

Set II

IRC -1 (Chemistry)

Full Marks: 75

Time: 3 Hours

Answer the questions as per instruction given.

The figures in the right-hand margin indicate marks.

Candidates are required to give answers in their own words as far as practicable.

Group A

(Short Answer Type Questions)

Answer all the following questions.

1. Answer the following questions in a few words or maximum in one sentence. (5x1=5)
 - a) Which series of lines of the hydrogen spectrum is obtained in the UV region?
 - b) Which element has the highest electronegativity?
 - c) What is the shape of methyl carbanion?
 - d) Write functional group isomer of dimethyl ether.
 - e) What is the IUPAC name of $\text{CH}_3\text{COOC}_2\text{H}_5$?
2. What is molality? Write down its unit. What is effect of increase in temperature on the molarity of a solution? (5)
3. What do you mean by ideal binary liquid solution? What are its features? (5)

Group B

(Long /Descriptive Answer Type Questions)

Answer any four of the following questions.

4.
 - a) What is Heisenberg's uncertainty principle?
 - b) Calculate the uncertainty in velocity of an electron if uncertainty in its position is 1 nm.
 - c) Write electronic configuration of Fe (Z=26) and Cu (Z = 29). (5+5+5)
5.
 - a) Define electron affinity and illustrate with an example.
 - b) Discuss the variation of electron affinity in the periodic table.
 - c) The electron affinity of nitrogen is positive while that of chlorine is negative, why? (5+5+5)
6.
 - a) What is hybridisation?
 - b) Explain the shape of SF_4 , NH_3 and ClF_3 molecules with the help of hybridisation. (6+9)
7.
 - a) What do you mean by ideal and real gases?
 - b) Why the real gases do not obey ideal gas equation?

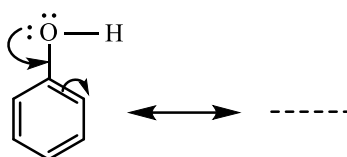
c) Under what conditions a real gas tends to behave like an ideal gas?

(5+5+5)

8. a) Why carbon forms such a large number of compounds?
b) Define functional group and give an example.
c) What is homologous series? Write the structure and IUPAC name of the next homologue of ethanoic acid.
d) What are aromatic compounds? Give an example.

(4+3+3+5)

9. a) What is substitution reaction? Give an example.
b) Define and explain inductive effect.
c) What are carbon free radicals? How are they generated?
d) Complete the following:



(4+4+4+3)

Answer:

- a) Lyman series
b) Fluorine
c) Trigonal pyramidal
d) $\text{CH}_3\text{CH}_2\text{OH}$ Ethanol
e) Ethyl ethanoate
- Molality:** The number of moles of solute present per kilogram of the solvent is called the molality of the solution.

$$\text{Molality} = \frac{\text{No. of mles of solute}}{\text{Mass of solvent (in kg)}}$$

Unit of molality = mole kg^{-1}

The molality of a solution does not change on increasing temperature because the mass of solvent does not change with increase in temperature.

3. Ideal binary liquid solution:

The solution of two liquids A and B is said to be an ideal solution when the following conditions are satisfied:

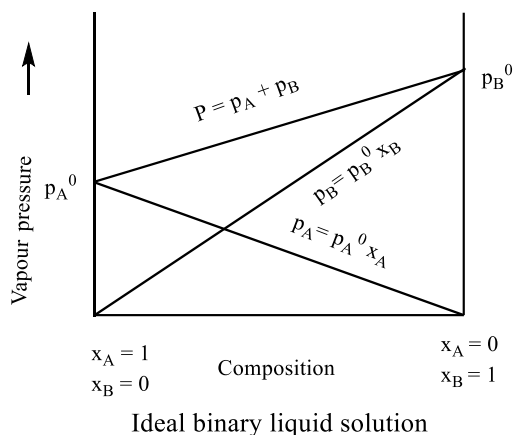
- The Raoult's law is obeyed completely.

ii) It means, $p_A = x_A \times p_A^0$ and $p_B = x_B \times p_B^0$
 $\Delta H_{\text{mixing}} = 0$

It means there is no enthalpy change during mixing up of two liquids. It is possible only when the A...B interaction is of almost same strength as A...A and B...B interactions.

iii) $\Delta V_{\text{mixing}} = 0$

It means there is no change in volume during mixing up two liquids. It is possible only when the liquids A and B have comparable molecular size.



