THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/1 **CHEMISTRY 1**

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2019**

Instructions

1. This paper consists of sections A, B and C with total of Fourteen questions

2. Each question carries ten marks

1. (a) Use s, p, d, f notation to designate atomic orbitals with the given pairs of quantum numbers n and l.

(i) $n = 2$ and $l = 1 \rightarrow 2p$
(ii) $n = 3$ and $l = 2 \rightarrow 3d$
(iii) $n = 4$ and $l = 3 \rightarrow 4f$
(iv) $n = 3$ and $l = 0 \rightarrow 3s$

(b) For the following sets of quantum numbers, state which are allowable and which are not allowable. Briefly explain your answer.

(i) $n = 2$; $l = 2$; $ml = 0$; $ms = +1/2$

Not allowable because for $n = 2$, l can only be 0 or 1, but $l = 2$ is invalid.

(ii) $n = 3$; $l = 1$; $ml = 0$; $ms = -1/2$

Allowable because $l = 1$ is valid for $n = 3$, $ml = 0$ is within the allowed range (-1 to +1), and $ms = -1/2$ is valid.

(iii) $n = 1$; $l = 0$; $ml = +1$; $ms = +1/2$

Not allowable because for $l = 0$, the only possible value of ml is 0.

(iv) $n = 3$; $l = 2$; $ml = +2$; $ms = -1/2$
Allowable because $l = 2$ is valid for $n = 3$, $ml = +2$ is within the allowed range (-2 to +2), and $ms = -1/2$ is valid.
(c) Define the following phrases:

(i) Atomic number

The atomic number (Z) is the number of protons in the nucleus of an atom, which determines the chemical identity of an element.

(ii) Mass number

The mass number (A) is the total number of protons and neutrons in the nucleus of an atom.

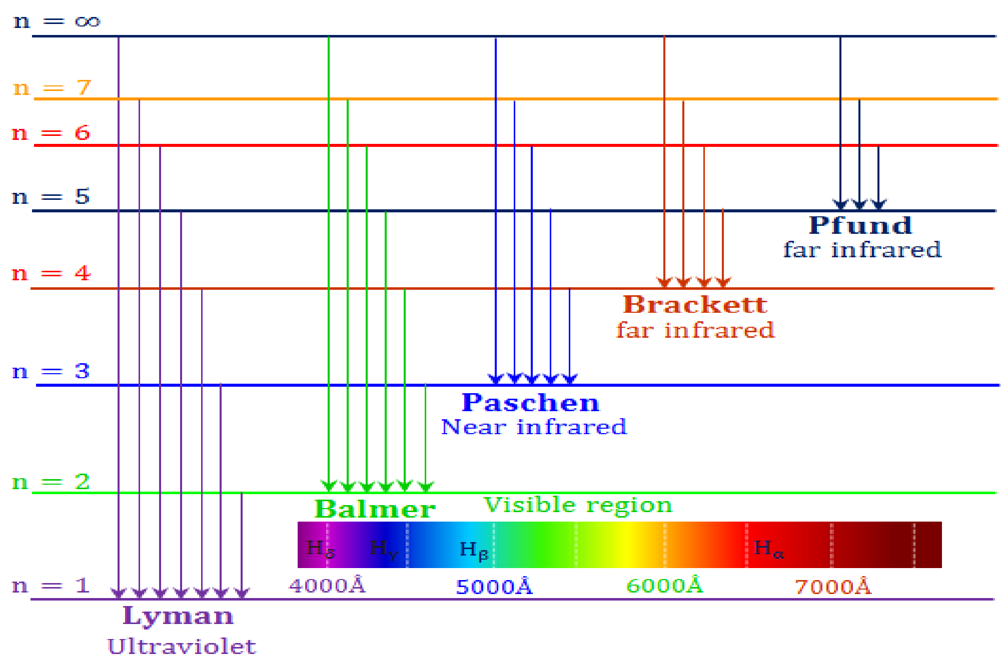
(d) A nucleus of a certain element is presented as $^{58}_{27}X$. What is the number of electrons and neutrons in atom X? Show your work clearly.

Atomic number = 27 -----> number of electrons = 27
Mass number = 58 -------> number of neutrons = 58 - 27 = 31

(e) Clearly state four postulates of Planck's quantum theory as derived from black body radiation.

