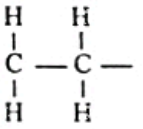
G.C.E. (A/L) Examination
2010 August
Chemistry II / Three hours

- Periodic Table is provided on page 13.
- Use of calculators is not allowed.

PART A - Structured Essay (Pages 2-7)

- Answer **all** the questions on this paper itself.
- Write your answer in the space provided for each question. Please note that the space provided is sufficient for the answer and that extensive answers are not expected.
- **In answering questions 3 and 4, you may represent alkyl groups in a condensed manner.**

e.g.  may be shown as CH_3CH_2 -

PART B and PART C - Essay (pages 8-13)

Answer **four** questions selecting **two** questions from each part. Use the paper supplied for this purpose.

At the end of the time allotted for this paper, tie the answers to three parts **A**, **B** and **C** together so that Part **A** is on top and hand them over to the Supervisor.

You are permitted to remove **only** Parts **B** and **C** of the question paper from the Examination Hall.

Take Universal gas constant, $R = 8.314\ JK^{-1}\ mol^{-1}$ and
Avogadro constant $N_A = 6.022 \times 10^{23}\ mol^{-1}$

PART A - STRUCTURED ESSAY

Answer **all four** questions on this paper itself. Each question carries **10 marks.**

1. (a) The following questions are based on the first 18 elements in the periodic table.

(i) Identify the **two** elements that form the bond with the highest ionic character. ..... and .....

(ii) Identify the element that forms the most stable diatomic molecule. .....

(iii) Identify the element that has the highest first ionization energy. .....

(iv) Identify two elements that form electron-deficient com pounds. ..... and .....

(v) Identify the element that has the highest melting point. .....

(vi) Identify the gaseous element that can be used as a fuel

(vii) There are seven consecutive elements where the maxi mum oxidation number of each element increases by one, when moving sequentially from the first to the seventh elements. Identify the first and the seventh elements in this sequence of elements.

First ..... Seventh .....

(viii) Identify one metallic element that is responsible for hardness in water. .....

(3.3 marks)

(b) X and Y are two elements in the same period of the periodic table where the atomic number of X is less than the atomic number of Y. The chlorides that are formed by X and Y with the maximum number of chlorine atoms are XCl_3 and YCl_5

(i) Write the chemical symbols of X and Y.

X = ... Y = ...

(ii) Name the shapes of XCl_3 and YCl_5 molecules.

XCl_3 : ..... YCl_5 : .....

(iii) XCl_3 reacts with YH_3 forming the compound Z. Draw the structure of Z in the box given below showing all the bonds.

(iv) Name the shapes (spatial arrangement of bonds) around X and Y in the molecule Z.

X : ..... Y : .....

(3.5 marks)

(c) Write the type of bond if any, and the type of intermolecular force if any (from those given in the table), present in each of the substances indicated in the table below.

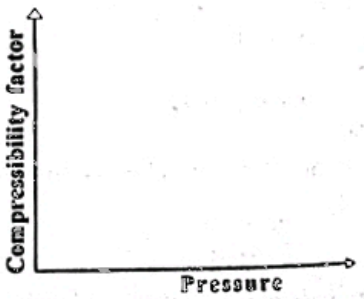
	Substance	Type of bond (ionic, polar covalent, nonpolar covalent)	Type of bintermolecular force (dipole-dipole, hydrogen bonding, London forces)
(i)	Iodine (solid)		
(ii)	Carbon tetracholoride (liquid)		
(iii)	Argon (liquid)		
(iv)	Sodium hydride (solid)		
(v)	Sulphur dioxide (gas)		

(3.5 marks)

2. (a) An alloy contains elements Mg and Al. The minimum volume of 3.60 mol dm^{-3} HCl that is required to completely dissolve a sample of the alloy of mass 0.396 g is 10.0 cm^3. Calculate the mass percentage of Mg in the alloy. (Mg = 24, Al = 27)

(4.0 marks)

(b) (i) Sketch below, the variation of the compressibility factor with pressure for an ideal gas. Indicate on the same diagram, the expected variation for a real gas.



