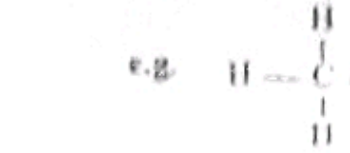
e.g.  may be shown as CH_3CH_3.

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.

Universal gas constant $R = 8.314\ JK^{-1}mol^{-1}$

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.**)

01 (a) Identify the elements described in (i) - (iv) below and write down their chemical symbols. Also write down these chemical symbols in the appropriate cages in the skeltal periodic table given in page 3.

(i) The element which is a liquid at room temperature and shows the maximum oxidation state of +7.

(ii) The element which forms a stable dichloride without completing the octet of electrons.

(iii) The non-metallic element of which an allotropic form is a good conductor of electricity.

(iv) The first row (3d) transition element forming a highly stable white coloured dioxide.

(b) A is non-transition element. It forms an oxide with molecular formula A_2O_3. The highest chloride formed by A is ACl_3. Identify A. (4 marks)

Write down the chemical symbol of A in the appropriate cage of the skeletal periodic table given in page 3.

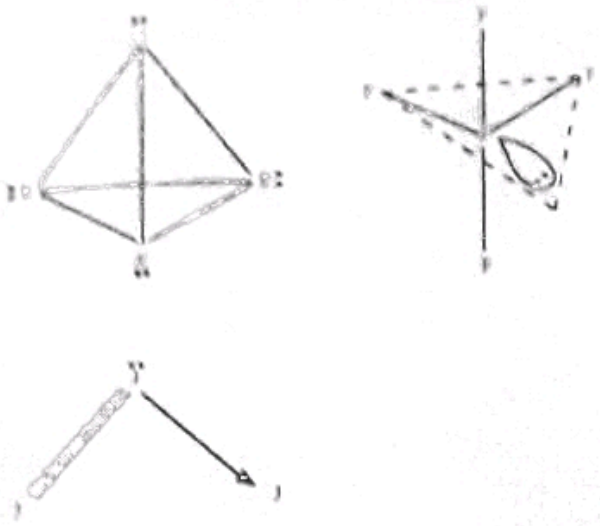
Write below the balanced chemical equations for reactions between water and (i) A_2O_3

(ii) ACl_3 (Use only chemical symbols)

(i) .....

(ii) ..... (3 marks)

(c) Identify the elements E, G and J in the structures of molecules E_4, GF_4 and J_3 given below.



E = ... G = ...

F = ...

Write down the chemical symbols of E, G and J in the appropriate cages in the skeletal periodic table given in page 3

(3 marks)

2. (a) A piece of pure magnesium was completely burnt in a mixture of N_2 and O_2 and the mix of MgO and Mg_3N_2 so obtained had a mass of 1.8 g. When this mixture was heated with excess water and the product obtained ignited, only MgO was formed. The mass of this MgO was 2.0 g.

Write **balanced chemical equations** for all the relevant reactions (Ignore the reaction between MgO and H_2O)

Calculate the mole ratio MgO : Mg_3N_2 in the mixture formed by burning the piece of magnesium
(Mg = 24 , O = 16 , N = 14)

MgO : Mg_3N_2 = ...

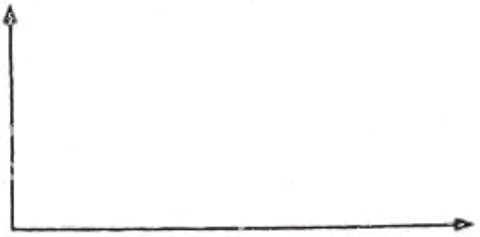
(3.5 marks)

(b) 6 moles of I ions react completely with one mole of $M_2O_7^{2-}$ ions in acidic medium, forming I_2 and M^{3+}. Write down the balanced equation representing the half reaction for the conversion of $M_2O_7^{2-}$ to M^{3+}

(1.5 marks)

(c) (i) What are the basic requirements that must be satisfied by the reactant molecules for any chemical reaction to occur?

