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: 2008**

Instructions

1. This paper consists of sections A, B and C with total of fourteen questions
2. Each question carries ten marks.

1. (a) Define the following terms:

(i) Radioactive decay
- Radioactive decay is the spontaneous process by which an unstable atomic nucleus loses energy by emitting radiation, such as alpha particles, beta particles, or gamma rays. This process leads to the transformation of one element into another over time.

(ii) Radioactive isotope
- A radioactive isotope, or radionuclide, is an isotope of an element that has an unstable nucleus and undergoes radioactive decay, emitting radiation in the form of alpha, beta, or gamma rays. Examples include Carbon-14 and Uranium-238.

(iii) Radioactivity
- Radioactivity is the property of certain atomic nuclei to spontaneously emit radiation due to nuclear instability. This phenomenon was discovered by Henri Becquerel and later studied by Marie Curie.

(b) A radioactive isotope of the element $^{226}_{88}Ra$ decays according to the following scheme:

$^{226}_{88}Ra$ ----> $^{222}_{86}Rn$ + α particle ----> $^{218}_{84}Po$ + α particle ----> $^{218}_{85}At$ + β particle ----> $^{218}_{86}Rn$ + β particle

Deduce the atomic number and mass of X, G, and H.

- The first decay releases an alpha particle (He nucleus, mass = 4, atomic number = 2), reducing Ra (Z = 88, A = 226) to Rn (Z = 86, A = 222).
- The second decay releases another alpha particle, reducing Rn (Z = 86, A = 222) to Po (Z = 84, A = 218).
- The third decay releases a beta particle, converting Po (Z = 84, A = 218) into At (Z = 85, A = 218).
- The final decay releases another beta particle, converting At (Z = 85, A = 218) into Rn (Z = 86, A = 218).

Thus:
- X = $^{222}_{86}Rn$
- G = $^{218}_{84}Po$
- H = $^{218}_{86}Rn$

(c) The mass number of two atoms X and Y with the same atomic number are 206 and 208, respectively. If X contains 124 neutrons in its nucleus, find the number of neutrons in the nucleus of Y. What is the atomic number of Y?

- The atomic number of an element is given by:
  Atomic number = Mass number - Number of neutrons

For X:
Atomic number = 206 - 124 = 82

Since X and Y have the same atomic number, the atomic number of Y is also 82.

For Y:
Number of neutrons = 208 - 82 = 126

Thus, the atomic number of Y is 82, and it has 126 neutrons.

2. (a) Write short notes on the following:

(i) Hydrogen bonding
- Hydrogen bonding is a type of intermolecular force that occurs when a hydrogen atom is covalently bonded to a highly electronegative atom (such as oxygen, nitrogen, or fluorine) and interacts with a lone pair on another electronegative atom. It is responsible for properties like the high boiling point of water and the structure of DNA.

(ii) Van der Waals forces
- Van der Waals forces are weak intermolecular forces arising from temporary dipoles induced in molecules. These forces include London dispersion forces and dipole-dipole interactions. They are significant in nonpolar molecules and contribute to boiling and melting points.

(iii) VSEPR theory
- Valence Shell Electron Pair Repulsion (VSEPR) theory is a model used to predict molecular geometry based on the repulsion between electron pairs around a central atom. It states that electron pairs arrange themselves to minimize repulsion, leading to specific molecular shapes such as linear, trigonal planar, tetrahedral, etc.

(b) Use the VSEPR theory to predict the molecular geometry of the following species:

(i) CF_4
- CF_4 has four bonding pairs and no lone pairs around the central carbon atom. According to VSEPR theory, it adopts a tetrahedral geometry with bond angles of approximately 109.5°.

(ii) SO_2
- SO_2 has two bonding pairs and one lone pair on the central sulfur atom. It adopts a bent (V-shaped) geometry with a bond angle of approximately 119° due to lone pair repulsion.

(iii) CS_2
- CS_2 has two bonding pairs and no lone pairs on the central carbon atom. It adopts a linear geometry with a bond angle of 180°.

