SCOTTISH CERTIFICATE OF EDUCATION

CHEMISTRY

Higher Grade—PAPER II

Friday, 6th May—1.30 p.m. to 4.00 p.m.

Candidates are reminded that 4 marks are allocated for communication skills, assessed in Part B of this paper.

Working should be shown in all answers involving calculations.

Necessary tables and data will be found in the booklets of Mathematical Tables and Science Data (1982 editions).

PART A (48 marks)

All questions should be attempted. It should be noted, however, that questions 5 and 12 contain a choice.

It is suggested that about $1\frac{1}{4}$ hours be spent on this part of the paper.

Marks

1. Name the type of chemical reaction in each of the following:

    (a) $Pb(NO_3)_2(aq) + 2NaI(aq) \rightarrow PbI_2(s) + 2NaNO_3(aq)$ **1**

    (b) $PCl_5(s) + H_2O(\ell) \rightarrow POCl_3(\ell) + 2HCl(g)$ **1**

    (2)

2. (a) Explain the change in atomic (covalent) radius of the elements

    (i) across the Periodic Table from lithium to fluorine;

    (ii) down Group I from lithium to caesium.   **2**

    (b) Which two elements, of all those considered in (a), form the compound with most ionic character?   **1**

    (3)

3. When an aqueous solution of sodium hydroxide is electrolysed, oxygen is formed at the positive electrode.

$$4OH^-(aq) \rightarrow 2H_2O(\ell) + O_2(g) + 4e^-$$

    If the volume of oxygen formed (at s.t.p.) is $112\,cm^3$, calculate

    (a) the number of moles of electrons involved;   **3**

    (b) the actual number of electrons this represents.   **1**

    (4)

4. (a) Part of a radioactive decay series is shown below.

$$^{231}_{90}Th \xrightarrow[\text{decay}]{\beta} \text{isotope X} \longrightarrow \text{isotope Y} \xrightarrow[\text{decay}]{\beta} {}^{227}_{90}Th$$

    (i) Identify isotopes X and Y.   **2**

    (ii) Which type of decay occurs between isotope X and isotope Y?   **1**

    (b) The radioactive isotope $^{210}_{84}Po$ decays to $^{206}_{82}Pb$, which is stable. Calculate the mass of lead which would be formed from 1 mole of $^{210}_{84}Po$ after **two** half-lives.   **2**

    (5)

5. Answer **EITHER** A **OR** B.

    A. $CH_3NHNH_2(\ell) + 2\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 3H_2O(\ell) + N_2(g)$ $\Delta H = -1305\,kJ\,mol^{-1}$
    methylhydrazine

    Using the above information, together with information on page 2 of the Data Booklet, calculate the Enthalpy of Formation of methylhydrazine.   **(5)**

OR

    B. $Si_2H_6(g) \rightarrow 2Si(s) + 3H_2(g)$ $\Delta H = -78\,kJ\,mol^{-1}$
    disilane

    Given that the Enthalpy of Sublimation of silicon is $439\,kJ\,mol^{-1}$, use the above information, together with information on page 7 of the Data Booklet, to calculate the bond enthalpy of the Si–H bond in disilane.   **(5)**

6.
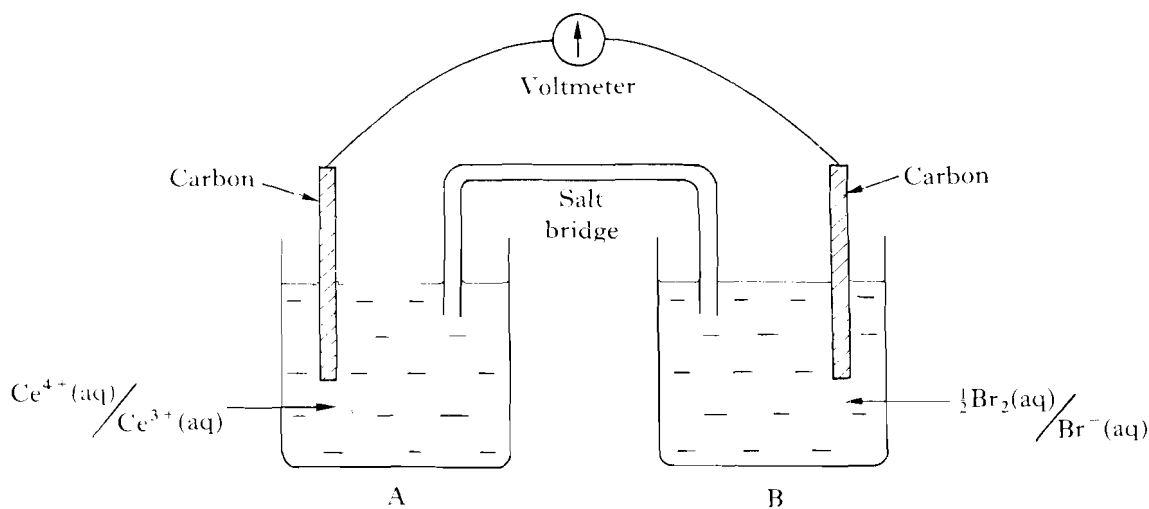
The half-reaction $Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq)$ has a Standard Reduction Potential of $+1.45\,V$.