II. State two reasons for the difference in the sketches you drew for the two types of gases.

(ii) At 300 K and at 3.0×10^5 Nm^{-2}, gas A exists in a vessel with a volume of 2.0 m^3. At 300 K and at 5.0×10^5 Nm^{-2}, gas B exists in a vessel with a volume of 3.0 m^3. The vessels are connected allowing the two gases to mix completely. During the mixing, no chemical reactions occur. Further, the temperature and the total volume of the two gases remain unchanged. Assuming the ideal gas behaviour, Calculate the following :

I. the total pressure in the connected vessels.

II. the mole fraction of gas B in the mixture.

III. the partial pressure of gas B in the connected vessels when the temperature of the gas mixture is increased to 350 K maintaining the total volume of the two vessels the same.

(6.0 marks)

3 (a) (i) Draw the structure of 2-methylpropene

(ii) Draw in the boxes P and Q respectively, the structures of the major product and the minor product formed when HBr is added to 2-methylpropene

P:Major product

Q: Minor product

(iii) Propose a mechanism for the addition of HBr to 2-methylpropene, explaining why the structure drawn in box P is the major product. [*Hint : In answering this part utilize your knowledge of the mechanism of addition of HBr to praopene, and the stability of carbocations.*]

(3.5 marks)

(b) Compound A (molecular formula, $C_6H_{14}O$). exhibits optical isomerism. It reacts with acidic $K_2Cr_2O_7$ at room temperature and gives a carboxylic acid.

(i) Draw possible structures for A in the boxes given below.

(ii) Compound A when heated with conc. H_2SO_4 gives com pound B (molecular formula, C_6H_{12}).

Compound B also exhibits optical isomerism. Draw the structures of A and B in the relevant boxes.

A B

(iii) When B is reacted with HBr,compound C is obtained as the major product. Compound C when reacted with alcoholic KOH gives compounds D and E. Compounds D and E are structural isomers of B. Draw the structures of C, D and E in the boxes given below.

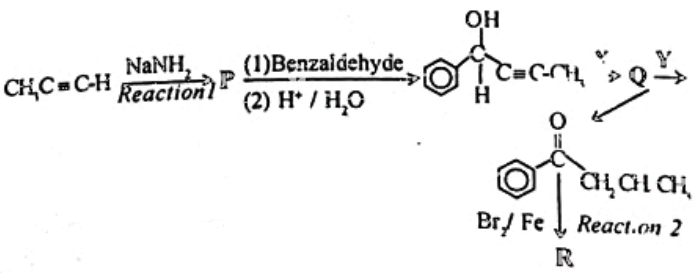
C D E

(iv) Both compounds D and E when reacted separately with dil. H_2SO_4 give the same compound F. Compound F is a structural isomer of A. Draw the structure of F in the box given below.

F

(6.5 marks)

4. (a) Consider the reaction scheme given below.



(i) Draw the structures of compounds P, Q and R in the boxes given below.

P Q R

(ii) Write the reagents, X and Y in the boxes given below.

X Y

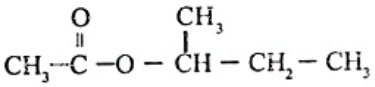
(iii) Classify the reactions labelled as *Reaction 1* and *Reaction 2*, as nucleophilic substitution (S_N), electrophilic substitution (S_E), nucleophilic addition (A_N), electrophilic addition (A_E), or acid-base reaction (A_B).

Reaction 1		*Reaction 2*	

(iv) Recalling the reaction of alkylhalides with KCN, write the structure of the product obtained when compound P reacts with CH_3Br.

(2.5 marks)

(b) Using only the chemicals and reagents given in the list propose a synthesis of the following compound.