(iv) SO_4^{2-}

- SO_4^{2-} has four bonding pairs and no lone pairs around sulfur, giving it a tetrahedral shape with bond angles of approximately 109.5°.

(c) Explain why CO_2 is a non-polar molecule while SO_2 is polar despite the fact that both have the same empirical formula.

- CO_2 is a linear molecule with symmetrical charge distribution, resulting in no net dipole moment. The equal and opposite dipoles cancel each other, making it non-polar.

- SO_2, on the other hand, has a bent molecular geometry due to lone pairs on sulfur. This leads to an asymmetric charge distribution, resulting in a net dipole moment and making SO_2 a polar molecule.

3. (a) Define Raoult's Law of vapor pressure.

- Raoult's Law states that the partial vapor pressure of a component in an ideal solution is directly proportional to its mole fraction in the solution. Mathematically,

$P_a = X_a P_a°$

where P_a is the partial vapor pressure of component A, X_a is the mole fraction of A, and $P_a°$ is the vapor pressure of pure A.

(b) Heptane and octane form an ideal solution. Give a mathematical expression for Raoult's vapor pressure law for a solution containing heptane and octane.

- The total vapor pressure of the solution is given by:

P_total = X_heptane P_heptane° + X_octane P_octane°

where X_heptane and X_octane are the mole fractions of heptane and octane, respectively, and P_heptane° and P_octane° are their pure vapor pressures.

(c) (i) Under what circumstances will two liquid mixtures behave as an ideal solution? Give three conditions.

1. The intermolecular forces between the two components should be similar to those in the pure components.
2. The solution should obey Raoult's Law at all concentrations.
3. There should be no significant heat change upon mixing.

(ii) Calculate the vapor pressure of a solution containing 50 g of heptane (C_7H_{16}) and 38 g of octane (C_8H_{18}) at 20°C. Vapor pressures of heptane and octane at 20°C are 47.32 Pa and 13.98 Pa, respectively.

- Molar masses:
  Molar mass of heptane = 100 g/mol
  Molar mass of octane = 114 g/mol

- Moles of each component:
  Moles of heptane = 50 / 100 = 0.5

Moles of octane = 38 / 114 = 0.333

- Mole fractions:
  X_heptane = 0.5 / (0.5 + 0.333) = 0.6
  X_octane = 0.333 / (0.5 + 0.333) = 0.4

- Vapor pressure contribution:
  P_heptane = 0.6 × 47.32 = 28.39 Pa
  P_octane = 0.4 × 13.98 = 5.59 Pa

- Total vapor pressure:
  P_total = 28.39 + 5.59 = 33.98 Pa

4. (a) Define the following terms:

(i) Le Chatelier's principle
- Le Chatelier's principle states that when a system at equilibrium is subjected to a change in concentration, pressure, or temperature, the system will shift its equilibrium position to counteract the imposed change.

(ii) Reversible reaction
- A reversible reaction is a chemical reaction where the reactants form products, and the products can convert back to reactants under suitable conditions.

(iii) Law of mass action
- The law of mass action states that the rate of a chemical reaction is proportional to the product of the molar concentrations of the reactants, each raised to a power equal to their stoichiometric coefficients.

(iv) Catalyst
- A catalyst is a substance that increases the rate of a chemical reaction without being consumed. It provides an alternative reaction pathway with a lower activation energy.
(b) Explain briefly how temperature affects the equilibrium reaction.

Temperature plays a significant role in determining the position of equilibrium in a chemical reaction. According to Le Chatelier's principle:

- For an exothermic reaction ($\Delta H < 0$): Increasing temperature shifts the equilibrium position to favor the reactants, decreasing the yield of products. This happens because heat is treated as a product, and adding more heat causes the system to counteract this by shifting toward the reactants.

- For an endothermic reaction ($\Delta H > 0$): Increasing temperature shifts the equilibrium position to favor the products, increasing the yield. Here, heat is treated as a reactant, so adding more heat pushes the reaction forward to produce more products.

