

**DIRECTORATE OF EDUCATION**  
**Govt. of NCT, Delhi**

**SUPPORT MATERIAL**  
**(2020-2021)**

**Class : XI**

**CHEMISTRY**

Under the Guidance of

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**MANISHA SAXENA**  
IAS



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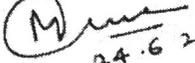
DO No. DE. 5/228/Exam/Message/S.M./2018  
Dated

**MESSAGE**

The importance of adequate practice during examinations can never be overemphasized. I am happy that support material for classes IX to XII has been developed by the Examination Branch of Directorate of Education. This material is the result of immense hard work, co-ordination and cooperation of teachers and group leaders of various schools. The purpose of the support material is to impart ample practice to the students for preparation of examinations. It will enable the students to think analytically & rationally and test their own capabilities and level of preparation.

The material is based on latest syllabus prepared by the NCERT and adopted by the CBSE for the academic session 2020-21 and covers different levels of difficulty. I expect that Heads of Schools and Teachers will enable and motivate students to utilize this material during zero periods, extra classes and regular classes best to their advantage.

I would like to compliment the team of Examination Branch for their diligent efforts of which made it possible to accomplish this work in time. I also take this opportunity to convey my best wishes to all the students for success in their endeavours.

  
24.6.2020  
(MANISHA SAXENA)

**BINAY BHUSHAN, IAS**



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**D.O. No.**

**Date :**

Dear Students,

Directorate of Education is committed to providing qualitative and best education to all its students. The Directorate is continuously engaged in the endeavor to make available the best study material for uplifting the standard of its students and schools.

Every year, the expert faculty of Directorate reviews and updates Support Material. The expert faculty of different subjects incorporates the changes in the material as per the latest amendments made by CBSE to make its students familiar with new approaches and methods so that students do well in the examination.

The book in your hand is the outcome of continuous and consistent efforts of senior teachers of the Directorate. They have prepared and developed this material especially for you. A huge amount of money and time has been spent on it in order to make you updated for annual examination.

Last, but not the least, this is the perfect time for you to build the foundation of your future. I have full faith in you and the capabilities of your teachers. Please make the fullest and best use of this Support Material.

  
**BINAY BHUSHAN**  
**DIRECTOR (EDUCATION)**

**Dr. (Mrs.) Saroj Bala Sain**  
Addl. Director of Education  
(School / Exam / EVGB/EB/ VOC.)



Govt. of NCT of Delhi  
Directorate of Education  
Old Secretariat, Delhi-110054  
Tel.: 23890023, 23890093

D.O. No. PA/Addl.DE(sen)/86  
Date : 03-10-2019

I am very much pleased to forward the Support Material for classes IX to XII. Every year, the Support Material of most of the subjects is updated/revised as per the most recent changes made by CBSE. The team of subject experts, officers of Exam Branch, members of Core Academic Unit and teachers from various schools of Directorate has made it possible to make available unsurpassed material to students.

Consistence use of Support Material by the students and teachers will make the year long journey seamless and enjoyable. The main purpose to provide the Support Material for the students of government schools of Directorate is not only to help them to avoid purchasing of expensive material available in the market but also to keep them updated and well prepared for exam. The Support Material has always been a ready to use material, which is matchless and most appropriate.

I would like to congratulate all the Team Members for their tireless, unremitting and valuable contributions and wish all the best to teachers and students.

(Dr. Saroj Bala Sain)  
Addl.DE (School/Exam)

**भारत का संविधान**  
**भाग 4क**  
**नागरिकों के मूल कर्तव्य**

**अनुच्छेद 51क**

**मूल कर्तव्य** - भारत के प्रत्येक नागरिक का यह कर्तव्य होगा कि वह -

- (क) संविधान का पालन करे और उसके आदर्शों, संस्थाओं, राष्ट्रध्वज और राष्ट्रगान का आदर करे;
- (ख) स्वतंत्रता के लिए हमारे राष्ट्रीय आंदोलन को प्रेरित करने वाले उच्च आदर्शों को हृदय में संजोए रखे और उनका पालन करे;
- (ग) भारत की संप्रभुता, एकता और अखंडता की रक्षा करे और उसे अक्षुण्ण बनाए रखे;
- (घ) देश की रक्षा करे और आह्वान किए जाने पर राष्ट्र की सेवा करे;
- (ङ) भारत के सभी लोगों में समरसता और समान भ्रातृत्व की भावना का निर्माण करे जो धर्म, भाषा और प्रदेश या वर्ग पर आधारित सभी भेदभावों से परे हो, ऐसी प्रथाओं का त्याग करे जो महिलाओं के सम्मान के विरुद्ध हों;
- (च) हमारी सामासिक संस्कृति की गौरवशाली परंपरा का महत्त्व समझे और उसका परिरक्षण करे;
- (छ) प्राकृतिक पर्यावरण की, जिसके अंतर्गत वन, झील, नदी और वन्य जीव हैं, रक्षा करे और उसका संवर्धन करे तथा प्राणिमात्र के प्रति दयाभाव रखे;
- (ज) वैज्ञानिक दृष्टिकोण, मानववाद और ज्ञानार्जन तथा सुधार की भावना का विकास करे;
- (झ) सार्वजनिक संपत्ति को सुरक्षित रखे और हिंसा से दूर रहे;
- (ञ) व्यक्तिगत और सामूहिक गतिविधियों के सभी क्षेत्रों में उत्कर्ष की ओर बढ़ने का सतत् प्रयास करे, जिससे राष्ट्र निरंतर बढ़ते हुए प्रयत्न और उपलब्धि की नई ऊँचाइयों को छू सके; और
- (ट) यदि माता-पिता या संरक्षक है, छह वर्ष से चौदह वर्ष तक की आयु वाले अपने, यथास्थिति, बालक या प्रतिपाल्य को शिक्षा के अवसर प्रदान करे।

# CONSTITUTION OF INDIA

Part IV A (Article 51 A)

## Fundamental Duties

**Fundamental Duties :** It shall be the duty of every citizen of India —

1. to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;
2. to cherish and follow the noble ideals which inspired our national struggle for freedom;
3. to uphold and protect the sovereignty, unity and integrity of India;
4. to defend the country and render national service when called upon to do so;
5. to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;
6. to value and preserve the rich heritage of our composite culture;
7. to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures.
8. to develop the scientific temper, humanism and the spirit of inquiry and reform;
9. to safeguard public property and to adjure violence;
10. to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement.
11. who is a parent or guardian to provide opportunities for education to his child or, as the case may be, ward between the age of six and fourteen years.

## भारत का संविधान उद्देशिका

हम, भारत के लोग, भारत को एक <sup>1</sup>[संपूर्ण प्रभुत्व-संपन्न समाजवादी पंथनिरपेक्ष लोकतंत्रात्मक गणराज्य] बनाने के लिए, तथा उसके समस्त नागरिकों को :

सामाजिक, आर्थिक और राजनैतिक न्याय,

विचार, अभिव्यक्ति, विश्वास, धर्म

और उपासना की स्वतंत्रता,

प्रतिष्ठा और अवसर की समता

प्राप्त कराने के लिए,

तथा उन सब में

व्यक्ति की गरिमा और <sup>2</sup>[राष्ट्र की एकता

और अखंडता] सुनिश्चित करने वाली बंधुता

बढ़ाने के लिए

दृढ़संकल्प होकर अपनी इस संविधान सभा में आज तारीख 26 नवंबर, 1949 ई. को एतद्वारा इस संविधान को अंगीकृत, अधिनियमित और आत्मार्पित करते हैं।

1. संविधान (बयालीसवां संशोधन) अधिनियम, 1976 की धारा 2 द्वारा (3.1.1977 से) "प्रभुत्व-संपन्न लोकतंत्रात्मक गणराज्य" के स्थान पर प्रतिस्थापित।
2. संविधान (बयालीसवां संशोधन) अधिनियम, 1976 की धारा 2 द्वारा (3.1.1977 से) "राष्ट्र की एकता" के स्थान पर प्रतिस्थापित।

# THE CONSTITUTION OF INDIA

## PREAMBLE

**WE, THE PEOPLE OF INDIA**, having solemnly resolved to constitute India into a <sup>1</sup>**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

**JUSTICE**, social, economic and political;

**LIBERTY** of thought, expression, belief, faith and worship;

**EQUALITY** of status and of opportunity; and to promote among them all

**FRATERNITY** assuring the dignity of the individual and the <sup>2</sup>[unity and integrity of the Nation];

**IN OUR CONSTITUENT ASSEMBLY** this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation" (w.e.f. 3.1.1977)



**DIRECTORATE OF EDUCATION**  
**Govt. of NCT, Delhi**

**SUPPORT MATERIAL**  
**(2020-2021)**

**CHEMISTRY**  
**Class : XI**

**NOT FOR SALE**

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**PUBLISHED BY : DELHI BUREAU OF TEXTBOOKS**



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**Class XI – Chemistry**

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6.	Mr. Ravindra Malik	PGT (Chem.)	SBV, Narela, Delhi



# Course Structure

## Class : XI (Theory) (2020-21)

### Chemistry

Total period (Theory 160 + Practical 60)

Time : 3 Hours]

Total Marks : 70

Unit No.	Title	No. of Periods	Marks
Unit I	Some Basic Concepts of Chemistry	12	11
Unit II	Structure of Atom	14	
Unit III	Classification of Elements and Periodicity in Properties	08	04
Unit IV	Chemical Bonding and Molecular Structure	14	21
Unit V	States of Matter: Gases, Liquids and solids	12	
Unit VI	Chemical Thermodynamics	16	
Unit VII	Equilibrium	14	
Unit VIII	Redox Reactions	06	16
Unit IX	Hydrogen	08	
Unit X	s -Block Elements	10	
Unit XI	p -Block Elements	14	
Unit XII	Organic Chemistry: Some Basic Principles and Techniques	14	18
Unit XIII	Hydrocarbons	12	
Unit XIV	Environmental Chemistry	06	
<b>Total</b>		<b>160</b>	<b>70</b>

**Unit I : Some Basic Concepts of Chemistry** **8 Periods**

General Introduction: Importance and scope of chemistry.

Nature of matter, laws of chemical combination, Dalton's atomic theory: concept of elements, atoms and molecules.

Atomic and molecular masses, mole concept and molar mass, percentage composition, empirical and molecular formula, chemical reactions, stoichiometry and calculations based on stoichiometry.

**Unit II : Structure of Atom** **10 Periods**

Bohr's model and its limitations, concept of shells and subshells, dual nature of matter and light, de Broglie's relationship, Heisenberg uncertainty principle, concept of orbitals, quantum numbers, shapes of s, p and d orbitals, rules for filling electrons in orbitals - Aufbau principle, Pauli's exclusion principle and Hund's rule, electronic configuration of atoms, stability of half-filled and completely filled orbitals.

**Unit III : Classification of Elements and Periodicity in Properties**

**06 Periods**

Modern periodic law and the present form of periodic table, periodic trends in properties of elements -atomic radii, ionic radii, inert gas radii, Ionization enthalpy, electron gain enthalpy, electronegativity, valency. Nomenclature of elements with atomic number greater than 100

**Unit IV : Chemical Bonding and Molecular Structure** **14 Periods**

Valence electrons, ionic bond, covalent bond, bond parameters, Lewis structure, polar character of covalent bond, covalent character of ionic bond, valence bond theory, resonance, geometry of covalent molecules, VSEPR theory, concept of hybridization, involving *s*, *p* and *d* orbitals and shapes of some simple molecules, molecular orbital theory of homonuclear diatomic molecules(qualitative idea only), hydrogen bond.

**Unit V : States of Matter: Gases, Liquids and Solids** **18 Period**

Three states of matter, intermolecular interactions, types of bonding, melting and boiling points, role of gas laws in elucidating the concept of the molecule, Boyle's law, Charles law, Gay Lussac's law, Avogadro's law, ideal behaviour, empirical derivation of gas equation,

Avogadro's number, ideal gas equation. Deviation from ideal behaviour, liquefaction of gases, critical temperature, kinetic energy and molecular speeds (elementary idea)

**Liquid State:** vapour pressure, viscosity and surface tension (qualitative idea only, no mathematical derivations)

**Solid state:** Classification of solids based on different binding forces: molecular, ionic, covalent and metallic solids, amorphous and crystalline solids (elementary idea). Unit cell in two dimensional and three dimensional lattices, calculation of density of unit cell, packing in solids, packing efficiency, voids, number of atoms per unit cell in a cubic unit cell, point defects, electrical and magnetic properties.

**Unit VI : Chemical Thermodynamics** **16 Periods**

Concepts of System and types of systems, surroundings, work, heat, energy, extensive and intensive properties, state functions. First law of thermodynamics -internal energy and enthalpy, heat capacity and specific heat, measurement of  $\Delta U$  and  $\Delta H$ , Hess's law of constant heat summation, enthalpy of bond dissociation, combustion, formation, atomization, sublimation, phase transition, ionization, solution and dilution. Second law of Thermodynamics (brief introduction). Introduction of entropy as a state function, Gibb's energy change for spontaneous and non- spontaneous processes, criteria for equilibrium. Third law of thermodynamics (brief introduction).

**Unit VII : Equilibrium** **14 Periods**

Equilibrium in physical and chemical processes, dynamic nature of equilibrium, law of mass action, equilibrium constant, factors affecting equilibrium- Le Chatelier's principle, ionic equilibrium- ionization of acids and bases, strong and weak electrolytes, degree of ionization, ionization of poly basic acids, acid strength, concept of pH, Henderson Equation, hydrolysis of salts (elementary idea), buffer solution, solubility product, common ion effect (with illustrative examples).

**Unit VIII: Redox Reactions** **06 Periods**

Concept of oxidation and reduction, redox reactions, oxidation number, balancing redox reactions, in terms of loss and gain of electrons and change in oxidation number, applications of redox reactions.

## Unit IX: Hydrogen

08 Periods

Position of hydrogen in periodic table, occurrence, isotopes, preparation, properties and uses of hydrogen, hydrides-ionic covalent and interstitial; physical and chemical properties of water, heavy water, hydrogen peroxide -preparation, reactions and structure and use; hydrogen as a fuel.

## Unit X : *s*-Block Elements (Alkali and Alkaline Earth Metals) 10 Periods

Group 1 and Group 2 Elements General introduction, electronic configuration, occurrence, anomalous properties of the first element of each group, diagonal relationship, trends in the variation of properties (such as ionization enthalpy, atomic and ionic radii), trends in chemical reactivity with oxygen, water, hydrogen and halogens, uses. Preparation and Properties of Some Important Compounds: Sodium Carbonate, Sodium Chloride, Sodium Hydroxide and Sodium Hydrogencarbonate, Biological importance of Sodium and Potassium. Calcium Oxide and Calcium Carbonate and their industrial uses, biological importance of Magnesium and Calcium

## Unit XI : *p*-Block Elements

18 Periods

### General Introduction to *p*-Block Elements :

**Group 13 Elements :** General introduction, electronic configuration, occurrence, variation of properties, oxidation states, trends in chemical reactivity, anomalous properties of first element of the group, Boron - physical and chemical properties, some important compounds, Borax, Boric acid, Boron Hydrides, Aluminium: Reactions with acids and alkalies, uses.

**Group 14 Elements :** General introduction, electronic configuration, occurrence, variation of properties, oxidation states, trends in chemical reactivity, anomalous behaviour of first elements. Carbon-catenation, allotropic forms, physical and chemical properties; uses of some important compounds: oxides. Important compounds of Silicon and a few uses: Silicon Tetrachloride, Silicones, Silicates and Zeolites, their uses.

**Group 15 Elements :** General introduction, electronic configuration, occurrence, oxidation states, trends in physical and chemical properties; Nitrogen preparation properties and uses; compounds of Nitrogen, preparation and properties of Ammonia and Nitric Acid, Oxides of



Nitrogen(Structure only) ; Phosphorus - allotropic forms, compounds of Phosphorus: Preparation and Properties of Phosphine, Halides and Oxoacids (elementary idea only).

**Unit XII : Organic Chemistry -Some Basic Principles and Technique**  
**14 Periods**

General introduction, methods of purification, qualitative and quantitative analysis, classification and IUPAC nomenclature of organic compounds. Electronic displacements in a covalent bond: inductive effect, electromeric effect, resonance and hyper conjugation. Homolytic and heterolytic fission of a covalent bond: free radicals, carbocations, carbanions, electrophiles and nucleophiles, types of organic reactions.

**Unit XIII: Hydrocarbons** **12 Periods**

**Classification of Hydrocarbons Aliphatic Hydrocarbons:**

Alkanes - Nomenclature, isomerism, conformation (ethane only), physical properties, chemical reactions including free radical mechanism of halogenation, combustion and pyrolysis.

Alkenes - Nomenclature, structure of double bond (ethene), geometrical isomerism, physical properties, methods of preparation, chemical reactions: addition of hydrogen, halogen, water, hydrogen halides (Markownikov's addition and peroxide effect), ozonolysis, oxidation, mechanism of electrophilic addition.

Alkynes - Nomenclature, structure of triple bond (ethyne), physical properties, methods of preparation, chemical reactions: acidic character of alkynes, addition reaction of - hydrogen, halogens, hydrogen halides and water.

Aromatic Hydrocarbons: Introduction, IUPAC nomenclature, benzene: resonance, aromaticity, chemical properties: mechanism of electrophilic substitution. Nitration, sulphonation, halogenation, Friedel Craft's alkylation and acylation, directive influence of functional group in monosubstituted benzene. Carcinogenicity and toxicity.

**Unit XIV : Environmental Chemistry** **06 Periods**

Environmental pollution - air, water and soil pollution, chemical reactions in atmosphere, smog, major atmospheric pollutants, acid rain, ozone and its reactions, effects of depletion of ozone layer, greenhouse effect and global warming- pollution due to industrial wastes, green chemistry as an alternative tool for reducing pollution, strategies for control of environmental pollution.

## PRACTICALS

Evaluation Scheme for Examination	Marks
Volumetric Analysis	08
Salt Analysis	08
Content Based Experiment	06
Project Work	04
Class record and viva	04
<b>Total</b>	<b>30</b>

## PRACTICAL SYLLABUS

**Total Periods 60**

Micro-chemical methods are available for several of the practical experiments.

Wherever possible such techniques should be used :

### A. Basic Laboratory Techniques

1. Cutting glass tube and glass rod
2. Bending a glass tube
3. Drawing out a glass jet
4. Boring a cork

### B. Characterization and Purification of Chemical Substances

1. Determination of melting point of an organic compound.
2. Determination of boiling point of an organic compound
3. Crystallization of impure sample of any one of the following: Alum, Copper Sulphate, Benzoic Acid.

### C. Experiments based on pH

(a) Any one of the following experiments :

- Determination of pH of some solutions obtained from fruit juices, solution of known and varied concentrations of acids, bases and salts using pH paper or universal indicator.
- Comparing the pH of solutions of strong and weak acids of same concentration.
- Study the pH change in the titration of a strong base using universal indicator.

(b) Study the pH change by common-ion in case of weak acid and weak bases.

### D. Chemical Equilibrium.

**CHEMISTRY (Code No. 043)**  
**Question Paper Design**  
**Class-XI (2020-21)**

Time : 3 Hours

Max. Marks : 70

S. No.	Typology of Questions	Very short Answer (VSA) (1 marks)	Short Answer-I (SA-I) (2 marks)	Short Answer-II (SA-II) (3 marks)	Long Answer (LA) (5 marks)	Total Marks	% Weightage
1.	<b>Remembering :</b> Exhibit memory of previously learned material by recalling facts, terms, basic concepts and answers.	2	1	1	–	7	10%
2.	<b>Understanding :</b> Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions and stating main ideas.	6	2	2	1	21	30%
3.	<b>Applying :</b> Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	6	2	2	1	21	30%
4.	<b>Analyzing :</b> Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	6	1	2	–	14	20%
5.	<b>Evaluating :</b> Present and defend opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria.	1	2	2	–	11	16%
6.	<b>Creating :</b> Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.	–	1	–	1	7	10%
<b>TOTAL</b>		<b>20×1=20</b>	<b>7×2=14</b>	<b>7×3=21</b>	<b>3×5=15</b>	<b>70(37)</b>	<b>100%</b>

## Question Wise Break Up

Type of Ques.	Mark per Ques.	Total No. of Ques.	Total Marks
VSA / Objective	1	20	20
SA-I	2	7	14
LA-I	3	7	21
LA-II	5	3	15
<b>Total</b>		37	70

1. No chapter was weightage. *Care to be taken to cover all the chapters.*
2. *Suitable internal variations may be made for generating various templates keeping the overall weightage to different form of questions and typology of questions same.*

### **Choice(s):**

There will be no overall choice in the question paper.

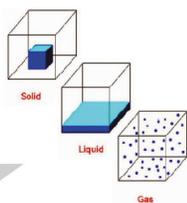
However, 33% internal choices will be given in all the sections.

# Chemistry - XI

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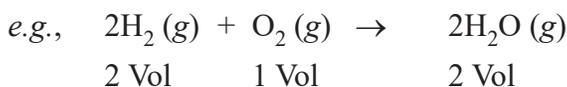
## Chapter - 1

# Some Basic Concepts of Chemistry

### FAST TRACK : QUICK REVISION

- **Matter** : Anything that has mass and occupies space.
- **Precision** : It refers to the closeness of various measurements for the same quantity.
- **Accuracy** : It refers to the agreement of a particular value to the true value of the result.
- **Mass and weight** : Mass of a substance is the amount of matter present in body, while weight is the force exerted by gravity on an object. The mass of a substance is constant whereas its weight may vary from one place to another due to change in gravity.
- **Volume** :  $1 \text{ L} = 1 \text{ dm}^3 = 10^3 \text{ cm}^3 = 10^{-3} \text{ m}^3$
- **Temperature** :  $\text{K} = ^\circ\text{C} + 273.15$ ;  $\frac{^\circ\text{F} - 32}{9} = \frac{^\circ\text{C}}{5}$
- **Standard Temperature Pressure (STP)** :  $0^\circ\text{C}$  (273.15 K) temperature and 1 atm pressure.
- **Normal Temperature Pressure (NTP)** :  $20^\circ\text{C}$  (293.15 K) temperature and 1 atm pressure.
- **Standard Ambient Temperature Pressure (SATP)** :  $25^\circ\text{C}$  (298.15 K) temperature and 1 atm pressure
- **Scientific Notation** : Expressing a number in the form  $N \times 10^n$ , and N can vary between 1 to 9.99.
- **Significant figures** : These are meaningful digits which are known with certainty.
- **Laws of Chemical Combination** :
  - **Law of Conservation of Mass (Antonie Lavoisier)** : Mass can neither be created nor be destroyed.
  - **Law of Definite Proportions (Joseph Proust)** : A given compound always contains the same elements in the same proportion by mass.

- **Law of Multiple Proportions (John Dalton)** : When two elements combine to form two or more compounds, then the different masses of one element, which combine with a fixed mass of the other, bear a simple ratio to one another.
- **Gay Lussac's Law** : When gases combine or are produced in a chemical reaction, they do so in a simple ratio provided all gases are in the same temperature and pressure.



(at same T, P)

- **Atomic Mass** : It is defined as the average relative mass of an atom of an element as compared to the mass of an atom of carbon – 12 taken as 12.

Atomic mass is represented by 'u' (unified mass).

$$1u = 1.66056 \times 10^{-24} \text{ g}$$

- **Molecular mass** : It is algebraic the sum of the atomic mass of the elements present in the molecule.

*For example* : Molecular mass of  $\text{CH}_4 = (1 \times 12) + (4 \times 1) = 16 \text{ u}$

- **Avogadro Number** : It is the amount of atoms or molecules present in one mole of a substance.

Avogadro number ( $N_A$ ) =  $6.022 \times 10^{23} \text{ mol}^{-1}$

- **Molar Mass** : The mass of one mole of a substance in grams is called its molar mass.

*For example* : Molar mass of  $\text{CH}_4 = (1 \times 12) + (4 \times 1) = 16 \text{ g mol}^{-1}$

- **Mole (n)** : It is amount of a substance that contains as many particles or entities as the number of atoms in exactly 12 grams of pure C-12.

1 mole of a substance = Molar mass of substance = Avogadro's Number of chemical units = 22.4L volume at STP of gaseous substance

*e.g.*, 1 mole of  $\text{CH}_4 = 16 \text{ g}$  of  $\text{CH}_4 = 6.022 \times 10^{23}$  molecules of  $\text{CH}_4 = 22.4 \text{ L}$  at STP

$$n = \frac{w \text{ g}}{M_m} = \frac{\text{VL (at STP)}}{22.4 \text{ L}} = \frac{x \text{ particles}}{N_A} = \frac{\text{MV}}{1000}$$

- **Molar Volume ( $V_m$ )** : It is volume occupied by one mole of gas at STP.

Molar volume of a gas = 22.4L at STP (273 K, 1 atm) or 22.7L at STP (273 K, 1 bar)

Calculating Molar Volume:  $PV = nRT$

$$\therefore V = \frac{nRT}{P} = \frac{1 \text{ mol} \times 0.082 \text{ L atm K}^{-1} \text{ mol}^{-1} \times 273 \text{ K}}{1 \text{ atm}} = 22.4 \text{ L}$$

Or

$$V = \frac{nRT}{P} = \frac{1 \text{ mol} \times 0.083 \text{ L bar K}^{-1} \text{ mol}^{-1} \times 273 \text{ K}}{1 \text{ bar}} = 22.7 \text{ L}$$

- **Percentage Composition** : Mass % of the element

$$= \frac{\text{Mass of element in a molecule of the compound} \times 100}{\text{Molecular mass of the compound}}$$

- **Empirical Formula** : It represents the simplest whole number ratio of various atoms present in a compound. For *e.g.*, CH is the empirical formula of benzene.
- **Molecular Formula** : It shows the exact number of different of atoms present in a molecule of a compound. For *e.g.*, C<sub>6</sub>H<sub>6</sub> is the molecular formula of benzene.
- **Relationship between empirical and molecular formulae** :  
Molecular formula =  $n \times$  Empirical formula

Where; 
$$n = \frac{\text{Molar mass}}{\text{Empirical formula mass}}$$

- **Information Conveyed by a chemical equation** :

$\text{N}_2(\text{g})$	+	$3\text{H}_2(\text{g})$	$\rightarrow$	$2\text{NH}_3(\text{g})$
(i) 1 molecule of $\text{N}_2$	+	3 molecules of $\text{H}_2$	$\rightarrow$	2 molecules of $\text{NH}_3$
(ii) 1 mole of $\text{N}_2$	+	3 mole of $\text{H}_2$	$\rightarrow$	2 mole of $\text{NH}_3$
(iii) $1 \times 28\text{g}$ of $\text{N}_2$	+	$3 \times 2\text{g}$ of $\text{H}_2$	$\rightarrow$	$2 \times 17\text{g}$ of $\text{NH}_3$
(iv) $1 \times 22.4\text{L}$ of $\text{N}_2$ at STP	+	$3 \times 22.4\text{L}$ of $\text{H}_2$ at STP	$\rightarrow$	$2 \times 22.4\text{L}$ of $\text{NH}_3$ at STP

- **Limiting Reagent** : It is the reactant which gets consumed first or limits the amount of product formed.
- **Mass Percent** : It is the mass of the solute in grams per 100 grams of the solution.

$$\text{Mass percent} = \frac{\text{Mass of solute in g} \times 100}{\text{Mass of solution in g}}$$

- **Parts per million (ppm)** : It is part of solute per million part of solution by mass.

$$\text{ppm} = \frac{\text{Parts of solute (by mass)} \times 10^6}{\text{Parts of solution (by mass)}}$$

- **Molarity (M)** : It is number of moles of solute dissolved per litre ( $\text{dm}^3$ ) of the solution.

$$\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{Volume of solution in L}}$$

$$\text{Molarity equation : } M_1 V_1 = M_2 V_2$$

(Before dilution) (After Dilution)

Molarity of a solution decreases on increasing temperature.

Molarity of pure water is  $55.56 \text{ mol L}^{-1}$

- **Molality (m)**—It is number of moles of solute dissolved per 1000g (1kg) of solvent.

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

Molality is independent of temperature.

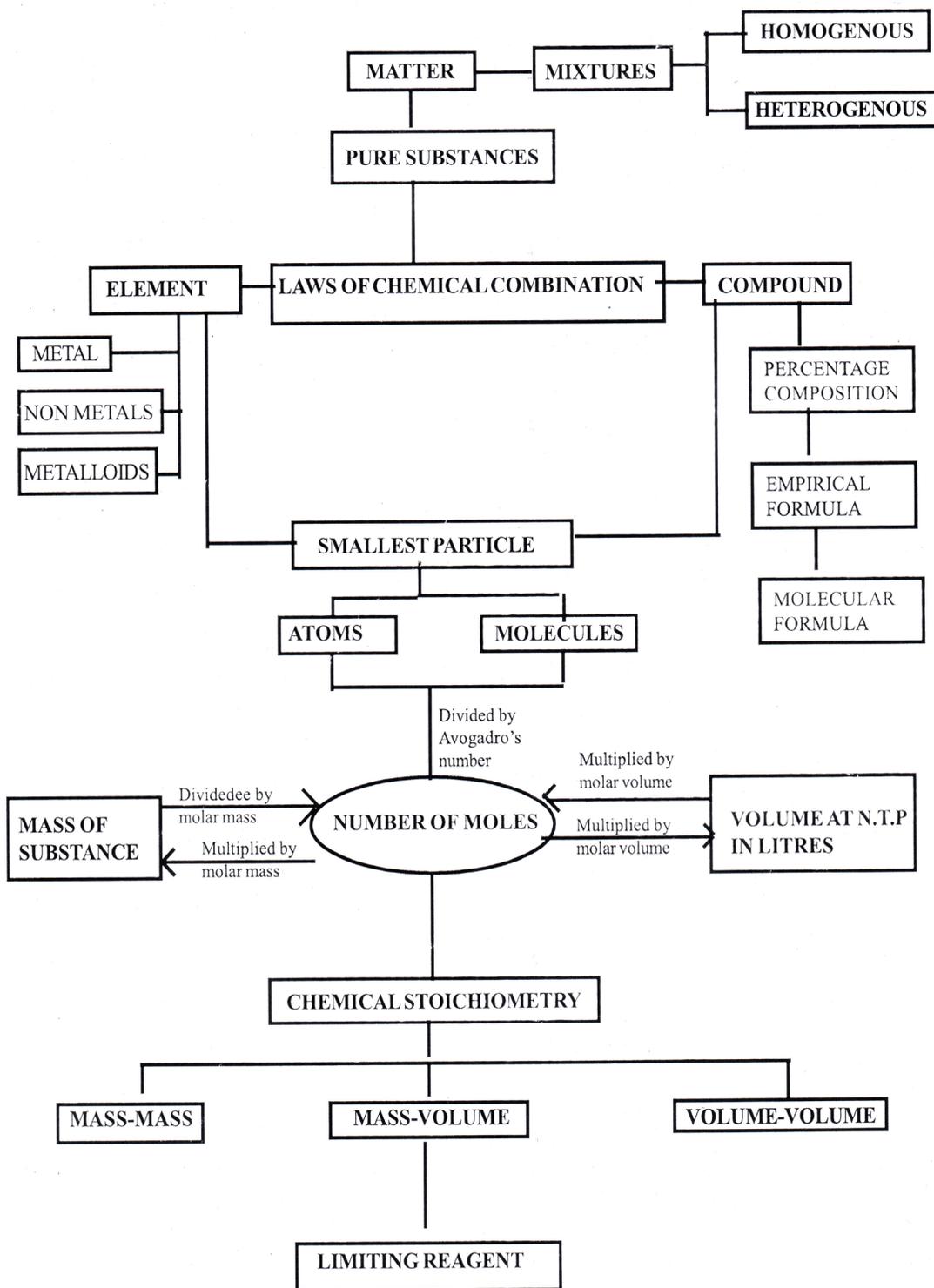
- **Mole Fraction(x)** is the ratio of number of moles of one component to the total number of moles (solute and solvents) present in the solution.

$$x_1 = \frac{n_1}{n_1 + n_2} \quad \text{and} \quad x_2 = \frac{n_2}{n_1 + n_2}$$

The sum of all the mole fractions in a solution is equal to one. *i.e.*,  $x_1 + x_2 = 1$

# MIND MAP

## SOME BASIC OF CONCEPTS OF CHEMISTRY



### MULTIPLE CHOICE QUESTIONS (MCQ)

- Which of the following is dependent of temperature ?
  - Molarity
  - Molality
  - Mole fraction
  - Mass percentage
- 4 g of NaOH dissolved in 100 ml solution. Molarity of the solution is
  - 1 M
  - 10 M
  - 0.1 M
  - 4 M
- Which has the maximum number of molecules among the following ?
  - 44g of  $\text{CO}_2$
  - 44g of  $\text{O}_2$
  - 8g of  $\text{H}_2$
  - 64g of  $\text{SO}_2$
- 10 mol of Zn react with 10 mol of HCl. Calculate the number of moles of  $\text{H}_2$  produced.
  - 5 mol
  - 10 mol
  - 20 mol
  - 2.5 mol
- The number of oxygen atoms in 4.4g of  $\text{CO}_2$  is approximately
  - $1.2 \times 10^{23}$
  - $6 \times 10^{22}$
  - $6 \times 10^{23}$
  - $12 \times 10^{23}$
- The molarity of a solution obtained by mixing 750 mL of 0.5 M HCl with 250 ml of 2 M HCl will be
  - 0.975 M
  - 0.875 M
  - 1.00 M
  - 1.175 M
- Number of atoms of He in 100 u of He ( Atomic mass of He is 4 u)
  - 25
  - 50
  - 100
  - 400
- $6.02 \times 10^{20}$  molecules of urea are present in 100 mL of its solution. The concentration of the solution is
  - 0.02 M
  - 0.01 M
  - 0.001 M
  - 0.1 M

9. A gaseous hydrocarbon gives upon combustion, 0.72 g of water and 3.08 g of  $\text{CO}_2$ . The empirical formula of the hydrocarbon is :
- (a)  $\text{C}_6\text{H}_5$  (b)  $\text{C}_7\text{H}_8$   
 (c)  $\text{C}_2\text{H}_4$  (d)  $\text{C}_3\text{H}_4$
10. The density of solution prepared by dissolving 120 g of urea ( Mol. mass = 60 u) in 1000 g of water is 1.15 g/mL. The molarity of the solution is
- (a) 0.50 M (b) 1.78 M  
 (c) 1.02 M (d) 2.05 M

**Ans:** 1. (a), 2. (a), 3. (b), 4. (a), 5. (a), 6. (b), 7. (a), 8. (b),  
 9. (b), 10. (d)

### FILL IN THE BLANKS

1. 17 g of  $\text{NH}_3$  gas will occupy a volume of \_\_\_\_\_  $\text{cm}^3$  at NTP.
2. The number of Li atoms in \_\_\_\_\_ g. is  $6.022 \times 10^{24}$  atoms.
3. (1/12)th of the mass of carbon atom is \_\_\_\_\_
4. Number of atoms of oxygen in 24 g of  $\text{O}_3$  is \_\_\_\_\_
5. The number of moles of barium carbonate which contains 1.5 moles of oxygen atoms is \_\_\_\_\_
6. A mixture having 2 g of  $\text{H}_2$  and 32 g of oxygen occupies a volume of \_\_\_\_\_ at NTP.
7. If the phosphate of a metal has the formula  $\text{MPO}_4$  the formula of the metallic sulphate is \_\_\_\_\_
8. At NTP, the mass of 1 litre of gas is 3 g. Molecular mass of the gas is \_\_\_\_\_
9. The percentage mass of magnesium in chlorophyll is 2.68% The number of magnesium atoms in 2 g of chlorophyll is \_\_\_\_\_
10. The mass of one molecule of carbon dioxide is \_\_\_\_\_
11. Percentage of nitrogen in urea is \_\_\_\_\_
12. Number of carbon atoms present in 18 g of glucose (  $\text{C}_6\text{H}_{12}\text{O}_6$  )

13. 0.5 mole of triatomic gas contains \_\_\_\_\_ atoms.
14. A binary compound contains 50% A (at. mass = 16) and 50% B (at. mass 32). The empirical formula of the compound is \_\_\_\_\_.
15. The number of hydrogen atoms in 60 u of ethane is \_\_\_\_\_

- Ans:** 1. 22400                      2. 70 g                      3. 1 u
4.  $9.033 \times 10^{23}$                       5. 0.5                      6. 44.8 litre
7.  $M_2(SO_4)_3$                       8. 67.2                      9.  $1.34 \times 10^{21}$
10.  $7.3 \times 10^{-23}$                       11. 46.67                      12.  $3.61 \times 10^{23}$
13.  $9.033 \times 10^{23}$                       14.  $A_2B$                       15.  $7.226 \times 10^{24}$

### TRUE AND FALSE TYPE QUESTIONS

**Write true or false for the following statements**

1. Equal volumes of different gases under similar conditions of temperature and pressure contain equal number of molecules.
2. 1 mole of  $C_{12}H_{22}O_{11}$  contain 22 hydrogen atoms.
3. Nitrogen forms five oxides. It proves the law of multiple proportions.
4. The atomicity of phosphorus is four.
5. Molarity change with change in temp.
6. Empirical formula = (Molecular formula)<sub>n</sub>.
7. Gram-atomic mass of an element may be defined as the mass of Avogadro's number of atoms.
8. Gay-Lussac's law of chemical combination is valid for all substances.
9. Avogadro's number varies with temperature and pressure.
10. 18 g of water vapour and 18 g of ice will contain the same number of molecules.

- Ans:** 1. (T)      2. (F)      3. (T)      4. (T)      5. (T)
6. (F)      7. (T)      8. (F)      9. (F)      10. (T)

## MATCH THE COLUMNS

1.

### Column X

- a. 8 g CH<sub>4</sub>
- b. 1.7 g NH<sub>3</sub>
- c. HCHO
- d. C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>

### Column Y

- i. 0.1 mol
- ii. 0.5 mol
- iii. 40% carbon
- iv. Vapour density = 15

2.

### Column X

- a. Molarity
- b. Molality
- c. mole fraction
- d. ppm

### Column Y

- i. For very dilute solution
- ii. No units
- iii. Mol L<sup>-1</sup>
- iv. independent of temperature

3.

### Column X

- a. 40 g of He
- b. 35 g of Li
- c. 40 u of He
- d. 16 g of O<sub>2</sub>

### Column Y

- i. 6.022×10<sup>23</sup> atoms
- ii. 10 atoms
- iii. 6.022×10<sup>24</sup> atoms
- iv. 3.011×10<sup>24</sup> atoms

4.

### Column X

- a. Petrol
- b. Graphite
- c. Sucrose
- d. Milk

### Column Y

- i. Heterogenous mixture
- ii. Compound
- iii. Element
- iv. Homogeneous mixture

- Ans:** 1. a.(ii), b.(i), c.(iv), d.(iii)    2. a.(iii), b.(iv), c.(ii), d.(i)  
3. a.(iii), b.(iv), c.(ii), d.(ii)    4. a.(iv), b.(iii), c.(ii), d.(i)

## ASSERTION AND REASON TYPE QUESTIONS

### Directions for Q. No.1-5

- A If both Assertion & Reason are true and the reason is the correct explanation of the assertion.
- B If both Assertion & Reason are true but the reason is not the correct explanation of the assertion.
- C If Assertion is true statement but Reason is false.
- D If both Assertion and Reason are false statements.

1. Assertion : A solution of table salt in a glass of water is homogeneous  
Reason : A solution having same composition throughout is heterogeneous
2. Assertion : The molecular weight of oxygen is 32 amu.  
Reason : The atomic weight of oxygen is 16 amu
3. Assertion : No of moles of  $H_2$  in 0.224 L of hydrogen is 0.01 mole.  
Reason : 22.4 L of  $H_2$  at STP contain  $6.023 \times 10^{23}$  moles.
4. Assertion : Atomic mass of Na is 23.  
Reason : An atom of sodium is 23 times heavier than 1/12th mass of C-12 isotope.
5. Assertion : Number of atoms of He in 60 u of He is 15.  
Reason : Atomic weight of He is 4 u.

**Ans:** 1.C 2.A 3.C 4.A 5.A

## ONE WORD ANSWER TYPE QUESTIONS

1. What is the SI unit of density?
2. What is the SI unit of molarity?
3. Calculate the number of atoms in 32 u of He. [Ans. : 8]
4. What is the volume of 17 g of  $NH_3$  gas at STP? [Ans. : 223.4 L]
5. How many molecules of  $SO_2$  are present in 11.2 L at STP?  
[Ans. :  $3.011 \times 10^{23}$ ]
6. Which has more number of atoms ? 1.0 g Na or 1.0 g Mg  
[Ans. : 1.0 g Na]

7. How many oxygen atoms are present in 16 g of ozone ( $O_3$ )?  
[Ans. :  $2.007 \times 10^{23}$ ]
8. Calculate the number of molecules present in 22.0 g of  $CO_2$ .  
[Ans. :  $3.011 \times 10^{23}$ ]
9. A substance has molecular formula  $C_6H_{12}O_6$ . What is its empirical formula.
10. Empirical formula of a compound X (Molar mass =  $78 \text{ mol}^{-1}$ ) is CH. Write its molecular formula.

### 1-MARK QUESTIONS

1. Name two chemical compounds used in treatment of cancer.
2. What is AZT ? Mention its use in medical science.
3. Classify following as pure substances and mixtures : air, glucose, gold, sodium and milk.
4. Which measurement is more precise 4.0g or 4.00g ? [Ans. 4.00 g]
5. How many significant figures are there in (i) 3.070 and (ii) 0.0025 ?  
[Ans. (i) 4 (ii) 2]
6. Express the following in the scientific notation : (i) 0.0048 (ii) 234,000
7. If ten volumes of dihydrogen gas react with five volumes of dioxygen gas, how much volume of water vapour would be produced ?  
[Ans. 10 volumes]
8. Define unified mass (u).
9. Define molar volume of a gas.
10. At STP, what will be the volume of  $6.022 \times 10^{23}$  molecules of  $H_2$  ?  
[Ans. 22.4L]
11. 1L of a gas at STP weighs 1.97g. What is molecular mass ?  
[Ans. 44.128  $\text{g mol}^{-1}$ ]
12. Write the relationship between empirical formula and molecular formula.
13. Which is more informative ? Empirical formula or Molecular formula.

14. How are 0.5 mol  $\text{Na}_2\text{CO}_3$  and 0.5 M  $\text{Na}_2\text{CO}_3$  different from each other ?
15. Why molality is preferred over molarity of a solution ?
16. Define molarity of a solution.
17. What is the effect of temperature on molarity of solution ?
18. What is limiting reactant in a reaction ?

### 2-MARKS QUESTIONS

1. Classify following substances as element, compounds and mixtures : water, tea, silver, steel, carbon dioxide and platinum.
2. The body temperature of a normal healthy person is  $37^\circ\text{C}$ . Calculate its value in  $^\circ\text{F}$ .
3. At what temperature will both the Celsius and Fahrenheit scales read the same value?
4. Convert 5L into  $\text{m}^3$ .
5. What does the following prefixes stand for :  
(a) pico      (b) nano      (c) micro      (d) deci
6. How many significant figures are present in the following :  
(i) 4.00005  
(ii) 0.004
7. Convert '450 pm' into SI unit and write the answer in scientific notation upto 2 significant figures.  
[Ans.  $4.5 \times 10^{-10}$  m]
8. Hydrogen peroxide and water contain 5.93% and 11.2 % of hydrogen respectively. Show that the data illustrate law of multiple proportions.
9. The density ( in  $\text{g mL}^{-1}$ ) of a 3.60 M sulphuric acid solution that is 29%  $\text{H}_2\text{SO}_4$  ( Molar mass =  $98 \text{ g mol}^{-1}$ ) by mass will be .....  
[Ans. 1.21 g/mL]
10. The cost of table salt ( NaCl ) is Rs. 10 per Kg. calculate its cost per mole.  
( Molar mass of NaCl is  $58.5 \text{ g mol}^{-1}$ ) [Ans. 0.58 Rs]
11. Calculate the mole fraction of the solute in a 1.00 molal aqueous solution.  
[Ans. 0.0177]

- 12 Dissolving 120 g of urea ( Molar mass of urea =  $60 \text{ g mol}^{-1}$  ) in 1000 of water gave a solution of density  $1.15 \text{ g/mL}$ . Calculate the molarity of the solution. [Ans. 2.05 M]
- 13 Calculate the percentage of N in urea. (Molar mass of urea =  $60 \text{ g mol}^{-1}$ ) [Ans. 46.66]
- 14 25 ml of 3.0 M HCl are mixed with 75 mL of 4.0 M HCl. If the volumes are additive, the molarity of the final mixture will be. [Ans. 3.75 M]
- 15 How many atoms and molecules are present in 124 gm of phosphorus (P<sub>4</sub>) [Ans. Atoms =  $4 N_A$  & Molecules =  $N_A$ ]
- 16 45.4 L of dinitrogen reacted with 22.7 L of dioxygen and 45.4 L of nitrous oxide was formed.  
The reaction is given below :  $2\text{N}_2 (\text{g}) + \text{O}_2 (\text{g}) \longrightarrow 2\text{N}_2\text{O} (\text{g})$   
Which law is being obeyed in this experiment? Write the statement of the law.
- 17 Give one example each of a molecule in which empirical formula and molecular formula is  
(i) Same (ii) Different.
- 18 Calculate the number of moles in the following masses :  
(i) 7.85g of Fe;  
(ii) 7.9mg of Ca
- 19 Calculate the percent of carbon, hydrogen and oxygen in ethanol (C<sub>2</sub>H<sub>5</sub>OH) [Ans. 52.14%, 13.13%, 34.73%]
- 20 How much copper can be obtained from 100 g of CuSO<sub>4</sub> ? [Ans. 39.8g]
- 21 Calculate the amount of water (g) produced by the combustion of 16 g of methane. [Ans. 36g]
- 22 How many moles of methane are required to produce 22 g CO<sub>2</sub> (g) after combustion? [Ans. 0.5 mol]
- 23 A solution is prepared by adding 2 g of a substance A to 18 g of water. Calculate the mass per cent of the solute. [Ans. 10%]
- 24 Calculate molarity of water if its density is  $1.00 \text{ g mL}^{-1}$ . [Ans. 55.56 M]

- 25 Calculate the molarity of NaOH in the solution prepared by dissolving its 4 g in enough water to form 250 mL of the solution. [Ans. 0.4 M]
- 26 The density of 3 M solution of NaCl is  $1.25 \text{ g mL}^{-1}$ . Calculate molality of the solution. [Ans. 2.8m]
- 27  $\text{NH}_3$  gas can be prepared by Haber's process as,  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$ . At a particular moment concentration of all the species is 2 moles; calculate the concentration of  $\text{N}_2$  and  $\text{H}_2$  taken initially. [Ans. 3 mole, 5 moles]

### 3-MARKS QUESTIONS

1. Calculate the average atomic mass of Mg using the following data:

	% Natural Abundance	Molar mass
$^{24}\text{Mg}$	80	24
$^{25}\text{Mg}$	10	25
$^{26}\text{Mg}$	10	26

2. The following data are obtained when dinitrogen and dioxygen react together to form different compounds :

	(i)	(ii)	(iii)	(iv)
Mass of dinitrogen	14	14	28	28
Mass of dioxygen	16	32	32	80

Which law of chemical combination is obeyed by the above experimental data ? Give its statement.

3. Calculate :

- (i) Mass in gram of 5.8 mol  $\text{N}_2\text{O}$   
 (ii) Number of moles in 8.0 g of  $\text{O}_2$   
 (iii) Molar mass if 11.2 L at STP weigh 8.5 g.

[Ans. (i) 255.2 g (ii) 0.25 mol (iii)  $17 \text{ g mol}^{-1}$ ]

4. In three moles of ethane ( $\text{C}_2\text{H}_6$ ), calculate the following :

- (i) Number of moles of carbon atom,  
 (ii) Number of moles of hydrogen atoms,  
 (iii) Number of molecules of ethane.

[Ans. (i) 6 moles, (ii) 18 moles, (iii)  $1.81 \times 10^{24}$ ]

5. 16 g of an ideal gas  $\text{SO}_x$  occupies 5.6 L at STP. What is its molecular mass ? What is the value of X ? [Ans. 64u,  $x = 2$ ]
6. Calculate the number of moles :  
 (i) 5.0 L of 0.75 M  $\text{Na}_2\text{CO}_3$   
 (ii) 7.85 g of Fe  
 (iii) 34.2 g of sucrose ( $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ) [Ans. (i) 3.75, (ii) 0.14, (iii) 0.1]
7. Calculate the number of atoms in each of the following :  
 (i) 52 moles of Ar. (ii) 52u of He (iii) 52g of He.  
 [Ans. (i)  $3.13 \times 10^{25}$  (ii) 13 (iii)  $7.83 \times 10^{24}$ ]
8. Vitamin C is essential for the prevention of scurvy. Combustion of 0.2000g of vitamin C gives 0.2998g of  $\text{CO}_2$  and 0.819g of  $\text{H}_2\text{O}$ . What is the empirical formula of vitamin C ? [Ans.  $\text{C}_3\text{H}_4\text{O}_3$ ]
9. A compound contains 4.07% hydrogen, 24.27% carbon and 71.65% chlorine. Its molar mass is 98.96 g. What are its empirical and molecular formulas? [Ans.  $\text{CH}_2\text{Cl}$ ,  $\text{C}_2\text{H}_4\text{Cl}_2$ ]
10. A compound made up of two elements A and B has A = 70%, B = 30%. Their relative number of moles in the compound is 1.25 and 1.88, calculate :  
 (i) Atomic masses of the elements A and B  
 (ii) Molecular formula of the compound, if its molecular mass is found to be 160. [Ans. (i) 56 and 16, (ii)  $\text{A}_2\text{B}_3$ ]
11. The reaction  $2\text{C} + \text{O}_2 \longrightarrow 2\text{CO}$  is carried out by taking 24.0 g of carbon and 96.0 g of  $\text{O}_2$ . Find out.  
 (i) Which reactant is left in excess ?  
 (ii) How much of it is left ?  
 (iii) How many grams of the other reactant should be taken so that nothing is left at the end of the reaction ? [Ans. (i)  $\text{O}_2$ , (ii) 64 g, (iii) 72]
12. A 10 g sample of a mixture of calcium chloride and sodium chloride is treated with  $\text{Na}_2\text{CO}_3$  to precipitate calcium as calcium carbonate. This  $\text{CaCO}_3$  is heated to convert all the calcium to  $\text{CaO}$  and the final mass of  $\text{CaO}$  is 1.62 g. Calculate % by mass of  $\text{NaCl}$  in original solution. [Ans. 67.9%]

13. 3.0 g of  $\text{H}_2$  react with 29.0 g of  $\text{O}_2$  yield  $\text{H}_2\text{O}$ .
- Which is the limiting reagent.
  - Calculate the maximum amount of  $\text{H}_2\text{O}$  that can be formed
  - Calculate the amount of reactant left unreacted
- [Ans.  $\text{H}_2$ , 26.8g  $\text{H}_2\text{O}$  & 5.2 g  $\text{O}_2$ ]
- 14 Zinc and hydrochloric acid react according to the reaction:
- $$\text{Zn(s)} + 2\text{HCl(aq)} \longrightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{(g)}$$
- If 0.30 mol Zn are added to hydrochloric acid containing 0.52 mol of HCl, How many moles of  $\text{H}_2$  are produced ?
- [ HCl is limiting reagent;  $\text{H}_2$  formed = 0.36 mol]
- 15 How many moles of Lead (II) chloride will be formed from a reaction between 6.5 g of PbO and 3.2 g of HCl ? [ Atomic mass of Pb = 207 U]
- [Ans. 0.029 mole]
- 16 What volume of oxygen at N.T.P is needed to cause the complete combustion of 200 ml of acetylene ? Also calculate the volume of carbon dioxide formed.
- [Ans. 500 mL of  $\text{O}_2$  & 400 mL of  $\text{CO}_2$ ]

### 5-MARKS QUESTIONS

- 1 (i) A black dot used as a full stop at the end of a sentence has a mass of about one attogram. Assuming that the dot is made up of carbon, calculate the approximate number of carbon atoms present in the dot. [Hint : 1 attogram =  $10^{-18}$ g] [Ans.  $5.02 \times 10^4$ ]
- (ii) Which one of the following will have largest number of atoms ?
- (a) 1g Au (s)   (b) 1g Na (s)   (c) 1g Li (s)   (d) 1g of  $\text{Cl}_2$ (g)
- [Ans.. (i) 39.81 g (ii) 1 g of Li]
2. (i) What is the difference between empirical formula and molecular formula ?
- (ii) A welding fuel gas contains carbon and hydrogen only. Burning a small sample of it in oxygen gas 3.38 g carbon dioxide, 0.690 g of water and no other products. A volume of 10.0 L (measured at STP) of this welding gas is found to weigh 11.6 g. Calculate
- (i) Empirical formula, (ii) molar mass of the gas, and (iii) Molecular formula. [Ans. (i) CH, (ii)  $26 \text{ g mol}^{-1}$ , (iii)  $\text{C}_2\text{H}_2$ ]

3. (i) What is the difference between Molarity and Molality.  
 (ii) The Molarity of a solution of sulphuric acid is 1.35 M. Calculate its molality. (The density of acid solution is  $1.02 \text{ g cm}^{-3}$ ).  
 [Ans.. 1.52 m]
4. (i) Define : (a) Mole fraction (b) Mass percentage.  
 (ii) If the density of methanol is  $0.793 \text{ kg L}^{-1}$ , what is its volume needed for making 2.5 L of its 0.25 M solution ?  
 [Ans. 0.0025 L]

### HOTS QUESTIONS

- 1 In a compound  $\text{C}_x\text{H}_y\text{O}_z$ , the mass % of C and H is 6:1 and the amount of oxygen present is equal to the half of the oxygen required to react completely  $\text{C}_x\text{H}_y$ . Find the empirical formula of the compound.  
 [Ans.  $\text{C}_2\text{H}_4\text{O}_3$ ]
- 2 A crystalline salt when heated becomes anhydrous and loses 51.2 % of its weight. The anhydrous salt on analysis gave the following percentage composition  
 Mg = 20.0% , S = 26.6 % , O = 53.33 %  
 Calculate the molecular formula of the anhydrous salt and the crystalline salt. Molecular weight of the anhydrous salt is 120.  
 [Ans.  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ]
- 3 An LPG cylinder weighs 14.8 Kg when empty. When full, it weighs 29.0 kg and shows a pressure of 2.5 atm. In the course of use at  $27^\circ\text{C}$ , the weight of cylinder is reduced to 23.2 Kg. Find the volume of n-butane in cubic meters used up at  $27^\circ\text{C}$  and 1 atm (Molecular weight of n-butane = 58).  
 [Ans.  $2.463 \text{ m}^3$ ]
- 4 2.5 g of  $\text{CaCO}_3$  was placed in 50 ml of a solution of HCl. 1.05 g of  $\text{CaCO}_3$  was left after the reaction. Calculate:  
 (a) the weight of HCl per litre  
 (b) the Molarity of HCl  
 [Ans. (a) 21.17 g, (b) 0.58 M]

## UNIT TEST

Time allowed : 1 hour

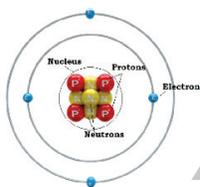
Maximum Marks : 20

General instructions :

- (i) All questions are compulsory.
  - (ii) Maximum marks carried by each question are indicated against it.
- 

1. If 30 mL of  $H_2$  and 20 mL of  $O_2$  react to form water, what is left at the end of the reaction ? (1)  
(a) 10 mL of  $H_2$  (b) 5 mL of  $H_2$   
(c) 10 mL of  $O_2$  (d) 5 mL of  $O_2$
2. 7.5 grams of a gas occupy 5.6 litres of volume at STP the gas is (1)  
(a) NO (b)  $N_2O$  (c) CO (d)  $CO_2$
3. What is AZT ? Write its use. (1)
4. Why molarity is preferred over molarity in expressing the concentration of solution ? (1)
5. Which has more number of atoms ? 1.0 g Na or 1.0g Mg? (1)
6. How many atoms and molecules are present in 124 g of phosphorus ( $P_4$ )? (2)
7. (a) Write the name of two life saving drugs. (2)  
(b) Define accuracy and precision.
8. A sample of drinking water was found to be severely contaminated with chloroform  $CHCl_3$ . The level of contamination was 15 ppm (by mass).  
(a) Express this in percent by mass.  
(b) Determine the molarity of chloroform in the water sample. (3)
9. A compound contains 4.07% hydrogen, 24.27% carbon and 71.65% chlorine. Its molar mass is 98.96 g. What are its empirical and molecular formula ? (3)
10. (a) Explain the following terms:  
(i) Gay Lussac's law (ii) Limiting reagent  
(b) 3.0 g of  $H_2$  react with 30.0 g of  $O_2$  yield  $H_2O$ .  
(i) Which is the limiting reagent?  
(ii) Calculate the maximum amount of  $H_2O$  that can be formed.  
(iii) Calculate the amount of reactant left unreacted. (5)

\*\*\*\*\*



## Chapter - 2

# Structure of Atom

### FAST TRACK : QUICK REVISION

#### • Information about fundamental particles of atom

Name of Constant	UNIT	Electron	Proton	Neutron
Mass	amu	0.000546	1.00728	1.008665
	kg	$9.109 \times 10^{-31}$	$1.673 \times 10^{-27}$	$1.675 \times 10^{-27}$
Charge	Coloumbs	$-1.602 \times 10^{-19}$	$+1.602 \times 10^{-19}$	Zero
	esu	$-4.8 \times 10^{-10}$	$+4.8 \times 10^{-10}$	Zero
	Relative Charge	-1	+1	Zero

- **Electromagnetic radiations** : Energy emitted from any source (in forms of waves) in which electric and magnetic fields oscillated perpendicular to each other and travelling with a velocity of light is known as EM radiation.

#### • Characteristics of waves :

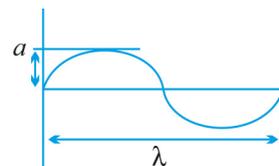
(a) **Wavelength** : The distance of one crest and one trough in a wave. Denoted by ' $\lambda$ '.

(b) **Frequency** : Number of waves passing through a given point in one second.

Denoted by  $\nu$ .

$$\left[ \nu = \frac{1}{t} \Rightarrow \text{sec}^{-1} \text{ or Hz} \right]$$

$t$  = Time period



(c) **Amplitude** : The height of crest or depth of a trough denoted by ' $a$ '.

(d) **Wave Number** : Number of waves per unit length denoted by  $\bar{\nu}$

$$\bar{\nu} = \frac{1}{\lambda} = \text{cm}^{-1} \text{ (or m}^{-1}\text{)}$$

(e) Velocity : Linear distance travelled by a wave in one second.

$$\text{velocity of light } c = \frac{\text{Distance}}{\text{Time}} = \lambda \times \frac{1}{t} = \nu \lambda$$

$$\therefore \nu = \frac{c}{\lambda}$$

- **Energywise** order for EM radiation.

cosmic <  $\gamma$  rays < X rays < UV < VIBGYOR < IR < Microwaves < Radiowaves

$\xrightarrow{\hspace{15em}}$   
 $\lambda$  (**Increases**)                       $\nu$  (**Decreases**)                      Energy (**Decreases**)

- **Photon** : A packet or particle of light energy is known as **Photon**.
- **Planck's quantum theory** : The energy emitted or absorbed by a source is discontinuous in form of small packet of energy, called **quantum**. Quantum of light is called **photon**.

$$E \propto \nu$$

$$E = h\nu \quad (h = \text{Planck's constant})$$

$$E = nh\nu \quad (h = 6.626 \times 10^{-34} \text{ J sec})$$

$$\text{If 'n' photons are emitted } E = nh\nu$$

- **Photo electric effect** : The phenomenon of ejection of electrons from a metal surface when a light of suitable frequency falls on metal surface.

$$h\nu - h\nu_0 = \frac{1}{2} m v^2$$

$h\nu \Rightarrow$  Energy of incident light on metal surface.

$h\nu_0 \Rightarrow$  Work function of metal.

$\frac{1}{2} m v^2 =$  Kinetic energy by which  $e^-$  is emitted from metal surface.

- **de Broglie equation** : All material particles in motion also exhibit wave like properties.

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

For microscopic particles mass is very less therefore Wavelength of wave associated with it can be detected.

For macroscopic particles mass is large,  $\lambda$  of wave associated with it can not be detected. Hence dominant wave character.

Hence microscopic bodies have dual nature, where as macroscopic bodies have particle nature.

### Heisenberg's Uncertainty Principle

It is impossible to determine the exact position and velocity of a moving subatomic particle simultaneously with accuracy.

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

$\Delta x$  = uncertainty in position

$\Delta v$  = uncertainty in velocity

### Bohr's theory for H [H like one $e^-$ systems $\text{He}^+$ ; $\text{Li}^{2+}$ ]

(1)  $e^-$  revolving round the nucleus in circular path [stationary state; SHELL]

with a definite angular momentum  $\frac{nh}{2\pi}$  [Here  $n$  = no. of shell of  $e^-$ ] and with definite energy

$$E_n = \left[ \frac{-2\pi^2 m e^4 z^2}{n^2 h^2} \right] \Rightarrow -2.18 \times 10^{-18} \frac{Z^2}{n^2} \text{ J/Atom.}$$

(2) As  $n$  increases, Energy of  $e^-$  becomes less – ve [Due to less force of Proton attraction]

As  $n$  decreases, Energy of  $e^-$  becomes More – ve [Due to more force of attraction by protons]

(3) In infinity shell  $e^-$  has zero force of attraction therefore zero energy.

(4) Electron energy only changes by definite values  $\Delta E = E_f - E_i$ .

**Hydrogen spectrum** : When  $e^-$  in hydrogen atom is provided energy it gets excited to higher shell from ground state, it comes back to ground state by emitting energy in definite values.

**“Quanta”** : The emission of light energy is known as emission spectra. It corresponds to each atom depending upon which energy shell  $e^-$  is excited.

It is **discontinuous** spectra as ‘ $\lambda$ ’ of light radiations do not merge with each other like in VIBGYOR (Continuous Spectra).

When  $e^-$  falls from any excited state to

$$\frac{1}{\lambda} = 1,09,678 \left[ \frac{1}{n_f^2} - \frac{1}{n_i^2} \right] Z^2 \quad R = \text{Rydberg constant} = 109678 \text{ cm}^{-1}$$

$n_i = 1, n_f = 2, 3, 4, \dots$  [Lyman series] (UV)

$n_i = 2, n_f = 3, 4, 5, \dots$  [Balmer series] (VIBGYOR)

$n_i = 3, n_f = 4, 5, 6$  [Paschen series] IR.

$n_i = 4, n_f = 5, 6, 7$  [Bracket series] IR.

$n_i = 5, n_f = 6, 7, 8$  [Pfund series] IR.

**Quantum numbers :** The numbers which **completely** define the **state** of  $e^-$  in an atom.

**(1) Principal Quantum No. :** It describes the distance of  $e^-$  from **nucleus ‘ $n$ ’** *i.e.*, defines the **shell** no. It is denoted by ‘ $n$ ’.

$n = 1, 2, 3, 4, 5, \dots$

K, L, M, N, O .....

**(2) Azimuthal ( $l$ ) Quantum No. :** It defines the path of  $e^-$  decided by angular momentum of  $e^-$ . Each angular momentum value corresponds to one subshell. The no. of subshells in a shell is 0 to  $n - 1$ .

$n$	$l$ (0 to $n-1$ )				
1	0	$l = 0$	‘ $s$ ’	subshell	
2	0, 1	$l = 1$	‘ $p$ ’	subshell	
3	0, 1, 2	$l = 2$	‘ $d$ ’	subshell	
4	0, 1, 2, 3	$l = 3$	‘ $f$ ’	subshell	

All subshells are wave functions for locating  $e^-$ .

In the same shell energy increase  $s < p < d < f$ .

(3) **Magnetic Quantum No. :** It gives the no. of magnetic orientations an  $e^-$  can have in a subshell. That is number of orbitals in a sub-shell.  
 $m_s = -l \dots \dots \dots 0 \dots \dots \dots + l = (2l + 1)$ .

(4) **Spin Quantum No. :** An  $e^-$  is continuously spinning on its own axis.

The value of  $s = \frac{1}{2}$  or  $-\frac{1}{2}$

An orbital can have maximum two  $e^-$  one with clockwise and other with anticlockwise spin.

### Aufbau principle

- (a) Electrons are filled in increasing order of energy of sub-shell.
- (b) As ' $n + l$ ' value increases energy of  $e^-$  increases in that sub-shell.
- (c) For two sub-shells with same ' $n + l$ ' value, as ' $n$ ' value increases energy of  $e^-$  increases.

### Pauli's principle

No two electrons can have same set of four quantum numbers in an atom.

### Hund's rule of maximum multiplicity

The pairing of  $e^-$  in degenerate orbitals (different orbitals with same energy) will get paired only once they have been singly occupied with same spin.

### IMPORTANT POINTS

The filling of  $e^-$  in subshells follows this order. (As per Aufbau principle)

(A)  $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p$

(B) Half filled and completely filled subshells have more **stability** than incompletely filled subshells.



(C) As the shell no. inc. size of subshell increases e.g., size of ( $2s > 1s$ ) ; ( $3p > 2p$ ); ( $4d > 3d$ )

(D) The region in an orbital where probability of finding the  $e^-$  is zero is known as **Nodal plane** (or Node).

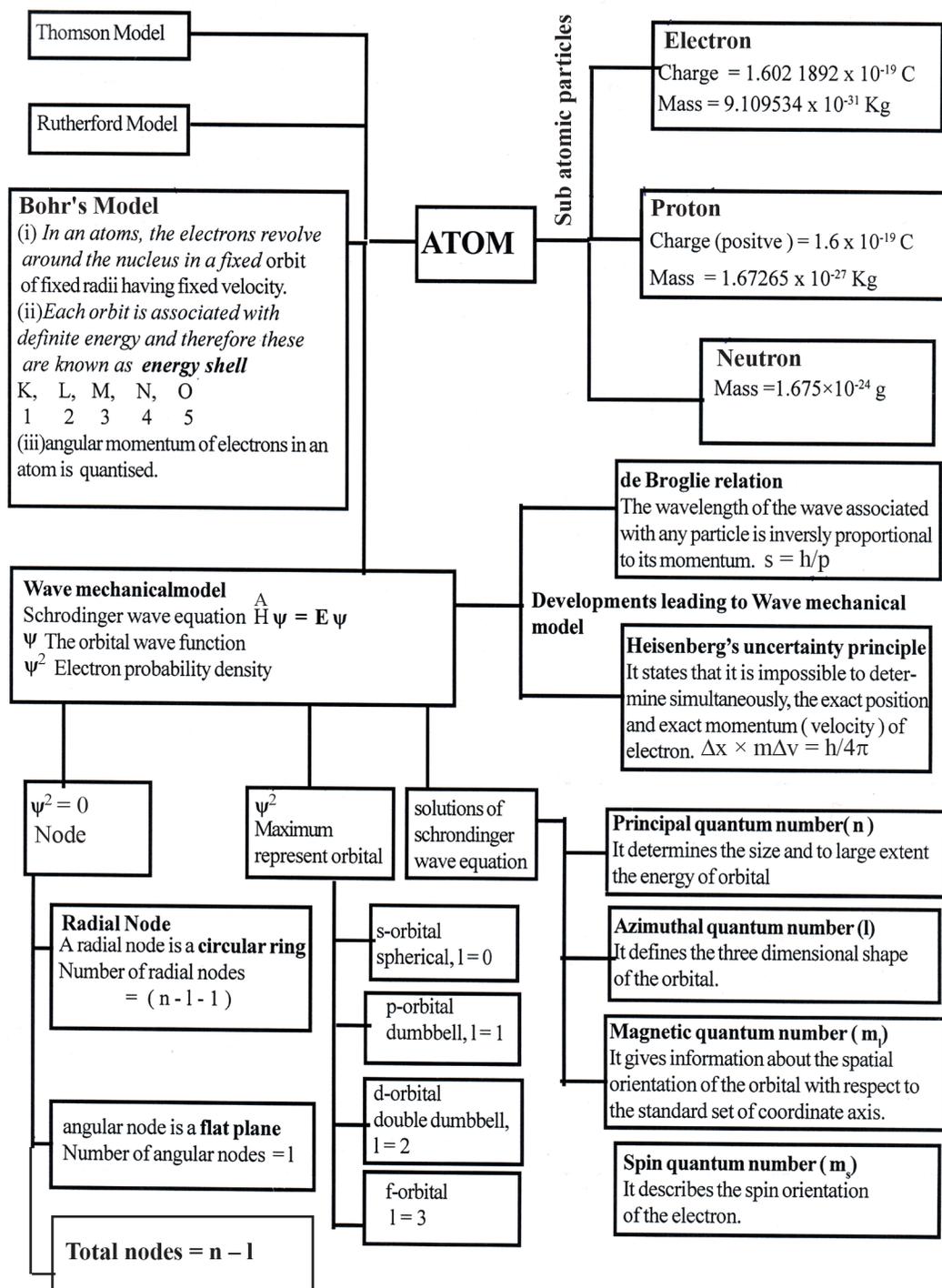
The no. of [radial nodes] =  $n - l - 1$  and Angular Nodes =  $l$ ,

Total nodes =  $n - 1$ .