1. Energy is emitted or absorbed in discrete packets called quanta or photons.
2. The energy of each quantum is directly proportional to its frequency, given by $E = h\nu$, where h is Planck's constant and ν is the frequency.
3. A body can emit or absorb energy only in discrete multiples of $h\nu$.
4. The emission of radiation from a black body is quantized and occurs in specific amounts rather than continuously.

2. (a) Sketch a hydrogen spectral series based on Bohr atom energy level.



(b) (i) How does a mass spectrograph of a pure element is used to detect the presence of isotopes?

A mass spectrograph separates isotopes based on their mass-to-charge ratio. The presence of multiple peaks in the mass spectrum indicates different isotopes of the element.

(ii) The following data were obtained for a certain pure element:

Isotope	Mass of isotope	Natural abundance (%)
1	28.0	92.0
2	29.0	5.0
3	30.0	3.0

Calculate the relative atomic mass of an element.

Relative atomic mass = $(\text{mass}_1 \times \text{abundance}_1) + (\text{mass}_2 \times \text{abundance}_2) + (\text{mass}_3 \times \text{abundance}_3) / 100$

$= (28.0 \times 92) + (29.0 \times 5) + (30.0 \times 3) / 100$
$= (2576 + 145 + 90) / 100$
$= 28.235$

(c) (i) Use wave and particle models for energy of a particle to derive the de Broglie equation.

Using the energy equation for photons:

$E = h\nu$ and $\nu = c/\lambda$

Momentum of a photon:

$p = h/\lambda$

For a particle, kinetic energy:

$E = 1/2\ mv^2$, where momentum $p = mv$

By analogy with photons, for particles:

$\lambda = h / p = h / mv$

3. (a) Use the following chemical structures of ethane and ethene molecules to answer the questions that follow.

(i) What are the hybridizations of carbon atoms in each compound?

Ethane: sp^3 hybridization
Ethene: sp^2 hybridization

(ii) Use well-labeled diagrams to describe types of C-C bonds in each compound.

Ethane: Single sigma (σ) bond
Ethene: One sigma (σ) bond and one pi (π) bond

(iii) In ethane molecule, each C-H has a bond length of 1.09 Å and C-C has bond length of 1.54 Å. Briefly explain this observation.

The C-H bond length is shorter because hydrogen is a smaller atom with strong overlap in sp^3 hybridization, while the C-C bond is longer due to greater orbital overlap in single bonds.

(iv) The C=C double bond in ethene (bond length 1.34 Å) is shorter than C-C single bond in ethane (bond length 1.54 Å). Briefly explain this observation.

The C=C bond in ethene has both a sigma (σ) and a pi (π) bond, leading to greater electron density between the two carbons, resulting in a shorter bond length than the single C-C bond in ethane.

(b) In chemical bond formation, the ionization enthalpy and electron affinity are involved. Briefly describe how:
(i) Ionic bond formation is favored by ionization enthalpy and electron affinity.
Lower ionization enthalpy allows a metal to lose an electron easily, and higher electron affinity allows a nonmetal to gain an electron easily, facilitating ionic bond formation.

(ii) Covalent bond formation is favored by ionization enthalpy and electron affinity.

Atoms with similar ionization enthalpy and electron affinity share electrons to achieve a stable configuration, leading to covalent bond formation.
(c) Briefly describe the following phrases. Give one example of a chemical structure for each:

(i) Hydrogen bond.
A hydrogen bond is a weak electrostatic attraction between a hydrogen atom covalently bonded to an electronegative atom (O, N, or F) and another electronegative atom.
Example: H_2O molecules form hydrogen bonds in liquid water.

(ii) Coordinate covalent bond.
A coordinate covalent bond is a covalent bond where both electrons in the bond are donated by one atom.
Example: Formation of NH_4^+ ion: $NH_3 + H^+$ ----------> NH_4^+

4. (a) (i) State Raoult’s law regarding solutions of liquids in liquids.

Raoult’s law states that the partial vapor pressure of a component in a solution is equal to the product of the mole fraction of that component in the liquid phase and its pure vapor pressure at the same temperature.

