NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2014

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 14 pages, a Data Sheet of 3 pages (i – iii) with data and formulae and an Answer Sheet. Please remove the Data Sheet and Answer Sheet from the middle of your paper.

2. Please check that your question paper is complete.

3. ALL the questions in this paper must be answered.

4. Question 1 consists of 10 multiple-choice questions. There is only one correct answer to each question. These questions are answered on the inside front 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.

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

6. Read the questions carefully.

7. Use the data and formulae whenever necessary.

8. Express ALL answers correct to TWO decimal places.

9. An approved calculator (non-programmable, non-graphical) may be used.

10. Show all the necessary steps in calculations.

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

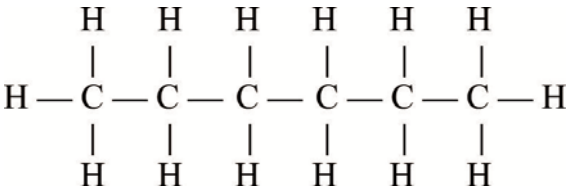
QUESTION 1

Answer these questions on the inside front cover of your Answer Book. Make a cross (X) over the letter of the response which you consider to be the most correct.

1.1 Sodium chloride (NaCℓ) is a solid which is soluble in water. Which one of the following describes the intermolecular forces that exist between sodium chloride and water in solution?

A Ion-dipole
B Dipole-dipole
C Ion-induced dipole
D Induced dipole-dipole

1.2 Consider the structure of hexane.



A molecule of hexane is considered to be non-polar. Which one of the following statements best describes the reason why hexane is non-polar?

A Hexane contains only single bonds between atoms
B The electronegativity difference between C and H atoms is so small as to be considered non-polar
C Hexane is a linear molecule hence is symmetrical
D The charge distribution of electrons within the hexane molecule is symmetrical

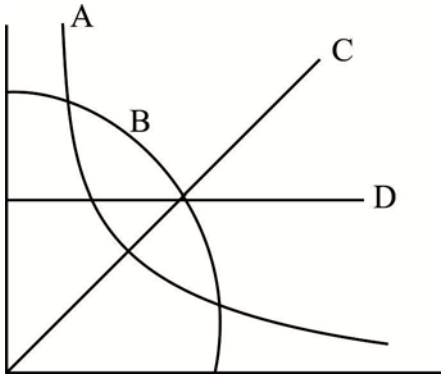
1.3 Hydrogen bonding is a type of intermolecular force that can exist between the molecules of certain compounds. Which one of the statements below best describes the conditions under which hydrogen bonding is most likely to occur?

It occurs between …

A small molecules which contain hydrogen atoms
B molecules in which hydrogen is bonded to small atoms with high electronegativity
C large molecules which contain both hydrogen and oxygen atoms
D molecules in which hydrogen is bonded to small atoms with low electronegativity

To answer Questions 1.4 and 1.5, refer to the description below and the graphs A to D that are provided.

In an experiment to determine the effect of concentration on reaction rate, a constant volume of HCℓ(aq) of concentration 2 mol·dm^{-3} is added to a constant volume of $Na_2S_2O_3$(aq) of varying concentrations.



1.4 Which one of the graphs A, B, C or D represents the plot of concentration of sodium thiosulphate (vertical axis) against time taken (horizontal axis) for the reaction?

1.5 Which one of the graphs A, B, C or D represents the plot of reciprocal of time $\left(\frac{1}{t}\right)$ (vertical axis) against concentration of sodium thiosulphate (horizontal axis) for this reaction?

1.6 Consider the following statements with respect to a chemical reaction in a state of dynamic chemical equilibrium:

I The concentrations of the reactants and products are identical provided the reaction occurs in a closed system.
II The rates of the forward and reverse reactions are identical provided the reaction occurs in a closed system.
III The amounts of reactant and product remain unchanged provided the reaction occurs in a closed system.

Which of the statement(s) above is/are true?

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

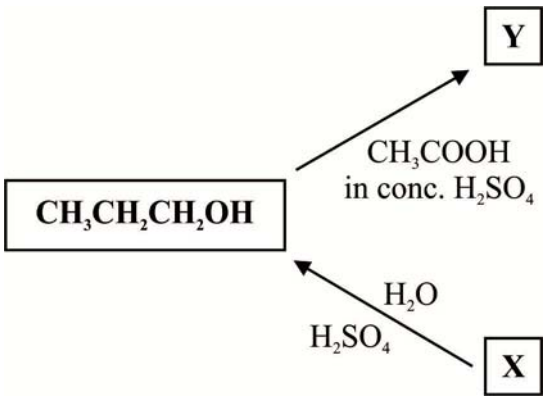
1.7 Consider the following equilibrium established in a closed container at constant temperature.

$$2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g) \qquad \Delta H < 0$$

Which one of the following sets of conditions listed below will produce the **lowest yield** of $N_2(g)$?