(E)	$\psi$ (psi)	$\psi^2$ (psi square)
	A wave function for locating an electron	The square of wave function where the probability of finding the $e^-$ is maximum. [Each value of $\psi^2$ is a region and <b>defines</b> one orbital]

(F)	Orbit	Orbital
	(1) A definite distance from the nucleus for finding the $e^-$ [ $e^-$ as a particle].	(1) A probability region for locating the $e^-$ around the nucleus. It is a wave function [ $e^-$ as a wave]
	(1) It has definite size and $e^-$ in this orbit has definite energy.	(2) It does not define definite size. But only a boundary region diagram of a wave for locating the $e^-$ .

# MIND MAP - STRUCTURE OF ATOM



### MULTIPLE CHOICE QUESTIONS (MCQ)

- Packet of energy is called
  - Electron
  - Photon
  - Position
  - Proton
- Orbital which is not possible
  - 2p
  - 3d
  - 3s
  - 3f
- the magnetic quantum number of an atom is related to the
  - size of the orbital
  - spin angular momentum
  - orbital angular momentum
  - orientation of the orbital in space
- The principal quantum number of an atom is related to the
  - size of the orbital
  - spin angular momentum
  - orbital angular momentum
  - orientation of the orbital in Spence
- The designation of an orbital with  $n = 4$  and  $l = 3$ 
  - 4s
  - 4p
  - 4d
  - 4f
- What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition  $n = 4$  to  $n = 2$  in the  $\text{He}^+$  spectrum?
  - $n = 4$  to  $n = 1$
  - $n = 3$  to  $n = 2$
  - $n = 3$  to  $n = 1$
  - $n = 2$  to  $n = 1$
- The wave number of first line of Balmer series of hydrogen is  $15200 \text{ cm}^{-1}$ . The wave number of the first Balmer line of  $\text{Li}^{2+}$  ion is
  - $15200 \text{ cm}^{-1}$
  - $60800 \text{ cm}^{-1}$
  - $76000 \text{ cm}^{-1}$
  - $136,800 \text{ cm}^{-1}$
- An electron is moving in Bohr's orbit. Its de Broglie wavelength is  $\lambda$ . What is the circumference of the fourth orbit?
  - $2/\lambda$
  - $2\lambda$
  - $3\lambda$
  - $3/\lambda$

9. Which of the following statements in relation to the hydrogen atom is correct?
- 3s-orbital is lower in energy than 3p-orbital
  - 3p-orbital is lower in energy than 3-d-orbital
  - 3s and 3p orbitals all have the same energy.
  - 3s, 3p and 3d orbitals all have the same energy.
10. For principle quantum number,  $n = 4$ , the total number of orbitals having  $l = 3$  is
- 3
  - 7
  - 5
  - 9
11. The number of d-electrons retained in  $\text{Fe}^{2+}$  (At. no. of Fe = 26) ion is
- 3
  - 4
  - 5
  - 6
12. Pauli exclusion principle helps to calculate the maximum number of electrons that can be accommodated in any
- orbital
  - subshell
  - shell
  - All of these

**Ans.** 1. (b), 2. (d), 3. (d), 4. (a), 5. (d), 6. (d), 7. (d), 8. (c), 9. (d),  
10. (b), 11. (d), 12. (a)

**FILL IN THE BLANK**

- Bohr's theory is based on \_\_\_\_\_ of radiation.
- The angular momentum of the electron in the 4th energy shell in the hydrogen atom is \_\_\_\_\_.
- Lines of Balmer series appear in \_\_\_\_\_ region.
- The maximum number of electrons in  $\text{Fe}^{3+}$  (At. No. 26) is \_\_\_\_\_.
- $\text{Li}^{2+}$  and  $\text{He}^+$  ions have spectrum similar to \_\_\_\_\_ atom.
- Bohr's atomic theory is not able to explain the atomic spectra of atoms containing \_\_\_\_\_ electron.
- An electron in the first shell will have \_\_\_\_\_ stability and \_\_\_\_\_ energy than an electron in the third shell.

8. The space or three-dimensional region round the nucleus where there is maximum probability of finding an electron of specific energy is called an \_\_\_\_\_
9. According to \_\_\_\_\_ no two electrons in an atom will have all the four quantum numbers \_\_\_\_\_
10. When there are two electrons in the same orbital they have \_\_\_\_\_ spins.
11. The s-subshells have \_\_\_\_\_ shape and the p-subshells have \_\_\_\_\_
12. The maximum number of electrons on a subshell is equal to \_\_\_\_\_ where  $l =$  \_\_\_\_\_

- Ans.**
- |                    |                     |
|--------------------|---------------------|
| 1. Planck's theory | 2. $\frac{2h}{\pi}$ |
| 3. Visible         | 4. 23               |
| 5. H-atom          | 6. more than 1      |
| 7. Larger, lower   | 8. orbital          |
9. Pauli exclusion principle; similar
  10. Opposite
  11. Spherical, dumb bell shape.
  12.  $2l + 1$ ; azimuthal quantum numbers

### TRUE AND FALSE TYPE QUESTIONS

**Write true or false for the following statements**

1. Bohr's theory cannot explain the spectra of multi-electron atoms.
2. Bohr's theory based on the Planck's quantum theory.
3. Size of orbital is determined by principal quantum number.
4.  $\text{Fe}^{2+}$  ion has more number of unpaired electrons than  $\text{Fe}^{3+}$ .
5. The outer electronic configuration of chromium atom is  $3d^44s^2$ .
6. The designation of an orbital  $n=4$  and  $l=0$  is 4s.
7. All photons of light have same energy.
8.  $\text{Fe}^{3+}$  has  $3d^5$  configuration.

9. The number of subshells is always equal to the order of the orbit.
10. Two electrons in the same orbital has antiparallel spin.
11. The second orbit in  $\text{He}^+$  ion has radius as the first orbit in hydrogen atom.
12. Heisenberg principle is applicable to microscopic particles.
13. 3s orbital has 2 radial nodes.

**Ans.** 1. (T)    2. (T)    3. (T)    4. (F)    5. (F)    6. (T)    7. (F)  
 8. (T)    9. (F)    10. (T)    11. (T)    12. (T),    13. (T)

**MATCH THE COLUMNS**

1. Match the following

**List-I**

- a. Lyman series
- b. Balmer series
- c. Paschen series
- d. Brackett series

**List-II**

- p. Visible region
- q. Infrared region
- r. Absorption spectrum
- s. Ultraviolet region

2. Match the following

**List-I**

- a. Principal quantum number
- b. Azimuthal quantum number
- c. Magnetic quantum number
- d. Spin quantum number

**List-II**

- p. Spin of electrons
- q. Size of orbital
- r. Orientation of the orbital
- s. Shape of the orbital

3. Match the following

**List-I**

- a. 2s
- b.  $2p_x$
- c.  $3d_{xy}$
- d.  $3d_z$

**List-II**

- p. Dough not shape
- q. Spherical
- r. Dumb bell
- s. Double dumb bell

4. Match the following

**List-I**

- a. 2s
- b.  $\psi^2$
- c. Heisenberg's uncertainty
- d.  $3d_{yz}$

**List-II**

- p. Two nodal planes
- q. One radial node
- r. Electron probability density principle
- s. Microscopic particles

**ASSERTION AND REASON TYPE QUESTIONS**

**Directions: (Questions 1 to 4)**

- A. If both Assertion & Reason are true and the reason is the correct explanation of the assertion.
- B. If both Assertion & Reason are true but the reason is not the correct explanation of the assertion.
- C. If Assertion is true statement but Reason is false.
- D. If both Assertion and Reason are false statements.

1. **Assertion :** Number of orbitals in 3rd shell is 9.

**Reason :** Number of orbitals for a particular value of  $n = n^2$ .

2. **Assertion :** Two nodal planes are present in  $3d_{xy}$ .

**Reason :** Number of nodal planes = 1

3. **Assertion :** The energy of an electron is largely determined by its principal quantum number.

**Reason :** The principal quantum number is a measure of the most probable distance of finding the electrons around the nucleus.

4. **Assertion :** An orbital cannot have more than two electrons, moreover, if an orbital has two electrons they must have opposite spins.

**Reason :** No two electrons in an atom can have same set of all the four quantum numbers.

**Ans.** 1. A    2. A    3. A    4. A

### ONE WORD ANSWER TYPE QUESTIONS

1. Write the name of the theory which explain the wave nature of light.
2. Write the name of the theory which explain the Black body radiations and photo electric effect
3. If the length of the crest of a wave is 4 pm. Write the wavelength of this wave. [Ans.8 pm]
4. A radiation emitted from a hot iron is photon or quantum ?
5. Out of the d orbitals which does not have four lobes ?
6. What is the lowest value of n that allows g orbitals to exist ?
7. Which quantum number is not obtained from solution of Schrödinger wave equation ?
8. Which of the following orbitals are possible ?  
1p, 2s, 2p and 3f
9. Write the name of non-directional subshell.
10. Write the name of quantum number which determines the orientation of orbitals ?
11. Write the name of quantum number which determines the shape of orbitals.
12. How many orbitals are present in 'g' subshell ?

### 1-MARK QUESTIONS

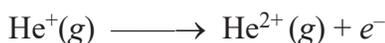
1. Write the relation between frequency and wave number.
2. Cs shows maximum photoelectric effect, why ?
3. Distinguish between a photon and a quantum.
4. The line spectrum of an element is known as fingerprints of its atom. Comment.
5. What is the value of the Bohr's radius for the third orbit of hydrogen atom?
6. What type of metals are used in photoelectric cell ? Give one example.  
[Ans. With large size, less work function.]
7. Which series of lines of the hydrogen spectrum lie in the visible region'?
8. Mention the physical significance of  $\psi$  and  $\psi^2$ .
9. Why did Heisenberg's uncertainty principle replace the concept of definite orbit by the concept of probability?

10. What is uncertain in uncertainty principle ?
11. Can a moving cricket ball have a wave character ? Justify your answer.
12. Heisenberg uncertainty principle has no significance in our everyday life. Explain.
13. Write the Schrodinger wave equation.
14. Why uncertainty in position is more when uncertainty in velocity is less for an electron ?
15. What are the four quantum numbers of 19th electron of copper ?  
(Given : Atomic number of copper = 29)
16. How many electrons will be present in the sub-shells having  $m_s$ , value of  $-1/2$  for  $n = 4$  ?
17. Write the electronic configuration of  $\text{Ni}^{3+}$ . (At. No. of Ni = 28)
18. How many radial and angular nodes are present in 2p orbital.

[Ans. Radial nodes = 0, Angular nodes = 1]

### 2-MARKS QUESTIONS

- Q. 1.** Define black body and black body radiations.
- Q. 2.** Give the essential postulates of Bohr's model of an atom. How did it explain?  
(i) the stability of the atom ?  
(ii) origin of the spectral lines in H-atom ?
- Q. 3.** What is quantisation ? How quantisation of energy was introduced in Bohr's model ?
- Q. 4.** What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition  $n = 4$  to  $n = 2$  of  $\text{He}^+$  spectrum?  
[Ans.  $n_1 = 1$  and  $n_2 = 2$ ]
- Q. 5.** What transition of  $\text{Li}^{2+}$  spectrum will have the same wavelength as that of the second line of Balmer series in  $\text{He}^+$  spectrum ?  
[Ans.  $n_2 = 6$  to  $n_1 = 3$ ]
- Q. 6.** Calculate the energy required for the process



The ionization energy for the H atom in the ground state is  $2.18 \times 10^{-18} \text{ J atom}^{-1}$  [Ans.  $8.72 \times 10^{-18} \text{ J}$ ]

- Q. 7.** Calculate the wave number for the longest wavelength transition in the Balmer series of atomic hydrogen. [Ans.  $1.523 \times 10^6 \text{ m}^{-1}$ ]
- Q. 8.** To which orbit the electron in H atom will jump on absorbing 12.1 eV energy? [Ans. 3rd orbit]
- Q. 9.** Calculate the energy associated with the first orbit of  $\text{He}^+$ . What is the radius of this orbit? [Ans.  $-54.38 \text{ eV}$ ,  $0.2645 \text{ \AA}$ ]
- Q. 10.** What is the distance of separation between 3rd and 4th orbit of H-atom? [Ans.  $3.703 \text{ \AA}$ ]
- Q. 11.** The energy of electron in the first Bohr's orbit is  $-13.6 \text{ eV}$ . Calculate the energy of electron in the first excited state. [Ans.  $-3.4 \text{ eV}$ ]
- Q. 12.** Calculate the number of protons emitted in 10 hours by a 60 W sodium lamp emitting radiations of wavelength  $6000 \text{ \AA}$ .
- Q. 13.** Which one has a higher energy, a photon of violet light with wavelength  $4000 \text{ \AA}$  or a proton of red light with wavelength  $7000 \text{ \AA}$ ?  
[Given.  $h = 6.62 \times 10^{-34} \text{ J sec.}$ ]
- Q. 14.** A 100 watt bulb emits monochromatic light of wavelength  $400 \text{ nm}$ . Calculate the number of photons emitted per second by the bulb. [Ans.  $2.012 \times 10^{20} \text{ s}^{-1}$ ]
- Q. 15.** What are the maximum number of emission lines when the excited electron of a H atom in  $n = 4$  drops to the ground state? [Ans. 6]
- Q. 16.** Which has more energy, light radiation of wavelength  $400 \text{ pm}$  or light radiation of frequency  $10^{15} \text{ Hz}$ ?
- Q. 17.** Find the energy of electron in 4th shell of  $\text{Li}^{2+}$  ion.
- Q. 18.** What is the wave number of an electron with shortest wavelength radiation in Lyman spectrum of  $\text{He}^+$  ion?
- Q. 19.** Write short note on :  
(a) Continuous and discontinuous spectrum.  
(b) Absorption and emission spectrum.
- Q. 20.** Calculate the mass of the photon with wavelength of  $3.6 \text{ \AA}$ . [Ans.  $6.135 \times 10^{-29} \text{ kg}$ ]

- Q. 21.** Calculate the mass of the photon with wavelength of 5 pm.
- Q. 22.** On the basis of uncertainty principle show that an electron cannot exist with in atomic nucleus. (Given : Nuclear radius =  $10^{-15}$  m)  
[Hint : Taking  $10^{-15}$  m as  $\Delta x$ , the  $\Delta v$  comes much higher than the velocity of light and hence is not possible]
- Q. 23.** Explain why the uncertainty principle is significant only from the motion of subatomic particles and is negligible for macroscopic particles?
- Q. 24.** List two differences between orbit and orbital .
- Q. 25.** Show that the circumference of the Bohr orbit for the hydrogen atom is an integral multiple of the de Broglie wavelength associated with the electron revolving around the orbit
- Q. 26.** Comment on “Bohr’s model is against the Heisenberg uncertainty principle”.
- Q. 27.** What are the similarities and difference in  $2s$  and  $2p_x$  orbitals and  $1s$  and  $2s$  orbitals ?
- Q. 28.** Draw shape of  $d_{x^2-y^2}$  orbital.
- Q. 29.** On the basis of Pauli’s exclusion principle show that the maximum number of electrons in the M -shell ( $n = 3$  ) of any individual atom is 18.
- Q. 30.** Designate each subshell with  $n = 4$ .
- Q. 31.** List the possible values for all the quantum numbers for the following subshell.  
(a)  $2p$  (b)  $4f$
- Q. 32.** Write down the electronic configuration of  $\text{Fe}^{3+}$  and  $\text{Ni}^{2+}$ . How many unpaired electrons are present? (Given Atomic number, Fe = 26, Ni = 28).
- Q. 33.** Out of principal, angular, magnetic and spin quantum number, which quantum number determines the ?  
(a) Shape of the orbital  
(b) Number of orbitals in an orbit  
(c) Size of the orbital  
(d) Spin orientation of the electron.

- Q. 34.** What is the Hund's rule of maximum multiplicity ? Explain with suitable example.
- Q. 35.** Explain why :
- The three electrons present in 2p subshell of nitrogen remain unpaired.
  - Cr has configuration  $3d^5 4s^1$  and not  $3d^4 4s^2$ .
- Q. 36.** (a) What is difference between 'l' and 'L'?
- (b) Nitrogen has 7 proton, 7 electron and 7 neutrons. Calculate the number of electron, protons and neutrons in  $N^{3-}$  ion.
- Q. 37.** Which one is having higher energy?
- Last electron of  $Cl^-$  or last electron of  $O^{2-}$ .
  - $n = 4, l = 3$  or  $n = 5, l = 2$ .

### 3-MARKS QUESTIONS

- Q. 1.**(i) The energy associated with the first orbit in the hydrogen atom is  $-2.18 \times 10^{-18} \text{ J atom}^{-1}$ . What is the energy associated with the fourth orbit ?
- (ii) Calculate the radius of Bohr's third orbit for hydrogen atom.  
[Ans.  $-1.36 \times 10^{-19} \text{ J atom}^{-1}$  .4.761 nm]
- Q. 2.** A bulb emits light of wave length  $4500\text{\AA}$ . The bulb is rated as 150 watt and 8% of the energy is emitted as light. How many photons are emitted by the bulb per second ? [Ans.  $n = 27.2 \times 10^{18}$ ]
- Q. 3.** When light with a wavelength of 400 nm falls on the surface of sodium, electrons with a kinetic energy of  $1.05 \times 10^5 \text{ J mol}^{-1}$  are emitted.
- What is the minimum energy needed to remove an electron from sodium ?
  - What is the maximum wavelength of light that will cause a photoelectron to be emitted ?  
[Ans.  $a = 3.2255 \times 10^{19} \text{ J}$ ,  $b = 616 \text{ nm}$ ]
- Q. 4.** Compare the frequency of light radiations emitted when electron falls from 5th shell to the 2nd shell in  $Li^{2+}$  ion and electron falls from 4th shell to the 1st shell in  $He^+$  ion.

- Q. 5.** Calculate the number of waves made by Bohr electron in one complete revolution in its third orbit. [Ans. 3]
- Q. 6.** What should be the ratio of velocities of  $\text{CH}_4$  and  $\text{O}_2$  molecules so that they are associated with de Broglie waves of equal wavelength? [Ans. 2]
- Q. 7.** Calculate the wavelength of an electron that has been accelerated in a particle accelerator through a potential difference of 1 kv.  
[Given  $1\text{eV} = 1.6 \times 10^{-19}\text{J}$ ] [Ans.  $3.87 \times 10^{-7}\text{m}$ ]
- Q. 8.** (i) Discuss the similarities and differences between a 1s and 2s orbital.  
(ii) Draw the shape of  $d_{z^2}$ .
- Q. 9.** Calculate the wavelength of a tennis ball of mass 60 gm moving with a velocity of 10 m per second. ( $h = 6.626 \times 10^{-34}\text{kg m}^2\text{s}^{-1}$ )  
[Ans.  $10^{-3}$  metre]
- Q. 10.** Calculate the wavelength of 1000 kg rocket moving with a velocity of 3000 km/hr. ( $h = 6.626 \times 10^{-34}\text{kg m}^2\text{s}^{-1}$ )  
[Ans.  $7.9512 \times 10^{-40}\text{m}$ ]
- Q. 11.** Calculate the uncertainty in the velocity of a cricket ball of mass 150 g, if uncertainty in its position is of the order of 1 Å.  
[Ans.  $3.5 \times 10^{-24}\text{m s}^{-1}$ ]
- Q. 12.** (a) What is de-Broglie wavelength for an electron moving with velocity of light?  
(b) What is the angular momentum of electron in 5th shell?
- Q. 13.** Two particles A and B have wavelength  $\lambda_A = 5 \times 10^{-10}\text{m}$  and  $\lambda_B = 10 \times 10^{-10}\text{m}$ . Find their frequency, wave number and energies. Which has more penetrating power and why?
- Q. 14.** (a) Which has max. uncertainty regarding position and why?  
Electron, proton and neutron.  
(b) Find the number of waves associated with a light radiation of time period 5 ns.
- Q. 15.** If an electron in  $\text{He}^+$  has angular momentum of  $5h/2\pi$ . Find its energy and wavelength associated with it. Find the kinetic energy of this electron.

- Q. 16.** (i) An atomic orbital has  $n = 2$ . What are the possible values of  $l$  and  $m_l$  ?  
 (ii) List the quantum numbers ( $m_l$  and  $l$ ) of electrons for  $3d$  orbital.  
 (iii) Which of the following orbitals are possible ?  
 $2d$ ,  $1s$ ,  $2p$  and  $3f$ .
- Q. 17.** (a) Write the maximum number of electron in a subshell with  $l = 3$  and  $n = 4$ .  
 (b) Write the maximum number of electron that can be associated with the following set of quantum numbers ?  
 $n = 3$ ,  $l = 1$  and  $m_l = -1$   
 (c) Write the maximum number of electron that can be accommodated in an atom in which the highest principal quantum number value is 4.
- Q. 18.** (i) Write the electronic configurations of the following ions :  
 (a)  $H^-$  (b)  $Na^+$  (c)  $O^{2-}$  (d)  $F^-$   
 (ii) What are the atomic numbers of elements whose outermost electrons are represented by (a)  $3s^1$  (b)  $2p^3$  and (c)  $3p^5$  ?  
 (iii) Which atoms are indicated by the following configurations ?  
 (a)  $[He] 2s^1$  (b)  $[Ne] 3s^2 3p^3$  (c)  $[Ar] 4s^2 3d^1$ .
- Q. 19.** Calculate:  
 (a) Total number of spherical nodes in  $3p$  orbital.  
 (b) Total number of nodal planes in  $3p$  orbital.  
 (c) Nodal planes in  $3d$  orbital.

### 5-MARKS QUESTIONS

- Q. 1.** (a) Define Photoelectric effect ? Mention its one practical application in daily life.  
 (b) Electrons are emitted with zero velocity from a metal surface when it is exposed to radiation of wavelength  $6800 \text{ \AA}$ . Calculate threshold frequency ( $\nu_0$ ) and work function ( $W_0$ ) of the metal.  
 [Ans.  $\nu_0 = 4.41 \times 10^{14} \text{ s}^{-1}$   $W_0 = 2.92 \times 10^{-19} \text{ J}$ ]
- Q. 2.** (a) The electronic energy in Bohr's orbit is negative. How will you account for it?  
 (b) The ionisation energy of hydrogen atom is  $13.6 \text{ eV}$ . What will be the energy of the first orbit of  $He^+$  and  $Li^{2+}$  ions ?  
 [Ans.  $E_1$  of  $He^+ = -54.4 \text{ eV}$ ,  $E_1$  of  $Li^{2+} = -122.4 \text{ eV}$ ]

**Q. 3.**(a) Define the following terms :

- (i) Threshold frequency      (ii) Work function.

(b) The work function for Cs atom is 1.9 eV. Find threshold wavelength ( $\lambda_0$ ) and threshold frequency ( $\nu_0$ ) of this light radiation. If Cs metal is irradiated with a radiation of wavelength 500 nm find kinetic energy and velocity of emitted electron.

**Q. 4.**(a) State de Broglie equation. Write its significance.

(b) A beam of helium atoms moves with a velocity of  $2.0 \times 10^3 \text{ m s}^{-1}$ . Find the wavelength of the particle constituting the beam

$$(h = 6.626 \times 10^{-34} \text{ J s}) \text{ [Ans. } 49.9 \text{ pm]}$$

**Q. 5.**(a) State Heisenberg's uncertainty principle. Give its mathematical expression. Also give its significance.

(b) Calculate the uncertainty in the position of a dust particle with mass equal to 1 mg if the uncertainty in its velocity is  $5.5 \times 10^{-20} \text{ m s}^{-1}$ .

$$\text{[Ans. } 9.55 \times 10^{10} \text{ m]}$$

**Q. 6.**(a) Cricket ball, a tennis ball and a proton which has more uncertainty in velocity and which follows Heisenberg uncertainty principle maximum.

(b) What is the similarity in de-Broglie and Heisenberg principle? Which is different from Bohr theory for structure of atom?

(c) Why energy in a given subshell is negative?

**Q. 7.**(a) Write short notes on:

- (i) Aufbau principle (ii) Pauli's principle (iii) Hund's rule.

(b) Write the electronic configuration of the following ions :

- (i)  $\text{Fe}^{3+}$  (ii)  $\text{Cu}^+$

[Given Atomic number of Fe and Cu are 26 & 29]

**Q. 8.**(a) Draw the shapes of the following orbitals.

- (i)  $3d_{xy}$  (ii)  $d_{z^2}$

(b) What is the total number of orbitals associated with the principal quantum number  $n = 3$  ?

(c) Using  $s$ ,  $p$ ,  $d$ ,  $f$  notations, describe the orbital with the following quantum numbers:-

- (a)  $n = 3, l = 0$ , (b)  $n = 4, l = 2$ , (c)  $n = 5, l = 3$ , (d)  $n = 1, l = 0$

**Q.9.** Explain the following :

- (i) Energy of electron is not decided by :  $n, l, m$  and  $s$ .
- (ii) Maximum number of electron with  $-1/2$  spin for  $n = 3$  is 6,9,12 or none.
- (iii) Maximum number of electron can be present for  $n + l = 4$ .
- (iv)  $3f$  subshell is not possible.
- (v) Maximum number of electrons in a subshell is :  
 $(2l + 1)$  or  $(4l + 1)$  or  $n^2$

**Q.10.**(a) A neutral atom has 2K, 8L and 15 M electrons. Find the total numbers of electrons in  $s, p, d$  and  $f$  subshell.

(b) How many unpaired electrons are present in the following ions :



(Given Atomic number :  $\text{Al}=13, \text{Cr} = 24, \text{Co} = 27$  &  $\text{Mn} = 25$ )

(c) One electron is present in  $4f$  subshell. What is the sum of  $n + l + m_l + m_s$  values assuming ' $f$ ' subshell follows  $-3$  to  $+3$  order of filling electron.

**Q.11.** Answer the following :

(a)  $n + l$  value for  $14^{\text{th}}$  electron in an atom.

(b) Increasing order of filling electron in  $4f, 5p$  and  $6d$  subshells.

(c) ' $m$ ' and ' $l$ ' value for last electron of Mg atom.

(Given atomic number of Mg is 12)

(d) Subshell in which last electron is present in Ga.

(Given Atomic number of Ga is 31)

(e) Sum of spin of all the electron in element having atomic number 14.

## UNIT TEST

Time allowed : 1 hour

Maximum Marks : 20

General instructions :

- (i) All questions are compulsory.
  - (ii) Maximum marks carried by each question are indicated against it.
- 

1. Designation for an orbital with  $n = 4$  and  $l = 3$  is (1)  
(a) 4s            (b) 4p            (c) 4d            (d) 4f
2. Maximum number of unpaired electrons in chromium is (1)  
(Given: Atomic number of Cr = 24)  
(a) 4            (b) 5            (c) 6            (d) 7
3. Which series of lines of the hydrogen spectrum lie in the visible region? (1)
4. Write the Schrodinger wave equation. (1)
5. Which of the following is not possible ?  
(a) 2p            (b) 3d            (c) 3f            (d) 4p (1)
6. Write four difference between orbit and orbital. (2)
7. Calculate the wave number for the longest wavelength transition in the paschen series of atomic hydrogen. (2)
8. (a) How many orbitals are associated with  $n = 4$  ? (3)  
(b) How many electrons will be present in the sub-shells having  $m_s$  value of  $-1/2$  for  $n = 3$  ?  
(c) Draw the shape of  $d_z^2$ .
9. Calculate the uncertainty in the position of a dust particle with mass equal to 1 mg if the uncertainty in its velocity is  $5.5 \times 10^{-20} \text{ ms}^{-1}$ . (3)
10. (i) The energy associated with the first orbit in the hydrogen atom is  $-2.18 \times 10^{-18} \text{ J atom}^{-1}$ . What is the energy associated with the fifth orbit?  
(ii) Calculate the radius of Bohr's fifth orbit for hydrogen atom.  
(iii) Calculate the radial and angular nodes in 2p orbital.  
(iv) Define the black body and black body radiations. (5)

\*\*\*\*\*



# Classification of Elements and Periodicity in Properties

## Chapter - 3

### FAST TRACK : QUICK REVISION

- **The first systematic classification of elements was provided by Russian chemist D.I. Mendeleev.**

#### 1. Mendeleev's periodic law

“The physical and chemical properties of elements are periodic functions of their atomic weight.”

#### 2. It was modified to **Modern Periodic law** :

“The physical and chemical properties of elements are periodic functions of their atomic numbers.”

It is the long form of periodic table :

7 Horizontal rows are called Periods and 18 Vertical columns are called Group

Group-1 are called **Alkali metals**      Group-2 are called **Alkaline earth metals**.

Group-15 are called **Pnicogens**      Group-16 are called **Chalcogens**

Group-17 are called **Halogens**      Group-18 are called **Noble gases**

- #### 3.
- |  |   |
|--|---|
| 1 <sup>st</sup> period – 2 elements                      | 2 <sup>nd</sup> and 3 <sup>rd</sup> period – 8 elements |
| 4 <sup>th</sup> and 5 <sup>th</sup> period – 18 elements | 6 <sup>th</sup> period – 32 elements                    |
| 7 <sup>th</sup> period – Incomplete (32 elements)        |   |

#### 4. Groups

1 and 2 – ‘s’ block elements last electron entered in ‘s’ subshell [ $s^1, s^2$ ]

3 to 12 – ‘d’ block elements last electrons entered in ‘d’ subshell [ $d^1$  to  $d^{10}$ ].

13 to 18 – ‘p’ block elements last electrons enter in ‘p’ subshell [ $p^1$  to  $p^6$ ].

Two f-block series lanthanoids and actinoids are placed in the bottom of periodic table.

5. (A) In 's' and 'p' block elements the electrons enters in outer most shell.  
 In 'd' block elements the electron enters in the penultimate shell ( $n - 1$ ).  
 'f' block elements last electron enter the antepenultimate shell ( $n - 2$ ).
- (B) 'f' block elements are placed in between 'd' block elements.  
 'f' block elements in 2 rows [4f lanthanoids, 5f actinoids]

## 6. General outer electronic configuration

's' block :  $ns^1, ns^2$  [Group 1 to 2]

'p' block :  $ns^1 np^1$  to  $ns^2 np^6$  Group 13 to 18

'd' block :  $ns^{0-2} (n - 1) d^1$  to  $10$  Group 3 to 12

'f' block :  $(n - 2)f^1$  to  $14 (n - 1)d^{0,1} ns^2$

## 7. General periodic trends in properties of elements

### • ATOMIC RADIUS

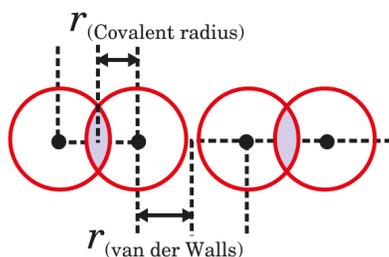
- (A) Left to right decreases due to effect of successive increasing nuclear charge without addition of a new shell.
- (B) From top to bottom atomic radius increases due to successive addition of shell.
- (C) Noble gases have large radius than **group 17** due to complete filling of electron in outer shell electron-electron repulsion mildly increases.

### • COVALENT RADIUS

It is half of the distance between the centre of nuclei of two adjacent similar atoms which are bonded to each other by single covalent bond.

### • van der Waal's Radius

van der Waal's radius is defined as one-half the distance between the centres of nuclei of two nearest like atoms belonging to two adjacent molecules of the element in the solid state.



- **METALLIC RADIUS**

Half of the distance between the centres of the nuclei of two adjacent atoms in the metallic crystal. A comparison of the three atomic radii show that van der Waal's radius is maximum while the covalent radius has the least value.

**van der Waal's radius > Metallic radius > Covalent radius**

- **IONIC RADIUS**

(A) Cation radius < Atomic radius – due to more no. of protons than number of electron coulombic force increases, size decreases.



(B) Anion radius > Atomic radius – Due to more number of electron than number of protons



Electron-Electron repulsion increase, coulombic force of attraction decreases.

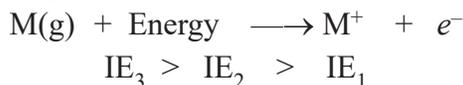
(C) For Isoelectronic species – More is the charge of cation lesser the size.

More is the charge of anion, more is the size.

(D) Order of size –  $\text{O}^{2-} > \text{F}^- > \text{Na} > \text{Na}^+ > \text{Mg}^{2+}$

8. (A) **Ionisation enthalpy :**

The minimum amount of energy which is required to remove the most loosely bound electron from an isolated atom in the gaseous state is called Ionisation enthalpy.



(B) **Variation of I.E along a period:**

Ionisation enthalpy increase along the period because atomic radii decrease and nuclear charge increase along the period.

I ionisation enthalpy  $\text{Li} < \text{B} < \text{Be} < \text{C} < \text{O} < \text{N} < \text{F} < \text{Ar}$

II ionisation enthalpy  $\text{Be} < \text{C} < \text{B} < \text{N} < \text{F} < \text{O} < \text{Ne}$

(C) **Variation down the group:**

Ionisation enthalpy decrease down the group because atomic radius increase down the group.

**Metallic behaviour :** Decrease from left to right due to increase in ionisation enthalpy.

**Non metallic behaviour :** Increase from left to right due to more number of electron in outershell and added electron goes towards nucleus.

### 9. Screening effect or shielding effect:-

It is the decrease in the force of attraction between nucleus and outermost electron due to presence of inner shell electrons. As a result, the outer most electrons does not feel full charge of the nucleus. The actual charge felt by an electron is called effective Nuclear charge.

Shielding effect is in the following order  $s > p > d > f$

d & f subshell show weak sheilding effect because their orbital size are large and are more diffused.

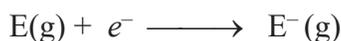
### 10. Isoelectronic species:

Ions of different elements which have the same number of electrons but different no. of protons are called isoelectronic ions.

	Na <sup>+</sup>	Mg <sup>2+</sup>	Al <sup>3+</sup>	N <sup>3-</sup>	O <sup>2-</sup>	F <sup>-</sup>
No. of Protons	11	12	13	7	8	9
No. of electrons	10	10	10	10	10	10
Ionic Radii	Al <sup>3+</sup> < Mg <sup>2+</sup> < Na <sup>+</sup> < F <sup>-</sup> < O <sup>2-</sup> < N <sup>3-</sup>					

### 11. Electron gain enthalpy:

The enthalpy change when an extra electron is added to neutral gaseous atom to form anion.



- **Trends : From left to right** – Increase due to decrease in size, more attraction of added electron by nucleus.
- **From top to bottom**—Decreases as the added electron is away from nucleus due to increase in size.
- **Cl has more negative electron gain enthalpy than fluorine** – Due to small size of fluorine extra added electron has more inter electronic repulsion than chlorine which has large size.
- Similarly Phosphorus and Sulphur have negative electron gain enthalpy than nitrogen and oxygen respectively.
- **Maximum electron gain enthalpy** – Chlorine (in periodic table)

■ **Electron gain enthalpy –**

Halogen > Oxygen > Nitrogen > Metal of group 1 and 13 and non metal of group 14 > metal of group 2.

- 2nd electron gain enthalpy is always positive.

## 12. Electro negativity:

The tendency of an atom to attract the shared pair of electron towards itself in a bonded state.

- Fluorine is the most electronegative element in the periodic table.
- Cesium is the least electronegative element in the periodic table.
- Electro-negativity decreases down the group and increases along the period

### **Difference between electron gain enthalpy and Electronegativity.**

Electron gain enthalpy is the energy, but electronegativity is not the energy, it is only the tendency of an atom in a molecule to attract the shared pair of electrons. Three highest electronegative atoms  $F > O > N$ .

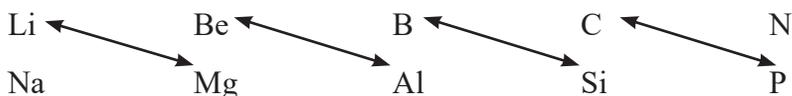
### **Maximum electronegative Assign to F.**

- \* Lightest element : **Hydrogen**
- \* Lightest metal : **Lithium**
- \* Heaviest metal (highest density) : **Osmium**
- \* Most reactive metal : **Caesium**
- \* Most reactive nonmetal : **Fluorine**
- \* Most malleable metal : **Gold**
- \* Electrically best conductor : **Silver**
- \* Metals which are relatively volatile : **Zn, Cd, Hg**
- \* Strongest reducing agent in aqueous solution : **Lithium**
- \* Strongest oxidising agent : **Fluorine**
- \* The element of lowest ionisation energy : **Caesium**
- \* The element of highest ionisation energy : **Helium**
- \* The most electronegative element : **Fluorine**
- \* The element of highest electron gain enthalpy : **Chlorine**
- \* The group containing most electropositive metals : **Group 1**
- \* The group containing most electronegative metals : **Halogens Group 17**
- \* The group containing maximum number of gaseous elements : **Group 18**

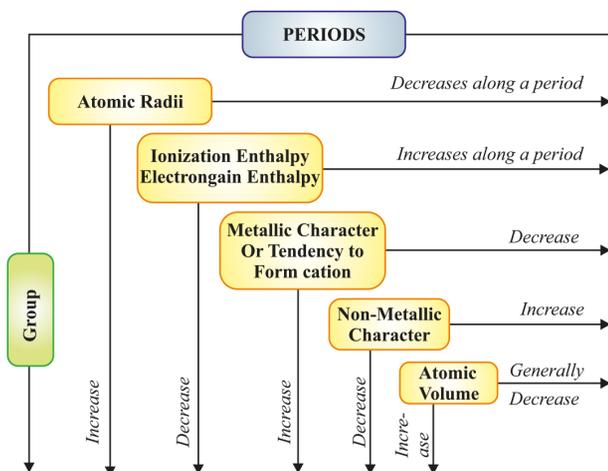
13. **Second period element**—Show different behaviour than I group **element**—  
Due to (a) small size (b) High electron negativity (C) High polarising power (d) absence of 'd' orbital.

$\text{Na}_3[\text{Al}(\text{OH})_6]$  exists but  $\text{Na}[\text{B}(\text{OH})_4]$  not exists.

14. The similarities in properties of first member of a group to second member of just next higher group due to comparable atomic radius, nearly same polarising power of ions is known as **diagonal relationship**.

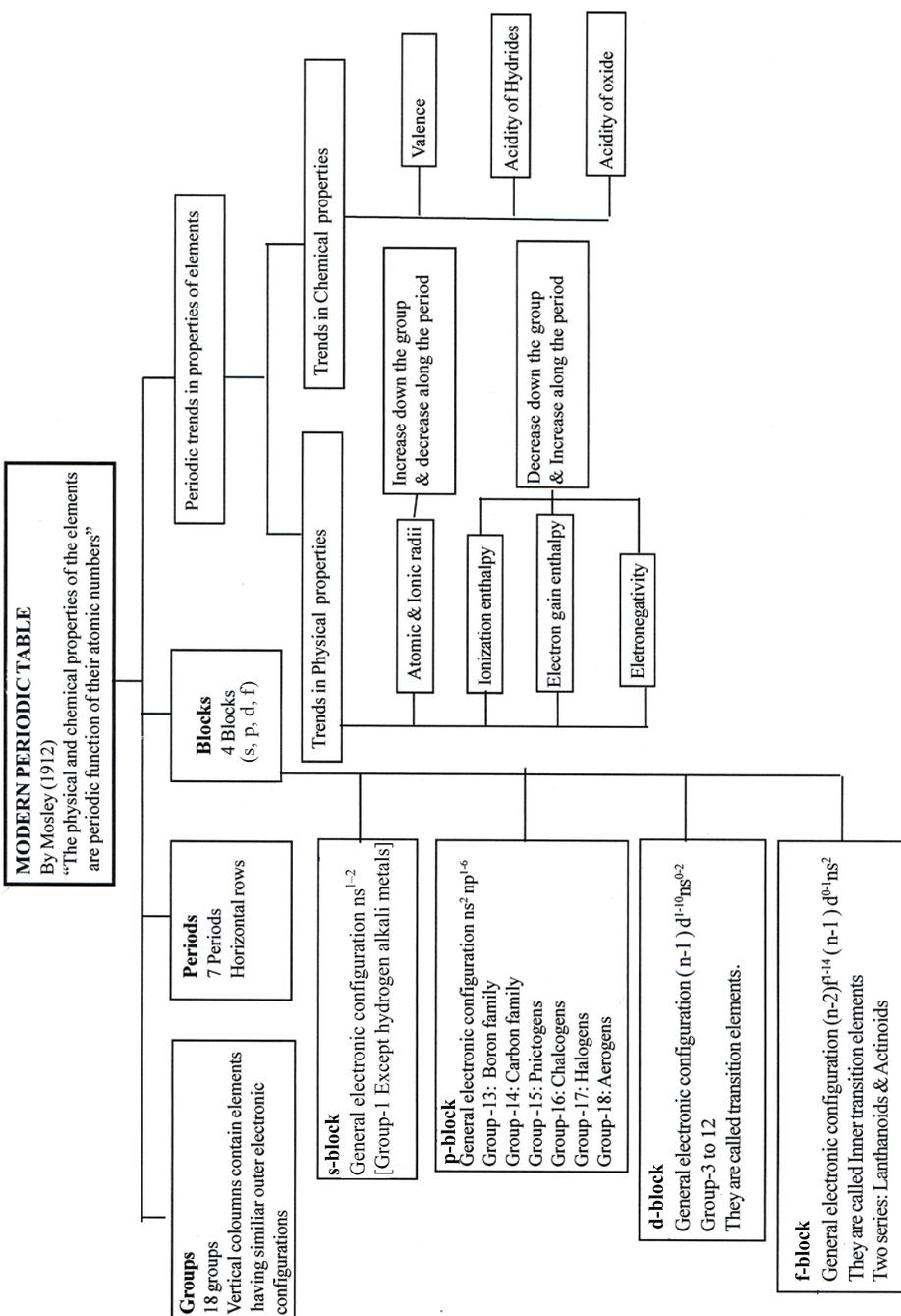


Elements with number of e <sup>-</sup>	in valance shell
(a) 1, 2, 3	metals
(b) 4	metalloids
(c) 5, 6, 7	non-metals
(d) 8	noble gas



## MIND MAP

# CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES



## MULTIPLE CHOICE QUESTIONS (MCQ)

1. According to modern periodic law, the physical and chemical properties of elements are the periodic functions of their ?  
(a) Density (b) Atomic Number  
(c) Mass Number (d) Atomic Mass
2. Highest electropositive element in the periodic table is  
(a) Cs (b) Rb  
(c) K (d) Na
3. The correct order of ionic radii of the species  $\text{N}^{3-}$ ,  $\text{O}^{2-}$ ,  $\text{Na}^+$  and  $\text{F}^-$  is  
(a)  $\text{Na}^+ < \text{F}^- < \text{O}^{2-} > \text{N}^{3-}$  (b)  $\text{F}^- < \text{O}^{2-} < \text{N}^{3-} > \text{Na}^+$   
(c)  $\text{O}^{2-} < \text{N}^{3-} < \text{F}^- > \text{Na}^+$  (d)  $\text{N}^{3-} < \text{Na}^+ < \text{F}^- > \text{O}^{2-}$
4. The basic strength of the oxides follows the order  
(a)  $\text{Al}_2\text{O}_3 > \text{MgO} > \text{Na}_2\text{O}$  (b)  $\text{Al}_2\text{O}_3 < \text{MgO} < \text{Na}_2\text{O}$   
(c)  $\text{Na}_2\text{O}_3 < \text{MgO} > \text{Al}_3\text{O}_2$  (d)  $\text{Al}_2\text{O}_3 > \text{MgO} > \text{Na}_2\text{O}$
5. The correct order of the size of C, N, P, S follows the order  
(a)  $\text{N} < \text{C} < \text{P} < \text{S}$  (b)  $\text{C} < \text{N} < \text{S} < \text{P}$   
(c)  $\text{C} < \text{N} < \text{P} < \text{S}$  (d)  $\text{N} < \text{C} < \text{S} < \text{P}$
6. Which of the following oxide is most acidic?  
(a)  $\text{Na}_2\text{O}$  (b)  $\text{Al}_3\text{O}_2$   
(c)  $\text{P}_2\text{O}_5$  (d)  $\text{SO}_3$
7. Downward in a group, electropositive character of elements  
(a) increases (b) decreases  
(c) remains same (d) none of these
8. Element which has more negative electron gain enthalpy is  
(a) F (b) O  
(c) Cl (d) S
9. The electronegativity of the following elements increase in the order  
(a) C, N, Si, P (b) N, Si, C, P  
(c) Si, P, C, N (d) P, Si, N, C

10. The ionisation enthalpy of nitrogen is more than that of oxygen molecules because of
- greater attraction of electrons by the nucleus
  - extra stability of the half filled p-orbitals
  - smaller size of nitrogen
  - more penetrating effect

**Ans:** 1. (b), 2. (a), 3. (a), 4. (b), 5. (d), 6. (d), 7. (a), 8. (c),  
9. (c), 10. (d)

### FILL IN THE BLANKS

- Lightest metal in s-block elements is \_\_\_\_\_.
- In the periodic table, horizontal rows are known as \_\_\_\_\_.
- Elements of s-blocks and p-blocks are collectively called \_\_\_\_\_.
- Most electropositive elements belong to \_\_\_\_\_ group.
- Most electronegative elements belong to \_\_\_\_\_ group.
- The elements above atomic number 92 are called \_\_\_\_\_.
- The inner-transition elements belong to \_\_\_\_\_ block of the periodic table and are shown separately at the \_\_\_\_\_ of the periodic table.
- An element having electronic configuration  $[\text{Ar}] 3d^5, 4s^2$  belongs to \_\_\_\_\_ block.
- $\text{Ca}^{2+}$  has smaller ionic radius than  $\text{K}^+$  ion because it has \_\_\_\_\_.
- The maximum electronegativity is shown by \_\_\_\_\_.
- The maximum ionisation enthalpy is shown by \_\_\_\_\_.
- The cation is \_\_\_\_\_ and the anion is \_\_\_\_\_ than the parent atom.

- Ans:**
- |   |                     |
|---|---------------------|
| 1. Lithium                                    | 7. F-, bottom       |
| 2. periods                                    | 8. s-               |
| 3. normal elements or representative elements | 9. more protons     |
| 4. 1 <sup>st</sup>                            | 10. F-              |
| 5. 17 <sup>th</sup>                           | 11. H               |
| 6. transuranic elements                       | 12. smaller, bigger |

## TRUE AND FALSE TYPE QUESTIONS

**Write true or false for the following statements**

1. First ionisation enthalpy of Be is higher than B.
2. Every period of the periodic table (except first period) starts with a member of alkali metal.
3. The energy liberated during the removal of one electron from an atom is called its ionisation potential.
4. Fluorine has more negative electron gain enthalpy than chlorine.
5.  $\text{Mg}^{2+}$  ion has smaller size than Mg.
6. Electronegativity of F is larger than that of Cl but electron gain enthalpy of Cl is larger than of F.
7. The decreasing order of electronegativity of F, O and N is  $\text{F} > \text{O} > \text{N}$ .
8. Group-18 contain maximum gaseous elements.
9.  $\text{Al}_2\text{O}_3$  is an amphoteric oxide.
10. Helium has the highest ionisation enthalpy.

**Ans:** 1. (T)    2. (T)    3. (T)    4. (F)    5. (T)  
6. (T)    7. (T)    8. (T)    9. (T)    10. (T)

## MATCH THE COLUMNS

1.

**Column A**

- a. Highest element
- b. Highest metal
- c. Heaviest metal
- d. Most reactive metal

**Column B**

- i. Cesium
- ii. Osmium
- iii. Lithium
- iv. Hydrogen

2.

**Column A**

- a. Fluorine
- b. Helium
- c. Chlorine
- d. Cesium

**Column B**

- i. High negative electron gain enthalpy
- ii. Most electropositive element
- iii. Most electronegative element
- iv. Highest ionisation enthalpy

3.

Column A	Column B
a. $\text{Na}_2\text{O}$	i. Amphoteric oxide
b. $\text{Cl}_2\text{O}_7$	ii. Acidic oxide
c. $\text{Al}_2\text{O}_3$	iii. Neutral oxide
d. CO	iv. Basic oxide

4.

Column A	Column B
a. s & p-block	i. Inner transition elements
b. d-block	ii. s-block elements
c. f-block	iii. Transition elements
d. group-1 and group-2	iv. Representative elements

**Ans:** 1. a.(iv), b.(iii), c.(ii), d.(i)    2. a.(iii), b.(iv), c.(i), d.(ii)  
3. a.(iv), b.(ii), c.(i), d.(iii)    4. a.(iv), b.(iii), c.(i), d.(ii)

### ASSERTION AND REASON TYPE QUESTIONS

#### Directions for Q. No.1-5

- A If both Assertion & Reason are true and the reason is the correct explanation of the assertion.  
B If both Assertion & Reason are true but the reason is not the correct explanation of the assertion.  
C If Assertion is true statement but Reason is false.  
D If both Assertion and Reason are false statements.

1. Assertion : Ionic radius of  $\text{Na}^+$  is smaller than Na  
Reason : Effective nuclear charge of  $\text{Na}^+$  is higher than Na
2. Assertion : First ionisation enthalpy of N is higher than O.  
Reason : Extra stability of fully filled up 2p subshell of N atom
3. Assertion : Electron gain enthalpy of Cl is more negative than F atom.  
Reason : F is more electronegative than Cl atom.
4. Assertion : First ionisation enthalpy of Gallium is higher than aluminium.  
Reason : Weak shielding effect of 3d subshell in Gallium.

**Ans:** 1. A    2. A    3. B    4. A

## ONE WORD ANSWER TYPE QUESTIONS

1. Metals are placed on which side of modern periodic table?
2. Which block of modern periodic table represent inner transition elements?
3. Name a halogen which has more negative electron gain enthalpy value?
4. Which element is iso-electronic with  $\text{Na}^+$  ? [Ans. Ne]  
[Given a atomic number of Sodium (Na) : 11]
5. An element is placed in 5th period and 3rd group what is its atomic number? [Ans. 39]
6. What is covalency of Al in  $[\text{AlCl}_4]^-$  ? [Ans. 4]
7. Write the IUPAC Symbol for the element having atomic number 120. [Ans. Ubn]
8. Write the name of the group containing maximum number of gaseous elements.
9. Write the name of the subshell which show weakest sheilding effect.
10. Write the name of most electropositive element in the periodic table.
11. In what period and group will an element with  $Z = 118$  will be present.

## 1-MARK QUESTIONS

1. Which pair of elements has similar properties?  
13, 31, 11 & 21
2. Name the element which exhibit diagonal relationship with Be. [Ans. 13, 31]
3. Which group elements are known as halogens?
4. The element with  $ns^2, np^5$  configuration is non-metal or metal?
5. Define van der Waal's radius.
6. Write the outer shell configuration of atomic number 31. [Ans.  $4s^2, p^1$ ]
7. Find the group number and period number of element having atomic number 52. [Ans. Period = 5th, Group = 16th]
8. Arrange  $\text{O}^{2-}, \text{O}^{-1}, \text{O}$  in decreasing radius (size). [Ans.  $\text{O}^{2-} > \text{O}^{-1} > \text{O}$ ]

9. Why noble gas have bigger size than halogens?
10. Why first electron gain enthalpy of sulphur is more negative then oxygen?
11. Write general outer electronic configuration of 4f series elements.  
[Ans.  $6s^2, 5d^{0-1}, 4f^1$  to 14]
12. Write two isoelectronic species with Br (35). [Ans.  $Kr^+, Se^{-1}$ ]
13. Show that 4th period can have maximum 18 elements in it.
14. Second I.E. is always more than first I.E., why?
15. Electronegativity of  $F > Cl > Br > I$ , why?
16. Arrange F and Cl in terms of increasing chemical reactivity?
17. Second I.E. of Na is more than second IE of Mg. Why?
18. I.E. for cation is more than neutral atom. Why?
19. Define diagonal relationship with the help of an example.
20. Out of  $O^-$  and O, which has more negative electron gain enthalpy?
21. Mention any two anomalous properties of second period elements.

### 2-MARKS QUESTIONS

1. Cations are smaller than their parent atom whereas anions are larger in size than their parent atom. Explain.
2. Ionisation energy of nitrogen is more than 'O' and 'C' both, why ?
3. First ionisation energy of boron is less than Be but size of Be is less than Boron. Why ?
4. Electron gain enthalpy of Mg is positive. Explain.
5. Define co-valency.
6. The reactivity of halogens decrease down the group but of alkali metals increases down the group. Why?
7. Name a halogen, a metal and a group13 element which are liquid at  $30^\circ C$ .  
[Ans. Br, Hg, Ga]
8. The reducing power of elements increases down the group but reverse is true for oxidising power along a period. Why ?

9. What is the formula of binary compound formed between :
- 1st element of I group and iodine ?
  - 2nd element of II group and 1st element of 17th group ?
10. Arrange in the following in increasing order of property indicated:
- Size I, F, Cl, Br
  - Oxidising power I, F, Br, Cl
11. Oxygen is more non-metallic than nitrogen but less than fluorine why ?
12. LiCl, LiBr, LiI are covalent as well as ionic why ?
13.  $\text{PbCl}_2$  is more stable than  $\text{PbCl}_4$ . Why ? [Ans. Inert pair effect]
14. [Magnesium and Lithium both form nitrides why ?
15. Which has least I.E. [ $3p^3$ ,  $3p^6$ ,  $2p^3$ ,  $2p^6$ ]?
16. (a) I.E. of sulphur is lower than chlorine.  
 (b) Arrange the following in decreasing order of their electro-negativity:  
 F, O, N, Cl, C, H.
17. Element 'A' in group 17 (2nd period)  
 'B' in group 16 (2nd period)  
 'C' in group 15 (2nd period)  
 Arrange 'A', 'B' and 'C' in their decreasing order of electro-negativity and ionisation enthalpy.
18. Element 'A' 13 group forms ionic compounds. Write the :
- Formula of its oxide.
  - Arrange the following in their decreasing electro-positive character  
 Mg, Na, Al, Si.
19. Write the atomic number of element placed diagonally to :
- Group 14, period 4
  - Group 2, period 5
  - Group 17, period 4
20. An element has outer shell electronic configuration  $4s^2 4p^3$ . Find :-
- The atomic number of element placed next below it.
  - Atomic number of next noble gas.

### 3-MARKS QUESTIONS

1. What is metallic radius, Covalent radius, van der waal's radius. Give one example for each.
2. Oxygen has first electron gain enthalpy exothermic while second endothermic still a large number of ionic oxides are formed. Why ?
3. In some properties Boron shows different properties with respect to rest of the membering the group. Justify.
4. Out of group 17, 18 and I, predict:-
  - (a) Which has most negative first electron gain enthalpy ?
  - (b) Which shows most metallic behaviour ?
  - (c) Which has highly positive electron gain enthalpy?
5. What are (a) representative elements, (b) Transition elements, (c) Lanthanoid and actinoids. Give their positions in modern periodic table.
6. Why LiF, NaF, KF, RbF, CsF are ionic ? But LiF is less ionic than CsF.
7.
  - (a) Why Ca has larger atomic radius than Al ?
  - (b) Why  $2s^2$  electron is difficult to remove than  $2p$  electron ?
8.
  - (a) Why the compounds of group 17 with group 13 elements are more ionic and stable than with (group 1) elements? (b)  $\text{Na}_2\text{O}$  is more ionic than  $\text{Li}_2\text{O}$ . why?
9. Explain the following data :  
Ionisation energy  $\text{Cl} < \text{H} < \text{O} < \text{N} < \text{F}$ .
10.  $\text{IE}_2$  of 3<sup>rd</sup> period elements is as follows. Why ?  
 $\text{Mg} < \text{Si} < \text{Al} < \text{P} < \text{S} < \text{Cl} < \text{Ar} < \text{Na}$ .
11. Account for the following:
  - (a) Halogens have very high negative electron gain enthalpy
  - (b) The electron gain enthalpy of Cl ( $Z = 17$ ) is more negative than that of Fluorine ( $Z = 9$ ).
  - (c) Ionisation enthalpy of Nitrogen ( $Z = 7$ ) is more than oxygen ( $Z = 8$ ).
12. What are the d- block elements? Write any four properties of d - block elements and give their general outer electronic configuration.

13. Explain the following:
- Modern Periodic law
  - Electro-negativity
  - Shielding effect
14. Among the second period elements the actual ionisation enthalpies are in the order  $\text{Li} < \text{B} < \text{Be} < \text{C} < \text{O} < \text{N} < \text{F} < \text{Ne}$ . Explain why?
- Be has higher  $(\Delta_i H)_1$  than B
  - O has lower  $(\Delta_i H)_1$  than N and F ?
15. What do you understand by the isoelectronic species ? Name a species that will be isoelectronic with each of the following atoms or ions.
- $\text{F}^-$
  - Ar
  - $\text{Ca}^{2+}$
  - $\text{Rb}^+$
16. (a) Show by a chemical reaction with water that  $\text{Na}_2\text{O}$  is a basic oxide and  $\text{Cl}_2\text{O}_7$  is an acidic oxide.
- (b) Name a species that will be isoelectronic with each of the following atoms or ions, (i)  $\text{F}^-$  (ii)  $\text{Ca}^{2+}$
17. The first ionisation enthalpy values (in  $\text{kJ mol}^{-1}$ ) of group-13 elements are:

B	Al	Ga	In	Tl
801	577	579	558	589

How would you explain this deviation from the general trend ?

18. The first ( $\text{IE}_1$ ) and the second ( $\text{IE}_2$ ) ionisation enthalpies ( $\text{kJ mol}^{-1}$ ) of three elements are given below:

	I	II	III
$\text{IE}_1$	403	549	1142
$\text{IE}_2$	2640	1060	2080

Identify the element which is likely to be:-

- a non metal
- an alkali metal
- an alkaline earth metal

### 5-MARKS QUESTIONS

1. (A) Which of the following have same chemical properties :
- (a) Atomic number 17, 53
  - (b) Atomic number 8, 52
  - (c) Both
  - (d) None
- (B) Answer the following :
- (i) B, Al, Ga (decreasing order of atomic radii).
  - (ii) C, S, N (decreasing order of  $(\Delta H_{eg})_1$ )
  - (iii) Al forms amphoteric oxide. Why ?
  - (iv) Si is a semiconductor while 'C' is a non-metal, why ?

2. Element	$\Delta_i H^{\ominus}_1$	$\Delta_i H^{\ominus}_2$	$\Delta_{eg} H^{\ominus}_1$
I	1681	3374	- 328
II	1008	1846	- 295
III	2372	5251	+ 48

- (a) The most reactive non-metal.
- (b) The least reactive non-metal.
- (c) The least reactive element. Give reasons also.

[Ans. (a) I (b) II (c) III]

## UNIT TEST

Time allowed : 1 hour

Maximum Marks : 20

General instructions :

- (i) All questions are compulsory.
- (ii) Maximum marks carried by each question are indicated against it.

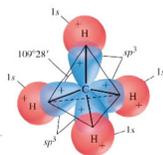
1. Which of the following show the weakest shielding effect ? (1)  
(a) s                      (b) p                      (c) d                      (d) f
2. Which has highest electronegativity ? (1)  
(a) Cl                      (b) O                      (c) N                      (d) S
3. Write the name of the group containing maximum number of gaseous elements. (1)
4. Write general outer electronic configuration of 4f series elements. (1)
5. Write the IUPAC symbol for the element having atomic number 120. (1)
6. (a) Explain why cation are smaller and anions larger in radii than their parent atoms? (2)  
(b) Define accuracy & precision.
7. The first ionisation enthalpy values (in  $\text{kJ mol}^{-1}$ ) of group-13 elements are : (2)

B	Al	Ga	In	Tl
801	577	579	558	589

How would you explain this deviation from the general trend?

8. (a) Show by a chemical reaction with water that  $\text{Na}_2\text{O}$  is a basic oxide and  $\text{Cl}_2\text{O}_7$  is an acidic oxide. (3)  
(b) Name a species that will be isoelectronic with each of the following atoms or ions. (i)  $\text{F}^-$  (ii)  $\text{Ca}^{2+}$
9. Explain the following :
  - (a) Shielding effect
  - (b) Diagonal relationship
  - (c) Anomalous behavior of second period elements.
10. (a) Alkali metals do not form dis-positive ions. Why? (5)  
(b) Why is the IUPAC name and symbol of the element having atomic number 117.  
(c) Are the oxidation state and covalency of Al in  $[\text{Al}(\text{H}_2\text{O})_6]^{2+}$  same?  
(d) Why are there fourteen elements in the Lanthanide series?

\*\*\*\*\*



## Chapter - 4

# Chemical Bonding and Molecular Structure

### FAST TRACK : QUICK REVISION

- ◆ **Kossel-Lewis Concept:** Atoms take part in chemical combination to complete octet in their valence shell. This is known as octet rule.
- ◆ **Limitation of Octet Rule:** The octet rule, though useful but have some exceptions e.g.  $\text{BF}_3$ ,  $\text{NO}_2$ ,  $\text{PCl}_5$ ,  $\text{SF}_6$  etc.
- ◆ **Lewis Symbol or Electron Dot Structure:** Representing valence electrons by dots placed around the letter symbol of the element.

### Types of Chemical Bonds:

#### (i) Covalent Bond:

- Formed by sharing of electrons.
- It may be polar and nonpolar.
- It is directional in nature.

#### (ii) Ionic Bond:

- Formed by transfer of electrons.
- Formation of ionic bond is favored by high lattice enthalpy, Low ionization enthalpy of metal atom and more negative electron gain enthalpy of nonmetal atom.
- It is non directional in nature.

#### ◆ Formal Charge (F.C.):

- It is charge appeared on individual atom in covalent molecule.
- $\text{F.C.} = (\text{Total No. of valence electrons in free atom}) - (\text{Total No. of unshared electrons}) - \frac{1}{2} (\text{Total No. of shared electrons})$

Greater the F.C on atoms lesser the stability of that Lewis structure.

- ◆ **Lattice Enthalpy:** Energy released when one mole of a crystalline solid is formed constituent gaseous ions.

**Bond length:**

- (i) It is equilibrium distance between the nuclei of two bonded atoms in a molecule.
- (ii) Greater the size of bonded atoms shorter the bond length.  
e.g.,  $\text{H-F} < \text{H-Cl} < \text{H-Br} < \text{H-I}$
- (iii) Greater the s character shorter the bond length.  
e.g.,  $\text{C}_{\text{sp}^3}\text{-H} > \text{C}_{\text{sp}^2}\text{-H} > \text{C}_{\text{sp}}\text{-H}$
- (iv) Bond length decreases with increase in bond order.  
e.g.,  $\text{C-C} > \text{C=C} > \text{C}\equiv\text{C}$

**◆ Bond angle:**

- (i) It is angle between the orbitals containing bonding electron pairs around central atom in a molecule or complex ion.
- (ii) Greater the electronegativity of central atom larger the bond angle  
e.g.,  $\text{NH}_3 > \text{PH}_3$
- (iii) Greater the number of lone pair around central atom smaller the bond angle. e.g.,  $\text{CH}_4 > \text{NH}_3 > \text{H}_2\text{O}$

**◆ Bond Enthalpy:**

- (i) It is defined as amount of energy required to break one mole of bonds of a particular type between two atoms in gaseous state.
- (ii) For diatomic molecules, Bond enthalpy = Bond dissociation enthalpy
- (iii) For polyatomic molecules, Bond enthalpy = Average of all possible bond dissociation enthalpies.
- (iv) Bond enthalpy  $\propto$  Bond order  $\propto$   $1/(\text{Bond length})$

**◆ Resonance:**

- (i) According to the concept of resonance, whenever a single Lewis structure cannot describe a molecule accurately, a number of structures with similar energy, position of nuclei, bonding and non-bonding pairs of electrons are taken as canonical structures of the resonance hybrid which describes the molecule accurately.
- (ii) Resonance averages the bond characteristics as a whole.

**◆ Partial ionic character of covalent bond A–B:**

$$= 16(X_A - X_B) + 3.5(X_A - X_B)^2,$$

where  $X_A$  and  $X_B$  are electro-negativities of A & B.

- ◆ **Partial covalent character in ionic bond (Fajan's rule):**
  - (i) Fajan's rule is used to predict partial covalent character in ionic bond.
  - (ii) Greater the polarizing power of cation and polarisability of anion greater the covalent character in ionic bond.
  - (iii) Polarising power of cation  $\propto$  Charge density [(Charge)/Radius].
  - (iv) Polarisability of anion  $\propto$  size of anion.
  
- ◆ **Dipole moment:**
  - (i) Dipole moment ( $\mu$ ) = charge (Q)  $\times$  distance of separation (d)
  - (ii) Unit: Debye (D),  $1D = 3.33564 \times 10^{-30}$  Cm
  - (iii) Being vector quantity, dipole moment of polyatomic molecule is taken as the resultant of all the bond moments.
  - (iv) If  $\mu = 0$ , molecule is non polar or symmetric.
  - (v) If  $\mu \neq 0$ , molecule is polar or asymmetric.
  
- ◆ **Hydrogen bond:**
  - (i) It is dipole-dipole interaction between molecules in which 'H' atom is inserted between two highly electronegative elements i. e. F, O or N only.
  - (ii) Hydrogen bond may be intra-molecular (when present within single molecule) and intermolecular (when present b/w two same or different molecules).
  - (iii) Hydrogen bonds are stronger intermolecular forces than van der Waal forces.
  
- ◆ **Sigma ( $\sigma$ ) and pi ( $\pi$ ) bonds:**
  - (i) Sigma bond is formed by axial overlapping and pi bond is formed by sideways overlapping of atomic orbitals.
  - (ii) Sigma bond is stronger than pi bond due to greater extent of overlapping.
  - (iii) Single covalent bond = 1  $\sigma$  bond  
 Double covalent bond = 1  $\sigma$  bond + 1  $\pi$  bond  
 Triple covalent bond = 1  $\sigma$  bond + 2  $\pi$  bond
  
- ◆ **VSEPR Theory:** (VSEPR = Valence Shell Electron Pair Repulsion): The shape of a molecule depends upon the number of valence shell electron pairs (lp and bp) around the central atom and magnitude of repulsive forces between them  
*i.e.,* lp-lp > lp-bp > bp-bp

♦ **Hybridisation:**

- (i) It is the phenomena of mixing of atomic orbitals of nearly same energy to form the new orbitals of equal energy and identical shape.
- (ii) The new orbitals are called hybrid orbitals and determine the shape of molecules.