Sketch the Boltzmann distribution for the molecules of a given gas at temperatures T_1 and T_2 where $T_2 > T_1$. Label your diagram/graph fully



(ii) Consider the reaction.

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta H = -490$ kJ

and explain the following parts (A) and (B)

(A) A mixture of $H_2(g)$ and $O_2(g)$ is stable at room temperature. However the mixture reacts rapidly when a small amount of platinum powder is added to it.

(B) This reaction is often accompanied by an explosion.

(3.0 marks)

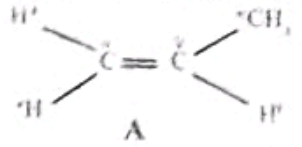
(d) This part is related to the experiment for the determination of the order of the reaction between thiosulphate ions and hydrochloric acid

(i) Write down the **balanced chemical equation** for the reaction studied in this experiment

(ii) Describe how a measure of the rate of the reaction is obtained in this experiment

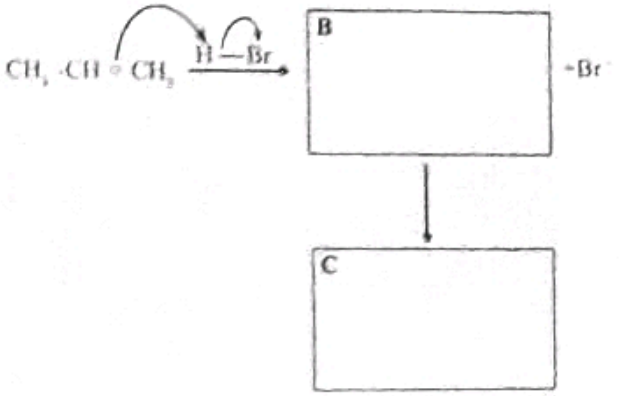
(2.0 marks)

3 (a) Consider the molecule **A** given below. (Superscripts *d, e, f, u, v* and *w* are used to label the **H** and **C** atoms.



A

(i) A part of the mechanism of the reaction of A with HBr is depicted below. Writing the structures corresponding to B and C in the boxes below complete the mechanism using curved arrows where appropriate.



(1.5 marks)

(ii) The following statements refer to **A** and its reaction with HBr. Indicate whether each of these statements is correct (✓) or wrong (x) in the appropriate box. If you are unable to evaluate any of these statements keep the box vacant.

N.B. For each correct answer 0.5 marks will be awarded.
For each incorrect answer 0.2 marks will be deducted.
If a box is kept vacant, no marks will be awarded or deducted.
However the minimum marks for this part [(a) (ii)] will be zero (0).

(1) Carbon atom denoted by *u* is sp^3 hybridised. (1) ☐

(2) Carbon atom denoted by *w* is sp^2 hybridised. (2) ☐

(3) The double bond between C atoms denoted by *u* and *v* consists of a σ bond and a π bond. (3) ☐

(4) A π bond is formed by the lateral overlap of two sp^2 orbitals. (4) ☐

(5) The bond between C atoms denoted by *v* and *w* is formed by the linear overlap of two hybridised orbitals. (5) ☐

(6) All the atoms in **A** lie in the same plane. (6) ☐

(7) In this reaction bonds undergo heterolytic cleavage. (7) ☐

(8) A curved arrow (↷) indicates the movement of an atom or a group of atoms, from one position to another. (8) ☐

(9) This reaction is a nucleophilic reaction. (9) ☐

(4.5 marks)

(b) (i) Write down in the box below, the structure of the acyclic hydrocarbon **D** (C_5H_{10}) which is optically inactive.

N.B : It is not necessary to draw the three dimensional structure.

D

(1.5 marks)

(ii) Does this compound show geometrical isomerism? (0.5 marks)

(iii) Write down the structure of the product **E** formed when **D** is treated with H_2/Pt. (0.5 marks)

E

(iv) Giving a reason state whether **E** could exist in optically active forms.