	Pressure	**Temperature**
A	Increase by decreasing volume	Decrease
B	Increase by decreasing volume	Increase
C	Decrease by increasing volume	Increase
D	Decrease by increasing volume	Decrease

1.8



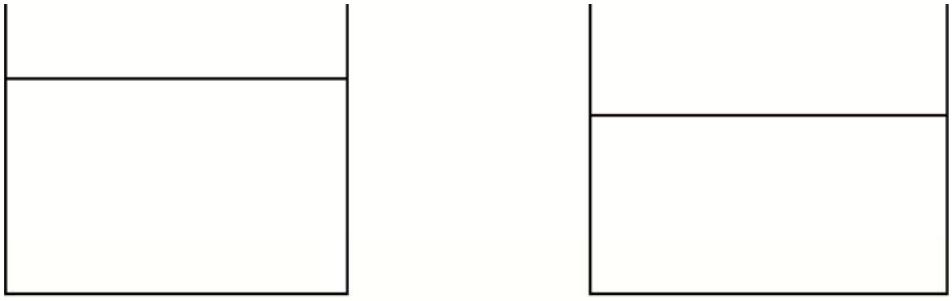
The compounds X and Y may respectively be:

A $CH_3CH_2CH_3$ and $CH_3CH_2OOCCH_2CH_3$
B CH_3CHCH_2 and $CH_3CH_2CH_2CH_2OOCH$
C CH_3CHCH_2 and $CH_3CH_2CH_2OOCCH_3$
D $CH_3CH_2CH_2$ and $CH_3CH_2CH_2OOCCH_3$

1.9 Which one of the acids listed below is an example of a polyprotic acid?

A HNO_3
B $HC\ell$
C H_2SO_4
D CH_3COOH

1.10 Consider beakers A and B as illustrated below.



20 cm^3 of the NaOH(aq) solution in beaker A is added to the NaCℓ(aq) solution in beaker B. Which one of the following represents the correct calculation for the **new concentration** of $Na^+(aq)$ ions in beaker B?

A $\dfrac{0,015 + 0,005}{0,17}$

B $\dfrac{0,015 + 0,05}{0,17}$

C $\dfrac{0,015 \times 0,05}{0,15}$

D $\dfrac{0,015 + 0,005}{0,15}$

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QUESTION 2

Calcium chloride is prepared according to the following balanced chemical equation:

$$Ca(s) + 2HC\ell(aq) \longrightarrow CaC\ell_2(aq) + H_2(g)$$

Hydrochloric acid is produced for this preparation by the ionisation of hydrogen chloride gas in water.

2.1 Define the term 'ionisation'. (2)

2.2 Write down a balanced chemical equation for the ionisation of hydrogen chloride gas in water. (2)

2.3 Name the type of bonding that is present in a molecule of hydrogen chloride. (1)

2.4 Define the term 'electronegativity'. (2)

2.5 Make use of the Pauling scale of electronegativities, as provided in the Periodic Table, to explain the type of bonding found in hydrogen chloride and crystalline calcium chloride. (4)

2.6 $HC\ell$ molecules are described as 'dipoles'. Explain what is meant by this term. (2)

2.7 Calcium chloride is soluble in water. The structure of its crystal lattice is broken down by the water molecules to form aqueous ions in solution.

2.7.1 Name the type of crystal lattice of which calcium chloride is an example. (1)

2.7.2 Using diagrams to illustrate your answer, explain how the crystal lattice of calcium chloride is broken down during the dissolving process. (4)