♦ **Molecular Orbital Theory (MOT):**

- (i) The overlap of atomic orbitals of same symmetry to form bonding and antibonding molecular orbitals by addition and subtraction of their wave functions is known as MO theory.

- (ii) The electrons are filled in molecular orbitals in order of their increasing energy.

*i.e.,*  $\sigma 1s, \sigma^* 1s, \sigma 2s, \sigma^* 2s, \pi 2p_x = \pi 2p_y, \sigma 2p_z, \pi^* 2p_x = \pi^* 2p_y, \sigma^* 2p_z$  (upto 14 electrons)

$\sigma 1s, \sigma^* 1s, \sigma 2s, \sigma^* 2s, \sigma 2p_z, \pi 2p_x = \pi 2p_y, \pi^* 2p_x = \pi^* 2p_y, \sigma^* 2p_z$  (For more than 14 electrons)

- (iii) Bond order =  $1/2 (N_b - N_a)$

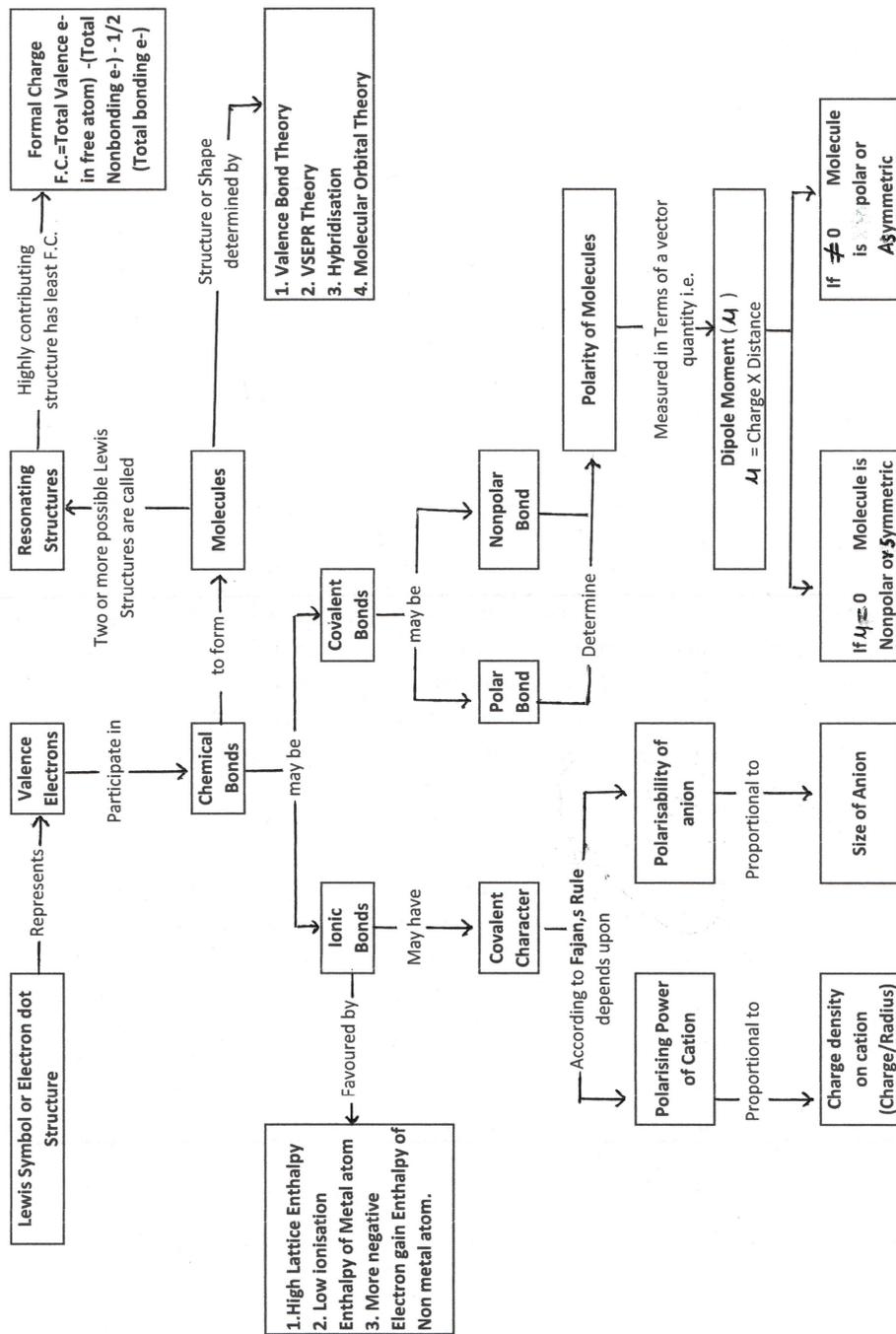
$N_a$  = No of electrons in anti-bonding molecular orbitals

$N_b$  = No of electrons in bonding molecular orbitals

Total electron pairs	Bond pairs	Lone pairs	Type of hybridization	Geometry due to repulsion	Bond angle	Example
2	2	0	sp	Linear	180°	BeCl <sub>2</sub>
3	3	0	sp <sup>2</sup>	Non-polar Planar	120°	BF <sub>3</sub>
3	2	1	sp <sup>2</sup>	Angular	< 120°	SO <sub>2</sub>
4	4	0	sp <sup>3</sup> or dsp <sup>2</sup>	Tetrahedral	109°28'	CH <sub>4</sub>
4	3	1	sp <sup>3</sup> or dsp <sup>2</sup>	Pyramidal	< 109°28'	NH <sub>3</sub>
4	2	2	sp <sup>3</sup> or sp <sup>2</sup>	Bent	< 109°28'	H <sub>2</sub> O
5	5	0	sp <sup>3</sup> d	Trigonal bipyramidal	120° & 90°	PCl <sub>5</sub>
5	4	1	sp <sup>3</sup> d	See Saw	< 120° & < 90°	SF <sub>4</sub>
5	3	2	sp <sup>3</sup> d	Bent T-shaped	< 90°	ClF <sub>3</sub>
5	2	3	sp <sup>3</sup> d	Linear	180°	I <sub>3</sub> <sup>-</sup>
6	6	0	sp <sup>3</sup> d <sup>2</sup>	Octahedral	90°	SF <sub>6</sub>
6	5	1	sp <sup>3</sup> d <sup>2</sup>	Square pyramidal	< 90°	BrF <sub>5</sub>
6	4	2	sp <sup>3</sup> d <sup>2</sup>	Square planar	90°	XeF <sub>4</sub>
7	7	0	sp <sup>3</sup> d <sup>3</sup>	Pentagonal bipyramidal	90° & 72°	IF <sub>7</sub>
7	6	1	sp <sup>3</sup> d <sup>3</sup>	Pentagonal pyramidal	< 90° & < 72°	
7	5	2	sp <sup>3</sup> d <sup>3</sup>	Pentagonal planar	72°	XeF <sub>5</sub> <sup>-</sup>

# MIND MAP

## CHEMICAL BONDING AND MOLECULAR STRUCTURE



### MULTIPLE CHOICE QUESTIONS (MCQ)

- Which of the following molecules has both covalent and ionic bond  
(a)  $\text{CH}_3\text{Cl}$       (b)  $\text{NH}_4\text{Cl}$       (c)  $\text{HCl}$       (d)  $\text{BeCl}_2$
- What is the maximum number of water molecules that can attach with one water molecule through intermolecular hydrogen bonds?  
(a) 2      (b) 3      (c) 4      (d) 1
- Which of the following molecules has maximum bond angle  
(a)  $\text{NH}_3$       (b)  $\text{CH}_4$       (c)  $\text{H}_2\text{O}$       (d)  $\text{CO}_2$
- Identify correct statement regarding  $\text{NH}_3$  and  $\text{BF}_3$   
(a) Both are Lewis acid  
(b) Both are iso structural  
(c) Both are Lewis base  
(d) Have different values of dipole moment
- Identify the molecule having sideways overlapping of atomic orbitals  
(a)  $\text{CH}_4$       (b)  $\text{CO}_2$       (c)  $\text{NH}_3$       (d)  $\text{H}_2\text{O}$
- Which of the following chemical species is most stable?  
(a)  $\text{O}_2$       (b)  $\text{O}_2^+$       (c)  $\text{O}_2^-$       (d)  $\text{O}_2^{2-}$
- Which of the following d orbitals involved in  $\text{Sp}^3\text{d}$  hybridization?  
(a)  $d_{xy}$       (b)  $d_{xz}$       (c)  $d_{x^2-y^2}$       (d)  $d_{z^2}$
- Which of the following molecule has net dipole moment?  
(a)  $\text{CO}_2$       (b)  $\text{H}_2\text{O}$       (c)  $\text{BF}_3$       (d)  $\text{CH}_4$
- Which of the following compound has highest covalent character  
(a)  $\text{LiCl}$       (b)  $\text{LiBr}$       (c)  $\text{LiF}$       (d)  $\text{LiI}$
- The shape of  $\text{XeF}_4$  molecule according to VSEPR theory is  
(a) Square planar      (b) Square pyramid  
(c) Tetrahedral      (d) Pyramidal

**Ans.** 1.(b) 2.(c) 3.(c) 4.(d) 5.(b) 6.(b) 7.(d) 8.(b) 9.(d) 10.(a)

### FILL IN THE BLANKS

- (i) The energy required to completely separate one mole of solid ionic compound into gaseous constituent ions is called.....
- (ii) Among alkali metal ions .....ion has highest polarizing power.
- (iii) According to molecular orbital theory molecules are said to be stable if the number of electrons in bonding molecular orbitals is ..... the number of electrons in antibonding molecular orbitals.
- (iv) Isoelectronic molecules and ions have identical.....
- (v) In  $\text{PCl}_5$  molecule the two equivalent axial P – Cl bonds are.....than three equivalent equatorial P – Cl bonds.
- (vi) The state of hybridization of sulphur in  $\text{SF}_6$  is.....
- (vii) The strongest intermolecular hydrogen bonding in water is present at...°C.
- (viii) A triple covalent bond consists of.....sigma and.....pi bonds.
- (ix) .....bond is directional in nature.
- (x) Atomic orbitals are.....centric and molecular orbitals are.....centric.

**Ans.** (i) Lattice enthalpy (ii)  $\text{Li}^+$  (iii) more (iv) bond order (v) longer  
(vi)  $\text{sp}^3\text{d}^2$  (vii) 4 (viii) 1, 2 (ix) covalent (x) mono, poly

### TRUE AND FALSE TYPE QUESTIONS

**Write true or false for following statements:**

- (i) Energy of resonance hybrid is less as compared to the contributing canonical structures.
- (ii)  $\text{BeF}_2$  has more dipole moment than  $\text{BeCl}_2$ .
- (iii) In water two O–H bond dissociation enthalpies are not identical.
- (ix) Only the half filled orbitals of nearly same energy can participate in hybridization.
- (v) No bond is purely ionic or purely covalent.
- (vi) Chemical species having identical bond order have same bond dissociation enthalpies.

- (vii)  $\text{BF}_3$  is stronger Lewis acid than  $\text{BCl}_3$ .  
 (viii) Among alkali metal halides LiI has highest covalent character.  
 (ix) Resonating structures of a chemical species have no real existence.  
 (x)  $\text{XeF}_2$  and  $\text{ICl}_2^-$  are iso structural.

**Ans.** (i) True (ii) False (iii) False (iv) False (v) True  
 (vi) False (vii) False (viii) True (ix) True (x) True

### MATCH THE COLUMNS

1. Match the species in Column I with the geometry/shape in Column II.

#### Column I

- (i)  $\text{PCl}_5$   
 (ii)  $\text{ClF}_3$   
 (iii)  $\text{NH}_4^+$   
 (iv)  $\text{H}_3\text{O}^+$

#### Column II

- (a) Tetrahedral  
 (b) Pyramidal  
 (c) Bent T shape  
 (d) Trigonal bipyramid

2. Match the species in Column I with the type of hybrid orbitals in Column II.

#### Column I

- (i)  $\text{BF}_3$   
 (ii)  $\text{H}_2\text{O}$   
 (iii)  $\text{PCl}_5$   
 (iv)  $\text{SF}_6$

#### Column II

- (a)  $\text{sp}^3\text{d}$   
 (b)  $\text{sp}^2$   
 (c)  $\text{sp}^3\text{d}^2$   
 (d)  $\text{sp}^3$

**Ans.** 1. (i)  $\rightarrow$  (d), (ii)  $\rightarrow$  (c), (iii)  $\rightarrow$  (a), (iv)  $\rightarrow$  (b).  
 2. (i)  $\rightarrow$  (b), (ii)  $\rightarrow$  (d), (iii)  $\rightarrow$  (a), (iv)  $\rightarrow$  (c).

### ASSERTION AND REASON TYPE QUESTIONS

In the following questions a statement of assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below for each question:

- (i) A and R both are correct, and R is correct explanation of A.  
 (ii) A and R both are correct, but R is not the correct explanation of A.  
 (iii) A is true but R is false.  
 (iv) A and R both are false.

- Assertion (A): Among the two O–H bonds in  $\text{H}_2\text{O}$  molecule, the energy required to break the first O–H bond and the other O–H bond is the same.  
Reason (R): This is because the electronic environment around the oxygen is the same even after breakage of one O–H bond.
- Assertion (A): Though the central atom of both  $\text{NH}_3$  and  $\text{H}_2\text{O}$  molecules are  $\text{sp}^3$  hybridised, yet H–N–H bond angle is greater than that of H–O–H.  
Reason (R): This is because nitrogen atom has one lone pair and oxygen atom has two lone pairs.
- Assertion (A):  $\text{SF}_6$  molecule is unstable.  
Reason (R): A stable molecule must have 8 electrons around the central atom. i.e. octet rule should be satisfied.
- Assertion (A): Pi bond is never formed alone. It is formed along with a sigma bond  
Reason (R): Pi bond is formed by sideway overlap of p- orbitals only.
- Assertion (A): Ionic compounds tend to be non-volatile.  
Reason (R): Ionic compounds are solid.

**Ans.** 1. (iv)    2. (i)    3. (iv)    4. (iii)    5. (ii)

### ONE WORD ANSWER TYPE QUESTIONS

- Write the formal charge on central oxygen atom in  $\text{O}_3$  molecule?
- Write the shape of  $\text{AB}_2\text{E}_3$  type molecule.
- Name the property used to measure the degree of polarity.
- Name the covalent bond formed by axial overlapping of atomic orbitals.
- Out of  $p_x$ ,  $p_y$ ,  $p_z$  orbitals which p orbital takes part in  $\text{sp}$  hybridization?
- Name the molecular orbital having energy greater than that of combining atomic orbitals.
- Name the intermolecular forces responsible for liquid state of water.
- Name the phenomena used to describe a molecule whose single Lewis structure cannot describe it.
- Name the geometry involved in  $\text{sp}^3\text{d}$  hybridization.
- Name the molecular theory that can explain magnetic character of molecules.

**Ans.** 1. +1, 2. Linear, 3. Dipole moment, 4. Sigma bond, 5.  $p_z$   
6. Antibonding molecular orbital, 7. Hydrogen bond, 8. Resonance,  
9. Trigonal bipyramid, 10. Molecular orbital theory

### 1-MARK QUESTIONS

1. Why noble gases exist in mono atomic form?
2. Write the Lewis structure of  $\text{NO}_2^-$ .
3. Why  $\text{NH}_3$  and  $\text{BF}_3$  have different shapes?
4. How many sigma and pi bonds are present in HCN molecule?
5. Why sigma bond is stronger than pi bond?
6. Explain why  $\text{BeH}_2$  molecule has zero dipole moment although the Be–H bonds are polar?
7. Which has highest bond angle?  $\text{NO}_2$ ,  $\text{NO}_2^-$ ,  $\text{NO}_2^+$
8. What is magnetic character of anion of  $\text{KO}_2$ ?
9. Why do atoms combine?
10. What is the significance of Lewis Symbols?
11. Why density of water is maximum at 277K?
12. Give structure of  $\text{BrF}_5$  according to VSEPR theory.
13. Why  $\text{NH}_3$  is liquid and  $\text{PH}_3$  is a gas?
14. Why  $\text{KHF}_2$  exist but  $\text{KCl}_2$  and  $\text{KBr}_2$  does not?  
[Ans. HF...HF hydrogen bonding].
15. Boiling point of p-nitrophenol is more than O-nitrophenol why?
16. How paramagnetic character of a compound is related to the no. of unpaired electrons?
17. Define the term bond length.
18.  $\text{He}_2$  molecule does not exist. Give reason.
19. Why  $\text{PCl}_5$  dissociates to give  $\text{PCl}_3$  and  $\text{Cl}_2$ ?
20. Write the state of hybridization of O in  $\text{H}_2\text{O}$ .
21. Predict the shape of  $\text{ClF}_3$  according to VSEPR theory.
22. Why ice has less density than water?
23. Why the H–P–H bond angle in  $\text{PH}_3$  is less than H–N–H bond angle in  $\text{NH}_3$ ?
24. At room temperature  $\text{H}_2\text{O}$  exist as liquid while  $\text{H}_2\text{S}$  exist as gas. Give reason.
25.  $\text{NH}_3$  has higher boiling point than  $\text{PH}_3$ . Give reason.
26. Identify the chemical species having identical bond order:  $\text{O}_2^{2+}$ ,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{O}_2^{2-}$ .

## 2-MARKS QUESTIONS

1. What is an Octet rule? What are its limitations?
2. The enthalpy needed to break the two O–H bonds in water are as follows:  
$$\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}(\text{g}) + \text{O}-\text{H}(\text{g}) \quad \Delta_{\text{a}}\text{H}_1^0 = 502 \text{ kJ mol}^{-1}$$
$$\text{O}-\text{H}(\text{g}) \rightarrow \text{H}(\text{g}) + \text{O}(\text{g}) \quad \Delta_{\text{a}}\text{H}_1^0 = 502 \text{ kJ mol}^{-1}$$
What is the average bond enthalpy of  $\text{H}_2\text{O}$ ?
3. Write two points of difference between sigma and pi bond.
4. Define Hydrogen bond. Is it weaker or stronger than van der Waal forces?
5. Define dipole moment. Give its significance.
6. Give applications of dipole moment.
7. Which is more polar and why,  $\text{CO}_2$  or  $\text{N}_2\text{O}$ ?
8. Discuss the partial ionic character of covalent bond by taking an example.
9. Draw the resonating structures of  $\text{O}_3$  and calculate formal charges on each O atom.
10. O-Nitrophenol is steam volatile while p-Nitrophenol is not. Give reason.
11. Define bond enthalpy. Why the bond enthalpy of  $\text{F}_2$  is less than that of  $\text{Cl}_2$ ?
12. Define resonance. Draw resonating structures of  $\text{CO}_2$ .
13. Assign reason for the following;
  - (i)  $\text{NH}_3$  is freely soluble in water while  $\text{PH}_3$  is not.
  - (ii)  $\text{B}_2$  is paramagnetic while  $\text{C}_2$  is not.
14. Out of  $\text{NH}_3$  and  $\text{NF}_3$  which is more polar. Explain with the help of dipole moment.
15.  $\text{N}_2$  is diamagnetic while  $\text{O}_2$  is paramagnetic. Explain on the basis of Molecular orbital theory.
16.  $\text{H}_2^+$  and  $\text{H}_2^-$  have same bond order. Which is more stable?
17. Differentiate between bonding and anti bonding molecular orbitals.
18. Discuss the conditions for the combination of atomic orbitals to form molecular orbitals.

19. Although Chlorine (EN = 3.2) is more electronegative than Nitrogen (EN = 3.0), yet chlorine does not form hydrogen bond while nitrogen does. Give reason. (Ans: larger atomic size of Cl).
20.  $\text{ClF}_3$  is T shaped but  $\text{BF}_3$  is planar. Explain.
21.  $\text{N}(\text{SiH}_3)_3$  and  $\text{N}(\text{CH}_3)_3$  are not isostructural. Give reason.
22. Draw molecular orbital diagram for  $\text{N}_2^+$  molecule.
23.  $\text{HCl}$  is a covalent compound but it ionises in the solution?
24. The molecule of  $\text{CO}_2$  is linear whereas that of  $\text{SnCl}_2$  is angular why?
25. Arrange the following in the order of property indicated for each set:
  - (i)  $\text{O}_2, \text{O}_2^+, \text{O}_2^-, \text{O}_2^{2-}$  (increasing stability)
  - (ii)  $\text{LiCl}, \text{NaCl}, \text{KCl}, \text{RbCl}$  (increasing covalent character)
  - (iii)  $\text{NO}_2, \text{NO}_2^+, \text{NO}_2^-$  (decreasing bond angle)
  - (iv)  $\text{H-F}, \text{H-Cl}, \text{H-Br}, \text{H-I}$  (increasing bond dissociation enthalpy)
26. Arrange the following in the order of property indicated for each set:
  - (i)  $\text{H}_2\text{O}, \text{NH}_3, \text{H}_2\text{S}, \text{HF}$  (increasing polar character)
  - (ii)  $\text{HF}, \text{HCl}, \text{HBr}, \text{HI}$  (decreasing dipole moment)
  - (iii)  $\text{NO}_3^-, \text{NO}_2^-, \text{NO}$  (decreasing 's' character of hybridization)
  - (iv)  $\text{BeCl}_2, \text{BCl}_3, \text{CCl}_4, \text{PCl}_3$  (increasing bond angle)

### 3-MARKS QUESTIONS

1. How is ionic bond formed? On what factors it depends?
2. Calculate the lattice enthalpy of  $\text{KCl}$  from the following data by Born-Haber's Cycle.
 

Enthalpy of sublimation of  $\text{K} = 89 \text{ kJ mol}^{-1}$   
 Enthalpy of dissociation of  $\text{Cl}_2 = 244 \text{ kJ mol}^{-1}$   
 Ionization enthalpy of potassium =  $425 \text{ kJ mol}^{-1}$   
 Electron gain enthalpy of chlorine =  $-355 \text{ kJ mol}^{-1}$   
 Enthalpy of formation of  $\text{KCl} = -438 \text{ kJ mol}^{-1}$
3. What is meant by hybridization? Describe the shape of  $sp$ ,  $sp^2$  and  $sp^3$  hybridised orbitals.

- Define bond order. Calculate the bond order in  $N_2$  and  $O_2$  molecules.
- Give molecular orbital energy level diagram of CO. Write its electronic configuration, magnetic behaviour and bond order.
- Which of the following in each pair has larger bond angle  
 (i)  $CO_2$ ,  $BF_3$       (ii)  $H_2O$ ,  $H_2S$       (iii)  $CH_4$ ,  $C_2H_2$
- What is meant by resonance? Draw the resonating structures of carbonate ion and explain why all the C–O bond lengths are identical in carbonate ion?
- Compare relative stability of following species and predict their magnetic properties:  
 $O_2$ ,  $O_2^+$ ,  $O_2^-$  (superoxide),  $O_2^{2-}$  (peroxide)
- Draw the Lewis structure of the species as mentioned below:  
 (i) In which the central atom has incomplete octet.  
 (ii) In which the central atom has an expanded octet,  
 (iii) An odd electron molecule is formed.
- Explain the structure of  $PCl_5$  according to hybridization. Why all P–Cl bonds lengths are not equivalent in  $PCl_5$ ?

### 5-MARKS QUESTIONS

- Give reasons for the following:  
 (a)  $NH_3$  has higher boiling point than  $PH_3$ .  
 (b) Ionic compounds do not conduct electricity in solid state.  
 (c)  $LiCl$  is more covalent than  $KCl$ .  
 (d)  $NH_3$  is more polar than  $NF_3$ .  
 (e)  $H_2O$  has bent structure.
- (a) Define the term bond dissociation enthalpy. How is it related to bond order?  
 (b) Explain why  $N_2$  has greater bond dissociation enthalpy than  $N_2^+$  while  $O_2$  has lesser bond dissociation enthalpy than  $O_2^+$ ?
- Draw the shape of following molecules according to VSEPR theory;  
 $XeO_3$ ,  $XeF_2$ ,  $XeOF_4$ ,  $SF_4$ ,  $XeF_4$

## HOTS QUESTIONS

1. The bond angle of  $\text{H}_2\text{O}$  is  $104.5^\circ$  while that of  $\text{F}_2\text{O}$  is  $102^\circ$ .

**Solution:** The bond pair of electrons are drawn more towards F in  $\text{F}_2\text{O}$ , whereas in  $\text{H}_2\text{O}$  it is drawn towards O. So bp–bp repulsion in  $\text{H}_2\text{O}$  is greater than that in  $\text{F}_2\text{O}$ .

2. Anhydrous  $\text{AlCl}_3$  is covalent. From the data given below, predict whether it would remain covalent or become ionic in aqueous solution.

$$\Delta_f H(\text{AlCl}_3) = 5137 \text{ kJ mol}^{-1}, \quad \Delta_{\text{hyd}} H(\text{Al}^{3+}) = -4665 \text{ kJ mol}^{-1},$$

$$\Delta_{\text{hyd}} H(\text{Cl}^-) = -381 \text{ kJ mol}^{-1}.$$

**Solution:** Total energy released =  $1\Delta_{\text{hyd}} H(\text{Al}^{3+}) + 3\Delta_{\text{hyd}} H(\text{Cl}^-)$

$$= [(-4665) + (3 \times -381)] \text{ kJ mol}^{-1} = -5808 \text{ kJ mol}^{-1}$$

Total energy required =  $\Delta_f H(\text{AlCl}_3) = 5137 \text{ kJ mol}^{-1}$

Since energy released is greater than the energy required, the compound will ionize in aqueous solution.

3. The dipole moment of HCl is 1.03 D, and the bond length is 127 pm. Calculate the percent ionic character of HCl molecule.

**Solution:**  $\mu_{\text{cal}} = Q \times r = (1.6 \times 10^{-19} \text{C}) \times (127 \times 10^{-12} \text{m}) = 2.032 \times 10^{-29} \text{C m}$

$$= (2.032 \times 10^{-29} \text{C m}) \times \frac{1\text{D}}{3.336 \times 10^{-30} \text{Cm}} = 6.09 \text{ D}$$

$$\% \text{ ionic character} = \frac{\mu_{\text{obs.}}}{\mu_{\text{cal}}} \times 100 = \frac{1.03\text{D}}{6.09\text{D}} \times 100 = 16.9\%$$

## UNIT TEST

**Time Allowed: 1 hr**

**Maximum Marks : 20**

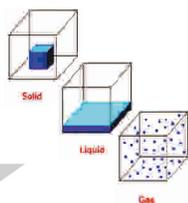
*General Instructions:*

- (i) All questions are compulsory.
  - (ii) Maximum marks carried by each question are indicated against it.
- 

1. Identify the molecule having sideways overlapping of atomic orbitals [1]  
(a) CH<sub>4</sub>                      (b) CO<sub>2</sub>                      (c) NH<sub>3</sub>                      (d) H<sub>2</sub>O
2. The shape of XeF<sub>4</sub> molecule according to VSEPR theory is [1]  
(a) Square planar                      (b) Square pyramid  
(c) Tetrahedral                      (d) Pyramidal
3. Write the Lewis structure of NO<sub>2</sub><sup>-</sup>. [1]
4. Which has highest bond angle? NO<sub>2</sub>, NO<sub>2</sub><sup>-</sup>, NO<sub>2</sub><sup>+</sup> [1]
5. Draw the resonating structures of CO<sub>2</sub>. [1]
6. The enthalpy needed to break the two O–H bonds in water are as follows:  
$$\text{H}_2\text{O}(\text{g}) \longrightarrow \text{H}(\text{g}) + \text{O}-\text{H}(\text{g}) \quad \Delta_a\text{H}_1^0 = 502 \text{ kJ mol}^{-1}$$
$$\text{O}-\text{H}(\text{g}) \longrightarrow \text{H}(\text{g}) + \text{O}(\text{g}) \quad \Delta_a\text{H}_2^0 = 427 \text{ kJ mol}^{-1}$$

What is the average bond enthalpy of H<sub>2</sub>O? [2]
7. Out of NH<sub>3</sub> and NF<sub>3</sub> which is more polar. Explain with the help of dipole moment. [2]
8. Compare relative stability of following species and predict their magnetic properties: O<sub>2</sub>, O<sub>2</sub><sup>+</sup>, O<sub>2</sub><sup>-</sup> (superoxide), O<sub>2</sub><sup>2-</sup> (peroxide) [3]
9. Explain the structure of PCl<sub>5</sub> according to hybridization. Why all P–Cl bonds lengths are not equivalent in PCl<sub>5</sub>? [3]
10. (i) N<sub>2</sub> is diamagnetic while O<sub>2</sub> is paramagnetic. Explain on the basis of Molecular orbital theory. [2]  
(ii) Give reasons for the following: [3]  
(a) NH<sub>3</sub> has higher boiling point than PH<sub>3</sub>.  
(b) Ionic compounds do not conduct electricity in solid state.  
(c) LiCl is more covalent than KCl.

\*\*\*\*\*



## Chapter - 5

# States of Matter : Gases, Liquids and Solids

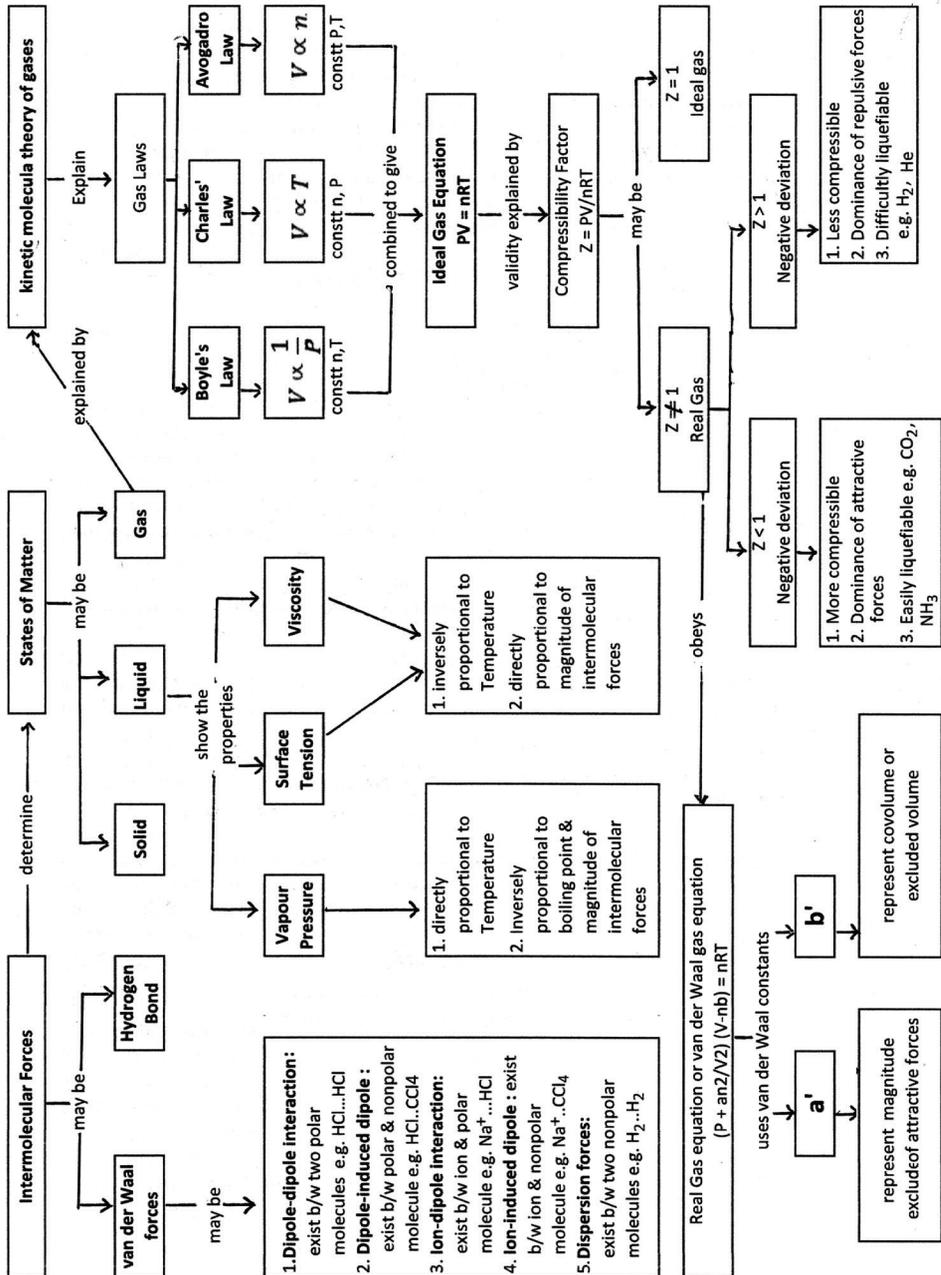
### FAST TRACK : QUICK REVISION

- ◆ **Magnitude of Intermolecular Forces:** Hydrogen bonds > van der Waal forces (dipole-dipole > dipole-induced dipole > Dispersion forces)
- ◆ **Gas Laws:**
  - (i) **Boyle's Law:**  $V \propto 1/P$  or  $PV = \text{constant}$   
or  $P_1V_1 = P_2V_2$  (at constant n, T)
  - (ii) **Charles' Law:**  $V \propto T$  or  $\frac{V_1}{T_1} = \frac{V_2}{T_2}$  (at constant n, P)
  - (iii) **Avogadro's Law:**  $V \propto n$  (at constant T, P)
  - (iv) **Gay Lussac's Law:**  $P \propto T$  (at constant n, V)
- ◆ **Combined Gas Law:**  $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- ◆ **Ideal Gas Equation:**  $PV = nRT$
- ◆ **Values of gas constant R:**
  - (i) 0.0821 L atm K<sup>-1</sup> mol<sup>-1</sup>
  - (ii) 0.083 L bar K<sup>-1</sup> mol<sup>-1</sup>
  - (iii) 8.314 J K<sup>-1</sup> mol<sup>-1</sup>
  - (iv) 1.99 Cal K<sup>-1</sup> mol<sup>-1</sup>
- ◆ **Density of gas (d):**  $d = PM/RT$  (M = molar mass of gas)
- ◆ **Absolute zero or lowest possible temperature:** -273°C or zero Kelvin, because at this temperature volume of gas becomes zero.

- ◆ **Dalton's Law of partial pressure:**  $P_{\text{total}} = p_1 + p_2 + p_3 + \dots$  (at constant T&V) for non reacting gases.
- ◆ **Ideal Gas:** A gas which obeys ideal gas equation at all temperature and pressure.
- ◆ **Boyle's temperature:** Temperature at which a real gas behaves like an ideal gas over an appreciable range of pressure.
- ◆ **Compressibility factor (Z):**  $Z = PV/nRT$ 
  - (i) For ideal gas  $Z = 1$
  - (ii) For non ideal gas  $Z \neq 1$ 
    - (a) **Positive deviation ( $Z > 1$ ):** shows dominance of repulsive forces and hence less compressibility e.g.  $H_2$ , He etc.
    - (b) **Negative deviation ( $Z < 1$ ):** shows dominance of attractive forces and hence more compressibility e.g.  $CH_4$ ,  $CO_2$  etc.
- ◆ **Conditions under which real gases deviates from ideal behavior:** Low T and high P.
- ◆ **Cause of deviation from ideal behavior:** At low T and high P gas molecules are close enough and hence volume occupied by the gas molecules and attractive forces between them cannot be negligible.
- ◆ **Conditions under which real gases behaves ideally:** High T and low P.
- ◆ **van der Waals' gas equation:**  $\left( P + \frac{an^2}{v^2} \right) (v - nb) = nRT$
- ◆ **van der Waals' constant 'a':**
  - (i) It represents magnitude of attractive forces between gas molecules.
  - (ii) Ease of liquefaction of gas  $\propto T_c$  ( $\alpha T_c =$  critical temperature) and Ease of liquefaction of gas  $\propto a$
  - (iii) Unit of 'a' is  $L^2 \text{ atm mol}^{-2}$
- ◆ **Van der Waals' constant 'b':**
  - (i) It represents co-volume or excluded volume i.e. effective volume of gas molecules.
  - (ii) It is four times of actual volume of gas
  - (iii) Unit of 'b' is  $L^2 \text{ mol}^{-1}$

- ◆ **Critical temperature:** It is the temperature above which a gas can not be liquefied however large the pressure may be.
- ◆ **Total Kinetic Energy of Gas**  $= \frac{3}{2} nRT$
- ◆ **Average Kinetic Energy of Gas**  $= \frac{3}{2} RT \text{ mol}^{-1}$  or  $\frac{3}{2} kT \text{ molecule}^{-1}$   
( $k = \text{Boltzmann constant} = R/N_A$ )
- ◆ **Different types of Molecular speeds:**
  - (i) Most probable speed:  $U_{mp} = \sqrt{(2RT/M)}$
  - (ii) Average speed:  $U_{av} = \sqrt{(8RT/\pi M)}$
  - (iii) Root mean square speed:  $U_{rms} = \sqrt{(3RT/M)}$  or  $\sqrt{(3PV/M)}$
- ◆ (i) Vapour pressure  $\propto T$
- ◆ (ii) Vapour pressure  $\propto \frac{1}{\text{Magnitude of intermolecular forces}}$
- ◆ (iii) Vapour pressure  $\propto \frac{1}{\text{Boiling point}}$
- ◆ **Surface tension:** It is tangential force acting along the surface of a liquid perpendicularly on one centimeter length of it.
- ◆ **Viscosity:** It is internal resistance to the flow possessed by a liquid.
- ◆ Increase in temperature decreases surface tension and viscosity of liquid.

# MIND MAP : STATES OF MATTER



### MULTIPLE CHOICE QUESTIONS (MCQ)

- Which of the following property explains the spherical shape of rain droplets:  
(a) Viscosity (b) Critical phenomena  
(c) Surface tension (d) Pressure
- A gas would be most likely to obey the ideal gas law at  
(a) Low T and high P (b) High T and high P  
(c) Low T and low P (d) High T and low P
- If P is the pressure and d is the density of gas, then P and d are related as:  
(a)  $P \propto 1/d$  (b)  $P \propto d$  (c)  $P \propto d^2$  (d)  $P \propto 1/d^2$
- A gas can be liquefied  
(a) above its critical temperature (b) at its critical temperature  
(c) below its critical temperature (d) at any temperature
- Which of the following gas is expected to have highest value of Van der Waal's constant 'a'  
(a)  $\text{NH}_3$  (b)  $\text{H}_2$  (c)  $\text{N}_2$  (d) He
- The compressibility factor (Z) for an ideal gas is:  
(a) 1.5 (b) 1.0 (c) 2.0 (d) zero
- Two separate bulbs contain ideal gas A and B. The density of A is twice that of B. The molecular mass of A is half that of B. If the two gases are at the same temperature, the ratio of pressure of A to that of B is:  
(a) 2 (b) 1/2 (c) 4 (d) 1/4
- At which temperature the volume of a gas is expected to be zero.  
(a)  $0^\circ\text{C}$  (b) 273 K (c)  $-273^\circ\text{C}$  (d)  $273^\circ\text{C}$
- Dominance of strong attractive forces among the molecules of the gas:  
(a) Depends on Z and indicates that  $Z=1$   
(b) Depends on Z and indicates that  $Z > 1$   
(c) Depends on Z and indicates that  $Z < 1$   
(d) Is independent of Z
- Which of the following properties of liquid increases on increasing temperature:  
(a) Vapour pressure (b) Viscosity  
(c) Surface tension (d) Boiling Point

**Ans.** 1.(c), 2.(d), 3.(b), 4.(c), 5.(a), 6.(b), 7.(c), 8.(c), 9.(c), 10.(a)

### FILL IN THE BLANKS

1. Pressure vs volume graph at constant temperature is known as.....
2. Surface tension of a liquid .....with increase in magnitude of intermolecular forces.
3. .... is the temperature at which a real gas behave like an ideal gas over appreciable range of pressure.
4.  $Z > 1$  indicates that the gas is ..... compressible than expected from ideal gas behavior.
5. The average kinetic energy of gas molecules is directly proportional to the.....
6. Internal resistance in flow of liquids is called.....
7. .... is the temperature above which a gas cannot be liquefied however large the pressure may be.
8. Poise (P) is the unit of .....
9. The vapour pressure of any liquid is ..... proportional to the magnitude of the intermolecular forces and is ..... proportional to the temperature employed.
- 10 Van der Waal constant..... represent co-volume and ..... represent magnitude of attractive forces.

**Ans.** 1. Isotherm                      2. increases      3. Boyle's temperature      4. less  
5. Kelvin temperature      6. viscosity      7. critical temperature  
8. viscosity      9. inversely, directly      10. 'b', 'a'

### TRUE AND FALSE TYPE QUESTIONS

**Write true or false for following statements:**

1. At a given temperature and pressure the density of  $N_2$  is more than that of  $O_2$ .
2. Liquid at higher altitudes boil at a lower temperature.
3. Gases having  $Z < 1$  cannot be liquefied easily.
4. According to the kinetic molecular theory, the collision between gas molecules is perfectly elastic.
5. Real gases deviate from ideal behavior at low temperature and high pressure.
6. A gas can be liquified above its critical temperature by applying high pressure.

7. Mosquito cannot walk on kerosene oil because its surface tension is less than that of water.
8. No gas is ideal gas, all gases are real gases.
9. Surface tension increases on increasing temperature.
10.  $0^{\circ}\text{C}$  is known as absolute zero temperature.

**Ans.** 1. False      2. True      3. False      4. True      5. True  
 6. False      7. True      8. True      9. False      10. True

### MATCH THE COLUMNS

1.

#### Column-I

- (i) Boyle's Law
- (ii) Charle's Law
- (iii) Dalton's Law
- (iv) Avogadro Law

#### Column-II

- (a)  $V \propto n$  at constant T & P
- (b)  $P_{\text{total}} = p_1 + p_2 + p_3 + \dots$  at constant T & V
- (c)  $V \propto T$  at constant n & p
- (d)  $p \propto 1/V$  at constant n & P

2.

#### Column-I

- (i) Critical Temperature
- (ii) Vapour Pressure
- (iii) Viscosity
- (iv) Surface Tension

#### Column-II

- (a) Boiling Point
- (b) Spherical shape of water droplet
- (c) Liquefaction of gases
- (d) Flow of Liquids

**Ans.** 1. (i)  $\rightarrow$  (d), (ii)  $\rightarrow$  (c), (iii)  $\rightarrow$  (b), (iv)  $\rightarrow$  (a).  
 2. (i)  $\rightarrow$  (c), (ii)  $\rightarrow$  (a), (iii)  $\rightarrow$  (d), (iv)  $\rightarrow$  (b).

### ASSERTION AND REASON TYPE QUESTIONS

In the following questions a statement of assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below for each question.

- (i) A and R both are correct, and R is correct explanation of A.
- (ii) A and R both are correct, but R is not the correct explanation of A.
- (iii) A is true but R is false.
- (iv) A is false but R is true.

1. Assertion (A): Gases do not liquefy above their critical temperature even on applying high pressure.

Reason (R): Above critical temperature, the molecular speed is high and intermolecular attractions can not hold the molecules together because the escape because of high speed.

2. Assertion (A): At constant temperature,  $pV$  vs  $V$  plot for real gases is not a straight line.  
Reason (R): At high pressure all gases have  $Z > 1$  but at intermediate pressure most gases have  $Z < 1$ .
3. Assertion (A): At zero degree Kelvin, the volume occupied by a gas is negligible.  
Reason (R): All molecular motion ceases at 0 K.
4. Assertion (A):  $\text{CO}_2$  has stronger intermolecular forces than  $\text{CH}_4$ .  
Reason (R): Critical temperature of  $\text{CO}_2$  is more.
5. Assertion (A): Lower the critical temperature of the gas, more easily can it be liquefied.  
Reason (R): Critical temperature is the temperature above which a gas can not be liquefied depending upon the pressure.

**Ans.** 1. (i)      2. (ii)      3. (iii)      4. (i)      5. (iv)

### ONE WORD ANSWER TYPE QUESTIONS

1. Write SI unit of pressure.
2. Write the value of lowest possible temperature.
3. Write the value of compressibility factor  $Z$  for ideal gas.
4. Write the unit of van der Waal constant which represent the magnitude of attractive forces between gas molecules.
5. Name the gas law which relates volume and pressure of gas at constant temperature.
6. Name the property responsible for spherical shape of water droplets.
7. Name the property which opposes the flow of liquids.
8. Two liquids A and B have vapour pressures 400 mm Hg and 450 mm Hg respectively at a given temperature. Which liquid has higher boiling point?
9. Critical temperature of  $\text{N}_2$  and  $\text{O}_2$  are 126 K and 154.3 K respectively. Which gas has greater magnitude of attractive forces?
10. Mention the volume occupied by one mole of an ideal gas at STP.

**Ans.** 1. Pascal    2.  $-273^\circ\text{C}$     3.  $Z = 1$     4.  $\text{L}^2 \text{ atm mol}^{-2}$     5. Boyle's law  
6. Surface tension    7. Viscosity    8. Liquid A    9.  $\text{O}_2$     10. 22.7 L

### 1-MARK QUESTIONS

1. Define Dalton's law of partial pressure of gases.
2. State Boyle's law.
3. Write van der Waal equation for  $n$  mol of gas.
4. Write the conditions in terms of temperature and pressure under which gases deviate from ideal behavior.
5. Write the relation between pressure and density of gas.
6. Write relation between average kinetic energy and temperature of a gas.
7. Define the term absolute zero.
8. In terms of Charles' law explain why  $-273^{\circ}\text{C}$  is known as lowest temperature?
9. Write SI unit for quantity  $(PV^2 T^2)/n^2$ .
10. Define the term Critical temperature.
11. Define Boyle's temperature.
12. Define surface tension.
13. What is the value of normal boiling point and standard boiling point of water?
14. At a particular temperature vapour pressure of ethanol is more than that of water. Give reason.
15. Why vegetables are cooked with difficulty at a hill station?

### 2-MARKS QUESTIONS

1. Name the intermolecular forces present in: (i)  $\text{H}_2\text{O}$  (ii)  $\text{HCl}$
2. Critical temperature for carbon dioxide and methane are  $31.1^{\circ}\text{C}$  and  $-81.9^{\circ}\text{C}$  respectively. Which of these has stronger intermolecular forces and why?
3. Explain the significance of van der Waal parameters.
4. A gas occupies 300 ml at  $27^{\circ}\text{C}$  and 730 mm pressure what would be its volume at STP. [Ans. 262.2 L]
5. Calculate the temperature at which 28g  $\text{N}_2$  occupies a volume of 10 litre at 2.46 atm. [Ans. 299.6 K]
6. Compressibility factor,  $Z$  of a gas is given as  $Z = PV/nRT$ 
  - (i) What is the value of  $Z$  for an ideal gas?
  - (ii) For real gas, what is the value of  $Z$  above Boyle's temperature?

[Ans. (i)  $Z = 1$  (ii)  $Z > 1$ ]

7. What will be the minimum pressure required to compress 500 dm<sup>3</sup> of air at 1 bar to 200 dm<sup>3</sup> at 30°C. [Ans. 2.5 bar]
8. Calculate the volume occupied by 8.8 g of CO<sub>2</sub> at 31.1°C and 1 bar pressure. R = 0.083 L bar K<sup>-1</sup> mol<sup>-1</sup>. [Ans. 5.05 L]
9. Calculate the temperature of 4 mol of a gas occupying in 5 dm<sup>3</sup> at 3.32 bar. R = 0.083 bar dm<sup>3</sup> K<sup>-1</sup> mol<sup>-1</sup>. [Ans. 50K]
10. The pressure of the atmosphere is  $2 \times 10^{-6}$  mm at about 100 mile from the earth and temperature is - 180°C. How many moles are there in 1 mL gas at this attitude? [Ans.  $3.45 \times 10^{-13}$  mol]
11. Calculate average kinetic energy of CO<sub>2</sub> molecules at 27°C. [Ans. 3741.3 J mol<sup>-1</sup>]
12. Calculate root mean square speed of methane molecules at 27°C. [Ans.  $6.84 \times 10^4$  cm s<sup>-1</sup>]
13. Name two phenomena that can be explained on the basis of surface tension.
14. The van der Waal constants of two gases are as follows:

Gas	$a$ (atm L mol <sup>-1</sup> )	$b$ (L mol <sup>-1</sup> )
A	1.39	0.0391
B	3.59	0.0427

Which of them is more easily liquefiable and which has greater molecular size?

15. Critical temperatures of NH<sub>3</sub> and SO<sub>2</sub> are 405.0 and 430.3 K respectively:
- Which one is easily liquefiable?
  - Which has higher value of van der Waal constant 'a'?
16. Arrange the following in the order of property indicated for each set:
- H<sub>2</sub>O, NH<sub>3</sub>, HCl, H<sub>2</sub> (increasing magnitude of intermolecular forces)
  - O<sub>2</sub>, H<sub>2</sub>, CO<sub>2</sub>, SO<sub>2</sub> (ease of liquefaction)
  - O<sub>2</sub>, He, CO<sub>2</sub>, NH<sub>3</sub> (decreasing critical temperature)
  - O<sub>2</sub>, He, CO<sub>2</sub>, CH<sub>4</sub> (increasing value of van der Waal constant 'a')
17. Arrange Water, ethanol, ether and glycerine in the order of property given below:
- increasing order of vapour pressure
  - increasing order of boiling point
  - decreasing order of surface tension
  - increasing order of viscosity

### 3-MARKS QUESTIONS

1. Explain the terms:  
(i) Viscosity (ii) Vapour pressure (iii) Boiling point temperature
2. Calculate the total pressure in a mixture of 8 g of dioxygen and 4 g of dihydrogen confined in a vessel of  $1 \text{ dm}^3$  at  $27^\circ\text{C}$ . [Ans. 56.025 bar]
3. What will be the pressure exerted by a mixture of 3.2 g of methane and 4.4 g of carbon dioxide contained in a  $9 \text{ dm}^3$  flask at  $27^\circ\text{C}$ . [Ans. 0.82 atm]
4. Pressure of one gram of an ideal gas A at  $27^\circ\text{C}$  is found to be 2 bar. When 2 g of another ideal gas B is introduced in the same flask at same temperature, the pressure becomes 3 bar. Find the relationship between their molar masses. [Ans.  $M_B = 4M_A$ ]
5. A 20g chunk of dry ice is placed in an empty 0.75 litre wire bottle tightly closed what would be the final pressure in the bottle after all  $\text{CO}_2$  has been evaporated and temperature reaches to  $25^\circ\text{C}$ ?  
[Ans. Pressure inside the bottle =  $P + \text{atm pressure} = 14.828 + 1 = 15.828 \text{ atm}$ ]
6. A gas at a pressure of 5 atm is heated from  $0^\circ\text{C}$  to  $546^\circ\text{C}$  and is simultaneously compressed to one third of its original volume. Find the final pressure of the gas. [Ans. 45 atm]
7. Calculate the compressibility factor for  $\text{CO}_2$ , if one mole of it occupies 0.4 litre at 300K and 40 atm. Comment on the result.  
[Ans. 0.65, since  $Z < 1$ ,  $\text{CO}_2$  is more compressible than ideal gas]
8. Find the pressure of 4 g of  $\text{O}_2$  and 2 g of  $\text{H}_2$  confined in a bulb of 1 L at  $0^\circ\text{C}$ . [Ans. 25.215 atm]

### 5-MARKS QUESTIONS

1. Mention the intermolecular forces present between:
  - (i)  $\text{H}_2\text{O}$  and  $\text{C}_2\text{H}_5\text{OH}$
  - (ii)  $\text{Cl}_2$  and  $\text{CCl}_4$
  - (iii) He and He atoms
  - (iv)  $\text{Na}^+$  ion and  $\text{H}_2\text{O}$
  - (v) HBr and HBr

2. (i) For Dalton's law of partial pressure derive the expression

$$P_{\text{gas}} = X_{\text{gas}} \cdot P_{\text{total}}$$

- (ii) A 2L flask contains 1.6 g of methane and 0.5 g of hydrogen at 27 °C. Calculate the partial pressure of each gas the mixture and calculate the total pressure.

$$[\text{Ans. } P_{\text{CH}_4} = 1.23 \text{ atm, } P_{\text{H}_2} = 3.079 \text{ atm, } P_{\text{total}} = 4.31 \text{ atm}]$$

3. Using van der Waal's equation calculate the constant 'a' when 2 mole of a gas confined in a 4 L flask exerts a pressure of 11.0 atm at a temperature of 300K. The value of 'b' is 0.05 L mol<sup>-1</sup>. [Ans. 6.49 atm L<sup>2</sup> mol<sup>-2</sup>]

### HOTS QUESTIONS

1. A mixture of CO and CO<sub>2</sub> is found to have density of 1.50 g L<sup>-1</sup> at 20 °C and 740 mm pressure. Calculate the composition of mixture.

**Solution:**

Let the mol % of CO in mixture = x

$$\therefore \text{mol \% of CO}_2 = (100 - x)$$

$$\therefore \text{Average molecular mass} = \frac{[(x \times 28) + (100 - x) \times 44]}{100}$$

$$\therefore \frac{[(x \times 28) + (100 - x) \times 44]}{100} = \frac{dRT}{P} \quad \left( \text{Because, } M = \frac{dRT}{P} \right)$$

$$= \frac{(x \times 28) + (100 - x) \times 44}{100} = 1.50 \text{ g L}^{-1} \times 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1} \times \frac{293 \text{ K}}{100}$$

$$\therefore \text{mol \% of CO} = 43.38 \text{ and mol \% of CO}_2 = (100 - x) \\ = 100 - 43.38 = 56.62$$

2. A cylindrical balloon of 21 cm diameter is to be filled up with H<sub>2</sub> at NTP from a cylinder containing the gas at 20 atm at 27°C. The cylinder can hold 2.82 litre of water at NTP. Calculate the number of balloons that can be filled up.

**Solution:**

$$\text{Volume of 1 balloon which has to be filled} = \frac{4}{3} \pi (21/2)^3 \\ = 4851 \text{ mL} = 4.851 \text{ litre}$$

Let n balloons be filled, then volume of H<sub>2</sub> occupied by balloons = 4.851 × n

Also, cylinder will not be empty and it will occupy volume of H<sub>2</sub> = 2.82 litre.

∴ Total volume occupied by H<sub>2</sub> at NTP = 4.851 × n + 2.82 litre

∴ At STP

$$P_2 = 1 \text{ atm Available H}_2$$

$$V_1 = 4.851 \times n + 2.82$$

$$T_1 = 273 \text{ K}$$

$$P_1 V_1 / T_1 = P_2 V_2 / T_2$$

$$P_2 = 20 \text{ atm}$$

$$T_2 = 300 \text{ K}$$

$$V_2 = 2.82 \text{ litre}$$

or  $1 \times (4.851n + 2.82 / 273) = 20 \times 2.82 / 300 \quad \therefore n = 10$

3. Calculate the temperature at which CO<sub>2</sub> has the same rms speed to that of O<sub>2</sub> at STP.

**Solution:**

$$\text{rms of O}_2 = \sqrt{3RT / M} \text{ at STP, rms of O}_2 = \sqrt{3R \times 273 / 32}$$

$$\text{For CO}_2 \text{ rms CO}_2 = \sqrt{3RT / 44}$$

$$\text{Given both are same; } 3R \times 273 / 32 = 2RT / 44$$

$$\therefore T = 375.38 \text{ K} = 102.38^\circ\text{C}$$

4. 50 litre of dry N<sub>2</sub> is passed through 36g of H<sub>2</sub>O at 27°C. After passage of gas, there is a loss of 1.20g in water. Calculate vapour pressure of water.

**Solution**

The water vapours occupies the volume of N<sub>2</sub> gas i.e. 50 litre

$$\therefore \text{For H}_2\text{O vapour } V = 50 \text{ litre, } w = 1.20\text{g, } T = 300\text{K, } m = 18 \text{ g mol}^{-1}$$

$$PV = w / m RT \text{ or } P \times 50 = 1.2 / 18 \times 0.0821 \times 300$$

$$\therefore P = 0.03284 \text{ atm} = 24.95 \text{ mm}$$

## UNIT TEST

**Time Allowed: 1 hr**

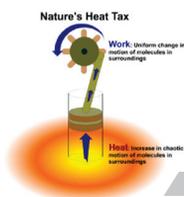
**Maximum Marks : 20**

*General Instructions:*

- (i) All questions are compulsory.
  - (ii) Maximum marks carried by each question are indicated against it.
- 

1. If P is the pressure and d is the density of gas, then P and d are related as:  
(a)  $P \propto 1/d$  (b)  $P \propto d$  [1]  
(c)  $P \propto d^2$  (d)  $P \propto 1/d^2$
2. At which temperature the volume of a gas is expected to be zero. [1]  
(a)  $0^\circ\text{C}$  (b)  $273\text{ K}$   
(c)  $-273^\circ\text{C}$  (d)  $273^\circ\text{C}$
3. Define Boyle's temperature. [1]
4. Write van der Waal equation for n mol of gas. [1]
5. Why vegetables are cooked with difficulty at a hill station? [1]
6. A gas occupies 300 ml at  $27^\circ\text{C}$  and 730 mm pressure what would be its volume at STP. [2]
7. Compressibility factor, Z of a gas is given as  $Z = PV/nRT$  [2]  
(i) What is the value of Z for an ideal gas?  
(ii) For real gas, what is the value of Z above Boyle's temperature?
8. Pressure of one gram of an ideal gas A at  $27^\circ\text{C}$  is found to be 2 bar. [3]  
When 2 g of another ideal gas B is introduced in the same flask at same temperature, the pressure becomes 3 bar. Find the relationship between their molar masses.
9. Calculate the total pressure in a mixture of 8 g of dioxygen and 4 g of dihydrogen confined in a vessel of  $1\text{ dm}^3$  at  $27^\circ\text{C}$ . [3]  
 $R = 0.083\text{ bar dm}^3\text{ K}^{-1}\text{ mol}^{-1}$
10. (a) Critical temperatures of  $\text{NH}_3$  and  $\text{SO}_2$  are 405.0 and 430.3 K respectively: [2]  
(i) Which one is easily liquefiable?  
(ii) Which has higher value of van der Waal constant 'a'?
- (b) Explain the terms: [3]  
(i) Viscosity (ii) Vapour pressure (iii) Boiling point temperature

\*\*\*\*\*



## Chapter - 6

# Chemical Thermodynamics

### FAST TRACK : QUICK REVISION

- ◆ **System:** Specific part of universe in which observations are made.
- ◆ **Surroundings:** Everything which surrounds the system.
- ◆ **Types of the System:**
  - Open System:** Exchange both matter and energy with the surroundings. For example – Reactant in an open test tube.
  - Closed System:** Exchange energy but not matter with the surroundings. For example – Reactants in a closed vessel.
  - Isolated System:** Neither exchange energy nor matter with the surroundings. For example – Reactants in a thermos flask.
- ◆ **Thermodynamic Processes:**
  - (i) Isothermal Process:  $\Delta T = 0$
  - (ii) Adiabatic process:  $\Delta q = 0$
  - (iii) Isobaric process:  $\Delta P = 0$
  - (iv) Isochoric process:  $\Delta V = 0$
  - (v) Cyclic process:  $\Delta U = 0$
  - (vi) Reversible process: Process which proceeds infinitely slowly by a series of equilibrium steps.
  - (vii) Irreversible process: Process which proceeds rapidly and the system does not have chance to achieve equilibrium.
- ◆ **Extensive Properties:** Properties which depend upon the quantity or size of matter present in the system. For example – mass, volume, internal energy, enthalpy, heat capacity, work etc.

- ◆ **Intensive Properties:** Properties which do not depend upon the quantity or size of matter present in the system. For example – temperature, density, pressure, surface tension, viscosity, refractive index, boiling point, melting point etc.

- ◆ **State Functions:** The variables of functions whose value depend only on the state of a system or they are path independent.

For example – pressure (P), volume (V), temperature (T), enthalpy (H), free energy (G), internal energy (U), entropy (S), amount (n) etc.

- ◆ **Internal Energy:** It is the sum of all kind of energies possessed by the system.
- ◆ **First Law of Thermodynamics:** “The energy of an isolated system is constant.”

Mathematical Form:  $\Delta U = q + w$

- ◆ **Sign Conventions for Heat (q) and Work (w):**

- $W = +ve$ , if work is done on system
- $W = -ve$ , if work is done by system
- $q = +ve$ , if heat is absorbed by the system
- $q = -ve$ , if heat is evolved by the system

- ◆ **Work of Expansion/ compression:**  $w = -P_{\text{ext}} (V_f - V_i)$

- ◆ **Work done in Isothermal Reversible Expansion of an Ideal Gas:**

$$w_{\text{rev}} = -2.303 nRT \log V_f / V_i$$

$$\text{or } w_{\text{rev}} = -2.303 nRT \log P_i / P_f$$

- ◆ **Significance of  $\Delta H$  &  $\Delta U$ :**  $\Delta H = q_p$  and  $\Delta U = q_v$
- ◆ **Relation between  $\Delta H$  &  $\Delta U$ :**  $\Delta H = \Delta U + (n_p - n_r)RT$  for gaseous reaction
  - $\Delta H = \Delta U$  if  $(n_p - n_r)$  is zero; *e.g.*  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \longrightarrow 2\text{HI}(\text{g})$
  - $\Delta H > \Delta U$  if  $(n_p - n_r)$  is positive; *e.g.*  $\text{PCl}_5(\text{g}) \longrightarrow \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
  - $\Delta H < \Delta U$  if  $(n_p - n_r)$  is negative; *e.g.*  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \longrightarrow 2\text{NH}_3(\text{g})$
- ◆ **Heat Capacity (C):** Amount of heat required to raise the temperature of a substance by  $1^\circ\text{C}$  or  $1\text{K}$ .

$$q = C \Delta T$$

- ◆ **Specific Heat Capacity ( $C_s$ ):** Amount of heat required to raise the temperature of 1 g of a substance by  $1^\circ\text{C}$  or 1 K.

$$q = C_s \times m \times \Delta T$$

- ◆ **Molar Heat Capacity ( $C_m$ ):** Amount of heat required to raise the temperature of 1 mole of a substance by  $1^\circ\text{C}$  or 1 K.

$$q = C_m \times n \times \Delta T$$

- ◆ **Standard State of a Substance:** The standard state of a substance at a specified temperature is its pure form at 1 bar.

- ◆ **Standard Enthalpy of Formation ( $\Delta_f H^\circ$ ):** Enthalpy change accompanying the formation of one mole of a substance from its constituent elements under standard condition of temperature (normally 298 K) and pressure (1 bar).

- $\Delta_f H^\circ$  of an element in standard state is taken as zero.
- Compounds with  $-ve$  value of  $\Delta_f H^\circ$  more stable than their constituents.
- $\Delta_r H^\circ = \sum a_i \Delta_f H^\circ (\text{products}) - \sum b_i \Delta_f H^\circ (\text{reactants})$ ; Where 'a' and 'b' are coefficients of products and reactants in balanced equation.

- ◆ **Standard Enthalpy of Combustion ( $\Delta_c H^\circ$ ):** Enthalpy change accompanying the complete combustion of one mole of a substance under standard conditions (298 K, 1 bar)

- ◆ **Hess's Law of Constant Heat Summation:** The total enthalpy change of a reaction remains same whether it takes place in one step or in several steps.

- ◆ **Bond Dissociation Enthalpy:** Enthalpy change when one mole of a gaseous covalent bond is broken to form products in gas phase.

For example,  $\text{Cl}_2 (\text{g}) \longrightarrow 2\text{Cl}(\text{g}); \Delta_{\text{Cl-Cl}} H^\circ = 242 \text{ kJ mol}^{-1}$

- For diatomic gaseous molecules; Bond enthalpy = Bond dissociation Enthalpy = Atomization Enthalpy
- For Polyatomic gaseous molecules; Bond Enthalpy = Average of the bond dissociation enthalpies of the bonds of the same type.
- $\Delta_r H^\circ = \sum \Delta_{\text{bond}} H^\circ (\text{Reactants}) - \sum \Delta_{\text{bond}} H^\circ (\text{Products})$
- ◆ **Spontaneous Reaction:** A reaction which can take place either on its own or under some initiation.

- ◆ **Entropy(S):** It is measure of degree of randomness or disorder of a system.

- $$\Delta S_{\text{sys}} = \frac{(q_{\text{rev}})_{\text{sys}}}{\Delta T} = \frac{\Delta H_{\text{sys}}}{\Delta T}$$

- Unit of Entropy =  $\text{JK}^{-1} \text{mol}^{-1}$

- ◆ **Second Law of Thermodynamics:** For all the spontaneous processes totally entropy change must positive.

$$\Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} > 0$$

- ◆ **Gibbs Helmholtz Equation for determination of Spontaneity:**

$$\Delta G = \Delta H - T\Delta S$$

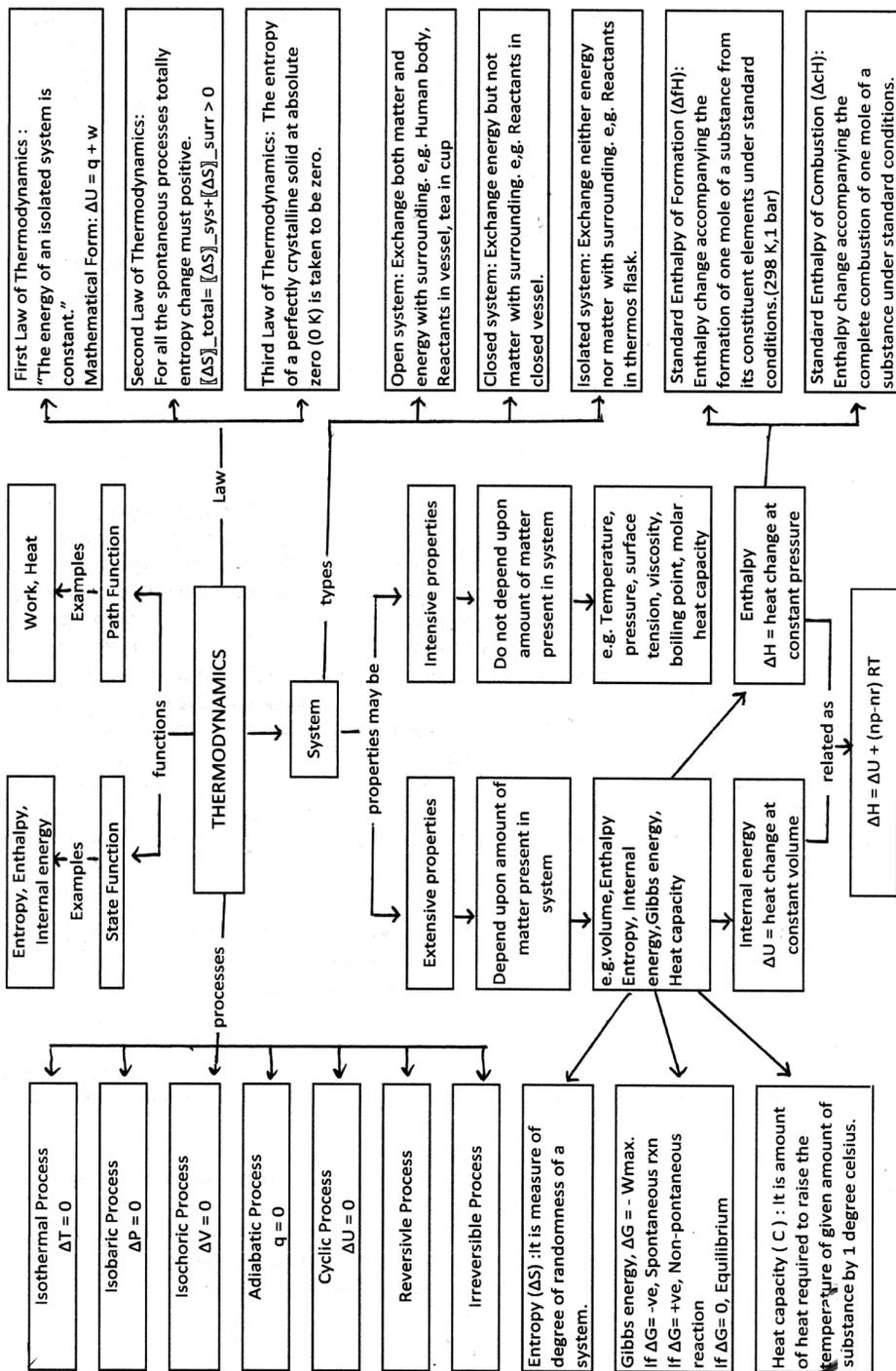
- (i) If  $\Delta G = -\text{ve}$ , the process is spontaneous
- (ii) If  $\Delta G = +\text{ve}$ , the process is non-spontaneous
- (iii) If  $\Delta G = 0$ , the process is in equilibrium

- ◆ **Relation between Gibbs Energy Change and Equilibrium Constant:**

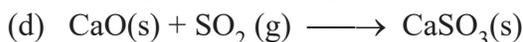
$$\Delta G^\circ = -2.303 RT \log K_c$$

- ◆ **Third Law of Thermodynamics:** The entropy of a perfectly crystalline solid at absolute zero (0 K) is taken to be zero.