.....

.....

(0.5 marks)

(v) Write down the structure of the product **F** formed when **D** is treated with Br_2/CCl_4.

F

(0.5 marks)

(vi) How many asymmetric carbon atoms are there in the molecule **F**? .....

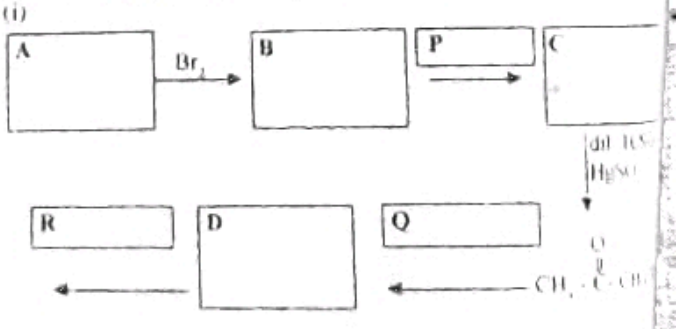
(0.5 marks)

4 (a) Consider the following reaction schemes.

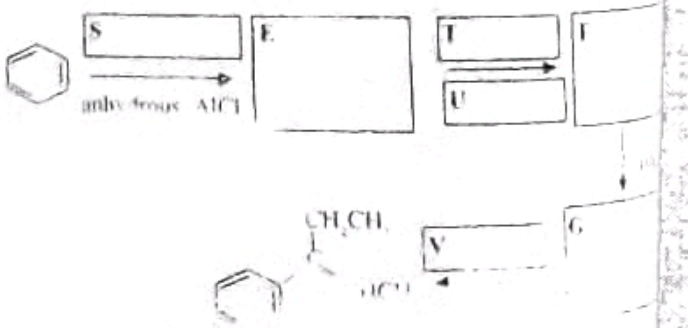
Write down in the appropriate boxes the structures corresponding to compounds, **A, B, C, D, E, F** and **G**.

Also indicate in the appropriate boxes the reagents corresponding to **P, Q, R, S, T, U** and **V**.

(i)



(ii)



(b) Show how you would carry out the following conversion

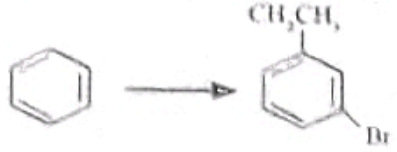
$C_6H_5COOH \rightarrow C_6H_5CH_2NHCH_3$

(The only organic compound which could be used as a reagent is C_6H_5CHO)

N.B : This conversion can be carried out in four steps. Marks will not be awarded to answers containing more than six steps.

(3.6 marks)

(c) Show how you would carry out the following conversion.



N.B : This conversion can be carried out in three steps. Marks will not be awarded to answers containing more than five steps.

(2.2 marks)

PART B - ESSAY

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

5 (a) Read the following passage and answer the question given below.

"A gas molecule has a mass **a**. Its relative molecular mass is **W**. **X** molecules (**y** mol) of this gas occupy a vessel of volume **G** at a temperature **T**. At this temperature **t**, the mean speed of the gas molecules is **b** while the root mean square speed is **d**. There are no intermolecular forces between the gas molecules. Volumes of the gas molecules can be considered to be negligible."

Using some or all the symbols given in the above passage, write down (no proof is required) in respect of the gas in the vessel, expressions for

(i) the gas pressure p

(ii) the product ZR (Z is the compressibility factor of the gas and R is the gas constant.)

N.B : If any symbol other than those given in the passage above appears in your expressions, no marks will be given for the relevant expressions.