(*a*) In which direction will electrons flow in the external circuit? (Data Booklet, page 6)   **1**

(*b*) What will gradually happen to the colour intensity of the solution in beaker B as the cell is operating?   **1**

(*c*) Write a balanced ionic equation for the overall reaction.   **1**

   (3)

7. A compound has the following percentage composition by mass:

Element	Hydrogen	Nitrogen	Oxygen
Percentage composition by mass	5	35	60

(*a*) Calculate the empirical (simplest) formula for the compound.   **2**

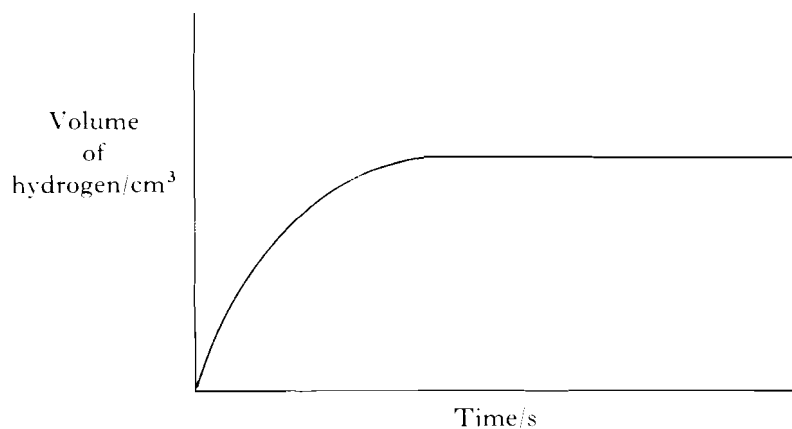(*b*) The compound gives a positive "brown ring" test. What is the name of the compound?   **1**

   (3)

[Turn over

8. (*a*) In an experiment on reaction rate, 6·5 g of powdered zinc was added to 25 cm^3 of 2 M sulphuric acid.

Show by calculation which reactant was in excess. **3**

(*b*) The following graph was obtained from the results of the experiment.

Copy the graph into your answer book (no graph paper required) and add a dotted line to represent the graph obtained when the same mass of powdered zinc is added to 25 cm^3 of 2 M hydrochloric acid. **1**
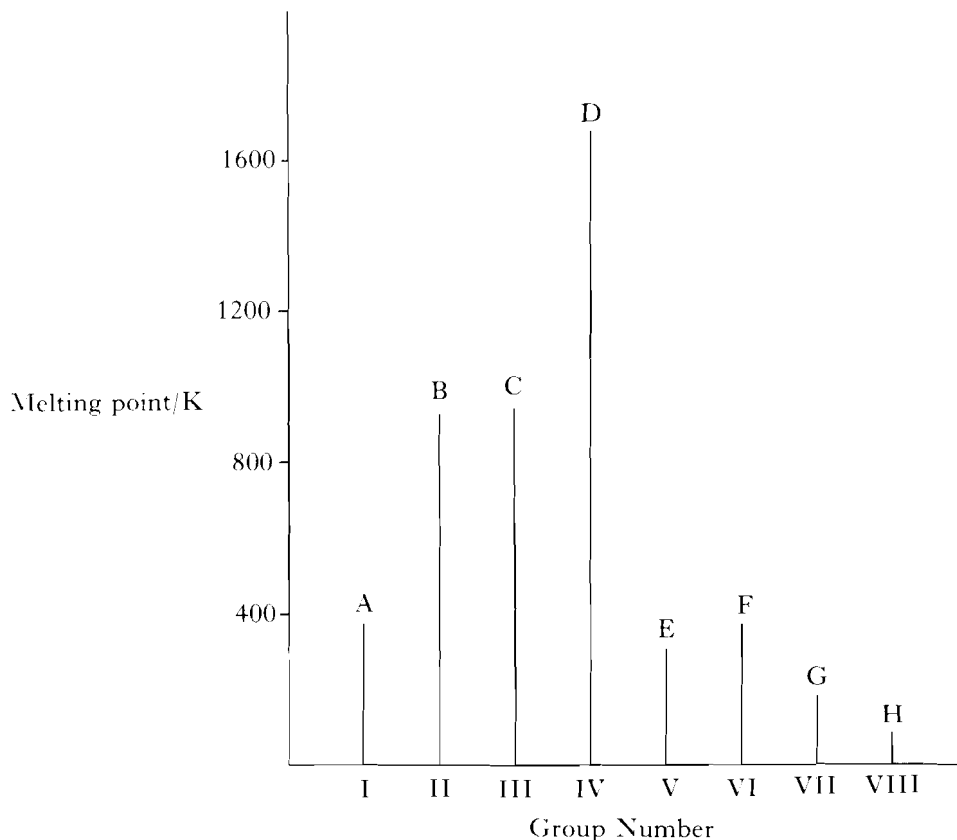
(4)