# MIND MAP : CHEMICAL THERMODYNAMICS







8. Which statement is true for reaction?  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\text{g})$

(a)  $S = +ve$

(b)  $H > U$

(c)  $H < U$

(d)  $H = U$

9. The heat of combustion of yellow phosphorous is  $-9.91 \text{ KJ}$  and the red phosphorous is  $-8.78 \text{ KJ}$ . The heat of transition of yellow phosphorous to red phosphorous is :

(a)  $-9.91 \text{ kJ}$

(b)  $-8.78 \text{ kJ}$

(c)  $-9.34 \text{ kJ}$

(d)  $-1.13 \text{ kJ}$

10. Entropy of universe is :

(a) Increasing

(b) decreasing

(c) Constant

(d) None of these

11. Which is state function?

(a)  $q$

(b)  $w$

(c)  $q + w$

(d) None of these

12. According to second law of thermodynamics

(a)  $\Delta S_{\text{total}} = +ve$

(b)  $\Delta S_{\text{total}} = -ve$

(c)  $\Delta S_{\text{system}} = +ve$

(d)  $\Delta S_{\text{system}} = -ve$

**Ans:** 1.(d), 2.(d), 3.(c), 4.(c), 5.(b), 6.(d), 7.(a),

8. (a), 9.(d), 10.(c), 11.(d), 12.(a), 13.(c), 14.(a)

### FILL IN THE BLANKS

(i) ..... is a measure of the degree of randomness or disorder of a system.

(ii) A process which can take place either of its own or under some initiation is known as .....

(iii) For evaporation of water the sign of  $\Delta H$  is..... and sign of  $\Delta S$  is.....

(iv) The entropy of a perfectly crystalline solid is zero at .....

(v) The heat energy exchanged between the system and surroundings at constant temperature and pressure is known as.....

(vi) ..... is the quantity of heat needed to raise the temperature of one mole of a substance by  $1^\circ\text{C}$

(vii)  $C_p - C_v = \dots\dots\dots$

(viii) ..... =  $\Delta H - T\Delta S$ .

(ix) According to ..... law of thermodynamics,  $\Delta S_{\text{total}} = +ve$ .

(x) If  $\Delta H = +ve$  and  $\Delta S = +ve$ , the reaction is spontaneous at ..... temperature

**Ans:** (i) Entropy (ii) spontaneous (iii) +ve, +ve (iv)  $-273^{\circ}\text{C}$

(v) Enthalpy (vi) molar heat capacity (vii) R (viii)  $\Delta G$

(ix) second (x) high

### TRUE AND FALSE TYPE QUESTIONS

**Write true or false for following statements:**

(i) For every chemical reaction at equilibrium  $\Delta G^0$  is zero.

(ii) Entropy is not a state function because its value depends upon the condition of temperature and pressure.

(iii) During isothermal expansion of an ideal gas, there is no change in internal energy.

(iv)  $q$  and  $w$  are not state function but  $q+w$  is a state function.

(v) The enthalpy of neutralization of a strong acid by a strong base is always constant.

(v) For a spontaneous process  $\Delta S_{\text{system}} = +ve$ .

(vii) The energy of universe is conserved while its entropy is increasing.

(viii) Volume is extensive property while temperature is intensive property.

(ix) At  $0^{\circ}\text{C}$  the entropy of a perfectly crystalline solid is zero.

(x) Hess' law is a corollary of the first law of thermodynamics.

**Ans:** (i) False (ii) False (iii) True (iv) True (v) True

(vi) False (vii) True (viii) True (ix) False (x) True

### MATCH THE COLUMNS

- | 1.    | Column I           | Column II         |
|-------|--------------------|-------------------|
| (i)   | State function     | (a) Pressure      |
| (ii)  | Extensive property | (b) Work          |
| (iii) | Intensive property | (c) $q + w$       |
| (iv)  | Path function      | (d) Heat capacity |

2.

Column I	Column II
(i) $\Delta H = +ve; \Delta S = +ve$	(a) Spontaneous at all temperatures
(ii) $\Delta H = -ve; \Delta S = +ve$	(b) Non-spontaneous at all temperatures
(iii) $\Delta H = +ve; \Delta S = -ve$	(c) Non-spontaneous at high temperature
(iv) $\Delta H = -ve; \Delta S = -ve$	(d) Spontaneous at high temperature

**Ans:** 1. (i)  $\rightarrow$  (c), (ii)  $\rightarrow$  (d), (iii)  $\rightarrow$  (a), (iv)  $\rightarrow$  (b).

2. (i)  $\rightarrow$  (d), (ii)  $\rightarrow$  (a), (iii)  $\rightarrow$  (b), (iv)  $\rightarrow$  (c).

### ASSERTION AND REASON TYPE QUESTIONS

In the following questions a statement of assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below for each question.

- A and R both are correct, and R is correct explanation of A.
  - A and R both are correct, but R is not the correct explanation of A.
  - A is true but R is false.
  - A and R both are false.
- Assertion (A): Enthalpy of graphite is lower than that of diamond.  
Reason (R): Entropy of graphite is greater than that of diamond.
  - Assertion (A): Enthalpy of formation of  $H_2O(l)$  is greater than that of  $H_2O(g)$ .  
Reason (R): Enthalpy change is negative for condensation reaction,  $H_2O(g) \rightarrow H_2O(l)$
  - Assertion (A):  $\Delta H$  and  $\Delta U$  are same for the reaction  $N_2(g) + O_2(g) \longrightarrow 2NO(g)$   
Reason (R): All the reactants and products are gases.
  - Assertion (A): if both  $\Delta H^0$  and  $\Delta S^0$  are positive than the reaction will be spontaneous at high temperature  
Reason (R): All processes with positive entropy change are spontaneous.
  - Assertion (A): Enthalpy of formation of HCl is equal to bond energy of HCl.  
Reason (R): Enthalpy of formation and bond energy both involve the formation of one mole of HCl from the elements.

**Ans:** 1. (ii)    2. (i)    3. (ii)    4. (iii)    5. (i)

## ONE WORD ANSWER TYPE QUESTIONS

1. 'w' amount of work is done by the system and 'q' amount of heat is supplied to the system. What type of system would it be?
2. What is the work done in free expansion of an ideal gas?
3. What is the sign of  $\Delta G^\ominus$  for spontaneous reaction?
4. Write the relation between  $\Delta H$  and  $\Delta U$  for  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$ .
5. Write the SI unit of entropy.
6. Name the calorimeter used to measure  $\Delta U$ .
7. What is the standard enthalpy of formation of graphite?
8. What is the sign of  $\Delta H$  for  $\text{H}_2(\text{g}) \longrightarrow 2\text{H}(\text{g})$ ?
9. If  $K_c = 1$ , what will be the value of  $\Delta G$ ?
10. An exothermic reaction is spontaneous at all temperature. What is the sign of  $S$ ?

**Ans:** 1. Closed system    2.  $W = 0$     3.  $\Delta G = -ve$     4.  $\Delta H = \Delta U$     5.  $\text{J K}^{-1} \text{mol}^{-1}$   
6. Bomb calorimeter    7. Zero    8.  $\Delta H = -ve$     9. Zero    10.  $\Delta S = +ve$

## 1-MARK QUESTIONS

1. Day temp Name the thermodynamic system to which following belong:  
(i) Human body    (ii) Milk in Thermos flask    (iii) Tea in steel kettle
2. Identify State functions out of the following: Enthalpy, Entropy, Heat, Temperature, Work, Free energy
3. Give two examples of state functions.
4. Write the mathematical statement of first law of thermodynamics.
5. Predict the internal energy change for an isolated system?    [**Ans.** Zero]
6. Why  $\Delta H$  is more significant than  $\Delta U$ ?
7. Write one example each of extensive and intensive properties.
8. Write a chemical equation in which  $\Delta H$  and  $\Delta U$  are equal.
9. Write the relationship between  $\Delta H$  and  $\Delta U$  for the reaction:  
$$\text{C}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$$
10. Define standard enthalpy of formation.

11. Why is the standard enthalpy of formation of diamond not zero although it is an element?
12. The enthalpy of atomization of  $\text{CH}_4$  is  $1665 \text{ kJ mol}^{-1}$ . What is the bond enthalpy of C – H bond? [Ans. 416.25 kJ]
13. Identify the species for which  $\Delta_f H^\theta = 0$ , at 298 K;  $\text{Br}_2$ ,  $\text{Cl}_2$ ,  $\text{CH}_4$ .  
[Hint:  $\text{Cl}_2$  ( $\text{Br}_2$  is liquid at 298K)]
14. For the reaction  $2\text{Cl}(\text{g}) \longrightarrow \text{Cl}_2(\text{g})$ ; what are the sign of  $\Delta H$  and  $\Delta S$ ?
15. For an isolated system  $\Delta U = 0$ , what will be  $\Delta S$ ?
16. Why entropy of steam is more than that of water at its boiling point?
17. Out of Diamond and Graphite which has higher entropy?
18. Write an example of endothermic spontaneous reaction.
19. State second law of thermodynamics.
20. State third law of thermodynamics.
21. Which has more entropy? 1 mol  $\text{H}_2\text{O}(\text{l})$  at  $25^\circ\text{C}$  or 1 mol  $\text{H}_2\text{O}(\text{l})$  at  $35^\circ\text{C}$ .
22. At what temperature the entropy of a perfectly crystalline solid is zero?
23. For a certain reaction  $\Delta G^\theta = 0$ , what is the value of  $K_c$ ?
24. How can a non spontaneous reaction be made spontaneous?
25. For a reaction both  $\Delta H$  and  $\Delta S$  are negative. Under what conditions does the reaction occur.

### 2-MARKS QUESTIONS

1. In a process 701 J of heat is absorbed by a system and 394 J work is done by the system. What is the change in internal energy for the process?  
[Ans. 307 J]
2. Neither  $q$  nor  $w$  is state functions but  $q + w$  is a state function. Explain.
3. Classify the following as extensive or intensive properties :-  
Heat capacity, Density, Temperature, Molar heat capacity.
4. Derive the relationship between  $\Delta H$  and  $\Delta U$ .
5. Derive the relationship  $C_p - C_v = R$ .
6. A 1.25g sample of octane ( $\text{C}_8\text{H}_{18}$ ) is burnt in excess of oxygen in a bomb calorimeter. The temperature of the calorimeter rises from 294.05 to

- 300.78K. If heat capacity of the calorimeter is  $8.93 \text{ kJ K}^{-1}$ . Find the heat transferred to calorimeter. [Ans.  $0.075 \text{ kJ}$ ]
- Show that for an ideal gas, the molar heat capacity under constant volume conditions is equal to  $3/2 R$ .
  - Expansion of a gas in vacuum is called free expansion. Calculate the work done and change in internal energy when 1 mol of an ideal gas expands isothermally from 1 L to 5 L into vacuum.
  - State and explain Hess's Law of Constant Heat Summation with a suitable example.
  - Derive the relationship between  $\Delta H$  and  $\Delta U$ .  
Given,  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \longrightarrow 2\text{NH}_3(\text{g}); \Delta_r H^\theta = -92.4 \text{ kJ mol}^{-1}$ ;  
What is the standard enthalpy of formation of  $\text{NH}_3$  gas?  
[Ans.  $-46.2 \text{ kJ mol}^{-1}$ ]
  - Calculate the enthalpy change for the reaction:  
 $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \longrightarrow 2 \text{HBr}(\text{g})$ .  
Given the bond enthalpies  $\text{H}_2$ ,  $\text{Br}_2$  and  $\text{HBr}$  are  $435 \text{ kJ mol}^{-1}$ ,  $192 \text{ kJ mol}^{-1}$  and  $368 \text{ kJ mol}^{-1}$  respectively. [Ans.  $-109 \text{ kJ mol}^{-1}$ ]
  - Is the bond dissociation enthalpy of all the four C – H bonds in  $\text{CH}_4$  same? Give reason in support of your.
  - Define the term entropy. Write its unit. How does entropy of a system change on increasing temperature?
  - Dissolution of ammonium chloride in water is endothermic but still it dissolves in water readily. Why?
  - Calculate the entropy change in the surroundings when 1.00 mol of  $\text{H}_2\text{O}(\text{l})$  is formed under standard conditions;  $\Delta_f H^\theta = -286 \text{ kJ mol}^{-1}$ .  
[Ans.  $959.7 \text{ J K}^{-1} \text{ mol}^{-1}$ ]
  - The enthalpy of vaporization of a liquid is  $30 \text{ kJ mol}^{-1}$  and entropy of vaporization is  $75 \text{ J K}^{-1} \text{ mol}^{-1}$ . Calculate the boiling point of liquid at 1 atm. [Ans.  $400 \text{ K}$ ]
  - The equilibrium constant for a reaction is 10. What will be the value of  $\Delta G^\theta$ ?  $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ ,  $T = 300 \text{ K}$ . [Ans.  $-5.527 \text{ kJ mol}^{-1}$ ]
  - Derive the relationship,  $\Delta G = -T\Delta S_{\text{total}}$  for a system.

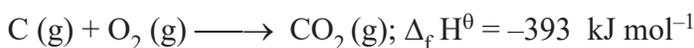
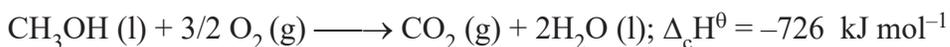
19. The  $\Delta H$  and  $\Delta S$  for  $2\text{Ag}_2\text{O}(s) \longrightarrow 4\text{Ag}(s) + \text{O}_2(g)$  are given  $+61.17\text{kJ mol}^{-1}$  and  $+132\text{ J K}^{-1}\text{mol}^{-1}$  respectively. Above what temperature will the reaction be spontaneous? [Ans.  $>463.4\text{ K}$ ]

### 3-MARKS QUESTIONS

- Differentiate between the following (with examples)
  - Open and Closed System.
  - Adiabatic and Isothermal process.
  - State function and path function
- Calculate the maximum work obtained when 0.75 mole of an ideal gas expands isothermally and reversibly at  $27^\circ\text{C}$  from a volume of 15L to 25L. [Ans.  $-955.7\text{ J}$ ]
- Calculate the number of kJ necessary to raise the temperature of 60 g of aluminium from  $35$  to  $55^\circ\text{C}$ . Molar heat capacity of Al is  $24\text{ J mol}^{-1}\text{ K}^{-1}$ . [Ans.  $1.067\text{ kJ}$ ]
- The reaction of cyanamide,  $\text{NH}_2\text{CN}(s)$ , with Dioxygen was carried out in a bomb calorimeter, and  $\Delta U$  was found to be  $-742.7\text{ kJ mol}^{-1}$  at  $298\text{K}$ . Calculate Enthalpy change for the reaction at  $298\text{K}$ ,  

$$\text{NH}_2\text{CN}(s) + 3/2\text{ O}_2(g) \longrightarrow \text{N}_2(g) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$$
 [Ans.  $-741.5\text{ kJ mol}^{-1}$ ]
- The enthalpy of combustion of methane, graphite and dihydrogen at  $298\text{K}$  are  $-890.3\text{ kJ mol}^{-1}$ ,  $-393.5\text{ kJ mol}^{-1}$  and  $-285.8\text{ kJ mol}^{-1}$  respectively. Calculate enthalpy of formation of methane gas. [Ans.  $-74.8\text{ kJ mol}^{-1}$ ]
- Explain the Born Haber Cycle to determine the lattice enthalpy of NaCl.
- Enthalpies of formation of  $\text{CO}(g)$ ,  $\text{CO}_2(g)$ ,  $\text{N}_2\text{O}(g)$  and  $\text{N}_2\text{O}_4(g)$  are  $-110$ ,  $-393$ ,  $81$  and  $9.7\text{ kJ mol}^{-1}$  respectively. Find the value of  $\Delta_f H$  for the reaction;  $\text{N}_2\text{O}_4(g) + 3\text{ CO}(g) \longrightarrow \text{N}_2\text{O}(g) + 3\text{CO}_2(g)$   
 [Ans.  $-777.7\text{ kJ mol}^{-1}$ ]
- The combustion of 1 mol of benzene takes place at  $298\text{K}$ . After combustion  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are formed and  $3267\text{ kJ mol}^{-1}$  of heat is liberated. Calculate  $\Delta_f H^0(\text{C}_6\text{H}_6)$ .  
 Given:  $\Delta_f H^0(\text{CO}_2) = -286\text{ kJ mol}^{-1}$ ,  $\Delta_f H^0(\text{H}_2\text{O}) = -393\text{ kJ mol}^{-1}$   
 [Ans.  $48.51\text{ kJ mol}^{-1}$ ]

9. Calculate the standard enthalpy of formation of  $\text{CH}_3\text{OH}(\text{l})$  from the following data:



[Ans.  $-239 \text{ kJ mol}^{-1}$ ]

10. For oxidation of iron,  $4 \text{Fe}(\text{s}) + 3 \text{O}_2(\text{g}) \rightarrow 2 \text{Fe}_2\text{O}_3(\text{s})$  entropy change is  $-549.4 \text{ J K}^{-1} \text{ mol}^{-1}$  at 298 K. In spite of negative entropy change of this reaction, why is the reaction spontaneous? ( $\Delta_r H^\ominus$  for this reaction is  $-1648 \text{ kJ mol}^{-1}$ )

[Ans.  $\Delta S_{\text{total}} = +4980.6 \text{ J K}^{-1} \text{ mol}^{-1}$ ]

11. Give reasons:

- Evaporation of water is an endothermic process but it is spontaneous.
- A real crystal has more entropy than an ideal crystal.
- Entropy of universe is increasing.

12. For the reaction at 298 K,  $2\text{A} + \text{B} \longrightarrow \text{C}$ ;  $\Delta H = 400 \text{ kJ mol}^{-1}$ ,  $\Delta S = 0.2 \text{ kJ K}^{-1} \text{ mol}^{-1}$ . At what temperature will the reaction become spontaneous considering  $\Delta H$  and  $\Delta S$  to be constant over the temperature range.

[Ans.  $T > 2000 \text{ K}$ ]

13. Reaction  $\text{X} \rightarrow \text{Y}$ ;  $\Delta H = +\text{ve}$  is spontaneous at temperature 'T'. Determine

- Sign of  $\Delta S$  for this reaction.
- Sign of  $\Delta G$  for  $\text{Y} \longrightarrow \text{X}$
- Sign of  $\Delta G$  at a temperature  $< T$

### 5-MARKS QUESTIONS

- What is reversible process in Thermodynamics?
  - Name the thermodynamic processes for which : (i)  $q = 0$  (ii)  $\Delta U = 0$  (iii)  $\Delta V = 0$  (iv)  $\Delta P = 0$
  - Water decomposes by absorbing 286.2 kJ of electrical energy per mole. When  $\text{H}_2$  and  $\text{O}_2$  combine to form one mole of  $\text{H}_2\text{O}$ , 286.2 kJ of heat is produced. Which thermodynamic law is proved? Write its statement.
- Although heat is a path function but heat absorbed by the system under certain specific conditions is independent of path. What are those conditions? Explain.  
[Hint:  $q_v = \Delta U$  and  $q_p = \Delta H$ ]

- (b) It has been found that 221.4 J is needed to heat 30g of ethanol from 15°C to 18°C. Calculate (a) specific heat capacity, and (b) molar heat capacity of ethanol. [Ans. (a) 2.46 Jg<sup>-1</sup> °C<sup>-1</sup>, (b) 113.2 J mol<sup>-1</sup> °C<sup>-1</sup>]
3. (a) Differentiate the terms Bond dissociation enthalpy & Bond Enthalpy.  
 (b) Calculate enthalpy change for the process CCl<sub>4</sub>(g) → C(g) + 4Cl(g) and calculate Bond enthalpy of C–Cl bond in CCl<sub>4</sub>.  
 Given: Δ<sub>vap</sub>H<sup>θ</sup> = 30.5 kJ mol<sup>-1</sup>; Δ<sub>f</sub>H<sup>θ</sup>(CCl<sub>4</sub>) = -135.5 kJ mol<sup>-1</sup>;  
 Δ<sub>a</sub>H<sup>θ</sup>(C) = 715 kJ mol<sup>-1</sup> and Δ<sub>a</sub>H<sup>θ</sup>(Cl<sub>2</sub>) = 242 kJ mol<sup>-1</sup>  
 [Ans. 1304 kJ mol<sup>-1</sup>, 326 kJ mol<sup>-1</sup>]
4. Predict the sign of ΔS for the following changes:  
 (i) Freezing of water.  
 (ii) C(graphite) → C(diamond)  
 (iii) H<sub>2</sub>(g) at 298 k and 1 bar → H<sub>2</sub>(g) at 298 k and 10 bar  
 (iv) H<sub>2</sub>(g) + I<sub>2</sub>(g) → 2HI(g)  
 (v) 2NaHCO<sub>3</sub>(s) → Na<sub>2</sub>CO<sub>3</sub>(s) + CO<sub>2</sub>(g) + H<sub>2</sub>O(g)
5. (i) Define Gibbs Energy. Give its mathematical expression. What is Gibb's energy criteria of Spontaneity.  
 (ii) For the reaction:  
 2A(g) + B(g) → 2D(g), ΔU<sup>θ</sup> = -10.5 kJ and ΔS<sup>θ</sup> = -44.1 J K<sup>-1</sup>.  
 Calculate Δ<sub>r</sub>G<sup>θ</sup> for the reaction, and predict whether the reaction will occur spontaneously.  
 [Ans. Δ<sub>r</sub>G<sup>θ</sup> = +0.16 kJ, Non-spontaneous]

### HOTS QUESTIONS

1. Does entropy increase or decrease when egg is boiled?  
 Ans.: On boiling egg, entropy decreases as due to denaturation, the helical structure of protein become more complicated and random coiled structure.
2. 10 g of argon is compressed isothermally and reversibly at a temperature of 27°C from 10 L to 5 l. Calculate q, w, ΔU and ΔH.  
**Solution:** q = -2.303 nRT log V<sub>2</sub> / V<sub>1</sub> = -2.303 × 10/40 mol × 2 Cal K<sup>-1</sup> mol<sup>-1</sup> × 300 K × log 5/10 = -103.635 Cal

For isothermal compression  $\Delta U = 0$

$$W = \Delta U - q = 0 - (-103.635) = +103.635 \text{ Cal}$$

Also when temperature is constant,

$$PV = \text{constant}, \Delta H = \Delta U + \Delta(PV) = 0 + 0 = 0$$

3. 1 mole of an ideal gas expand isothermally and reversibly from a pressure of 10 atm to 1 atm at 300 K. Calculate the height to which an object of 50 kg can be lifted by this expansion.

**Solution:**  $w_{(\text{exp.})} = -2.303 nRT$

$$\begin{aligned} \log P_i / P_f &= -2.303 \times 1 \text{ mol} \times 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 300 \text{ K} \times \log 10/1 \\ &= 5.74 \times 10^3 \text{ J} \end{aligned}$$

Now,  $mgh = 5.74 \times 10^3 \text{ J}$  or  $50 \text{ kg} \times 9.81 \text{ m s}^{-2} \times h = 5.744 \times 10^3 \text{ J}$

$$\therefore h = 11.7 \text{ m}$$

## UNIT TEST

**Time Allowed: 1 hr**

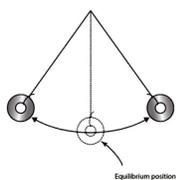
**Maximum Marks : 20**

*General Instructions:*

- (i) All questions are compulsory.
  - (ii) Maximum marks carried by each question are indicated against it.
- 

1. For the reaction  $2\text{Cl}(\text{g}) \longrightarrow \text{Cl}_2(\text{g})$ ; what are the sign of  $\Delta H$  and  $\Delta S$ ? [1]
2. Write an example of endothermic spontaneous reaction. [1]
3. 'w' amount of work is done by the system and 'q' amount of heat is supplied to the system. What type of system would it be? [1]
4. In a process 701 J of heat is absorbed by a system and 394 J work is done by the system. What is the change in internal energy for the process? [2]
5. State and explain Hess's Law of Constant Heat Summation with a suitable example. [2]
6. Calculate the number of kJ necessary to raise the temperature of 60 g of aluminium from 35 to 55°C. Molar heat capacity of Al is  $24 \text{ J mol}^{-1} \text{ K}^{-1}$ . [3]
7. Calculate the standard enthalpy of formation of  $\text{CH}_3\text{OH}(\text{l})$  from the following data:  
 $\text{CH}_3\text{OH}(\text{l}) + 3/2 \text{ O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l});$   
 $\Delta_c H^\theta = -726 \text{ kJ mol}^{-1}$   
 $\text{C}(\text{g}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}); \Delta_f H^\theta = -393 \text{ kJ mol}^{-1}$   
 $\text{H}_2(\text{g}) + 1/2 \text{ O}_2(\text{g}) \longrightarrow \text{H}_2\text{O}(\text{l}); \Delta_f H^\theta = -286 \text{ kJ mol}^{-1}$
8. (a) For oxidation of iron,  $4 \text{ Fe}(\text{s}) + 3 \text{ O}_2(\text{g}) \longrightarrow 2 \text{ Fe}_2\text{O}_3(\text{s})$  entropy change is  $-549.4 \text{ J K}^{-1} \text{ mol}^{-1}$  at 298 K. In spite of negative entropy change of this reaction, why is the reaction spontaneous? ( $\Delta_r H^\theta$  for this reaction is  $-1648 \text{ kJ mol}^{-1}$ ) [2]
- (b) For the reaction:  $2\text{A}(\text{g}) + \text{B}(\text{g}) \longrightarrow 2\text{D}(\text{g})$ ,  $\Delta U^\theta = -10.5 \text{ kJ}$  and  $\Delta S^\theta = -44.1 \text{ J K}^{-1}$ . Calculate  $\Delta_r G^\theta$  for the reaction, and predict whether the reaction will occur spontaneously. [3]

\*\*\*\*\*



## Chapter - 7

# Equilibrium

### FAST TRACK : QUICK REVISION

- **Equilibrium** : It is a state in a process when two opposing processes (forward and reverse) occur simultaneously at the same rate. The free energy change at equilibrium state is zero *i.e.*,  $\Delta G = 0$ .

- **Equilibrium constant** : For a general reaction :

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \text{ and } K_p = \frac{P_C^c \times P_D^d}{P_A^a \times P_B^b}$$

- **Relationship between  $K_p$  and  $K_c$**  :

$$K_p = K_c (RT)^{\Delta n_g}$$

$$\Delta n_g = n_p(g) - n_r(g)$$

- Magnitude of equilibrium constant depends upon the way in which a reaction is written :

Chemical equation	Equilibrium constant
$aA + bB \rightleftharpoons cC + dD$	$K$
$cC + dD \rightleftharpoons aA + bB$	$K_1 = \frac{1}{K}$
$naA + nbB \rightleftharpoons ncC + ndD$	$K_2 = K^n$
$\frac{1}{n}aA + \frac{1}{n}bB \rightleftharpoons \frac{1}{n}cC + \frac{1}{n}dD$	$K_3 = K^{1/n}$

- **Predicting the direction of reaction :**

If  $Q_c = K_c \Rightarrow$  The reaction is in a state of equilibrium.

$Q_c > K_c \Rightarrow$  The reaction proceeds in reverse direction.

$Q_c < K_c \Rightarrow$  The reaction proceeds in forward direction.

- **Ostwald's dilution law :** Degree of dissociation of weak electrolyte,

$$\alpha = \sqrt{\frac{K}{C}}$$

- **Ionic Product of water ( $K_w$ ) =  $[\text{H}_3\text{O}^+][\text{OH}^-] = 10^{-14}$  at 298K**

- **Le-Chatelier's Principle :** When a system of equilibrium is subjected to a change in temperature, pressure or concentration, the equilibrium shifts itself in such a way so as to undo or nullify the effect of change.

- **Outcomes of Le-Chatelier's Principle**

Change at equilibrium	Shift in equilibrium
Increase in temperature	Endothermic direction
Decrease in temperature	Exothermic direction
Increase in pressure	Towards lesser gaseous moles
Decrease in pressure	Towards greater gaseous moles
Increase in Conc. of reactants	Forward direction
Increase in Conc. of products	Reverse direction

- **Conjugate Acid or Base :** Acid-base pair which differ by  $\text{H}^+$  ion.

Species  $- \text{H}^+ =$  Conjugate base

Species  $+ \text{H}^+ =$  Conjugate acid

- **pH of solution :**

$\text{pH} = -\log [\text{H}_3\text{O}^+]$  or  $[\text{H}^+] = 10^{-\text{pH}}$ ,  $\text{pOH} = -\log [\text{OH}^-]$

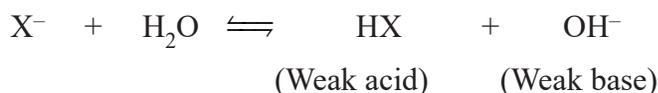
$\text{pH} + \text{pOH} = \text{p}K_w = 14$  at 298K

- **Common ion effect :** The depression of ionisation of weak electrolyte by the presence of common ion from a strong electrolyte is called common ion effect. For example degree of dissociation of  $\text{NH}_4\text{OH}$  decreases in the presence of strong electrolyte  $\text{NH}_4\text{Cl}$ .

+

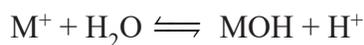
- **Hydrolysis of salts and pH of their solutions** : Hydrolysis of salt is defined as the reaction of cation or anion with water as a result of which the pH of water changes.

1. Salts of strong and strong bases (*e.g.*, NaCl) do not hydrolyse. The solution pH will be 7.
2. Salts of weak acids and strong bases (*e.g.*, CH<sub>3</sub>COONa) hydrolyse, pH >7 (The anion acts as a base).



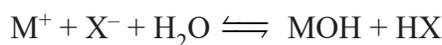
$$\text{pH} = 7 - \frac{1}{2} (\text{pK}_a + \log C)$$

3. Salt of strong acids and weak bases (*e.g.*, NH<sub>4</sub>Cl) hydrolyse, pH < 7. (The cation acts as an acid).



$$\text{pH} = 7 - \frac{1}{2} (\text{pK}_b + \log C)$$

4. Salt of weak acids and weak base (*e.g.*, CH<sub>3</sub>COONH<sub>4</sub>) hydrolyse. The cation acts as an acid and anion as a base but whether the solution is acidic or basic depends upon the relative values of K<sub>a</sub> and K<sub>b</sub> for these **ions**.



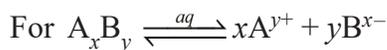
$$\text{pH} = 7 + \frac{1}{2} (\text{pK}_a - \text{pK}_b)$$

- **Buffer solutions** : The solutions, which resist the change in pH on dilution or addition of small amounts of acid or base, are called buffer solutions.
- **Basic buffer** : Solution of weak base and its salt with strong acid, For *e.g.*, NH<sub>4</sub>OH + NH<sub>4</sub>Cl
- **Acidic buffer** : Solution of weak acid and its salt with strong base, For *e.g.*, CH<sub>3</sub>COOH + CH<sub>3</sub>COONa.
- **Henderson Hasselbalch Equation for the pH of Buffer solution—**

$$\text{pH} = \text{pK}_a + \log \frac{[\text{Salt}]}{[\text{Acid}]} \quad (\text{for acidic buffer})$$

$$\text{pOH} = \text{pK}_b + \log \frac{[\text{Salt}]}{[\text{Base}]} \quad (\text{for basic buffer})$$

- **Solubility Product ( $K_{sp}$ )** : The equilibrium constant that represent the equilibrium between undissolved salt (solute) and its ions in a saturated solution is called solubility product constant ( $K_{sp}$ ).



$$K_{sp} = [A^{y+}]^x [B^{x-}]^y = (xs)^x (ys)^y = x^x \cdot y^y \cdot s^{(x+y)}$$

where  $s$  = Molar solubility

If ionic product  $< K_{sp}$  ; salt remain dissolve.

If ionic product  $> K_{sp}$  ; salt will be precipitated.

- **Relationship between solubility ( $s$ ) and solubility product ( $K_{sp}$ ).**

$$K_{sp} = x^x \cdot y^y \cdot s^{x+y}$$

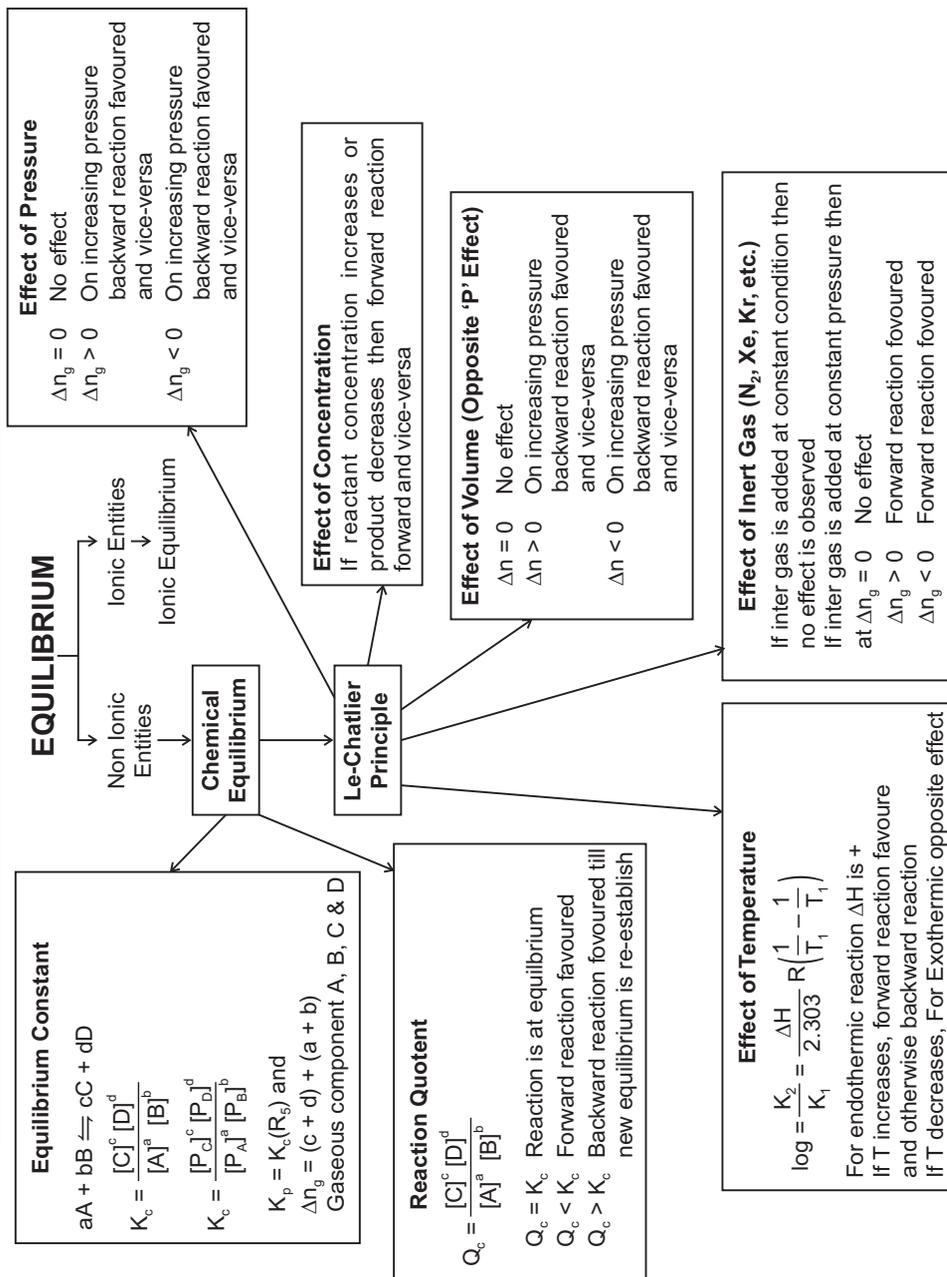
For binary salts (e.g., AgCl, AgBr, AgI)

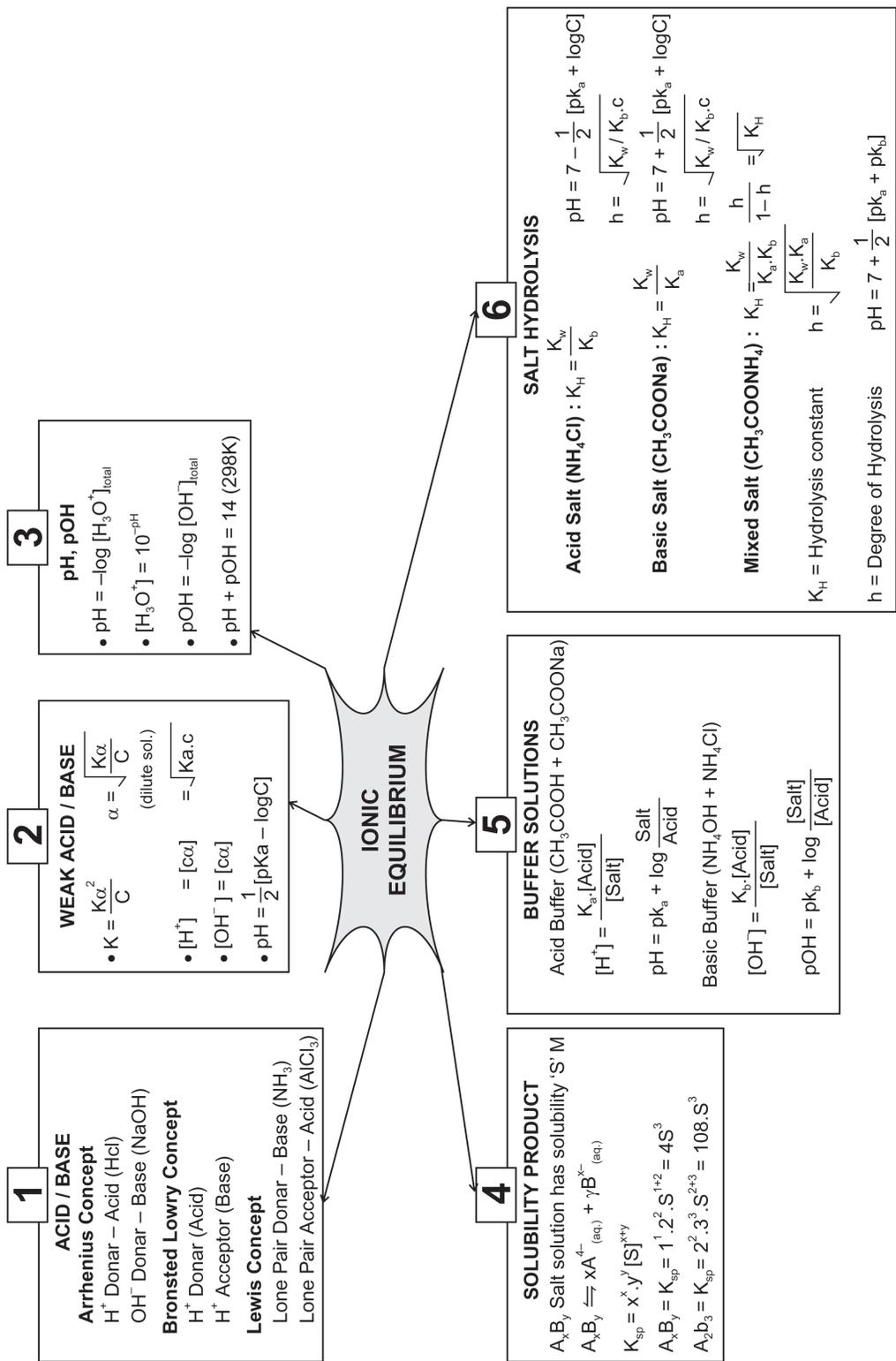
$$K_{sp} = s^2$$

For Ternary salts (e.g.,  $PbI_2$ )

$$K_{sp} = 4s^3$$

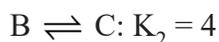
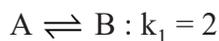
# MIND MAP : EQUILIBRIUM





**MULTIPLE CHOICE QUESTION (MCQ)**

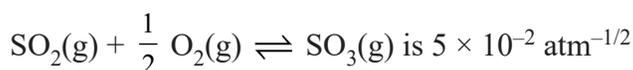
1. For the hypothetical reactions, the equilibrium constant (k) values are given



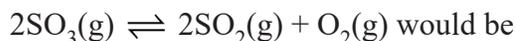
The equilibrium constant (K) for the reaction  $A \rightleftharpoons D$  is

- (a) 48      (b) 24      (c) 12      (d) 64

2. The equilibrium constant for the reaction



The equilibrium constant for the reaction



- (a) 100 atm      (b)  $25 \times 10^{-4}$  atm      (c) 400 atm      (d)  $125 \times 10^{-6}$  atm<sup>-3/2</sup>

3.  $A(g) + 3B(g) \rightleftharpoons 4C(g)$  initial concentration of A is equal to that of B. The equilibrium concentrations of A and C are equal. What is the equilibrium constant for



- (a) 4      (b) 1/8      (c) B      (d) 16

4. The equilibrium reaction that is not affected by volume change at constant temperature is



5. For the reaction  $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$ , the value of  $K_c/K_p$  is equal to

- (a) RT      (b) RT      (c) 1/RT      (d) 1.0

6. At 90°C pure water has  $K_w = 10^{-12}$ . The solution with pH value 6.5 is

- (a) Acidic      (b) Basic      (c) Amphoteric      (d) Data insufficient

7. 40 ml of 0.1 M  $\text{NH}_4\text{OH}$  is mixed with 20 mL of 0.1 M  $\text{HCl}$ . What is the pH of the mixture? ( $\text{pK}_b$  of ammonia solution = 4.74)
- (a) 4.74      (b) 2.26      (c) 9.26      (d) 5
8. Identify Bronsted Lowry Acids in the reaction
- $$[\text{Al}(\text{H}_2\text{O})_6]^{3+} + \text{HCO}_3^- \rightleftharpoons [\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{H}_2\text{CO}_3$$
- (X)                      (Y)                      (P)                      (Q)
- (a) X, Y      (b) Y, P      (c) P, Q      (d) X, Q
9. The  $\text{pK}_a$  of weak acid HA is 4.80 and  $\text{pK}_b$  of a weak base BOH is 4.78. The pH of an aqueous solutions of corresponding salt BA will be
- (a) 7.01      (b) 4.79      (c) 9.22      (d) 10.0
- 10 If 'P' M is the solubility of  $\text{KAl}(\text{SO}_4)_2$ , then  $\text{K}_{\text{sp}}$  is equal to
- (a)  $\text{p}^3$       (b)  $4\text{p}^4$       (c)  $\text{p}^4$       (d)  $4\text{p}^3$

### TRUE AND FALSE TYPE QUESTIONS

- Equilibrium state can be achieved if a reversible reaction is carried out in closed or open container.
- For a reaction  $2\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g})$   $Q_c > K$  if 'A' is added maintaining  $Q_c > K$ , the reaction will move in backward direction.
- For the reaction at equilibrium  
 $\text{CaCO}_3 \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$   
 What  $\text{CaO}(\text{s})$  is removed reaction moves in forward direction.
- For a reaction  $a\text{A} + b\text{B} \rightleftharpoons c\text{C} + d\text{D}$  at equilibrium  $G^0 = 0$  always.
- For a reaction at equilibrium  $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g})$   
 $K = 4$ , the value of  $\frac{K_b[\text{HCl}]^2}{K_f[\text{H}_2][\text{Cl}_2]}$  is 1.
- For the electrolyte  $\text{A}_2\text{B}$  if  $\text{K}_{\text{sp}}$  is solubility product then its solubling 'S' M is  $[\text{K}_{\text{sp}}]^{1/3} \div 4$ .
- $\text{HCO}_3^-$  is conjugate base of  $\text{H}_2\text{CO}_3$ .
- $\text{H}_2\text{O}$  can act as acid as well as base.
- The pH of buffer solution remain same when any amount of dilution is done.

10. For a salt  $AB_2(s)$  solution if Ionic product (I.P)  $> K_{sp}$ , then precipitation will take place.

- Ans.** 1. False      2. True      3. False      4. False      5. True  
 6. True      7. True      8. True      9. False      10. True

### FILL IN THE BLANKS

1. At equilibrium rate of forward reaction is always equal to .....
2.  $K_p$  &  $K_c$  are ..... for reaction at equilibrium of type  $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$ .
3. If  $K_c$  for reaction  $CH_3COOH(l) + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$  is 4. Then  $Q_c$  and  $K_c$  are .....
4. If  $A+B -70J/mol \rightleftharpoons D$ , reaction temperature is increased then reaction moves in ..... direction.
5. Presence of catalyst will ..... the equilibrium constant.
6. The conjugate acid of  $H_2O$  is .....
7. On dilution, the degree of dissociation of acetic acid will .....
8. The presence of  $NH_4Cl$  in  $NH_4OH$  solution will ..... the degree of dissociation of  $NH_4OH$ .
9. If Ionic product (IP)  $< K_{sp}$  for a salt solution of AB, then addition of AB further ..... lead to precipitation initially.
10.  $K_p$  is always equal to  $K_c$  if  $\Delta n_g$  is .....

- Ans.** 1. rate of backward reaction, 2. equal, 3. equal, 4. forward,  
 5. not change, 6.  $H_3O^+$ , 7. increase, 8. decrease, 9. will not, 10. zero

### MATCH THE COLUMNS

1.

- | Column-I   | Column-II   |
|--|---|
| A) $Na(g) + 3H_2(g) \rightleftharpoons 2NH_3(g); \Delta H = -ve$ | P) K increases with increase in temp  |
| B) $2N_2(g) + 2O_2(g) \rightleftharpoons 4NO(g); \Delta H = +ve$ | Q) K decreases with increase in temperature                                   |
| C) $X(g) \rightleftharpoons 2Y(g) \Delta H = +ve$                | R) Pressure has no effect   |
| D) $PCl_5(g) \rightleftharpoons PCl_3 + Cl_2; \Delta H = +ve$    | S) Product moles increases due to addition of inert gas at constant pressure. |

- Ans.** (A) Q    (B) P, R    (C) P, S    (D) P, S

2.

Column-I

- A) Salt of weak acid and weak base
- B) Salt of weak Acid and strong Base
- C) Salt of strong acid and strong base
- D) Salt of strong acid and weak base

Column-II

- P)  $\text{pH} = \frac{1}{2} (\text{pK}_w + \text{pK}_a + \log c)$
- Q)  $\text{pH} = \frac{1}{2} (\text{pK}_w + \text{pK}_a - \text{pK}_b)$
- R)  $\text{pH} = \frac{1}{2} (\text{pK}_w - \text{pK}_b - \log c)$
- S)  $\text{pH} = \frac{1}{2} (\text{pK}_w)$

Ans. (A) Q (B) P (C) S (D) R

### ASSERTION - REASON TYPE QUESTION

Each question contains statement-1 (assertion) and Statement-2 (Reason)  
Examine the statements carefully and mark the correct answer according to the instruction given below :

- A. If both the statements are true and statement -2 is the correct explanation of statement-I
  - B. If both the statements are true but statement-2 is not the correct explanation of statement-I
  - C. If statement-I is true and statement-2 is false
  - D. If statement-I is false and statement-2 is true.
1. Statement-1 : The endothermic reactions are favoured at lower temperature and the exothermic reactions are favoured at higher temperature.  
Statement-2 : when a system in equilibrium is disturbed by changing the temperature, it will tend to adjust itself so as to overcome the effect of change.
  2. Statement-1 : The melting point of ice decreases with increase of pressure  
Statement-2 : Ice contracts on melting.
  3. Statement -1 : The gas phase reaction  $\text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{PCl}_5(\text{g})$  shifts to the right on increasing pressure.  
Statement-2 : When pressure increase, equilibrium shifts towards more number of moles.
  4. Statement-1 : The physical equilibrium is not static but dynamic in nature.  
Statement-2: The physical equilibrium is a state in which two opposing process are proceeding at the same rate.
  5. Statement-1 : The catalyst does not after the equilibrium constant.  
Statement-2 : Because for the catalysed reaction and uncatalysed reaction  $\Delta H$  remains same and equilibrium constant depends on  $\Delta H$ .

6. Statement-1 : If water is heated to 59°C, the pH will increase.  
Statement-2 :  $K_w$  increases with increase in temperature.
7. Statement-1: Addition of HCl(aq.) to CH<sub>3</sub>COOH (aq.) decrease the ionisation of CH<sub>3</sub>COOH (aq.).  
Statement-2 : Due to common ion effect H<sup>+</sup>, ionisation of CH<sub>3</sub>COOH decreases.
8. Statement-1: Sparingly soluble salts AB and XY<sub>2</sub> with the same solubility product, will have different solubility.  
Statement 2: Solubility of sparingly soluble salts depends upon solubility product.
9. Statement-1 : The ionisation constants of weak diprotic acid are in the order of  $K_{a1} > K_{a2}$ .  
Statement-2 : Removal of H<sup>+</sup> from anion is difficult as compared to neutral atom.
10. Statement-1 : In a titration of weak acid with strong base, the pH at the half equivalence point is  $pK_a$ .  
Statement-2 : At half equivalence point, it will form acidic buffer at its maximum capacity where [Acid] = [Salt].

**Ans.:** 1. D, 2. A, 3. C, 4. A, 5. A, 6. D, 7. A, 8. B, 9. A, 10. A

### ONE WORD ANSWER TYPE QUESTIONS

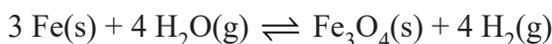
1. What is sum of pH + pOH at 25°C? [Ans. 14]
2. Write the Henderson Hasselbalch equation for acidic buffer  
**Ans.**  $pH = pka + 10g \frac{[SALT]}{[ACID]}$
3. How is degree of dissociation related with concentration terms and  $K_a$ , for weak electrolyte. **Ans.**  $\alpha = \sqrt{K_a / c}$
4. How NH<sub>3</sub> is defined as Lewis base?  
[Ans. It contain Lone paid of electrons]
5. How are  $K_p$  and  $K_c$  related? [Ans.  $K_p = K_c (RT)^{\Delta n}$ ]
6. How does K affected for endothermic reaction if temperature is increased?  
[Ans. K get decreased]
7. What is the effect of catalyst on K? [Ans. K remains unaffected]
8. How is pH scale affected by increasing temperature?  
[Ans. pH scale gets contracted]
9. What is the conjugate base of HCO<sub>3</sub><sup>-</sup>? [Ans. CO<sub>3</sub><sup>2-</sup>]
10. What is the nature of CH<sub>3</sub>COOH in conc. HCl solution?  
[Ans. Bronsted Base]

### 1-MARK QUESTIONS

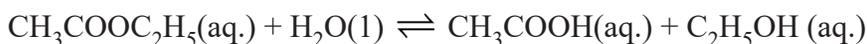
1. Define physical equilibrium. Give an example also.
2. Fizz is observed when soda water bottle is opened. Why ?
3. Justify the statement : 'Both physical and chemical equilibrium are dynamic in nature'
4. State Henry's law.
5. In a reversible reaction, the two substances are in equilibrium. If the concentration of each one is reduced to half, then what is the effect on the equilibrium constant ?
6.  $K_1$  and  $K_2$  are equilibrium constant for reactions (1) and (2)  
(i)  $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{NO}(\text{g})$   
(ii)  $\text{NO}(\text{g}) \rightleftharpoons 1/2 \text{N}_2(\text{g}) + 1/2 \text{O}_2(\text{g})$

Calculate the relation between  $K_1$  and  $K_2$ .

7. Write the equilibrium constant expression for the following reaction :



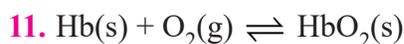
8. Classify the equilibrium as homogeneous or heterogeneous :



$$9. K_p = \frac{(P_{\text{NH}_3})}{(P_{\text{H}_2})^{3/2} (P_{\text{N}_2})^{1/2}}$$

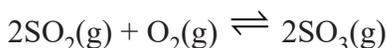
Write the balanced chemical equation corresponding to the above expression.

10. Give the direction in which the reaction would proceed if  $Q_c > K_c$ .

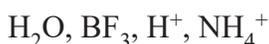


Predict the direction in which equilibrium gets shifted if partial pressure of  $\text{O}_2(\text{g})$  is lowered.

12. Discuss the position of equilibrium if the following reaction is carried out in the presence of catalyst.



13. Which of the following are Lewis acids ?



14. Write the conjugate acids for the following Bronsted bases.  
 $C_6H_5OH$ ,  $H_2O$
15. Write the conjugate bases for the following Bronsted acids.  
 $H_2O$ ,  $CH_3COOH$ .
16. Which of the following are Lewis acids ?  
 (a)  $H_2O$     (b)  $AlCl_3$     (c)  $NH_4^+$
17. Define Ostwald's dilution law.
18.  $SO_3^{2-}$  is Bronsted base or acid and why ?
19. Why pH of our blood remains almost constant at 7.4 though we quite often eat spicy food ?
20. pH of black coffee is 5.0 at  $25^\circ C$ . Is black coffee acidic or basic ?  
 [Ans. Acidic]
21. What will be the value of  $(pK_a + pK_b)$  at  $25^\circ C$ .
22. What will be the pH of 1 M  $KNO_3$  solutions at  $25^\circ C$ ?
23.  $CaCl_2(s) + H_2O(l) \rightleftharpoons CaCl_2(aq.) + \text{Heat}$   
 Discuss the solubility of  $CaCl_2$  if temperature is increased.
24. Why does the solubility of  $CO_2$  decrease with rise in temperature ?
25. The solubility of  $A_2 X_3$  is  $y \text{ mol dm}^{-3}$ . Calculate its solubility product.
26. Write the  $K_{sp}$  expression for  $Al(OH)_3$ .
27. What is the condition for precipitation of a salt ?
28. Predict whether the solution is acidic, basic or natural when  $NH_4NO_3$  undergo hydrolysis.
29. Explain why pure  $NaCl$  precipitates out when  $HCl$  gas is passed through the solution of  $NaCl$  ?
30. Give the Henderson's Hasselbalch equation for an acidic buffer solution.
31. On which of the factors the equilibrium depend : Temperature, nature of reactant and product, initial concentration and pressure of the reactants.
32. Arrange the following in increasing acidic strength  $HCl$ ,  $HBr$ ,  $HF$ ,  $HI$   
 [Ans.  $HF < HCl < HBr < HI$ ]

33. Arrange the following in increasing Lewis base strength



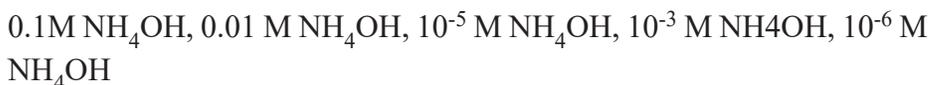
[Ans.  $\text{BiH}_3 < \text{SbH}_3 < \text{AsH}_3 < \text{PH}_3 < \text{NH}_3$ ]

34. Arrange following in increasing pH value



[Ans.  $0.1\text{M HCl} < 0.1\text{M CH}_3\text{COOH} < 0.1\text{M NaCl} < 0.1\text{M NH}_4\text{OH} < 0.1\text{M NaOH}$ ]

35. Arrange following in increasing order of degree of hydrolysis.



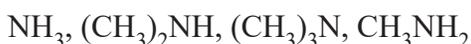
[Ans.  $0.1\text{M NH}_4\text{OH} < 10^{-2}$  M  $\text{NH}_4\text{OH}$ ,  $10^{-3}$  M  $\text{NH}_4\text{OH} < 10^{-5}$  M  $\text{NH}_4\text{OH} < 10^{-6}$  M  $\text{NH}_4\text{OH}$ ]

36. Arrange following in increasing order of acidic strength



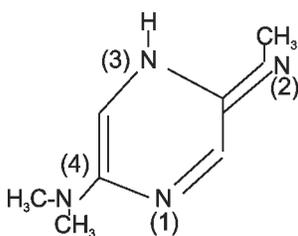
[Ans.  $\text{CH}_3\text{COOH} < \text{C}_6\text{H}_5\text{COOH} < \text{HCOOH} < \text{CH}_2\text{FCOOH}$ ]

37. Arrange following in increasing order of basic strength in gas phase



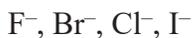
[Ans.  $\text{NH}_3 < \text{NH}_3\text{NH}_2 < (\text{CH}_3)_2\text{NH} < (\text{CH}_3)_3\text{N}$ ]

38. Arrange the following  $\text{pK}_b$  in increasing order



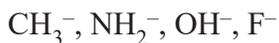
[Ans.  $\text{pK}_2 < \text{pK}_1 < \text{pK}_4 < \text{pK}_3$ ]

39. Arrange the basic strength of following



[Ans.  $\text{I}^- < \text{Br}^- < \text{Cl}^- < \text{F}^-$ ]

40. Arrange the following in increasing base strength



[Ans.  $\text{F}^- < \text{OH}^- < \text{NH}_2^- < \text{CH}_3^-$ ]

## 2-MARKS QUESTIONS

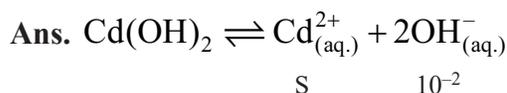
1. The standard Gibbs energy change at 300 K for the reaction  $2A \rightleftharpoons B + C$  is 2494.2 J. At a given temperature, and time, the composition of the reaction mixture is  $[A] = \frac{1}{2}$ ,  $[B] = 2$ ,  $[C] = \frac{1}{2}$ . The reaction proceeds in the (R = 8.314 J/K/mol, = 2.718) [Ans. Reverse direction]
  
2. The equilibrium constant for  $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$  is K, then calculate equilibrium constant for  $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons NO(g)$ . [Ans.  $\sqrt{K}$ ]
  
3. For the reversible reaction  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$  at 500°C, the value of  $K_p$  is  $1.44 \times 10^{-5} \text{ atm}^{-2}$ . Find the  $K_c$  value. [Ans.  $1.44 \times 10^{-5} / (0.082 \times 773)^{-2}$ ]
  
4. The equilibrium constant at 298 K for the reaction  $A + B \rightleftharpoons C + D$  is 100. If the initial concentration of all the four species were 1M each, then equilibrium concentration of D will be [Ans. 1.818]
  
5. For the reaction  $NH_4COO NH_2(g) \rightleftharpoons 2NH_3(g) + CO_2(g)$   
If equilibrium pressure is 3 atm. Find the value of  $K_p$  [Ans. 4]
  
6. A buffer solution with pH 9 is to be prepared by mixing  $NH_4Cl$  that should be added to one litre of 1.0M  $NH_4OH$   $K_b = 1.8 \times 10^{-5}$  [Ans.  $NH_4Cl = 1.8 \text{ M}$ ]
  
7. Calculate the solubility of silver chloride in water at room temperature if the  $K_{sp}$  of  $AgCl$  is  $1.6 \times 10^{-10}$ . [Ans.  $1.26 \times 10^{-5} \text{ M}$ ]
  
8. Calculate the molar solubility of  $Ni(OH)_2$  in 0.10M  $NaOH$ . The ionic product of  $Ni(OH)_2$  is  $2.0 \times 10^{-15}$ . [Ans.  $2.0 \times 10^{-13} \text{ M}$ ]
  
9. Calculate the pH of  $10^{-8} \text{ M HCl}$  solution. [Ans. 6.96]
  
10. How many grams of  $NaOH$  must be dissolved in 1L of the solution to give it a pH value of 12? [Ans. 0.4g]

### 3-MARKS QUESTIONS

1. The equilibrium constant for the reaction  $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightleftharpoons 2\text{HBr}(\text{g})$  at 1024 K is  $1.6 \times 10^5$ . Find the equilibrium pressure of all gases if 10.0 bar of HBr is introduced into a sealed container at 1024K. [Ans. 10 bar]
2. For the reaction  $2\text{BrCl}(\text{g}) \rightleftharpoons \text{Br}_2(\text{g}) + \text{Cl}_2(\text{g})$   $K_c$  is 32 at 500 K. If initially pure BrCl is present at a concentration of  $3.30 \times 10^{-3}$  M, what is its molar concentration in the mixture at equilibrium? [Ans.  $3.0 \times 10^{-4}$  M]
3. What is the equilibrium constant  $K_p$  and  $K_c$  for the reaction  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$  if the pressure is 1.0 atm in 8.0L container at equilibrium. [Ans.  $K_c = 0.04$   $K_p = 1.77$ ]
4. The  $K_p$  for the reaction,  $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$  is 640 mm at 775 K. Calculate the percentage dissociation of  $\text{N}_2\text{O}_4$  at equilibrium pressure of 160mm. At what pressure the dissociation will be 50%. [Ans. 70.7%,  $P = 480$  mm]
5. Show that degree of dissociation ( $\alpha$ ) for the dissociation of  $\text{PCl}_5$  into  $\text{PCl}_3$  and  $\text{Cl}_2$  at pressure P is given by  $\alpha = \left[ \frac{K_p}{P + k_p} \right]^{1/2}$
6. How much of 0.3M  $\text{NH}_4\text{OH}$  should be mixed with 30 mL of 0.2m solution of  $\text{NH}_4\text{Cl}$  to give a buffer solution of pH 10.  $\text{p}K_b$  for  $\text{NH}_4\text{OH}$  is 4.75. [Ans.  $V = 112.5$  mL]
7. Predict whether a precipitate will be formed or not on mixing 20 mL of 0.001 N NaCl solution with 80 mL of 0.01 M  $\text{AgNO}_3$  solution.  $K_{sp}$  for  $\text{AgCl}$  is  $1.5 \times 10^{-10}$ . [Ans. Yes, ppt will formed.]
8. The values of  $K_{sp}$  of two sparingly soluble salts  $\text{Ni}(\text{OH})_2$  and  $\text{AgCN}$  are  $2.0 \times 10^{-15}$  and  $6.0 \times 10^{-17}$  respectively. Which salt is more soluble. Explain [Ans.  $S_{\text{Ni}(\text{OH})_2} = 5.8 \times 10^{-5}\text{M}$  :  $S_{(\text{AgCN})} = 7.8 \times 10^{-9}\text{M}$ .  $\text{Ni}(\text{OH})_2$  is more soluble]
9. The ionization constant of propanoic acid is  $1.32 \times 10^{-5}$ . Calculate the degree of ionization if its solution is 0.05 M. What will be its degree of ionization if the solution is 0.01 M in HCl solution. [Ans.  $1.62 \times 10^{-2}$ ,  $1.32 \times 10^{-3}$ ]
10. Calculate the pH of a solution obtained by mixing 50ml of 0.2M HCl with 49.9 mL of 0.2m NaOH solution. [Ans. 3.699]

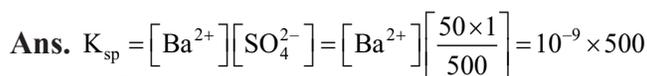
## HOTS QUESTIONS

1. The molar solubility of  $\text{Cd}(\text{OH})_2$  is  $1.84 \times 10^{-5}\text{M}$ . Calculate the expected solubility of  $\text{Cd}(\text{OH})_2$  in a buffer solution of  $\text{pH} = 12$ .



$$2.49 \times 10^{-14} = \text{S}(10^{-2})^2 \quad \therefore \text{S} = 2.49 \times 10^{-10}\text{M}$$

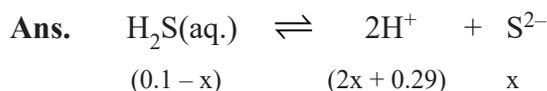
2. An aqueous solution contains an unknown concentration of  $\text{Ba}^{2+}$ . When 50 ml of a 1M solution of  $\text{Na}_2\text{SO}_4$  is added.  $\text{BaSO}_4$  just begins to precipitate. The final volume is 500ml. The solubility product of  $\text{BaSO}_4$  is  $1 \times 10^{-10}$ . Find the original concentration.



$$\text{Ba}^{2+} = 10^{-9}\text{M}$$

$$10^{-9} \times 500 = 450 \times \text{M} \quad \therefore \text{M} = 1.11 \times 10^{-9}\text{M}$$

3. An aqueous solution contains 0.10 M  $\text{H}_2\text{S}$  and 0.20 M  $\text{HCl}$ . If the equilibrium constants for the formation of  $\text{HS}^-$  from  $\text{H}_2\text{S}$  is  $1.0 \times 10^{-7}$  and that of  $\text{S}^{2-}$  from  $\text{HS}^-$  ions is  $1.2 \times 10^{-13}$ , then find the concentration of  $\text{S}^{2-}$  ions in aqueous solution.



$$K_a = K_{a_1} \times K_{a_2} = 1.2 \times 10^{-20}$$

$$1.2 \times 10^{-20} = \frac{(0.2)^2 [\text{S}^{2-}]}{0.1}, [\text{S}^{2-}] = 3 \times 10^{-20}$$

4. How many litres of water must be added to 1 litre of an aqueous solution of  $\text{HCl}$  with a  $\text{pH}$  of 1 to create an aqueous solution with  $\text{pH}$  of 2?

**Ans.**  $0.1 \times 1 = (1 + v)(0.01) \Rightarrow v = 9\text{L}$

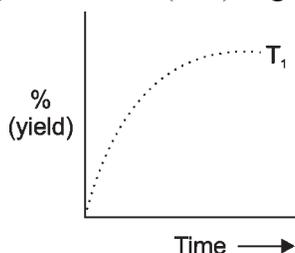
5. A certain buffer solution contains equal concentration of  $\text{X}^-$  and  $\text{HX}$ . The  $K_b$  for  $\text{X}^-$  is  $10^{-10}$ . Find the  $\text{pH}$  of the buffer .

**Ans.**  $k_a \cdot k_b = 10^{-14} \quad \therefore k_a = \frac{10^{-14}}{10^{-10}} = 10^{-4}$

$$\text{pH} = \text{pka} + \log \frac{[\text{X}^-]}{[\text{HX}]}$$

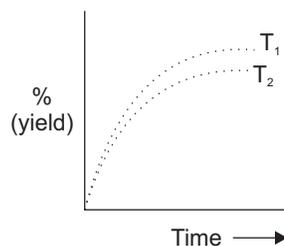
$$\therefore \text{pH} = 4 + \log \frac{1}{1} = 4 \quad \therefore \text{pH} = 4$$

6. The % yield of Ammonia as a function of time in the reaction  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ ,  $\Delta H < 0$  at (P, T) is given below:



If this reaction is conducted at  $T_2 > T_1$ , then plot the % yield of  $\text{NH}_3$  as a function of time on same graph

**Ans.** Initially on increasing temperature the rate of reaction increases, however since the reaction is exothermic therefore % yield of  $\text{NH}_3$  get decreased overall after a certain interval of time.