$P\_A = X\_A \times P\_A^0$

where P_A is the partial vapor pressure of component A, X_A is the mole fraction of A, and P_A^0 is the pure vapor pressure of A.

(ii) Define azeotropic mixture.

An azeotropic mixture is a liquid mixture of two or more components that has a constant boiling point and composition, and cannot be separated into its components by simple distillation.

(iii) Use a well-labeled hand sketch to show the difference between minimum boiling point azeotropic mixture and maximum boiling point azeotropic mixture.

(Draw two separate phase diagrams:
- One showing a minimum boiling azeotrope where the azeotropic composition has the lowest boiling point.
- One showing a maximum boiling azeotrope where the azeotropic composition has the highest boiling point.)

(b) Briefly explain the meaning of the following phrases:

(i) Freezing point depression.

Freezing point depression is the decrease in the freezing point of a solvent when a non-volatile solute is added to it, due to the lowering of the solvent's chemical potential.

(ii) Boiling point elevation.

Boiling point elevation is the increase in the boiling point of a solvent when a non-volatile solute is added, due to the decrease in vapor pressure.

(iii) Van't Hoff's factor (i).

Van't Hoff's factor (i) is the ratio of the actual number of particles in solution to the number of formula units of the solute initially dissolved. It accounts for dissociation or association of solute particles in solution.

(c) Study the following liquid-vapor phase diagram and then answer the questions that follow.

(i) If a liquid mixture of composition I is heated to temperature C, what will be the composition of the vapor phase?

The composition of the vapor phase will correspond to the intersection of the temperature C with the upper curve of the phase diagram.

(ii) If the vapor at E is cooled to temperature F, what will be the composition of the vapor phase?

The composition of the vapor phase will correspond to the intersection of temperature F with the upper curve of the phase diagram.

(iii) What temperature represents the boiling point of composition J?

The temperature at which the composition J intersects the upper boundary of the phase diagram represents its boiling point.

5. (a) (i) Boiling point of a solvent is elevated by addition of a non-volatile solute. Briefly explain.

When a non-volatile solute is added to a solvent, it reduces the solvent's vapor pressure by disrupting solvent molecules from escaping into the gas phase. This means that a higher temperature is required for the solvent to reach its boiling point, resulting in boiling point elevation.

(ii) Arrange the following aqueous solutions in order of increasing freezing point: 0.01 M C_2H_5OH, 0.01 M $Ba_3(PO_4)_2$, 0.01 M Na_2SO_4, 0.01 M KCl, 0.01 M Li_3PO_4. Provide clear reason(s) for the arrangement.

Since freezing point depression is directly proportional to the number of particles (ions) in solution, we determine the number of ions each compound produces upon dissociation:

- C_2H_5OH (ethanol) does not ionize -----> i = 1
- KCl dissociates into K^+ and Cl^- ---------> i = 2
- Na_2SO_4 dissociates into $2Na^+$ and SO_4^{2-} -----> i = 3
- Li_3PO_4 dissociates into $3Li^+$ and PO_4^{3-} ------> i = 4
- $Ba_3(PO_4)_2$ dissociates into $3Ba^{2+}$ and $2PO_4^{3-}$ --- i = 5

Increasing order of freezing point: $Ba_3(PO_4)_2 < Li_3PO_4 < Na_2SO_4 < KCl < C_2H_5OH$.

(b) You are provided with the following information:

Entry	Value
Molal boiling point constant for benzene, K_b	2.53 °C kg mol^{-1}
Molal freezing point constant for benzene, K_f	5.12 °C kg mol^{-1}
Boiling point of benzene	80.1 °C
Freezing point of benzene	5.5 °C

Calculate the boiling point and freezing point of a solution made by dissolving 2.40 g of biphenyl, $C_{12}H_{10}$, in 75.0 g of benzene. Show your work clearly including manipulations of units.

Step 1: Calculate moles of biphenyl.

Molar mass of biphenyl ($C_{12}H_{10}$) = 154 g/mol

Moles = 2.40 g / 154 g/mol
= 0.0156 mol

Step 2: Calculate molality.

Molality (m) = moles of solute / kg of solvent
= 0.0156 mol / 0.075 kg
= 0.208 mol/kg

Step 3: Calculate boiling point elevation.