- Lowering temperature has the opposite effect:
  - In exothermic reactions, it shifts the equilibrium to the products.
  - In endothermic reactions, it shifts the equilibrium to the reactants.

For example, in the equilibrium reaction:
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{Heat}$

- Increasing temperature shifts equilibrium left, reducing ammonia yield.
- Decreasing temperature shifts equilibrium right, increasing ammonia yield.

However, in industrial processes like the Haber process, a balance is required between temperature and reaction rate to optimize production.

(c) In an experiment, 0.206 moles of hydrogen and 0.144 moles of iodine were heated (at 723 K) to equilibrium in the reaction

$H_2 + I_2 \rightleftharpoons 2HI$

0.258 moles of hydrogen iodide was formed. Calculate the equilibrium constant of the reaction.
Solution

Step 1: Write the ICE table for the reaction:

Species	Initial Moles	Change in Moles	Equilibrium Moles
H_2	0.206	-x	0.206 - x
I_2	0.144	-x	0.144 - x
HI	0	+2x	2x

From the given data, at equilibrium, the moles of HI formed is 0.258, so:

$2x = 0.258$
$x = 0.129$

Step 2: Calculate the equilibrium moles of H_2 and I_2:

$H_2 = 0.206 - 0.129 = 0.077$
$I_2 = 0.144 - 0.129 = 0.015$

Step 3: Write the equilibrium constant expression:

$Kc = [HI]^2 / ([H_2] [I_2])$

Substituting the values:

$Kc = (0.258)^2 / (0.077 \times 0.015)$
$Kc = 0.066564 / 0.001155$
$Kc = 57.64$
$Kc = 57.64$ at 723 K.

5. (a) The atomic nuclei of isotopic atoms X and Y contain the following:
X - 8 neutrons and 8 protons
Y - 20 neutrons and 19 protons

Write the:

(i) Mass number of X and Y
- The mass number (A) is the sum of protons and neutrons.
For X: A = 8 + 8 = 16
For Y: A = 20 + 19 = 39

(ii) Atomic number of X and Y
- The atomic number (Z) is the number of protons.
For X: Z = 8
For Y: Z = 19

(iii) Electronic configurations of X and Y
- Electronic configuration follows the Aufbau principle.
For X (Z = 8): $1s^2\ 2s^2\ 2p^4$
For Y (Z = 19): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

(iv) Groups and periods in the periodic table of elements to which X and Y belong
- Group is determined by valence electrons, period by energy levels.
For X (Oxygen): Group 16, Period 2
For Y (Potassium): Group 1, Period 4

(v) Most probable oxidation states of X and Y
- Oxygen (X) commonly exhibits an oxidation state of -2.
- Potassium (Y) exhibits an oxidation state of +1.

(vi) Possible chemical formula for a compound formed between X and Y
- Since X (oxygen) has an oxidation state of -2 and Y (potassium) has +1, they combine in a 2:1 ratio.
Formula: K_2O (Potassium oxide).

(b) The energy of the electron in a hydrogen atom when it is in the ground state is given by:

$E_1 = -2.178 \times 10^{-18} (1/n_1^2)$ Joules

The energy of the same electron if it occupies a higher energy level (n = 2) is given by:

$E_2 = -2.178 \times 10^{-18} (1/n_2^2)$ Joules

Calculate the energy, in joules, and the wavenumber, in meters, of the light which must be absorbed by a hydrogen atom to excite its electron from n = 1 to n = 2.

Solution:

Step 1: Energy difference
$\Delta E = E_2 - E_1$
$= -2.178 \times 10^{-18} (1/2^2 - 1/1^2)$
$= -2.178 \times 10^{-18} (1/4 - 1)$
$= -2.178 \times 10^{-18} (-3/4)$
$= 1.634 \times 10^{-18}$ J

Step 2: Wavenumber calculation
Wavenumber ($\bar{v}$) = E / (h × c)

Using Planck's constant $h = 6.626 \times 10^{-34}$ J·s and speed of light $c = 3.00 \times 10^8$ m/s:

$\bar{v} = (1.634 \times 10^{-18}) / (6.626 \times 10^{-34} \times 3.00 \times 10^8)$
$\bar{v} = 8.23 \times 10^6\ m^{-1}$

Final Answers:
- Energy required = 1.634×10^{-18} J
- Wavenumber = $8.23 \times 10^6\ m^{-1}$

6. (a) What do you understand by the following terms?

