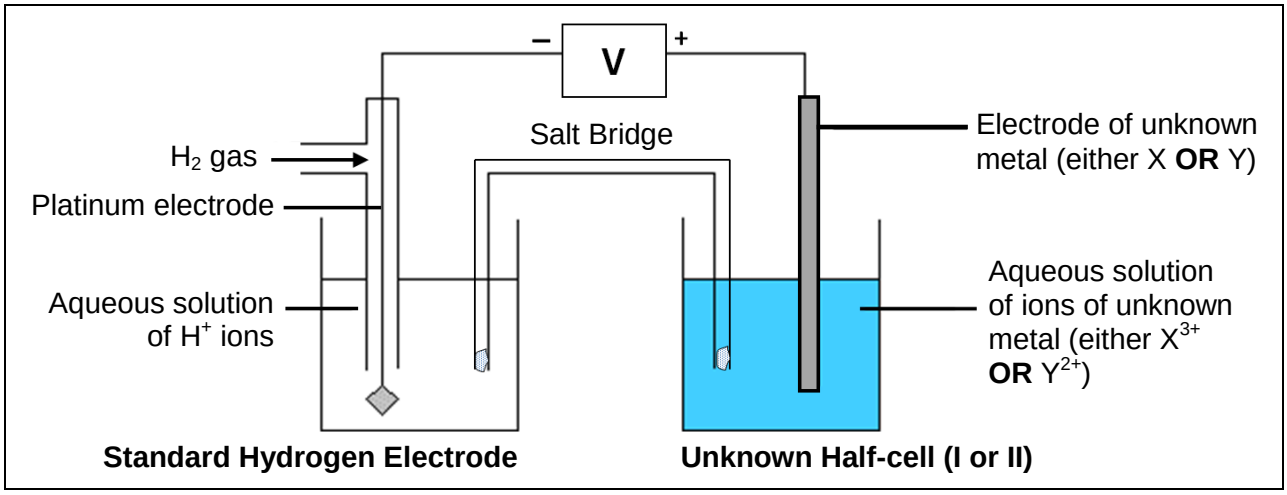
QUESTION 8 GALVANIC CELLS

Robert is required to determine the standard electrode potential of two unknown hypothetical half-cells I and II. The half-reaction taking place in each of the half-cells is given below.

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

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

Robert connects each half-cell, under standard conditions, to a standard hydrogen electrode. He connects the standard hydrogen electrode to the negative terminal of a digital voltmeter as shown in the diagram below. The standard electrode potential (E^o) for each half cell, as given by the reading on the voltmeter, is then recorded.



Results

Cell		Reading on voltmeter (V)
P	Standard hydrogen electrode + Half-cell I	+0,61
Q	Standard hydrogen electrode + Half-cell II	–2,14

8.1 State the standard conditions for the standard hydrogen electrode. (3)

8.2 Give the symbol of the chemical species which acts as the oxidising agent in cell **P**. (1)

8.3 Write a balanced ionic chemical equation to represent the net cell reaction for cell **P**. (3)

8.4 State how each of the following will affect the reading on the voltmeter in cell **P**. Choose from: INCREASES, DECREASES OR REMAINS THE SAME.

8.4.1 Replacing the electrode in Half-cell I with a larger strip of metal X. (1)

8.4.2 Increasing the concentration of X^{3+} ions in Half-cell I. (1)

8.4.3 Increasing the concentration of the electrolyte in the salt bridge. (1)

8.5 Which metal, **X** or **Y**, is a stronger reducing agent? (1)

8.6 Fully explain the significance of the negative reading on the voltmeter in cell **Q** in comparison to the half-cell potential of the standard hydrogen electrode. (3)

8.7 Robert now connects Half-cell I to Half-cell II under standard conditions to make cell **R**.

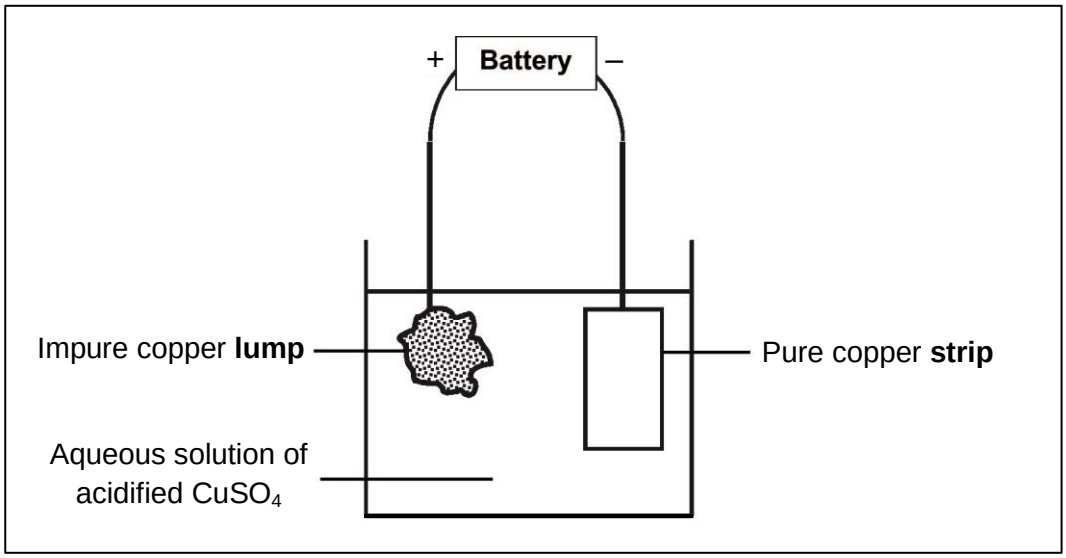
8.7.1 Write down the cell notation for cell **R**. Standard conditions and state symbols do not need to be shown. (3)