4. a) Heisenberg's uncertainty principle

"It is impossible to determine both position and momentum (or velocity) of an extremely small fast-moving particle (such as an electron) accurately and simultaneously."

It is known as Heisenberg's uncertainty principle. It can be expressed mathematically as follows:

$$\Delta p \times \Delta x \geq \frac{h}{4\pi}$$

Where, Δp = uncertainty, i.e., error in the measurement of momentum of particle

Δx = uncertainty, i.e., error in the measurement of position of particle

b) We know that –

$$\Delta p \times \Delta x = \frac{h}{4\pi} \quad (i)$$

$$\because p = mv$$

$$\therefore \Delta p = \Delta(mv)$$

$$\text{or, } \Delta p = m\Delta v \quad (ii)$$

From equation (i) and (ii), we have

$$m\Delta v \times \Delta x = \frac{h}{4\pi}$$

$$\text{or, } \Delta v = \frac{h}{4\pi m \times \Delta x}$$

$$\text{or, } \Delta v = \frac{6.626 \times 10^{-34} \text{ J s}}{4 \times 3.14 \times 9.109 \times 10^{-31} \text{ kg} \times 10^{-9} \text{ m}} = 5.27 \times 10^{-26} \text{ ms}^{-1}$$

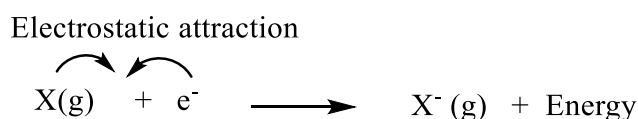
$$\text{or, } \Delta v = 5.79 \times 10^4 \text{ ms}^{-1}$$

c) Electronic configuration of Fe (Z = 26) = $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^6, 4s^2$

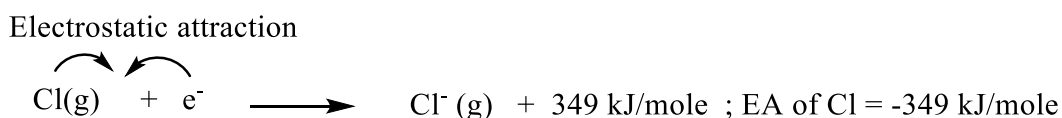
Electronic configuration of Cu (Z = 29) = $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^1$

5. a) Electron affinity:

“The amount of energy released when an extra electron is introduced to an isolated neutral gaseous atom of an element in its ground state to produce a gaseous anion is called the electron affinity of that element.” It is abbreviated as EA. It is expressed in kJ/mole.



Let us illustrate it by taking the following example:



The negative sign is used before electron affinity because energy is released during adding electron. The greater the negative value of electron affinity of an atom, the greater will be its tendency to gain electron.

b) Variation of electron affinity in the periodic table:

On moving down a group in the periodic table, the Z_{eff} remains almost constant but atomic radius increases. As a result, the electrostatic attractive force acting on the electron to be added towards the nucleus becomes increasingly weaker and hence the electron affinity goes on decreasing as illustrated below:

Group 17	
Elements	EA(kJ/mole)
F	-333
Cl	-349
Br	-325
I	-296

On moving from left to right in a period in the periodic table, the atomic radius decreases and the Z_{eff} increases. As a result, the electrostatic attractive force acting on the electron to be added towards the becomes increasingly stronger and hence the electron affinity goes on increasing as illustrated below:

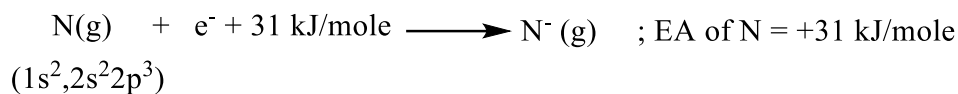
Period	Elements	Li	Be	B	C	N	O	F	Ne
2	EA(kJ/mole)	-57	+66	-15	-121	+31	-142	-333	+116

Be, N and Ne have exceptional positive electron affinity due to their stable half-filled / full-filled electronic configuration.

c) The electron affinity of nitrogen is positive while that of chlorine is negative:

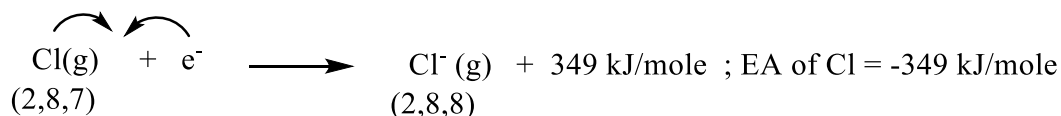
If an atom has already extra stable half-filled or full-filled subshell in the valence shell, it has no tendency to gain electron. The electron affinity of such atom is

positive. It means, energy is absorbed and not released during adding extra electron to such atom. For example, the electron affinity of nitrogen having extra stable half-filled $2p^3$ subshell is positive.