9. A constant current was passed through molten tin(II) chloride for 16 minutes 5 seconds and the mass of tin deposited was 2·38 g. Calculate the current used. **(3)**

10.

The graph shows the melting points for the elements across a Period in the Periodic Table.

(a) Identify the Period represented by the graph. **1**

(b) The bonding in both elements A and B is metallic.

Suggest why the melting point of element B is higher than that of element A. **1**

(c) Elements D and E are both covalently bonded. In terms of structure, account for the large difference in their melting points. **1**

(3)

11. Using information from the Data Booklet (page 5) show, by calculation, whether iron(II) oxide is more likely to have a crystal structure similar to sodium chloride or similar to caesium chloride. **(2)**

[Turn over

12. Answer **EITHER** A **OR** B

A.   Consider the reactions which occur between the reactants shown in boxes "A to F".

$C_2H_4(g) + H_2(g) \rightarrow$		$HCOOH(aq) + NaOH(aq) \rightarrow$		$CH_3I(\ell) + KOH(aq) \rightarrow$	
	A		B		C
$HCHO(g) + CuO(s) \rightarrow$		$C_2H_5OH(\ell) + Na(s) \rightarrow$		$C_2H_5COOCH_3(\ell) +$ $NaOH(aq) \rightarrow$	
	D		E		F

Answer the questions which follow by giving the **box reference letter.**

(*a*)   Which reaction involves the hydrolysis of an ester?

(*b*)   In which reaction will hydrogen gas be formed?

(*c*)   Which reaction will produce an **organic product** which in aqueous solution will have a pH less than that of the **organic reactant**?

(*d*)   Which reaction involves the combination of $H^+(aq)$ and $OH^-(aq)$ ions?

(*e*)   Which reaction will give a product the same as the organic product obtained in reaction C?   **(5)**

OR

B.   Consider the changes shown in boxes "M to R".

$Cl_2(g) \rightarrow Cl(g) + Cl(g)$		$Cl_2(\ell) \rightarrow Cl_2(g)$		$HCl(g) \rightarrow H(g) + Cl(g)$	
	M		N		O
$Cl(g) + H_2(g) \rightarrow HCl(g) + H(g)$		$HCl(g) \xrightarrow{\text{water}} H^+(aq) +$ $Cl^-(aq)$		$Cl(g) + e^- \rightarrow Cl^-(g)$	
	P		Q		R

Answer the questions which follow by giving the **box reference letter.**

(*a*)   In which change are only van der Waals' forces broken?

(*b*)   For which change would the ΔH value be the bond enthalpy of a polar covalent bond?

(*c*)   Which change does not involve any endothermic steps?

(*d*)   Which change results in a pH decrease?

(*e*)   Which change could be an intermediate (propagating) step in a chain reaction?   **(5)**

13.

$$C_{12}H_{25} \underset{\text{a sodium sulphonate}}{\bigcirc} SO_3^- Na^+$$
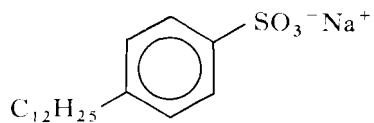
a sodium sulphonate

(*a*) Some sodium sulphonates are used as soapless detergents. They are designed to contain two distinct parts—one hydrophilic ("water loving"), the other hydrophobic ("water hating").