(i) Mole
A mole is the amount of substance that contains as many elementary entities (atoms, molecules, or ions) as there are atoms in 12 g of carbon-12, which is equal to Avogadro's number (6.022×10^{23} particles).

(ii) Mole fraction
Mole fraction is the ratio of the number of moles of a component to the total number of moles in a mixture. It is given by:
Mole fraction = moles of component / total moles of all components.

(iii) Molarity
Molarity (M) is the number of moles of solute dissolved in one liter of solution. It is given by:

Molarity = moles of solute / volume of solution in liters.

(iv) Molality
Molality (m) is the number of moles of solute dissolved in one kilogram of solvent. It is given by:
Molality = moles of solute / mass of solvent in kg.

(v) Normality
Normality (N) is the number of gram-equivalents of solute per liter of solution. It depends on the reaction type and is given by:
Normality = Molarity × Equivalent factor.

(b) Sulphuric acid solution containing 571.6 g of H_2SO_4 per dm^3 of solution at 20°C has a density of 1.329 g/ml. Calculate the:

(i) Molarity of sulphuric acid
Molar mass of H_2SO_4 = 2(1) + 32 + 4(16) = 98 g/mol

Moles of H_2SO_4 = 571.6 g / 98 g/mol = 5.83 mol

Volume of solution = 1 dm^3 = 1 liter

Molarity (M) = moles of solute / volume of solution in liters
= 5.83 mol / 1 L
= 5.83 M

(ii) Percentage by mass of H_2SO_4
Percentage by mass = (mass of solute / mass of solution) × 100

Mass of 1 liter of solution = density × volume
= 1.329 g/ml × 1000 ml
= 1329 g

Percentage by mass = (571.6 g / 1329 g) × 100
= 43.02%

(iii) Mole fractions of the solution components
Mole fraction of H_2SO_4 = moles of H_2SO_4 / (moles of H_2SO_4 + moles of water)

Mass of water in solution = total mass - mass of H_2SO_4
= 1329 g - 571.6 g
= 757.4 g

Moles of water = 757.4 g / 18 g/mol

= 42.08 mol

Mole fraction of H_2SO_4 = 5.83 / (5.83 + 42.08)
= 0.121

Mole fraction of water = 1 - 0.121 = 0.879

Final Answers:
(i) Molarity = 5.83 M
(ii) Percentage by mass = 43.02%
(iii) Mole fraction of H_2SO_4 = 0.121, Mole fraction of water = 0.879

7. (a) Give three reasons to support hydrogen being grouped in group seven together with halogens in the periodic table

Solution:
i. Hydrogen has one valence electron similar to halogens, which have seven valence electrons and require one more electron to complete their octet.
ii. Hydrogen forms diatomic molecules (H_2), just like halogens (Cl_2, Br_2, I_2, etc.).
iii. Hydrogen exhibits both oxidation states of -1 (as in hydrides) and +1 (as in acids), similar to halogens that exhibit multiple oxidation states.

(b) Give four diagonal similarities between aluminium and beryllium

Solution:
i. Both aluminium and beryllium have high ionization energies compared to other elements in their respective groups.
ii. Both form amphoteric oxides, meaning they react with both acids and bases to form salts.
iii. Both exhibit covalent character in their compounds due to their high charge density and small atomic size.
iv. Both metals form strong complexes with ligands such as hydroxide and fluoride.