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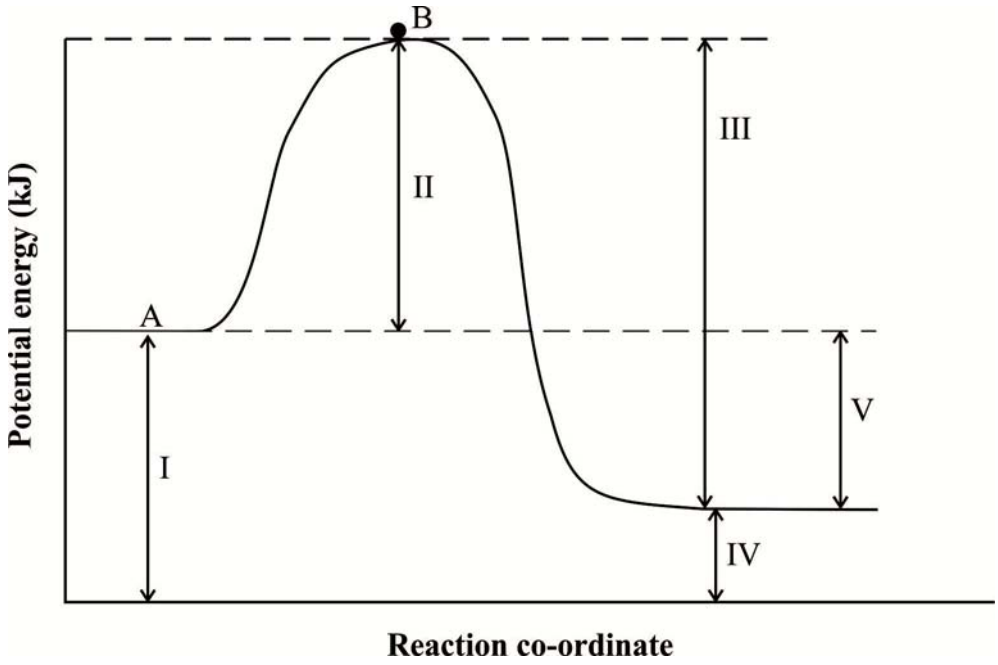
QUESTION 3

In order to investigate the rate of the reaction between a carbonate and an acid, calcium carbonate and excess of 2 mol·dm^{-3} hydrochloric acid react in a reaction vessel. The balanced chemical equation for this reaction is

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

Consider the potential energy profile for this reaction as illustrated below:



3.1 The graph has been labelled I – V to represent the various energies that are illustrated by this energy profile. Identify each of these energies on the profile. (5)

3.2 Using the molecular collision theory, explain why the chemical reaction must gain potential energy between position A and position B according to the energy profile. (2)

3.3 Provide a name for the position on the graph labelled B and what significant process takes place at this point. (2)

3.4 Name the type of reaction this graph represents. Explain how you came to this conclusion. (3)

3.5 The same reaction takes place in the presence of a catalyst. On the potential energy profile provided, show how the graph would change in the presence of a catalyst. (2)

3.6 How would the presence of a catalyst affect the value of the energy labelled V? Explain you answer. (3)

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QUESTION 4

Organic chemistry can be described as the study of the structure, properties and reactions of carbon based compounds. The carbon atom is unique in that it has certain features that enable it to be the building block of all organic compounds.

4.1 State THREE features of the carbon atom responsible for giving carbon this uniqueness. (3)

4.2 Draw a Lewis Diagram to represent a molecule of methane. (2)

4.3 Consider the organic compounds represented by the letters **A** to **F** listed below:

A	$CH_3CH_2CH_2C\ell$	**B**	CH_3COOCH_3	**C**	$CH_3CH_2CH_3$
D	$CH_3CH_2CH_2OH$	**E**	CH_3CHCH_2	**F**	HCOOH

4.3.1 Give the IUPAC name for compound **A**. (2)

4.3.2 Which formula represents an unsaturated hydrocarbon? Write down only the correct letter. (1)

4.3.3 Give the names of the homologous series to which
(a) compound A
(b) compound B
belong. (2)

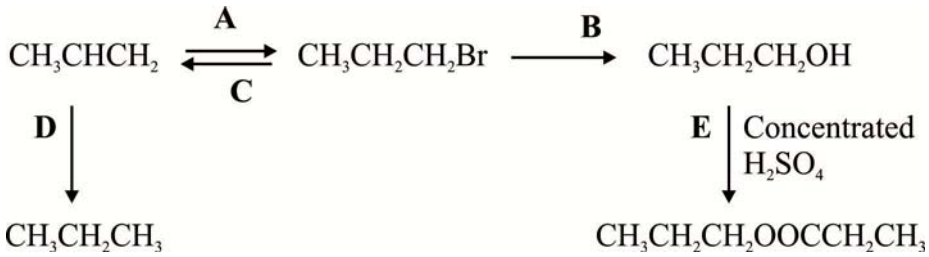
4.3.4 Give the names of the functional groups represented in compounds **D** and **F**. (2)