Draw the part of the above detergent which is hydrophobic.   **1**

(*b*)   (i) Give the formulae of **two** ions present in hard water which interfere with the cleansing action of soap.   **1**

    (ii) Explain why these ions do not cause the same problem with soapless detergents.   **1**

(*c*) The above sodium sulphonate is alkaline in aqueous solution.

    (i) What does this tell you about the sulphonic acid from which it is made?   **1**

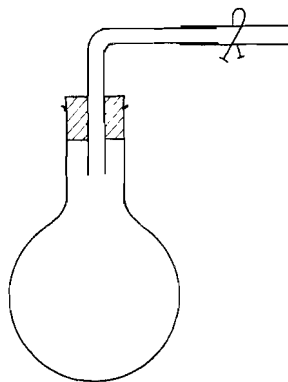   (ii) Explain why the sodium sulphonate solution is alkaline.   **2**

           (6)

[Turn over

All four questions should be attempted. It should be noted however that question 17 contains a choice.

Candidates are advised to spend about $1\frac{1}{4}$ hours on this part.

Marks

14. (*a*) The following apparatus was used to determine experimentally the volume of one mole of sulphur dioxide.


The flask was carefully dried, evacuated, then accurately weighed. Sulphur dioxide was allowed to enter the flask and the apparatus reweighed. The results obtained were:

mass of evacuated flask $= 512 \cdot 97 \, g$
mass of flask + sulphur dioxide $= 514 \cdot 57 \, g$
capacity of flask $= 600 \, cm^3$

(i) Use these results to calculate the volume of 1 mole of sulphur dioxide (under the experimental conditions of temperature and pressure). **2**

(ii) Give a reason why the apparatus has to be dry before the experiment is carried out. **1**

(iii) Describe how the capacity of the flask could be measured experimentally. **1**

(iv) Using the same flask, the experiment was repeated with gas X which was known to have a density of $2 \cdot 14 \times 10^{-3} \, g \, cm^{-3}$.

Explain whether the result "mass of flask + gas X" should be greater than or less than $514 \cdot 57 \, g$. (Data Booklet page 9) **1**

(*b*) The conversion of sulphur dioxide to sulphur trioxide is an equilibrium reaction. Assuming an equilibrium situation exists in which only 50% of the available sulphur dioxide is converted to sulphur trioxide, calculate the volume and composition of the resulting gas mixture when $100 \, cm^3$ of sulphur dioxide is mixed with $100 \, cm^3$ (excess) oxygen. **3**

(*c*) In another experiment, sulphur dioxide was dissolved in water to give sulphurous acid solution.

Given $0 \cdot 1 \, M$ sodium hydroxide solution, describe

(i) how you would determine experimentally the molarity of the sulphurous acid solution; **2**

(ii) how you would work out the results. **2**

(12)

15. Synthesis gas, a mixture of hydrogen and carbon monoxide, is prepared as shown below. Nickel is known to catalyse the reaction.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$$
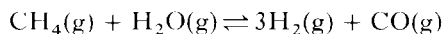
(*a*)　(i) An increase in temperature increases the yield of synthesis gas. What information does this give about the enthalpy change in the forward reaction?　**1**

(ii) Using Le Chatelier's Principle, explain how a change in pressure will affect the composition of the equilibrium mixture.　**2**

(iii) State how the rate of formation of synthesis gas will be affected by the use of the catalyst.　**1**

(iv) State how the composition of the equilibrium mixture will be affected by the use of the catalyst.　**1**

(*b*)　A reaction sequence involving an addition reaction between synthesis gas and propene is shown below.

$$2H_2(g) + 2CO(g) + 2C_3H_6(g) \rightarrow CH_3CH_2CH_2CHO(\ell) + \text{compound B}$$

compound A

↓ 　　　　　　　↓

butan-1-ol 　　　alkanol C
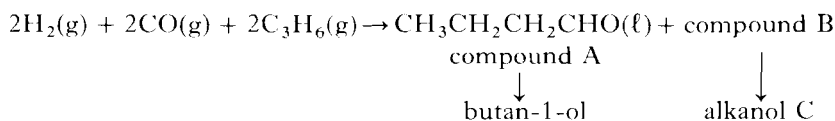
Compound A and compound B are isomers and belong to the same class of organic compounds.