(c) Explain the following chemical phenomena using equations or other illustrations whenever possible

(i) Aluminium chloride is a good Lewis acid

Solution:
- A Lewis acid is a substance that accepts an electron pair.
- Aluminium chloride ($AlCl_3$) has an incomplete octet and readily accepts an electron pair, making it a strong Lewis acid.
Equation:
$AlCl_3 + Cl^- \text{---->} AlCl_4^-$

(ii) Concentrated nitric acid renders aluminium passive

Solution:
- Aluminium reacts with concentrated nitric acid to form an inert Al_2O_3 layer that prevents further reaction.
Equation:
$Al + 6HNO_3$ ----> $Al_2O_3 + 6NO_2 + 3H_2O$

(iii) The relative molecular mass of aluminium chloride in the vapour state is twice the expected value

Solution:
- In the vapour state, $AlCl_3$ exists as a dimer (Al_2Cl_6), leading to a molecular mass twice the expected value.
Equation:
$2AlCl_3$ ----> Al_2Cl_6

8. (a) Write balanced chemical equations for the following reactions

(i) Excess carbon dioxide is bubbled in sodium hydroxide solution

Equation:
$CO_2 + NaOH$ ----> $NaHCO_3$

(ii) Excess sulphuric acid is added to sodium sulphate solution

Equation:
$H_2SO_4 + Na_2SO_4$ ----> No reaction (since Na_2SO_4 is already a neutral salt)

(iii) A white precipitate is observed when sodium sulphate solution is added to barium chloride solution in the presence of hydrochloric acid

Equation:
$Na_2SO_4 + BaCl_2$ ----> $BaSO_4$ (white precipitate) + 2NaCl

(b) (i) What is the difference between hydrolysis and hydration?

Solution:
- Hydrolysis is a chemical reaction in which water breaks down a compound into two or more products.
- Hydration is the addition of water molecules to a substance without breaking chemical bonds.

(ii) Give two supporting reaction equations to show clearly the contrast between hydrolysis and hydration

Equation for hydrolysis:
$NaCl + H_2O$ ----> $Na^+ + Cl^-$

Equation for hydration:
$CuSO_4 + 5H_2O$ ----> $CuSO_4 \cdot 5H_2O$

(c) Elements in group I and group II are normally extracted by electrolysis of their fused chlorides. Explain why

Solution:
- Group I and II metals are highly reactive and form strong ionic bonds, making them difficult to extract using conventional reduction methods.
- Electrolysis is used because it provides sufficient energy to break these strong ionic bonds and release pure metal.

9. (a) What do you understand by the following terms?

(i) Mole
- A mole is the amount of substance that contains Avogadro's number (6.022×10^{23}) of particles, atoms, or molecules.

(ii) Avogadro's constant
- Avogadro's constant (6.022×10^{23} mol^{-1}) is the number of atoms, ions, or molecules in one mole of a substance.

(b) SO_2 is used in the manufacture of sulphuric acid and it is obtained from sulphide ores

Equation:
$4FeS_2 + 11O_2$ ----> $2Fe_2O_3 + 8SO_2$

Find the mass of oxygen, in grams, reacting when 75 L of SO_2 is produced at 100°C and 1.04 atm

Solution:
Using the ideal gas equation:
$PV = nRT$
(1.04 atm) (75 L) = n (0.0821 L·atm/mol·K) (373 K)

Solving for n:
$n = (1.04 \times 75) / (0.0821 \times 373)$
n = 2.54 moles of SO_2

From the equation, 4 moles of FeS_2 produce 8 moles of SO_2, using mole ratio:
O_2 required = (2.54 moles SO_2 × 11 moles O_2) / 8 moles SO_2
O_2 = 3.49 moles

Mass of O_2 = 3.49 × 32 g/mol = 111.68 g

Final Answer:
Mass of oxygen = 111.68 g

(c) A mixture of 5 g of sodium carbonate and sodium bicarbonate is heated. The loss in mass is 0.31 g. Calculate the percentage by mass of sodium carbonate in the mixture

Solution:
Equation:
$2NaHCO_3$ ----> $Na_2CO_3 + CO_2 + H_2O$

Loss in mass comes from CO_2 and H_2O.