(3.0 marks)

(b) (i) Estimate the standard enthalpy change for the reaction

$C_2H_5OH(l) + CH_3CO_2H(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l)$

Standard bond enthalpies (kJ mol^{-1})

C - H	414	C = O	724
C - C	347	O - H	464
C - O	360		

(ii) Explain why your estimated value found above is different from the experimental value (6 kJ mol^{-1}) obtained for this reaction.

(3.0 marks)

(c) Steam reacts with carbon at high pressures and temperatures above 450°C to produce an equimolar mixture of H_2 and CO, known as "syn gas." This equilibrium reaction takes place in accordance with the following equation

$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

A rigid vessel whose volume remains constant at 5.0 dm^3 contains N_2 gas and 0.843 dm^3 of powdered carbon at a pressure of 10^5 Pa and at a temperature of 127°C. 0.5 mol of steam is then introduced into the vessel and the temperature of the vessel is increased to 527°C. At this temperature only the above reaction takes place. When equilibrium is attained, the pressure inside the vessel is found to be 13.2×10^5 Pa.

Assuming that the change in volume of the carbon powder due to the reaction is negligible and **stating any other assumptions you make**, answer the following.

(i) Calculate the number of moles of N_2 gas present in the vessel.

(ii) After equilibrium is attained at 527°C, calculate

(A) the total number of moles of gas.

(B) the number of moles each of steam, H_2 and CO, and

(C) the partial pressures of steam, H_2, CO and N_2 present inside the vessel.

(iii) Calculate the equilibrium constant, K_p, for the above reaction at 527°C.

(iv) If the above reaction is repeated in a similar manner, but in the absence of N_2 gas, deduce

(A) the partial pressure of steam

(B) the partial pressure of CO

(C) the partial pressure of H_2

(D) the total pressure

inside the vessel.

(v) Suggest **one** possible industrial use for "syn gas".

(9.0 marks)

6 (a) Two liquids **L** and **M** are fully miscible and form ideal solutions with one another. The standard boiling point of **L** is higher than the standard boiling point of **M**.

(i) Draw the temperature - composition phase diagram of the above **L** - **M** system at one standard atmosphere pressure.

Label your diagram fully.

(ii) Clearly mark the following on this diagram, using the relevant symbols given within brackets.

(A) the composition of the liquid (X_L) with mole fraction of **L** = 0.8

(B) the standard boiling point (T_1) of the liquid with the liquid boiling at T_1

(C) the composition (Y_1) of the vapour in equilibrium with the liquid boiling at T_1

(D) the composition (X_2) of the liquid obtained by condensing vapour of composition Y_1

(E) the standard boiling point (T_2) of the liquid with composition X_2)

(F) the composition (Y_2) of the vapour in equilibrium with the liquid boiling at T_2.]

(iii) Answer the following questions.

(A) When a mixture of **L** and **M** is boiling, the vapour obtained is condensed and the solution obtained from the condensation is boiled again. If this process is repeated many times, what will be the final composition of the vapour that will be obtained?

(B) State one industrial process in Sri Lanka that uses a technique based on the above procedure.

(b) (i) Inside an unopened bottle of soda water there exists the following equilibrium between $CO_2(g)$ and $CO_2(aq)$

$CO_2(g) \rightleftharpoons CO_2(aq)$ (Equilibrium constant, K_c at 27°C = 0.9)

as well as the following equilibrium among $CO_2(aq)$, $H^+(aq)$ and $HCO_3^-(aq)$

$CO_2(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ (Equilibrium constant, at 27°C = K_1)

Here, $CO_2(g)$ can be assumed to behave as an ideal gas. Further dissociation of $HCO_3^-(aq)$ can be neglected. Write down expressions for K_c and K_1.

(ii) Inside the unopened bottle of soda water at 27°C, the pressure of $CO_2(g)$ is 498 500 Pa and pH of the soda water is 4.0. calculate and express the following to the first decimal place.