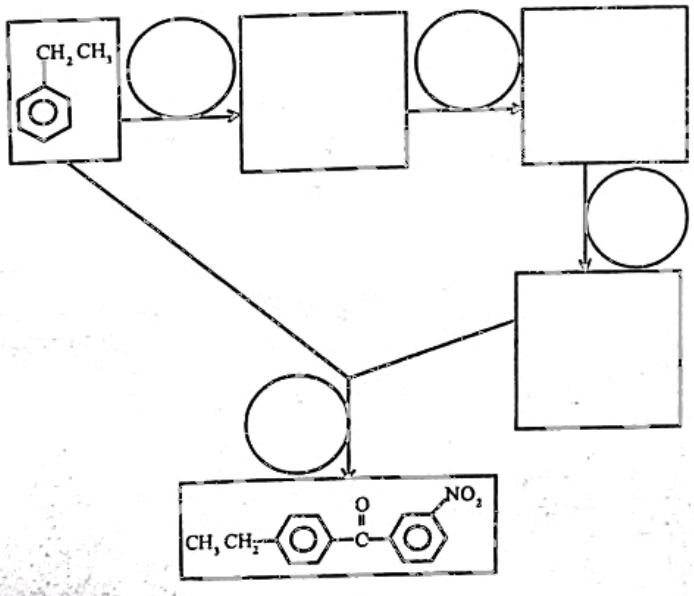


List of chemicals and reagents :

CH_3CHO, PBr_3, Mg, ether, dil H_2SO_4, $NaBH_4$, $K_2Cr_2O_7$, conc.H_2SO_4

(4.7 marks)

(c) Complete the following reaction scheme, by writing the structures of compounds in the boxes and the reagents in circles.



(4.7 marks)

PART B - ESSAY

Answer two questions only. (Each question carries 15 marks.)

Universal gas constant. $R = 8.314\ JK^{-1}\ mol^{-1}$ and Avogadro Constant $N_A = 6.022 \times 10^{23}\ mol^{-1}$

5. (a) Calculate the enthalpy change for the reaction,

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

at 25°C , using the thermochemical data given below.
At 25°C,

Bond dissociation enthalpy of $O_2(g)$	=	498 kJ mol^{-1}
First electron affinity of O(g)	=	-149 kJ mol^{-1}
Second electron affinity of O(g)	=	798 kJ mol^{-1}
Enthalpy of sublimation of Mg (s)	=	148 kJ mol^{-1}
First ionization energy of Mg(g)	=	738 kJ mol^{-1}
Second ionization energy of Mg(g)	=	1451 kJ mol^{-1}
Lattice energy of MgO(s)	=	-3791 kJ mol^{-1}

(6.0 marks)

(b) The following equilibrium exists between A(g) and B(g) at temperatures above 300°C.

$$A(g) \rightleftharpoons 2B(g)$$

Both A(g) and B(g) behave ideally.

(i) 0.45 mol of A(g) were initially placed in a rigid, closed vessel of volume 4.157 dm^3. The vessel was then heated to 327°C to achieve the above equilibrium. The total pressure of the contents of the vessel was then found to be $9.00 \times 10^5\ Nm^{-2}$.

Calculate the following :

I. the total number of moles of the two gases A(g) and B(g) at equilibrium

II. the number of moles of each gas A(g) and B(g) at equilibrium.

III. the equilibrium constants K_p and K_c for the above equilibrium.

(ii) Then 0.30 mol of B(g) were added to the vessel and the system was allowed to reach equilibrium at the same temperature. The amount of A(g) after equilibrium is reached, is x mol more than the amount of A(g) that was present in the vessel before the addition of B(g). Derive a mathematical expression for the new partial pressure. P_A of A(g) in the vessel in terms of x. (This expression should not contain symbols other than x.)

(9.0 marks)

6. (a) Consider the raction, X(aq) + Y(aq) → Z(aq). Kinetic data obtained for different initial concentrations of X(aq) and Y(aq) in the reaction mixture are given in the table below.