$\Delta T_b = K_b \times m$
= (2.53 °C kg mol^{-1}) x (0.208 mol/kg)
= 0.526 °C

Boiling point = 80.1 + 0.526
= 80.63 °C

Step 4: Calculate freezing point depression.
$\Delta T_f = K_f \times m$
= (5.12 °C kg mol^{-1}) x (0.208 mol/kg)
= 1.06 °C

Freezing point = 5.5 - 1.06
= 4.44 °C

(c) An aqueous solution of urea, $CO(NH_2)_2$, at a concentration of 1.754 g dm^{-3} is isotonic at the same temperature with an aqueous solution of sugar at a concentration of 10.00 g dm^{-3}. Calculate the relative molecular mass of sugar.

Since both solutions are isotonic, they have the same osmotic pressure.
$\pi = cRT$
Since R, T, and π are the same, the molarity of both solutions must be equal.

Step 1: Calculate molarity of urea solution.
Molar mass of urea = 60 g/mol
Moles of urea in 1 dm^3 = 1.754 g / 60 g/mol
= 0.0292 mol

Step 2: Calculate molar mass of sugar.
Moles of sugar in 1 dm^3 = 10.00 g / Molar mass of sugar
Since both solutions are isotonic, their molarities are equal:
0.0292 mol = 10.00 g / Molar mass of sugar
Molar mass of sugar = 10.00 g / 0.0292 mol
= 342.5 g/mol

6. (a) Briefly explain the following phrases, giving one example for each:

(i) Reversible reaction.

A reversible reaction is a chemical reaction in which the products can react to reform the reactants under suitable conditions.

Example:
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(ii) Heterogeneous equilibrium.

A heterogeneous equilibrium is a state in which reactants and products of a reaction are present in different phases.

Example:
$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

(b) (i) State the equilibrium law and provide the corresponding expression.

The equilibrium law states that at a given temperature, the ratio of the product of the concentrations of the reaction products raised to their respective stoichiometric coefficients to the product of the concentrations of the reactants raised to their respective stoichiometric coefficients is a constant.

For a reaction:
$aA + bB \rightleftharpoons cC + dD$

The equilibrium expression is:
$Kc = ([C]^c [D]^d) / ([A]^a [B]^b)$

(ii) List four characteristics of chemical equilibrium.

1. The rate of the forward reaction equals the rate of the reverse reaction.
2. The concentrations of reactants and products remain constant over time.
3. It is a dynamic process, meaning both forward and reverse reactions occur simultaneously.
4. Equilibrium can be influenced by changes in temperature, pressure, and concentration (Le Chatelier's Principle).

(iii) Write the expression for the equilibrium constant, Kc, for the equation:

$CuS(s) + 2Ag^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2Ag(s)$

$Kc = [Cu^{2+}] / [Ag^+]^2$

(c) The equilibrium equation for the oxidation of hydrogen chloride to chlorine is:

$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$

In a certain experiment, 0.80 moles of hydrogen chloride was mixed with 0.20 moles of oxygen in a closed vessel of capacity 10.00 dm^3. At equilibrium, it was found that the mixture contained 0.20 moles of hydrogen chloride. Calculate the equilibrium constant, Kc, for the reaction. Show your work clearly including manipulations of units.

Step 1: Define the change in moles using the ICE table.

Initial moles:
$HCl = 0.80$, $O_2 = 0.20$, $Cl_2 = 0$, $H_2O = 0$

Change in moles:
Since $0.80 \rightarrow 0.20$, 0.60 moles of HCl reacted.
From the reaction: 4 moles of HCl react with 1 mole of O_2, forming 2 moles of Cl_2 and 2 moles of H_2O.

O_2 reacted = 0.60/4 = 0.15
Cl_2 formed = (0.60 × 2) / 4 = 0.30
H_2O formed = 0.30

Equilibrium moles:
$HCl = 0.20$, $O_2 = 0.05$, $Cl_2 = 0.30$, $H_2O = 0.30$

Step 2: Convert to molarity (divide by 10 dm^3).

$[HCl] = 0.20 / 10 = 0.02$ M
$[O_2] = 0.05 / 10 = 0.005$ M
$[Cl_2] = 0.30 / 10 = 0.03$ M
$[H_2O] = 0.30 / 10 = 0.03$ M

Step 3: Write the equilibrium expression.