7. Consider the reaction  $\text{NH}_4\text{COONH}_2(\text{s}) \rightleftharpoons 2\text{NH}_3(\text{g}) + \text{CO}_2(\text{g})$  at a certain temperature, the equilibrium pressure of the system is 0.318 atm. Find  $K_p$  of the decomposition of ammonium carbonate.

**Ans.**  $P_{\text{total}} = 3P \quad \therefore P = 0.318/3 = 0.106$   
 $K_p = 4P^3 = 4.76 \times 10^{-3}$

8. The equilibrium constant for the reaction  $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$  is 5. How many moles of  $\text{CO}_2$  must be added to 1 litre container already containing 3 moles each of  $\text{CO}$  and  $\text{H}_2\text{O}$  to make 2M equilibrium concentration of  $\text{CO}$ ?

**Ans.**

	$\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + \text{H}_2$			
<b>t = 0</b>	3	2	x	0
<b>At equilibrium</b>	2	2	x+1	1

$$\therefore S = \frac{x+1}{4} \Rightarrow x = 19$$

9. At constant temperature, the equilibrium constant  $K_p$

$\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$  is given by

$$k_p = \frac{4x^2P}{1-x} \quad \text{where, } P = \text{Pressure and } X = \text{Extent of reaction}$$

How does the value of  $K_p$  change on following changes

- (a) 'P' increases
- (b) X changes
- (c) 'P' decreases

**Ans.**  $K_p$  is equilibrium constant which does not change on changing the P, x.  $K_p$  depends on temperature.

10. When two reactants A and B are mixed to give product 'c' and 'p' the reaction quotient 'Q' at the initial stages of the reaction will be?

**Ans.** In the beginning of the reaction  $Q = 0$ . As the reaction proceeds in the forward direction Q starts increasing.

At chemical equilibrium  $Q = K$

## UNIT TEST

Time Allowed: 1 hr

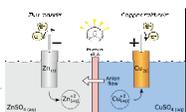
Maximum Marks : 20

General Instructions:

- (i) All questions are compulsory.  
(ii) Maximum marks carried by each question are indicated against it.
- 

1. What is the pH  $10^{-3}$  M HCl solution ? [1]  
(a) 1                      (b) 11                      (c) 3                      (d) 14
2. Which one can act as Arrhenius Acid ? [1]  
(a)  $\text{NH}_3$                       (b)  $\text{H}_2\text{O}$                       (c) HCl                      (d)  $\text{C}_6\text{H}_5\text{OH}$
3. Write the conjugate base of  $\text{CH}_3\text{COOH} + \text{H}_2$ . [1]
4. Write the relation between  $K_p$  and  $K_c$ . [1]
5. What is the nature of following reaction [1]  
Exothermic or endothermic  
 $\text{A} + \text{B} - 70\text{J} \longrightarrow \text{C}$
6. The  $\text{pK}_a$  of  $\text{CH}_3\text{COOH}$  and  $\text{pK}_b$  of  $\text{NH}_4\text{OH}$  are 4.76 and 4.75 respectively. Calculate the pH of  $\text{CH}_3\text{COONH}_4$ . [2]
7. What is a buffer solution. Calculate the pH of the solution obtained by adding 4mol of  $\text{CH}_3\text{COOH}$  with 3 mol of NaOH in 1 litre container. [2]  
 $\text{pK}_a$ ,  $\text{CH}_3\text{COOH} = 4.74$   $\log 2 = 0.3010$   $\log 3 = 0.4771$
8. Calculate the molar solubility of  $\text{Ni}(\text{OH})_2$  in 0.1M KOH solution. The  $K_{sp}$  for  $\text{Ni}(\text{OH})_2$  is  $2.0 \times 10^{-15}$ . [3]
9.  $K_p = 0.04$  atm at 899 K for the equilibrium shown below. What is the equilibrium concentration of  $2\text{H}_6$  when it is placed in a flask at 4.0 atm pressure and allowed to come to equilibrium. [3]  
 $\text{C}_2\text{H}_6(\text{g}) \rightleftharpoons \text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g})$
10. Ionization constant of Benzoic acid is  $6.46 \times 10^{-5}$  and  $K_{sp}$  for silver benzoate is  $2.5 \times 10^{-13}$ . How many times is silver benzoate more soluble in buffer of pH 3.19 compared to its solubility in pure water. [5]  
 $[\text{H}^+] = 6.46 \times 10^{-4}$

\*\*\*\*\*



## Chapter - 8

# Redox Reactions

### FAST TRACK : QUICK REVISION

#### Oxidation and Reduction :

##### Oxidation

1. Addition of oxygen
2. Removal an Hydrogen
3. Addition of an electronegative element.
4. Removal of an electropositive element
5. Loss of electron(s)
6. Increase in oxidation number.

##### Reduction

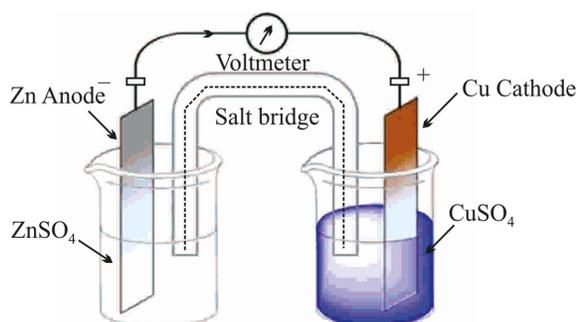
1. Removal of oxygen
2. Addition of Hydrogen
3. Removal of an electronegative element.
4. Addition of an electropositive element.
5. Gain of electron(s)
6. Decrease in oxidation number.

- **Reducing Agent** : Donor of electrons.
- **Oxidising Agent** : Acceptor of electrons.
- **Redox Reaction** : Reactions in which oxidation and reduction takes place simultaneously.
- **Oxidation Number** : It is charge that an atom appears to have in a given species when the bonding electron are counted towards more electro-negative atom.
- **Calculation of Oxidation Number** :
  - (a) Oxidation number of all the elements in their elemental form (in standard state) is taken as zero. Oxidation number of element in a molecule  $\text{Cl}_2$ ,  $\text{F}_2$ ,  $\text{O}_2$ ,  $\text{P}_4$ ,  $\text{O}_3$ , Fe,  $\text{H}_2$ ,  $\text{N}_2$ , C (graphite) is zero.
  - (b) Common Oxidation number of elements of first group is +1. Common Oxidation number of elements of second group + 2.
  - (c) For ions composed of only one atom, the oxidation number is equal to the charge on the ion.



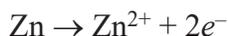
In reality no element can have a fractional oxidation state.

- **Balancing of Redox Reactions :**
  - (A) Oxidation number method
  - (B) Half reaction method
- **Electrode Potential (E) :** Potential difference between electrode and electrolytic solution due to charge separation.
- **Standard Electrode Potential (E<sup>θ</sup>) :** Electrode Potential measured at 298 K and 1M concentration of metal ions (or 1 bar pressure of gas).
- **Electrochemical Cell :** A device in which chemical energy of a spontaneous redox reaction is converted into electrical energy.

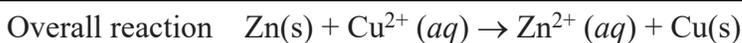


**Cell diagram:**  $\text{Zn} \mid \text{Zn}^{2+} \parallel \text{Cu}^{2+} \mid \text{Cu}$

LHS oxidation,



RHS reduction



- Representation of an Electrochemical cell :

————— Flow of electrons —————→

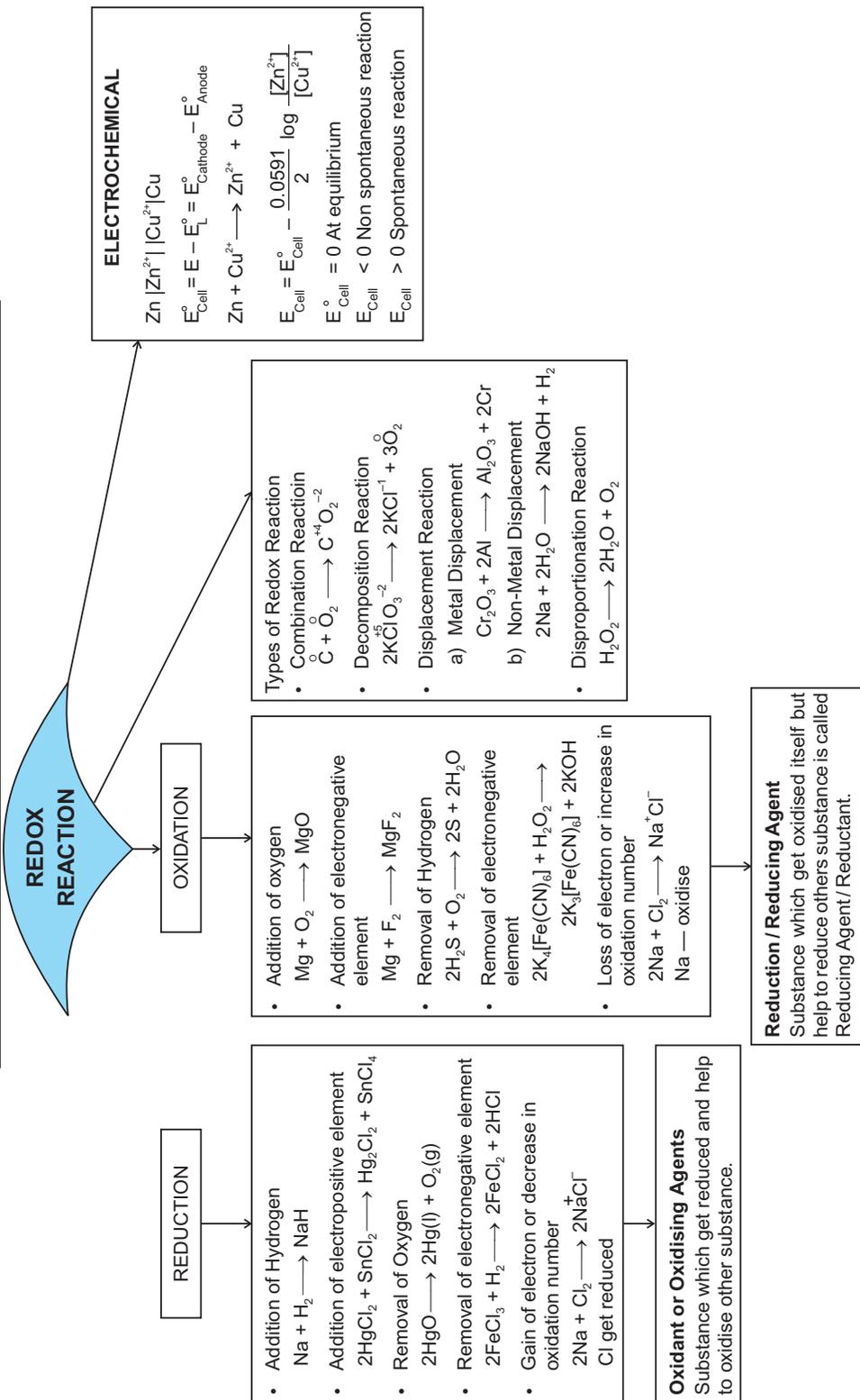
←————— Flow of current —————



	Left Electrode	Salt Bridge	Right Electrode
<b>LOAN</b>	<b>Oxidation</b>		<b>Reduction</b>
	Anode		Cathode
	Negative		Positive

- **Functions of Salt Bridge :** (i) To complete inner circuit. (ii) To maintain electrical neutrality around electrodes.

# MIND MAP : REDOX REACTIONS



### MULTIPLE CHOICE QUESTIONS (MCQ)

1. The oxidation state of Fe in  $\text{Fe}_3\text{O}_4$  is  
(a) +2 (b) +3  
(c)  $\frac{8}{3}$  (d) +2, +3
2. The oxidation state of 'S' in  $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$  is  
(a) -2 (b) -1  
(c) 2 (d) +6
3. Oxidation state carbon in  $\text{C}_3\text{O}_2$  is  
(a)  $\frac{4}{3}$  (b) 0  
(c) 2 (d) 0, 2
4. The reaction  $\text{S}_8 + 12\text{OH}^- \longrightarrow 4\text{S}^{2-} + 2\text{S}_2\text{O}_3^{2-} + 6\text{H}_2\text{O}$  is  
(a) Combination reaction (b) Decomposition reaction  
(c) Non-metal displacement (d) Disproportionation reaction
5.  $E^0$  for  $\text{H}^+/\text{H}_2$  is  
(a) 0 (b) +1V  
(c) -1.0V (d) -2.0V
6. Which one act as strong oxidising agent  
 $\text{K}^+/\text{K} = -2.93\text{V}$ ,  $\text{Ag}^+/\text{Ag} = 0.80$ ,  $\text{Hg}^{2+}/\text{Hg} = 0.79\text{V}$   
(a)  $\text{K}^+$  (b) K  
(c)  $\text{Hg}^{2+}$  (d)  $\text{Ag}^+$
7. The coefficient of HCl in balance reaction is  
 $\text{Pb}_3\text{O}_4 + \text{HCl} \longrightarrow \text{PbCl}_2 + \text{Cl}_2 + \text{H}_2\text{O}$   
(a) 1 (b) 8  
(c) 3 (d) 4
8. Sum of oxidation numbers of all Bromine atoms in  $\text{Br}_3\text{O}_8$  is  
(a) 6 (b) 4  
(c) 16 (d) 20
9. In the reaction  $6\text{ClO}_2^- \longrightarrow 4\text{ClO}_3^- + 2\text{Cl}^-$ ,  $\text{Cl}^-$  ion is  
(a) Oxidised Reduced (b) Reduced  
(c) Odixised and (d) Neither Oxidised nor reduced

10. 'I' can not act as reducing agent in following state

- (a) -1 (b) +1  
(c) +7 (d) +5

**Ans:** 1. (d) 2. (d) 3. (d) 4. (d) 5. (a) 6. (d) 7. (b) 8. (c) 9. (c) 10. (d)

### FILL IN THE BLANKS

- (i) Oxidation is \_\_\_\_\_ of electrons.  
(ii) S.H.E. stands for \_\_\_\_\_.  
(iii) Oxidation state of Oxygen in  $O_2F_2$  is \_\_\_\_\_.  
(iv) Disproportionation is a type of \_\_\_\_\_ reaction.  
(v) Oxidant is one which \_\_\_\_\_ electron..  
(vi)  $Cl_2 + 2OH^- \longrightarrow ClO^- + Cl^-$  is a \_\_\_\_\_ type of reaction.  
(vii) Oxidation state of F is always either \_\_\_\_\_ or \_\_\_\_\_.  
(viii) Oxidation state of Oxygen in  $O_3$  is \_\_\_\_\_.  
(ix) Reducing agent are also called \_\_\_\_\_.  
(x) Hydrogen economy is use of Hydrogen as \_\_\_\_\_.

**Ans:** (i) loss, (ii) standard hydrogen electrode, (iii) +1, (iv) redox, (v) gain, (vi) disproportionation, (vii) 0, -1, (viii) zero, (ix) reductant, (x) fuel

### TRUE AND FALSE TYPE QUESTIONS

- (i) In Redox reaction first oxidation take place.  
(ii) Oxidising agents are also called reductant.  
(iii) Fluorine cannot have +1 oxidation state.  
(iv)  $O_2^+$  has oxidation state of oxygen as  $+1/2$ .  
(v) If for the reaction  $Ca^{2+} + 2e^- \longrightarrow Ca(s)$ ;  $E^\ominus = -2.87$   
Then for the reaction  $2Ca^{2+} + 4e^- \longrightarrow 2Ca(s)$ ;  $E^\ominus = 2(-2.87)V$   
(vi) Salt bridge is used for enhancing  $E^\ominus$  values of individual half reaction.  
(vii) Anode is -ve charged in Galvanic cell.  
(viii) KCl can be use in salt bridge.  
(ix) Current flows in galvanic cell from Anode to cathode.  
(x)  $MnO_4^-$  is colourless in basic medium.

**Ans:** (i) False (ii) False (iii) True (iv) True (v) False  
(vi) False (vii) True (viii) True (ix) False (x) False



4. Statement - 1 : For the reaction  $\text{Zn} + \text{Cu}^{2+} \longrightarrow \text{Zn}^{2+} + \text{Cu}$ ;  $E_{\text{cell}}$  is +ve.  
Statement - 2 : For standard Hydrogen electrode  $E^\circ = 0$
5. Statement - 1 :  $2\text{H}_2\text{O}_2 \longrightarrow 2\text{H}_2\text{O} + \text{O}_2$  is Decomposition reaction (Redox).  
Statement - 2 : Oxygen has -2 oxidation state in  $\text{H}_2\text{O}$ .
6. Statement - 1 :  $\text{C} + \text{O}_2 \longrightarrow \text{CO}_2$  ; carbon get oxidised.  
Statement - 2 : Gain of Hydrogen is reduction.
7. Statement - 1 :  $\text{CaCO}_3 \longrightarrow \text{CaO} + \text{CO}_2$  is not redox reaction.  
Statement - 2 : C, Ca, O do not change their oxidation number in the reaction.
8. Statement - 1 : Oxidation also occurs when decrease in electron density is observed.  
Statement - 2 : Oxidation is gain of electro-positive element.
9. Statement - 1 :  $\text{Cr}_2\text{O}_7^{2-}$  is a self indicator.  
Statement - 2 :  $\text{MnO}_4^-$  acts as a self indicator.
10. Statement - 1 : Equivalence point comes first before end point.  
Statement - 2 : Equivalence point cannot be obtained even by graphical method.

**Ans:** 1. (a) 2. (a) 3. (a) 4. (b) 5. (d) 6. (b) 7. (a) 8. (c) 9. (d) 10. (d)

### ONE WORD ANSWER TYPE QUESTIONS

1. What is the oxidation number of S in  $\text{S}_8$ .
2. What is the oxidation state of Oxygen in  $\text{H}_2\text{O}_2$ .
3. Name the substance used in salt-bridge.
4. Name an indicator which can act as self-indicator.
5. When a substance gains electron, it is called :
6. Name the ion which is used for balancing the hydrogen atom in acidic medium.
7. In the reaction  $3\text{Mg} + \text{N}_2 \longrightarrow \text{Mg}_3\text{N}_2$ , Nitrogen is oxidised or reduced.

**Ans:** 1. zero            2. 1            3.  $\text{NH}_4\text{Cl}$  or  $\text{KCl}$             4.  $\text{KMnO}_4$   
5. Reduction    6.  $\text{H}^+$             7. Reduced

### 1-MARK QUESTIONS

1. Define oxidation and reduction according to electronic concept.
2. Define oxidation and reduction according to oxidation number.
3. A freshly cut apple is almost white but it turns reddish brown after sometime. Give reason.
4. Define oxidation number.
5. Write oxidation number of Mn in  $\text{KMnO}_4$ .
6. Write oxidation number of Cr in  $\text{Cr}_2\text{O}_7^{2-}$ .
7. Write Stock notation of  $\text{MnO}_2$  and  $\text{AuCl}_3$ .
8. Define redox reaction with example.
9. Define disproportionation reaction. Give one example.
10. Define the term redox titration.
11. Name the indicator used in redox titration involving  $\text{K}_2\text{Cr}_2\text{O}_7$  as an oxidizing agent.
12. At what concentration of  $\text{Cu}^{2+}$  (aq.) will electrode potential become equal to its standard electrode potential ?
13. The standard reduction potentials of three metals cations X, Y and Z are + 0.52, - 3.03 and - 1.18 V respectively. Arrange X, Y and Z in order of increasing reducing power.
14. An electrochemical cell consists of two electrodes *i.e.*, Anode and Cathode. What is the direction of flow of electrons in this cell ?
15. Why anode is negatively charged in an electrochemical cell?
16. Out of Zn and Cu vessel one will be more suitable to store 1 M HCl?

[Ans. 1 M]

[Ans.  $X < Z < Y$ ]

[Ans. Cu]

$$\text{Given } E_{\text{Zn}^{2+}/\text{Zn}}^{\theta} = -0.76 \text{ V, } E_{\text{Cu}^{2+}/\text{Cu}}^{\theta} = +0.34 \text{ V.}$$

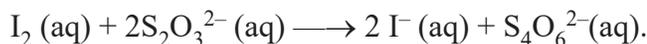
15. Is it safe to stir 1 M  $\text{AgNO}_3$  solution with copper spoon ?

$$\text{Given } E_{\text{Ag}^+/\text{Ag}}^{\theta} = +0.80 \text{ V, } E_{\text{Cu}^{2+}/\text{Cu}}^{\theta} = +0.34 \text{ V.}$$

[Ans. No]

## 2-MARKS QUESTIONS

1. Identify oxidant and reductant in the reaction :



2. Calculate oxidation number of Fe in  $\text{Fe}_3\text{O}_4$  and write a suitable justification of your answer.
3. Oxidation-reduction reactions are complementary. Explain.
4. Write formula for the following compounds :
- (i) Mercury (II) chloride
  - (ii) Nickel (II) sulphate
  - (iii) Iron (III) sulphate
  - (iv) Chromium (III) oxide
5. Justify that the reaction :  $\text{H}_2\text{O}(\text{s}) + \text{F}_2 \longrightarrow \text{HF} + \text{HOF}$  is a redox reaction.
6. A decomposition reaction may or may not be a redox reaction. Write two decomposition reactions in support of the statement.
7. Split the reaction  $2 \text{K} (\text{s}) + \text{Cl}_2 (\text{g}) \longrightarrow 2 \text{KCl} (\text{s})$  into oxidation and reduction half reactions.
8. Calculate the oxidation number of underlined elements in following compounds :
- (i)  $\text{Ca}\underline{\text{O}}_2$     (ii)  $\text{H}_2\underline{\text{S}}_2\text{O}_7$     (iii)  $\text{K}_2\underline{\text{Mn}}\text{O}_4$     (iv)  $\text{K}\underline{\text{I}}_3$
9. Write the functions of salt bridge in an electrochemical cell.
10. Define the term redox couple. Write the practical application of redox couple.
11. The standard reduction potentials of two metals A and B are  $-0.76 \text{ V}$  and  $+0.34 \text{ V}$  respectively. An electrochemical cell is formed using electrodes of these metals.
- (i) Identify the cathode and anode.
  - (ii) Write the direction of flow of electron.

### 3-MARKS QUESTIONS

- Calculate oxidation number of :
  - Cr in  $\text{Cr}_2\text{O}_4^{2-}$
  - O in  $\text{KO}_2$
  - Na in  $\text{Na}_2\text{O}_2$ .
- Account for the following :
  - $\text{HNO}_3$  acts as oxidizing agent while  $\text{HNO}_2$  can act both as reducing and oxidizing agent.
  - $\text{AgF}_2$  is unstable compound and act as a strong oxidizing agent.
  - Ozone acts as an oxidising agent.
- Permanent ion ( $\text{MnO}_4^-$ ) reacts with sulfur dioxide gas in acidic medium to produce  $\text{Mn}^{2+}$  ion and hydrogen sulphate ion. Write ionic equation and balance by ion electron method.
- Balance the following equation by oxidation number method :  
$$\text{P}_4(\text{s}) + \text{OH}^-(\text{aq}) \longrightarrow \text{PH}_3 + \text{H}_2\text{PO}_2^-(\text{aq})$$
 [*Basic Medium*]
- Balance the following equation by ion electron method :  
$$\text{Cl}_2\text{O}_7(\text{g}) + \text{H}_2\text{O}_2(\text{l}) \longrightarrow \text{ClO}_2^-(\text{aq}) + \text{O}_2(\text{g})$$
 [*Basic medium*]
- Depict the galvanic cell in which the reaction  
$$\text{Zn}(\text{s}) + 2\text{Ag}^+(\text{aq}) \longrightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{Ag}(\text{s})$$
 takes place. Further show :
  - Which electrode is negatively charged ?
  - The carriers of the current in the cell
  - Individual reaction at each electrode.
- Explain with suitable reasons :
  - Reaction  $\text{FeSO}_4(\text{aq}) + \text{Cu}(\text{s}) \longrightarrow \text{CuSO}_4(\text{aq}) + \text{Fe}$  does not occur.
  - Zinc can displace copper from aqueous  $\text{CuSO}_4$  solution but Ag cannot.
  - Solution of  $\text{AgNO}_3$  turns blue when copper rod is immersed in it.

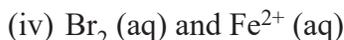
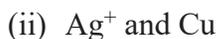
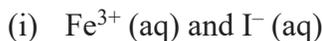
### 5-MARKS QUESTIONS

1. (i)  $\text{MnO}_4^{2-}$  undergoes disproportionation reaction in acidic medium but  $\text{MnO}_4^-$  does not. Give reason.
- (ii) Give one example each of the following redox reactions:
- Combination reaction
  - Decomposition reaction
  - Metal displacement reaction
2. Consider the cell reaction of an electrochemical cell :  $\text{Ni(s)} + 2 \text{Ag}^+(\text{aq}) \rightarrow \text{Ni}^{2+}(\text{aq}) + 2 \text{Ag(s)}$  and answer the following questions :
- Write anode and cathode half reactions.
  - Mention the direction of flow of electrons.
  - How is the electrical neutrality maintained in the solutions of the two half cells ?
  - Write the formula for calculating standard emf of this cell.
  - How does the emf change when the concentration of silver ions is decreased ?
3. Justify the reason that following reactions are redox reactions.
- $\text{CuO(s)} + \text{H}_2(\text{g}) \longrightarrow \text{Cu(s)} + \text{H}_2\text{O(g)}$
  - $\text{Fe}_2\text{O}_3 + 3\text{CO(g)} \longrightarrow 2\text{Fe(g)} + 3\text{CO}_2(\text{g})$
  - $\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \longrightarrow 4\text{NO(g)} + 5\text{H}_2\text{O(g)}$
  - $\text{BCl}_3(\text{g}) + 3\text{LiAlH}_4 \longrightarrow \text{B}_2\text{H}_6 + \text{LiCl} + \text{AlCl}_3$
  - $2\text{K} + \text{F}_2 \longrightarrow 2\text{KF}$

[Hints:– CuO is oxidizing agent,  $\text{H}_2$  is acting as reducing agent because Cu (II) is changing to Cu (0) by gain of  $e^-$   $\text{H}_2$  is getting oxidised to  $\text{H}_2\text{O(g)}$ , its oxidation state is changing from 0 to +1, by loss of electrons.

- (ii) It is redox reaction:  $\text{Fe}_2\text{O}_3$  is getting reduced to Fe. CO is getting oxidised to  $\text{CO}_2$ .]

4. Using standard electrode : Predict if the reaction between as the following is feasible.



**Hint:**–  $E^{\theta}_{\text{I}_2/\text{I}^{-}} = 0.541 \text{ V}$ ,  $E^{\theta}_{\text{Cu}^{2+}/\text{Cu}} = 0.34 \text{ V}$ ,  $E^{\theta}_{\text{Br}_2/\text{Br}^{-}} = 1.09 \text{ V}$ ,  $E^{\theta}_{\text{Ag}^{+}/\text{Ag}} = 0.80 \text{ V}$ ,  
 $E^{\theta}_{\text{Fe}^{3+}/\text{Fe}^{2+}} = 0.77 \text{ V}$ .

5. Draw the diagram for the galvanic cell which would have overall chemical reaction as



**Answer the following :**

(i) Write the reactions occurring at each electrode.

(ii) In which directions do the electrons flow in the external circuit?

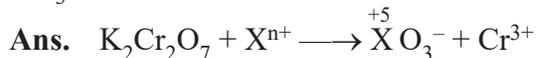
(iii) Name the salt to be taken in salt bridge.

(iv) Label the anode and cathode.

(v) How does the EMF change when the concentration of solvers ions is decreased?

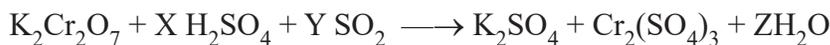
### HOTS QUESTIONS

1.  $6 \times 10^{-3}$  mole  $\text{K}_2\text{Cr}_2\text{O}_7$  reacts completely with  $9 \times 10^{-3}$  mole  $\text{X}^{n+}$  to give  $\text{XO}_3^{-}$  and  $\text{Cr}^{3+}$ . Find the value of X.

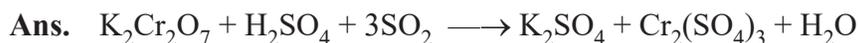


$$6 \times 10^{-3} \times 6 = (5-n) \times 9 \times 10^{-3} \longrightarrow n = 1$$

2. For the redox reaction



What is the sum of  $x + y + z$



$$\therefore x = 1 \quad y = 3 \quad z = 1 \quad \therefore x + y + z = 5$$

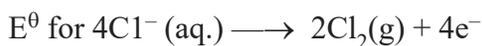
3. An aqueous solution containing 1M each of  $\text{Au}^{3+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Ag}^+$ ,  $\text{Li}^+$  is being electrolysed using inert electrodes the value of standard potentials are  $E^\theta_{\text{Ag}^+/\text{Ag}} = 0.80 \text{ V}$ ,  $E^\theta_{\text{Cu}^{2+}/\text{Cu}} = 0.34 \text{ V}$ ,  $E^\theta_{\text{Au}^{3+}/\text{Au}} = 1.50 \text{ V}$ ,  $E^\theta_{\text{Li}^+/\text{Li}} = -3.03 \text{ V}$ . With increasing voltage, find the sequence of deposition of metals on the cathode.

**Ans.** Only  $\text{Au}^{3+}$ ,  $\text{Ag}^+$  and  $\text{Cu}^{2+}$  will deposit at cathode.

$\text{Li}^+$  will not deposit at cathode because SRP of water is  $-0.8274 \text{ V}$

So after  $\text{Cu}^{2+}$ ;  $\text{H}_2$  will evolve at cathode.

4.  $E^\theta$  for  $\text{Cl}_2(\text{g}) + 2\text{I}^- \longrightarrow 2\text{Cl}^-(\text{aq.})$  is  $1.36 \text{ V}$ , then calculate.



**Ans.**  $E^\theta_{\text{Cl}^-/\text{Cl}_2} = -1.36 \text{ V}$   $E^\theta$  is independent of amount of substance

5. Why salt bridge is made up of saturated solution of  $\text{KNO}_3$  in agar-agar.

**Ans.** Velocities of both  $\text{K}^+$  and  $\text{NO}_3^-$  are nearly the same.

## UNIT TEST

Time Allowed: 1 hr

Maximum Marks : 20

General Instructions:

- (i) All questions are compulsory.  
(ii) Maximum marks carried by each question are indicated against it.
- 

1. Identify the oxidised and Reduced species in the following reaction [1]  
$$\text{H}_2\text{S} + \text{Cl}_2 \longrightarrow 2\text{HCl} + \text{S}$$
  
(a)  $\text{H}_2\text{S}$       (b)  $\text{Cl}_2$       (c) Both  $\text{H}_2$ ,  $\text{Cl}_2$       (d) None of these
2. What is the oxidation state of Br in  $\text{BrO}_3^-$ ? [1]  
(a) +1      (b) +3      (c) +4      (d) +5
3. Classify the type of reaction in Redox Reaction form : [1]  
$$3\text{H}_2\text{O} + \text{P}_4 + 3\text{OH}^- \longrightarrow \text{PH}_3 + 3\text{H}_2\text{PO}_2^-$$
4. What is a redox couple? Give one example.
5. Identify oxidant in reaction given below : [1]  
$$\text{CuO(s)} + \text{H}_2(\text{g}) \longrightarrow \text{Cu(s)} + \text{H}_2\text{O(g)}$$
6. Assign oxidation number to the underlined elements [2]  
(a)  $\text{NaH}_2\underline{\text{P}}\text{O}_4$       (b)  $\text{H}_4\underline{\text{P}}_2\text{O}_7$       (c)  $\text{K}_2\underline{\text{Mn}}\text{O}_4$       (d)  $\text{H}_2\underline{\text{S}}_2\text{O}_7$
7. Predict product of electrolysis in following case [2]  
- An aqueous solution of  $\text{CuCl}_2$  with platinum electrodes.
8. Consider the reaction  $\text{Zn(s)} + 2\text{Ag}^+(\text{aq.}) \longrightarrow \text{Zn}^{2+}(\text{aq.}) + 2\text{Ag(s)}$   
Answer following : [3]  
(i) Which electrode is negatively charged ?  
(ii) What are carrier of current in the cell ?  
(iii) Individual reaction at each electrode.
9.  $E^0$  values are given :  $\text{K}^+/\text{K} = -2.93\text{V}$ ,  $\text{Ag}^+/\text{Ag} = 0.80\text{V}$  [3]  
 $\text{Hg}^{2+}/\text{Hg} = 0.79\text{V}$   $\text{Mg}^{2+}/\text{Mg} = -2.37\text{V}$ ,  $\text{Cr}^{3+}/\text{Cr} = -0.74\text{V}$   
(i) Which one is strong reducing agent ?  
(ii) Which one is strong oxidising agent ?  
(iii) Which redox couple is a stronger reducing agent than  $\text{H}^+/\text{H}_2$  ?
10. Balance the reaction (ion-electron or oxidation number) [5]  
$$\text{P}_4(\text{s}) + \text{OH}^-(\text{aq.}) \longrightarrow \text{PH}_3(\text{g}) + \text{H}_2\text{PO}_2^-(\text{aq.})$$
 [Basic medium]

\*\*\*\*\*



## Chapter - 9

# Hydrogen

### FAST TRACK : QUICK REVISION

- Hydrogen is the first element in the periodic table and also the lightest element known. Electronic configuration of Hydrogen is  $1s^1$ .
- **Isotopes of hydrogen :**
  - (i) Protium ( ${}_1^1\text{H}$ )
  - (ii) Deuterium ( ${}_1^2\text{H}$  or  ${}_1^2\text{D}$ )
  - (iii) Tritium ( ${}_1^3\text{H}$  or  ${}_1^3\text{T}$ )
- **Preparation of Dihydrogen :**
  - (i) **Laboratory preparation :**  $\text{Zn} + 2\text{H}^+ \rightarrow \text{Zn}^{2+} + \text{H}_2$ .
  - (ii) **Commercial preparation :** By electrolysis of acidified water.
  - (iii) High purity dihydrogen is obtained by electrolyzing warm aqueous barium hydroxide.
- **Properties :**
  - \* Reaction with halogen:  $\text{H}_2 + \text{X}_2 \longrightarrow 2\text{HX}$  [ $\text{X} = \text{F}, \text{Cl}, \text{Br}, \text{I}$ ]
  - \* Reaction with oxygen:  $\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \xrightarrow{\Delta} 2\text{H}_2\text{O}(\text{l});$   
 $\Delta H^\ominus = -285.9 \text{ kJ mol}^{-1}$
  - \* Reaction with nitrogen:  $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \xrightarrow{\Delta} 2\text{NH}_3(\text{g});$   
 $\Delta H^\ominus = -92 \text{ kJ mol}^{-1}$
  - \* Reaction with alkali metals:  $\text{H}_2(\text{g}) + 2\text{M}(\text{g}) \xrightarrow{\Delta} 2\text{MH}(\text{s})$

It is relatively inert at room temperature due to the high H-H bond enthalpy.
- **Uses of Dihydrogen :**
  - (i) For synthesis of Ammonia ( $\text{NH}_3$ )

- (ii) For production of Methanol ( $\text{CH}_3\text{OH}$ )
- (iii) In oxyhydrogen torches
- (iv) In a fuel cell.

- **Hydrides**

- (i) **Ionic or salt like or saline hydrides** are formed with most of the *s*-block elements. Significant covalent character is found in  $\text{LiH}$ ,  $\text{BeH}_2$  and  $\text{MgH}_2$ .
- (ii) **Covalent or Molecular hydrides** are formed with most of the *p*-block elements. There are further classified as :
  - (a) **Electron deficient hydrides** are formed by group 13 elements *e.g.*,  $\text{B}_2\text{H}_6$ . They acts as Lewis acid.
  - (b) **Electron Precise hydrides** are formed by group 14 elements *e.g.*,  $\text{CH}_4$ .
  - (c) **Electron rich hydrides** have lone pair of electrons on central atoms of the molecules. Elements of group 15-17 form these types of hydrides.  $\text{NH}_3$ ,  $\text{HF}$  has high m.p./b.p. due to presence of intermolecular hydrogen bonding.
- (iii) **Metallic or Non-stoichiometric or Interstitial hydrides** are formed by *d* and *f*-block elements. For example  $\text{LaH}_{2.87}$  or  $\text{NiH}_{0.6-0.7}$ .

- **Water : ( $\text{H}_2\text{O}$ )**

**Hard water :** Hard water contains calcium and magnesium salts in the form of hydrogencarbonate, chloride and sulphate. Hard water does not give lathers with soap.

**Soft water :** Water free from soluble salts of calcium and magnesium is soft water.

**Types of Hardness :**

**Temporary hardness** is due to presence of calcium or magnesium hydrogen carbonate in water. Temporary hardness can be removed by :

- (i) Boiling
- (ii) Clark's Method

**Permanent hardness :**

Such hardness is due to presence of calcium or magnesium chlorides and sulphates.

Permanent hardness can be removed by :

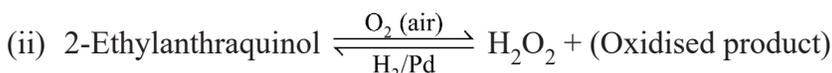
- (i) Treatment with washing soda
- (ii) Calgon's method
- (iii) Ion exchange method.

**Demineralised or Deionised water :** Water free from all soluble mineral salts is known as **demineralised water**.

- **Hydrogen Peroxide (H<sub>2</sub>O<sub>2</sub>)**

**Preparation :**

- (i) By electrolytic oxidation of acidified sulphate solutions at high current density.



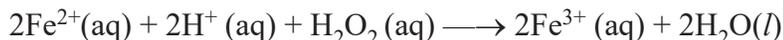
- **Physical Properties**

- (i) Miscible with water in all proportions.
- (ii) A 30% of H<sub>2</sub>O<sub>2</sub> solution is marked as '**100 volume**' hydrogen peroxide.

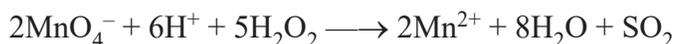
- **Chemical Properties :**

- (i) It acts as an oxidising as well as reducing agent.

- (ii) **Oxidising action in acidic medium :**



- (iii) **Reducing action in acidic medium :**



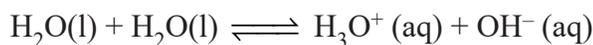
- **Storage of H<sub>2</sub>O<sub>2</sub> :**

- (i) Stored in wax-lined glass or plastic vessels in dark. Urea can be added as a stabiliser.
- (ii) It is kept away from dust because dust can induce explosive decomposition of the compound.

- **Uses of H<sub>2</sub>O<sub>2</sub> :**

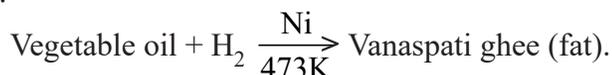
- (i) As an antiseptic it is sold in the market name **perhydrol**.
- (ii) In synthesis of hydroquinone.
- (iii) As a bleaching agent.

1. **Auto-protolysis of water:** Water accepts a proton from other water molecule to form  $\text{H}_3\text{O}^+$  and  $\text{OH}^-$  this process is called auto-protolysis of water

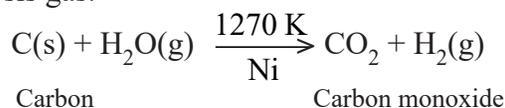


Its significance is that water can act as acid as well as base i.e. it is amphoteric in nature.

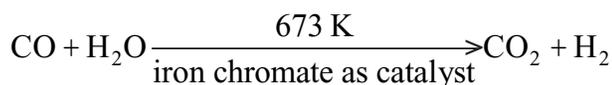
2. **Hydrogen economy:** It is transportation and storage of energy in the form of liquid or gaseous hydrogen. Advantage of hydrogen economy is that energy is transmitted in the form of dihydrogen and not as electric power
3. **Hydrogenation:** It is a process of converting polyunsaturated oils in edible fats.



4. **Syngas:** It is a mixture of  $\text{CO}$  and  $\text{H}_2$  in 1:1 ratio and also known as water gas or synthesis gas.

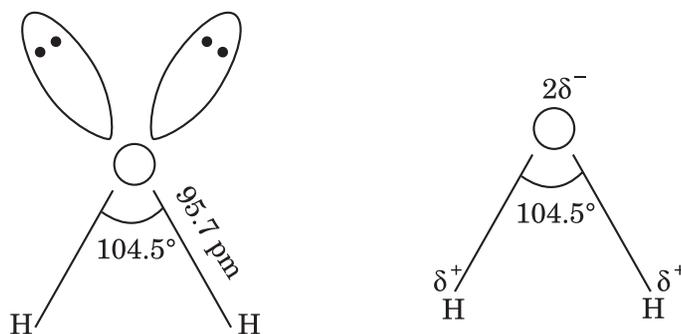


5. Water gas shift reaction.



6. **Fuel-cell:** Fuel cell is a cell in which chemical energy of fuel is converted into electrical energy.

7. **Structure of water:** It is bent molecule in gas phase with HOH bond angle  $104.5^\circ$  and O-H bond length of  $95.7\text{ pm}$  as shown in figure



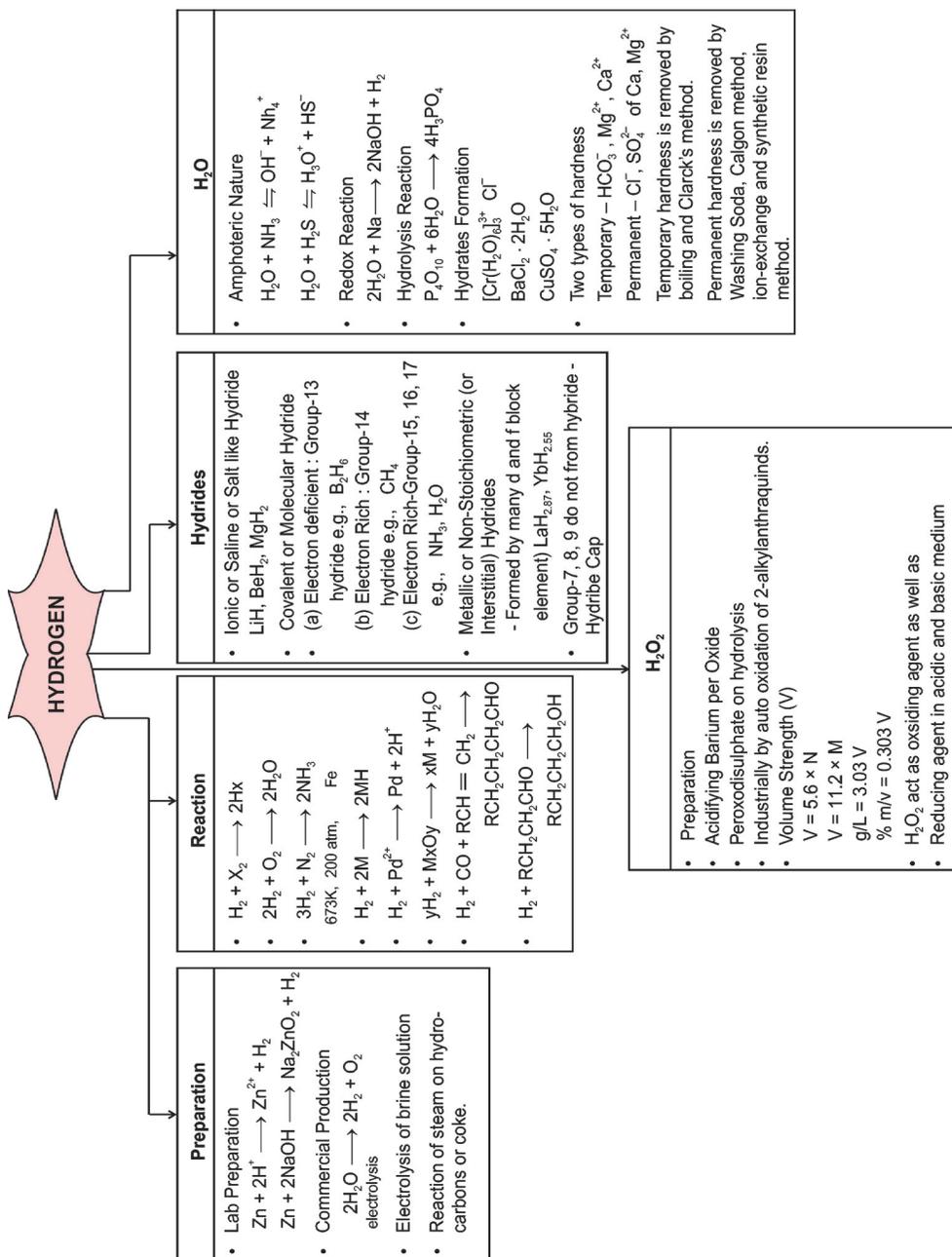
8. **Calgon:**– It is sodium polymetaphosphate  $(\text{NaPO}_3)_n$  it is used to remove. Permanent hardness of water.
9. **De-ionized water:**– Pure di-mineralised (ionized water) free from all soluble mineral matter is obtained by passing water successively through a cation exchanger (in the  $\text{H}^+$  form) and an anion exchanger for removal by cation and anions



(R is the resin anion  $\text{M}^{2+}$  is cation)



# MIND MAP : HYDROGEN





## TRUE AND FALSE TYPE QUESTIONSE

1.  $\text{H}_2\text{O}_2$  decomposes slowly on exposure to light.
2.  $\text{H}_2\text{O}_2$  on reaction with Pbs convert Pbs into Pb.
3. Chemically calgon is sodium hexametaphosphate  $\text{Na}_6\text{P}_6\text{O}_{18}$ .
4.  $\text{NH}_3$  is electron rich hydride.
5. Phosphorus form  $\text{PH}_5$ .
6.  $\text{H}_2$  gas cannot reduce  $\text{Pb}^{2+}$  ion.
7. Hydroformylation of olefins yields aldehydes which further undergoes reduction to give alcohols.
8. Hydrogenation of vegetable oils using nickel as catalyst gives edible fats.
9. Ice has cage like structure with air spaces.
10. Soft water gives lather with Soap.

**Ans:** 1. True    2. False    3. True    4. True    5. False  
6. False    7. True    8. True    9. True    10. True

## FILL IN THE BLANKS

1. Cation exchange resin contain large organic molecule with \_\_\_\_\_ group.
2. At atmospheric pressure ice crystallises in \_\_\_\_\_ for.
3. Due to high \_\_\_\_\_ of  $\text{H}_2\text{O}$ ,  $\text{H}_2\text{O}$  has a very strong hydrating tendency.
4. Water is present in  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} \cdot 3\text{Cl}^-$  in the form of \_\_\_\_\_.
5. The H-H bond dissociation enthalpy of  $\text{H}_2$  is \_\_\_\_\_, is the highest for a single bond between two atoms of any elements.
6. In the Clark's method for softening compound \_\_\_\_\_ is used.
7. During photosynthesis  $\text{H}_2\text{O}$  is \_\_\_\_\_.
8.  $\text{BeH}_2$  and  $\text{MgH}_2$  are ionic and \_\_\_\_\_ in nature.
9. When  $\text{NaH}$  is electrolysed, then \_\_\_\_\_ is released at anode.
10. Hydrated sodium aluminium silicate is \_\_\_\_\_.

**Ans:** 1.  $\text{SO}_3\text{H}$                       2. Hexagonal    3. Dielectric    4. Coordinated water  
5.  $435.88 \text{ kJ mol}^{-1}$     6.  $\text{Ca}(\text{HCO}_3)_2$     7. Oxidised    8. Polymeric  
9.  $\text{H}_2$                                 10. Zeolite/Permutit

## MATCH THE COLUMNS

- |    |   |                        |
|----|---|------------------------|
| 1. | <b>Column -I</b>  | <b>Column-II</b>       |
|    | A. Boiling  | p. $\text{CaCO}_3$     |
|    | B. Clark's Method   | q. $\text{Mg(OH)}_2$   |
|    | C. Washing soda   | r. $\text{NaAlSiO}_4$  |
|    | D. Ion-exchange method  | s. $\text{NaCl}$       |
| 2. | <b>Column -I</b>  | <b>Column-II</b>       |
|    | A. $\text{H}_2\text{O} + \text{NH}_3 \rightleftharpoons \text{OH}^- + \text{NH}_4^+$                                    | p. Hydroformylation    |
|    | B. $2\text{H}_2\text{O} + 2\text{Na} \longrightarrow 2\text{NaOH} + \text{H}_2$   | q. Acid base reaction  |
|    | C. $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \longrightarrow 4\text{H}_3\text{PO}_4$                               | r. Redox Reaction      |
|    | D. $2\text{H}_2 + \text{CO} + \text{RCH}=\text{CH}_2$<br>$\longrightarrow \text{RCH}_2\text{CH}_2\text{CH}_2\text{O}_4$ | s. Hydrolysis reaction |

- Ans.** 1. A  $\rightarrow$  q, B  $\rightarrow$  p, C  $\rightarrow$  s, D  $\rightarrow$  r  
 2. A  $\rightarrow$  q, B  $\rightarrow$  r, C  $\rightarrow$  s, D  $\rightarrow$  p

## ONE WORD ANSWER TYPE QUESTIONS

1. Name the gas release when zinc reacts with NaOH.
2. When brine solution is electrolysed then nature of solution will be?
3. What happens when  $\text{Al}_4\text{C}_3$  reacts with  $\text{D}_2\text{O}$ ?
4. In which medium  $\text{H}_2\text{O}_2$  act as reducing agent?
5. What is the chemical name of calgon's?
6. What happens when LiH reacts with  $\text{Al}_2\text{C}_{16}$ ?
7. What happens when warm aqueous Barium hydroxide solution is electrolysed?
8. What type of particles are emitted by Tritium?
9. What is the name for the following chemical reaction?



10. What is the term used to refer “Transportation and storage of energy in the form of liquid or gaseous dihydrogen”

- Ans:** 1.  $H_2$                       2. Basic                      3.  $Al_4C_3 + 12D_2O \longrightarrow 3CD_4 + 4Al(OD)_3$   
4. Acidic, Basic  
5. Sodium hexameter phosphate ( $Na_6P_6O_{18}$ )  
6.  $8LiH + Al_2Cl_6 \longrightarrow 2LiAlH_4 + 6 LiCl$   
7.  $H_2$  gas is produced                      8.  $\beta^-$  (beta negative)  
9. Water gas shift reaction                      10. Hydrogen economy

### ASSERTION AND REASON TYPE QUESTIONS

Each question contain statement-1 (Assertion) and statement-2 (Reason). Examine the statements carefully and mark the correct answer according to the instruction given below :

- (A) If both the statements are True and statement-2 is the correct explanation of statement-1  
(B) If both the statements are True and statement-2 is not the correct explanation of statement-1  
(C) If statement-1 is true and statement-2 is false  
(D) If statement-1 is false and statement-2 is true

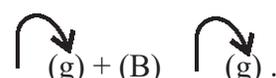
1. Statement-1 : HF form extensive hydrogen bonding.  
Statement-2 : F has highest tendency to form hydrogen bonding.
2. Statement-1 :  $MgCl_2$  solution produces lather with soap.  
Statement-2 : Hard water does not produce lather with soap.
3. Statement -1 : Density of ice is less than water.  
Statement-2 : Ice has open cage structure.
4. Statement-1 : Water can act as acid as well as base.  
Statement-2 : Water can accept as well as donate  $H^+$  ion.
5. Statement-1 :  $KMnO_4$  act as self indicator.  
Statement-2 :  $KMnO_4$  only act as reducing agent.
6. Statement-1 : Washing soda ( $Na_2CO_3$ ) is use to remove temporary hardness.  
Statement-2 : Clark's method is used to remove temporary hardness.

7. Statement-1 : In cation exchange process,  $H^+$  exchanges for  $Na^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ .  
Statement-2 : In anion exchange process  $OH^-$  exchanges for anion like  $Cl^-$ ,  $HCO_3^-$ ,  $SO_4^{2-}$ .
8. Statement-1 : When Na reacts with  $H_2O$ ,  $H_2$  gas is release.  
Statement-2 :  $P_4O_{10}$  on hydrolysis produce  $H_3PO_3$ .
9. Statement-1 :  $CH_4$  is a covalent hydrides.  
Statement-2 :  $CH_4$  is dectron precise type hydrides.
10. Statement-1 :  $H_2$  gas is use in metallurigical process.  
Statement-2 :  $H_2$  gas is use as fuel.

**Ans:** 1. (a) 2. (d) 3. (a) 4. (a) 5. (c) 6. (d) 7. (b) 8. (c) 9. (a) 10. (b)

### 1-MARK QUESTIONS

1. Name the isotope of hydrogen which is radioactive in nature. [**Ans.** Tritium]
2.  $H^+$  ions does not exist freely and is always associated with other atoms or molecule. Explain.
3. Give the composition of water gas. [**Ans.**  $CO$ ,  $H_2$ ]
4. Name the compound whose electrolysis in aqueous state, give high purity (99.95%) dihydrogen. [**Ans.** aq  $Ba(OH)_2$  solution]
5. Give the main purpose of water gas shift reaction.
6. Write the chemical reaction occuring during coal gasification.
7. Name the element used in fuel cell for generating electricity. [**Ans.**  $H_2$ ]
8. Give an example of electron deficient covalent hydride. [**Ans.**  $B_2H_6$ ]
9. Name the hydrides which have high potential for hydrogen storage. [**Ans.** Metallic hydrides]
10. Name the groups in *d*-block elements which do not form metallic hydrides. [**Ans.** 7, 8, 9]
11.  $H_2$  is relatively inert at room temperature. Explain.
12. Complete the reaction :  

$$C(s) + H_2O(g) \xrightarrow{1270\text{ K}} (A) \underline{\hspace{1cm}}(g) + (B) \underline{\hspace{1cm}}(g).$$


13. Name the phenomenon as a reason of which water has unusual boiling point. [Ans. Extensive hydrogen bonding]
14. Draw structure of water.
15. At atmospheric pressure ices crystallised in the ..... form but at very low temperature it condenses to ..... form. [Ans. Hexagonal, cubic]
16. Mention the temperature at which density of ice is maximum. [Ans. 4°C]
17. Density of ice is ..... than density of liquid water. [Ans. Less]
18. Complete the reaction :
- $$2\text{H}_2\text{O}(l) + 2\text{Na}(s) \longrightarrow$$
19. How many hydrogen-bonded water molecules (s) are associated in  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ . [Ans. One]
20. Name the compound used in Clark's method to remove temporary hardness of water. [Ans. Lime]
21. Write the chemical formula of "Calgon". [Ans.  $\text{Na}_4\text{P}_6\text{O}_{18}$ ]
22. A 30% solution of  $\text{H}_2\text{O}_2$  is marketed as ..... volume. [Ans. 100 volume]
23. Draw gas phase structure of  $\text{H}_2\text{O}_2$ .
24. Name the organic compound whose auto-oxidation is used to produce  $\text{H}_2\text{O}_2$  commercially or industrially. [Ans. 2-Ethylanthraquinol]
25. How is heavy water obtained from ordinary water?

### 2-MARKS QUESTIONS

1. Complete the following reactions :
- (i)  $\text{CO}(g) + \text{H}_2(g) \xrightarrow[\text{Catalyst}]{\Delta}$
- (ii)  $\text{Zn}(s) + \text{NaOH}(aq) \xrightarrow{\Delta}$
2. Among  $\text{NH}_3$ ,  $\text{H}_2\text{O}$  and  $\text{HF}$  which would you expect to have highest magnitude of hydrogen bonding and why ?
3. How do you expect the metallic hydrides to be useful for hydrogen storage? Explain.
4. How can the production of dihydrogen obtained from "Coal gasification" be increased ?

5. Write the name of isotopes of hydrogen. What is the mas ratio of these isotopes ?
6. Complete the reactions :
- (i)  $\text{CO}(g) + 2\text{H}_2(g) \xrightarrow[\text{Catalyst}]{\text{Cobalt}}$
- (ii)  $\text{CH}_4(g) + \text{H}_2\text{O}(g) \xrightarrow[\text{Ni}]{1270\text{K}}$
7. Comment on the reactions of dihydrogen with :
- (i) Chlorine, (ii) Sodium.
8. Arrange the following :
- (i) LiH, NaH, CsH (In increasing order of ionic character)
- (ii) H—H, D—D, F—F (In decreasing order of bond dissociation enthalpy)
9. List two uses of dihydrogen.
10. Complete the reactions :
- (i)  $\text{H}_2 + \text{CO} + \text{RCH} = \text{CH}_2 \longrightarrow$
- (ii)  $\text{H}_2 + \text{RCH}_2\text{CH}_2\text{CHO} \longrightarrow$
11. Give two reactions to show amphoteric nature of water.
12. Complete the reactions :
- (i)  $2\text{F}_2(g) + 2\text{H}_2\text{O}(l) \longrightarrow$
- (ii)  $6\text{CO}_2(g) + 12\text{H}_2\text{O}(l) \longrightarrow$
13. What is the difference between the term hydrolysis and hydration.
14. What do you understand by term ‘autoprotolysis’ of water ? What is its significance ?
15. What causes the temporary and permanent harness of water ?
16. Is demineralised or distill water useful for drinking purposes ? If not, how can it be made useful ?
17. Explain the terms :
- (i) Hydrogen economy.
- (ii) Fuel cell.
18. Write chemical reactions to justify that hydrogen peroxide can function as an oxidising as well as reducing agent.

19. Compare the structure of  $\text{H}_2\text{O}$  and  $\text{H}_2\text{O}_2$ .
20. How does  $\text{H}_2\text{O}_2$  behaves as a bleaching agent ?
21.  $\text{H}_2\text{O}_2$  acts as an oxidizing as well as reducing agent. Why?

### 3-MARKS QUESTIONS

1. Complete the chemical reactions :
  - (i)  $8\text{LiH} + \text{Al}_2\text{Cl}_6 \longrightarrow$
  - (ii)  $2\text{LiH} + \text{B}_2\text{H}_6 \longrightarrow$
2. What do you understand by : (i) Electron deficient, (ii) Electron precise, (iii) Electron rich compounds of hydrogen ? Provide justifications with suitable examples.
3. What do you understand by the term “non-stoichiometric hydrides” ? Do you expect this type of the hydrides to be formed by alkali metals. Explain and Justify your answer.
4. Arrange the following :
  - (i)  $\text{CaH}_2$ ,  $\text{BeH}_2$ ,  $\text{TiH}_2$  (in order of increasing electrical conductance)
  - (ii)  $\text{NaH}$ ,  $\text{MgH}_2$ ,  $\text{H}_2\text{O}$  (in order of increasing bond dissociation enthalpy)
  - (iii)  $\text{Li}$ ,  $\text{F}$ ,  $\text{H}$  (in order of increasing ionisation enthalpy)
5. What do you understand by the terms :
  - (i) Syn gas    (ii) Water gas shift reaction    (iii) Producer gas.
6. Would gas except the hydrides of  $\text{N}$ ,  $\text{O}$  and  $\text{F}$  to have lower boiling point than the hydrides of their subsequent group members ? Give reasons.
7. Can phosphorous with outer electronic configuration  $3s^23p^3$  form  $\text{PH}_5$  ? Explain.
8. Why and how the hydrogen is regarded as a fuel of future ? Explain.
9. Write the reactions when dihydrogen reacts with (i)  $\text{O}_2$  (ii)  $\text{N}_2$  (iii)  $\text{Cl}_2$  under specific conditions.
10. Name the hydrides :
  - (i) Which is non stoichiometric in nature ?
  - (ii) Which are stoichiometric compounds ?
  - (iii) Which has electron rich type hydrides ?

- 11.** Complete the reactions :
- (i)  $\text{CaO}(s) + \text{H}_2\text{O}(g) \longrightarrow$
- (ii)  $\text{AlCl}_3(g) + \text{H}_2\text{O}(l) \longrightarrow$
- (iii)  $\text{Ca}_3\text{N}_2(s) + \text{H}_2\text{O}(l) \longrightarrow$
- 12.** Discuss the principle and method of softening of hard water by synthetic exchange of resin method.
- 13.** What is meant by ‘demineralised’ water and how can it be obtained ?
- 14.** What properties of water make it useful as a solvent ? What types of compound can it (i) dissolved (ii) hydrolyse ?
- 15.** Calculate the strength of 10 volume solution of  $\text{H}_2\text{O}_2$ .
- 16.** Complete the reactions :
- (i)  $2\text{Fe}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{H}_2\text{O}_2(\text{aq}) \longrightarrow$
- (ii)  $\text{HOCl} + \text{H}_2\text{O}_2 \longrightarrow$
- (iii)  $\text{Mn}^{2+} + \text{H}_2\text{O}_2 \longrightarrow$
- 17.** Give three uses of  $\text{H}_2\text{O}_2$ .
- 18.** Complete the reactions :
- (i)  $\text{CaC}_2 + 2\text{D}_2\text{O} \longrightarrow$
- (ii)  $\text{SO}_3 + \text{D}_2\text{O} \longrightarrow$
- (iii)  $\text{Al}_4\text{C}_3 + 12\text{D}_2\text{O} \longrightarrow$
- 19.** Give the limitations of using  $\text{H}_2$  as a fuel.
- 20.**  $\text{H}_2\text{O}_2$  is stored in a wax lined glass or plastic vessels. Explain an equation showing decomposition of  $\text{H}_2\text{O}_2$  on exposure to light.

### 5-MARKS QUESTIONS

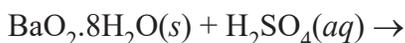
- 1.** Answer the following :
- (a) Name the most abundant form of hydrogen isotope. [Ans.  ${}_1^1\text{H}$ ]
- (b) Name the particles emitted by tritium. [Ans.  $\beta^-$ ]
- (c) Mixture of CO and  $\text{H}_2$  is used for preparation ..... . [Ans. Methanol]
- (d) Name the catalyst used in Haber’s Process for manufacture of  $\text{NH}_3(g)$ .  
[Ans. Fe]
- (e) Name two electron rich hydrides. [Ans.  $\text{NH}_3, \text{H}_2\text{O}$ ]

2. Answer the following :

(a) During Clark's method. Name the compound in which Mg is precipitated out. [Ans. Magnesium Hydroxide]

(b) Give the formula of Zeolite used in ion exchange method to remove permanent hardness of water. [Ans. NaAlSiO<sub>4</sub>]

(c) Complete the reaction :



(d) H<sub>2</sub>O<sub>2</sub> is miscible with water. Assign reason.

(e) Name the compound when can be used as a hair beach, mild antiseptic in the form of perhydrol. [Ans. H<sub>2</sub>O<sub>2</sub>]

3. (a) Complete the following chemical equations

(b) \_\_\_\_\_ + water  $\longrightarrow$  CaCO<sub>3</sub> + NH<sub>3</sub> (Ammonia)

(c) \_\_\_\_\_ + Hydrogen peroxide  $\xrightarrow{\text{H}^+}$  CrO<sub>5</sub> + \_\_\_\_\_

(d) Na<sub>2</sub>O + H<sub>2</sub>O  $\longrightarrow$  \_\_\_\_\_

(e) D<sub>2</sub>O + Na<sub>3</sub>As  $\longrightarrow$  \_\_\_\_\_

4. Describe the usefulness of water in biosphere and biological systems.

### HOTS QUESTIONS

1. Calculate the hardness of water sample which contains 0.001 mole of MgSO<sub>4</sub> dissolved per litre of water.

Ans. 1 mole MgSO<sub>4</sub> = 1 mole CaCO<sub>3</sub>

10<sup>-3</sup> Mole MgSO<sub>4</sub> = 10<sup>-3</sup> mol CaCO<sub>3</sub>

∴ 0.120g MgSO<sub>4</sub> = 0.1g CaCO<sub>3</sub> in 1000 mL

∴ Hardness = =100ppm

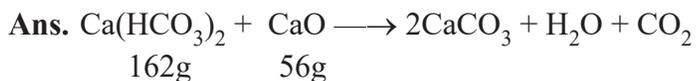
2. 2g of Al is treated separately with excess dilute H<sub>2</sub>SO<sub>4</sub> and excess NaOH. The ratio of volumes of Hydrogen evolved under similar condition is  $\frac{x}{y}$ . Find  $\frac{x}{y}$

Ans.  $2\text{Al} + 3\text{H}_2\text{SO}_4 \longrightarrow \text{Al}_2(\text{SO}_4)_3 + 3\text{H}_2$

$2\text{Al} + 2\text{NaOH} + 2\text{H}_2\text{O} \longrightarrow 2\text{NaAlO}_2 + 3\text{H}_2$

∴ Ratio is 1 : 1

3. What mass of CaO will be required to remove the hardness of 1000 litres of water containing 1.62g of  $\text{Ca}(\text{HCO}_3)_2$  per litre?



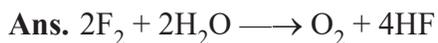
$\therefore 5.6 \times 10^2$ g be cause solution has 1620 g  $\text{Ca}(\text{HCO}_3)_2$

4. What is the volume of  $\text{O}_2$  liberated at N.T.P. by complete decomposition of 100mL of 2m solution of  $\text{H}_2\text{O}_2$ ?

**Ans.** Volume strength =  $11.2 \times M = 22.4$

100mL = 0.1L i.e.  $22.4 \times 0.1 = 2.24\text{L O}_2$  released

5. Mention an example in which  $\text{H}_2\text{O}$  acts as reducing agent.



## UNIT TEST

**Time Allowed: 1 hr**

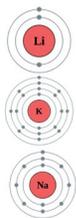
**Maximum Marks : 20**

*General Instructions:*

- (i) All questions are compulsory.
  - (ii) Maximum marks carried by each question are indicated against it.
- 

1. Hydrogen has maximum oxidation state in [1]  
(a) NaH      (b)  $\text{MgH}_2$       (c)  $\text{H}_2\text{O}$       (d) C & H
2. Which one does not cause hardness of water?  
(a)  $\text{MgCl}_2$       (b)  $\text{CaCl}_2$       (c)  $\text{MgSO}_4$       (d)  $\text{AlCl}_3$
3. Give one reaction for preparation of hydrogen gas in laboratory. [1]
4. What causes the hardness of water? [1]
5. Draw the structure of  $\text{H}_2\text{O}_2$ . [1]
6. Complete the reaction with balancing [2]  
(a)  $\text{Fe}^{2+}(\text{aq.}) + \text{H}^+(\text{aq.}) + \text{H}_2\text{O}_2(\text{aq.}) \longrightarrow$   
(b)  $\text{HOCl} + \text{H}_2\text{O}_2 \longrightarrow$
7. What is Hydrogen Economy. What are its advantage? [2]
8. Explain the following [3]
  - (i) Atomic hydrogen or oxy-hydrogen torch function for cutting and welding purposes. Why?
  - (ii)  $\text{CaH}_2$ ,  $\text{BeH}_2$  and  $\text{TiH}_2$  arrange in order of increasing electrical conductance and give reason.
  - (iii) Water shows amphoteric behaviour, support by giving appropriate example.
9. What are different types of hydrides? Give example. [3]
10. Discuss the principle and method of softening of hard water by synthetic ion-exchange resins. [5]

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## Chapter - 10

# s-Block Elements

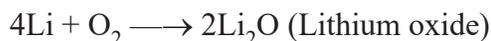
### FAST TRACK : QUICK REVISION

- s-block elements consists of group-I (Alkali metals) and group-2 (Alkaline earth metals).
- Group 1<sup>st</sup> elements — Li, Na, K, Rb, Cs, Fr.
- Group 2<sup>nd</sup> elements — Be, Mg, Ca, Sr, Ba, Ra.
- **Atomic radius** : Atomic radius of alkali metals are greater than alkaline earth metals.
- **Hydration enthalpy** : Decreases with increases in ionic sizes.
- **Ionic mobility** : Smaller the size of ion, more highly it is hydrated and hence lower is its ionic mobility.