Experiment number	Temperature / °C	Initial concentration/ mol dm^{-3}			Initial rate mol dm^{-3} s^{-1}
		X(aq)	Y(aq)	D(aq)	
1	30	1.0	0.50	–	0.0020
2	30	0.50	0.50	–	0.0010
3	30	0.50	1.0	–	0.0040
4	30	0.50	1.0	0.50	0.020
5	30	0.50	1.0	1.0	0.020
6	50	0.50	1.0	–	0.016

Experiments number 4 and 5 were conducted in the presence of substance D.

(i) Write a mathematical expression for the rate of the above reaction in terms of the concentrations of X(aq) and Y(aq)

(ii) Calculate the order of the above reaction with respect with respect to each reactant X(aq) and Y(aq) at 30 °C.

(iii) Calculate the initial rate of the above reaction at 30 °C, when the initial concentration of X(aq) is 0.50 mol dm^{-3} and the initial concentration of Y(aq) is 2.0 mol dm^{-3}.

(iv) What is the role of D(aq) in the reaction,

$X(aq) + Y(aq) \rightarrow Z(aq)$?

(v) Sketch the energy versus reaction coordinate curve for the rate determining step of the reaction in the absence of D. On the same diagram, sketch the curve for the reaction that occurs in the presence of D. Label the axes and both curves clearly in your diagram.

(vi) How would you explain the result of the initial rate of experiment number 6 in comparison with that of the initial rate of experiment number 3 ?

(6.0 marks)

(b) (i) Consider the solutions P,Q.R and S given below, that have been prepared at 25°C.

P : 100.0 cm3 of 0.056 mol dm^{-3} CH_3COOH.

Q : Mixture of 50.0 cm^3 of 0.056 mol dm^{-3} CH_3COOH and 50.0 cm^3 of 0.200 mol dm^{-3} HCl

R : Mixture of 50.0 cm^3 of 0.020 mol dm^{-3} HCl and 50.0 cm^3 of 0.022 mol dm^{-3} NaOH

S : 100.0 cm^3 of 0.056 mol dm^{-3} NaOH.

The dissociation constant, K_a of CH_3COOH and the ionic product of water, K_w at 25 °C are 1.8×10^{-5} mol dm^{-3} and 1.0×10^{-14} $mol^2 dm^{-6}$, respectively.

I. Calculate the pH of solution P, solution Q and solu tion R.

Stare assumptions, if any, you used in each of the calculations.

II. Indicate how you could prepare a buffer solution by using two of the solutions from among P, Q, R and S.

(ii) I. You are provided with a very dilute aqueous solution of an acid-base colour indicator. Very dilute aqueous solutions of HCl and NaOH together with facilities to measure pH of a solution are also provided. Briefly describe how you would determine the colour changing pH range of this indicator.

II. Figures 1 and 2 show pH - titration curves for titra tions of two acid/base pairs. A list of indicators with their colour changing pH rangges is provided in the table below. Select from the table, one suitable indicator each to be used in each of the titrations shown in Figres 1 and 2.

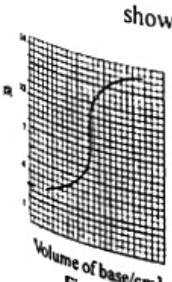


Figure 1

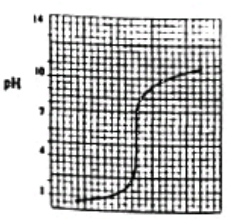


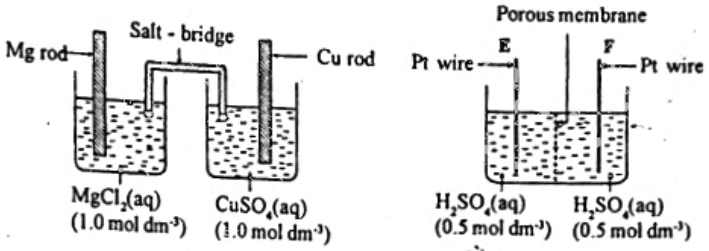
Figure 2

Table : Indicators and their pH ranges

Indicator	Colour changing pH
K	1.5 - 3.4
L	4.8 - 6.4
M	6.0 - 7.8
N	8.3 - 9.8
U	9.0 - 11.0

(9.0 marks)

7. (a) Consider the following two electrochemical cells. Which are operated at 25°C.