$Kc = ([Cl_2]^2 [H_2O]^2) / ([HCl]^4 [O_2])$
$Kc = (0.03^2 \times 0.03^2) / (0.02^4 \times 0.005)$

$Kc = (0.0009 \times 0.0009) / (0.00000016 \times 0.005)$
$Kc = 8.1 \times 10^3$

7. (a) Use the kinetic gas equation to explain the following concepts:

(i) The pressure exerted by an ideal gas increases when it is heated at constant volume.

According to the kinetic gas equation:

$PV = nRT$

If volume is constant, increasing temperature increases kinetic energy of gas molecules, causing them to collide more frequently and forcefully with container walls, increasing pressure.

(ii) The volume occupied by an ideal gas increases when it is heated at constant pressure.

At constant pressure, increasing temperature increases the kinetic energy of gas molecules, making them move faster and spread further apart, leading to an increase in volume.

(b) A flammable gas made up of carbon and hydrogen is generated by certain anaerobic bacteria in sewage drains. A pure sample of a gas was found to effuse through a certain porous barrier in 1.50 minutes. Under the same conditions of temperature and pressure, it takes 4.73 minutes for an equal volume of bromine gas to effuse through the same barrier. Calculate the molar mass of the unknown gas and suggest the name of the gas.

Using Graham's law:

$Rate_1 / Rate_2 = \sqrt{(M_2 / M_1)}$

$(4.73 / 1.50) = \sqrt{(159.8 / M_1)}$

Squaring both sides:

$(4.73 / 1.50)^2 = (159.8 / M_1)$

$(3.153)^2 = 159.8 / M_1$

$9.94 = 159.8 / M_1$

$M_1 = 159.8 / 9.94$
$M_1 = 16.08$ g/mol

The gas is methane (CH_4).

8. (a) State the following gas laws, then provide their mathematical expressions:

(i) Boyle's law: At constant temperature, the volume of a given mass of gas is inversely proportional to its pressure.

$P_1V_1 = P_2V_2$

(ii) Charles' law: At constant pressure, the volume of a given mass of gas is directly proportional to its temperature.

$V_1 / T_1 = V_2 / T_2$

(iii) Graham's law: The rate of effusion of a gas is inversely proportional to the square root of its molar mass.

$Rate_1 / Rate_2 = \sqrt{(M_2 / M_1)}$

(iv) Dalton's law of partial pressures: The total pressure of a gas mixture is equal to the sum of the partial pressures of the individual gases.

$P\_total = P_1 + P_2 + P_3 + ...$

(b) State five assumptions of the kinetic theory of gases.

1. Gas particles move in constant, random motion.
2. Gas particles undergo elastic collisions, with no loss of kinetic energy.
3. The volume of individual gas particles is negligible compared to the total volume of the gas.
4. Gas particles do not exert intermolecular forces on each other.
5. The average kinetic energy of gas particles is proportional to the absolute temperature.

9. (a) The enthalpy for the formation of ammonia, $NH_3(g)$, under standard conditions is -46.2 kJ mol^{-1}. Calculate the enthalpy for the reaction:

$2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$

Since formation of NH_3 is -46.2 kJ/mol, the reverse reaction is:

$\Delta H = -2(-46.2)$
$\Delta H = +92.4$ kJ

(b) (i) Calculate the enthalpy for the reaction:

$N_2(g) + 2O_2(g)$ -----> $2NO_2(g)$

Using Hess's Law:

$\Delta H = 2(90) + 2(74)$
$\Delta H = 328$ kJ

(ii) Which of the two species $NO_2(g)$ and $NO(g)$ is more thermodynamically stable?

Since NO has a higher positive enthalpy change (+90 kJ) than NO_2 (+74 kJ), NO_2 is more stable because it has a lower energy state.

9. (c) At 25 °C, the dissociation energies of $H_2(g)$ and $Cl_2(g)$ are +435.4 kJ mol^{-1} and +243 kJ mol^{-1} respectively. The enthalpy of formation of HCl(g) is -92.2 kJ mol^{-1}. Calculate the dissociation energy for HCl(g).

Step 1: Consider the bond dissociation reactions.