(i) Name the class of organic compounds to which A and B belong.　**1**

(ii) Draw the full structural formula of compound B and name it.　**2**

(iii) If hexan-1-ol was required as a product instead of butan-1-ol, which reagent would be used in place of propene?　**1**

(iv) Will alkanol C be primary, secondary or tertiary?　**1**

(*c*)　(i) Which type of chemical reaction occurs when butan-1-ol reacts with ethanoic acid in the presence of concentrated sulphuric acid?　**1**

(ii) Draw the full structural formula for the organic product in (*c*) (i).　**1**

(12)

[Turn over

16. (*a*) The electrolysis of a saturated, aqueous solution of sodium chloride produces chlorine in commercial quantities at the positive electrode.

    (i) From a consideration of the Standard Reduction Potentials, predict which ion in the solution should be discharged at the positive electrode. (Data Booklet pages 6, 7)   **1**

    (ii) Explain why, in practice, the chloride ion is discharged.   **1**

    (iii) Which solution will also be available in commercial quantities as a result of this electrolysis?   **1**

(*b*) A gas jar of dry chlorine can be prepared by adding dilute mineral acid, at a controlled rate, to bleaching powder and drying the resulting gas with concentrated sulphuric acid.

Draw a labelled diagram of apparatus which could be used to prepare, dry and collect a jar of chlorine gas.   **2**

(*c*) In the redox reaction between solutions of sodium persulphate ($Na_2S_2O_8$) and sodium iodide, persulphate ions are reduced to sulphate ions. Iodine is the other product.

    (i) Write the ion-electron half-reaction equations for this reaction.   **2**

    (ii) Given that the E° value for the reduction of persulphate ions to sulphate ions is $+2\cdot01$ V, predict the voltage which would be obtained if the reaction in (i) was carried out in the form of a cell. (Data Booklet page 6)   **1**

(*d*)

Halogen	b.p./K	1st Ionisation Energy/kJ mol^{-1}
Fluorine	85	1690
Chlorine	238	1260
Bromine	332	1150
Iodine	457	1020

Hydrogen halide	b.p./K	Effect of heating
Hydrogen fluoride	293	does not decompose
Hydrogen chloride	159	very slight decomposition
Hydrogen bromide	186	decomposes to some extent
Hydrogen iodide	238	decomposes very readily

State, in each case, the main factor influencing

    (i) the steady increase in the boiling points of the halogens;   **1**

    (ii) the steady decrease in the first Ionisation Energies of the halogens;   **1**

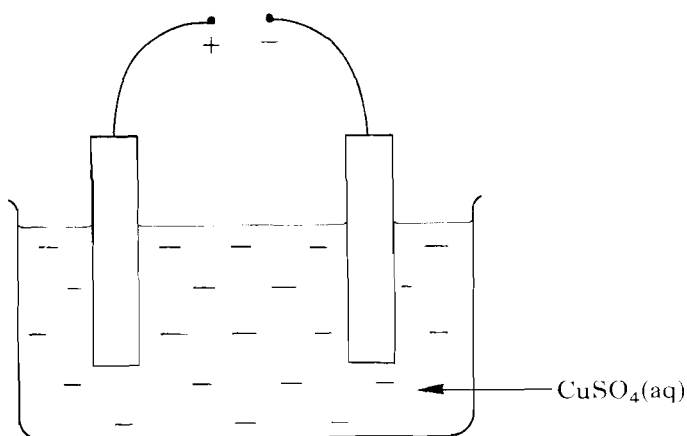   (iii) the anomalous boiling point of hydrogen fluoride;   **1**

    (iv) the different effects of heat on the hydrogen halides.   **1**

    (12)

17. ANSWER EITHER A OR B

A. There are two main stages in the extraction of copper from sulphide ores such as chalcopyrite ($CuFeS_2$).

Stage 1   Matte Smelting

This stage produces a liquid sulphide (called the matte) and a liquid slag. The finely divided concentrated ore is mixed with sand and blown into the furnace by oxygen as shown in the diagram.

$$4CuFeS_2(s) + 2SiO_2(s) + 5O_2(g) \rightarrow 2Cu_2S.FeS(\ell) + 2FeSiO_3(\ell) + 4SO_2(g) \quad (\Delta H \ -ve)$$
(chalcopyrite) (sand)   (matte)   (slag)