At 25 °C $E^0_{Mg^{2+}(aq)/Mg(s)} = -2.37$ V

$E^0_{Cu^{2+}(aq)/Cu(s)} = 0.34$ V

Questions (i) to (iii) relate to electrochemical cell A

(i) Calculate the electromotive force (e.m.f.) of the cell.

(ii) State whether teh cell e.m.f. would change, if a 1.0 mol dm^{-3} $MgSO_4$ solution was used instead of 1.0 mol dm^{-3} $MgCl_2$ solution in the cell. Explain your answer, briefly.

(iii) What is the function of the salt bridge?
Give an example of a compound that can be used to prepare the salt-bridge.

Questions (iv) and (v) relate to the electrochemical cell A in which the two electrodes are connected by a Cu wire.

(iv) State which electrode would function as the cathode.

(v) Write balanced equations for the following.
I. Cathodic reaction
II. anodic reaction
III. overall cell reaction

Questions (vi) to (viii) relate to the cell arrangement where the Cu rod and the Mg rod in cell A are connected respectively to electrode E and electrode F in cell B, using Cu wires.

(vi) Which electrode would behave as the cathode in cell B?

(vii) Write balanced equations for the reactions taking place at the following electrodes.
I. electrode E
II. electrode F

(viii) If the current circulating in the cell arrangement remains constant, state the change you would expect in the amount of product formed at electrode F in a given time interval, when
I. the areas of both electrodes E and F are increased,
II. the concentration of H_2SO_4 in cell B is increased.

(7.5 marks)

(b) At 25 °C, an aqueous solution of $AgNO_3$ of concentration 0.050 mol dm^{-3} was slowly added to a 100.0 cm^3 aqueous solution that contained Cl^- at a concentration of 0.0020 mol dm^{-3} and Br^- at a concentration of 0.0010 mol dm^{-3}

(i) Calculate the minimum concentration of Ag^+ ions required in solution to initiate the precipitation of AgBr.

(ii) Calculate the maximum concentration of Br^- ions that could remain in the solution when AgCl begins to precipitate.

(iii) State assumptions, if any, you used in the above calculations.

(iv) In qualitative analysis, once Cl^- ions are precipitated as AgCl, its solubility is tested using aqueous ammonia. Briefly explain the chemistry behind this process using suitable chemical equations.

At this temperature,

solubility product of AgCl = 1.7×10^{-10} $mol^2 dm^{-6}$
solubility product of AgBr = 5.0×10^{-13} $mol^2 dm^{-6}$

(7.5 marks)

PART C - ESSAY

Answer two questions only. (Each question carries **15 marks.**)

8. (a) The following questions are based on the oxides of nitrogen.

(i) Write the chemical formulae and common names of **five** oxides of nitrogen where the oxidation numbers of nitrogen are different from one another.
Give the oxidation number of nitrogen in each oxide you identified.
Indicate whether each oxide is acidic, basic or neutral.

(ii) Indicate how any three of the oxides listed in (i) above can be prepared in the laboratory.

(iii) Draw the resonance structures of the oxide of nitrogen where the oxidation number of nitrogen is +1.

(iv) Give **two** oxides of nitrogen which have unpaired electrons at room temperature and atmospheric pressure. State the chemical change that would take place when these oxides are cooled.

(6.0 marks)

(b) The 3d block element M forms a compound A, which has the formula $2MXO_3.M(OH)_2$. Here, the element X belongs to the p block. The compound A reacts with conc. HCl to give a colourless, odourless gas B and a yellow coloured solution C. When A reacts with dil. Hcl, it gives the same (colourless, odourless) gas B and a green coloured solution D containing two complex ions of M. When solution D is diluted with water, a light blue coloured solution E is formed. When a small amount of NH_4OH is added to E, a blue coloured gelatinous precipitate F is formed. F dissolves in excess NH_4OH to give a dark blue coloured solution G. When solution E is treated with excess KI, the precipitate MI and iodine are formed as the only products.