4.3.5 Name the chemical test that is carried out to distinguish between compounds **C** and **E** and list the observations that are made. (3)

4.3.6 Explain, with reference to the relevant intermolecular forces, why compound **D** is a liquid at room temperature whereas compound **C** is a gas. (4)

4.3.7 Write down a balanced chemical equation for the complete combustion of compound **D** in oxygen using molecular formulae. (3)

4.4 Consider the following sequence of organic reactions and then answer the questions that follow. Reactions are labelled **A** to **E**.



4.4.1 Which one of the reactions **A** to **E** is …?
(Only write down the question number (a) to (d) and the letter you choose next to it).

(a) a hydrolysis reaction
(b) a hydrohalogenation reaction
(c) a hydrogenation reaction
(d) a dehydration reaction (4)

4.4.2 Provide the chemical formula of a reagent that needs to be added for the following to occur:

(a) Reaction **B**
(b) Reaction **A** (2)

4.4.3 Consider the product formed in reaction **E**. It is able to exist in two distinct isomeric forms, one as a positional isomer and the other as a functional isomer.

(a) Define the term 'isomers'. (2)
(b) State the difference between positional and functional isomerism. (4)
(c) (i) Draw the structural formula of a positional and a functional isomer of the product formed in reaction **E**. (2)
(ii) Write down the IUPAC name of each isomer in Question 4.4.3 (c)(i). (4)

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QUESTION 5

Nitrogen monoxide, released from the combustion engines of motor vehicles, reacts with oxygen in the atmosphere to produce nitrogen dioxide. This reaction can be simulated in a closed reaction container of volume 500 cm^3 at a temperature of 100 ^oC. The reaction reaches equilibrium according to the following chemical equation:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

Initially 4 mol of NO and 2,5 mol of O_2 were placed in the reaction container with an unknown amount of NO_2. When equilibrium was established, it was found that the concentration of NO present in the reaction container was 6,5 $mol \cdot dm^{-3}$. The equilibrium constant, K_c, for the reaction at 100 ºC is 0,25.

5.1 State Le Chatelier's Principle. (3)

5.2 A chemical equilibrium occurs in a 'closed system'. State what is meant by the term 'closed system'. (2)

5.3 Calculate the number of moles of NO present at equilibrium. (3)

5.4 Calculate the number of moles of NO that were used up in reaching equilibrium. (2)

5.5 Calculate the concentration of O_2 at equilibrium. (4)

5.6 Write down the expression for the equilibrium constant (K_c) for this reaction. (1)

5.7 Using the expression in Question 5.6 to assist in your calculation, determine the number of moles of NO_2 present in the system at equilibrium. (4)

5.8 Calculate the number of moles of NO_2 initially present in the reaction container. (4)

5.9 When the temperature of the reaction mixture was increased from 100 ^oC to 175 ^oC, the value of K_c decreased to 0,15. Is the forward reaction exothermic or endothermic? Explain your answer by using Le Chatelier's principle. (5)

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QUESTION 6

6.1 Indicators (generally represented as HIn) are organic compounds which display characteristic colours when placed in either an acidic or basic solution. They are generally weak acids which will ionise in water to reach the following dynamic equilibrium.

$$\underset{\text{(yellow)}}{HIn(aq)} + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + \underset{\text{(blue)}}{In^-(aq)}$$

Bromothymol blue is an indicator which is yellow in an acidic medium and blue in an alkali.

6.1.1 Define an acid **and** a base in terms of the Brønsted-Lowry model. (2)

6.1.2 Indicators are said to be weak acids. State what is meant by the term 'weak acid'. (2)

6.1.3 By referring to Le Chatelier's principle, explain why bromothymol blue displays a blue colour when placed in a solution of sodium hydroxide. (4)

6.2 Potassium hydroxide is a strong base that dissociates when placed in water. A standard solution of potassium hydroxide of concentration 0,45 mol·dm^{-3} is prepared in a 250 cm^3 volumetric flask at a temperature of 298 K.