On the other hand, Cl atom having 7 electrons in the valence shell, has a tendency to complete the octet of electrons in the valence shell by gaining one electron and hence its electron affinity is negative.

Electrostatic attraction



6. a) Hybridisation:

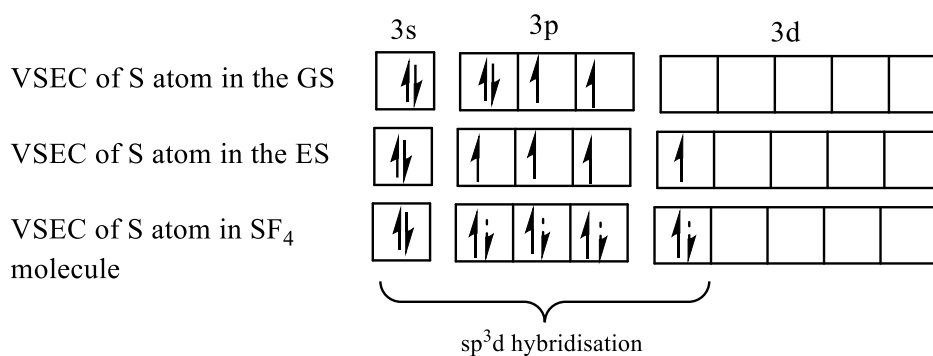
“The mixing up of atomic orbitals of comparable energies lying on the same atom to produce entirely new orbitals is called hybridisation and the new orbitals produced in this way are called hybrid orbitals.”

The following facts are noteworthy regarding hybridisation:

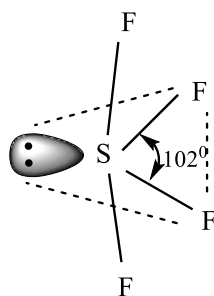
- i. It is the mixing up of orbitals and not of electrons.
- ii. The hybrid orbitals are generally identical in shape, size and energy.
- iii. The number of hybrid orbitals produced is always equal to the number of atomic orbitals taking part in hybridisation.
- iv. The hybrid orbitals have a definite arrangement in the space depending on the type of hybridisation.
- v. A hybrid orbital forms stronger bond than pure atomic orbital.
- vi. A hybrid orbital can form only σ - bond and not π – bond because the overlapping of hybrid orbitals at two positions is not possible.

b) Shape of SF₄

S is the central atom in SF₄ molecule.



It must be noted that in the trigonal bipyramidal geometry, the lone pair occupies the equatorial corner to minimise the repulsion.



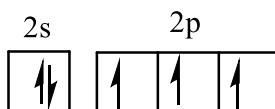
Structure: Distorted TBP with one equatorial corner occupied by lone pair
Shape: See-saw

Shape of NH₃

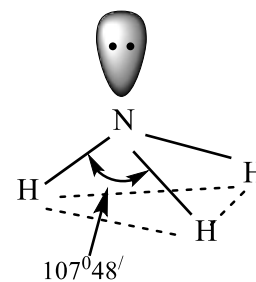
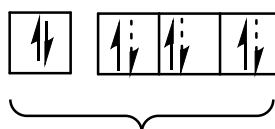
N is the central atom in NH₃ molecule.

N(7) 1s²2s²2p³

VSEC of N atom in the GS



VSEC of N atom in NH₃ molecule



Structure: Distorted tetrahedral with one corner occupied by lone pair

Shape: Trigonal pyramidal

Shape of ClF₃

Cl is the central atom in ClF₃ molecule.