Molar mass of $NaHCO_3$ = 84 g/mol
Molar mass of $CO_2 + H_2O$ = 44 + 18 = 62 g/mol

Mass ratio:
62 g lost for every 168 g $NaHCO_3$ decomposed
So, if 0.31 g is lost:
Mass of $NaHCO_3$ decomposed = (168 × 0.31) / 62
= 0.84 g

Mass of Na_2CO_3 = 5 - 0.84 = 4.16 g

Percentage by mass of Na_2CO_3 = (4.16 / 5) × 100
= 83.2%

Final Answer:
Percentage by mass of sodium carbonate = 83.2%

10. (a) With two examples in each case, explain the terms:

(i) Cationic complexes
Solution:
Cationic complexes are coordination compounds where the central metal ion carries a positive charge and is surrounded by ligands.
Examples:
1. $[Cr(NH_3)_6]^{3+}$ (Hexaamminechromium(III) ion)
2. $[Co(H_2O)_6]^{2+}$ (Hexaaquacobalt(II) ion)

(ii) Anionic complexes
Solution:
Anionic complexes are coordination compounds where the central metal ion carries a negative charge due to negatively charged ligands.

Examples:
1. $[Fe(CN)_6]^{4-}$ (Hexacyanoferrate(II) ion)
2. $[CoCl_4]^{2-}$ (Tetrachlorocobaltate(II) ion)

(iii) Neutral complexes
Solution:
Neutral complexes are coordination compounds where the overall charge on the complex is zero.
Examples:
1. $[Ni(CO)_4]$ (Tetracarbonylnickel)
2. $[Pt(NH_3)_2Cl_2]$ (Cisplatin)

(b) Give all the isomers of $CoCl_3 \cdot 6NH_3$

Solution:
$CoCl_3 \cdot 6NH_3$ exists in two isomeric forms:
1. $[Co(NH_3)_6]Cl_3$ (Coordination isomer, all ammonia molecules are coordinated to cobalt, and chloride ions are counter ions).
2. $[CoCl(NH_3)_5]Cl_2$ (One chloride ligand is coordinated to cobalt, and two chloride ions remain as counter ions).
3. $[CoCl_2(NH_3)_4]Cl$ (Two chloride ligands are coordinated to cobalt, and one chloride ion remains as a counter ion).

(ii) Addition of excess silver nitrate solution to an aqueous solution containing 0.01 M of $CoCl_3 \cdot 6NH_3$ leads to an immediate precipitate of 0.03 M of silver chloride. What is the structure of $CoCl_3 \cdot 6NH_3$?

Solution:
- Since 0.03 M of AgCl is precipitated, it suggests that all three Cl^- ions are free in solution and not coordinated to Co^{3+}.
- This indicates that the complex has the structure $[Co(NH_3)_6]Cl_3$, where all six NH_3 molecules are coordinated to cobalt and the three Cl^- ions are free in solution, reacting with $AgNO_3$ to form AgCl precipitate.

(c) With the help of equations, explain what happens when

(i) An acid is added to a chromate (VI)

Solution:
- When an acid (H^+) is added to chromate (CrO_4^{2-}), it converts into dichromate ($Cr_2O_7^{2-}$) in an equilibrium reaction.
Equation:
$2CrO_4^{2-} + 2H^+ \text{---->} Cr_2O_7^{2-} + H_2O$
- This reaction shifts the yellow chromate solution to an orange dichromate solution.

(ii) A base is added to a dichromate (VI)

Solution:
- When a base (OH^-) is added to dichromate ($Cr_2O_7^{2-}$), it converts back into chromate (CrO_4^{2-}).
Equation:
$Cr_2O_7^{2-} + 2OH^- \longrightarrow 2CrO_4^{2-} + H_2O$
- This reaction shifts the orange dichromate solution to a yellow chromate solution.