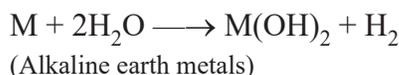
- **Ionisation enthalpies** : 1<sup>st</sup> I.E. of group 1<sup>st</sup> is smaller than group 2<sup>nd</sup> elements but 2<sup>nd</sup> I.E. of group 2<sup>nd</sup> is smaller than group 1<sup>st</sup> elements.
- **Flame colouration** : Due to low I.E., s-block elements and their salts imparts characteristics colour of oxidising flame (except Be and Mg). Be and Mg do not show flame colouration because they have small size and very high ionisation enthalpy.
- **Reducing character** : Due to large negative electrode potentials alkali metals are stronger reducing agent than alkaline earth metal.

- **Reactivity towards air** :

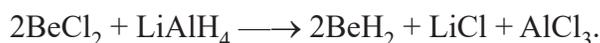


Alkaline earth metals being smaller in size do not form superoxides.

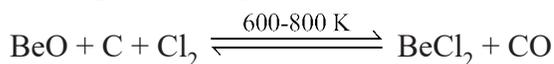
- **Reactivity towards H<sub>2</sub>O :**



- **Reactivity towards hydrogen :**



- **Reactivity towards halogens :**



- **Solution in liquid ammonia :** The fresh solution of alkali metals and alkaline earth metals (except Be and Mg) is deep blue, paramagnetic and highly reducing due to presence of ammoniated electrons.

- **Solubility of alkaline earth metal carbonate in water :**



- **Solubility of alkaline earth metal carbonates in water.**



- **Solubility of alkaline earth metal sulphates in water :**



- **Thermal stability of alkali metal carbonates :**



- **Thermal stability of alkaline earth metal carbonates :**

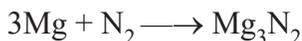


- **Anomalous behaviour of Li and Be :** It is due to very small size, high I.E. and high polarising power (*i.e.*, charge/radius)

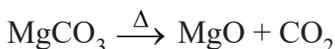
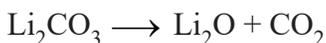
- **Diagonal relationship (similarities) between Li and Mg :**

(i) Both Li and Mg are hard.

(ii) Both react with  $N_2$  to form nitrides.



(iii) **Decomposition of carbonates :**



(iv) Both  $LiCl$  and  $MgCl_2$  are deliquescent. They form hydrates salts  $LiCl \cdot 2H_2O$  and  $MgCl_2 \cdot 6H_2O$ .

(v) **Decomposition of nitrates :**



● **Diagonal relationship (similarities) between Be and Al :**

(i) Both are passive to acids due to formation of oxide layer.

(ii) Hydroxides of both dissolve in alkali to form  $[Be(OH)_4]^{2-}$  and  $[Al(OH)_4]^-$ .

(iii) Chloride of both has bridged structure.

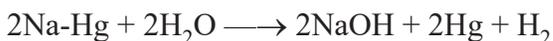
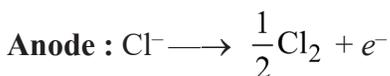
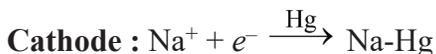
(iv) Both have tendency to form complexes of  $BeF_4^{2-}$ ,  $AlF_6^{3-}$ .

● **Manufacturing of washing soda ( $Na_2CO_3 \cdot 10H_2O$ ) :**

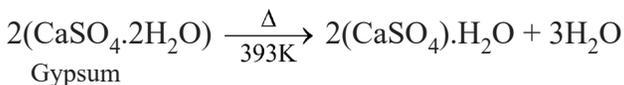
**Solvay process :**



● **Manufacturing of caustic soda ( $NaOH$ ) :** Castner-Kellner cell.



● **Plaster of paris :** ( $CaSO_4 \cdot \frac{1}{2}H_2O$ )



## MULTIPLE CHOICE QUESTIONS (MCQ)

- The alkali metals are low melting. Which of the following alkali metal is expected to melt if the room temperature rises to  $30^{\circ}\text{C}$ ?
  - Na
  - K
  - Rb
  - Cs
- Alkali metals react with water vigorously to form hydroxides and dihydrogen. Which of the following alkali metals reacts with water least vigorously?
  - Li
  - Na
  - K
  - Cs
- The reducing power of a metal depends on various factors. Suggest the factor which makes Li, the strongest reducing agent in aqueous solution.
  - Sublimation enthalpy
  - Ionisation enthalpy
  - Hydration enthalpy
  - Electron-gain enthalpy
- Metal carbonates decompose on heating to give metal oxide and carbon dioxide. Which of the metal carbonates is most stable thermally?
  - $\text{MgCO}_3$
  - $\text{CaCO}_3$
  - $\text{SrCO}_3$
  - $\text{BaCO}_3$
- Which of the carbonates given below is unstable in air and is kept in  $\text{CO}_2$  atmosphere to avoid decomposition.
  - $\text{BeCO}_3$
  - $\text{MgCO}_3$
  - $\text{CaCO}_3$
  - $\text{BaCO}_3$
- Metals form basic hydroxides. Which of the following metal hydroxide is the least basic?
  - $\text{Mg}(\text{OH})_2$
  - $\text{Ca}(\text{OH})_2$
  - $\text{Sr}(\text{OH})_2$
  - $\text{Ba}(\text{OH})_2$
- Some of the Group 2 metal halides are covalent and soluble in organic solvents. Among the following metal halides, the one which is soluble in ethanol is
  - $\text{BeCl}_2$
  - $\text{MgCl}_2$
  - $\text{CaCl}_2$
  - $\text{SrCl}_2$

8. The order of decreasing ionisation enthalpy in alkali metals is
- (a)  $\text{Na} > \text{Li} > \text{K} > \text{Rb}$                       (b)  $\text{Rb} > \text{Na} > \text{K} > \text{Li}$   
 (c)  $\text{Li} > \text{Na} > \text{K} > \text{Rb}$                       (d)  $\text{K} > \text{Li} > \text{Na} > \text{Rb}$
9. The solubility of metal halides depends on their nature, lattice enthalpy and hydration enthalpy of the individual ions. Amongst fluorides of alkali metals, the lowest solubility of LiF in water is due to
- (a) Ionic nature of lithium fluoride  
 (b) High Lattice enthalpy  
 (c) High hydration enthalpy of lithium atom  
 (d) Low ionisation enthalpy of lithium atom
10. Amphoteric hydroxides react with both alkalies and acids. Which of the following Group 2 metal hydroxides is soluble in sodium hydroxide?
- (a)  $\text{Be}(\text{OH})_2$                                       (b)  $\text{Mg}(\text{OH})_2$   
 (c)  $\text{Ba}(\text{OH})_2$                                       (d)  $\text{Ca}(\text{OH})_2$

### ASSERTION-REASON TYPE QUESTIONS

The question given below contains statement -1 (Assertion) and Statement-2 (Reason) Each question has four choice (a), (b), (c) and (d) out of which only one is correct. Choose the correct option as under.

- (a) Statement-1 is true, statement-2 is true.  
 Statement-2 is a correct explanation for statement-1.
- (b) Statement-1 is true, statement-2 is true ;  
 Statement-2 is not a correct explanation of statement-1.
- (c) Statement -1 is true, statement-2 is false.
- (d) Statement-1 is false, statement-2 is true.
1. Statement-1 : Sodium metal is softer than potassium metal.  
 Statement-2 : Metallic bonding in Potassium is weaker than in Sodium.
2. Statement-1 :  $\text{Be}(\text{OH})_2$  is soluble in HCl and NaOH.  
 Statement-2 :  $\text{Be}(\text{OH})_2$  is amphoteric in nature.
3. Statement-1 : Metallic character of alkali metals increases on going down a group from top to bottom.

Statement-2 : Ionisation enthalpy of alkali metals increases on going down from top to bottom.

4. Statement-1 : Super oxides of alkali metals are diamagnetic.

Statement-2 : Super oxides contain the ion  $O_2^-$ -which has one unpaired electron.

5. Statement-1 : Alkali metals do not impart colour to the flame.

Statment-2 : Their ionization enthalpies are very low.

6. Statement-1 : Sodium cannot be obtained by chemical reduction of its ore.

Statment-2 : Sodium is one of the strongest reducing agent.

7. Statement-1 : Beryllium hydroxide becomes soluble in excess alkali forming beryllate ion  $[Be(OH)_4]^{2-}$ .

Statment-2 : Beryllium ion has greater tendency to form complexes.

### FILL IN THE BLANKS

1. In the synthesis of sodium carbonate, the recovery of ammonia is done by treating  $NH_4Cl$  with  $Ca(OH)_2$ . The by product obtained in this process is .....

(a) NaCl

(b) NaOH

(c)  $CaCl_2$

(d)  $NaHCO_3$

2. When sodium is dissolved in liquid ammonia, a solution of deep blue colour is obtained. The colour of the solution is due to.....

(a) Sodium ion

(b) Ammoniated electron

(c) Sodium amide

(d) Ammoniated sodium ion

3. By adding gypsum to cement.....

(a) Setting time of cement becomes less.

(b) Setting time of cement increases

(c) Colour of cement becomes light

(d) Shining surface is obtain.

4. A substance which gives crimson red flame and breaks on heating to give oxygen and a brown gas is

(a) Magnesium nitrate

(b) Calcium nitrate

(c) Barium nitrate

(d) Strontium nitrate





11. Why Be and Mg do not give characteristics colour to the flame ?
12. Arrange the alkaline earth metal carbonate in the decreasing order of thermal stability.
13. Why do alkaline earth metals not form any superoxide ?
14. Why gypsum is added to cement ?
15. How plaster of paris is obtained from gypsum ?
16. BeO is insoluble in water but BeSO<sub>4</sub> is soluble in water ? Why ?
17. Why second I.E. of group II elements is less than group I elements ?
18. What is quick lime ? How is it prepared ?
19. Why does Be show similarities with Al ?
20. Name the alkaline earth metal hydroxide which is amphoteric.

### 2-MARKS QUESTIONS

1. Why are alkali metals soft and have low melting points ?
2. Write any four similarities between Li and Mg.
3. Why are potassium and caesium rather than Lithium used in photoelectric cells ?
4. Why is Li<sub>2</sub>CO<sub>3</sub> decomposed at a lower temperature whereas Na<sub>2</sub>CO<sub>3</sub> at higher temperature ?
5. Among the alkali metals which has :
  - (i) Highest melting point.
  - (ii) Most electropositive character
  - (iii) Lowest size of ion.
  - (v) Strongest reducing character.      [Ans. (i) Li (ii) Cs (iii) Li (iv) Li]
6. Why does the solubility of alkali earth metal carbonates and sulphates decrease down the group ?
7. Draw the structure of BeCl<sub>2</sub> in (i) Vapour phase (ii) Solid state.
8. When CO<sub>2</sub> gas is passed in lime water it turns milky but in case of excess CO<sub>2</sub> milkiness disappears. Support the statement by giving suitable reaction equations.
9. (i) E<sup>0</sup> for M<sup>2+</sup> (aq) + 2e<sup>-</sup> → M(s) (where M = Ca, Sr, Ba) is nearly constant.

- (ii) What is dead burnt plaster ? How is it obtained from gypsum?
10. Write two important uses of (i) Limestone (ii) Quick lime.

### 3-MARKS QUESTIONS

- Assign reason for the following :
  - Compounds of lithium are generally covalent.
  - Alkali metals are strong reducing agent.
  - LiCl is more covalent than NaCl.
- Discuss the various reactions that occur in Solvay process.
- Explain why ?
  - Lithium salts are commonly hydrated.
  - Sodium peroxide is widely used as oxidising agent.
  - Sodium wire is used to remove moisture from benzene but can't be used for drying alcohol.
- Sodium hydroxide is generally prepared by electrolysis of brine solution in the Castner-Kellner cell :
  - Write the reactions that occur in the cell.
  - Write any two uses of NaOH.
- Explain with suitable reasons :
  - A solution of  $\text{Na}_2\text{CO}_3$  is alkaline.
  - Alkali metals are prepared by electrolysis of their fused chlorides.
  - Sodium is found to be more useful than potassium ?
- Arrange the following in order of property mentioned against each :
  - $\text{BaCl}_2$ ,  $\text{MgCl}_2$ ,  $\text{BeCl}_2$ ,  $\text{CaCl}_2$  (Increasing ionic character)
  - $\text{Mg}(\text{OH})_2$ ,  $\text{Sr}(\text{OH})_2$ ,  $\text{Ba}(\text{OH})_2$ ,  $\text{Ca}(\text{OH})_2$  (Increasing solubility in water)
  - $\text{BeO}$ ,  $\text{MgO}$ ,  $\text{BaO}$ ,  $\text{CaO}$  (Increasing basic strength)
- What happens when :
  - Mg is burnt in air.
  - Quick lime is heated with silica.
  - Chlorine is heated with slaked lime.
- Write the raw material required for the manufacture of portland cement ? Why gypsum is added into it ?
- Why alkaline earth metals cannot be obtained by reduction of their oxides ?

- (ii) Why the elements of group 2 are known as alkaline earth metals ?
10. (i) Alkaline earth metals forms ionic salt having bivalent cations. Explain. Why?
- (ii) A piece of magnesium ribbon continues to burn in  $\text{SO}_2$ . Why ?

### 5-MARKS QUESTIONS

1. Explain the following observation :
- LiI is more soluble than KI in ethanol.
  - Sodium reacts with water less vigorously than potassium.
  - LiF is insoluble in water.
  - The mobilities of the alkali metal ions in aqueous solution are  $\text{Li}^+ < \text{Na}^+ < \text{K}^+ < \text{Rb}^+ < \text{Cs}^+$ .
  - Lithium is the only alkali metal to form a nitride directly.
2. Complete the following reaction equations :
- $\text{BeCl}_2 + \text{LiAlH}_4 \longrightarrow$
  - $\text{CaO} + \text{SiO}_2 \longrightarrow$
  - $\text{Ca}(\text{OH})_2 + \text{Cl}_2 \longrightarrow$
  - $\text{CaO} + \text{P}_4\text{O}_{10} \longrightarrow$
  - $\text{Ca}(\text{OH})_2 + \text{CO}_2 \longrightarrow$
3. Compare the solubility and thermal stability of the following :  
Compounds of the alkali metals with those of alkaline earth metals  
(a) nitrates (b) carbonates (c) sulphates.
4. Explain the significance of Sodium (Na), Potassium (K), Magnesium (Mg) and Calcium(Ca) in biological fluids.
5. Explain the significance of Sodium Potassium, Magnesium and Calcium biological fluids.
6. (i) A solutions of  $\text{Na}_2\text{CO}_3$  is alkaline why?  
(ii) BeO insoluble but  $\text{BeSO}_4$  in soluble in water. Why?  
(iii) Lithium salts are commonly hydrated and those of other alkali metal ions are usually anhydrous give reasons.  
(iv) What is the importance of cement?  
(v) What happen when quick lime is heated with silica?

## UNIT TEST

**Time Allowed: 1 hr**

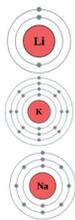
**Maximum Marks : 20**

*General Instructions:*

- (i) All questions are compulsory.  
(ii) Maximum marks carried by each question are indicated against it.
- 

1. Photoelectric effect is maximum in [1]  
(a) Cs            (b) K            (c) Na            (d) Li
2. Flame test is not shown by [1]  
(a) Be            (b) Sr            (c) K            (d) Ca
3. Oxidation state of K in  $\text{KO}_2$  is \_\_\_\_\_. [1]
4. LiCl is soluble in organic solvent. Why? [1]
5. Why is sodium kept under kerosene? [1]
6. Write only four similarities in properties of Li and Mg. [2]
7. Write two important uses of CaO and  $\text{CaCO}_3$ . [2]
8. Discuss the various reactions that occur in solvay process. [3]
9. What happens when :— [3]
  - (a) Mg is burnt in air.
  - (b) Quick lime is heated with silica.
  - (c) Chlorine is heated with slaked lime.
10. Complete the following chemical reactions : [5]
  - (a)  $\text{CaO} + \text{SiO}_2 \longrightarrow$
  - (b)  $\text{Ca(OH)}_2 + \text{CO}_2 \longrightarrow$
  - (c)  $2\text{Mg(NO}_3)_2 \longrightarrow$
  - (d)  $3\text{Mg} + \text{N}_2 \xrightarrow{\Delta}$
  - (e)  $\text{NH}_4\text{HCO}_3 + \text{NaCl} \longrightarrow$

\*\*\*\*\*



## Chapter - 11

# p-Block Elements

### FAST TRACK : QUICK REVISION

**General outer Electronic configuration :**  $ns^2np^{1-6}$ .

**Inert Pair Effect:**

- Reluctance of  $ns^2$  electrons of valence shell to participate in bond formation is termed as inert pair effect.
- It arises due to poor or insufficient shielding of  $ns^2$  electrons by intervening d- or f-electrons & hence increases down the group.

**Causes of Anomalous Behaviour of First Element in groups of p-Block:**

- Very small size
- Unavailability of vacant d-orbital
- Tendency to form  $p_\pi - p_\pi$  multiple bonds.

**Group No-13 Elements:** (B, Al, Ga, In, Tl, Nh)

- **General Electronic Configuration:**  $ns^2 np^1$
- **Atomic radius:**  $B < Ga < Al < In < Tl$   
 $r_{Ga} < r_{Al}$  due to ineffective shielding of valence electrons by intervening 3d-electrons in Ga.
- **Ionization Enthalpies:**  $B > Tl > Ga > Al > In$
- **Electronegativity:**  $B > Tl > In > Ga > Al$
- **Oxidation States:** B (+3), Al (+3), Ga (+3, +1), In (+3, +1), Tl (+1, +3)  
 Tl (+1) is more stable than Tl (+3) due to inert pair effect.
- **Nature of Compounds:** Compounds of group 13 elements are electron deficient i.e. Lewis Acid and hence used as industrial catalyst e.g.  $BF_3$ ,  $AlCl_3$ .
- **Oxides:**

$B_2O_3$	$Al_2O_3, Ga_2O_3$	$In_2O_3$	$Tl_2O$
Acidic	Amphoteric	Basic	Strongly Basic

- **Halides:**  $MX_3$  type, Electron deficient (Lewis acid),  $AlCl_3$  exist as dimer
- **Borax:**  $Na_2B_4O_7 \cdot 10H_2O$ . On heating it form transparent glassy bead consisting of  $NaBO_2 + B_2O_3$ .
- **Boric acid:**  $H_3BO_3$ , It acts as a Lewis acid by accepting electron pair from  $OH^-$  ions of water.
- **Diborane:**  $B_2H_6$ , Colourless & toxic gas, acts as Lewis acid due to having electron deficient  $3c-2e^-$  bonds. Obtained by treating  $BF_3$  with  $LiAlH_4$  or  $NaH$ , Also obtained by treating  $NaBH_4$  with  $I_2$ .
- **Borazine:**  $B_3N_3H_6$ , It is isostructural with benzene and hence known as inorganic benzene. Prepared by heating  $B_2H_6$  with  $NH_3$

### Group -14 Elements: (C, Si, Ge, Sn, Pb,Fl)

- **General Electronic Configuration:**  $ns^2 np^2$
- **Atomic radius:**  $C < Si < Ge < Sn < Pb$
- **Ionisation Enthalpy:**  $LiH_x : C > Si > Ge > Sn < Pb$
- **Oxidation States:** C (+4), Si (+4), Ge (+4, +2), Sn (+4, +2), Pb (+4, +2)  
Pb (+2) is more stable than Pb (+4) due to inert pair effect.
- **Oxides:** Form di oxides ( $MO_2$ ) & mono oxides (MO).  
 $PbO_2$  is powerfull oxidizing agent because Pb stabilizes in +2 oxidation state due to inert pair effect.  $CO_2$  is gas while  $SiO_2$  is network solid because C has ability to form  $p_\pi - p_\pi$  multiple bonds.
- **Halides:** Form tetra halides ( $MX_4$ ) & dihalides ( $MX_2$ ).  
Tetra halides are more covalent due to greater polarizing power of cation.  
 $CCl_4$  is not hydrolysed with water as C has no vacant d-orbital to accept electron pair from water.
- **Catenation:**  $C \gg Si > Ge \approx Sn \gg Pb$
- **Allotropes of carbon:** Diamond ( $sp^3$ ), Graphite ( $sp^2$ ), Fullerenes ( $sp^2$ )
- **Silicones:** Silicones are synthetic organosilicon compounds containing  $R_2SiO$  repeating units. Silicones are water repellent, heat resistant, chemically inert, electrical insulators, resistant to oxidation.
- **Silicates:** Silicates are compounds in which anions are derived from Si-o-si- tetrahedral units.
- **Zeolites:** Zeolites are 3D silicates in which some of the Si atoms are replaced by  $Al^{3+}$  ions and negative charge is balanced by cations such as  $Na^+$ ,  $K^+$ ,  $Ca^{2+}$  etc.
- ZSM-5 is used in petrochemical industries to convert methanol into petrol.

### MULTIPLE CHOICE QUESTIONS (MCQ)

- The element which exists in liquid state for a wide range of temperature and can be used for measuring high temperature is
  - B
  - Al
  - Ca
  - Ga
- Which of the following is Lewis acid?
  - $\text{AlCl}_3$
  - $\text{MgCl}_2$
  - $\text{CaCl}_2$
  - $\text{BaCl}_2$
- The geometry of a complex species can be understood from the knowledge of type of hybridisation of orbitals of central atom. The hybridisation of orbitals of central atom in  $[\text{Be}(\text{OH}_4)]^-$  and the geometry of the complex are respectively
  - $\text{sp}^3$ , tetrahedral
  - $\text{sp}^3$ , square planar
  - $\text{sp}^3\text{d}^2$ , octahedral
  - $\text{dsp}^2$ , square planar
- Which of the following oxides is acidic in nature?
  - $\text{B}_2\text{O}_3$
  - $\text{Al}_2\text{O}_3$
  - $\text{Ga}_2\text{O}_3$
  - $\text{In}_2\text{O}_3$
- The exhibition of highest co-ordination number depends on the availability of vacant orbitals in the central atom. Which of the following elements is not likely to act as central atom in  $\text{MF}_6^{3-}$ ?
  - B
  - Al
  - Ga
  - In
- Boric acid is an acid because its molecule
  - Contains replaceable  $\text{H}^+$  ion
  - Gives up a proton
  - Accepts  $\text{OH}^-$  from water releasing proton
  - Combines with proton from water molecule
- Catenation i.e., linking of similar atoms depends on size and electronic configuration of atoms. The tendency of catenation in Group 14 elements follows the order:
  - $\text{C} > \text{Si} > \text{Ge} > \text{Sn}$
  - $\text{C} \gg \text{Si} > \text{Ge} = \text{Sn}$
  - $\text{Si} > \text{C} > \text{Sn} > \text{Ge}$
  - $\text{Ge} > \text{Sn} > \text{Si} > \text{C}$





## ASSERTION-REASON TYPE QUESTIONS

**In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question**

1. Assertion (A) : If aluminium atoms replace a few silicon atoms in three dimensional network of silicon dioxide, the overall structure acquires a negative charge

Reason (R) : Aluminium is trivalent while silicon is tetravalent.

- (i) Both A and R are correct and R is the correct explanation of A.
  - (ii) Both A and R are correct but R is not the correct explanation of A.
  - (iii) Both A and R are not correct
  - (iv) A is not correct but R is correct.
2. Assertion (A) : Silicon is water repelling in nature.

Reason (R) : Silicon is organosilicon polymers, which have  $(-R_2SiO-)$  as repeating unit

- (i) A and R both are correct and R is the correct explanation of A.
- (ii) Both A and R are correct but R is not the correct explanation of A
- (iii) A and R both are not true.
- (iv) A is not true but R is true.

## 1-MARK QUESTIONS

1. Mention two important ores of boron.
2. Name the elements of group 13 which forms only covalent compounds.
3. Why the atomic radius of gallium is less than that of Al ?
4. Why does Boron form electron deficient compounds ?
5. Boron does not exist as  $B^{3+}$  ion. Why ?
6. Why the trihalide of group 13 elements fume in moist air ?
7. Aluminum form  $[AlF_6]^{3-}$  but boron does not form  $[BF_6]^{3-}$ .
8. Why boric acid is a monobasic acid ?
9. White fumes appear around the bottle of anhydrous  $AlCl_3$ . Give reason.
10.  $AlCl_3$  exist as dimer while  $BCl_3$  exist as monomer, why ?

11. Mention the type of hybridization of Boron in  $B_2H_6$ . [Ans.  $sp^3$ ]
12. Write the formula of inorganic benzene.
13. Why aluminum utensils should not be kept in water overnight.
14. Explain what happens when boric acid is heated.
15.  $BCl_3$  exists but  $BH_3$  does not. Explain.
16. Why  $SnCl_4$  is more covalent than  $SnCl_2$  ?
17. Why  $PbCl_4$  is good oxidising agent ?
18. What are germanes and plumbanes ?
19. Give one example of zeolite.
20. Mention the type of hybridization of carbon in diamond and graphite.
21. Why  $CCl_4$  is insoluble in water but  $SiCl_4$  is soluble in water? Explain.
22. Give two uses of silicones.
23. Why graphite is used as lubricant ?
24. Lead (Pb) do not form  $PbI_4$ . Why ?
25.  $CO_2$  is gas while  $SiO_2$  is solid at room temperature. Explain why ?
26. Explain why silicon shows a higher covalency than carbon?
27. Out of carbon and silicon which can form multiple bonds and why ?
28. Write the formula of dry ice.
29. Mention the basic building unit of all silicates.
30. Graphite is a good conductor of electricity, but diamond is not. Why ?

### 2-MARKS QUESTIONS

1. Draw the structure of diborane.
2. What happens when :
- (a) Borax is heated strongly.
- (b) Boric acid is added to water.
3. Write balanced chemical equations for :
- (a)  $BF_3 + LiH \longrightarrow$
- (b)  $B_2H_6 + NH_3 \longrightarrow$

4. Write chemical reactions to justify amphoteric nature of Al.
5. Suggest reason why the B-F bond length in  $\text{BF}_3$  and  $\text{BF}_4^-$  differ.
6. Give reason for the following :
  - (i)  $\text{BF}_3$  act as weak Lewis acid.
  - (ii) Boron cannot show covalency more than four.
7. How can you explain higher stability of  $\text{BCl}_3$  as compared to  $\text{TlCl}_3$ ?
8. Give reason for the following :
  - (i) Aluminium alloys are used to make aircraft body.
  - (ii) Aluminium wire is used to make transmission cables.
9. Describe the shapes of  $\text{BF}_3$  and  $\text{BH}_4^-$ . Assign the hybridization of boron in these species.
10. Explain the chemistry of borax bead test.
11.  $[\text{SiF}_6]^{2-}$  is known whereas  $[\text{SiCl}_6]^{2-}$  not. Give reason.
12. Hydrolysis of  $\text{SiCl}_4$  take place but of  $\text{CCl}_4$  does not. Why ?
13. Account for the following :
  - (a)  $\text{CO}_2$  is gas while  $\text{SiO}_2$  is solid at room temperature.
  - (b) Solid  $\text{CO}_2$  is known as dry ice.
14. Elemental silicon does not form graphite like structure as carbon does. Give reason.
15. Suggest a reason as to why CO is poisonous?
16. How is excessive content of  $\text{CO}_2$  responsible for global warming ?
17. What is allotropy ? Name two elements which exhibit allotropy.
18. Write equations for the production of water gas and producer gas from coke.
19. Define zeolite. Name the zeolite which converts alcohols directly into gasoline.
20. Arrange the hydrides of group 14 elements in increasing order of :
  - (a) Thermal stability
  - (b) Reducing power.

### 3-MARKS QUESTIONS

1. Give reasons of the following :
  - (i) In diborane, two B – H – B bonds are different from common covalent bonds.
  - (ii) Aluminium metal shows amphoteric behaviour.
  - (iii) Quartz is used to develop extremely accurate clocks.
2. A certain salt X gives the following results :
  - (i) Its aqueous solution is alkaline to litmus.
  - (ii) It swells up to a glassy material Y on strong heating.
  - (iii) When conc.  $\text{H}_2\text{SO}_4$  is added to a hot solution of X, white crystal of an acid Z separates out. Write equations for all the above reactions and identify X, Y and Z.
3. Write balanced chemical equation for :
  - (i)  $\text{B}_2\text{H}_6 + \text{H}_2\text{O} \longrightarrow$
  - (ii)  $\text{Al} + \text{NaOH} \longrightarrow$
  - (iii)  $\text{NaOH} + \text{B}_2\text{H}_6 \longrightarrow$
4. List two important properties in which boron differs from the rest of the members of group. Mention the main reasons for the difference.
5. What are electron deficient compounds? Are  $\text{BCl}_3$  and  $\text{SiCl}_4$  electron deficient species ? Explain.
6. Select the member(s) of group 14 that :
  - (i) Forms the most acidic dioxide.
  - (ii) Is commonly found in + 2 oxidation state.
  - (iii) Used as semiconductor.
7. What are allotropes ? Sketch the structure of two allotropes of carbon namely diamond and graphite.
8. Give suitable reasons for the following :
  - (a)  $\text{CO}_2$  turns lime water milky, but if passed for a long time, the solution become transparent again.
  - (b) Graphite is a good conductor of electricity but diamond is insulator.
  - (c) Lead (IV) chloride is highly unstable towards heat.

9. (i) Write the resonance structure of  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$ .  
 (ii) Write the name of thermodynamically most stable form of carbon.
10. (i) Explain why is there a phenomenal decreases in ionisation enthalpy from carbon to silicon ?  
 (ii) Write an industrial application of silicones.

### 5-MARKS QUESTIONS

1. When metal X is treated with NaOH, a white precipitate 'A' is obtained, which is soluble in excess of NaOH to give soluble complex (B). Compound 'A' is soluble in dilute HCl to form compound 'C'. The compound 'A' when heated strongly gives 'D', which is used to extract metal. Identify X, A, B, C and D. Write suitable equations to support their identities.
2. (i) If B-Cl bond has dipole moment explain why  $\text{BCl}_3$  molecules has zero dipole moment.  
 (ii) A mixture of dil. NaOH and aluminium pieces is used to open drain. Give reason.  
 (iii) Aluminium wire is used to make transmission cables. Why ?
3. (i) Identify the compounds X and Y in the following reactions :  
 (a)  $\text{Na}_2\text{B}_4\text{O}_7 + 2\text{HCl} + 5\text{H}_2\text{O} \rightarrow 2\text{NaCl} + \text{X}$   
 (b)  $\text{X} \xrightarrow{370\text{K}} \text{HBO}_2 \xrightarrow{>370\text{K}} \text{Y}$
- (ii) Write the name of group 13 element which is used to measure high temperature.  
 (iii) Why in case of thallium + 1 oxidation state is more stable than + 3?
4. Compare the general trend in the following properties of the elements of group 13 and 14 :  
 (a) Atomic size, (b) Ionisation enthalpy, (c) Metallic character, (d) Oxidation states, (e) Nature of halides.

5. Name the following :
- (a) The crystalline form of silica used in modern radio and T.V. broadcasting and mobile radio communication.
  - (b) The oxides of carbon which form a complex with haemoglobin 300 times more faster than oxygen.
  - (c) The allotrope of carbon which has  $\Delta_f H^\theta = 0$ .
  - (d) A type of polymer is semiorganic in nature.
  - (e) Two man made silicates.
6. Explain the formation of (i) water gas (ii) producer gas. Give their uses. What happens when  $\text{CO}_2$  is passed through limewater?
- (i) for short duration
  - (ii) for long duration.

## UNIT TEST

Time Allowed: 1 hr

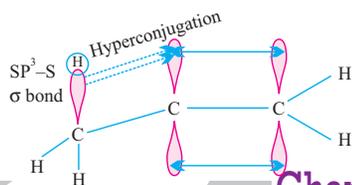
Maximum Marks : 20

General Instructions:

- (i) All questions are compulsory.
- (ii) Maximum marks carried by each question are indicated against it.

- 
1. Which of the following is Lewis acid? [1]  
(a)  $\text{AlCl}_3$       (b)  $\text{MgCl}_2$       (c)  $\text{CaCl}_2$       (d)  $\text{BaCl}_2$
  2. Dry ice is [1]  
(a) Solid  $\text{CO}_2$     (b) Solid  $\text{SO}_2$     (c) Solid  $\text{N}_2$     (d) Solid  $\text{NH}_3$
  3. Chemical formula of diborane is \_\_\_\_\_. [1]
  4. Write an example of shape relative catalyst. [1]
  5. Allotrope of carbon with  $\text{sp}^3$  hybridisation state is \_\_\_\_\_? [1]
  6. Complete the following chemical equations : [2]  
(a)  $\text{B}_2\text{H}_6 + \text{NH}_3 \longrightarrow$   
(b)  $\text{BF}_3 + \text{LiH} \longrightarrow$
  7. Write the chemical reactions involved in borax bead test. [2]
  8. What are allotrope? Sketch the structure of two allotrope of carbon namely diamond and graphite. [3]
  9. Compare the properties of the elements of group-13 and 14 [3]  
(a) Atomic size  
(b) Ionisation enthalpy  
(c) Oxidation state
  10. (a) Explain the formation of (i) water gas (ii) producer gas [5]  
(b) Identify the compound X and Y in the following reactions  
(i)  $\text{Na}_2\text{B}_4\text{O}_7 + 2\text{HCl} + 5\text{H}_2\text{O} \longrightarrow 2\text{NaCl} + \text{X}$   
(ii)  $\text{X} \xrightarrow{370\text{ K}} \text{HBO}_2 \xrightarrow{\geq 370\text{ K}} \text{Y}$   
(c) Write two important applications of silicons.

\*\*\*\*\*



## Chapter - 12

# Organic Chemistry : Some Basic Principles and Techniques

### FAST TRACK : QUICK REVISION

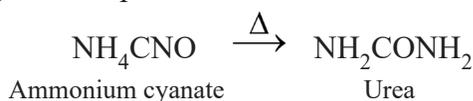
## ORGANIC CHEMISTRY

It deals with the study of hydrocarbons (compounds of carbon and hydrogen elements) and their derivatives.

Some organic compounds may also contain nitrogen, oxygen, sulphur, phosphorus, halogens, etc.

Berzelius, proposed that a 'vital force' was responsible for the formation of organic compounds.

This was rejected by F. Wohler who synthesised first organic compound urea from an inorganic compound.

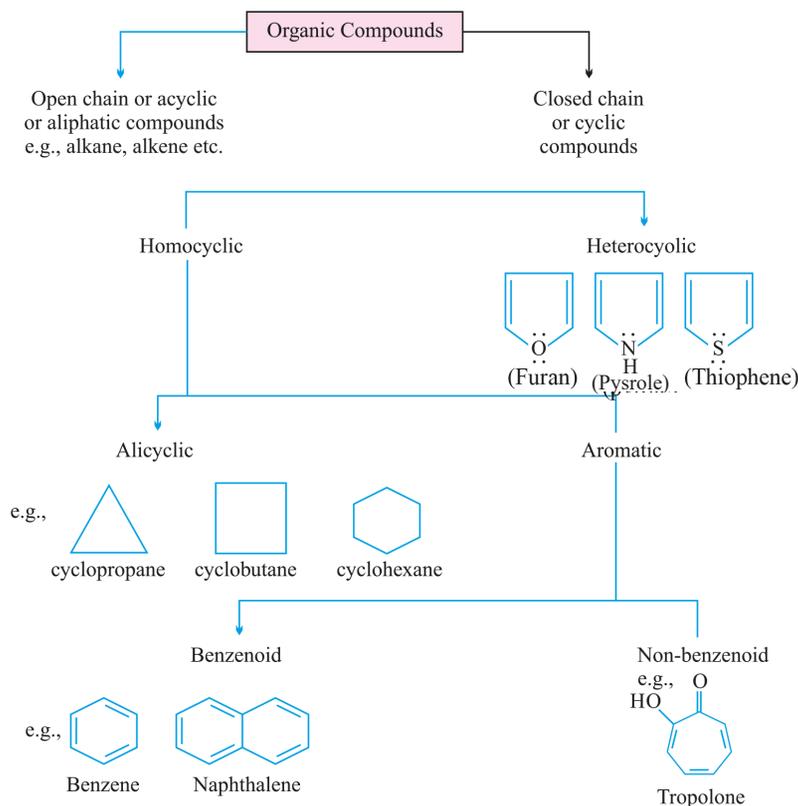


- Acetic acid was synthesised by Kolbe and methane by Berthelot.
- **Types of hybridisation of C-atom :**

Hybridisation	Structure	Bond angle	Examples
$sp^3$	Tetrahedral	$109^\circ 28'$	Ethane, Methane
$sp^2$	Trigonal	$120^\circ$	Ethene, Propene
$sp$	Linear	$180^\circ$	Ethyne, Propyne

- **Reasons for existence of large number of organic compounds:**
- **Catenation :** The property of atoms of an element to link with one another forming chains of identical atoms is called *catenation*. Carbon exhibits catenation to the maximum extent.
- **Isomerism :** It is the property by virtue of which two or more compounds have the same molecular formula but different physical or chemical properties.

- **Formation of multiple bonds :** Because of its small size carbon atom is capable of forming multiple bonds with other atoms and this gives a variety of compounds.
- **CLASSIFICATION OF ORGANIC COMPOUNDS**

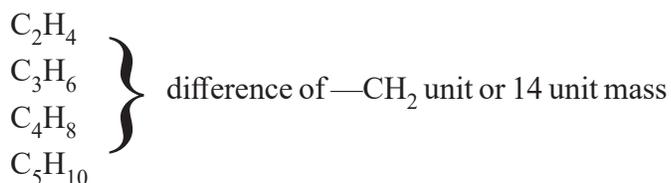


- **CLASSIFICATION OF CARBON ATOMS**

**On the basis of number of C attached**

- Primary carbon atom :** when carbon atom is attached with one other carbon atom only, it is called **primary or 1°** carbon atom.
  - Secondary carbon atom :** When carbon atom is attached with two other carbon atoms, it is called **secondary or 2°** carbon atom.
  - Tertiary carbon atom :** When carbon atom is attached with three other carbon atoms, it is called **tertiary or 3°** carbon atom.
  - Quaternary carbon atom :** When carbon atom is attached with four other carbon atoms, it is called **quarterly or 4°** carbon atom.
- **Functional Group :** The atom *e.g.*,  $-\text{Cl}$ ,  $-\text{Br}$ , etc., or group of atoms *e.g.*,  $-\text{COOH}$ ,  $-\text{CHO}$ , which is responsible for the chemical properties of the molecule, is called **functional group**.

- **Homologous Series :** The series in which the molecular formula of adjacent members differ by a  $-\text{CH}_2$  unit, is called homologous series and the individual members are called homologous, *e.g.*, The homologous series of alkene group is



The general characteristics of this series are :

1. All the homologues contain same functional group. That's why their chemical properties are almost similar.
2. All the members of a series have same general formula, *e.g.*,

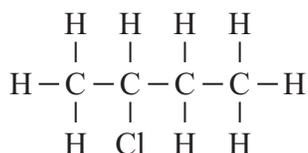
Series	General Formula
Alkanes	$\text{C}_n\text{H}_{2n+2}$
Alkenes	$\text{C}_n\text{H}_{2n}$
Alkynes	$\text{C}_n\text{H}_{2n-2}$
Alcohol and ether	$\text{C}_n\text{H}_{2n+2}\text{O}$
Aldehyde and ketone	$\text{C}_n\text{H}_{2n}\text{O}$
Acid and ester	$\text{C}_n\text{H}_{2n}\text{O}_2$

3. All the members can be prepared by almost similar methods.
4. With increase in the molecular weight of a series, the physical properties vary gradually.

- **Representation of Organic Compounds :**

Organic compounds can be represented by the following ways:

- (i) **Complete Structural Formula :** All the bonds present between any two atoms are shown clearly. *e.g.*,

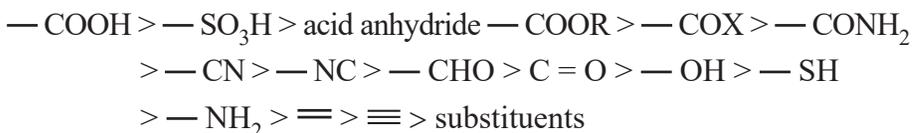




**Rule 2 : Lowest number rule :** Numbering is done in such a way so that

- (i) branching if present gets the lowest number.
- (ii) the sum of numbers of side chain is lowest.
- (iii) principal functional group gets the lowest number.

Select the principal functional group from the preference series :



Functional group other than the principal functional group are called substituents.

**Rule 3: Naming the prefix and suffixes :** Prefix represents the substituent and suffix is used for principal functional group.

Primary suffix are **ene**, **ane** or **yne** used for double, single and triple bonds respectively.

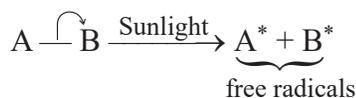
**Secondary suffixes are tabulated below :**

No.	Class	Formula	Prefix	Suffix
1.	Acid halides	$\begin{array}{c} \text{O} \\    \\ -\text{C}-\text{X} \end{array}$	halocarbonyl	—oyl halide —carbonyl halide
2.	Alcohols	—OH	hydroxy	—ol
3.	Aldehydes	—CHO	formyl	—al —carbaldehyde
4.	Ketones	$\text{>C}=\text{O}$	oxo (keto)	—one
5.	Amides	—CONH <sub>2</sub>	carbamoyl	—amide
6.	Amine	—NH <sub>2</sub>	amino	—amine
7.	Carboxylic acid	—COOH	carboxy	—carboxylic acid
8.	Ester	—COOR	alkoxy carbonyl	—alkyl alkanoate
9.	Nitriles	—CN	cyano	—nitrile
10.	Sulphonic acid	—SO <sub>2</sub> —OH	sulpho	—sulphonic acid



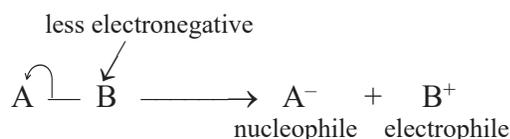
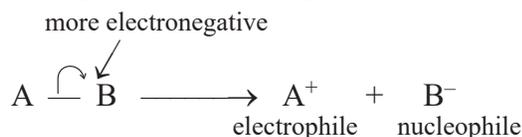
- **Fission of a Covalent Bond :**

- (i) **Homolytic Fission :** In this one of the electrons of the shared pair in a covalent bond goes with each of the bonded atoms. The neutral chemical species thus formed, are called free radicals. Generally, homolytic fission takes place in non-polar covalent molecules in the presence of sunlight or high temperature.



Free radicals are highly reactive, neutral and electron deficient species.

- (ii) **Heterolytic Fission :** The covalent bond breaks in such a fashion that the shared pair of electrons goes with one of the fragments.



Heterolytic fission generally takes place in polar covalent molecules but in non-polar molecules, it takes place in the presence of catalyst like  $AlCl_3$  (anhy.),  $FeCl_3$  (anhy.) etc.

- **Attacking Reagents :**

These are of two types

- (i) **Electrophiles or Electrophilic Reagents**

These are electron deficient species, i.e., behave as Lewis acids.

e.g.,  $Cl^+$ ,  $\overset{+}{N}O_2$ ,  $CH_3CO^+$  etc.

$BF_3$ ,  $ZnCl_2$  (anhydrous),  $FeCl_3$  (anhydrous),  $AlCl_3$  (anhydrous)

- (ii) **Nucleophiles or Nucleophilic Reagents**

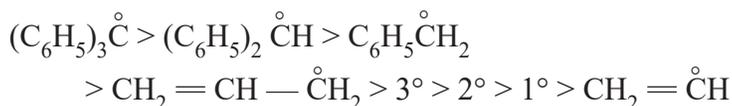
These are negatively charged or neutral molecules with unshared electron pair.

e.g.,  $\overset{-}{O}H$ ,  $CN^-$ ,  $\overset{\circ\circ}{R}NH_2$ ,  $\overset{\circ\circ}{N}H_3$

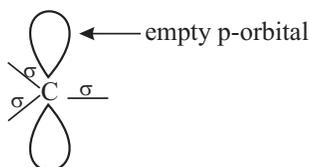
- **Reaction Intermediates :**

- (i) **Free radicals :** These are the product of homolysis and contain an odd electron. These are highly reactive planar species with  $sp^2$  hybridisation.

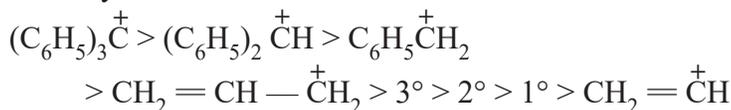
Their order of stability is



- (ii) **Carbocations** : These are the product of heterolysis and contain a carbon bearing positive charge. These are electron deficient species. These are also polar chemical species i.e.,  $sp^2$  hybridised with an empty p-orbital.

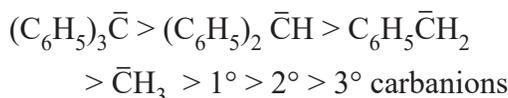


Stability order of carbocation is



- (iii) **Carbanions** : These are the product of heterolysis and contain a carbon bearing negative charge and 8 electrons in its valence shell.

These have pyramidal shape with  $sp^3$  hybridised carbon (having one lone pair) order of stability of carbanions is



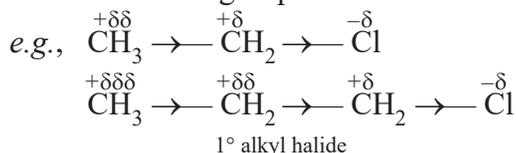
● **Electron Displacement in Covalent Bond**

1. **Inductive Effect** : If shared pair is more shifted towards more electronegative atom, the less electronegative atom acquires slight positive charge and more electronegative atom acquires partial negative charge,



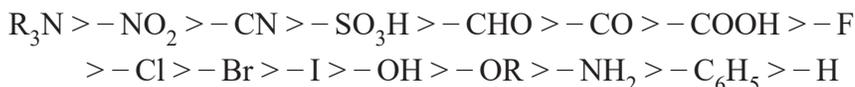
Permanent effect and propagates through carbon chain.

Atoms or groups having greater electron affinity than hydrogen are said to have electron attracting or negative inductive effect ( $-I$ ) while that having, smaller electron affinity than hydrogen are said to have electron releasing or positive inductive effect ( $+I$ ).

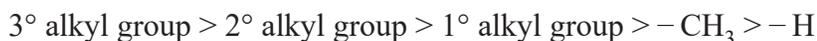


Cl has  $-I$  effect and alkyl group has  $+I$  effect.

Order of groups producing  $-I$  effect is



Order of groups producing  $+I$  effect is

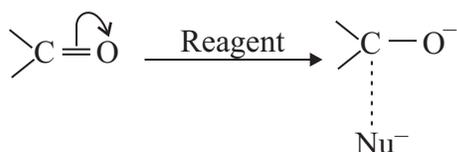
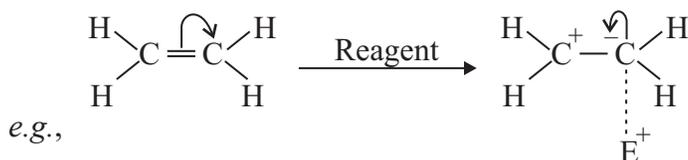


● **Applications of Inductive Effect**

- (i) Presence of groups showing  $+I$  effect increases the stability of carbocation while presence of groups showing  $-I$  effect decreases their stability.
- (ii) Strength of acid increases with the attachment of group showing  $-I$  effect and decreases with the attachment of group showing  $+I$  effect.
- (iii) Presence of  $+I$  showing groups increases the basic strength of amines.

2. **Electromeric Effect** : Defined as the polarity produced in a multiple bonded compound as a reagent approaches it. In the presence of attacking reagent, the two  $\pi$  electrons are completely transferred to any of the one atom. This effect is temporary.

It may be of  $+E$  type (when displacement of electron pair is away from the atom of group) or of  $-E$  type (when displacement is towards the atom or group).



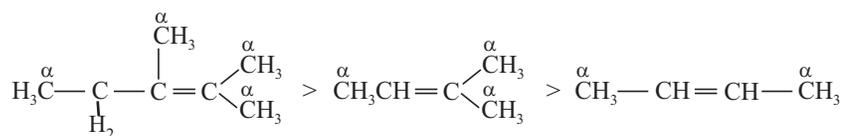
3. **Hyper-conjugation** : It involves delocalisation of  $\sigma$  electron of a C - H bond of an alkyl group attached directly to an atom of unsaturated system or to an atom with an unshared p-orbital.



This effect is also called no bond resonance or Baker Nathan effect.

## Applications of Hyper-conjugation

**Stability of alkenes :** More the number of  $\alpha$ -hydrogen atoms, more stable is the alkene.



**Stability of Carbocation :** Greater the number of alkyl groups attached to positively charged carbon atom, the greater is the stability.



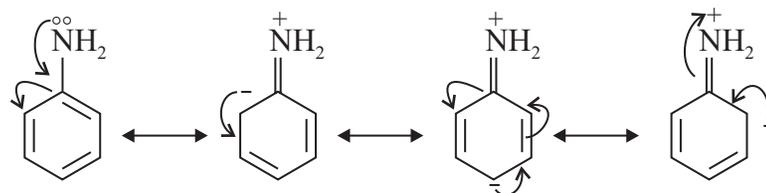
4. **Resonance Effect :** When the properties of a molecule cannot be shown by a single structure and two or more structures are required to show all the properties of that molecule, then the structures are called resonating structures or canonical forms and the molecule is referred as resonance hybrid. This phenomenon is called resonance.

### Conditions for resonance

- The arrangement of atoms must be identical in all the formula.
- The energy content of all the canonical forms must be nearly same.
- Each canonical of  $\pi$  electrons. This effect may be of +R type or -R type.

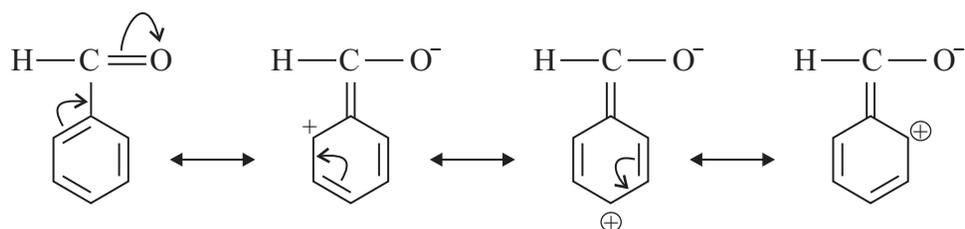
### Positive Resonance Effect (+R)

Electron donating groups with respect to conjugated system show +R effect. Central atom of functional groups should be more electronegative than the surrounding atoms or groups to show +R effect. *e.g.*, halogens, -OH, -OR, -NH<sub>2</sub>, NHCOR, etc.



### Negative Resonance Effect (-R)

Electron withdrawing groups with respect to conjugate system show -R effect. Central atom of functional groups should be less electronegative than surrounding atoms or groups to show -R effect. *e.g.*, halogens, -COOH, -COOR, CHO, -CN, -NO<sub>2</sub>, etc.



## • Methods of Purification of Organic Compounds

Method	Principle	Applications
Crystallization	Different solubilities of a given organic compound and its impurities in the same solvent.	<ul style="list-style-type: none"> <li>Crystallization of sugar (containing an impurity of common salt) is achieved by shaking the impure solid with hot ethanol at 348K (sugar dissolves whereas common salt remains insoluble).</li> </ul>
Sublimation	Some solid substances change from solid to vapour state without passing through liquid state. Sublimable compounds get separated from non-sublimable impurities.	<ul style="list-style-type: none"> <li>Iodine from sodium chloride (as iodine sublimes readily leaving behind sodium chloride).</li> <li>Camphor, naphthalene, anthracene, benzoic Acid, etc. are purified.</li> </ul>
Distillation	It is used to separate <ul style="list-style-type: none"> <li>• Volatile liquids from non-volatile impurities.</li> <li>• Liquids having sufficient difference in their boiling points.</li> </ul>	<ul style="list-style-type: none"> <li>• Hexane (b.p. 342K) and toluene (b.p. 384K)</li> <li>• Chloroform (b.p. 334K) and aniline (b.p. 457K)</li> </ul>
– Fractional Distillation	If the difference in boiling points of two liquids is not much, this method is used.	• Crude oil in petroleum industry is separated into various useful fractions such as gasoline, kerosene oil, diesel oil, lubricating oil, etc.
– Steam Distillation	This method is used to separate substances which are (i) steam volatile, (ii) immiscible with water, (iii) possess a vapour pressure of 10-15 mm Hg and (iv) contain non-volatile impurities.	<ul style="list-style-type: none"> <li>• Aniline is separated from aniline water mixture.</li> <li>• Essential oils, turpentine oil, o-nitrophenol, bromobenzene nitrobenzene, etc. can be purified.</li> </ul>
Differential Extraction	By shaking an aqueous solution of an organic compound with an organic solvent in which the organic compound is more soluble than in water. The organic solvent and the aqueous solution should be immiscible with each other so that they can form two distinct layers which can be separated by using separating funnel.	• Benzoic acid can be extracted from its water solution using benzene.

Chromatography	Differential movement of individual components of a mixture through a stationary phase under the influence of a mobile phase.	<ul style="list-style-type: none"> <li>Widely used for separation purification, identification and characterization of the components of a mixture, whether coloured or colourless.</li> </ul>
– Adsorption Chromatography	Differential adsorption of the various components of a mixture on a suitable adsorbent such as silica gel or alumina.	
– Column Chromatography	The mixture is passed through adsorbent packed in glass tube.	<ul style="list-style-type: none"> <li>Mixture of naphthalene and benzophenone.</li> </ul>
– Thin Layer Chromatography	The mixture is passed over adsorbent on a thin glass plate.	<ul style="list-style-type: none"> <li>Amino acids can be detected by spraying the plate with ninhydrin solution.</li> </ul>
– Partition Chromatography	Differential partitioning of components of a mixture between stationary and mobile phases.	
– Paper Chromatography	A special quality paper known as chromatography paper is used. It contains water trapped in it, which acts as the stationary phase.	<ul style="list-style-type: none"> <li>For separation of sugars and amino acids.</li> </ul>

Types of Chromatography	Mobile / Stationary Phase
Column Chromatography	Liquid / Solid
Thin Layer Chromatography	Liquid / Solid
High Performance Liquid Chromatography (HPLC)	Liquid / Solid
Gas Liquid Chromatography (GLC)	Gas / Solid
Partition or Paper Chromatography	Liquid / Solid

Element	Detection	Confirmatory Test	Reactions
Carbon	$2\text{CuO} + \text{C} \xrightarrow{\Delta} 2\text{Cu} + \text{CO}_2$	$\text{CO}_2$ gas turns lime water milky.	$\text{CO}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O}$ Lime water      Milkiness
Hydrogen	$\text{CuO} + 2\text{H} \xrightarrow{\Delta} \text{Cu} + \text{H}_2\text{O}$	Water droplets appear on the cooler part of the ignition tube and also turns anhydrous $\text{CuSO}_4$ blue.	$\text{CuSO}_4 + 5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ White                      Blue
Nitrogen	Lassaigne's extract (L.E.) $\text{Na} + \text{C} + \text{N} \xrightarrow{\Delta} \text{NaCN}$ (L.E.)	L.E. + $\text{FeSO}_4 + \text{NaOH}$ , boil and cool + $\text{FeCl}_3 + \text{conc. HCl}$ . Gives blue or green colour.	$\text{FeSO}_4 + 2\text{NaOH} \rightarrow \text{Fe}(\text{OH})_2 + \text{Na}_2\text{SO}_4$ $\text{Fe}(\text{OH})_2 + 6\text{NaCN} \rightarrow \text{Na}_4[\text{Fe}(\text{CN})_6] + 2\text{NaOH}$ $3\text{Na}_4[\text{Fe}(\text{CN})_6] + 4\text{FeCl}_3 \rightarrow \text{Fe}_4[\text{Fe}(\text{CN})_6]_3 + 12\text{NaCl}$ Prussian blue

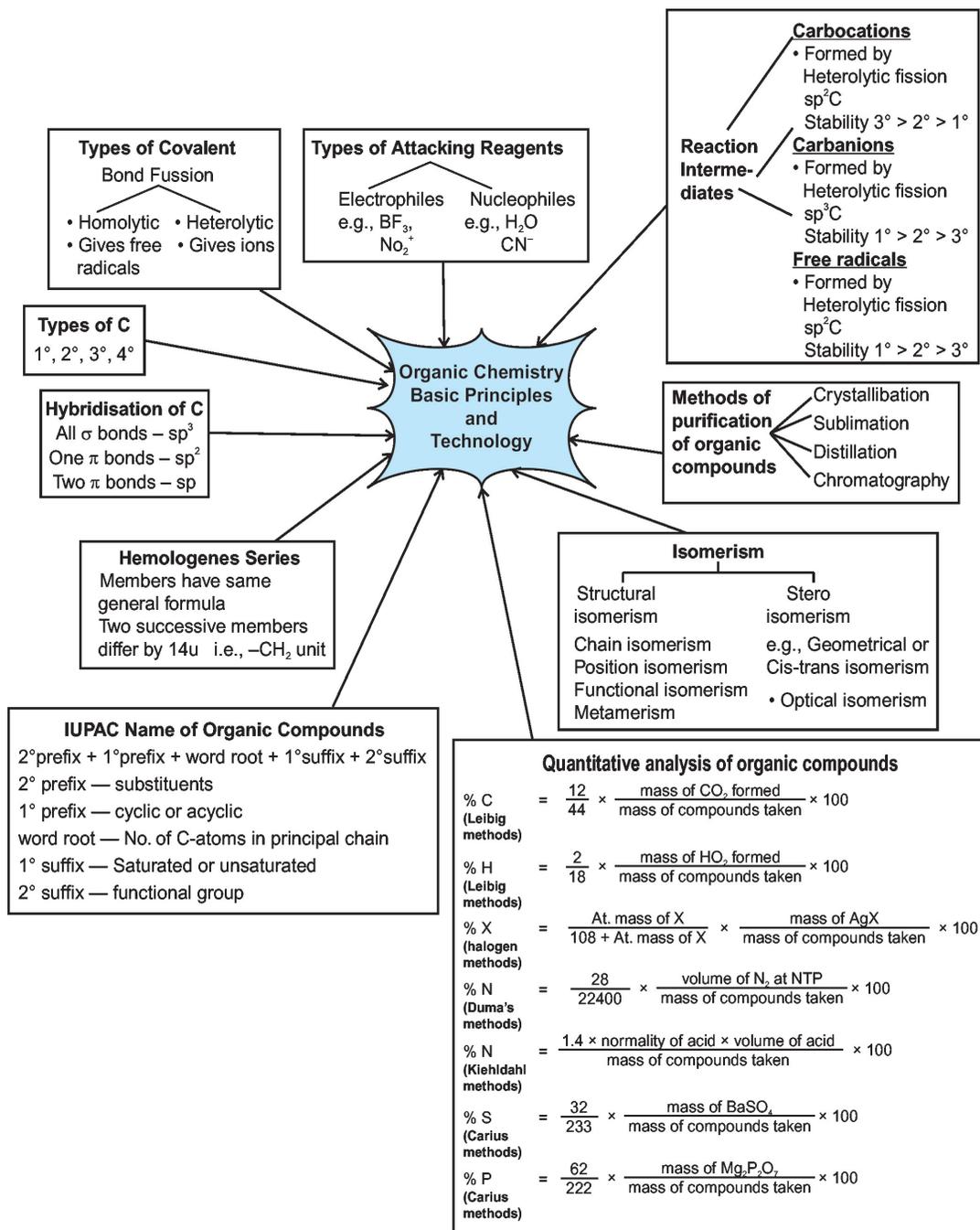
Sulphur	$2\text{Na} + \text{S} \xrightarrow{\Delta} \text{Na}_2\text{S}$ (L.E.)	<p>– L.E. + sodium nitroprusside A deep violet colour.</p> <p>– L.E. + <math>\text{CH}_3\text{COOH} + (\text{CH}_3\text{COO})_2\text{Pb}</math> Gives a black ppt.</p>	<p><math>\text{Na}_2\text{S} + \text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}] \longrightarrow</math> Sodium nitroprusside <math>\text{Na}_4[\text{Fe}(\text{CN})_5\text{NOS}]</math> Deep violet</p> <p><math>\text{Na}_2\text{S} + (\text{CH}_3\text{COO})_2\text{Pb} \xrightarrow{\text{CH}_3\text{COOH}}</math> <math>\text{Pbs}\downarrow + 2\text{CH}_3\text{COONa}</math> Black ppt.</p>
Halogens	$\text{Na} + \text{X} \xrightarrow{\Delta} \text{NaX}$ (L.E.)	<p>L.E. + <math>\text{HNO}_3 + \text{AgNO}_3</math> – White ppt. soluble in aq. <math>\text{NH}_3</math> (or <math>\text{NH}_4\text{OH}</math>) confirms Cl. – Yellow ppt. partially soluble in aq. <math>\text{NH}_3</math> (or <math>\text{NH}_4\text{OH}</math>) confirms Br. – Yellow ppt. insoluble in aq. <math>\text{NH}_3</math> (or <math>\text{NH}_4\text{OH}</math>) confirms I.</p>	<p><math>\text{NaX} + \text{AgNO}_3 \xrightarrow{\text{HNO}_3} \text{AgX}\downarrow</math> ppt.</p> <p><math>\text{AgCl} + 2\text{NH}_3(\text{aq.}) \longrightarrow [\text{Ag}(\text{NH}_3)_2]\text{Cl}</math> White ppt. Soluble</p>
Nitrogen and sulphur together	$\text{Na} + \text{C} + \text{N} + \text{S} \xrightarrow{\Delta} \text{NaSCN}$ Sodium thiocyanate (L.E.)	As in test for nitrogen; instead of green or blue colour, blood red colouration confirms presence of N and S both.	$\text{NaSCN} + \text{FeCl}_3 \longrightarrow$ $[\text{Fe}(\text{SCN})\text{Cl}_2] + \text{NaCl}$ Blood red colour
Phosphorus	$\text{P} \xrightarrow{\text{Na}_2\text{O}_2, \text{boil}} \text{Na}_3\text{PO}_4$	Solution is boiled with nitric acid and then treated with ammonium molybdate $(\text{NH}_4)_2\text{MoO}_4$ . Formation of yellow ppt. indicates presence of phosphate (hence, phosphorus) in organic compound.	$\text{Na}_3\text{PO}_4 + 3\text{HNO}_3 \longrightarrow \text{H}_3\text{PO}_4 + 3\text{NaNO}_3$ $\text{H}_3\text{PO}_4 + 12(\text{NH}_4)_2\text{MoO}_4 + 21\text{HNO}_3$ $\longrightarrow (\text{NH}_4)_3\text{PO}_4 \cdot 12\text{MoO}_3$ Ammonium phosphomolybdate (yellow ppt.) $+ 21\text{NH}_4\text{NO}_3 + 12\text{H}_2\text{O}$

- Quantitative analysis of organic compounds :** The percentage composition of elements present in an organic compound is determined by the methods based on the following principles :

Elements	Method
Carbon and Hydrogen	<p><b>Liebig's Combustion method :</b> A known mass of an organic compound is burnt in the presence of excess of O<sub>2</sub> and CuO.</p> $C_xH_y + \left(x + \frac{y}{4}\right)O_2 \xrightarrow{\Delta} xCO_2 + \frac{y}{2}H_2O$ <p>CO<sub>2</sub> evolved is absorbed by conc. solution of KOH or ascarite (NaOH + CaO). H<sub>2</sub>O produced is absorbed by anhydrous CaCl<sub>2</sub> or Mg(ClO<sub>4</sub>)<sub>2</sub>. Increase in masses of these absorbing compounds gives the masses of CO<sub>2</sub> and H<sub>2</sub>O produced.</p> <p>% of C = <math>\frac{12}{44} \times \frac{\text{mass of CO}_2 \text{ formed}}{\text{mass of compound taken}} \times 100</math>;</p> <p>% of H = <math>\frac{2}{18} \times \frac{\text{mass of H}_2\text{O formed}}{\text{mass of compound taken}} \times 100</math></p>
Halogens	<p><b>Carius method :</b> Halogen in organic compound is precipitated as silver halide by boiling with conc. HNO<sub>3</sub> and then adding AgNO<sub>3</sub>.</p> $X \xrightarrow[\text{AgNO}_3]{\text{HNO}_3, \Delta} \text{AgX} \downarrow$ <p>% of X = <math>\frac{\text{At. mass of X}}{108 + \text{At. mass of X}} \times \frac{\text{mass of AgX formed}}{\text{mass of compound taken}} \times 100</math></p>
Nitrogen	<p><b>Dumas method :</b> Nitrogen containing organic compound is heated with CuO in an atmosphere of CO<sub>2</sub>.</p> $C_xH_yN_z + \left(2x + \frac{y}{2}\right)CO_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O + N_2 + \left(2x + \frac{y}{2}\right)Cu$ <p>N<sub>2</sub> evolved gets collected over conc. KOH solution which absorbs all other gases.</p> <p>% of N = <math>\frac{28}{22400} \times \frac{\text{Vol. of N}_2 \text{ at STP}}{\text{mass of compound taken}} \times 100</math></p> <p><b>Kjeldahl's method :</b> Organic compound + H<sub>2</sub>SO<sub>4</sub> (conc.) <math>\longrightarrow</math> (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> <math>\xrightarrow{2NaOH}</math> Na<sub>2</sub>SO<sub>4</sub> + 2NH<sub>3</sub> + 2H<sub>2</sub>O + 2NH<sub>3</sub> + H<sub>2</sub>SO<sub>4</sub> <math>\longrightarrow</math> (Na<sub>4</sub>)<sub>2</sub>SO<sub>4</sub></p> <p>% of N = <math>\frac{1.4 \times \text{molarity of acid} \times \text{vol. of acid used} \times \text{basicity of acid}}{\text{mass of compound taken}}</math></p>

Sulphur	<p><b>Carius method :</b> Sulphur in organic compound is converted into <math>\text{H}_2\text{SO}_4</math> by boiling with <math>\text{Na}_2\text{O}_2</math> or conc. <math>\text{HNO}_3</math> and is precipitated as <math>\text{BaSO}_4</math> by adding excess of <math>\text{BaCl}_2</math> solution in water.</p> <p>(i) <math>\text{HNO}_3, \Delta</math>  <math>\text{S} \xrightarrow{\text{(i) HNO}_3, \Delta} \text{BaSO}_4 \downarrow</math>  (ii) <math>\text{BaCl}_2</math>                      white ppt.</p> $\% \text{ of S} = \frac{32}{233} \times \frac{\text{mass of BaSO}_4 \text{ formed}}{\text{mass of compound taken}} \times 100$
Phosphorus	<p><b>Ignition method :</b></p> $\text{P} \xrightarrow[\text{heat}]{\text{HNO}_3} \text{H}_3\text{PO}_4$ $\text{H}_3\text{PO}_4 + \text{Mg}^{2+} + \text{NH}_4\text{Cl} \xrightarrow{\Delta} \text{MgNH}_4\text{PO}_4 + \text{HCl}$ <p style="text-align: center;">Magnesium ammonium phosphate (white ppt.)</p> $2\text{MgNH}_4\text{PO}_4 \xrightarrow{\Delta} \text{Mg}_2\text{P}_2\text{O}_7 + 2\text{NH}_3 + \text{H}_2\text{O}$ <p style="text-align: center;">Magnesium pyrophosphate</p> $\% \text{ of P} = \frac{62}{222} \times \frac{\text{mass of Mg P}_2\text{O}_7 \text{ formed}}{\text{mass of compound taken}} \times 100$

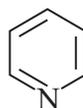
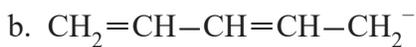
# MIND MAP : ORGANIC CHEMISTRY



## MULTIPLE CHOICE QUESTIONS (MCQ)

- Homolytic fission of C-C bond in ethane gives an intermediate in which carbon is:
  - $sp^3$  hybridised
  - $sp^2$  hybridised
  - sp-hybridised
  - $sp^3d$ - hybridized
- The kind of delocalization involving sigma bond in conjugation with pi electrons is called:
  - Inductive effect
  - Hyperconjugation effect
  - Electromeric effect
  - Mesomeric effect
- Which organic species has only one type of hybridized carbon?
  - $CH_2=C=CH_2$
  - $CH_3-\overset{\oplus}{C}H-CH_3$
  - $CH_3-C=CH$
  - $CH_2=\overset{\oplus}{C}H-CH_2$
- Which of the following can act as an electrophile?
  - $CN^-$
  - $OH^-$
  - $H_2O$
  - $BF_3$
- Which of the following is correct about the species:  $(CH_3)_3-C^+$ 
  - It is planar
  - Its  $C^+$  is  $sp^2$  hybridised
  - A nucleophile can attack on its  $C^+$
  - All of these
- Which of the following has all the effects namely Inductive, Mesomeric and Hyperconjugative ?
  - $CH_3Cl$
  - $CH_3CH=CH_2$
  - $CH_3CH=CHCOCH_2Cl$
  - $CH_2=CH-CH=CH_2$
- The most stable free radical among the following is:
  - $C_6H_5\overset{\bullet}{C}H_2CH_2$
  - $C_6H_5\overset{\bullet}{C}HCH_3$
  - $\overset{\bullet}{C}H_3CH_2$
  - $CH_3\overset{\bullet}{C}HCH_3$
- Isomers of a compound must have :
  - Same physical properties
  - Same chemical properties
  - Same structural properties
  - Same molecular weight
- The type of isomerism not found in alkenes is :
  - Chain isomerism
  - Geometrical isomerism
  - Metamerism
  - Position isomerism

10. Which of the following species have six  $\pi$  conjugated electrons?



d. All of these

11. The correct decreasing order of priority for the functional groups of organic compounds in the IUPAC system of nomenclature is:

a.  $-\text{COOH}$ ,  $-\text{SO}_3\text{H}$ ,  $-\text{CONH}_2$ ,  $-\text{CHO}$

b.  $-\text{SO}_3\text{H}$ ,  $-\text{COOH}$ ,  $-\text{CONH}_2$ ,  $-\text{CHO}$

c.  $-\text{CHO}$ ,  $-\text{COOH}$ ,  $-\text{SO}_3\text{H}$ ,  $-\text{CONH}_2$

d.  $-\text{CONH}_2$ ,  $-\text{CHO}$ ,  $-\text{SO}_3\text{H}$ ,  $-\text{COOH}$

12. The IUPAC name of  $\text{CH}_3-\text{CH}=\text{CH}-\text{C}\equiv\text{CH}$  is:

a. pent-3-en-1-yne

b. pent-3-en-4-yne

c. pent-2-en-4-yne

d. pent-2-en-3-yne

13. Different structures generated due to rotation about C-C axis of an organic molecule are example of:

a. Geometrical isomerism

b. Conformational isomerism

c. Optical isomerism

d. Structural isomerism

14. Which of the following process is not used for the preparation of solid impurities?

a. Distillation

b. Sublimation

c. Crystallisation

d. Vapourisation

15. Quantitative measurement of nitrogen in an organic compound is done by the method:

a. Berthelot method

b. Lassaigne method

c. Carius method

d. Kjeldahl method

## ANSWERS

1. a    2. b    3. d    4. d    5. d    6. c    7. b    8. d    9. c    10. d

11. a    12. a    13. b    14. d    15. a

## FILL IN THE BLANKS

1. The  $\text{CH}_4$  molecule has \_\_\_\_\_ structure.
2. The property of carbon responsible for the large number of carbon compounds is called \_\_\_\_\_.
3. A triple bond between two carbon atoms is composed of one \_\_\_\_\_ and \_\_\_\_\_ bonds.