Cl(17) [Ne]3s²3p⁵

VSEC of Cl atom in the GS



VSEC of Cl atom in the ES

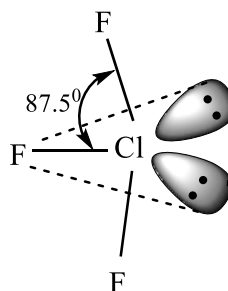


VSEC of Cl atom in ClF₃ molecule



sp³d hybridisation

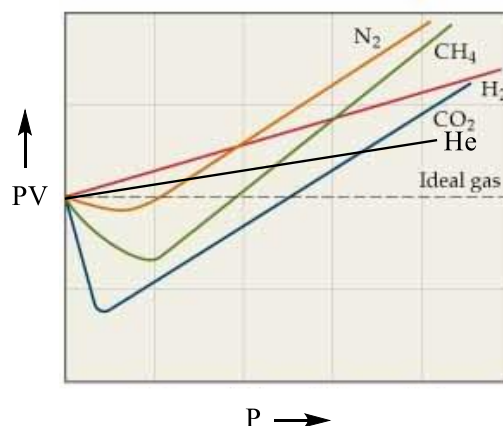
Structure: Distorted TBP with two equatorial corners occupied by lone pairs
Shape: Bent - T



7. a) Ideal and real gases

The gas which obeys the kinetic gas equation and ideal gas equation completely at all the temperatures and pressures is called an ideal gas.

But it has been found that there is no gas which obeys the ideal gas equation completely as evident from the following figure:



All the existing gases are called real gases. It is obvious from the above figure that Helium gas is the closest to the ideal gas behaviour.

b) The real gases do not obey ideal gas equation due to two faulty assumptions in the kinetic theory of gases and these are

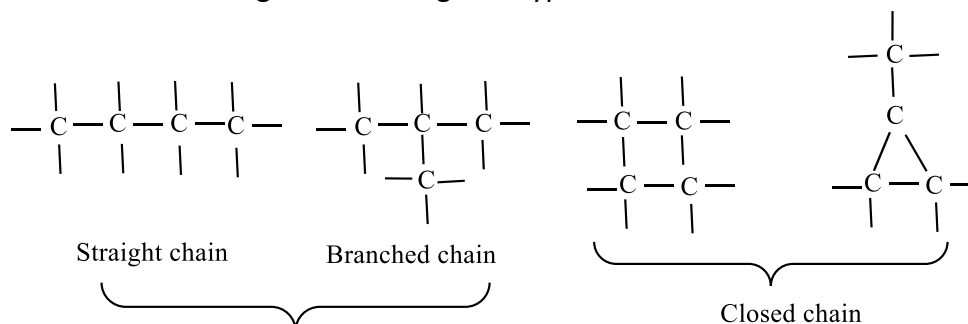
- i. The total volume of the gaseous molecules is negligible in comparison to the volume of the vessel.
- ii. There exists neither attractive nor repulsive force among the molecules of a gas.

In actual practice, the gaseous molecules do occupy some space and an attractive force acts among the gaseous molecules.

c) At low pressure and high temperature, a real gas tends to behave like an ideal gas.

8. a) Carbon forms such a large number of compounds due to following reasons:

- i. **Catenation property of carbon:** The property of an element due to which its atoms unite together forming long chains is called catenation property. Carbon has the highest catenation property among all the elements due to very strong C – C single bond with bond energy 348 kJ mole^{-1} . It is only next to H – H bond with bond energy 436 kJ mole^{-1} . Hydrogen cannot exhibit catenation property because it is monovalent.
- ii. **Tetravalency of carbon:** Carbon is tetravalent due to which carbon atoms can unite together forming various types of chains. For example, four carbon atoms can link together forming four types of chains as follows:



- iii. **Multiple bond forming ability:** Carbon atom is small and tetravalent. It can form multiple bonds with other small and multivalent atoms such as C, N and O.

Examples: $C \equiv C$, $C \equiv N$, $C = C$, $C = N$, $C = O$, etc.

- iv. **Isomerism:** The organic compounds exhibit isomerism due to which a single molecular formula may represent more than one organic compound. For example, $C_{10}H_{22}$ represents 75 organic compounds.

b) Functional group:

An atom or a group of atoms bonded in a specific manner on which the properties of organic compounds depend is called functional group. In other words, the organic compounds having the same functional group have similar properties. The number of organic compounds is large (about 10 million) but the number of functional groups is limited (about 15). Therefore, the functional groups have made the study of organic compounds easier.