$H_2(g) \rightarrow 2H(g)$ $\Delta H = +435.4$ kJ
$Cl_2(g) \rightarrow 2Cl(g)$ $\Delta H = +243$ kJ
$2H(g) + 2Cl(g) \rightarrow 2HCl(g)$ $\Delta H = 2(-92.2$ kJ)

Step 2: Apply Hess's Law:

Total bond dissociation enthalpy:

D(HCl) = [(ΔH of H_2) + (ΔH of Cl_2)] - [ΔH of formation of HCl]

D(HCl) = [(435.4) + (243)] - [2(-92.2)]
D(HCl) = (678.4) - (-184.4)
D(HCl) = 464 kJ/mol

(d) Use the given average bond enthalpies to calculate the change in enthalpy, ΔH, for the reaction:

$C_3H_8 + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

Given bond enthalpies:

C-H = 414 kJ/mol
C-C = 347 kJ/mol
C=O = 741 kJ/mol
H-O = 464 kJ/mol
O=O = 498 kJ/mol

Step 1: Calculate total bond energy for reactants.

C_3H_8 contains:

8 C-H bonds = 8 × 414 = 3312 kJ
2 C-C bonds = 2 × 347 = 694 kJ
5 O_2 molecules (O=O) = 5 × 498 = 2490 kJ

Total bond energy of reactants = 3312 + 694 + 2490 = 6496 kJ

Step 2: Calculate total bond energy for products.

3 CO_2 molecules:
Each CO_2 has 2 C=O bonds → 3 × 2 × 741 = 4446 kJ

4 H_2O molecules:
Each H_2O has 2 H-O bonds → 4 × 2 × 464 = 3712 kJ

Total bond energy of products = 4446 + 3712 = 8158 kJ

Step 3: Calculate ΔH.

ΔH = Total bond energy of reactants - Total bond energy of products
ΔH = 6496 - 8158
ΔH = -1662 kJ

10. (a) Define the following phrases as applied in energetics concept in chemistry:

(i) Heat (enthalpy) of formation.

The enthalpy change when one mole of a compound is formed from its elements in their standard states under standard conditions.

(ii) Standard enthalpy of formation.

The enthalpy change when one mole of a substance is formed from its constituent elements in their standard states under standard conditions (298 K, 1 atm).

(iii) Heat (enthalpy) of fusion.

The amount of heat required to convert one mole of a solid into its liquid state without a change in temperature.

(iv) Heat (enthalpy) of neutralization.

The enthalpy change when one mole of water is formed from the reaction of an acid and a base in dilute aqueous solution.

(b) (i) State Hess's law of constant heat summation.

Hess's law states that the total enthalpy change of a reaction is the same regardless of the route taken, as long as the initial and final conditions remain the same.

(ii) Given a hypothetical reaction aA + bB → cC + dD, where A, B, C, and D are compounds and a, b, c, and d are stoichiometric values, determine an expression for enthalpy change ΔH_r of the reaction.

$\Delta H\_r = [c\Delta H\_f(C) + d\Delta H\_f(D)] - [a\Delta H\_f(A) + b\Delta H\_f(B)]$

(c) The standard heat of combustion of ethanol, $\Delta H\_c = -1386$ kJ mol^{-1}. The standard heat of formation of carbon dioxide, $\Delta H\_f(CO_2) = -393$ kJ mol^{-1}, and the standard heat of formation of water, $\Delta H\_f(H_2O) = -287$ kJ mol^{-1}. Calculate the standard heat (enthalpy) of formation of ethanol.

Step 1: Write the balanced equation for ethanol combustion.

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Step 2: Use Hess's Law equation.

$\Delta H\_c = [2\Delta H\_f(CO_2) + 3\Delta H\_f(H_2O)] - \Delta H\_f(C_2H_5OH)$

$-1386 = [(2 \times -393) + (3 \times -287)] - \Delta H\_f(C_2H_5OH)$

$-1386 = [-786 - 861] - \Delta H\_f(C_2H_5OH)$

$-1386 = -1647 - \Delta H\_f(C_2H_5OH)$

$\Delta H\_f(C_2H_5OH) = -1647 + 1386$
$\Delta H\_f(C_2H_5OH) = -261$ kJ/mol

(d) The following data were obtained for Born-Haber cycle formation for one mole of crystalline NaCl.