- An organic compound which decomposes below its boiling point can be purified by \_\_\_\_\_.
- The central atom of  $\text{CH}_2=\text{C}=\text{CH}_2$  is \_\_\_\_\_ hybridized.
- There is a difference of \_\_\_\_\_ mass units between two consecutive members of a homologous series.
- Geometrical isomerism happens due to \_\_\_\_\_ around p bond.
- Electrophiles are the species which attack the regions of \_\_\_\_\_ electron density.
- Hyperconjugation effect is also known as \_\_\_\_\_ resonance.
- In Duma's method, the nitrogen present in an organic compound is set free as \_\_\_\_\_.

### ANSWERS

1. Tetrahedral    2. Catenation    3.  $\sigma$ , two  $\pi$     4. Vacuum distillation    5. sp  
6. 14    7. Restricted rotation    8. high    9. No-bond    10. Nitrogen

### TRUE AND FALSE TYPE QUESTIONS

- In homologous series all the members have the same physical properties.
- IUPAC name of  $\text{CH}_3\text{CN}$  is Methanenitrile.
- Cis-trans isomers have different dipole moments.
- Ethanol and methoxymethane are position isomers.
- A free radical is a species with an unpaired valence electron.
- Acetylene is a linear molecule.
- Resonance brings down the stability of molecule.
- Inductive effect is observed in  $\pi$  bond in presence of attacking reagent.
- The percentage of carbon and hydrogen are estimated simultaneously in an organic compound by Liebig method.
- Chromatography is the method used to separate and purify compounds when present in small amounts.

### ANSWERS

1. F    2. F    3. T    4. F    5. T    6. T    7. F    8. F    9. T    10. T

### ASSERTION REASON TYPE QUESTIONS

The questions given below are Assertion (A) and Reason (R). Use the following key to select the correct answer.

- (a) If both assertion and reason are correct and reason is correct explanation for assertion.

- (b) If both assertion and reason are correct but reason is not correct explanation for assertion.
- (c) If reason is correct but assertion is incorrect.
- (d) If both assertion and reason are incorrect.
1. Assertion: But-1-ene and 2-Methylprop-1-ene are position isomers.  
Reason: Position isomers have same molecular formula but different arrangement of carbon atoms.
  2. Assertion: All the carbon atoms of But-2-ene lie in one plane.  
Reason: All the carbon atoms in But-2-ene are  $sp^2$  hybridized.
  3. Assertion: Alkanes having more than three carbon atoms exhibit chain isomerism.  
Reason: All carbon atoms in alkanes are  $sp^3$  hybridised.
  4. Assertion: In  $CH_2=C=CH_2$ , all the carbon atoms are  $sp^2$  hybridised.  
Reason: All the hydrogen atoms lie in one plane.
  5. Assertion: Butane and 2-Methylbutane are homologues.  
Reason: Butane is a straight chain alkane while 2-Methylbutane is branched chain alkane.
  6. Assertion: Tertiary carbocations are generally formed more easily than primary carbocations.  
Reason: Hyperconjugation as well as inductive effect due to additional alkyl groups stabilize tertiary carbocations.
  7. Assertion: Alkyl carbanions like ammonia have pyramidal shape.  
Reason: The carbon atom carrying negative charge has an octet of electrons
  8. Assertion: Carbocations are planar in nature.  
Reason: Carbocations are  $sp^2$  Hybridised.
  9. Assertion: IUPAC name of compound  $CH_3CH=CH-CHO$  is But-2-enal.  
Reason: Functional group gets preference over multiple in IUPAC name of a compound.
  10. Assertion: Compounds with difference in their boiling points by about  $30^\circ C$  can be separated by simple distillation.  
Reason: All liquid mixture can be separated by distillation method.

## ANSWERS

1. d 2. c 3. c 4. d 5. b 6. a 7. b 8. a 9. a 10. c

## MATCH THE COLUMNS

Match the statements (a,b,c,d) in column I with the statements (I,ii,iii,iv) in column II.

- |    |                                   |   |
|----|-----------------------------------|---|
| 1. | <b>Column I</b>                   | <b>Column II</b>  |
|    | a. Leibig method                  | i. $N_2$  |
|    | b. Dumas method                   | ii. AgX   |
|    | c. Kjehldahl method               | iii. $CO_2$ and $H_2O$                                      |
|    | d. Carius method                  | iv. $NH_3$  |
| 2. | <b>Column I</b>                   | <b>Column II</b>  |
|    | a. Nonbenzenoid aromatic compound | i. 50% s character  |
|    | b. Catenation                     | ii. Species containing single unpaired nonbonding electrons |
|    | c. Free radical                   | iii. Chain-forming property of an element                   |
|    | d. sp-hybridised carbon atom      | iv. Tropolone   |

## ANSWERS

- a. iii    b. iv    c. i    d. ii
- a. iv    b. iii    c. ii    d. i

## ONE WORD ANSWER TYPE QUESTIONS

- Write the formula of next higher homologue of  $C_2H_5OH$ .
- Mention the hybridisation of underlined carbon in  $CH_3\text{C}\equiv N$ .
- What type of isomerism is shown by Pentane and 2-Methylbutane?
- Nucleophiles are Lewis acids or Lewis bases?
- What type of bond fission results in the formation of free radicals?
- What is the number of electrons present in the outermost shell of carbon in the methyl radical?
- What is the other name for no-bond resonance?
- What is the name of the Prussian blue coloured compound formed in Lassaigne's test for nitrogen in an organic compound?
- $SO_3$  is an electrophile or nucleophile in sulphonation reaction of benzene?
- Name suitable technique of separation of the components from a mixture of calcium sulphate and camphor.

## 1-MARK QUESTIONS

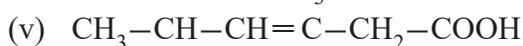
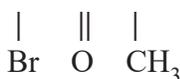
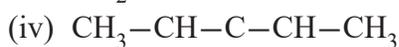
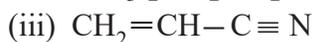
1. Which unique property of carbon is responsible for the large number of carbon compounds?
2. How many  $\sigma$  and  $\pi$  bonds are there in propyne?
3. What is the hybridization of carbon in ethyne?
4. Which has the longest C–C bond length among ethane, ethene and ethyne.
5. How many secondary carbon atoms are present in 2-Methylpentane?
6. Draw structure of 3-Isopropyl-2-methylhexane.
7. Draw bond line structure of  $\text{CH}_3(\text{CH}_2)_6\text{CH}=\text{CH}(\text{CH}_2)_2-\text{COOH}$
8. What are the bond angles in  $\text{sp}^3$ ,  $\text{sp}^2$  and  $\text{sp}$  hybrid orbitals?
9. Write the formulae of first four members of homologous series of alkyne family.
10. Write the correct order of priority of the following functional groups:  
 $-\text{C}\equiv\text{N}$ ,  $>\text{C}=\text{O}$ ,  $-\text{OH}$ ,  $-\text{COOH}$ ,  $-\text{CONH}_2$
11. Write IUPAC name of :
  - (i)  $\text{CH}_3-\text{CH}_2-\text{CN}$
  - (ii)  $\text{CH}_2=\text{CHCH}_2\text{OH}$
  - (iii)  $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)-\text{CO}-\text{CH}_2\text{CH}_3$
  - (iv)  $\text{CH}_3\text{CH}_2-\text{O}-\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$
  - (v)  $\text{Cl}-\text{CH}_2-\text{C}\equiv\text{CH}$
12. What type of isomerism is exhibited by Propanal and Propanone?
13. What is the essential condition for a compound to exhibit geometrical isomerism?
14. Classify the following into electrophiles and nucleophiles:  
 $\text{H}^+$ ,  $\text{NH}_3$ ,  $\text{AlCl}_3$ ,  $\text{NO}_2^+$ ,  $\text{CN}^-$ ,  $\text{H}_2\text{O}$ ,  $\text{ROH}$ ,  $\text{RNH}_2$ , Carbocation
15. What type of attacking reagents are produced by heterolytic cleavage of covalent bond?
16. Name each of the following species and indicate which member of each pair is more stable:
  - (i)  $\text{CH}_3^+$ ,  $\text{CH}_3\text{CH}_2^+$
  - (ii)  $\text{C}_6\text{H}_5\overset{+}{\text{C}}\text{HCH}_3$ ,  $\text{CH}_3\overset{+}{\text{C}}\text{HCH}_3$
  - (iii)  $\text{CH}_2=\text{CH}-\overset{\bullet}{\text{C}}\text{H}_2$ ,  $\overset{\bullet}{\text{C}}\text{H}=\text{CH}-\text{CH}_3$
  - (iv)  $\text{CH}_3-\overset{-}{\text{C}}\text{H}_2$ ,  $\text{CH}_3-\overset{-}{\text{C}}\text{H}-\text{CH}_3$

17. Identify electrophilic centre in  $\text{CH}_3\text{CHO}$ .
18. What is state of hybridization of positively charged carbon atom in carbocation?
19. What is the effect of introducing an alkyl group on the stability of carbocation?
20. Out of Benzyl and ethyl carbocation which is more stable and why?
21. Arrange the following in increasing order of acidic strength:  
 $\text{ClCH}_2\text{COOH}$ ,  $\text{CH}_3\text{CH}_2\text{COOH}$ ,  $\text{ClCH}_2\text{CH}_2\text{COOH}$
22. Name two solvents which are commonly used to dissolve organic solids.
23. Name the technique that can be used for purification of iodine that contains traces of  $\text{NaCl}$ .
24. A liquid (10 mL) has three components A, B, C. which technique is suitable to separate A, B, C from such a small amount of mixture?
25. Name one commonly used adsorbent in column chromatography.
26. Under what condition do we use fractional distillation?
27. A liquid compound starts decomposing well before its boiling point under normal pressure. How will you purify it?
28. Which elements are normally not detected in an organic compound?
29. For which type of compounds Kjeldahl's method is not useful?
30. How do you precipitate sulphur in Carius method?
31. Which method is used to estimate carbon and hydrogen?
32. What do we notice in Lassaigne's test if the compound contains both nitrogen and sulphur?

### 2-MARKS QUESTION

1. How will you account for the presence of large number of organic compounds?
2. Draw the structural formulae of the following compounds:
  - (i) Ethoxypropane
  - (ii) But-1-en-3-yne
  - (iii) 3,4,4-Trimethylhex-1-yne
  - (iv) sec-butyl alcohol
  - (v) But-2-enoic acid
3. How is alkyl group represented? Give the structure and the names of the alkyl groups which originate from (i) n-Butane (ii) isobutene

4. Give IUPAC name of the following compounds:



5. What is functional isomerism? Give two examples.
6. Distinguish between position isomerism and functional isomerism.
7. What is metamerism? Give example.
8. How are free radicals formed?
9. What is the effect of introducing an alkyl group on the stability of a free radical?
10. Give two examples each of the groups exerting  $-I$  and  $+I$  effect when attached to a chain of carbon atoms.
11. A tertiary butyl carbocation is more stable than isobutyl carbocation. Justify.
11. What do you understand by  $+R$  and  $-R$  effect?
12. Define hyperconjugation.
13. What is the difference between inductive and electromeric effect?
14. All electrophiles are Lewis acids while nucleophile are Lewis bases. Explain.
15. What is the purpose of filtration through hot water funnel?
16. What precautions are necessary while purifying an organic solid with the help of crystallization process?
17. Discuss the principle of steam distillation.
18. Discuss the role of fractionating column in fractional distillation.
19. How will you prepare Lassaigne's extract? Name the elements which can be detected from this extract?
20. Why do we boil Lassaigne's extract with conc.  $\text{HNO}_3$  while detecting halogens in an organic compound?

### 3-MARKS QUESTIONS

1. Discuss the orbital structure of ethene.
2. Define (i) Functional group (ii) Homologous series.
3. What do you understand by  $1^\circ$ ,  $2^\circ$ ,  $3^\circ$  and  $4^\circ$  carbon? Write one example having atleast one carbon of each type.
4. Why stability of carbocations follows the order: tertiary > secondary > primary?
5. What are the various conditions essential for resonance?
6. Write resonance structures of  $\text{CH}_2=\text{CH}-\text{CHO}$ . Indicate relative stability of the contributing structures.
7. Inductive effect is of permanent nature while electromeric effect is only temporary. Explain.
8. What is chromatography? Name different types of chromatographic processes.
9. You are given a mixture of methanol and acetone. Discuss the process which you will employ to separate them.
10. Explain the reason for the fusion of an organic compound with metallic sodium for testing nitrogen, sulphur and halogens.

### 5-MARK QUESTIONS

1. What are free radicals? Justify the stability of the aliphatic primary, secondary and tertiary free radicals.
2. What is a carbanion? How is it formed? Discuss relative stability of primary, secondary and tertiary carbanion.
3. Arrange the following in the order of property indicated against each set:
  - (i)  $-\text{C}_6\text{H}_5$ ,  $-\text{NO}_2$ ,  $-\text{COOH}$ ,  $-\text{I}$ ,  $-\text{F}$ ,  $-\text{CH}_3$ ,  $-\text{C}_2\text{H}_5$  ( In the increasing order of  $-\text{I}$  effect)
  - (ii)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2^+$ ,  $(\text{CH}_3)_3\text{C}^+$ ,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_3$  (In the order of increasing stability)
  - (iii)  $-\text{Cl}$ ,  $-\text{CONH}_2$ ,  $-\text{CHO}$  (In the increasing priority order if present in same molecule)

4. Draw the resonance structures for the following compounds. Show the electron shift using curved arrow notation.
- $C_6H_5NO_2$
  - $CH_3CH=CHCHO$
  - $C_6H_5OH$
  - $C_6H_5CH_2^+$
  - $CH_3CH=CHCH_2^+$
5. Suggest a method to separate the constituents from the following mixture:
- Mixture of two miscible liquids
  - A mixture of oil and water
  - A mixture of plant pigments
  - A mixture of solid benzoic acid and sodium chloride
  - o-Nitrophenol and p-Nitrophenol present in the mixture.
6. 0.378g of an organic compound containing carbon and hydrogen was subjected to combustion by Leibig's method, the  $CO_2$  and  $H_2O$  formed were passed through potash bulbs and anhydrous  $CaCl_2$  tube. At the end of the experiment, the increase in the respective weights were 0.264g and 0.162g. Calculate the percentage of carbon and hydrogen.
- (Ans: C = 19.05% , H = 4.76%)

## UNIT TEST

Time Allowed: 1 hr

Maximum Marks : 20

General Instructions:

- (i) All questions are compulsory.  
(ii) Maximum marks carried by each question are indicated against it.
- 

1. Write bond line formula for the following compound: [1]  
 $\text{HOCH}_2\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}(\text{CH}_3)\text{COOH}$

2. Write IUPAC name of the following compound: [1]  
$$\begin{array}{ccccccc} \text{CH}_3 & - & \text{CH} & - & \text{C} & - & \text{CH} & - & \text{CH}_3 \\ & & | & & || & & | & & \\ & & \text{NO}_2 & & \text{O} & & \text{CH}_3 & & \end{array}$$

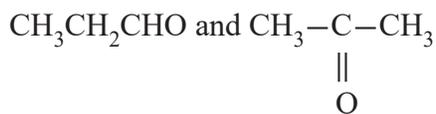
3. The central atom of compound  $\text{CH}_2=\text{C}=\text{CH}_2$  is \_\_\_\_\_ hybridized. [1]

4. There is a difference of \_\_\_\_\_ mass units between two consecutive members of a homologous series. [1]

5. Which of the following has all the effects namely : Inductive, Mesomeric and Hyperconjugative ? [1]

- (a).  $\text{CH}_3\text{Cl}$  (b).  $\text{CH}_3\text{CH}=\text{CH}_2$   
(c).  $\text{CH}_3\text{CH}=\text{CHCOCH}_2\text{Cl}$  (d).  $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$

6. (i) What type of isomerism is exhibited by the following pair of compounds? [1]



(ii) Give one example each of nucleophile and electrophile.

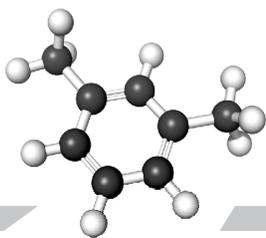
7. (i) Arrange the following in increasing order of stability:



(ii) Differentiate between inductive and electromeric effect.

8. (i) When do we use hot water funnel for filtration?  
 (ii) How will you separate a mixture of two organic compounds which have different solubilities in the same solvent?  
 (iii) An organic liquid decomposes below its boiling point. How will you purify it?
9. Draw the resonating structures of (a) Phenol (b) Benzaldehyde.
10. Arrange the following in the order of property indicated against each set:
- (i)  $-\text{C}_6\text{H}_5$ ,  $-\text{NO}_2$ ,  $-\text{COOH}$ ,  $-\text{I}$ ,  $-\text{F}$ ,  $-\text{CH}_3$ ,  $-\text{C}_2\text{H}_5$   
**(In the increasing order of -I effect)**
- (ii)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2^+$ ,  $(\text{CH}_3)_3\text{C}^+$ ,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_3$   
 +  
**(In the order of increasing stability)**
- (iii)  $-\text{COOH}$ ,  $-\text{CONH}_2$ ,  $-\text{CHO}$   
**(In the increasing priority order if present in same molecule)**
- (iv)  $\text{HCOOH}$ ,  $\text{CH}_3\text{COOH}$ ,  $\text{ClCH}_2\text{COOH}$   
**(Increasing order of acidic strength)**
- (v)  $\text{O}_2\text{NCH}_2\text{CH}_2\text{O}^-$ ,  $\text{CH}_3\text{CH}_2\text{O}^-$   
**(species having greater stability)**

\*\*\*\*\*



## Chapter - 13

# Hydrocarbons

### FAST TRACK : QUICK REVISION

Hydrocarbons are the organic compounds containing carbon and hydrogen only. Depending upon the types of carbon-carbon bonds present, hydrocarbons can be classified into three categories- (i) Saturated (ii) Unsaturated (iii) Aromatic hydrocarbons.

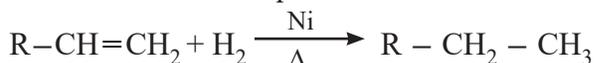
Saturated hydrocarbons contain carbon-carbon multiple bonds—double bonds, triple bonds or both.

**ALKANES** : Saturated open chain hydrocarbons containing carbon-carbon single bonds. These are inert under normal conditions i.e. do not react with acids, bases and other reagents. Alkanes exhibit Chain isomerism, Position isomerism and conformational isomerism.

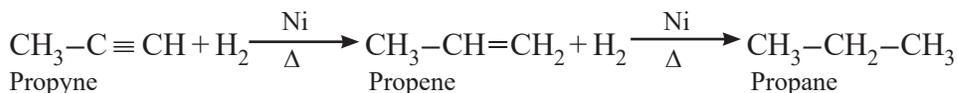
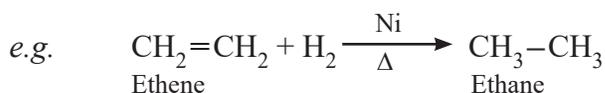
#### General methods of preparation of alkanes :

- From Unsaturated hydrocarbons** : By hydrogenation in the presence of platinum, palladium or nickel as catalyst.

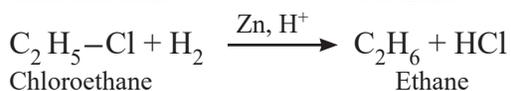
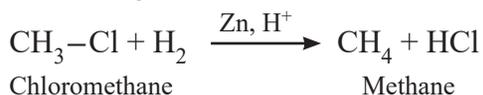
General Chemical Equation :

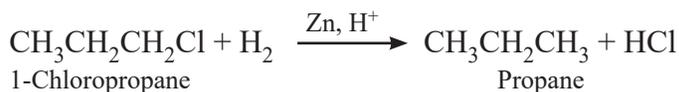


[Where R is H or Alkyl group]

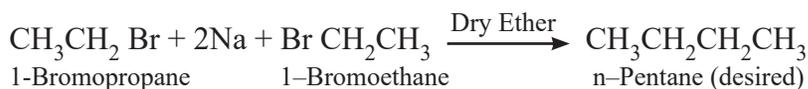
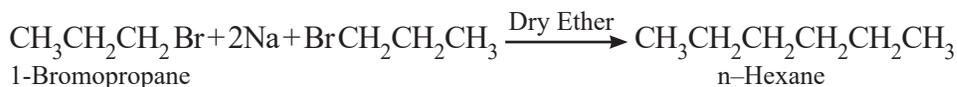
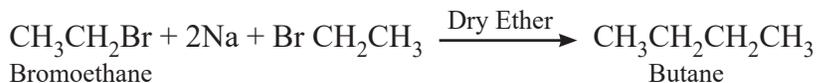


- From alkyl halides** : on reduction with Zinc and dilute hydrochloric acid

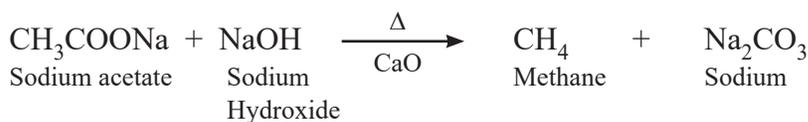




3. **From alkyl halides by Wurtz reaction :** Reaction of alkyl halide with sodium in dry ether, useful only for the preparation of symmetrical alkanes.



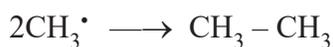
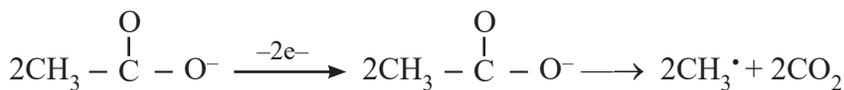
4. **From Carboxylic acids :** By decarboxylation with soda lime



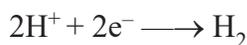
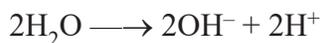
5. **By Kolbe's electrolytic method :** Electrolysis of an aqueous solution sodium or potassium salt of carboxylic acid. Alkane containing even number of carbon atoms is formed at anode.



**At Anode :** (Oxidation)



**At Cathode :** (Reduction)



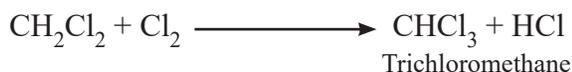
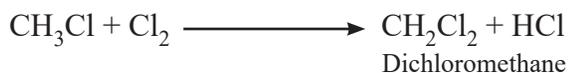
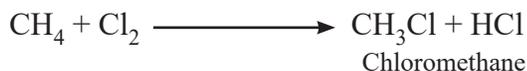
### Physical Properties of alkanes :

- Boiling point of alkanes decreases on branching due to decrease in surface area of molecule with branching which decreases magnitude of van der Waal's forces of attraction.
- Alkanes being non-polar in nature are soluble in non-polar solvents.

## Chemical properties of Alkanes :

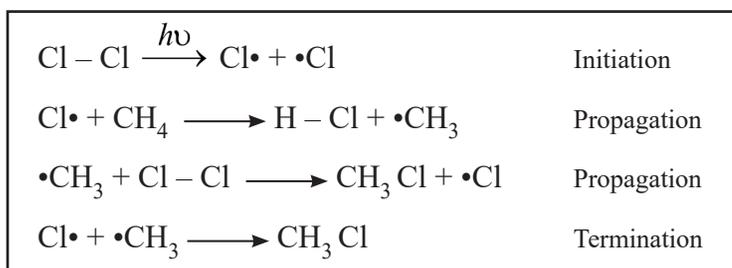
- Alkanes undergo substitution reactions.  
*e.g.*, Halogenation, Nitration, Sulphonation.

Halogenation : For example Chlorination of methane



Rate of reaction of alkanes with halogens is  $\text{F}_2 > \text{Cl}_2 > \text{Br}_2 > \text{I}_2$ . Rate of replacement of hydrogen in alkanes is  $3^\circ > 2^\circ > 1^\circ$ . Fluorination is too violent to be controlled. Iodination is reversible and it is therefore carried out in the presence of oxidising agent like  $\text{HNO}_3$ .

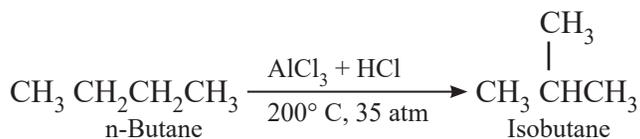
**Mechanism of halogenation :** Free radical mechanism



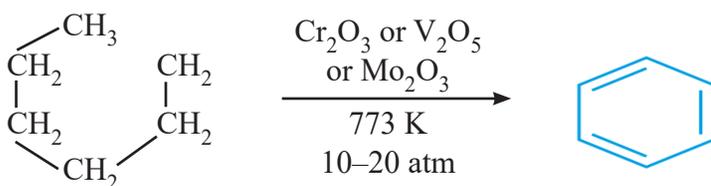
**Combustion :** Complete combustion gives carbon dioxide and water.



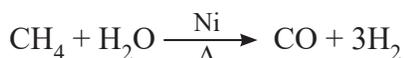
**Isomerisation :**



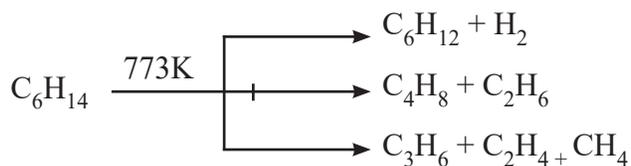
### Aromatisation :



### (vi) Reaction with steam



**Pyrolysis :** Decomposition of higher alkanes to lower alkanes on heating.



### Conformations :

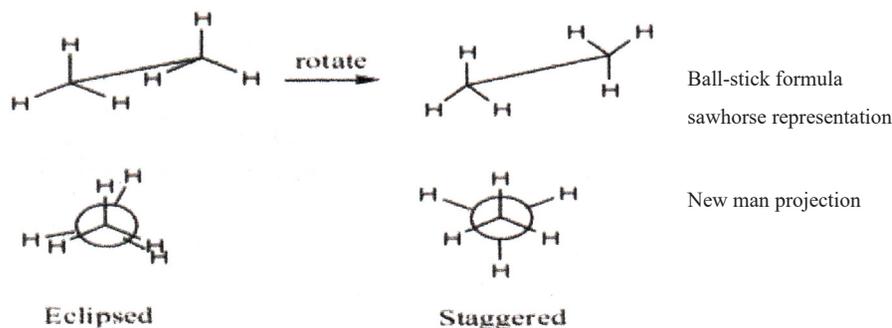
Different spatial arrangement of atoms arising due to rotation around C-C single bond.

### Conformation of ethane, CH<sub>3</sub>CH<sub>3</sub>

Two conformational isomers or conformers.

**Eclipsed form** = all hydrogen atoms nearest to each other.

**Staggered form** = all hydrogen atoms are farthest apart.



Stability of eclipsed conformation is least while staggered conformation is most stable. The energy difference between two extreme forms is  $12.5\text{kJmol}^{-1}$ . Due to this small energy difference the two forms are easily inter-convertible at ordinary temperature and cannot be separated and isolated.

## ALKENES

These are unsaturated non-cyclic hydrocarbons which have  $sp^2$  -hybridisation with  $120^\circ$  bond angle.

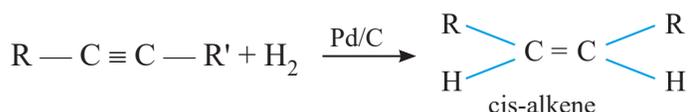
Alkenes are also called olefins [oil-forming] which indicates their high reactive nature.

Alkenes have general formula  $C_n H_{2n}$ , where  $n = 2, 3, 4, \dots$

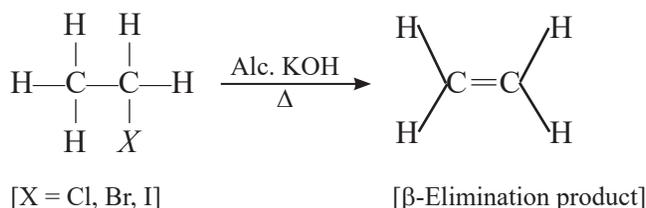
$C_2H_4$  (ethene),  $C_3H_6$  (propene), etc.

### • Methods of Preparation of Alkenes

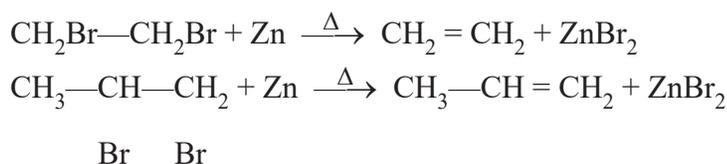
#### (i) From alkynes



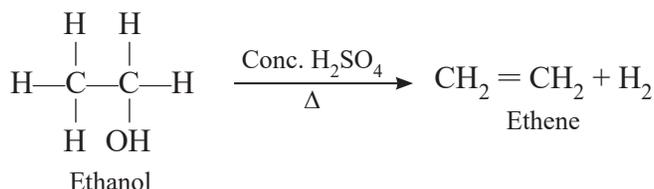
#### (ii) From alkyl halide [Dehydrohalogenation]



#### (iii) From vicinal dihalides

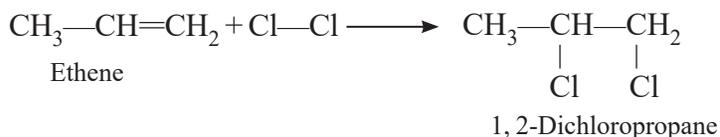
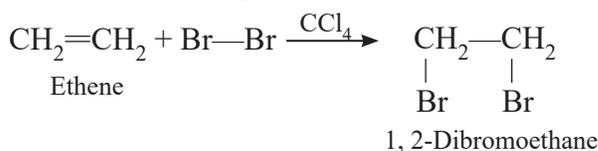


#### (iv) From alcohols by acidic dehydrogenation



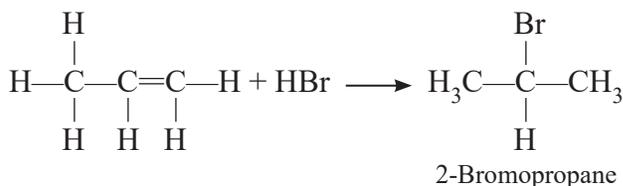
● **Chemical Properties of Alkenes :**

**1. Addition of Halogens :**

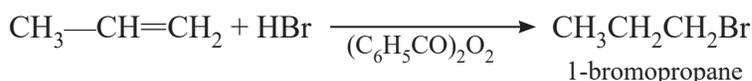


**2. Addition of hydrogen halides HCl, HBr, HI :** Add up to alkenes to form alkyl halides as per their reactivity order in  $\text{HI} > \text{HBr} > \text{HCl}$ .

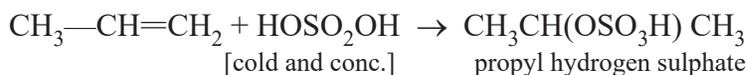
Addition reaction of HBr to unsymmetrical alkenes (Markownikov's rule) According to Markownikov's rule, the negative part of the addendum (adding molecule) gets attached to that carbon atom which possesses lesser number of hydrogen atoms.



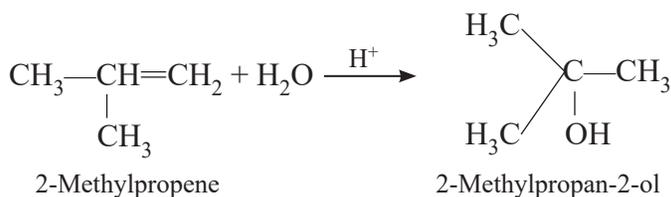
Anti Markownikov addition or peroxide effect or Kharasch effect in the presence of organic peroxide, addition of only HBr molecule on unsymmetrical alkene takes place contrary to the Markownikov's rule. Peroxide effect is not observed in case of HF, HCl and HI.



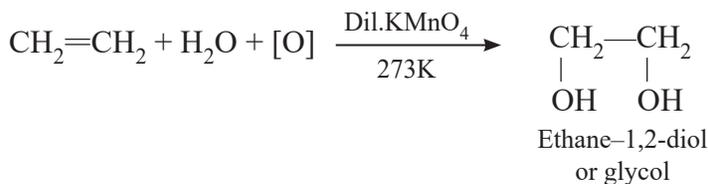
**3. Addition of sulphuric acid**



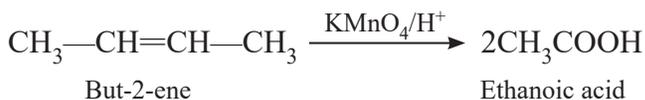
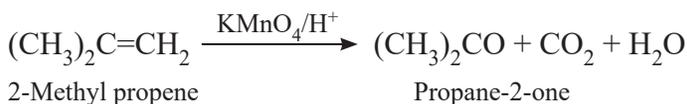
**4. Addition of water**



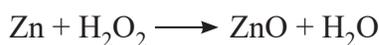
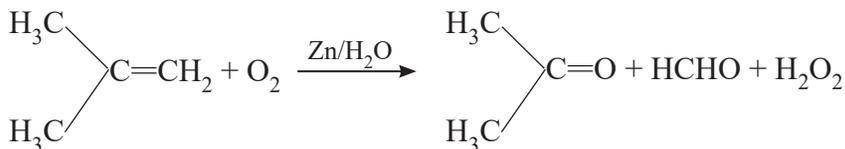
5. **Oxidation** : Alkenes decolourise cold dilute aqueous solution potassium permanganate (Baeyer's reagent). It is used as a test for unsaturation.



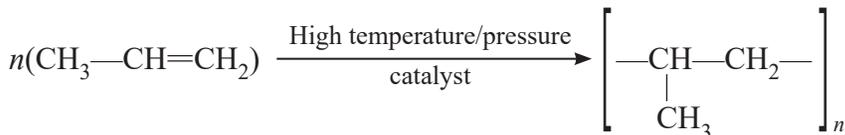
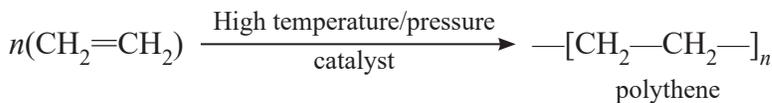
Acidic  $\text{KMnO}_4$  or acidic  $\text{K}_2\text{Cr}_2\text{O}_7$  oxidises alkenes to ketones and/or acids depending upon the nature of alkene and the experimental conditions.



6. **Ozonolysis** : Reaction of ozone with alkene to form ozonide which on subsequent reductive cleavage with zinc dust and water give carbonyl compounds (aldehydes & ketones).



7. **Polymerization**



## ALKYNES

These are unsaturated hydrocarbons with general formula  $C_nH_{2n-2}$  e.g.,  $C_2H_2$  (ethyne),  $C_3H_4$  (propyne).

Alkynes also exhibit electrophilic addition reaction but less reactive than alkenes because the dissociation of  $\pi$ -electron cloud requires more energy.

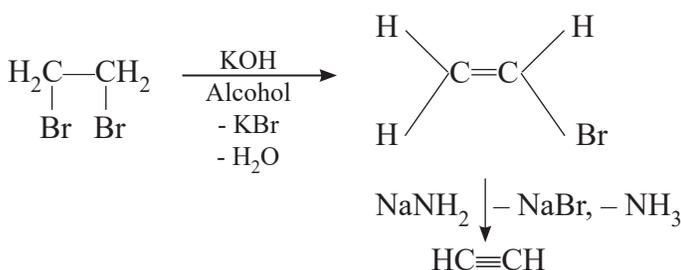
$H-C\equiv C-H$  contains  $3\sigma$  and  $2\pi$  -bonds and bond length is 120 pm. In acetylene.  $H-C-C$  bond angle is  $180^\circ$ .

### • Methods of Preparation of Alkynes

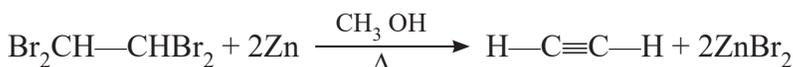
#### 1. From calcium carbide



#### 2. From vicinal dihalides



#### 3. From tetrahalides



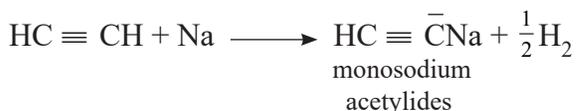
### Physical Properties of Alkynes :

1. The first two members are gases next eight members ( $C_5 - C_{12}$ ) are liquids and higher members are solids.
2. They are all colourless and odourless with the exception of acetylene which has slightly garlic odour due to the presence of  $PH_3$  and  $H_2S$  as impurities.
3. Alkynes are insoluble in water but soluble in organic solvents like ethers, carbon tetrachloride and benzene.
4. Melting point, boiling point and density increase with increase in molar mass.

- **Chemical properties of Alkynes**

Alkynes show electrophilic as well as nucleophilic addition reactions.

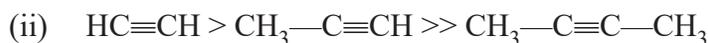
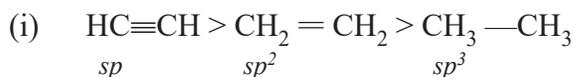
(i) **Acidic character of alkyne**



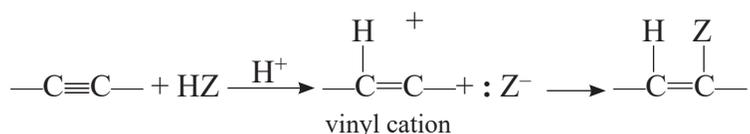
These reactions are not shown by alkenes, alkanes and non-terminal alkynes, hence used for distinction between alkane, alkene and alkyne.

Acetylenic hydrogens are acidic in nature due to 50% s-character in sp-hybridised orbitals. Acidity of alkynes is lesser than water.

**Acidic behaviour order**



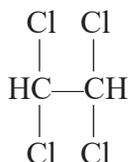
(ii) **Electrophilic addition reactions**



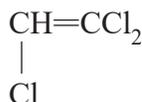
The addition product formed depends upon the stability of vinylic cation. Addition on unsymmetrical alkynes takes place according to Markovnikov's rule.



### Addition of halogens

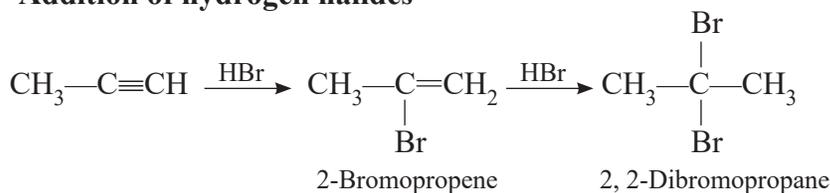


1, 1, 2, 2-Tetrachloroethane  
or westron

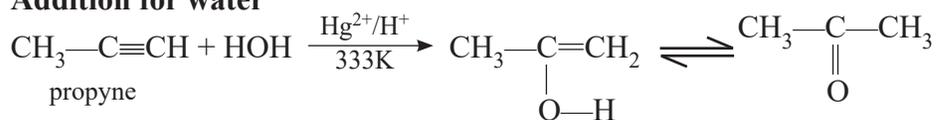


westrosol (1, 1, 2-Trichloroethene)

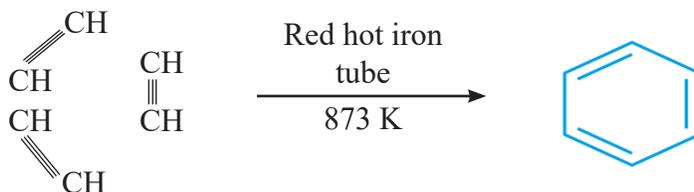
### Addition of hydrogen halides



### Addition for water



### (iii) Cyclic polymerisation of ethyne

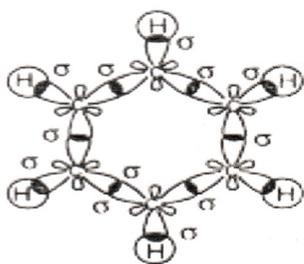


## AROMATIC HYDROCARBONS

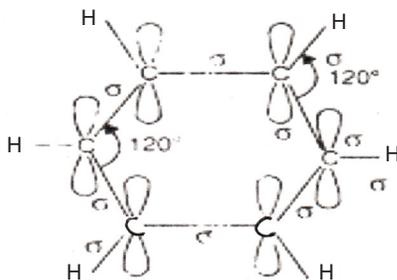
These hydrocarbon are also known as arenes. The parent member of the family aromatic hydrocarbons is benzene.

Aromatic compounds containing benzene ring are known as benzenoids.

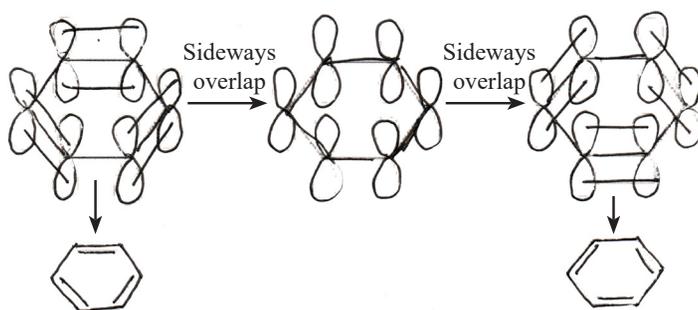
**Structure of benzene :** Hexagonal ring of carbon atoms with alternate single and double bonds. Each carbon atom is  $sp^2$  hybridised. Planar ring, bond angle  $120^\circ$ . All C-C bond lengths are equal due to complete delocalisation of  $\pi$  electrons.



Formation of C-C and C-H sigma bonds



Sigma skeleton of benzene molecule



## HUCKEL'S RULE

- **Huckel's rule, (based on calculations) :** a planar cyclic molecule with alternating double and single bonds has aromatic stability if it has  $(4n + 2\pi)$  electrons ( $n$  is 0, 1, 2, 3, 4)
- For  $n = 1 : 4n+2 = 6$ ; benzene is stable and electrons are delocalized.

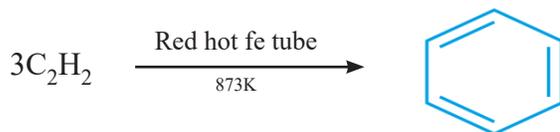
### Benzene



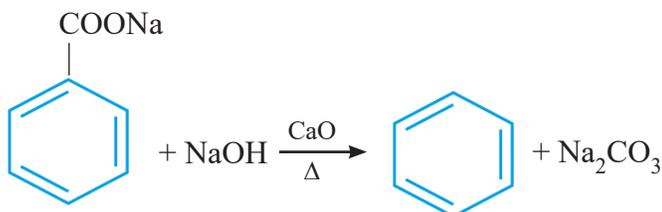
Three double bonds;  
six  $\pi$  electrons

## ● METHODS OF PREPARATION

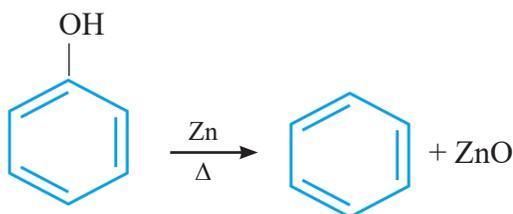
### 1. Cyclic polymerisation of ethyne



### 2. Decarboxylation of aromatic acids



### 3. Reduction of phenol



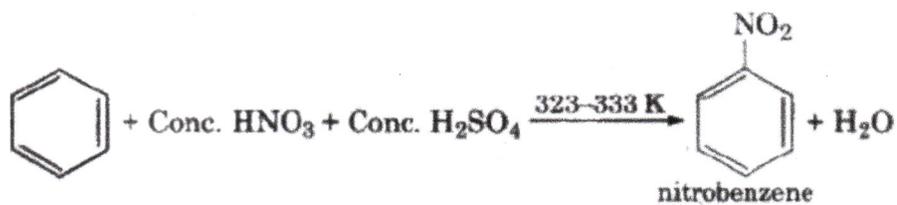
### Physical Properties of Benzene :

- (i) Aromatic hydrocarbons are non-polar molecules and are usually colourless liquids or solids with a characteristic aroma.
- (ii) Aromatic hydrocarbons are immiscible with water but readily miscible with organic solvents.
- (iii) Aromatic compounds burn with sooty flame.

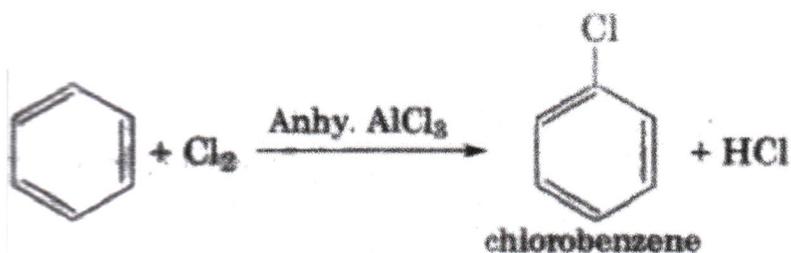
### Chemical Reactions of Benzene :

- (i) Benzene gives electrophile substitution reactions.
- (ii) According to experimental evidences, electrophile substitution reaction involve following three steps :
  - Generation of electrophile
  - Formation of carbocation intermediate.
  - Removal of proton from the carbocation intermediate.

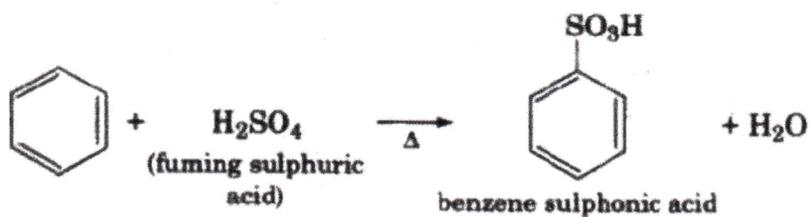
(i) Nitration



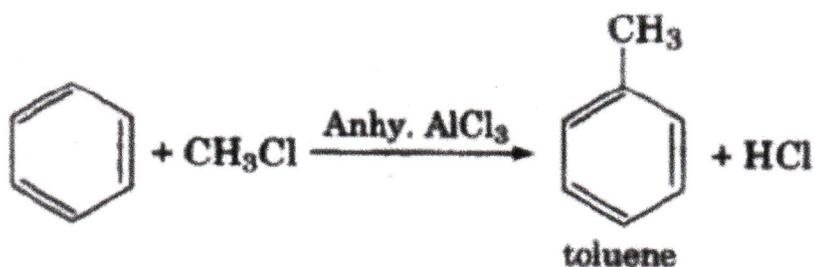
(ii) Halogenation



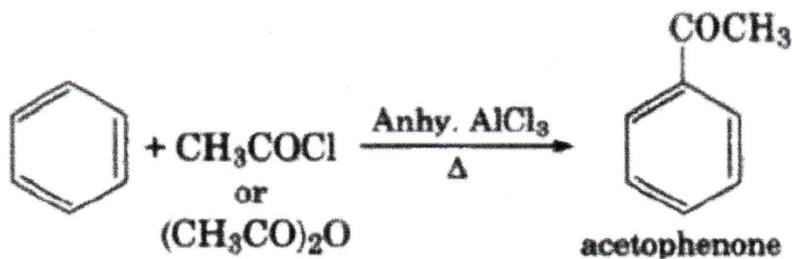
(iii) Sulphonation



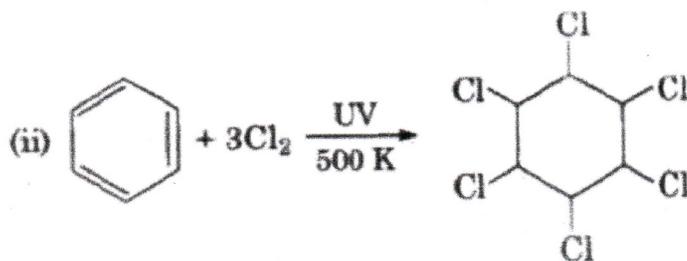
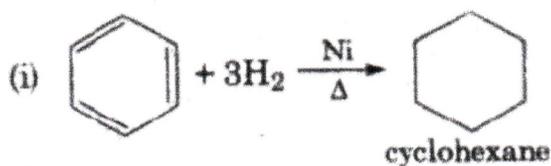
(iv) Friedel-Craft's alkylation reaction



(v) Friedel-Crafts acylation reaction



Benzene also undergoes addition reactions e.g.



benzene hexachloride or 666  
(BHC or Gammexane or lindane)

• COMBUSTION



**Directing influence of substituents in monosubstituted benzene**

- (i) **Ortho and para directing groups** : Ring activating groups  
e.g.,  $\text{NH}_2$ ,  $-\text{CH}_3$ ,  $-\text{C}_2\text{H}_5$ ,  $-\text{OCH}_3$  etc. (+ R effect)
- (ii) **Meta directing groups** : Ring deactivating groups  
e.g.  $-\text{NO}_2$ ,  $-\text{CN}$ ,  $-\text{CHO}$ ,  $-\text{COOH}$ ,  $-\text{SO}_3\text{H}$  (– R effect).

## MULTIPLE CHOICE QUESTIONS (MCQ)

1. Which of the following has zero dipole moment?  
(a.) cis-But-2-ene                      (b) trans-But-2-ene  
(c) But-1-ene                              (d) 2-Methylprop-1-ene
2. Bond length of (I) ethane, (II) ethene, (III) Acetylene, (IV) Benzene follows the order:  
(a) I > II > III > IV                      (b) I > II > IV > III  
(c) I > IV > II > III                      (d) III > IV > II > I
3. The methyl group in benzene ring is:  
(a) Ortho directing                      (b) Ortho and meta directing  
(c) Para directing                      (d) Ortho and para directing
4. The dihedral angle in the staggered conformation of  $C_2H_6$   
(a)  $120^\circ$                                       (b)  $60^\circ$   
(c)  $0^\circ$     (d)  $90^\circ$
5. On heating  $C_2H_2$  in red hot tube copper tube, the compound formed is:  
(a) Ethylene                                  (b) Benzene  
(c) Ethane                                      (d) Methane
6. Action of acetylene on dilute  $H_2SO_4$  gives:  
(a) Acetic acid                                  (b) Acetone  
(c) Acetaldehyde                              (d) Ethyl alcohol
7. Which of the following compounds will exhibit cis-trans (geometrical) isomerism?  
(a) Butanol                                      (b) 2-Butyne  
(c) 2-Butenol                                      (d) 2-Butene
8. Hydrolysis of ozonide of But-1-ene gives  
(a) Ethylene only  
(b) Acetaldehyde and formaldehyde  
(c) Propionaldehyde and formaldehyde  
(d) Acetaldehyde only
9. Reaction of hydrogen bromide with propene in the absence of a peroxide is a/an  
(a) free radical reaction                      (b) nucleophilic substitution  
(c) electrophilic addition                      (d) nucleophilic substitution

10. Among the following compounds, the one which is most reactive towards electrophilic nitration is:

- (a) Benzoic acid                      (b) Nitrobenzene  
(c) Toluene                              (d) Benzene

**ANSWERS:** 1.b 2.c 3.d 4.b 5.b 6.c 7.d 8.c 9.c 10.c

### FILL IN THE BLANKS

1. Alkanes mainly undergo \_\_\_\_\_ reaction.
2. Halogenation of alkanes does not occur in \_\_\_\_\_.
3. The H – C – H bond angle in ethene is \_\_\_\_\_.
4. The addition of HBr to an unsymmetrical alkene takes place in accordance with \_\_\_\_\_ rule.
5. Baeyer's reagent is used for testing \_\_\_\_\_.
6. Benzene favours \_\_\_\_\_ substitution reaction.
7. The Dipole moment of Benzene is \_\_\_\_\_.
8. The nitro group in the benzene nucleus is \_\_\_\_\_ directing. It \_\_\_\_\_ the reactivity of the benzene ring.
9. Melting point and boiling point increase as the molar masses \_\_\_\_\_.
10. The reaction of solid calcium carbide with water produces \_\_\_\_\_, a flammable gas.

**ANSWERS :** 1. Substitution      2. Dark              3. 120°      4. Markownikov's  
5. Unsaturation      6. electrophilic      7. Zero      8. Meta, decreases  
9. Increase              10. Ethyne

### TRUE AND FALSE TYPE QUESTIONS

1. Alkanes mainly undergo substitution reactions using the free-radical mechanism.
2. The decreasing order of boiling points among the isomeric pentanes is neo > iso > n.
3. The acidic character of three types of hydrocarbons follows the order alkanes > alkenes > alkynes.
4. The peroxide effect is observed only in addition of HBr, and not with HCl and HI.

- Wurtz reaction is suitable for the preparation of both symmetrical and unsymmetrical alkanes.
- For a compound to be aromatic it must have  $(4n + 2)\pi$  electrons.
- Benzene has planar structure.
- The benzene molecule has two different carbon-carbon bond lengths, corresponding to alternate single and double bonds.
- In Friedel-Crafts reaction,  $\text{AlCl}_3$  is an electrophile.
- An electron-donating substituent in benzene ring gives a meta product.

**ANSWERS:** 1. T 2. F 3. F 4. T 5. F 6. T 7. T 8. F 9. F 10. F

### MATCH THE COLUMNS

Match the statements (a,b,c,d) in column I with the statements (i, ii, iii, iv) in column II.

- |    |                           |                                |
|----|---------------------------|--------------------------------|
| 1. | <b>Column I</b>           | <b>Column II</b>               |
|    | a. $\text{C}_2\text{H}_6$ | i. Electrophilic addition      |
|    | b. $\text{C}_2\text{H}_4$ | ii. Electrophilic substitution |
|    | c. $\text{C}_2\text{H}_2$ | iii. Free radical substitution |
|    | d. $\text{C}_6\text{H}_6$ | iv. Free radical addition      |
| 2. | <b>Column I</b>           | <b>Column II</b>               |
|    | a. Alkanes                | i. Saturated nature            |
|    | b. Alkenes                | ii. Ozonolysis                 |
|    | c. Alkynes                | iii. Geometrical isomerism     |
|    | d. Arenes                 | iv. Aromatic character         |

**ANSWERS:** 1. a.  $\rightarrow$  iii    b.  $\rightarrow$  i    c.  $\rightarrow$  i    d.  $\rightarrow$  ii  
 2. a.  $\rightarrow$  i    b.  $\rightarrow$  ii, iii    c.  $\rightarrow$  ii    d.  $\rightarrow$  i, iv

### ASSERTION-REASON TYPE QUESTIONS

Type 1. The questions given below consist of Assertion(A) and Reason (R). Use the following key to select correct answer.

- If both assertion and reason are correct and reason is correct explanation for assertion.
- If both assertion and reason are correct but reason is not correct explanation for assertion.
- If assertion is correct but a reason is incorrect.
- If assertion and reason both are incorrect.

- Assertion:** The IUPAC name of  $\text{CH}_3\text{CH}=\text{CH}-\text{C}\equiv\text{CH}$  is pent-3-en-1-yne and not pent-2-en-4-yne.

**Reason:** While deciding the locants of double and triple Bonds, lowest sum rule is always followed.
- Assertion:** Tropylium cation  is aromatic in character.

**Reason:** The only property which decides the aromatic character is its planar nature.
- Assertion:** Friedel-craft reaction between benzene and acetic anhydride in the presence of anhydrous  $\text{AlCl}_3$  yields acetophenone and not poly-substituted products.

**Reason:** Acetophenone formed poisons the catalyst preventing further reaction.
- Assertion:** But-1-ene on reacting with  $\text{HBr}$  in the presence of peroxide, products 1-bromobutane.

**Reason:** It involves the formation of a primary free radical.
- Assertion:** Alkanes with more than three carbon atoms exhibit chain isomerism.

**Reason:** Branching of the carbon atom chain is necessary for exhibiting chain isomerism.
- Assertion:** Benzene reacts with chlorine in the form of light to form BHC.

**Reason:** BHC is also called gammexane or 666.
- Assertion:** All the hydrogen atoms in  $\text{CH}_2=\text{C}=\text{CH}_2$  lie in one plane.

**Reason:** All the carbon atoms in it are  $\text{sp}^2$  hybridised.
- Assertion:** Propene reacts with  $\text{HBr}$  in the presence of benzoyl peroxide to yield 2-bromopropane.

**Reason:** In the presence of peroxide, the addition of  $\text{HBr}$  to propene follows ionic mechanism.
- Assertion:** Benzene does not decolourise bromine water.

**Reason:** Benzene is stabilised by resonance due to delocalisation of  $\pi$  electrons.
- Assertion:** Acidity of C-H bond decreases in the order:  
 $\text{HC}\equiv\text{CH} > \text{H}_2\text{C}=\text{CH}_2 > \text{H}_3\text{C}-\text{CH}_3$

**Reason:** Greater the percentage s-character, more is the acidity of C-H bond.

**ANSWERS:** 1.a 2.c 3.c 4.c 5.a 6.b 7.c 8.d 9.a 10.a

### ONE WORD TYPE QUESTIONS

1. What is the state of hybridisation of Carbon atoms in alkanes?
2. What is self linking property of atoms called?
3. What is the general formula of alkenes?
4. What is the other name for Geometrical isomerism?
5. Which out of Ethane, Ethene and Ethyne has longest C-C bond?
6. What is the number of bonds in But-3-en-1-yne?
7. Name the product formed when Propyne is treated with aqueous  $\text{H}_2\text{SO}_4$  in the presence of  $\text{dil.HgSO}_4$ .
8. What is C—C—C bond angle in benzene?
9. Name the product formed when Benzene reacts with  $\text{CH}_3\text{Cl}$  in the presence of anhydrous aluminium chloride.
10.  $-\text{COOH}$  is ortho, para directing or Meta directing group?

### 1-MARK QUESTIONS

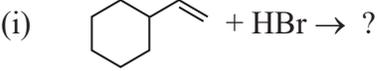
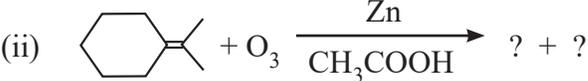
1. Name the chain isomer of  $\text{C}_5\text{H}_{12}$  which has tertiary carbon atom.
2. Give the IUPAC name of the lowest molecular weight alkane that contains a quaternary carbon.
3. Write the reaction involved in Kolbe's electrolytic method to prepare ethane.
4. Define term decarboxylation.
5. Why dry ether and not water is used as a solvent in the preparation of alkane by Wurtz reaction?
6. Sodium salt of which carboxylic acid will be needed for the preparation of propane by decarboxylation method?
7. Complete the following reaction:  
$$\text{CH}_3\text{Cl} + \text{Na} \xrightarrow{\text{dry ether}}$$
8. Amongst the following which one has the maximum boiling point?  
n-Pentane, iso-pentane, neo-pentane.
9. Define the term conformation.
10. Write IUPAC name of  $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}=\underset{\begin{array}{c} | \\ \text{CH}_2\text{CH}_3 \end{array}}{\text{C}}\text{CH}_2\text{CH}=\text{CH}_2$

11. Draw the cis and trans isomers of  $\text{CHCl}=\text{CHCl}$ .
12. What happens when 2-Bromobutane is being treated with alc. KOH?
13. Name the reagents used to carry out the following conversions:  
 $\text{CH}_3-\text{CH}=\text{CH}_2 \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{OH}$
14. Complete the following reaction :  

$$\text{CH}_3-\text{CH}=\text{CH}_2 + \text{HBr} \xrightarrow{\text{Organic peroxide}}$$
15. An alkene A on ozonolysis gives a mixture of ethanol and pentan-3-one. Write IUPAC name of element.
16. When alkyne is treated with bromine water then what will be the colour of the product?
17. Why alkynes do not exhibit geometrical isomerism?
18. Complete the following reaction:  
 (i)  $\text{CH}_3\text{C} \equiv \text{CH} \xrightarrow{\text{H}_2\text{O}, \text{Hg}^{2+}/\text{H}^+}$  ?  
 (ii)  $\text{CaC}_2 + 2\text{H}_2\text{O} \longrightarrow$  \_\_\_\_\_ + \_\_\_\_\_
19. How will you convert ethyne to benzene?
20. Write chemical equation for combustion reaction of Hexyne.
21. Write IUPAC name of  $\text{C}_6\text{H}_5-\text{CH}_2-\text{CH}_2-\text{CH}=\text{CH}_2$ .
22. Why is benzene extraordinarily stable although it contains three double bonds?
23. Write chemical reaction to exemplify Friedel-Crafts alkylation of benzene.
24. What is the nature of substitution in benzene?
25. Why  is not aromatic?
26. C-C bond length in benzene is intermediate between C-C and C=C. Why?
27. Starting from benzene, how would you synthesize m- Bromonitrobenzene.
28. Give one example each of o, p-directing group and m-directing group.
29. Complete the reaction:  

$$\text{C}_6\text{H}_6 + \text{CH}_3\text{COCl} \xrightarrow{\text{Anhy. AlCl}_3}$$
30. Write the electrophile which is involved in the nitration of benzene.

## 2-MARKS QUESTIONS

1. What effect does branching have on the boiling point of an alkane and why?
2. What is the difference between isomers and conformers?
3. Is it possible to isolate pure staggered ethane or pure eclipsed ethane at room temperature? Give reason.
4. Draw Newman projection formula for conformations of ethane.
5. How will you convert methyl bromide to ethane?
6. Wurtz reaction cannot be used for the preparation of unsymmetrical alkanes? Give reason.
7. How can ethene be prepared from (i) Ethanol (ii) Ethyl bromide?
8. Melting point of cis-But-2-ene is lower than that of trans-But-2-ene. Give reason.
9. Draw the structures of cis and trans Hex-2-ene.
10. Explain with the help of equation : Ozonolysis of propene.
11. Give a chemical test to distinguish between ethene and ethane.
12. What do you understand by peroxide effect (Kharasch effect)?
13. What factor determines the stability of alkene?
14. Arrange the following alkenes in decreasing order of stability :  
 $\text{CH}_3-\text{CH}=\text{CH}-\text{CH}_3$ ,  $\text{CH}_2=\text{CH}_2$ ,  $\text{CH}_3-\text{CH}=\text{CH}_2$
15. Complete the reaction:
  - (i)  + HBr → ?
  - (ii)  + O<sub>3</sub>  $\xrightarrow[\text{CH}_3\text{COOH}]{\text{Zn}}$  ? + ?
16. An alkene on treatment with HBr in presence of peroxide can generate two types of free radicals  $\text{CH}_3-\underset{\text{CH}_3}{\text{C}}\cdot-\text{CH}_2\text{-Br}$  and  $\text{CH}_3-\underset{\text{Br}}{\text{C}}(\text{CH}_3)-\text{CH}_2\cdot$   
 Predict the final product of the reaction and give reason.  
 (Hint: Stability of free radicals)
17. What happens when But-2-ene reacts with acidified potassium permanganate solution?

18. You are provided with But-2-yne, how will you convert it into:
- cis-But-2-ene
  - trans-But-2-ene
19. An alkene  $C_4H_8$  reacts with HBr both in the presence and absence of peroxide to give the same product. Identify the alkene.
20. Arrange ethane, ethene and ethyne in the order of increasing acidity.
21. Identify A and B in the following reaction:
- $$A \xrightarrow{Na} CH \equiv CH \xrightarrow[873K]{\text{Red hot iron tube}} B$$
22. Write the structures of the products A and B of the following reactions:
- $HC \equiv CH \xrightarrow{Na} A \xrightarrow{CH_3Br} B$
  - $BrH_2C-CH_2Br \xrightarrow{\text{Alc.KOH}} A \xrightarrow{NaNH_2} B$
23. Give a chemical test to distinguish between ethyne and ethene.
24. Out of benzene and toluene, which will undergo nitration easily and why?
25. Why does presence of a nitro group make the benzene ring less reactive in comparison to the unsubstituted benzene ring? Explain.
26. What happens when Chlorine is passed through benzene in the presence of sunlight and absence of halogen carrier?