11. (a) Write the structural formulae for the following compounds:

(i) 2,3-dibromopentane
Solution:
The structure of 2,3-dibromopentane consists of a five-carbon chain (pentane) with bromine atoms attached to the second and third carbon atoms.
Structure:
CH_3-CHBr-CHBr-CH_2-CH_3

(ii) 3,3-dimethylheptane
Solution:
3,3-dimethylheptane consists of a seven-carbon chain (heptane) with two methyl (-CH_3) groups attached to the third carbon.
Structure:
CH_3-CH_2-$C(CH_3)_2$-CH_2-CH_2-CH_2-CH_3

(iii) 3,3-dichlorobutan-1,3-diene
Solution:
This compound has a four-carbon chain (butane) with two chlorine atoms at the third carbon, and double bonds between carbons 1 and 3.
Structure:
CH_2=CH-$C(Cl)_2$-CH=CH_2

(iv) 1,4-hexadiene
Solution:
1,4-hexadiene consists of a six-carbon chain (hexane) with double bonds at the first and fourth carbon positions.
Structure:
CH_2=CH-CH_2-CH=CH-CH_3

(b) Write an equation for the reaction of propylene with each of the following:

(i) Hydrogen bromide in presence of Peroxide
Solution:
CH_3-CH=CH_2 + HBr ----> CH_3-CH_2-CH_2Br (Anti-Markovnikov addition)

(ii) H_2O, H^+
Solution:
CH_3-CH=CH_2 + H_2O ----> CH_3-CHOH-CH_3 (Hydration reaction forming isopropanol)

(iii) Hot Conc. alkaline $KMnO_4$ followed by acidification
Solution:
CH_3-CH=CH_2 + [O] ----> CH_3-COOH + CO_2 + H_2O (Oxidation to acetic acid and carbon dioxide)

(iv) Cl_2, UV light
Solution:
CH_3-CH=CH_2 + Cl_2 ----> CH_3-CHCl-CH_2Cl (Radical chlorination)

(v) Br_2/CCl_4 solution
Solution:
CH_3-CH=CH_2 + Br_2 ----> CH_3-CHBr-CH_2Br (Bromine test, forms a dibromo compound)

12. (a) For each of the following pairs of alcohols, suggest one observable distinguishing test:

(i) $CH_3CH_2CH_2$-OH and CH_3CH_2OH
Solution: Lucas Test - $CH_3CH_2CH_2OH$ (1° alcohol) does not react immediately, whereas CH_3CH_2OH (2° alcohol) gives a cloudy solution with Lucas reagent ($ZnCl_2$/HCl).

(ii) CH_3C-OH and 2-methylpropan-1-ol
|
CH_3
Solution: 2,4-Dinitrophenylhydrazine (2,4-DNP) Test - The ketone group in CH_3C-OH reacts with 2,4-DNP to form a yellow/orange precipitate, while 2-methylpropan-1-ol does not.

(b) Which alcohol will be made if pentan-3-one is reacted with $LiAlH_4$?
Solution:
Pentan-3-one ($CH_3CH_2COCH_2CH_3$) will be reduced to pentan-3-ol ($CH_3CH_2CHOHCH_2CH_3$).

(ii) What will be the products of the following reaction?
Pent-2-ene + Conc H_2SO_4 ----> H_2O
Solution:
Pent-2-ene undergoes hydration to form pentan-2-ol as the major product.

(c) An alcohol B reacts with conc H_2SO_4 at 170°C to form an alkene Q. Q reacts with ozone, zinc dust, and water to give propanone and ethanol.

(i) Deduce the structural formulae of Q and B.
Solution:

- Q must be but-2-ene ($CH_3CH=CHCH_3$), as its ozonolysis produces propanone and ethanol.
- B must be butan-2-ol ($CH_3CHOHCH_2CH_3$), which dehydrates to form Q.

(ii) Give balanced equations for the formation of all compounds mentioned.

Dehydration:
$CH_3CHOHCH_2CH_3$ ----> $CH_3CH=CHCH_3 + H_2O$

Ozonolysis:
$CH_3CH=CHCH_3 + O_3$ ----> $CH_3COCH_3 + CH_3CH_2OH$

13. (a) You are provided with the following pairs of organic compounds. Which compound has a higher boiling point in each pair? Give reasons for your choice.