6.2.1 State what is meant by the term 'standard solution'. (2)

6.2.2 Write down a chemical equation to show the dissociation of potassium hydroxide in water. (2)

6.2.3 Calculate the mass of potassium hydroxide used in the preparation of the standard solution. (5)

6.2.4 The ionisation constant for water (K_w) is 1×10^{-14} at 298 K. Calculate the concentration of hydronium ions in the potassium hydroxide solution at 298 K. (4)

The standard potassium hydroxide solution prepared in Question 6.2 is used to determine the unknown concentration of a solution of the weak acid, oxalic acid $(COOH)_2$. 25 cm^3 of oxalic acid is placed in a conical flask with a few drops of indicator. Exactly 15 cm^3 of potassium hydroxide is required to reach the equivalence point in the titration according to the following balanced chemical equation:

$$(COOH)_2(aq) + 2KOH(aq) \longrightarrow (COOK)_2(aq) + 2H_2O(\ell)$$

6.2.5 State what is meant by the term 'equivalence point' in a titration. (2)

6.2.6 Calculate the number of moles of potassium hydroxide used in the titration. (2)

6.2.7 Calculate the number of moles of oxalic acid that were neutralised by the potassium hydroxide. (2)

6.2.8 Calculate the unknown concentration of the oxalic acid. (3)

The table below lists the indicators that are most commonly used in a school laboratory.

Indicator	pH range or sensitivity range
Bromothymol blue	6,0 to 7,6
Methyl orange	3,1 to 4,4
Phenolphthalein	8,3 to 10

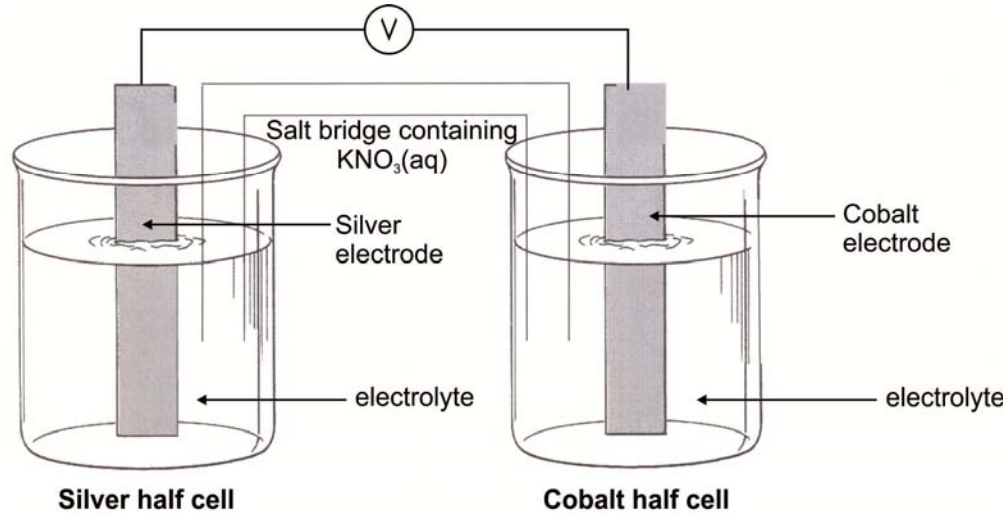
6.2.9 Explain what is meant by the term 'hydrolysis'. (2)

6.2.10 Which indicator would best be suited for the titration of the potassium hydroxide solution against the oxalic acid solution? Use your knowledge of hydrolysis to explain your answer. (4)

[36]

QUESTION 7

Consider the silver-cobalt galvanic cell that is shown in the diagram below which is operated under standard conditions. The two half cells are connected by a salt bridge which contains an aqueous saturated solution of potassium nitrate.



7.1 State what is meant by the following terms:

7.1.1 electrolyte (2)

7.1.2 half cell (2)

7.2 State the energy conversion that takes place in a galvanic cell. (2)

7.3 Name a suitable electrolyte that could be used in the silver half cell. (1)

7.4 State what is meant by the term 'standard conditions' with particular reference to the silver half cell. (2)

7.5 Identify the half cell that is the anode in this galvanic cell. (1)

7.6 Will the electrode in the cathode half cell increase or decrease in mass as the galvanic cell delivers current? Explain your answer. (3)

7.7 The cell delivers 0,75 A of current for 10 minutes. Calculate the increase or decrease in mass that the cathode will experience during this time period (assume concentrations of electrolytes remain constant). (5)

7.8 Write down the net cell reaction for the silver-cobalt galvanic cell. (3)

7.9 With reference to the changing ionic conditions in each half cell, explain how the salt bridge functions to maintain half cell neutrality within each half cell. (4)