For example, the functional group of aldehydes is $-CHO$.

c) Homologous series:

The series of organic compounds having the same functional group in which the molecular formulae of two consecutive members differ by $-CH_2-$ is called homologous series. The members of a homologous series are called homologues and this property is called homology.

The homologous series of monohydric alcohols is given below:

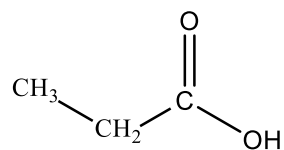
CH_3OH : Methyl alcohol

CH_3CH_2OH : Ethyl alcohol

$CH_3CH_2CH_2OH$: n-Propyl alcohol

$CH_3CH_2CH_2CH_2OH$: n-Butyl alcohol

Structure and IUPAC name of the next homologue of ethanoic acid:

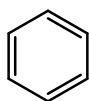


Propanoic acid

d) Aromatic compounds:

“The cyclic planar compounds containing $(4n+2)$ completely delocalised π -electrons are called aromatic compounds, where $n = 0, 1, 2, 3$, etc. and the property of such compounds is called aromaticity.” It is known as Huckel’s rule for aromaticity. In other words, the cyclic planar compounds containing 2, 6, 10, 14, etc. completely delocalised π -electrons are called aromatic compounds.

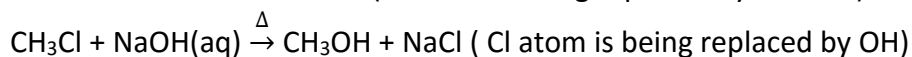
Benzene is the simplest example of aromatic compound.



It is a cyclic planar compound containing 6 ($n=1$) completely delocalised π -electrons.

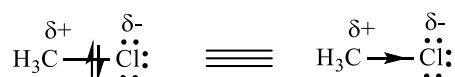
9. a) Substitution reactions:

The organic reactions in which an atom or a group of atoms of the substrate molecule is replaced by another atom or group are called substitution reactions. Some examples of substitution reactions are given below:



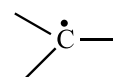
b) Inductive effect:

The polarity produced within the substrate molecule due to slight displacement of the σ -bond pair towards more electronegative atom is called inductive effect. It is denoted by an arrow in the direction of displacement of electron. Example: In CH_3Cl molecule, the Cl atom is attached to C atom. Cl is more electronegative than C atom. Hence, the σ -bond pair is displaced towards Cl atom. As a result, Cl atom becomes partially negatively charged and C atom becomes partially positively charged as shown below:



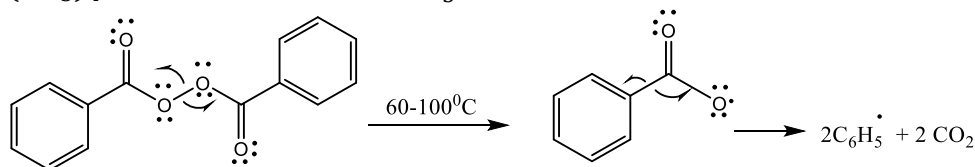
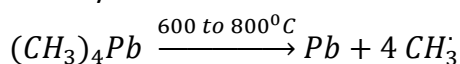
c) Free radicals:

The organic reaction intermediate containing trivalent neutral carbon atom bearing a non-bonding unpaired electron is called carbon free radical.



Free radical

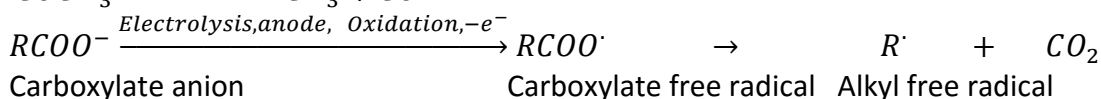
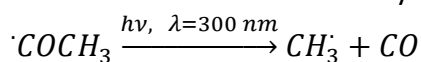
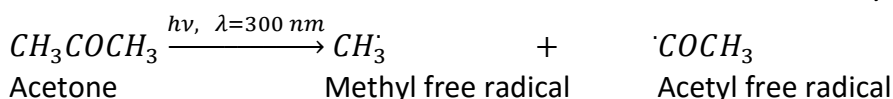
Formation: The free radical intermediate is generally produced when a molecule is supplied sufficient amount of thermal, electrical or radiation energy to cause homolytic fission of covalent bond.



Benzoyl peroxide

Benzoate free radical

Phenyl free radical



d)