(i) CH_3CH_2OH and CH_3OCH_3
Solution: Ethanol (CH_3CH_2OH) has a higher boiling point than dimethyl ether (CH_3OCH_3) because ethanol forms strong hydrogen bonds between its molecules, whereas dimethyl ether only has weak van der Waals forces and dipole-dipole interactions.

(ii)
 OH
 |
C_6H_4-NO_2
 and
 OH
 |
C_6H_4-NO_2
Solution: The para isomer has a higher boiling point than the ortho isomer because the para isomer has a more symmetrical structure, allowing better molecular packing and stronger intermolecular forces, whereas the ortho isomer has intramolecular hydrogen bonding, which reduces intermolecular interactions.

(iii) $CH_3CH_2CH_2CH_2CH_3$ and $CH_3CH_2CH_2CH_2OH$
Solution: 1-Butanol ($CH_3CH_2CH_2CH_2OH$) has a higher boiling point than pentane ($CH_3CH_2CH_2CH_2CH_3$) because alcohols form hydrogen bonds, while alkanes only experience van der Waals forces.

(iv) $CH_3CH_2CH_2CH_2CH_3$ and CH_3-C-CH_3
 ||
 O
Solution: The ketone (CH_3-C-CH_3) has a higher boiling point than pentane due to stronger dipole-dipole interactions, while pentane only has weak van der Waals forces.

(b) Arrange the following compounds A, B, and C in order of increasing acidic strength and give reasons for your order.

A: CH_3OH
B: C_6H_5OH
C: $C_6H_4(OH)NO_2$

Solution:
Order of increasing acidic strength: $CH_3OH < C_6H_5OH < C_6H_4(OH)NO_2$
- Methanol (CH_3OH) is the least acidic because it lacks electron-withdrawing groups to stabilize the conjugate base.
- Phenol (C_6H_5OH) is more acidic because the phenoxide ion is stabilized by resonance.
- p-Nitrophenol ($C_6H_4(OH)NO_2$) is the most acidic because the nitro group is an electron-withdrawing group, further stabilizing the conjugate base through resonance and inductive effects.

14. (a) With the help of chemical equations, explain the following observations.

(i) Nitration of methylbenzene gives ortho and para nitromethylbenzene.
Solution:
- Methylbenzene (toluene) is an electron-donating group due to the +I and hyperconjugation effects of the methyl group.
- The presence of a methyl group directs electrophilic substitution reactions (such as nitration) to the ortho and para positions relative to the $-CH_3$ group.
- The nitration reaction occurs when toluene is treated with a nitrating mixture (HNO_3 and H_2SO_4), forming ortho-nitrotoluene and para-nitrotoluene as the main products.
- The reaction can be represented as:

$C_6H_5CH_3 + HNO_3$ -----> o-Nitrotoluene + p-Nitrotoluene + minor m-Nitrotoluene

(ii) Addition of a methyl group to nitrobenzene gives meta nitromethylbenzene.
Solution:
- In nitrobenzene, the nitro ($-NO_2$) group is an electron-withdrawing group due to its strong -I and -M effects.
- This causes a reduction in electron density at the ortho and para positions, making them less reactive to electrophilic substitution.
- As a result, the incoming methyl group (CH_3) preferentially attaches to the meta position.
- The reaction can be written as:

$C_6H_5NO_2 + CH_3$ -----> m-Nitrotoluene

(b) Give the systematic IUPAC names of each of the following compounds.

(i) CH_3Cl
Solution: Chloromethane

(ii)

```
  CH3-C-CH-CH-CH3
        |     |
      CH3   CH3
```

Solution: 2,3-Dimethylpentane

(iii)

```
 CH3CH2CH2CH- C = C
              |    |
            CH3   H
```

Solution: 4-Methylhex-2-ene

(iv)

Solution: 1-Methylcyclohexane

(v)

Solution: 4-Hydroxybenzaldehyde (or p-Hydroxybenzaldehyde)