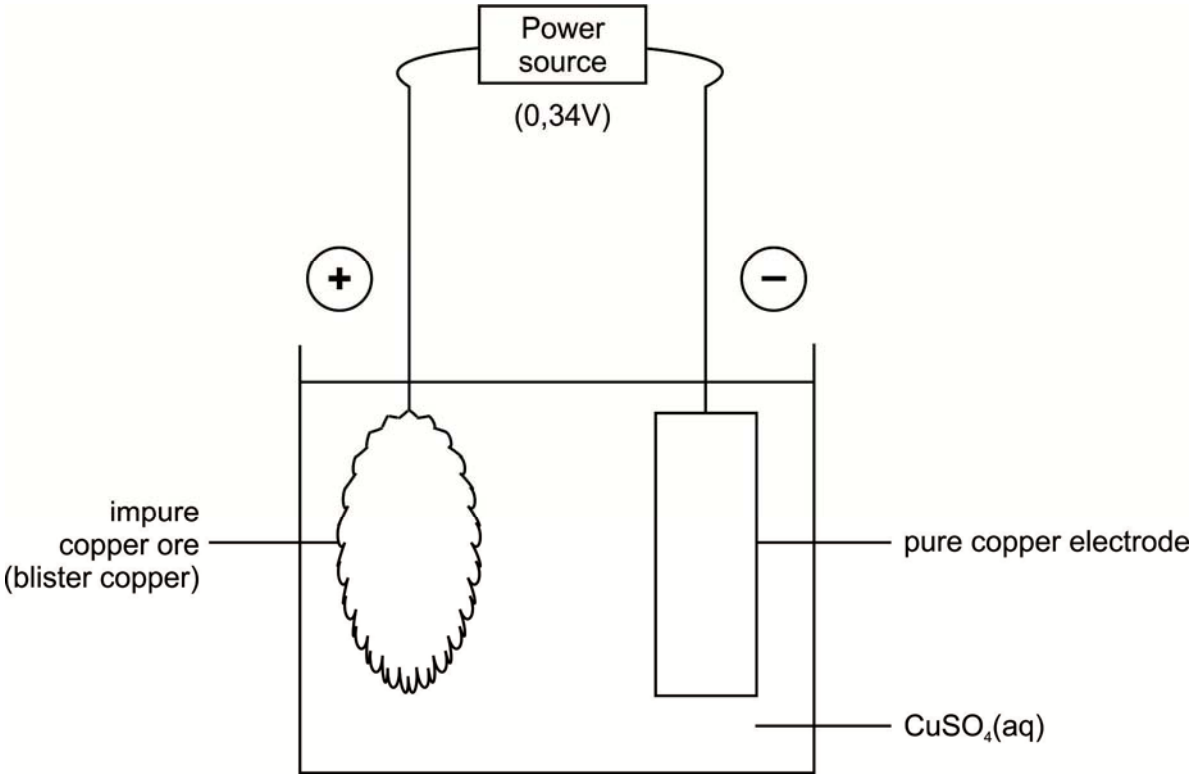
7.10 Aqueous potassium nitrate is a very popular electrolyte used in the salt bridge of a galvanic cell. Explain the significance of using an electrolyte such as potassium nitrate. (2)

7.11 With reference to the standard cell conditions, write the full cell notation for this galvanic cell. (3)

[30]

QUESTION 8

Copper is a metal that can be purified from its ore through an electrolytic technique. The impure copper ore, known as blister copper, is the anode of the cell while a pure copper plate is used as the cathode. These electrodes are placed in an electrolyte of aqueous copper sulphate as shown in the diagram below



Blister copper contains several metal impurities, most commonly silver (Ag), gold (Au), iron (Fe) and zinc (Zn).

8.1 Name the electrolytic technique described in this question. (1)

8.2 Write down the half reaction that occurs at the cathode. (1)

8.3 Use the table of Standard Electrode Potentials to explain each of the following:

8.3.1 Why copper metal and not water is oxidised at the anode. (2)

8.3.2 With reference to the potential difference applied in the purification, explain why iron and zinc will be oxidised at the anode, but gold and silver are not. (3)

8.3.3 Why $Fe^{2+}(aq)$ and $Zn^{2+}(aq)$ are not reduced at the cathode. (2)

8.4 Write down the net cell reaction for the purification of impure copper metal. (2)

[11]

Total: 200 marks