(A) the concentration of $CO_2(g)$ in mol dm^{-3}

(B) the concentration of $CO_2(aq)$ in mol dm^{-3}

(C) the value of K_1

(iii) The bottle of soda water was opened and its contents poured into a beaker. The soda water was then allowed to reach equilibrium in air at 27°C. Under these conditions, the partial pressure of CO_2 in air is 30 Pa. Calculate the pH value of the soda water in equilibrium with atmospheric CO_2 at 27°C.

(9.0 marks)

7 (a) (i) **Write down** an expression for the dissociation constant, K_a, of a **very weak** monobasic acid **HA** in an aqueous solution in terms of the concentrations of $H^+(aq)$, $A^-(aq)$ and $HA(aq)$ in the solution.

(1.0 marks)

(ii) Hence, show that

$$pK_a = pH - \log_{10} \frac{[A^-(aq)]}{[HA(aq)]} \text{ where } pK_a = -\log_{10} K_a$$

(1.5 marks)

(iii) At a particular temperature, 2.00×10^{-3} mol of the acid **HA** was dissolved in water and the solution diluted until the volume was 75.00 cm^3. When 25.00 cm^3 of a 0.01 mol dm^{-3} **NaOH** solution was added to that acid solution, the **pH** of the resulting solution was found to be 6.0. Calculate the dissociation constant, K_a, of the acid **HA** at that temperature.

(3.5 marks)

(b) (i) **Write down** the expression for the solubility product of Ba_3S_2 in aqueous solution.

(1.0 marks)

(ii) In a qualitative analytical experiment, Co^{2+} ions are planned to be precipitated as CoS by saturating a solution containing Co^{2+} and Ni^{2+} ions with gaseous H_2S. If the initial concentrations of Co^{2+} and Ni^{2+} ions in the solution are 0.01 mol dm^{-3} and 0.10 mol dm^{-3} respectively, calculate the minimum H^+ ion concentration that should be present in the solution to prevent precipitation of NiS.

The solubility products of CoS and NiS at the relevant temperature are 8.0×10^{-45} mol^2 dm^{-6} and 1.0×10^{-21} mol^2 dm^{-6} respectively. At the same temperature.

(c) Two half reactions related to the corrosion of iron are given below with the relevant standard electrode potentials.

$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ $E^\circ = +0.44$ V

$2H_2O + O_2(g) + 4e^- \rightarrow 4OH^-(aq)$ $E^\circ = +0.40$ V

(i) **Write the balanced chemical equation** for the overall reaction that occurs during the corrosion of iron considering only the half reactions given above.

(1.5 marks)

(ii) Using your knowledge of electro-chemical cells, calculate the standard e.m.f. of the electro-chemical cell in which the above mentioned overall reaction occurs during the discharge of the cell.

(1.5 marks)

(iii) An iron tank is to be protected against corrosion by the cathodic protection method. Stating briefly the relevant principle, deduce which of the two metals, **Q** and **R** described below would be suitable for this purpose.

$Q^{2+}(aq) + 2e^- \rightarrow Q(s)$ $E^\circ = -0.60$ V

$R^{2+}(aq) + 2e^- \rightarrow R(s)$ $E^\circ = -0.13$ V

(1.0 mark)

PART C - ESSAY

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

8 (a) Explain the following statements involved with the industrial manufacture of sulphuric acid.

(i) The conversion of $SO_2(g)$ to $SO_3(g)$ is favoured at high pressures and at low temperatures.

(ii) Temperatures lower than 450°C and pressures higher than 250 atmospheres are not used for the conversion of $SO_2(g)$ to $SO_3(g)$.

(iii) V_2O_5 is generally used in this process.

(6.0 mark)

(b) The mixtures **A** and **B** are identical in colour and colour intensity

Mixture **A**	5 cm^3 of tube - well water	5 cm^3 of distilled water	5cm^3 of 0.001 mol dm^{-3} salicylic acid
Mixture **B**	1.5 cm^3 of 0.002 mol dm^{-3} Fe^{3+} ion solution.	8.5 cm^3 of distilled water	5 cm^3 of 0.001 mol dm^{-3} salicylic acid

(i) Calculate the concentration of Fe^{3+} in the tube-well water sample and give it in mg dm^{-3} (Fe = 55)

(ii) What is the colour of the complex formed between Fe^{3+} ions and salicylic acid?