Step	Heat (Enthalpy)
Sublimation of Na metal to gaseous Na atoms	+107.3 kJ
Ionization of Na atoms to Na^+ ions	+495.8 kJ
Formation of $Cl^-(g)$ by addition of e^- to Cl(g)	-348.6 kJ

| Formation of NaCl crystals from Na^+ and Cl^- | -787.3 kJ |

In a single step, $Na(s) + \frac{1}{2} Cl_2(g) \rightarrow NaCl(s)$, it was found that $\Delta H\_f(NaCl, crystal) = -412.3$ kJ mol^{-1}. Calculate heat (enthalpy) of dissociation of one mole of Cl_2 gas.

Using Born-Haber cycle:

$\Delta H\_d(Cl_2) = [\Delta H\_f(NaCl) - (\Delta H\_s(Na) + \Delta H\_i(Na) + \Delta H\_e(Cl) + \Delta H\_L(NaCl))]$

$\Delta H\_d(Cl_2) = [-412.3 - (107.3 + 495.8 - 348.6 - 787.3)]$

$\Delta H\_d(Cl_2) = [-412.3 - (-533.2)]$

$\Delta H\_d(Cl_2) = +533.2 - 412.3$
$\Delta H\_d(Cl_2) = 120.9$ kJ/mol

11. (a) Suggest suitable tests to distinguish the following pairs of compounds:

(i) Chlorobenzene and chloromethylbenzene.

Add aqueous silver nitrate ($AgNO_3$) in ethanol:
- Chlorobenzene does not react.
- Chloromethylbenzene gives a white precipitate of AgCl.

(ii) Cyclopentene and pent-2-yne.

Add bromine water:
- Cyclopentene decolorizes bromine water.
- Pent-2-yne does not react.

(iii) Chloroform and carbon tetrachloride.

Heat with silver nitrate in ethanol:
- Chloroform gives a slow reaction.
- Carbon tetrachloride does not react.

12. (a) (i) Define the term isomerism.

Isomerism is the phenomenon where compounds have the same molecular formula but different structural arrangements or spatial orientations, leading to different chemical and physical properties.

(ii) Pentane has three isomers. Draw their chemical structures and provide their corresponding IUPAC names.

1. n-Pentane - CH_3-CH_2-CH_2-CH_2-CH_3
2. Isopentane (2-Methylbutane) - CH_3-$CH(CH_3)$-CH_2-CH_3
3. Neopentane (2,2-Dimethylpropane) - $C(CH_3)_4$

(b) Give the IUPAC names of the following organic compounds:

(i) 2,2,3-Trimethylpentane
(ii) 3,3-Dimethylhex-1-yne
(iii) 1,3-Hexadiyne
(iv) 4-Chloropent-2-ene

(c) Compound A is known to be aromatic and contains 66.4% carbon, 5.5% hydrogen, and 28.1% chlorine by mass. The vapor density of pure A was found to be 63.

(i) Find the empirical formula of compound A.

Step 1: Convert percentages to moles.

C = (66.4 / 12) = 5.53
H = (5.5 / 1) = 5.5
Cl = (28.1 / 35.5) = 0.79

Step 2: Divide by the smallest value (0.79).

C = 5.53 / 0.79 = 7
H = 5.5 / 0.79 = 7
Cl = 0.79 / 0.79 = 1

Empirical formula = C_7H_7Cl

(ii) Find the relative molecular formula of compound A.

Molecular mass = 2 × vapor density
= 2 × 63
= 126 g/mol

Empirical formula mass = (7 × 12) + (7 × 1) + (35.5 × 1)
= 126 g/mol

Since empirical formula mass = molecular mass, the molecular formula is C_7H_7Cl.

(iii) Give the chemical structures of the four isomers of compound A and their corresponding IUPAC names.

1. Benzyl chloride ($C_6H_5CH_2Cl$)
2. p-Chlorotoluene (1-Chloro-4-methylbenzene)
3. o-Chlorotoluene (1-Chloro-2-methylbenzene)
4. m-Chlorotoluene (1-Chloro-3-methylbenzene)

(iv) Which of the isomers of compound A will react with dilute KOH? Briefly explain your answer.