### 3-MARKS QUESTIONS

- Write the structures and name of products obtained in the reaction of sodium with a mixture of 1-Iodo-2-methylpropane and 2-Iodopropane.
- State Markownikov's rule. Using this rule, write the reaction of propene with (i) HCl & (ii)  $H_2O$ .
- Complete the following reactions:
  - $CH_3CH_2Br \xrightarrow{\text{Alc.KOH}}$
  - $CH_3CH=CH_2 + O_3 \xrightarrow{Zn/H_2O}$
  - $CH_2=CH_2 + H_2O + [O] \xrightarrow{\text{Dil.KMnO}_4}$
- Write the structure of 3, 4-Dimethylhept-3-ene.
  - Name the compounds obtained by ozonolysis of 3-Methylpent-2-ene.

5. Complete the following reactions:
- (i)  $\text{CH}\equiv\text{CH} \xrightarrow{\text{NaNH}_2, \text{CH}_3\text{Br}} ?$
- (ii)  $\text{CH}\equiv\text{CH} \xrightarrow{\text{H}_2\text{O}, \text{HgSO}_4/\text{H}_2\text{SO}_4} ?$
- (iii)  $\text{CH}_3\text{C}\equiv\text{CH} + \text{H}_2 \xrightarrow{\text{Pt}} ? \xrightarrow{\text{H}_2} ?$
6. Write the mechanism of nitration of benzene.
7. Arrange in the order of decreasing relative reactivity with an electrophile and explain:  
Toluene, p-Nitrotoluene, 1, 4-Dinitrobenzene
8. What is meant by delocalization of  $\pi$  electrons? How does it affect stability of benzene?
9. What are the conditions for a compound/species to be aromatic according to Huckel's rule?
10. How will you convert benzene into
- (i) Acetophenone
- (ii) m- Chloronitrobenzene?

### 5-MARKS QUESTIONS

- Define isomerism. Write all the structural isomers of hexane( $\text{C}_6\text{H}_{14}$ ) and arrange them in increasing order of boiling points.
- Write short note on (i) Wurtz reaction (ii) Kolbe's electrolysis (iii) Ozonolysis
- Alkenes show geometrical isomerism while alkanes do not. Give a suitable explanation.
- An alkene 'A' of molecular mass '28u' on treatment with bromine gives a product 'B'. The Compound 'B' on further dehalogenation with zinc gives back 'A'. Give the structures of 'A' and 'B' and also the sequence of reactions.
- An organic compound 'A' with formula  $\text{C}_4\text{H}_9\text{Br}$  on treatment with  $\text{KOH}(\text{alc.})$  gave two isomeric compounds 'B' and 'C' with formula  $\text{C}_4\text{H}_8$ . Ozonolysis of 'B' gave only one product  $\text{CH}_3\text{CHO}$  while 'C' gave two different products. Identify A, B and C.
- How will you convert Ethyne into (i) 1, 1, 2, 2-Tetrachloroethane (ii) Ethene (iii) Ethanal (iv) Benzene (v) Sodium ethynide
- Discuss the structure of benzene with an emphasis on resonance and orbital pictures.

## UNIT TEST

Time Allowed: 1 hr

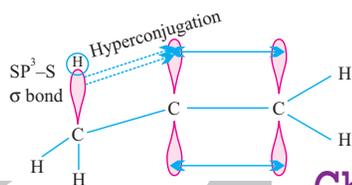
Maximum Marks : 20

General Instructions:

- (i) All questions are compulsory.  
(ii) Maximum marks carried by each question are indicated against it.

- 
1. Amongst the following which one has the maximum boiling point and why? n-Pentane, iso-pentane, neo-pentane [1]
  2. What is the number of  $\sigma$  and  $\pi$  bonds in But-3-en-1-yne? [1]
  3. Action of acetylene on dilute  $\text{H}_2\text{SO}_4/\text{dil.HgSO}_4$  gives: [1]  
(a) Acetic acid (b) Acetone (c) Acetaldehyde (d) Ethyl alcohol
  4. An alkene A on ozonolysis gives a mixture of ethanal and pentan-3-one. Write IUPAC name of element. [1]
  5. The nitro group in the benzene nucleus is \_\_\_\_\_ directing. [1]  
It \_\_\_\_\_ the reactivity of the benzene ring.
  6. Arrange the following alkenes in decreasing order of stability and give reason. [1]  
 $\text{CH}_3-\text{CH}=\text{CH}-\text{CH}_3$ ,  $\text{CH}_2=\text{CH}_2$ ,  $\text{CH}_3-\text{CH}=\text{CH}_2$
  7. (i) Give a chemical test to distinguish between ethyne and ethene. [2]  
(ii) Melting point of cis-But-2-ene is lower than that of trans-But-2-ene. Give reason.
  8. Complete the following reactions: [3]  
(i)  $\text{CH}_3\text{CH}_2\text{Br} \xrightarrow{\text{Alc.KOH}}$   
(ii)  $\text{CH}_3\text{CH}=\text{CH}_2 + \text{O}_3 \xrightarrow{\text{Zn/H}_2\text{O}}$   
(iii)  $\text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} + [\text{O}] \xrightarrow{\text{Dil.KMnO}_4}$
  9. (i) What are the conditions for a compound/species to be aromatic according to Huckel's rule? [3]  
(ii) How will you convert Benzene to acetophenone?
  10. (i) An alkene 'A' of molecular mass '28u' on treatment with bromine gives a product 'B'. The Compound 'B' on further dehalogenation with zinc gives back 'A'. Give the structures of 'A' and 'B' and also the sequence of reactions. [5]  
(ii) Why is benzene extraordinarily stable although it contains three double bonds?  
(iii) How can we convert ethyne into benzene?

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## Chapter - 14

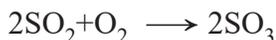
# Environmental Chemistry

### FAST TRACK : QUICK REVISION

- ▶ **Environmental pollution:** Environmental pollution is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. A substance which causes pollution is known as pollutant. Pollutants can be degradable and non-degradable.
- ▶ **Atmospheric pollution:** Any undesirable changes in their atmosphere which adversely effect living beings is called air pollution. Air pollution is generally limited to troposphere and stratosphere.  
Ozone is present in stratosphere and prevents UV radiations of sun from reaching the earth's surface.
- ▶ **Tropospheric pollution:** It is due to gaseous and particulate pollutants.

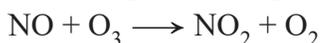
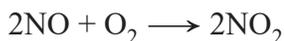
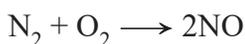
#### 1. Gaseous air pollutants:

**Oxides of sulphur:** Major sources of oxides of sulphur (mainly  $\text{SO}_2$ ) are burning of fossil fuels containing sulphur. Sulphur dioxide is converted to sulphur trioxide in presence of particulat matter.



Sulphur dioxide is a corrosive gas which produces acid rain that causes damage and destruction of vegetation and degradation of soils, building materials and watercourses.  $\text{SO}_2$  in ambient air is also associated with asthma and chronic bronchitis. It also causes irritation to eyes.

- **Oxides of nitrogen:** Major sources of nitrogen oxides are high temperature combustion processes, oxidation of nitrogen in the air and fuel respectively, denitrifying bacteria, etc.



Finally, these gases are converted into nitric acid ( $\text{HNO}_3$ ) which comes down to the surface of the earth in the form of acid rain.

—  $\text{NO}_2$  is a respiratory irritant,

— The oxides produce eye irritation, injury to liver and kidneys.

- **Hydrocarbons:** They are majorly produced naturally (e.g. marsh gas) as well as due to incomplete combustion of automobile fuel.

— Hydrocarbons are carcinogenic, these harm plants.

- **Oxides of carbon:** two major pollutants are oxides of carbon i.e., carbon monoxide and carbon dioxide.

- **Carbon monoxide:** Carbon monoxide ( $\text{CO}$ ) is a toxic gas which is emitted into atmosphere by incomplete combustion of coal and firewood and by oxidation of hydrocarbons and other organic compounds.

$\text{CO}$  may reduce the oxygen carrying capacity of the blood by combining with haemoglobin to produce carboxyhaemoglobin, This oxygen deficiency results in headache weak eyesight, choking and cardiovascular disorders.

- **Carbon dioxide:**  $\text{CO}_2$  is released into atmosphere by respiration burning of fossil fuels, forest fire decomposition of limestone in cement industry, etc.

— It is a greenhouse gas, the concentration of which is constantly raising.

— In excess it causes headache and nausea.

- ▶ **Greenhouse effect and global warming:** The greenhouse effect is the process in which the emission of infrared radiation by the atmosphere warms the Earth surface.

- Greenhouse gases include carbon dioxide, methane, ozone chlorofluorocarbons (CFCs) and water vapour.

- Earth absorbs energy from sunlight entering the atmosphere and emit energy out to space in form of infrared rays. The outgoing radiation emitted by the surface is in the absorption range of many atmospheric gases, including carbon dioxide, methane, and water vapour. These radiations are thus locked in the earth's atmosphere. This results in the steady increase in the temperature of the earth resulting in global warming.

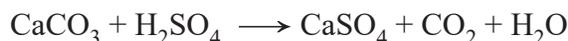
- ▶ **Acid rain:** Rainwater normally has a pH of 5.6 due to dissolution of  $\text{CO}_2$  present in the atmosphere.



- When the pH Falls below 5.6, the rain water becomes acidic, It is caused due to presence of acidic gases into the atmosphere the common ones are sulphur dioxide and nitrogen oxides which are changed into sulphuric acid and nitric acid by combining with oxygen and water.



- Harmful effects of acid rain: It causes extensive damage to buildings and statues made by marble, limestone due to the reaction,



— It is toxic to vegetation and aquatic life.

— It corrodes water pipes resulting in the leaching of the heavy metals such as Fe, Pb, and Cu into the drinking water which have toxic effects.

**2. Particulate pollutants:** Particulate pollutants are small solid particles and liquid droplets suspended in air.

**Smoke:** it consists of solid or mixture of solid and liquid particles formed by combustion of organic matter. e.g., cigarette smoke, oil smoke, smoke from fossil fuel etc.

**Dust:** It consists of fine particles produced during crushing and grinding of solid materials. Common dust particulate emission include cement, fly ash, silica dust, from Industries, dust storm, ground limestone, etc.

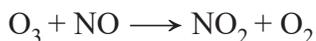
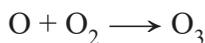
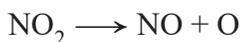
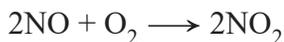
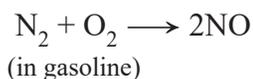
**Mist:** These are formed by particles of spray liquids and condensation of vapours in air. For example, sulphuric acid, mist herbicide or insecticide that miss their targets and travel through air from mist.

**Fumes:** These are produced by condensation of vapours. For example, metal fumes, metallurgical fumes and alkali fumes.

**Smog:** The word smog has its origin from smoke and fog. It is a major air pollutant.

Classical smog	Photochemical smog
Also called as London smog.	Also called as Los Angeles smog.
Form due to oxides of sulphur.	Formed due to oxides of Nitrogen.
Contains primary pollutants.	Content secondary pollutants.
Causes bronchitis and problem in lungs.	Causes irritation in Eyes.
It is reducing in nature.	It is oxidising in nature.

**Formation of photochemical smog:** It is formed through sequence of following reactions:



Ozone reacts with hydrocarbons to form Peroxyacetyl nitrate (PAN), formaldehyde, acrolein etc. Effects of photochemical smog:

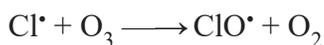
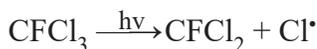
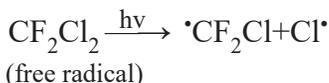
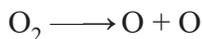
Ozone and PAN are eye irritants. Photochemical smog also corrodes metals stones buildings materials rubber and painted surfaces.

**Measures to control photochemical smog:**

Catalytic converters are used in automobiles, which prevent the release of Nitrogen oxide and hydrocarbon to the atmosphere. Certain plants e.g. Pinus, Juniparus, Quercus, Pyrus and Vitis can metabolize nitrogen oxide and therefore their plantation could help in this matter.

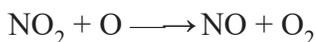
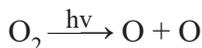
- **Stratospheric pollution:** The upper stratosphere consists of considerable amount of ozone ( $\text{O}_3$ ) which protects us from the harmful ultraviolet (UV) radiations coming from the sun. These radiations causes skin cancer in humans.

Depletion of Ozone layer : Nitric Oxide and chlorofluorocarbons are found to be most responsible for depletion of Ozone layer.



- **Ozone depletion by oxides of Nitrogen:**

Nitrous oxide is quite inert, in the stratosphere it is photochemically converted into more reactive nitric oxide.



Thus NO is regenerated in chain reaction.

- **Effects of ozone depletion:**

With the depletion of Ozone layer, more UV radiation filters into troposphere.

— UV radiations leads to ageing of skin, cataract, Sunburn, skin cancer, killing of many phytoplanktons, damage to fish productivity, etc.

**Water pollution:** Water pollution may be defined as any change in its physical, chemical, biological properties or contamination with foreign materials that can adversely affect human beings or reduce its utility for the intended use.

**Major water pollutants and their sources:**

Pollutants	Major sources
natural waste	Leaching of minerals slits from soil erosion falling of organic matter from bank, etc.
organic Chemicals	Pesticides, surfactants, detergents, Industrial waste
metals	Nuclear power plants, mining, metal plating industries.
man-made wastes	Sewage domestic waste, soaps and detergents, waste from animal sheds and slaughter houses, run off from agricultural fields, industrial wastes, oil pollution.

- **Eutrophication:** The process in which nutrient enriched water bodies support a dense plant population, which kills animal life by depriving it of Oxygen and results in subsequent loss of biodiversity is known as eutrophication.

- **BOD:** The amount of oxygen required by bacteria to break down the organic matter present in a certain volume of a sample of water, is called Biochemical Oxygen Demand (BOD)

#### International standards for drinking water:

Element	Permissible limit	Effect of excess amount
Fluoride	1 ppm or $1\text{ mg dm}^{-3}$	Over 10 ppm causes harmful effect to bones and teeth.
Lead	50ppb	Excess amount can damage kidney, liver reproductive system, etc.
Nitrate	50ppm	Excess amount can cause blue baby syndrome.
Sulphate	500ppm	Excess can cause laxative effects.

- ▶ **Soil pollution:** Soil pollution is the addition of such chemical substances (in an indefinite proportion) which deteriorates the quality, texture and mineral content of the soil and disturbs the biological balance of the organisms in it and has little effect on the plant growth.

#### Some major soil pollutants and their sources:

Pollutants	Major sources
Industrial wastes	Waste products from paper, sugar, chemical Industries dumped into the soil.
Agricultural wastes	Chemical such as fertilizers pesticides extra used for killing insects fungi and weeds.
Soil conditioners	Used to protect soil fertility but contains several toxic metals like Pb, As, Hg, Cd, etc
Farm wastes	Wet slurry, faecal wastes are seeped into the soil.
Radioactive pollutants	Dumping of nuclear waste into the soil.

#### ▶ Remedial measures:

- Forestation should be done to check the spread of desert.
  - Use of chemical fertilizers should be minimised.
  - Recycling, digestion and incineration of urban waste and organic waste should be done.
  - The industrial effluents should not be allowed to discharge into fields.
  - The fertility of the soil can be improved by soil rotation and mixed farming.

▶ **Control of environmental pollution:**

- **Waste management:** Environmental pollution can be controlled to a certain extent by managing the waste disposal in a proper way.
- **Recycling:** A large amount of disposed waste materials can be reduced by recycling the waste.

Thus, it reduces the landfill and converts waste into usable products.

▶ **Green chemistry:** Green Chemistry may be defined as a strategy to design chemical process and products that reduces or eliminate the use and generation of hazardous substances.

- It is an alternative tool for reducing pollution. Green Chemistry includes concepts such as waste minimization, solvent selection, atom utilisation, intensive processing and alternative synthetic routes from sustainable resources.

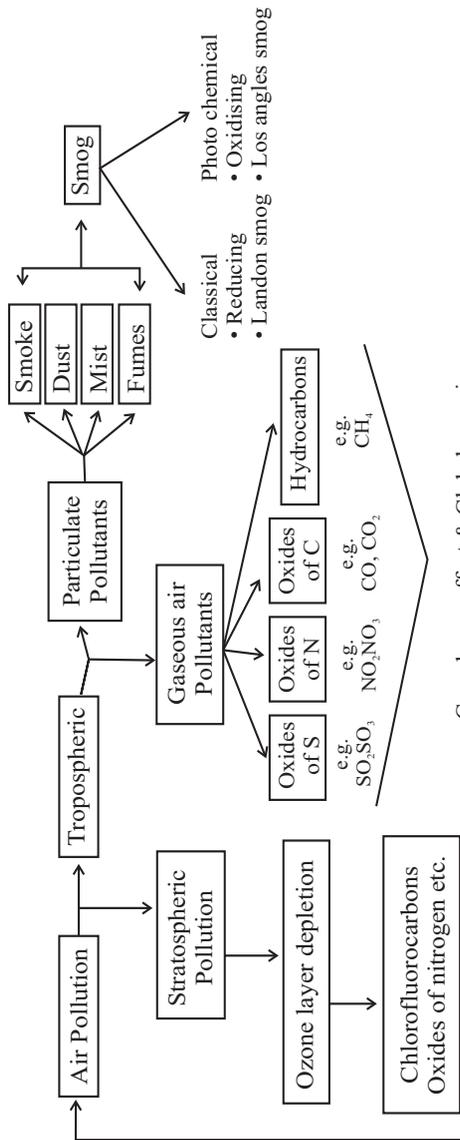
- **Green chemistry in day-to-day life:**

- Dry cleaning of clothes: Tetra chloroethene ( $\text{Cl}_2\text{C} = \text{CCl}_2$ ) was earlier used as solvent for dry cleaning. The compound contaminates the ground water and is also a suspected carcinogen.

The process using this compound is now being replaced by a process, where liquefied carbon dioxide, with suitable present is used.

- Bleaching of paper: Chlorine gas was used earlier for bleaching paper. These days, hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) with suitable catalyst, which promotes the bleaching action of hydrogen peroxide, is used.

# MIND MAP : ENVIRONMENTAL CHEMISTRY



**Classical**

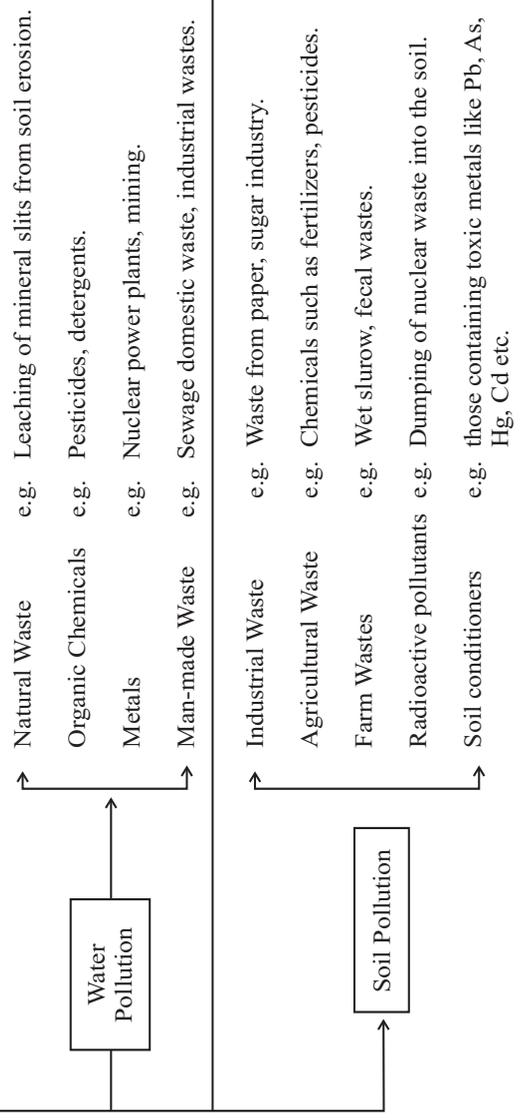
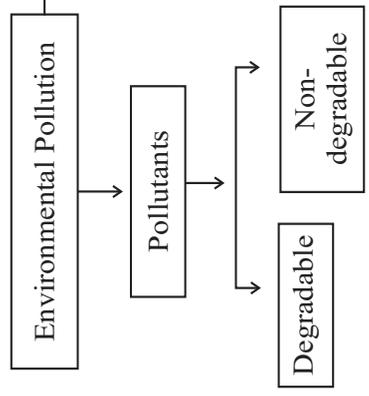
- Reducing
- Landon smog

**Photo chemical**

- Oxidising
- Los angles smog

• Greenhouse effect & Global warming

• Acid rain



## MULTIPLE CHOICE QUESTIONS (MCQ)

1. Which of the following is not the consequence of global warming?
  - (a) Increase in average temperature of Earth.
  - (b) Melting of Himalayan glaciers
  - (c) Rise in sea level
  - (d) Eutrophication
2. Which of the following statement is incorrect?
  - (a) Oxidize of Nitrogen in atmosphere can cause depletion of Ozone layer
  - (b) Ozone absorbs infrared rays
  - (c) Depletion of  $O_2$  is due to its chemical reaction with halo alkanes
  - (d) None of these
3. Which of the following are the hazardous pollutants present in automobile exhaust gases?

(i) $N_2$	(ii) CO	(iii) $CH_4$	(iv) Oxides of nitrogen
(a) ii and iii		(b) i and ii	
(c) ii and iv		(d) i and iii	
4. Which of the following gas causes green house effect to maximum extent?

(a) $CH_4$	(b) Water vapour
(c) $N_2O$	(d) $CO_2$
5. The lowest region of atmosphere is?

(a) Stratosphere	(b) Troposphere
(c) Mesosphere	(d) Hydrosphere
6. Classical smog occurs in place of

(a) Excess of $NO_2$	(b) Warm dry climate
(c) Cool humid climate	(d) All of these
7. When huge amount of sewage is dumped in a river, the BOD

(a) Will increase	(b) Will remain unchanged
(c) Will in decrease	(d) May increase or decrease
8. Which of the following practices will not come under Green chemistry?
  - (a) Use of  $CO_2$  as solvent instead of  $Cl_2$
  - (b) Use of  $H_2O_2$  instead of  $Cl_2$  for bleaching
  - (c) Synthesis of ethanal from ethane in one step
  - (d) Use of tetrachloroethene as a solvent for dry cleaning

9. Eutrophication causes reduction in  
 (a) Dissolved salts (b) Dissolved oxygen  
 (c) Nutrients (d) All of these
10.  $\text{SO}_2$  and  $\text{NO}_2$  cause pollution by increasing  
 (a) Acidity (b) Alkalinity  
 (c) Buffer action (d) Both (a) and (c)

**ANSWERS:** 1.d 2.b 3.c 4.d 5.b 6.c 7.a 8.d 9.d 10. a.

### FILL IN THE BLANKS

1. Three substances normally considered as primary pollutant are \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
2. Sulphur dioxide is mainly produced by the burning of \_\_\_\_\_.
3. BOD stands for \_\_\_\_\_.
4. The single plant nutrient mainly responsible for eutrophication is \_\_\_\_\_.
5. The lowest layer of atmosphere is the \_\_\_\_\_.
6. A crucially important species formed by oxygen in stratosphere is \_\_\_\_\_.
7. \_\_\_\_\_ is a greenhouse gas.
8. A major class of organic halides that are thought to pose a threat to stratospheric ozone are \_\_\_\_\_.
9. The component that distinguishes classical smog from photochemical smog is \_\_\_\_\_.
10. Carbon dioxide traps heat in the atmosphere. This is called the \_\_\_\_\_.

**Answers :** 1.  $\text{CO}$ ,  $\text{NO}_2$ ,  $\text{SO}_2$  2. Coal 3. Biochemical oxygen demand 4. Phosphate 5. Troposphere 6. Ozone 7. Carbon dioxide 8. Chlorofluorocarbons 9. Sulphur dioxide 10. Greenhouse effect

### TRUE AND FALSE TYPE QUESTIONS

1. The troposphere is the region above the stratosphere.
2. Dust, mist, fumes, smoke and smog are particulate pollutants.
3. Carboxyhaemoglobin is less stable than oxyhaemoglobin.
4. Ozone occurs naturally in the troposphere.

5. Plants such as Pinus, Juniparus, Pyrus and Vitis metabolize nitrogen oxides.
6. Clean water should have BOD of 17 ppm or more.
7. Photochemical smog is a mixture of oxidising pollutants.
8. The exhaust from jet aeroplanes contains nitric oxide, which can destroy the ozone layer.
9. PAN is one of the constituents of photochemical smog.
10. DDT is non-biodegradable and persistent.

**Answers :** 1. F 2. T 3. F 4. F 5. T 6. F 7. T 8. T 9. T 10. T

### MATCH THE COLUMNS

#### Match the column:

- | 1. Column I        | Column II  |
|--------------------|--|
| a. CO <sub>2</sub> | i. a gas produced by the partial combustion of many fuels  |
| b. CO              | ii. a gas that occurs naturally in the atmosphere and which is needed for photosynthesis           |
| c. O <sub>3</sub>  | iii. a dangerous gaseous pollutant with corrosive properties formed by combustion of fossil fuels. |
| d. SO <sub>2</sub> | iv. an allotrope of oxygen found in the upper atmosphere   |
2. Match the pollutants (a, b, c, d) in column I with the effects (i, ii, iii, iv) in column II.

Column I	Column II
a. Phosphate fertilisers in water	i. BOD level of water increases
b. Methane in air	ii. Acid rain
c. PAN	iii. Global warming
d. Nitrogen oxides in air	iv. Photochemical oxidant

**ANSWERS:** 1. a. ii    b. i    c. iv    d. iii  
 2. a. i    b. iii    c. iv    d. ii

## ASSERTION-REASON TYPE QUESTIONS

In the following questions a statement of Assertion (A) followed by reason(R) is given. Use the following key to select correct answer.

- (a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
- (b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
- (c) Both Assertion and Reason are incorrect.
- (d) Assertion is not correct but Reason is correct.

1. **Assertion:** The pH of acid rain is less than 5.6.

**Reason:** Carbon dioxide present in the atmosphere dissolves in rain water and forms carbonic acid.

2. **Assertion:** Photochemical smog is oxidizing in nature.

**Reason :** Photochemical smog contains  $\text{NO}_2$  and  $\text{O}_3$ , which are formed during the sequence of reactions.

3. **Assertion:** If BOD level of water in a reservoir is less than 5ppm, it is highly polluted.

**Reason:** High biological oxygen demand means low activity of bacteria in water.

4. **Assertion:** Ozone is destroyed by solar radiation in upper atmosphere.

**Reason:** Thinning of the ozone layer allows excessive UV radiations to reach the surface of earth.

5. **Assertion:** Carbondioxide is an of the important greenhouse gas.

**Reason:** It is largely produced by respiratory function of animals and plants.

**ANSWERS :** 1. b    2. a    3. c    4. d    5. b

## ONE WORD TYPE QUESTIONS

1. Name the gas which reacts with haemoglobin in blood.
2. In which part of atmosphere is ozone layer present?
3. Besides  $\text{CO}_2$  name one other green house gas.
4. Which acid is most abundant in acid rain?
5. Name the gas whose release was responsible for Bhopal gas tragedy.

6. What is the nature of photochemical smog?
7. Write full form of BOD.
8. What is the lowest region of the atmosphere which extends upto a height of 10 km from sea level?
9. Name the gas which is produced by the incomplete combustion of gasoline.
10. What does CFC stand for?

### 1-MARK QUESTIONS

1. Name two gaseous pollutants.
2. What is the size range of particulates?
3. What are primary pollutants?
4. Name two greenhouse gases.
5. What is the composition of photochemical smog?
6. What is the composition of classical smog?
7. Which are the compounds responsible for ozone layer depletion?
8. Name the pollutants which has affected Taj Mahal.
9. Name two strong acids present in acid rain.
10. What is PAN?
11. Name two sources of phosphate pollution.
12. When a huge amount of sewage is dumped into a river, what will be the effect on BOD?
13. How is NO formed in atmosphere?
14. In which season the depletion of ozone on Antarctica takes place and when is it replenished?
15. Define acid rain.

### 2-MARKS QUESTIONS

1. Explain giving reason: The presence of CO reduces the amount of haemoglobin available in the blood for carrying oxygen to body cells.

- Oxygen plays a key role in the troposphere while ozone in stratosphere. Explain.
- What is meant by Eutrophication?
- Define BOD.
- What is the importance of measuring BOD of a water body?
- Why does water with excessive algae growth become polluted?
- A person was using water supplied by municipality. Due to shortage of water, he started using underground water, he felt laxative effect. What could be the cause?
- What do you understand by the term Green chemistry?
- Give two examples each of biodegradable and non-biodegradable waste.
- List few ways to control photochemical smog.

### 3-MARKS QUESTIONS

- Give three harmful effects of oxides of sulphur.
- What is Global warming? What is its cause?
- What is photochemical smog and what are its harmful effects?
- How is classical smog different from photochemical smog?
- State briefly the reactions causing ozone layer depletion in the stratosphere.
- How does rain water get contaminated with acidic impurities?
- Discuss the harmful effects of acid rain.
- Suggest any four methods for waste management.

### 5-MARKS QUESTIONS

- What is Green house effect? How is it responsible for global warming?
- How can you apply green chemistry in for the following?
  - To control photochemical smog
  - To avoid use of halogenated solvents in dry cleaning
  - To reduce the use of detergents
  - To reduce the consumption of petrol and diesel.

## UNIT TEST

**Time Allowed: 1 hr**

**Maximum Marks : 20**

*General Instructions:*

- (i) All questions are compulsory.
  - (ii) Maximum marks carried by each question are indicated against it.
- 

1. The lowest region of atmosphere is [1]  
(a) Stratosphere (b) Troposphere  
(c) Mesosphere (d) Hydrosphere
2. Classical smog occurs in place of [1]  
(a) Excess of  $\text{NO}_2$  (b) Warm dry climate  
(c) Cool humid climate (d) All of these
3. Name two Greenhouse gases. [1]
4. A major class of organic halides that are thought to pose a threat [1]  
to stratospheric ozone are \_\_\_\_\_.
5. The single plant nutrient responsible for eutrophication is [1]  
\_\_\_\_\_.
6. Explain giving reason: The presence of CO reduces the amount of [2]  
haemoglobin available in the blood for carrying oxygen to body cells.
7. How is classical smog different from photochemical smog? [2]
8. Define BOD. What is the importance of measuring BOD of a [3]  
water body?
9. How does rain water get contaminated with acidic impurities? [3]  
Write one harmful effect of acid rain.
10. How can you apply green chemistry for the following? [5]  
(i) To control photochemical smog  
(ii) To avoid use of halogenated solvents in dry cleaning  
(iii) To reduce the use of detergents  
(iv) To reduce the consumption of petrol and diesel.

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**SAMPLE PAPER - I**  
**SUB : CHEMISTRY**  
**CLASS - XI**

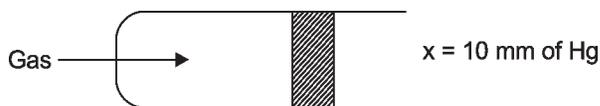
**Time Allowed: 1 hr**

**Maximum Marks : 70**

*General Instructions:*

- All question are compulsory
  - Q 1 to 20 are very short answer objective type and each carries 1 mark each.
  - Q 21 to 27 are short answer question and carry 2 marks each.
  - Q 28 to 34 are also short answer question and carry 3 marks each.
  - Q 35 to 37 are long answer questions and carry 5 marks each.
  - There is no overall choice. However internal choice have been provided in some questions.
  - Use of log tables if necessary. Use of calculators is not allowed.
- 

1. What are the oxygen moles in 0.5 mol of  $\text{CaCO}_3$  ?  
(a) 1 mol (b) 0.2 mol  
(c) 1.5 mol (d) 3.0 mol
2. What is the unit of wave number ( $\nu$ ) ?
3. The general configuration of 'f' block is  
(a)  $(n-1) f^{1-14} n d^{0-1} n s^2$  (b)  $(n-1) f^{0-1} n d^2 n s^2$   
(c)  $(n-2) f^{1-14} (n-1) d^{0-1} n s^2$  (d)  $(n-2) f^{1-14} (n-1) d^{0-2} n s^{0-1}$
4. The shape of  $\text{IBr}_2^-$  is  
(a) Tetrahedral (b) Planar  
(c) Linear (d) V-shape
5. What is the pressure of the gas in tube



6. Arrange the following in order of decreasing boiling point : Be, Mg, Ca, Sr
7.  $\Delta_f H^0$  for Graphite is \_\_\_\_\_ .
8. Nature of NaH is \_\_\_\_\_ .

### Q.9 - Q.10 Assertion-Reason Type Questions

Each question contains statements-1 (Assertion) and Statement-2 (Reason)

Examine the statements carefully and mark the correct answer according to the instruction given below:

- A. If both the statements are true and statement-2 is the correct explanation of statement-1.
- B. If both the statements are true but statement-2 is not the correct explanation of statement-1.
- C. If statement-1 is true and statement-2 is false.
- D. If statement-1 is false and statement-2 is true.

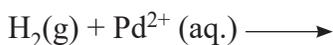
9. Statement-1 For reaction  $A + B \rightleftharpoons C$ ,  $K = 4$  on addition of catalyst  $K$  becomes more than 4.

Statement-2 Catalyst only helps to attain the equilibrium faster from either end of reaction.

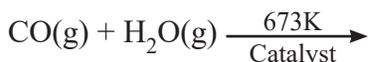
10. Statement-1  $Cl_2 + 2OH^- \longrightarrow ClO^- + Cl^-$  is a disproportionation reaction.

Statement-2 In disproportionation, the same element get oxidised as well as reduce.

11. Complete the reaction



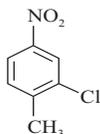
OR



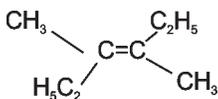
12. Why ammoniacal solution of alkali metal is blue in colour?

13. What is a producer gas?

14. Write the IUPAC name of following



OR



15. What does B.O.D. stands for?

16. Calculate number of atoms in 52u of He.

17. Which series of lines of the hydrogen spectrum lie in the visible region?

18. Write the name of element with highest electron gain enthalpy.

19. Draw the shape of  $\text{ClF}_3$ .  
OR, Draw the shape of  $\text{SF}_6$ .
20. What is the unit of 'a' in van der Waal's equation?
21. (i) What are the number of waves made by a Bohr electron in an orbit of maximum magnetic quantum number 3?  
(ii) If kinetic energy of a particle is doubled. What will happen to de Broglie wavelength as compared to previous de Broglie wavelength.
22. (i) Why  $\text{PbCl}_2$  is more stable than  $\text{PbCl}_4$ ?  
(ii) Why Electron gain enthalpy of Mg is positive?

OR

- (i) Second I.E. (Ionisation Enthalpy) is always more than first Ionisation energy.  
(ii) Why first electron gain enthalpy of sulphur is more negative than oxygen.
23. Balance the following reaction by (ion-electron or oxidation number method)  
 $\text{Cl}_2\text{O}_7(\text{g}) + \text{H}_2\text{O}_2(\text{aq.}) \longrightarrow \text{ClO}_2^-(\text{aq.}) + \text{O}_2(\text{g}) + \text{H}^+(\text{Acidic medium})$
24. (i) What is the difference between hydrolysis and hydration?  
(ii) Arrange the following in order of increasing electrical conductance  $\text{CaH}_2$ ,  $\text{BeH}_2$  and  $\text{TeH}_2$ .
25. A sample of 0.5g of an organic compound was treated according to Kjeldahl's method. The ammonia evolved was absorbed in 50 ml of 0.5 M  $\text{H}_2\text{SO}_4$ . The residual acid required 60 mL of 0.5 solution of NaOH for neutralisation. Find the percentage composition of nitrogen in the compound.
26. (i) Out of benzene, m-dinitrobenzene and toluene, which will undergo nitration most easily and why?  
(ii) What effect does branching of an alkane chain has on its boiling point?
27. (i) What is Eutrophication?  
(ii) What is the action of  $\text{F}^-$  on enamel present on the surface of teeth?

OR

- (i) What is the upper limit concentration of lead in drinking water?  
(ii) What is smog? Classify them as reducing smog or oxidising smog.

28. A crystalline salt on being rendered anhydrous loses 45.6% of its weight. The percentage composition of the anhydrous salt is  
Al = 10.50%, K = 15.1%, S = 24.96%, O = 49.92%  
Find the simplest formula of the anhydrous and crystalline salt.  
(Atomic  $M_{\text{mass}}$  : K = 39, Al = 27, S = 32, O = 16).

29. Explain following with example :

- (i) Aufbau's Rule    (ii) Hund's Rule    (iii) Pauli's Exclusion Principle

OR

An ion with mass number 81 contains 31.7% more neutrons as compared to protons. Assign the atomic symbol.

30. Explain the bonding in  $\text{SF}_6$  using hybridisation concept and define what is hybridisation.

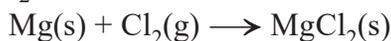
OR

On the basis of molecular orbital theory find the bond order, molecular orbital configuration and magnetic nature of  $\text{O}_2^+$ .

31. Derive van der Waal's equation :

$$\left( P + \frac{an^2}{v^2} \right) (v - nb) = nRT$$

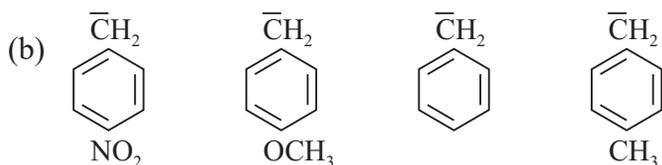
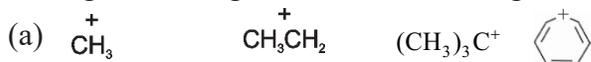
32. Explain Born Haber cycle with by considering example of formation of  $\text{MgCl}_2$  as given in the chemical reaction

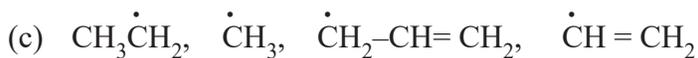


33. Give suitable reasons :

- (i) A solution of  $\text{Na}_2\text{CO}_3$  is alkaline why?  
(ii) BeO insoluble but  $\text{BeSO}_4$  soluble in water why?  
(iii) Lithium salts are commonly hydrated as compare to other alkali metal ions. Why?

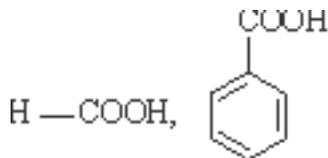
34. Arrange following in order of increasing stability





OR

- (i) What is ambident nucleophile? Mention one example.  
 (ii) Distinguish between homolytic and heterolytic bond cleavage.  
 (iii) Which one is stronger acid and why



35. (a) What is a buffer solution? Give example.  
 (b) What is common ion effect?  
 (c) Define Le-Chatelier principle and explain effect of following :  
 (i) Change of concentration (ii) Change of pressure

OR

- (a) Find out  $K_c$  for following reaction  
 $2\text{NOCl(g)} \rightleftharpoons 2\text{NO(g)} + \text{Cl}_2\text{(g)}$ ;  $K_p = 1.8 \times 10^{-4}$  at 500K  
 (b)  $K_p = 0.04$  atm at 899K. What is the equilibrium concentration of  $\text{C}_2\text{H}_6$  where it is placed in a flask at 4.0 atm pressure and allow to come to equilibrium  
 $\text{C}_2\text{H}_6 \rightleftharpoons \text{C}_2\text{H}_4\text{(g)} + \text{H}_2\text{(g)}$   
 (c) What is the unit of  $K_p$  for the following chemical reaction?  
 $2\text{NH}_3\text{(g)} \rightleftharpoons \text{N}_2\text{(g)} + 3\text{H}_2\text{(g)}$

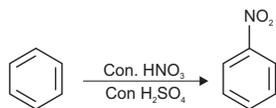
36. (i) Show with the help of chemical reaction that Al shows amphoteric behaviour.  
 (ii) Draw the structure of (a)  $\text{B}_2\text{H}_6$  (b) Boric acid.  
 (iii) Write the formula of Borax.

OR

- (i) Explain Lewis acid strength  
 $\text{BF}_3 < \text{BCl}_3 < \text{BBr}_3 < \text{BI}_3$

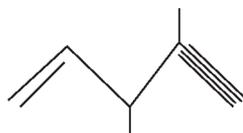
- (ii) What are silicones? Give reaction for formation of chain silicones.  
 (iii) Why CO is poisonous in nature?

37. (i) Explain with the help of mechanism



- (ii) Draw the Newman structure of (a) 2-Methyl butane  
 (b) 1-Methyl prop-1-ene

(iii) Calculate total number of  $\sigma$  and  $\pi$  bond(s) in

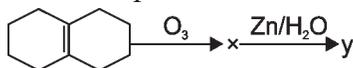


OR

- (i) Explain Kolbe's electrolysis with mechanism.  
 (ii) State Huckel Rule's.

Check whether  is an aromatic or non aromatic, anti-aromatic.

(iii) Write the product



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**SAMPLE PAPER - II**  
**SUB : CHEMISTRY**  
**CLASS - XI**

**Time Allowed: 1 hr**

**Maximum Marks : 70**

*General Instructions:*

- All question are compulsory
  - Q 1 to 20 are very short answer objective type and each carries 1 mark each.
  - Q 21 to 27 are short answer question and carry 2 marks each.
  - Q 28 to 34 are also short answer question and carry 3 marks each.
  - Q 35 to 37 are long answer questions and carry 5 marks each.
  - There is no overall choice. However internal choice have been provided in some questions.
  - Use of log tables if necessary. Use of calculators is not allowed.
- 

**SECTION-A**

1. The number of nodal planes in  $p_x$  orbitals is  
(a) 1            (b) 2            (c) 3            (d) 0
2. Which of the following has smallest bond angle?  
(a)  $H_2O$         (b)  $H_2S$             (c)  $NH_3$             (d)  $SO_2$
3. For a reaction to be spontaneous at all the temperature:  
(a)  $\Delta G$  -ve,  $\Delta H$  +ve,  $\Delta S$  +ve  
(b)  $\Delta G$  +ve,  $\Delta H$  -ve,  $\Delta S$  +ve  
(c)  $\Delta G$  -ve,  $\Delta H$  -ve,  $\Delta S$  - ve  
(d)  $\Delta G$  -ve,  $\Delta H$  -ve,  $\Delta S$  +ve
4. Which is is most strongly hydrated?  
(a)  $Li^+$             (b)  $Na^+$             (c)  $K^+$             (d)  $Rb^+$
5. Which of the following has largest ionic radii?  
(a)  $Na^+$             (b)  $Mg^{2+}$             (c)  $F^-$             (d)  $O^{2-}$
6. When carbon is bonded to four other atoms or groups it uses \_\_\_\_\_ hybrid orbitals.
7. Surface tension \_\_\_\_\_ with increase in temperature.
8. The second electron gain enthalpy is \_\_\_\_\_.

**Directions for Question No. 9 and 10 :** A statement of assertion (A) followed by a statement of reason (R) is given. Choose the correct option out of the choices given below for each question:

- (a) A and R both are correct and R is the correct explanation of A.
- (b) A and R both are correct but R is not the correct explanation of A.
- (c) A is true but R is false.
- (d) A and R both are false.

9. **Assertion:** The entropy of ice is less than that of water.

**Reason:** Ice has a cage like structure.

10 **Assertion:** London forces are much more stronger between Xenon atoms than between Helium atoms.

**Reason:** Xenon atom is bigger than Helium atom.

11. Write empirical formula of  $\text{CH}_3\text{COOH}$  and  $\text{K}_2\text{CO}_3$

Or

Define mole fraction.

12. Mention the quantum number which determines the energy of electron in the H-atom.

Or

How many unpaired electrons are there in  $\text{Ni}^{2+}$  ion? (Given :  $Z = 28$ )

13. State the condition for the formation of precipitate.

Or

Write the conjugate acid and conjugate base of  $\text{HSO}_4^-$ .

14. Using VSEPR theory draw the shape of  $\text{XeF}_4$  molecule.

15. Write IUPAC name of  $\text{CH}_2 = \text{CH} - \text{CH}(\text{OH})\text{C} \equiv \text{CH}$ .

16. In a reaction between an oxidant and a reductant which will give up electrons and which will accept electrons?

Or

Calculate oxidation number of Cr in  $\text{K}_2\text{Cr}_2\text{O}_7$  and Mn in  $\text{KMnO}_4$ .

17. Elements of which group form electron precise hydrides?

Or

Which part of periodic table is known as hydride gap?

18. State the reason of using certain alkali metals in photoelectric cells.

Or

Name those alkaline earth metals which do not impart colour to the flame.

19. Mention the compounds which are responsible for ozone layer depletion.

20. Cis But-2-ene has lower melting point than trans But-2-ene. Give reason.

### SECTION: B

21. Balance the following redox reaction in acidic medium by ion electron method.



22. (i)  $\text{Mg}^{2+}$  ion is smaller than  $\text{O}^{2-}$  ion, although both are isoelectronic. Give reason.  
(ii) Write IUPAC name and symbol for the element with atomic no. 120.
23. (i) Mention the number of radial nodes in 6s orbitals.  
(ii) Write electronic configuration of  $\text{Fe}^{2+}$  ion. (Given,  $Z = 26$ )

Or

Calculate the wavelength of a ball of mass 0.1kg moving with a velocity of  $10\text{ms}^{-1}$ . (Given,  $h = 6.626 \times 10^{-34} \text{ Js}$ )

24. Describe one method to remove permanent hardness of water.

Or

Give one chemical reaction each to show that hydrogen peroxide can act as oxidising as well as reducing agent.

25. Write a short note on Greenhouse effect and global warming.

Or

State the point of differences between Classical and photochemical smog.

26. (i) Stability of carbocations follows the order  $3^\circ > 2^\circ > 1^\circ$ . Explain this order of stability of carbocations.  
(ii) In what manner is Electromeric effect different from Inductive effect?
27. (i) Mention the reason of not using Wurtz reaction for the preparation of unsymmetrical alkanes from alkyl halides.  
(ii) How will you convert Benzene to p-Nitrobromobenzene?

### SECTION-C

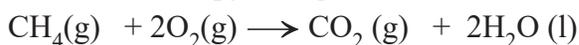
28. The density of 3M solution of NaCl is  $1.25\text{g/mL}$ . Calculate the molality of the solution. (Given: Atomic masses:  $\text{Na}=23\text{u}$ ,  $\text{Cl}=35.5\text{u}$ )

Or

Calculate the molarity of nitric acid ( $\text{HNO}_3$ ) in a sample having a density  $1.41\text{g/mL}$  and mass percent of nitric acid in it being 69%. (Atomic mass:  $\text{N}=14\text{u}$ ,  $\text{H}=1\text{u}$ ,  $\text{O}=16\text{u}$ )

29. (i) The ball hit with a hockey by a player does not form a wave. State reason.  
 (ii) Write the possible values of 'm' for an electron with  $l=2$ .  
 (iii) Chromium has configuration  $3d^54s^1$  and not  $3d^44s^2$ . Explain.
30. (i) Explain non linear shape  $H_2S$  and non-planar shape of  $PCl_3$  using VSEPR theory.  
 (ii) Can we have a diatomic molecule with its ground state molecular orbitals full with electrons. Give reason for your answer.

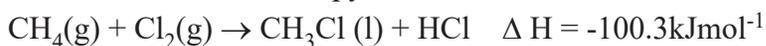
31. Calculate enthalpy change for the reaction:



The enthalpy of formation of  $CH_4(g)$ ,  $CO_2(g)$  and  $H_2O(l)$  are  $-74.8\text{kJmol}^{-1}$ ,  $-393.5\text{kJmol}^{-1}$  and  $285.8\text{kJmol}^{-1}$  respectively.

Or

Calculate the bond enthalpy of Cl-Cl bond from the following data:



Given: bond enthalpies of C — H, C — Cl and H — Cl bonds are 413, 326 and 431  $\text{kJmol}^{-1}$  respectively.

32. A neon-dioxygen mixture contains 70.6 g dioxygen and 167.5 g neon. If pressure of the mixture of gases in the cylinder is 25 bar, what is the partial pressure of dioxygen and neon in the mixture? (Atomic mass: O = 16u, Ne = 20u)
33. (i) Compounds of beryllium are much more covalent than other group 2 elements. Give reason.  
 (ii) Why does the solubility of alkaline earth metal carbonates and sulphates in water decrease down the group?  
 (iii) When a metal of group 1 is dissolved in liquid ammonia a blue solution is obtained initially. How do you account for the blue colour of the solution?
34. (i) State the necessary compound to be aromatic according to Huckel's rule.  
 (iii) Explain why alkyl groups act as electron donors when attached to a  $\pi$  system.

Or

- (i) Draw the resonance structures of Phenol.  
 (ii) Suggest a method used to purify the liquids which have high boiling points and decompose below their boiling points.

### SECTION-D

35. (i) Boron trihalides( $BX_3$ ) act as Lewis acids. Why?  
(ii) Conc.  $HNO_3$  can be transported in aluminium containers. Give reason.  
(iii)  $Pb(IV)$  is less stable than  $Pb(II)$ . Give reason.  
(iv) Gallium has higher ionisation enthalpy than aluminium. Why?  
(v) What do you understand by diagonal relationship?

Or

- (i) Why  $CCl_4$  is resistant to hydrolysis but  $SiCl_4$  is readily hydrolysed?  
(ii) Explain why there is a decrease in ionisation enthalpy from carbon to silicon?  
(iii) Boron does not form  $B^{3+}$  ion. Give reason.  
(iv) How can you explain greater stability of  $BCl_3$  as compared to  $TiCl_3$ ?  
(v) Define diagonal relationship between elements in modern period table.
36. (i) Explain common ion effect with example.  
(ii) The concentration of hydrogen ion in a sample of soft drink is  $4 \times 10^{-3}$  M. Calculate its pH.  
(iii) What is the effect of removal of  $CH_3OH$  on the equilibrium of the reaction,  $2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$ .

Or

- (i) Calculate  $H_3O^+$  ion concentration of a water sample having  $pH = 6.78$ .  
(ii) Define buffer solutions.  
(iii) State Lewis definition of acids and bases. Give one example of each.
37. (i) An alkene A on ozonolysis gives a mixture of propanal and pentan-3-one. Write the structural formula of A.  
(ii) Complete the following reactions:  
(a)  $CH_3CH=CH_2 + HBr \xrightarrow{\text{organic peroxide}}$   
(b)  $CH_3CH_2Br + Na \xrightarrow{\text{Dry Ether}}$   
(iii) Write a short note on Friedel Crafts alkylation.

Or

- (i) Why eclipsed form and staggered form of ethane cannot be isolated at room temperature?  
(ii) State Markovnikov's rule.  
(iii) Which out of Ethene or Ethyne is more acidic and why?  
(iv) What happens with 2-Bromobutane is being treated with  $KOH$  (alcoholic)?

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**SAMPLE PAPER - III**  
**SUB : CHEMISTRY**  
**CLASS - XI**

**Time Allowed: 1 hr**

**Maximum Marks : 70**

*General Instructions:*

- All question are compulsory
  - Q 1 to 20 are very short answer objective type and each carries 1 mark each.
  - Q 21 to 27 are short answer question and carry 2 marks each.
  - Q 28 to 34 are also short answer question and carry 3 marks each.
  - Q 35 to 37 are long answer questions and carry 5 marks each.
  - There is no overall choice. However internal choice have been provided in some questions.
  - Use of log tables if necessary. Use of calculators is not allowed.
- 

1. Which of the following d-orbital has double disc (body shooter shape)  
(a)  $d_{xy}$             (b)  $d_{z^2}$             (c)  $d_{x^2-y^2}$             (d)  $d_{yz}$
2. Among the following, the compound that contains, ionic, covalent and Coordinate linkage is  
(a)  $\text{NH}_4\text{Cl}$             (b)  $\text{NH}_3$             (c)  $\text{NaCl}$             (d)  $\text{CO}_2$
3. Which of the following is a state function  
(a)  $q$  (b)  $w$             (c)  $q + w$             (d) None of these
4. Which of the following alkali metal ion has highest ionic mobility  
(a)  $\text{Li}^+$             (b)  $\text{Na}^+$             (c)  $\text{K}^+$             (d)  $\text{Cs}^+$
5. The correct order of electron gain enthalpy with negative sign of F, Cl, Br and I having atomic number 9, 17, 35 and 53 respectively is  
(a)  $\text{I} > \text{Br} > \text{Cl} > \text{F}$             (b)  $\text{F} > \text{Cl} > \text{Br} > \text{I}$   
(c)  $\text{Cl} > \text{F} > \text{Br} > \text{I}$             (d)  $\text{Br} > \text{I} > \text{Cl} > \text{F}$
6. Arrange the following carbonations in order of their increasing stability  
 $(\text{CH}_3)_3\text{C}^+$ ,  $\text{CH}_3\text{CH}_2^+$ ,  $(\text{CH}_3)_2\text{CH}^+$ ,  $\text{CH}_3^+$
7. The IUPAC name and symbol of element with  $Z = 120$  is \_\_\_\_\_.
8. Direction for Question No. 9 to 10 : A statement of assertion (A) followed by a statement of Reason (R) is given.
  - (i) A and R both are correct, and R is correct explanation of A.
  - (ii) A and R both are correct, but R is not correct explanation of A.
  - (iii) A is true but R is false.
  - (iv) A and R both are false.

9. Assertion (A) : Enthalpy of graphite is lower than that of diamond.  
Reason (R) : Enthalpy of graphite is greater than that of diamond.
10. Assertion (A) : Lower the critical temperature of the gas; more easily can it be liquified.  
Reason (R) : Critical temperature is the temperature above which a gas cannot be liquified depending upon the pressure.
11. If ten volumes of dihydrogen gas react with five volumes of dioxygen gas, how much volume of water vapour would be produced?

OR

Calculate the number of atoms in 32.0 u of He.

12. Why are alkali metals used in photoelectric cells?

OR

Write electronic configuration of  $\text{Cr}^{3+}$  ion. (Atomic No. of Cr = 24)

13. Draw the shape of  $\text{ClF}_3$  molecule according to VSEPR theory?

14. Write the conjugate acid and conjugate base of  $\text{H}_2\text{O}$ .

OR

Write the relation between solubility and solubility product of  $\text{Cr}_2(\text{SO}_4)_3$ .

15. Consider the given standard reduction potentials of following elements A, B, C & D and arrange them in order of their increasing reducing power.

$A = -3.71\text{V}$ ,  $B = -0.76\text{V}$ ,  $C = +0.34\text{V}$ ,  $D = +0.80\text{V}$

OR

16. Write the cause of temporary and permanent hardness of water.
17. Why do magnesium and beryllium not impart colour to the flame in the flame test?
18. Write IUPAC name of  $\text{CH}_3 - \text{CO} - \text{CH}_2 - \text{CHO}$ .
19. Out of Cis-But-2-ene and Trans-but-2-ene which has greater boiling point and why?
20. Define Biochemical oxygen demand.
21. (i) What is the lowest value of n that allows 'g' orbitals to exist?  
(ii) Why 4s orbital is filled before 3d?

OR

Calculate wave number for the longest wavelength transition in the Balmer Series of hydrogen atom.

22. Explain why?
- $\Delta_f H_1$  of 'N' is more than that of 'O'.
  - A cation is smaller than parent atom.
23. Balance the following redox reaction in acidic medium by ion electron method.
- $$\text{Cr}_2\text{O}_7^{2-}(\text{aq.}) + \text{SO}_2(\text{g}) \longrightarrow \text{Cr}^{3+}(\text{aq.}) + \text{SO}_4^{2-}(\text{aq.})$$
24. Write chemical reactions to justify that  $\text{H}_2\text{O}_2$  can act as an oxidising as well as reducing agent.

OR

- What is water gas shift reaction?
  - What do you mean by 20 vol.  $\text{H}_2\text{O}_2$ ?
25. In sulphur estimate, 0.157 g of an organic compound gave 0.4813 g of barium sulphate. What is the percentage of sulphur in the compound?
26. Write chemical equations to convert:
- Ethyne to Ethanal
  - Benzene to m-Nitrotoluene
27. Define smog. How is classical smog different from photochemical smog?

OR

Explain the following terms:

- Green house effect
  - Green chemistry
28. Calcium carbonate reacts with aqueous HCl according to the reaction:
- $$\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq.}) \longrightarrow \text{CaCl}_2(\text{aq.}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$$
- What mass of  $\text{CaCO}_3$  is required to react completely with 25 mL of 0.75 M HCl?
29. (i) State Hund's rule of maximum multiplicity of electrons.  
(ii) The mass of an electron is  $9.1 \times 10^{-31}$  kg. If its K.E.  $3.0 \times 10^{-25}$  J, calculate its wavelength.
30.  $\text{N}_2$  is diamagnetic while  $\text{O}_2$  is paramagnetic. Explain on the basis of molecular orbital theory.

OR

Explain the structure of  $\text{PCl}_5$  according to hybridization. Why all P — Cl bonds.

31. What will be the pressure exerted by a mixture of 3.2 g of methane and 4.4 g of carbon dioxide contained in 9 dm<sup>3</sup> flask at 27°C.

OR

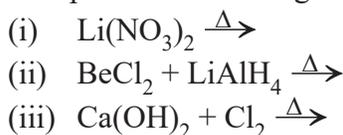
Calculate the compressibility factor for CO<sub>2</sub>, if one mole of it occupies 0.4 litre at 300K and 40 atm. Comment on the result.

32. The combustion of 1 mol of benzene takes place at 298K. After combustion CO<sub>2</sub> and H<sub>2</sub>O are formed and 3267 kJ mol<sup>-1</sup>,  $\Delta_f H^\ominus(\text{H}_2\text{O}) = -393 \text{ kJ mol}^{-1}$ .

OR

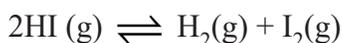
For the reaction :  $2\text{A}(\text{g}) + \text{B}(\text{g}) \longrightarrow 2\text{D}(\text{g})$ ,  $\Delta U^\ominus = -10.5 \text{ kJ}$  and  $\Delta S^\ominus = -44.1 \text{ J K}^{-1}$ . Calculate  $\Delta G^\ominus$  for the reaction, and predict whether the reaction will occur spontaneously.

33. Complete the following reaction equations:



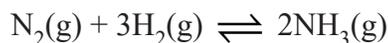
34. (i) Out of NO<sub>2</sub> — CH<sub>2</sub> — O and CH<sub>3</sub> — CH<sub>2</sub> — O<sup>-</sup> which is more stable and why?  
(ii) Why is it necessary to prepare Lassaigne extract for detection of N, S and halogens?  
(iii) Define the term hyperconjugation.

35. (i) State Le Chatelier's principle.  
(ii) Calculate the pH of 10<sup>-8</sup> M HCl.  
(iii) A sample of HI (g) is placed in flask at a pressure of 0.2 atm. At equilibrium the partial pressure of HI (g) is 0.04 atm. What is the K<sub>p</sub> for given equilibrium?



OR

- (i) Define common ion effect.  
(ii) Write the relationship between K<sub>p</sub> and K<sub>c</sub> for the reaction:



- (iii) Equal volume of 0.002 M solutions of sodium iodate and cupric chlorate are mixed together. Will it lead to precipitation of copper iodate? (For cupric iodate K<sub>sp</sub> = 7.4 × 10<sup>-8</sup>)

36. (i) Draw the structure of Diborane indicating electron precise and electron deficient bonds.
- (ii) Give reason for the following :
- $\text{PbCl}_4$  is powerful oxidising agent.
  - Fullerenes are the purest allotropes of carbon.
  - N — N bond dissociation enthalpy is less than P — P bond dissociation enthalpy.

OR

- (i) What happens when (give chemical equation) :
- Borax is heated strongly.
  - $\text{BF}_3$  is treated with LiH.
- (ii) Give reason for the following :
- $\text{NaBiO}_3$  is good oxidising agent.
  - Graphite acts as a good lubricant.
  - Boric acid is a weak acid.
37. (i) Propanal and pentan-3-one are the ozonolysis product of an alkene. What is the structural formula and IUPAC name of alkene?
- (ii) Give the main products of the reactions:
- $\text{C}_6\text{H}_6 + \text{CH}_3\text{Cl} \xrightarrow{\text{Anhydrous AlCl}_3}$
  - $\text{CH}_3\text{Cl} + \text{Na} \xrightarrow{\text{Dry ether}}$
  - $\text{CH}_3 - \text{CHCl} - \text{CH}_2 - \text{CH}_3 + \text{KOH(alc.)} \longrightarrow$

OR

- (i) Give chemical equation for each of the following :
- Decarboxylation
  - Friedel Craft acetylation
- (ii) Addition of HBr to propene yields 2-Bromopropane, while in the presence of benzoyl peroxide, the same reaction yields 1-Bromopropane. Explain and give mechanism.

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Direction for Question No. 7 and 8 :

- (i) If both assertion & reason are true and the reason is the correct explanation of the assertion.
- (ii) If both assertion & reason are true but the reason is the correct explanation of the assertion.
- (iii) If assertion is true statement but reason is false.
- (iv) If both assertion and reason are false statements.

7. Assertion : Number of orbitals in 3rd shell is 9.

Reason : Number of orbitals for a particular value of  $n = n^2$ .

8. Assertion : Ionic radius of  $\text{Na}^+$  is smaller than Na.

Reason : Effective nuclear charge of  $\text{Na}^+$  is higher than Na.

9. What is the IUPAC name of picric acid.

10. Why noble gases have positive electron gain enthalpy?

11. How many molecules of  $\text{SO}_2$  are present in 11.2 L at STP?

OR

Calculate the number of atoms in 35 g of Li (Atomic mass of Li = 7 u).

12. For an isolated system,  $\Delta U = 0$ , what will be  $\Delta S$  ?

OR

Write the statement of third law of thermodynamics.

13. Calculate the number of sigma and pie bonds in  $\text{C}_2\text{H}_2$ ?

14. Give the relation between  $K_a$  and  $K_b$ .

OR

Write the conjugate base of  $\text{H}_2\text{CO}_3$ .

15. Write the oxidation number of Cr in  $\text{K}_2\text{Cr}_2\text{O}_7$ .

OR

Write the stock notation  $\text{MnO}_2$ .

16. Give an example of electron deficient covalent hydride.

OR

Name the isotope of hydrogen which is radioactive in nature.

17. Potassium carbonate cannot be prepared by solvay process. Why?

18. Define the Boyle temperature or Boyle point.

19. Out of staggered and eclipsed form which is more stable and why?

20. What is the meaning of the term eutrophication with regards to water pollution.

## SECTION-B

21. Explain why :
- The three electron present in 2p subshell of nitrogen remain unpaired.
  - Cr has configuration  $3d^5 4s^1$  and not  $3d^4 4s^2$ .

OR

Calculate the radius of Bohr's fifth orbit for hydrogen atom.

22. (a) Show by a chemical reaction with water that  $\text{Na}_2\text{O}$  is a basic oxide and  $\text{Cl}_2\text{O}_7$  is an acidic oxide.
- (b) Name a species that will be isoelectronic with each of the following atoms or ions, (i)  $\text{F}^-$  (ii)  $\text{Ca}^{2+}$

23. Balance the following redox reaction in acidic medium



24. What do you understand by the terms :

- Syn gas
- Hydrogen economy

OR

What causes the temporary and permanent hardness of water?

25. 0.40 g of an organic compound gave 0.3 g of silver bromide of Carius method. Find the percentage of bromine in the compound. [Atomic mass of Ag & Br are 105 and 80 u]
26. Propanal and pentan-3-one are the ozonolysis product of an alkene. What is the structural formula of alkene?

OR

Convert the following :

- 1-Bromopropane to 2-Bromopropane
  - Ethanol to Glycol
27. Explain the following terms :
- Acid Rain
  - Global warming

OR

What are the reactions involved for ozone layer depletion in the stratosphere?

- Green house effect
  - Green chemistry
28. In a compound  $\text{C}_x\text{H}_y\text{O}_z$ , the mass % of C and H is 6 : 1 and the amount of oxygen present is equal to the half of the oxygen required to react completely  $\text{C}_x\text{H}_y$ . Find the empirical formula of the compound.

29. When light with a wavelength of 400 nm falls on the surface of sodium, electrons with a kinetic energy of  $1.05 \times 10^5 \text{ J mol}^{-1}$  are emitted.
- What is the minimum energy needed to remove an electron from sodium?
  - What is the maximum wavelength of light that will cause a photoelectron to be emitted?
30. (a) Describe the hybridisation in case of  $\text{C}_2\text{H}_2$ .
- Which out of  $\text{NH}_3$  and  $\text{NF}_3$  has higher dipole moment and why?

OR

- Use molecular orbital theory to predict why the  $\text{He}_2$  molecule does not exist?
  - Compare the stability of  $\text{O}_2$  and  $\text{O}_2^+$  on the basis of molecular theory.
31. Pressure of one gram of an ideal gas A at  $27^\circ\text{C}$  is found to be 2 bar. When 2g of another gas (ideal) B is introduced in the same flask at the same temperature the pressure becomes 3 bar. Find a relationship between their molecular masses.

OR

Explain the following terms :

- Dalton's law of partial pressure
  - Surface tension
  - Coefficient of viscosity
32. The standard enthalpy of combustion of Sucrose ( $\text{C}_{12}\text{H}_{32}\text{O}_{11}$ ) at 298 K producing  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{l})$  is  $-5200.7 \text{ kJ mol}^{-1}$ . If  $\Delta_f H^\circ$  of  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{l})$  are  $-393.0 \text{ kJ mol}^{-1}$  and  $-286 \text{ kJ mol}^{-1}$ .

OR

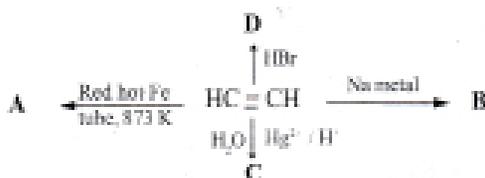
Explain the First law of thermodynamics and how can you prove the following relation :

$\Delta H = \Delta U + P \Delta V$  from the first law of the thermodynamics ( $\Delta U = q + w$ )?

33. Assign reason for the following :
- Potassium carbonate cannot be prepared by solvay process.
  - Be and Mg do not give characteristic colour to the flame.
  - Alkali metals are strong reducing agent.
34. Explain the resonance effect and draw the resonance structures of  $\text{CH}_2 = \text{CH} - \text{CHO}$ . Indicate the relative stability of the contributing structures.

### SECTION-D

35. (a) Addition of HBr to propene yields 2-bromopropane, while in the presence of benzoylperoxide, the same reaction yields 1-bromopropane. Explain and give its mechanism.
- (b) Identify A, B, C & D



- (c) Give a chemical test between ethene and ethane.
- OR
- (a) Out of benzene and toluene, which will undergo nitration more easily and why?
- (b) Explain the following :
- (i) Friedel-Crafts reaction
  - (ii) Wurtz reaction
36. (a) What is solubility product? How is it different from ionic product?
- (b) Equal volume of 0.02 M solutions of sodium iodate and cupric chlorate are mixed together. Will it lead to precipitation of copper iodate? (For cupric iodate  $K_{sp} = 7.4 \times 10^{-8}$ ).
- OR
- (a) Define Le-Chatelier principle.
- (b) Explain ionic product of water. What is the effect of temperature on ionic product of water?
- (c) Calculate the pH of  $10^{-10}$  M NaOH solution.
37. (a) Draw the structure of diborane.
- (b) Explain the following reactions :
- (i) Silicon is heated with methyl chloride at high temperature in the presence of Cu.
  - (ii) Hydrated alumina is treated with aqueous NaOH solution.
- OR
- (a) What are silicons. If the starting material for the manufacture of silicons is  $\text{RSiCl}_3$ , write the structure of the product formed.
- (b) Complete the following reactions :
- (i)  $\text{B}_2\text{H}_6 + \text{NH}_3 \longrightarrow$
  - (ii)  $\text{H}_3\text{BO}_3 + \text{H}_2\text{O} \longrightarrow$
- (c) Explain Inert pair effect.

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