(iii) What is the stoichiometric ratio between Fe^{3+} ions and salicylate ions and salicylate ions in the above mentioned complex?

(iv) State an appropriate method for the removal of Fe^{3+} and Fe^{2+} ions in water.

(5.0 marks)

(c) (i) Give names of **three** plants from which essential oils are extracted in Sri Lanka.

(ii) Write down the name of **one** major constituent present in the essential oils extracted from each of the plants you mentioned in (i) above.

(iii) Steam distillation is generally used to extract essential oils. Give **two** advantages of using this method.

(4.0 marks)

09. (a) Motor vehicle emissions, constitute a major source of air pollution. Considering these emissions **only**, answer the following.

(i) Name **five** major gaseous pollutants.

(ii) Name **two** elemental pollutants released.

(iii) Name **two** pollutants that form stable complexes with haemoglobin.

(iv) Name **two** pollutants responsible for acid rain.

(v) Name **three** pollutants causing the greenhouse effect.

(vi) State one method that can be used to minimise the pollutants in motor vehicle emissions. (No description of the method is required.)

(4.5 marks)

(b) A large quantity of dolomite containing silica (SiO_2) as the only impurity is available. Using this dolomite, water and dilute HCl only, outline a method to prepare a sample of pure $MgCO_3$.

(4.5 marks)

(c) Write down the relevant **balanced chemical** equations and necessary conditions for all the steps involved the following processes.

(i) Industrial manufacture of $NH_4NO_3(s)$, starting with N_2 and H_2.

(ii) Synthesis of $Na_2CO_3(s)$ by the solvay process.

(6.0 marks)

10. (a) **M** is a first row (3d) transition element. The atoms of this element have six unpaired electrons each.

(i) Identify **M**.

(ii) Write down the complete electronic configuration of **M**.

(iii) Write down the **balanced chemical equation** for the reaction that occurs when an aqueous solution containing M^{3+} is warmed with NaOH and H_2O_2. (The accepted chemical symbol should be used for **M**.)

(iv) What is the colour of the solution obtained after carrying out the reaction mentioned in (iii) above?

(v) Give **two** other compounds of **M** where **M** is in the same oxidation state as in product obtained in (iii) above.

(vi) Write down **one** important industrial use of **M**.

(5.2 marks)

(b) Write down **balanced chemical equations** for the following.

(i) The thermal decomposition of $NaNO_3$

(ii) The thermal decomposition of $Mg(NO_3)_2$

(iii) The thermal decomposition of $AgNO_3$

(iv) The thermal decomposition of NH_4NO_3

(v) The oxidising action SO_2

(vi) The reducing action SO_2

(vii) The oxidising action of H_2S

(viii) The reducing action of H_2S

(4.8 marks)

(c) Labels of bottles containing aqueous solutions of KI, H_2O_2, $FeCl_3$ and $K_3[Fe(CN)_6]$ have fallen off. In an attempt to identify these solutions, the bottles were labelled **A**, **B**, **C** and **D**. The solutions were mixed in pairs in separate test tubes as indicated below. Each of the mixtures so obtained was then acidified and shaken with $CHCl_3$. The colours of the $CHCl_3$ layers are given below.

Experiment Solutions mixed	(i) **A + B**	(ii) **B + C**	(iii) **C + D**	(iv) **B + D**
Colour of $CHCl_3$ layer	Colourless	Colourless	Purple	Purple

Addition of **A** to the mixture obtained in experiment (iv) above, produced a deep blue precipitate in the aqueous layer.

Identify, giving reasons, the solutions in bottles **A**, **B**, **C** and **D**.

(5.0 marks)