Stage 2 —Conversion to copper

Air is blown through a mixture of liquid matte and more sand at a temperature of about 1400 K. The iron(II) sulphide content of the matte reacts with oxygen and sand to form more slag and sulphur dioxide. (This reaction is exothermic.) When the iron content of the matte falls to about $1°_0$, impure copper is formed. The equation for this reaction is

$$Cu_2S(\ell) + O_2(g) \rightarrow 2Cu(\ell) + SO_2(g)$$

(a) Why is the ore blown into the furnace as a fine powder?   1

(b) From the equation, calculate the volume of oxygen (at s.t.p.) required to react completely with 1472 kg of chalcopyrite in Stage 1.   3

(c) Referring to the diagram, suggest a property of the matte which allows the matte and slag to be tapped off separately.   1

(d) The whole extraction process is economic as regards use of external fuel. Explain why this is so.   1

(e) Write a balanced equation for the reaction in Stage 2 when iron(II) sulphide is converted to slag.   2

[Turn over

17. A. (continued)

(*f*) The impure copper can be refined by electrolysis as follows:


(i) The impure copper acts as one electrode, with pure copper being used as the other electrode. Which is which?   **1**

(ii) Write the ion-electron equations for the half-reactions occurring at the electrodes, indicating which represents oxidation and which represents reduction.   **2**

(iii) Explain why iron, present as an impurity, is not deposited on the pure copper electrode.   **1**

                                                                                                                                                  (12)

OR

B. The flow diagram shows how a polyamine, used in the preparation of polyurethane foam, is manufactured.
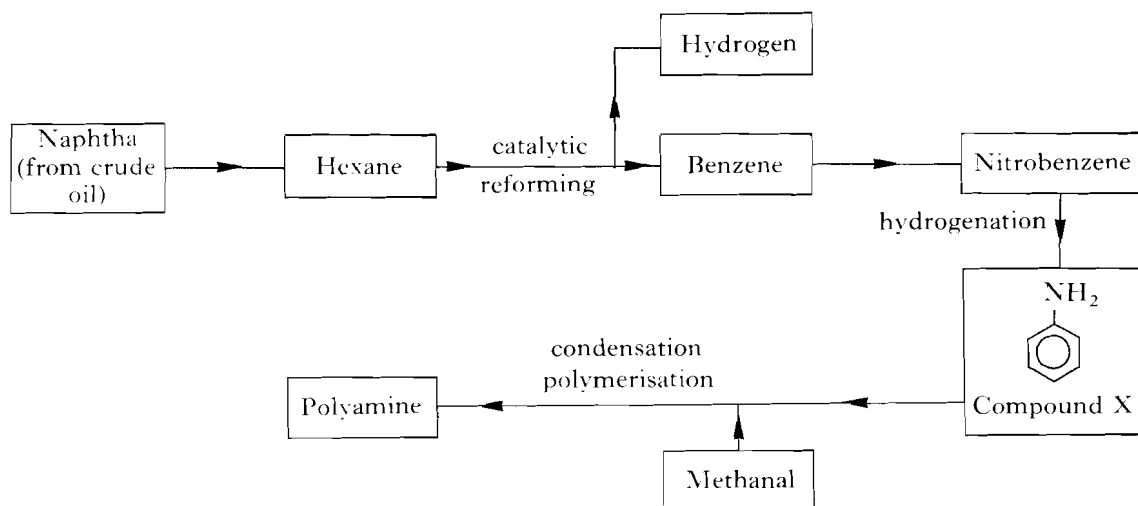
(a) Name the process by which naphtha is obtained from crude oil. 1

(b) (i) Write a balanced equation for the reforming of hexane to benzene and hydrogen. 1

   (ii) Calculate the volume of hydrogen (at s.t.p.) produced when 172 g of hexane is reformed. 2

(c) Give, in relation to the above process, an economic use for this hydrogen. 1

(d) The hexane often contains an impurity. When one mole of this impurity is reformed, it produces the same volume of hydrogen as hexane, but methylbenzene instead of benzene. Name this impurity. 1

(e) Which type of chemical reaction takes place when the benzene is converted to nitrobenzene? 1

(f) (i) Name compound X. 1

   (ii) Write a balanced equation to show the reaction between compound X and hydrochloric acid, showing the ionic product. 1

   (iii) Draw the full structural formula of methanal. 1

   (iv) Draw a possible structure of the compound formed when two molecules of compound X and one molecule of methanal react by a condensation reaction. 1

(g) The following compounds are basic:

NH_3 $CH_3CH_2NH_2$
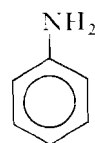
Arrange the three compounds in increasing order of strength as bases. 1

(12)

[END OF QUESTION PAPER]