(i) Identify the elements M and X.

(ii) Give the electronic configuration of M.

(iii) Give the common oxidation numbers of M.

(iv) Write the formulae of the ionic species responsible for the colours of the following solutions and give their IUPAC names.

I. solution C
II. solution D
III. solution E
IV. solution G

(v) Identify the gas B and the precipitate F.

(vi) Give the balanced chemical equation for the reaction of solution E with excess KI.

(vii) Using the reaction of E with KI, state the steps involved in the experimental determination of the mass percentage of M in a sample of A provided.

Indicate how you would calculate the mass percentage of M from your experimental data.

(viii) Write separate balanced chemical equations for the reactions of M and X with hot conc. H_2SO_4.

(ix) When common salts of M are heated with certain easily oxidizable compounds under **basic** conditions, M_2O is precipitated. Write a balanced **half reaction** for this process and give **one** important use of this reaction.

(x) Give **two** important commercial uses of M.

(9.0 marks)

9. (a) The colourless aqueous solution P contains **three** metal ions as their nitrates. The tests performed with solution P together with their observations are given below.

Test	Observation
(1) Excess NH_4OH was added to solution P.	A white precipitate (soluble in dil. NaOH) was formed.
(2) The filtrate from test (1) was acidified with dil HCl.	A white precipitate (insoluble in dil. HNO_3) was formed.
(3) NH_4OH was addeddropwise to the filtrate from test (2).	A white precipitate was formed which dissolved on further addition of NH_4OH.

(i) Identify the metal ions in solution P.

(ii) Identify the white precipitates formed in tests (1), (2) and (3).

(iii) Give the observations that are expected when the precipitates of tests (1) and (3) are subjected to charcoal block test in the presence of cobalt nitrate.

(iv) Give the balanced chemical equation for the reaction of the white precipitate formed in test (1) with dil. NaOH.

(b) An aqueous solution Q contains **two** anions as their sodium salts. The tests performed with solution Q together with their observations are given below.

Test	Observation
(4) A solution of $BaCl_2$ was added to solution Q.	A white precipitate (soluble in dil. HNO_3) was formed.
(5) Acidified $KMnO_4$ was added to solution Q.	$KMnO_4$ solution was decolourized.
(6) A solution of $BaCl_2$ was added to the solution obtained after performing test (5).	A White precipitate (insoluble in dil HNO_3)
(7) (7.1) $Pb(NO_3)_2$ solution was added to solution Q.	A White precipitate was formed.
(7.2) The solution containing the white precipitate was boiled.	A portion of the precipitate dissolved.
(7.3) The mixture from (7.2) was filtered while hot.	A White precipitate in the form of needles was formed in the filtrate on cooling.

(i) Identify the two anions in solution Q.

(ii) Identify the white precipitates formed in tests (4) and (6).

(iii) Identify the white precipitate formed in the form of needles in test (7.3).

(iv) Give the balanced chemical equation for the reaction in test (5).

(3.5 marks)

(c) A sample of haematite are (Fe_2O_3) containing some amount of Fe_3O_4 and inert material was analysed to determine its purity using the following procedure.

An 8.00 g sample of the ore was treated with excess of aqueous KI(50 cm^3) in an acidic medium to convert all iron in the ore to Fe^{2+}. The solution was then diluted to 100.00 cm^3. When a 25.00 cm^3 portion of the diluted solution was titrated with 1.00 mol dm^{-3} $Na_2S_2O_3$, a volume of 24.00 cm^3 was required to reach the end point. Another 25.00 cm^3 portion of the diluted solution was shaken thoroughly with CCl_4 to completely remove the iodine and the resulting solution then titrated with a 1.00 mol dm^{-3} $KMnO_4$ solution. The end point was reached upon the addition of 5.20 cm^3 of the $KMnO_4$ solution.