Benzyl chloride will react with dilute KOH because it contains a benzylic halide ($-CH_2Cl$) that is susceptible to nucleophilic substitution, forming benzyl alcohol.

13. (a) Write all the isomers of C_5H_{12}.

1. n-Pentane
2. Isopentane (2-Methylbutane)
3. Neopentane (2,2-Dimethylpropane)

(b) Draw the structural formulae of the following organic compounds:

(i) 2,2-Dimethylpropane - $(CH_3)_3CCH_3$
(ii) 4-Methylpent-2-yne - $CH_3C{\equiv}CCH(CH_3)CH_3$

(c) Name the following compounds:

(i) $CH_3CH{=}CHCH_3$ --------> But-2-ene
(ii) $CH_3C{\equiv}CCH_2CH_3$ -------> Pent-2-yne

(d) Ozonolysis of a hydrocarbon R (C_5H_{10}) in the presence of zinc dust gives compounds S (C_2H_4O) and T (C_3H_6O). While compound S gives a negative iodoform test, compound T responds positively to the iodoform test.

(i) Give the structures of the compounds R, S, and T.

- R (C_5H_{10}): Pent-2-ene
- S (C_2H_4O): Ethanal (CH_3CHO)
- T (C_3H_6O): Propanone (CH_3COCH_3)

(ii) Write all reaction equations that took place during the whole process.

1. Ozonolysis of pent-2-ene
$C_5H_{10} + O_3$ ---------> $CH_3CHO + CH_3COCH_3$

2. Reaction of T with iodine (Iodoform test)

$CH_3COCH_3 + 3I_2 + 4NaOH$ -------> $CHI_3 + CH_3COONa + 3NaI + 3H_2O$

(e) Using equations, briefly explain how you can differentiate $CH_3C{\equiv}CH$ from $CH_3C{\equiv}CCH_3$.

- Reaction with ammoniacal silver nitrate (Tollen's reagent):
$CH_3C{\equiv}CH + AgNO_3$ ---------> $AgC{\equiv}CCH_3 + NO_3^-$ (forms a white precipitate)
$CH_3C{\equiv}CCH_3$ does not react.

- Reaction with bromine water:
Both will decolorize bromine water, but $CH_3C{\equiv}CH$ reacts faster due to higher reactivity of terminal alkynes.

14. (a) Show a one-step reaction, how the following molecules can be prepared. Indicate suitable reagents and conditions for their preparation.

(i) Butan-2-ol from 2-iodobutane
C_4H_9I + KOH (aq) ------> C_4H_9OH + KI

(ii) Propane from 1-chloropropane
$C_3H_7Cl + Zn + HCl$ -------> $C_3H_8 + ZnCl_2$
(iii) Ethylamine from iodoethane
$C_2H_5I + NH_3$ ---> $C_2H_5NH_2 + HI$

(iv) Butane from bromoethane
$2C_2H_5Br + 2Na$ -----> $C_4H_{10} + 2NaBr$

(v) Methylbenzene from bromomethane
$C_6H_6 + CH_3Br + AlCl_3$ -----> $C_6H_5CH_3 + HBr$

(vi) But-2-ene from 2-bromobutane
C_4H_9Br + NaOH (ethanol) -----> $C_4H_8 + H_2O + NaBr$

(b) A haloalkane P ($C_5H_{11}Br$) reacts with aqueous sodium hydroxide to give Q ($C_5H_{12}O$). Q reacts with concentrated H_2SO_4 at 170°C to form R (C_5H_{10}) which decolorizes bromine water. When R is reacted with ozone followed by hydrolysis, methanal and a branched aldehyde S is formed.

Deduce the structural formula of P, Q, R, and S by showing the chemical reactions involved.

1. P ($C_5H_{11}Br$) - 2-Bromopentane
$C_5H_{11}Br$ + NaOH (aq) -----> $C_5H_{12}O$ + NaBr

2. Q ($C_5H_{12}O$) - Pentan-2-ol
$C_5H_{12}O + H_2SO_4$ (170°C) -----> $C_5H_{10} + H_2O$

3. R (C_5H_{10}) - 2-Methylbut-2-ene
C_5H_{10} + O_3 -------> CH_2O + CH_3CHCHO (Methanal + 2-Methylpropanal)

4. S (C_4H_8O) - 2-Methylpropanal