8.7.2 Calculate the initial emf of cell **R**. (3)

[20]

QUESTION 9 ELECTROLYTIC CELL

The following diagram shows the electrorefining of a lump of impure copper. The electrolyte is an aqueous solution of acidified copper (II) sulphate.



9.1 Define the term *oxidation*. (2)

9.2 The lump of impure copper contains impurities of cobalt, silver, nickel, gold and zinc. Some of the impurities may undergo oxidation here.

9.2.1 Identify one impurity that may be oxidised. (1)

9.2.2 Explain the answer to Question 9.2.1. (2)

9.2.3 State what happens to the impurities that are not oxidised. (1)

9.3 Write a balanced chemical equation for the half-reaction taking place at the cathode. (2)

9.4 A current was passed though the solution for a certain period of time. The electrodes were weighed before and after electrolysis. The results are given in the table below.

	Mass of impure copper lump (g)	**Mass of pure copper strip (g)**
Before electrolysis	435	156
After electrolysis	265	283

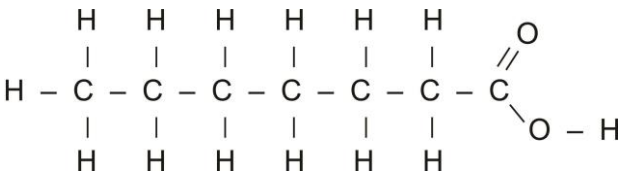
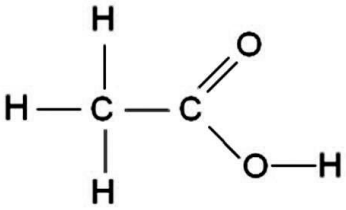
Use the information in the table to calculate the percentage of copper present in the material that was lost from the impure lump. (4)

9.5 Explain why the electrorefining process described here could not be used to purify a lump of impure aluminium. (Assume the electrolyte is an acidified solution of $A\ell^{3+}$ ions and a pure aluminium strip is used in place of the copper strip.) (3)

[15]

QUESTION 10 ORGANIC CHEMISTRY (1)

Consider compounds **A** to **H** given in the table below before answering the questions which follow.

A	2-methylbuta-1,3-diene	**B**	C_5H_{12}
C		**D**	
E	Propan-1-ol	**F**	C_3H_6
G	$CH_3CHBrCH(CH_2CH_3)CH_2CH_2CH_3$	**H**	Propyl butanoate

10.1 Write down ONLY the letters **A** to **H** when answering the questions which follow.

10.1.1 Give ONE compound which is an alkane. (1)

10.1.2 Give TWO compounds which are unsaturated hydrocarbons. (2)

10.1.3 Give TWO compounds which are functional isomers of each other. (2)

10.2 Name the homologous series to which compound **E** belongs. (1)

10.3 Draw the structural formula of compound **A**. (4)

10.4 Write down the IUPAC name of compound **G**. (4)

10.5 Write down a balanced chemical equation, using structural formulae for the organic compounds, for the preparation of compound **H**. (Reaction conditions need not be given.) (5)

10.6 Draw the structural formula of a **branched** chain isomer of compound **B** and write down its IUPAC name. (4)

10.7 Compounds **D** and **E** have the same molar mass (60 $g \cdot mol^{-1}$) yet compound **D** has a boiling point of 118 ^oC and compound **E** has a boiling point of 97 ^oC.

With reference to the relevant intermolecular forces, explain this difference in boiling point. (4)

[27]

QUESTION 11 ORGANIC CHEMISTRY (2)

11.1 A student was given three colourless liquids that were labelled **X**, **Y** and **Z**. They were known to be ethanoic acid, methanol, and hex-1-ene, but the exact identity of each liquid was unknown. The student carried out various tests on liquids **X**, **Y** and **Z** and obtained the results shown in the table below.

	X	**Y**	**Z**
Solubility in water	Soluble	Insoluble	Soluble
Addition of bromine water, $Br_2(aq)$	No immediate colour change	Bromine water rapidly becomes colourless	No immediate colour change
Addition of sodium carbonate powder, $Na_2CO_3(s)$	No reaction	No reaction	Fizzing due to gas being given off

Identify each of compounds **X**, **Y** and **Z**. (3)

11.2 Write a balanced chemical equation using condensed structural formulae for the reaction of propene with bromine. (3)

11.3 Write a balanced chemical equation using condensed structural formulae for the acid catalysed dehydration of butan-1-ol. (Reaction conditions need not be given.) (3)
[9]

Total: 200 marks