(i) Write balanced chemical equations for the reactions of the following with aqueous potassium iodide in acidic medium.
(I) Fe_2O_3 (II) Fe_3O_4

(ii) Calculate the mass percentage of Fe_2O_3 in the ore.
(Fe = 56, O = 16)

(7.0 marks)

10. (a) Gases emitted from motor vehicles is one of the major sources of air pollution.

(i) List **six** pollutants present in motor vehicle emissions.

(ii) Name **two** pollutants given in answer to (i) above responsible for acid rain.

(iii) Indicate briefly how the **two** pollutants stated in (ii) above are formed during the combustion process.

(iv) Name **two** pollutants among the answers given in (i) above, responsible for the greenhouse effect.

(v) Indicate briefly how the pollutants given in (iv) above brings about the greenhouse effect?

(vi) Give **two** consequences of the greenhouse effect.

(vii) Name **two** methods used to minimize environmental pollution that occurs from motor vehicle emission.

(7.5 marks)

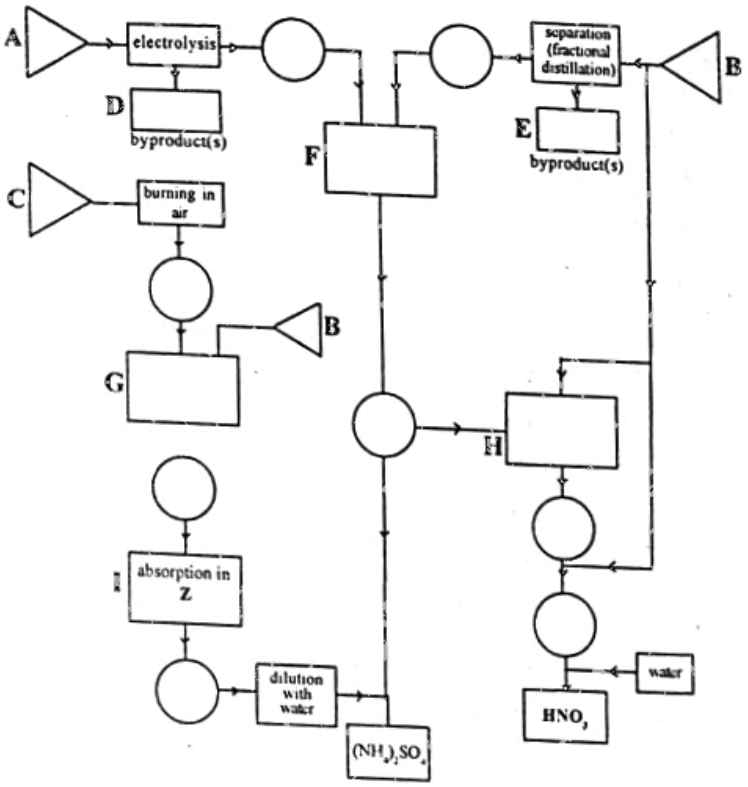
(b) Consider the flow chart given on **page 14** (See last page of **PART A**) for the manufacture of HNO_3 and $(NH_4)_2SO_4$ from the starting materials **A**, **B** and **C**. Complete the flow chart according to the instructions (o) given below and answer the questions given on page 14, relating to flow chart.

- Write in the triangles the names of the naturally available starting materials, **A**, **B** and **C**.
- Write in the circles the chemical formulae of the substances encountered in the process.
- Write in the boxes **F**, **G** and **H**, the conditions employed for the relevant reactions.
- Write in the boxes **D** and **E**, the byproducts of the relevant reactions/ processes.

(7.5 marks)

- **Only Use this page to answer question Number 10 of PART C. (Question Number 10 is not compulsory).**

10. (b)



(i) Identify **Z** : .....

(ii) Write balanced equations for the chemical reactions taking place at **F**, **G**, and **H**.

F : .....

G : .....

H : .....

The Periodic Table

1	1 H																2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	La-Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	Ac-Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub	113 Uut	....				

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr