रसायन विज्ञान
Chemistry

कक्षा / Class XI

2026-27

विद्यार्थी सहायक सामग्री
Student Support Material

केन्द्रीय विद्यालय संगठन~Kendriya Vidyalaya Sangathan

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संदेश

शिक्षा केवल पुस्तकों तक सीमित ज्ञान नहीं है; यह स्वयं को पहचानने, अपने विचारों को विस्तार देने और जीवन की चुनौतियों का आत्मविश्वास से सामना करने की सतत् यात्रा है। केन्द्रीय विद्यालय संगठन का सदैव यह प्रयास रहा है कि प्रत्येक विद्यार्थी के लिए ऐसा शिक्षण वातावरण हो, जहाँ जिज्ञासा को प्रोत्साहन मिले, सीखना आनंददायी बने और प्रत्येक बालक अपनी अंतर्निहित क्षमताओं को पहचानकर उन्हें विकसित कर सके।

राष्ट्रीय शिक्षा नीति 2020 ने शिक्षा को सिर्फ रटने से समझने, सूचना से ज्ञान और ज्ञान से जीवनोपयोगी दक्षताओं की ओर अग्रसर किया है। आज का समय कृत्रिम बुद्धिमत्ता (Artificial Intelligence – AI), डिजिटल नवाचार और निरंतर बदलती तकनीकों का है। ऐसे युग में केवल तथ्यों का ज्ञान पर्याप्त नहीं है; आवश्यक है कि विद्यार्थी मनन- चिंतन करना सीखें, प्रश्न पूछें, समस्याओं का समाधान खोजें और नए विचारों के साथ आगे बढ़ें। यही क्षमताएँ उन्हें भविष्य के लिए तैयार करेंगी।

इन्हीं उद्देश्यों को ध्यान में रखते हुए केन्द्रीय विद्यालय संगठन के पाँचों आंचलिक शिक्षा एवं प्रशिक्षण संस्थानों (ZIETs) के माध्यम से, समर्पित एवं अनुभवी शिक्षकों द्वारा कक्षा 9 से 12 के विद्यार्थियों के लिए यह विद्यार्थी सहायक सामग्री तैयार की गई है। यह केवल परीक्षा की तैयारी की संकलन सामग्री नहीं है, बल्कि विषयों को सरलता से समझने, अवधारणाओं को स्पष्ट करने, नियमित अभ्यास करने और आत्मविश्वास के साथ आगे बढ़ने का एक विश्वसनीय साथी है।

इस सामग्री में विषय-वस्तु को विद्यार्थियों की आवश्यकताओं के अनुरूप सरल, व्यवस्थित एवं दक्षता-आधारित दृष्टिकोण से प्रस्तुत किया गया है। मुझे प्रसन्नता है कि इसे हमारे शिक्षकों के अनुभव, नवाचार और विद्यार्थियों के प्रति उनकी प्रतिबद्धता ने समृद्ध बनाया है। मुझे विश्वास है कि यह सामग्री विद्यार्थियों की सीखने की यात्रा को अधिक सहज, रोचक और प्रभावी बनाएगी तथा उन्हें बोर्ड परीक्षाओं के साथ-साथ जीवन की व्यापक चुनौतियों के लिए भी तैयार करेगी।

मेरा विश्वास है कि जब एक जिज्ञासु विद्यार्थी, प्रेरित शिक्षक और सार्थक शिक्षण संसाधन एक साथ आते हैं, तब शिक्षा केवल उपलब्धि का माध्यम नहीं रहती, बल्कि व्यक्तित्व निर्माण की एक सशक्त प्रक्रिया बन जाती है। यही भावना इस विद्यार्थी सहायक सामग्री के केंद्र में है।

मेरी हार्दिक शुभकामनाएँ हैं कि आप सभी सीखने की इस यात्रा में निरंतर आगे बढ़ें, अपने सपनों को नए आयाम दें और ज्ञान, संवेदनशीलता तथा नवाचार के साथ राष्ट्र निर्माण में अपना महत्वपूर्ण योगदान दें।

शुभकामनाओं सहित।

(विकास गुप्ता)

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INDEX

UNIT- 1 SOME BASIC CONCEPTS OF CHEMISTRY (7 MARKS)

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.

- Chemistry is the branch of science that deals with the Preparation , properties, structure , composition and composition of material substance.
- **Important Role of chemistry**

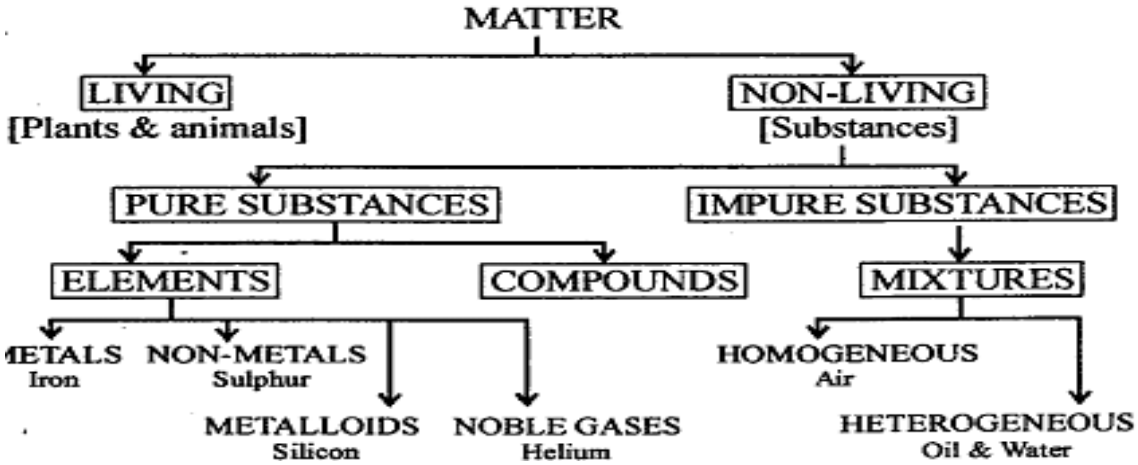
  -The drug AZT (Azidothymidine) is used for helping AIDS patients.

  -The drugs cisplatin and taxol, which are effective in cancer therapy.

  -Environmentally hazardous refrigerants, like CFCs (chlorofluorocarbons), responsible for ozone depletion in the stratosphere, have been successfully synthesised.

  -The management of the Green House gases, like methane, carbon dioxide, etc.

  -Chemistry contributes in a big way to the national economy and plays an important role in meeting human needs for food, healthcare products and other material aimed at improving the quality of life.
- **Matter:** Matter is anything that occupies space, has a definite mass and can be felt by any of our sense organs .Such as book, pen, pencil, water, air, all living beings. But Energy, heat, soul etc. are not matter.
- **Chemical Classification of matter---:**



- **States of Matter With Properties – Based on Physical State**

a) Solid State--- Fixed shape + Fixed volume
--- Particles tightly packed, vibrate only --- Ex: Ice, Wood, Iron.

b) Liquid State --- No fixed shape + Fixed volume
--- Particles loosely packed, can flow-- Ex: Water, Milk, Oil

c) Gas States --- No fixed shape + No fixed volume
--- Particles far apart, move freel --- Ex: Air, Oxygen, Ste

d) Plasma State (4th state)--- Superheated gas, charged particles
--- Ex: Sun, Lightning, Neon lights.

e) Bose-Einstein Condensate (5th state) --- At near 0 Kelvin
--- Particles behave a single quantum entities
--- Ex: Lab-made, ultra-cold atoms.

- **Interchange of states/Phases of matter.**

-
- **Sublimation**-The process in which solid state is directly change into gaseous state (without change into liquid) i.e. known as sublimation.e.g. Dry Ice, Camphor, Naphthalene balls, Iodine crystals, Frost etc.
- **Properties of Matter-**

Physical Properties-It can be measured or observed without changing the identity or the composition of the substance e.g. colour, odour, melting point, boiling point, freezing pint,density, etc	Chemical properties- It can be measured or observed with changing the identity or the composition of the substanc e.g. combustion, reaction with acids and bases, oxidation, reduction etc.

- Physical Quantities and their Measurement- SI-System of Measurement

Base Physical Quantity	Symbol for Quantity	Name of SI Unit	Symbol for SI Unit
Length	l	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Electric current	I	ampere	A
Thermodynamic temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I_v	candela	cd

- Fundamental Units -The Units which are used to measure the physical quantities i.e. known as fundamental units eg. Fundamental Unit of temperature – Kelvin.
- Derived Units-Units of quantities are derived from Fundamental Units is known as Derived Unit e.g. It is also SI unit. Derived Unit of Density- kgm^{-3}.
- Mass and Weight- Mass of a substance is the amount of matter present in it, while Weight is the force exerted by gravity on an object.
- Temperature-Degree of measurement of heat of an object. It is measured by — °C (degree celsius), °F (degree fahrenheit) and K (kelvin).
  -The kelvin scale is related to celsius scale - K = °C + 273.15 Kelvin

-The Celsius scale is related Fahrenheit scale - $^{\circ}F = \frac{9}{5}(^{\circ}C) + 32$

-At -40^{0}C ,both ^{O}C and ^{O}F temperature are same.

Prefiexes used in the SI system

Multiple	Prefix	Symbol
10^{-24}	yocto	y
10^{-21}	zepto	z
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10	deca	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zeta	Z
10^{24}	yotta	Y

- **Uncertainty in Measurement: Precision and Accuracy**

  Precision refers to the closeness of various measurements for the same quantity.

  But, accuracy is the agreement of a particular value to the true value of the result.

- **Scientific Notation**: In which any number can be represented in the form N × 10 e.g. We can write 232.508 as 2.32508 x10^2 in scientific notation. Similarly, 0.00018 can be written as 1.8 x 10^{-4}.
- Significant figures are meaningful digits which are known with certainty

There are certain rules for determining the number of significant figures. These are:

a) All non-zero digits are significant.
b) Only zeros preceding to the first non-zero digit are not significant.
c) Zeros between two non-zero digits are significant.
d) Zeros at the end or right of a number are significant provided they are on the right side of the decimal point.
e) point; otherwise, they are not significant.
f) Exact numbers have an infinite number of significant figures.

- Laws of chemical combinations

(a) Law of conservation of mass- Given by Antoine Lavoisier in 1789.

- It states that matter can neither be created nor be destroyed.
- For a reaction Mass of Reactant = Mass of Product

e.g. In dissociation of $CaCO_3$ - $CaCO_3 \longrightarrow CaO + CO_2$

mass of $CaCO_3$(100) = Mass of CaO and CO_2(56+44)

(a)Law of definite proportions- Given by, a French chemist, Joseph Proust.

-It states that a given compound always contains exactly the same proportion of elements by weight . It is also knwon as law of Definite Composition.

e.g. pure sample of water (River,Tap , lake etc) always contains hydrogen and oxygen in the ratio of 1:8 by mass in each source of water.

(c)Law of Multiple Proportions- Given by Dalton in 1803.

It states that When two elements combine with one another to give more than one product, then the masses of one of the element which combine with fixed mass of the other, bear a simple whole number ratio.

e.g. in CO, 12 part by mass of carbon combine with 16 part by mass of oxygen whereas in CO2 ,12 part by mass of carbon combine with 32 part by mass of oxygen. Ratio of oxygen which combine with fixed mass of carbon in thesecompound is (16 : 32) 1:2.

(d) Gay Lussac's Law of Gaseous Volumes – Given by Gay Lussac in 1808.

-When gases combine or produced in a chemical reaction they do so in a simple ratio by provided all gases are at same temperature and pressure.

-$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$. The volumes of hydrogen and oxygen wiwhich combine together bear a simple ratio of 1:2:1 .

(e) Avogadro's Law- Given by Avogadro in 1811.

Equal volume of all gases contain equal number of moles under condition of constant temperature of Pressure . $V \alpha n$ N_A = Avgadros Number = 6.022×10^{23}

$V = N_A \times n$

- **Dalton's Atomic Theory**- Given by John Dalton in 1808.

The important postulates of this theory are:

1. Matter is made up of minute and indivisible particles called atoms.
2. Atoms can neither be created nor be destroyed.
3. Atoms of same element are identical in their properties and mass. While atoms of different elements have different properties and mass.
4. Atoms combined to form compound atoms called molecules.
5. When atoms combine, they do so in a fixed ratio by mass

- **Atomic Mass** is the mass of an atom of an element is divided by one Twelth part of mass of an atom of carbon C – 12 i.e.known as Atomic mass.

Mass of an atom at this scale 1 amu = 1.66×10^{-24}

$$\text{Atomic Mass} = \frac{\text{Mass of an atom of an element}}{\text{1/12 x mass of an atom of carbon (C-12)}}$$

- **Average Atomic mass of isotope**

$$\frac{(\text{mass of isotope A x \%}) + (\text{mass isotope B x \%})}{100}$$

- **Molecular mass**: Molecular mass is the sum of atomic masses of the elements present in a molecule

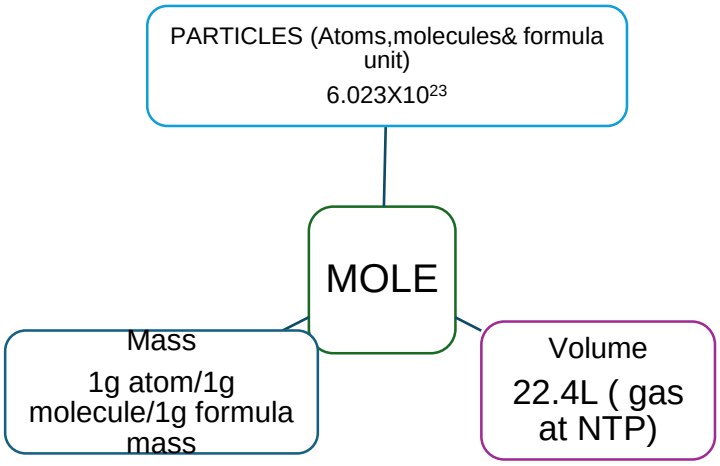
e.g. Molecular mass of methane (CH4) = (12.011 u) + (1.008u)

= 16.043 u

- **Formula mass** – In case of ionic compounds (NaCI etc.),the compound does not represent its molecule, but only represents the ratio of different inos in the compounds. This is called Formula unit of the compound, in such compound instead of molecular mass we use formula mass. Formula mass is obtained by adding atomic masses of all the atoms in a formula unit.
  e.g. Formula mass of NaCI = atomic mass of Na + atomic mass of chlorine
  (23u+35.5u)=58.5u

Mole Concept

- Moles- A mount of substances is divided by molar mass of substances i.e. known as Moles.
- Denoted by n and measured in Mol. - MOLES=$\frac{\text{Given mass}}{Molar mass}$ [n = w / M]
- N = No. of Particles / 6.022 X10^{23} .
- Molar Mass - the mass of one mole of a substance in grams is called its molar mass.
  Denoted by M and measured in gMoI^{-1} .e.g Molar mass of water = 18.02 g moll^{-1}



- **Percentage Composition** - lt is the relative mass of the each of the constituent elements in 100 part of it.

$$\textbf{Mass\% of an element} = \frac{\text{Mass of an element}}{\text{Molar mass of comp.}} \times 100$$

- **Empirical Formula and Molecular Formula**—
  An empirical formula represents the simplest whole number ratio of various atoms present in a Compound. eg. CH is the empirical formula of benzene(C6H6).
  The molecular formula represents the exact number of different types of atoms present in a molecule of a compound e.g. C_6H_6 is the molecular formula of benzene
  Relationship between Empirical and molecular formula-

  Molecular Formula = n X Empirical Formula

  $$n = \frac{\text{Molecular formula mass}}{\text{Empirical formula mass}}$$

- **Limiting Reagent**- When two or more reactant take part in the reaction.The reactant which gets consumed first the product is formed e.g. known as limiting reagent.
- **Mass percentage**(%w/w)-Mass of a component is divided by total mass of solution i.e. known as mass percentage.Unitless quantity.

$$\text{Mass per cent} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

Mole Fraction - It is the ratio of number of moles of a component and the total number of moles of the solution.Denoted by(chi) χ .Unitless quantity .

e.g. If a substance 'A' dissolves in substance 'B'.

$$\text{Mole fraction of A} = \frac{\text{No. of moles of A}}{\text{No. of moles of solutions}}$$

$$= \frac{n_A}{n_A + n_B}$$

Thus the Mole fraction of B

$$= \frac{n_B}{n_A + n_B}$$

$[\chi_A + \chi_B = 1]$

Molarity- Moles of substances which are present in the per litre of solution i.e. known as Molarity .Denoted by M and measured in Mol L^{-1}. It is temperature dependent.

$[M = n / V(L)]$ and $[M = w \times 1000/M' \times V]$

Relation between Molarity density and Mass Percentage-

$[M = M.P. \times 10 \times d / M']$ M' – Molar mass

Molality- It is defined as the number of moles of solute(W2) present in 1 kg of solvent(W1). It is denoted by m and measured in Mol kg^{-1}. It is temperature Independent.

$[m = n / W(kg)]$ and $[M = W_2 \times 1000/M' \times W_1]$

Relation between Molarity density and molarity-

$[m = 1000 \times M / 1000 \times d - (M \times M')]$

Unit-1: Some Basic Concepts of Chemistry

CHEMISTRY – The study of matter and the changes it undergoes.

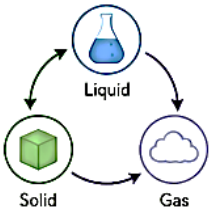
1. MATTER

Anything that has mass and occupies space.

STATES OF MATTER

- Solid
- Liquid
- Gas

(Interconversion possible)



2. NATURE OF MATTER

Matter is made up of very small particles.

PROPERTIES OF PARTICLES OF MATTER

- Particles have space between them.
- Particles are in constant motion.
- Particles attract each other.
- Particles have kinetic energy.

3. CLASSIFICATION OF MATTER

PURE SUBSTANCE

Fixed composition and properties.

- **ELEMENT**: Made up of only one type of atom. e.g., Fe, O_2, Cu
- **COMPOUND**: Made up of two or more elements chemically combined in a fixed ratio. e.g., H_2O, NaCl

MIXTURE

Variable composition; components retain their properties.

- **HOMOGENEOUS** (Mixture of uniform composition) e.g., Salt solution, Air
- **HETEROGENEOUS** (Mixture of non-uniform composition) e.g., Sand and water, Oil and water

4. MEASUREMENT IN CHEMISTRY

Measurement gives quantitative idea.

BASICS OF MEASUREMENT

- Accuracy
- Precision
- Error

5. SIGNIFICANT FIGURES

Expressing measured values with proper precision.

RULES FOR SIGNIFICANT FIGURES

- All non-zero digits are significant.
- Zeros between non-zero digits are significant.
- Leading zeros are not significant.
- Trailing zeros are significant only if a decimal point is present.

6. UNITS OF MEASUREMENT

To express a physical quantity in terms of standard unit.

FUNDAMENTAL UNITS (SI)

Base quantities.

- Length – metre (m)
- Mass – kilogram (kg)
- Time – second (s)
- Temperature – kelvin (K)
- Amount of substance – mole (mol)
- Luminous intensity – candela (cd)

DERIVED UNITS

From combination of fundamental units.

e.g., Area (m^2), Volume (m^3), Density ($kg\ m^{-3}$), Speed ($m\ s^{-1}$), Concentration ($mol\ L^{-1}$)

7. DIMENSIONAL ANALYSIS

Technique to check the correctness of a chemical equation or expression.

DIMENSIONS OF PHYSICAL QUANTITIES

Expressed in terms of fundamental quantities

[M, L, T, K, N, J]

e.g., [Mass] = M

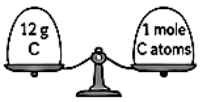
[Length] = L

[Time] = T

APPLICATIONS

- To check validity of equations.
- To derive relations between physical quantities.

8. MOLE CONCEPT



Relates microscopic world (atoms/ molecules) with macroscopic measurements.

MOLE (mol)

Amount of substance containing as many entities (atoms, molecules, ions, etc.) as there are atoms in 12 g of ^{12}C ($\approx 6.022 \times 10^{23}$ entities).

MOLAR MASS (M)

Mass of one mole of a substance.

Unit: $g\ mol^{-1}$

APPLICATIONS

- Moles ↔ Mass
- Moles ↔ Number of particles
- Moles ↔ Volume of gas (at STP)

OVERALL UNDERSTANDING

Chemistry begins with understanding matter—its nature, classifications and the way we measure it. Using standard units and dimensional analysis, we ensure accuracy and consistency in chemical calculations. The mole concept bridges the gap between the microscopic world of atoms and molecules and the macroscopic world of measurable quantities.

QUESTION BANK

SECTION – A (1 MARK)

Q .1 Following concentration method varies with temperature.

(a) Molarity (b) Molality (c) Mole fraction(d) Mass percentage

Q.2 A system has three components, its total mole fraction will be

(a) 3 (b) 2 (c) 1 (d)1.5

Q.3 Find out the correct statement

(a) 28 g CO contains 12g Carbon and 16g Oxygen

(b) One mole of CO reacts completely with half mole of O_2 to form CO_2

(c) N_2 and CO has same molar mass

(d) All of these

Q.4 The significant figures in 0.0005014are

(a) 2 (b) 5 (c) 6 (d) 4

Q.5 ……. Is the SI unit of Luminous Intensity?

(a) Candela (b) Kelvin (c) Mole (d) Ampere

Q.6 Ratio of empirical formula mass to molecular formula mass of benzene will be

(a) 1:6 (b) 2:3 (c) 6:1 (d) 3:2

Q.7 In CH_4 the mass % of C and H will be

(a) 60 & 40 % respectively (b) 75 & 25% respectively

(c) 80 & 20% respectively (d) 40 and 60 % respectively

Q8. One 'u' stands for the mass of

(a) An atom of C-12 (b) $1/12^{th}$ of C-12

(c) $1/12^{th}$ of hydrogen atom (d) one atom of any of the elements

Q.9 Element X forms five stable oxides with oxygen of formula X_2O,XO,X_2O_3,X_2O_4 and X_2O_5. The formation of these oxides explains:

(a) Law of definite proportions (b) Law of partial pressure

(c) Law of multiple proportions (d) Avogadro's law

Q.10 Gay Lussac law is not valid in

(a) $H_{2\,(g)} + CI_{2(g)} \longrightarrow 2HCI_{\,(g)}$ (b) $3H_{2\,(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(c) $2SO_{2\,(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$ (d) $CaCO_{3(s)}\Delta \longrightarrow CaO_{(S)} + CO_{2(g)}$

ASSERTIONREASON 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.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

Q.11.Assertion: There are four significant numbers in 1007.

Reason: Zeros between two non-zeros are significant.

Q.12Assertion: The average atomic mass of chlorine is 35.5.

Reason: Chlorine has three naturally occurring isotopes.

Q.13Assertion: Matter can neither be created nor be destroyed -law of conservation of mass.

Reason: It is applicable for all type of reactions.

Q14 .Assertion: A limiting reagent stops the formation of product in a reaction.

Reason: Limiting reagent is completely consumed during the reaction.

Q15. Assertion: Compounds are prepared by mixing two or more substances in a fixed ratio.

Reason: Compounds can be prepared by physical methods only.

ANSWERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a	C	d	A	a	A	B	b	C	D	A	c	c	A	c

SECTION-B (2 MARKS)

Q.1 Justify that 0.50 mol Na_2CO_3 and 0.50 M Na_2CO_3 are not same.

[Hint:0.50 M Na_2CO_3 means 0.50 mol,.53 g of Na_2CO_3 are present in I L of the solution]

Q2. A solution contains 10 mol of sucrose in 1 kg of solvent. Calculate the molality of solution.

[Hint: 10 mol /kg]

Q3. Adjust the following numbers to four significant figures.

(a) 1.81234×10^3 (b) 0.008837

[Hint: a-1.812×10^3, b-8.8837×10^{-3}]

Q4. Nitrogen occurs in nature inthe form of two isotopes with atomic mass 14 and 15 respectively. If average atomic mass of nitrogen is 14.0067, what is the % abundance of two isotopes?]

[Hint: N-14= 99.3 & N-15= 0.67; Ref summary for formula]

Q5. A compound has C=54.54%,H=9.09% and O=36.37%. Determine the molecular formula of the compound if its vapour density is 88.

[Hint: Atomic wt. of C=12,H=1, O= 16, M.M= 2 X Vapourdensity, Molecular formula $C_8H_{16}O_4$]

SECTION - C(3 MARKS)

Q1. Chlorine is prepared in the laboratory by treating manganese dioxide (MnO_2) with aqueous hydrochloric acid according to the reaction

$4HCl\ (aq) + Mn0_2\ (s) \longrightarrow 2H_2O\ (l) + MnCl_2(aq) + Cl_2(g)$

How many grams of HCl react with 5.0 g of manganese dioxide?

(Atomic mass of Mn = 55 u)

[Hint:1 Mol MnO_2 (87g) reacts with 146 g of HCl, so 5 g will react=(146/87)X 5= 8.4 g]

Q2. Calculate (a) the no of atoms in 3 mol of NH_3 (b) the no. of molecules in 1ml of CO_2 at STP.

[Hint: a- $3x4x6.023x10^{23}$, b- 1ml CO_2 contains= $6.023x10^{23}$/22400 molecules]

Q3. Out of 1M KCI and 1m KCI, which one is stronger justify your answer with suitable reason.

[Hint: 1M KCl is studied in solution]

Q4. Calculate the amount of carbon dioxide that could be produced when-

(i)1 mole of carbon is burnt in air.

(ii)1 mole of carbon is burnt in 16 g of dioxygen.

(iii) 2 moles of Carbon is burnt in 16 g of dioxygen

[Hint: i- 44 g, ii- 22 g,iii- 22g]

Q5. Are the following terms same?, if not give possible reason/ comment.

a. Empirical formula and Molecular formula

b. Calculate the molecular mass of Sucrose($C_{12}H_{22}O_{11}$) and Fructose($C_6H_{12}O_6$)

[Hint :a-Ref: Summary b- 342 and 120]

SECTION – D CASE BASED QUESTIONS (4 MARKS)

Read the following passage carefully and give answers of the questions

1.Chemistry is the science of molecules and their transformations. It is the science not so much of the one hundred elements but of the infinite variety of molecules that may be built from them. Chemistry plays a central role in science and is often intertwined with other branches of science. Chemistry has very important role in our daily life. It is used in several industries like fertilizer, pharmaceuticals, textile, cosmetic etc. Insecticides and pesticides like D,D,T., GAMMEXANE,etc are prepared by chemical processes. Several lifesaving drugs such as CISPLATIN and TAXOL (used in cancer therapy) and AZT (Aidothymidine is used in treatment of AIDS) are also prepared by chemical process.

It has important role in making preservatives, dyes, Water purifier etc.

Q. (i). …… is used as an insecticide

(a) AZT (b) CISPLATIN (c) TAXOL (d) D.D.T

Q(ii). The Drug used in treatment of cancer is

(a) Taxol (b) Gammexane (c) Aspirine (d) AZT

Q(iii). Give an example of each natural and synthetic preservative

[Hint: i-d, ii- a,]

2.At Standard Temperature and Pressure (STP) (0°C and 1 atm pressure), 1 mole of any ideal gas occupies 22.4 liters of volume. This means that gases with the same number of moles will have the same volume when measured at STP, regardless of their chemical nature. In this case, you are working with two different gases—oxygen (O_2) and hydrogen (H_2)—and comparing their volumes. This comparison allows us to understand the ideal behavior of gases and how they relate to each other in terms of volume when they are under the same temperature and pressure conditions.

(i) At STP, how many liters of hydrogen gas would contain the same number of molecules as 11.2 liters of oxygen gas?

[Hint: Use Avogadro's law to find the relation]

(ii) At STP 0.5 mole of oxygen will have volume…….

(a) 22.4 L (b) 11.2 L (c) 0.8 L (d) 16 L

(iii) The number of molecule present in 1ml of O_2 at NTP will be

(a) $6.023x10^{23}$ (b) $2.69x10^{19}$ (c) $3.023x10^{23}$ (d) $3.023\ x10^{19}$

[Hint: (ii)-b (iii) –b]

SECTION - E(5 MARKS)

1. Is there any unit for mole fraction If not why ? A solution is prepared by adding 360gof glucose to 864g of water. Calculate the mole fraction of glucose
(M.M. of glucose is 180g mol^{-1})
[(Hint- no, mole fraction is a ratio, $X_{glucose}= \underline{n_{glucose}}/ n_{H2O} + n_{glucose}$, Ans= 0.04]
2. Calcium carbonate reacts with aqueous HCl to give $CaCl_2$ and CO_2 according to the reaction given :

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

What mass of $CaCl_2$ will be formed when 250 ml of 0.76 M HCl reacts with 1000 g of $CaCO_3$?
Name the limiting reagent. Calculate the number of moles of $CaCl_2$ formed in the reaction
[Hint: Moles of HCI= 0.76x0.25= 0.19moles,Moles of $CaCO_3$ = 10 moles 10 mole $CaCO_3$ reacts with 20 moles of HCI,So H is limiting reagent Moles of $CaCI_2$ formed= 1/2X0.19= 0.095 moles]

3.(a) In three moles of ethane (C2H6), calculate the following:

(i) Number of moles of carbon atoms. (ii)Number of moles of hydrogen atoms.

(iii) Number of molecules of ethane.

(b) What is the concentration of sugar (C12 H22 O11) in mol L–1 if its 20 g are dissolved in enough water to make a final volume up to 2L?

(c)How are 0.50 mol Na2CO3 and 0.50 M Na2CO3 different?

[HINT-(a)(2x3) 6Mol ,(6x3) 18 Mol and molecules of Ethane = $3x6.022 \times 10^{23}$]

4. (a)Convert the following into basic units:

(i) 28.7 pm (ii) 15.15 pm (iii)25365 mg

(b) Calculate the concentration of nitric acid in moles per litre in a sample which has a density, 1.41 g mL–1 and the mass per cent of nitric acid in it being 69%.

(c) f 10 volumes of dihydrogen gas reacts with five volumes of dioxygen gas, how many volumes of water vapour would be produced?

UNIT 2-STRUCTURE OF ATOM (9 MARKS)

Discovery of Electron, Proton and Neutron, atomic number, isotopes and isobars. Thomson's model and its limitations. Rutherford's model and its limitations, 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.

The **atomic structure** of an element describes the arrangement of subatomic particles **protons**, **neutrons**, and **electrons** in an atom.

SUB ATOMIC PARTICLES	**PROTON-:**
ELECRON-: **-Discovered by Sir J.J.Thomson in 1897** **-Charge** = -1.6 x 10^{-19} Coulombs -**Mass** = 9.1 x 10^{-31} kg -Charge/Mass Ratio**:** e/m=1.602×10^{-19} / 9.109×10^{-31} =1.76×10^{11}C/kg	**-Discovered by** ***Goldstein in 1886***. -Proton was named by **Rutherford in 1917.** **-Charge =** 1.6 x 10^{-19} Coulombs **-Mass = 1.673×10^{-27} kg** -Charge/Mass Ratio**:** e/m=1.602×10^{-19}/1.673×10^{-27} =9.58×10^{7}C/kg

Neutrons

The neutron was discovered by **James Chadwick in 1932,** leading to the discovery of nuclear fission in 1938, the first self-sustaining nuclear reactor (Chicago Pile-1, 1942) and the first nuclear weapon (Trinity, 1945). -It is Neutral particle **-Mass 1.6749 × 10^{-27} kg.**

Dalton's Atomic Theory (1808)-	**Limitations-**
-Atoms constitute matter, -Atoms are indivisible and indestructible particle . -Similar atoms constitute an element. But later discovery of subatomic particles contradicted this concept of indivisibility of atoms.	-It could not give idea about the existence of isotopes. -It does not have any explanation of the internal structure atom.

Thomson's Atomic Model (1898)- It proposed that- -An atom has spherical shape in which the positive
charge is uniformly distributed.
-The electrons embedded into it in such a manner as to give the most stable electrostatic arrangement.
-This model was able to explain the overall neutrality of the atom.
-This Model is also known as plum pudding,raisin pudding or watermelon.
Limitations: It Could not explain atom's stability and discovery of nucleus

Rutherford's Alpha particle scattering experiment - :

(i) Most of the α–particles passed through the gold foil undeflected.It proves that Most of the space in the atom is empty.
(ii) A small fraction of the α–particles deflected by small angles It proves that it is due to repulsion of positive charge of nucleus
(iii A very few α–particles (~1 in 20,000) bounced back .It proves that The positive charge and total

Rutherford's Atomic Model (1911)-

-The positive charge and most of the mass
of the atom was densely concentrated in the very small portion of the atom is called nucleus
-Atom is spherical and electrons revolve in very high speed in circular path .
- Electrons and the nucleus are held together by electrostatic forces of attraction.
This model is also known as Planatery model of solar system because electrons revolve around the nucleus as like planets around the sun.
Limitations:
- This Model unable to explain the stability of atom.
-This Model unable to explain the continuous spectrum of atom.
-This Model could not give idea about the presence of Proton and Neutron in nucleus.

Bohr's Atomic Model (1913)-

-There are two part of atom atomic nouleus and orbits or shells.
-Electrons revolve around the nucleus in the fixed circular orbit or shell without radiating energy.
- Electrons move only in those
orbits for which its angular momentum is
integral multiple of h/2π.

$$m_e vr = \frac{nh}{2\pi}$$ (n=1,2,3...shell/orbit/PrincipalQ.No.)

-Electrons can jump between orbits by absorbing or emitting specific amounts of energy .

$$\Delta E = E_2 - E_1$$

-The energy of the orbits is quantised.

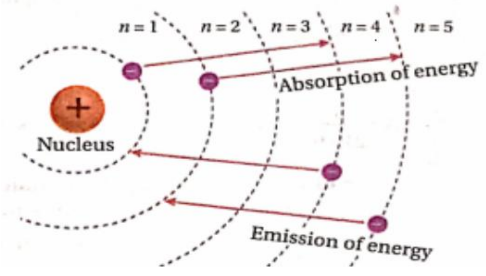
- The stationary orbits for electron are
  - numbered n = 1,2,3.....digits and K,L.M,N,------ capital letters .
  - **Limitations:**
  - - It Explains the stability of the atom and the line spectra of elements .
  - - It Explains only single electron containing atoms /ions.
  - -It could not Explain multi electron containing atoms /ions.
  - -It could not Explain Zeeman effect and Stark effect and also dual nature of subatomic particle.

Hydrogen spectrum

Hydrogen spectrum is a unique pattern of lines in the electromagnetic spectrum resulting from the emission of light by excited hydrogen atoms. These lines correspond to specific wavelengths of light. Wavelengths are given by the Rydberg formula

$$\frac{1}{\lambda} = Z^2 R_\infty \left(\frac{1}{n'^2} - \frac{1}{n^2}\right)$$

$R\infty = 1.09677, \times 107\ m^{-1}$ for H atom
n_1 and n_2 are principal quantum numbers.



Lyman	Balmer	Paschn	Bracket	Pfund
n_1 =1	n_1 =2	n_1 -3	n_1=4	n_1=5

Bohr's Energy of H Atom:

$$E_n = -2.18 \times 10^{-18} \left(\frac{Z^2}{n^2}\right) J$$ Z = atomic number

Radius of Bohr's Orbit:

$$r_n = \frac{52.9(n^2)}{Z} pm$$ n= 1,2,3----(orbit/shell)

Orbit / Shell -: Electron revolve around the nucleus in the circular Path i.e. known as Orbit / Shell .
-These are also known as Principal Energy level / Main Energy level /stationary Energy level.
-Dented by n = 1 ,2 ,3 ,4 ----------
= K ,L ,M,N ----------

Sub Shell – Main energy level are made up of sub energy level i.e. known as Sub Shell.
-There are four sub shell. Denoted by s ,p ,d and f.
- Maximum No of Electron in the sub shell = 2 , 6 , 10 , 14

Atomic Number - The total positive charge present in the nucleus of any atom i.e. known as atomic number (Z).Discovered by Moseley in 1916 .

- Atomic number (Z) = number of protons (P) in the nucleus of an atom
= number of electrons (e) in a nuetral atom

Mass Number -: The total number of Proton and Neutron of the nucleus i.e. known as mass number (A) of the atom. It is also known as nucleons.
- Mass number (A) = number of protons (Z) + number of neutrons (n)

Isotopes- Atoms of Elements which are identical atomic number but different atomic mass number are known as isotopes. Discovered by Thomsons in Neon isotopes.
-There are three isotopes of Hydrgen = Protium ($_1H^1$) Normal Hydrogen
= Deuterium ($_1D^2$) Heavy Hydrogen
= Tritium ($_1T^3$) Radioactive Hydrogen
-Isotopes have similar chemical Properties but different physical properties .

Isobars- Atoms of Elements which are identical atomic mass number but different atomic number are known as isotopes. e.g. $_6C^{14}$ and $_7N^{14}$.
-Isobars have similar physical Properties but different chemical properties .

Heisenberg's Uncertainty Principle-:
-Werner Heisenberg a German physicist in 1927.
- it states that it is impossible to determine the exact position and exact momentum (or velocity) of material particles during motion simultaneously .
- Mathematical formulation of this principle-

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

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

$$\Delta x \times \Delta(mv_x) \geq \frac{h}{4\pi}$$

-where Δx = the uncertainty in position ΔP (or mΔv) = uncertainty in momentum (or velocity).

-If the position of the electron is known with high degree of accuracy (Δx is small), then the velocity of the electron will be uncertain [Δ(v) is large] and it is vice – versa**.**

-Significance of Uncertainty Principle- This Principle has significant only for motion of microscopic objects and is negligible for that of macroscopic objects.

IMPORTANT FEATURES OF THE QUANTUM MECHANICAL MODEL OF ATOM-:

- The energy of electrons in atoms is quantized.
-The quantised electronic energy levels is a direct result of the wave like properties of electrons.
- The path of an electron in an atom can never be determined or known accurately.
- An atomic orbital is the wave function ψ for an electron in an atom.
- The probability of finding an electron at a point within an atom is proportional to the square of the orbital wave function $|\psi|^2$ at that point.
$|\psi|2$ is known as probability density and is always positive.

Schrodinger'sequation: (1925) Schrodinger described wave motion of an electron.This model describes the electron as a three dimensional wave in the electronic field of positively charged nucleus.

Schrodinger'sequation - [$\hat{H}\Psi = E\Psi$]

Where $\hat{H}$ = mathematical operator called Hamiltonian.Ψ - the wave function of atomic orbita

Orbitals – The three dimensional area around the nucleus, where the probability if finding electron is maximum i.e. known as Orbitals.

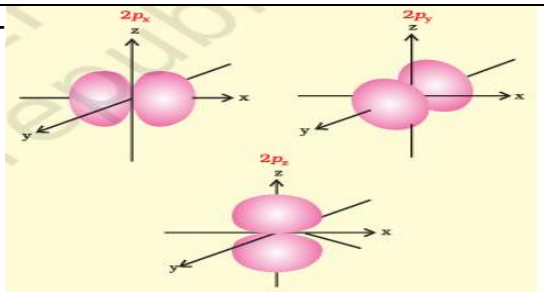
Types of orbitals-

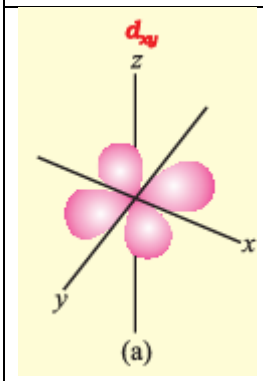
Atomic Orbitals	No. of orbitals	Maximum No. of electron	Structure of orbital
s- orbital	1	2	Spherical shaped
p- orbitals	3	6	Dumb Bell Shaped
d- orbitals	5	10	Duoble Dumb Bell Shaped
f- orbitais	7	14	Complicated

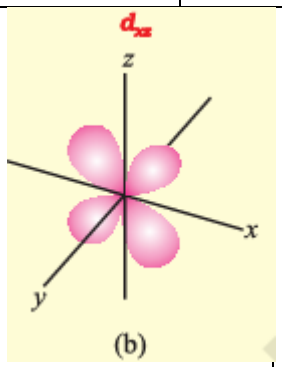
Structure of Orbitals-

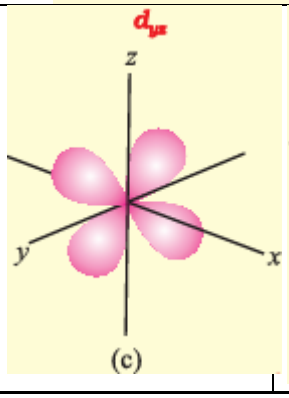
s- orbital -

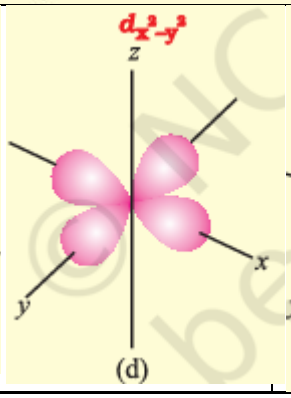
p- orbital-

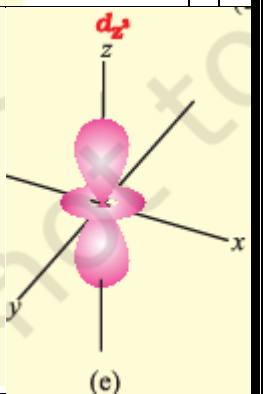












Quantum numbers -: The numbers which Provide the size , shape and orientation of atomic orbital.i.e. known as Quantum Numbers**.**

Types of Quantum Numbers.

Principal quantum number (n)-: -The Q. No. which determine the shell or orbit the i.e. known as Principal quantum number.

-It Signifies the no. & size of orbit and Energy of shell

The value of n = 1 ,2 ,3 ,4 ----------

shell = K ,L ,M,N ----------

Energy of shell = E1 , E2 , E3 , E4----------

the maximum number of electrons in any shell = 2n

Azimuthal quantum number (l) : It tells us information about sub energy level (s,p,d,f) .

Its value depends on the value of n .

[l = 0 to (n-1)]

If n = 1 , Then l = 0 It represents s – subshell.

If n = 2 , Then l = 0 , 1 It represents s and p - subshell.

If n = 3 , Then l = 0 , 1 ,2 It represents s , p and d - subshell.

If n = 4 , Then l = 0 , 1 ,2 , 3 It represents s , p , d and f - subshell.

It signifies subshell and Shape of orbitals.

For any value of n , Total value of l = n

e.g. If n = 4 , Then Total value of l = n = 4 such as 4s , 4p , 4d , 4f .

Magnetic quantum number (m) : It tell us information about the spatial orientation of orbitals. These different orientations are called orbitals.

Its value depends on the value of l .

[m = - l to + l]

If l = 0 , Then m = 0 It represents s – orbitals.

If l = 1 , Then m = -1 , 0 , +1 It represents p - orbitals.

If l = 2 , Then m = -2 , -1 , 0 , +1 , +2 It represe`nts d - orbitals.

If l = 3 , Then m = -3 , -2 , -1 , 0 , +1 , +2 , +3 It represents f - orbitals.

For any l value Total number of orbitals = (2l + 1)

For any n value Total (Number of orbital) value of m = n^2**.**

Value of *l*	0	1	2	3	4	5
Subshell notation	*s*	*p*	*d*	*f*	*g*	*h*
number of orbitals	1	3	5	7	9	11

n	*l*	Subshell notation
1	0	*1s*
2	0	*2s*
2	1	*2p*
3	0	*3s*
3	1	*3p*
3	2	*3d*
4	0	*4s*
4	1	*4p*
4	2	*4d*
4	3	*4f*

Spin quantum number (s) : The quantum number which tells us about the movement of electron arund the nucleus i.e. known as Spin Q.No. .

For any Two electrons in an orbital ,

The value of s for first e = + 1/ 2 , Direction of rotation of e = Clockwise

The value of s for second e = - 1/ 2 , Direction of rotation of e = Anti Clockwise

For any value of n , Total value of s = $2n^2$

-In 1925, George Uhlenbeck and Samuel Goudsmit proposed the Spin quantum number .

Note—There are five m values are (–2, –1, 0, +1 and +2) for l = 2 ,five d – orbitals . The five d-orbitals are designated as dxy , dyz , dxz, dx2–y2 and dz2.

Nodal plane and Nodal surface :- The space where probability of finding an e– is zero.It ie known as Radial Nodes. Radial Nodes = n – l – 1

Number of angular nodes = l

The total number of nodes = (n–1),

Nodal plane = l

Nodal surface = n - l – 1

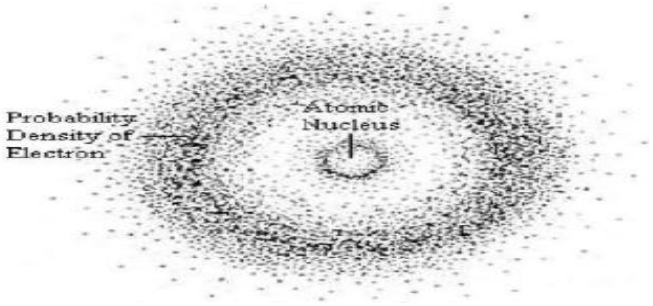


Fig. *Structure of Atom According to Quantum mechanical Model*

RULES FOR FILLING OF ORBITALS IN AN ATOM

Aufbau's Principle:The word 'aufbau' in German means 'building up'. The building up of orbitals means the filling up of orbitals with electrons. The principle states : -In the ground state of the atoms, the orbitals are filled in order of their increasing energies. -The electrons first occupy the lowest energy orbitals and again then in the increasing order of the energy of orbitals.	**The following order of energies of** **the orbitals by filling of electrons:** 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p……. **(n +l) Rule (For multi electron species)** :The subshell with lowest (n + l) value is filled up first, when two or more subshell have same (n + l) value then the subshell with lowest value of n is filled up first.
Hund's rule of maximum multiplicity It states : pairing of electrons in the orbitals same subshell (p, d or f) does not take place until each orbital subshell has got one electron each (i.e.singly occupied.) There are three p, five d and seven f orbitals, therefore, the pairing of electrons will start in the p, d and f orbitals with the entry of 4th, 6th and 8th electron.	Extended learning :Hund gave three rules: 1. maximum multiplicity 1. spin alignment 2. Total angular momentum

Pauli's exclusion principle : Given by the Austrian scientist Wolfgang Pauli (1926)
-According to this rule no two electron within an atom can have same values of all four quantum numbers.
e.g.The all value of Q.No.both electroof $1s^2$
For 1^{st} electron n = 1 , l = 0 , m = 0 , s = +1/2

For 2nd electron n = 1 ,l = 0 , m = 0 , s = -1/2

The value of n , l and m are same but the value of s ie different.It means that each orbital has maximum 2 electron of opposite spin.

The Pauli'sExclusion Principle is a fundamental concept in quantum mechanics, stating that no two identical fermions (particles with half-integer spin, like electrons) can occupy the same quantum state within a system at the same time

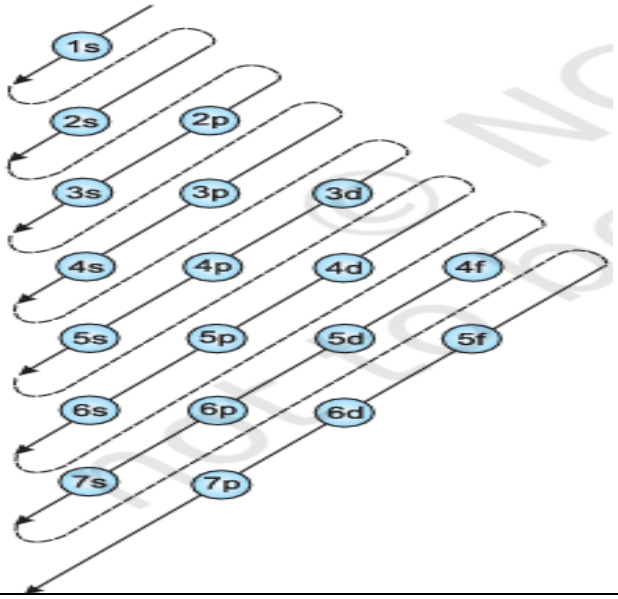
Stability of half filled and fully filled atomic orbitals: Half-filled and fully-filled orbitals (p^3, p^6, d^5, d^{10}, f^7, f^{14})exhibit greater symmetry compared to partially filled orbitals. This symmetry minimizes electron-electron repulsion and enhances stability.

-An electron shifts from a subshell of lower energy (4s) to a subshell of higher energy (3d), provided such a shift results in all orbitals of the subshell of higher energy getting either completely filled or half filled.

Exceptions : elements in d- and f- block elements primarily due to increased extra stability of half filled and fully filled orbitals. Cu, Cr,Ag,Au,Ru etc.

Electronic Configuration of Elements -: The distribution of electrons into orbitals of an atom is called its electronic configuration.

Degenerate Orbitals-: Orbitals which have similar energy i.e. known as degenerate orbitals.



Fermions:are fundamental particles having half-integer spin (e.g., 1/2, 3/2) and obey the Pauli exclusion principle, like Electrons, quarks, protons, neutrons, and most composite particles.Bosons have integer spin values (e.g., 0, 1, 2). like Photons, gluons etc.Bosons can occupy the

Unit-2: Structure of atom

Matter
Anything that has mass and occupies space.

Matter is made up of particles
(Atoms, molecules, ions)

Atom
The smallest particle of an element that can take part in a chemical combination.

1. Discovery of Sub-atomic Particles

- Cathode ray tube experiments (J. J. Thomson)
  → Discovery of electron (e^-)
- Canal ray experiments (E. Goldstein)
  → Discovery of proton (p^+)
- Experiments on radioactivity (E. Rutherford)
  → Discovery of neutron (n^0)

2. Fundamental Sub-atomic Particles

Particle	Symbol	Charge	Relative Mass
Electron	e^-	−1	1/1836
Proton	p^+	+1	1
Neutron	n^0	0	1

Note: Nearly all the mass of an atom is concentrated in the nucleus.

3. Atomic Models

- **Thomson's Model**
  ("Plum pudding model")
  Electrons embedded in a positively charged sphere.
- **Rutherford's Nuclear Model**
  (α-particle scattering experiment)
  Atom has a small, dense, positively charged nucleus. Most of the space is empty.
- **Bohr's Model**
  Electrons revolve around the nucleus in fixed circular orbits (energy levels).

4. Bohr Model – Important Features

- Electrons revolve in certain permitted orbits without radiating energy.
- Each orbit has a fixed energy (stationary state).
- Energy is absorbed or emitted only when an electron jumps from one orbit to another.
- Angular momentum is quantized:
  $mvr = \frac{nh}{2\pi}$
  $(n = 1, 2, 3, \ldots)$

5. Limitations of Bohr Model

- Fails to explain the spectrum of multi-electron atoms.
- Does not account for the fine structure of hydrogen spectrum.
- Contradicts with Heisenberg's uncertainty principle.

6. Quantum Mechanical Model (Modern View)

- Introduced by de Broglie, Heisenberg, Schrödinger.
- Electrons have dual nature (particle + wave).
- Electrons do not revolve in fixed orbits.
- The exact position and velocity cannot be determined simultaneously (Uncertainty Principle).
- Electrons are described by a wave function ψ.
- The square of wave function, $|\psi|^2$ gives the probability of finding an electron in a region.

7. Important Quantum Mechanical Terms

- **Orbital:** Region around the nucleus where the probability of finding an electron is maximum.
- **Shell (n):** Main energy level
  $n = 1, 2, 3, \ldots$
- **Sub-shell:** s, p, d, f
- **Orbital:** Specific region within a sub-shell. Each orbital can hold maximum 2 electrons with opposite spins.

8. Quantum Numbers

Each electron in an atom is described by a set of four quantum numbers.

1. Principal quantum number (n)
   → Shell, size, energy level
2. Azimuthal quantum number (l)
   → Sub-shell, shape ($l = 0$ to $n-1$)
3. Magnetic quantum number (m_l)
   → Orientation ($m_l = -l$ to $+l$)
4. Spin quantum number (m_s)
   → Spin of electron ($+½$ or $-½$)

9. Electronic Configuration

Distribution of electrons in various shells, sub-shells and orbitals in an atom.

- aufbau principle
- Pauli's exclusion principle
- Hund's rule of maximum multiplicity

10. Significance of Electronic Configuration

- Determines valency
- Explains periodic properties
- Explains chemical behaviour of elements

11. Isobars, Isotopes and Isotones

- **Isobars:** Same mass number (A), different atomic number (Z)
- **Isotopes:** Same atomic number (Z), different mass number (A)
- **Isotones:** Same number of neutrons (N), different Z

Where, $A = Z + N$

12. Summary

- Atom consists of a small, positively charged nucleus containing protons and neutrons.
- Electrons occupy the space around the nucleus in orbitals.
- Modern atomic structure is based on quantum theory.

13. Applications

- Understanding periodicity of elements
- Explaining chemical bonding
- Basis for advanced topics in chemistry and physics

Key Takeaway: Atom is mostly empty space with a tiny nucleus at the centre.
Electrons occupy orbitals around the nucleus and their arrangement governs the properties of elements.

QUESTION BANK

Section- A (1 Mark)

Q.1) Bohr model can explain :

(a) the solar spectrum

(b) the spectrum of hydrogen molecule

(c) spectrum of any atom or ion containing one electron only

(d) the spectrum of hydrogen atom only

Q.2) Two fast moving particles X and Y are associated with de Broglie wavelengths 1nm and 4 nm respectively. If mass of X in nine times the mass of Y, the ratio of kinetic energies of X and Y would be- :

(a) 3 : 1 (b) 9 : 1 (c) 5 : 12 (d) 16 : 9

Q.3) An electron has principal quantum number 3. The number of its subshells and orbitals would be respectively.

(a) 3 and 5 (b) 3 and 7 (c) 3 and 9 (d) 2 and 5

Q.4)Uncertainty in position of a n electron (mass = 9.1×10^{-28} g) moving with a velocity of 3×10^4 cm/s accurate upto 0.001% will be (use $h/4\pi$) in uncertainty expression where h = 6.626×10^{-27} erg-second).

(a) 1.93 cm (b) 3.84 cm (c) 5.76 cm (d) 7.68 cm

Q.5) Which of the following is responsible to rule out the existence of definite paths or trajectories of electrons?

(a) Pauli's exclusion principle. (b) Heisenberg's uncertainty principle.

(c)Hund's rule of maximum multiplicity. (d) Aufbau principal

Q.6) Rutherford's α-particle scattering experiment concludes

(a) all positive ions are deposited at small part

(b) all negative ions are deposited at small part

(c) proton moves around the electron(d) neutrons are charged particles.

Q.7) Which of the following is related with both wave nature and particle nature ?

(a) Interference (b) $E = mc^2$ (c) Diffraction (d) $E = h\nu$

Q.8) Which one of the following pairs is not correctly matched ?

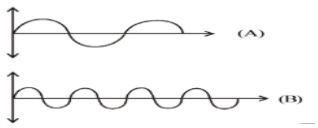
(a) Rutherford-Proton (b) J.J. Thomson-Electron

(c) J.H. Chadwick-Neutron (d) Bohr-Isotopes

Q.9)Maximum number of electrons in a subshell of an atom is determined by the following:

(a) $2l + 1$ (b) $4l - 2$ (c) $2n^2$ (d) $4l + 2$

Q.10)What will be the difference between electromagnetic radiation shown in A and B respectively ?



(a) wavelength only (b) frequency and wavelength

(c) wavelength, frequency and energy (d) energy

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.

(a) **Assertion** is correct, reason is correct; reason is a correct explanation for **assertion**.

(b) **Assertion** is correct, reason is correct; reason is not a correct explanation for **assertion**

(c) **Assertion** is correct, reason is incorrect

(d) **Assertion** is incorrect, reason is correct.

Q.11)**Assertion** : The (n+l) rule is often used to determine the order of filling orbitals Orbitals with a lower (n+l) value are filled first. If two orbitals have the same (n+l) value, the one with the lower n value is filled first.

Reason : The Aufbau principle helps determine the electronic configuration of an atom, which is a representation of how electrons are arranged in orbitals.

Q.12)**Assertion** : Pauli's exclusion principle is the fundamental principle in quantum mechanics.

Reason : It applies to fermions, particles with half-integer spin like electrons and neutrons. It is not applicable to bosons, particles with integer spin like photons.

Q.13) **Assertion**: Electrons orbit the nucleus in a circular path with a fixed radius and energy.

Reason : Electrons can also radiate energy while revolving in these orbits.

Q.14) **Assertion**: The effect of the uncertainty principle is significant only for the motion of microscopic particles

Reason : Although the energy of photons can cause significant effect on macroscopic particles too.

Q.15) **Assertion**: Each electron in an atom is described by a unique set of quantum numbers, defining its energy, shape, and spatial orientation.

Reason : Quantum numbers are quantities that characterize the possible states of the system.

knowledge

Fermions:are fundamental particles having half-integer spin (e.g., 1/2, 3/2) and obey the Pauli exclusion principle, like Electrons, quarks, protons, neutrons, and most composite particles.**Bosons** have integer spin values (e.g., 0, 1, 2). like Photons, gluons etc.Bosons can occupy the

ANSWERS:

MULTIPLE CHOICE QUESTIONS

1.c	2.d	3.c	4.a	5.c	6.a
7.d	8.d	9.a	10.c	11.a	12.a
13.c	14.c	15.b			

SECTION- B (2 Marks)

Q.1)We don't we see a car moving as a wave on the road why?

(Hint :large mass makes wave character negligible : de Broglie)

Q.2)Why is the energy of 1s electron lower than 2s electron?

(Hint: force of attraction is inversely proportional to square root of distance from nucleus.)

Q.3)Which quantum number determines. (i) energy of electron (ii) Orientation of orbitals.

Ans.) (i) principal quantum number (ii) magnetic quantum number

Q.4 How orbit is different from orbital?

[Hint : orbit is well defined two dimensional path but orbital is not well defined path rather a region around nucleus having maximum probability of finding electron.

Q.5) Which among the following orbitals are degenerate?

3dxy , 4dxy, $3dz^2$, 3dxz , $4d_{x^2-y^2}$, $4dz^2$

[Hint::similar value of principal quantum number in this case]

Q.6) Using s, p, d, f notations, describe the orbital with the following quantum numbers (a) n = 2, l = 1, (b) n = 4, l = 0, (c) n = 5, l = 3, (d) n = 3, l = 2

SECTION- C (3 Marks)

Q.1)Why do atoms emit a line spectrum instead of a continuous spectrum, based on the concept of quantization?

[Hint : Due to quantization, electrons in an atom can only occupy discrete energy levels.line spectrum is actually discrete wavelengths produced due to difference in energy levels.]

Q.2)Calculate the uncertainty in the velocity of a wagon of mass 4000 kg whose position is known accurately of ±10m.

[Hint : use Heisenberg uncertainityformula ,$\Delta v = 1.3 \times 10^{-39}$ m sec^{-1}]

Q.3)2.36. 2×10^8 atoms of carbon are arranged side by side. Calculate the radius of carbon atom if the length of this arrangement is 2.4 cm.

[Hint :Diameter of each C-atom = (2.4 cm) / (2×10^8) = 1.2×10^{-8} cm

Radius of each C-atom = ½ x 1.2×10^{-8} cm = 6.0×10^{-9} cm = 0.06 nm]

Q.4)What designations are given to the orbitals having

(i) n=2,I=1 (ii) n=2,I=0 (iii) n=4,I=3 (iv) n=4,I=2 (v) n=1,I=1

Q.5)What is the wavelength of the light emitted when the electron in a hydrogen atom undergoes transition from the energy level with n = 4 to energy level n = 2? What is the colour corresponding to this wavelength? (Given R_H = 109678 cm^{-1})

[Hint :Use Balmer formula,

Wave number ($\bar{\upsilon}$) = $I/\lambda = R_H[1/n_1^2 - 1/n_2^2]$ cm^{-1}

= $109678[1/2^2 - 1/4^2]$ cm^{-1}

λ= 486 nm]

Q.6) A golf ball has a mass of 40g, and a speed of 45 m/s. If the speed can be measured within accuracy of 2%, calculate the uncertainty in the position..

[Hint :

The uncertainty in the speed is 2%, i.e.,

$$45 \quad \frac{2}{100} = 0.9 \text{ m s}^{-1}$$

Using the equation (2.22)

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

$$= \frac{6.626 \times 10^{-34} \text{ Js}}{4 \times 3.14 \times 40\text{g} \times 10^{-3} \text{ kg g}^{-1} (0.9 \text{ m s}^{-1})}$$

$$= 1.46 \times 10^{-33} \text{ m}$$

SECTION – D CASE BASED QUESTIONS (4 MARKS)

Passage - 1.Read the following passage carefully and give answers of the questions

The quantization of atomic energy levels and Niels Bohr's atomic theory, pivotal in modern chemistry and physics, were rigorously explored in early 20th-century journals. In 1913, Bohr introduced his model in Philosophical Magazine (Series 6, Vol. 26, 1913), building on Planck's quantum hypothesis (Annalen der Physik, 1900) and Rutherford's nuclear atom (Philosophical Magazine, 1911). Bohr proposed that electrons orbit the nucleus in discrete, quantized energy levels, with transitions between these levels emitting or absorbing specific quanta of electromagnetic radiation, explaining hydrogen's spectral lines with remarkable precision. His model integrated classical mechanics with quantum postulates, asserting that angular momentum of electrons in stable orbits is quantized ($L = n\hbar$, where n is an integer).

This was a breakthrough, as it resolved inconsistencies in classical electrodynamics, where orbiting electrons were expected to radiate energy continuously and collapse. Max Planck's earlier work on blackbody radiation (Annalen der Physik, 1900) laid the foundation for quantization, introducing the concept of energy packets (quanta). Subsequent refinements came with Louis de Broglie's wave-particle duality (ComptesRendus, 1923) and Erwin Schrödinger's wave mechanics (Annalen der Physik, 1926),

which generalized Bohr's orbits into probabilistic electron clouds. Despite its limitations for multi-electron atoms, Bohr's theory, as debated in journals like Zeitschrift für Physik and Physical Review through the 1920s, catalyzed quantum mechanics' development, providing a framework for understanding atomic stability and spectral phenomena that remains foundational in chemical bonding and spectroscopy.

Q. 1)What experimental evidence did Bohr's model explain, as per the paragraph ?
Hint : spectral lines of Hydrogen
Q.2)How do electrons move according to Bohr's model?
Q.3)Calculate energy if 2mole of photons of radiation whose frequency is 5×10^{14}Hz
Hint : use $E = h\nu$
Q.4) **What is the energy in joules required to shift the electron of the hydrogen atom from the first Bohr orbit to the fifth Bohr orbit ? The ground state electronic energy is -2.18×10^{-11} ergs.**
Hint : Energy of electron (E_n) = (- 2.18 x 10^{-11}ergs) / n^2= (- 2.18 x 10^{-18} J) / n^2
Energy in Bohr's 1st orbit (E_1) = (- 2.18 x 10^{-18} J) / 1^2
Energy in Bohr's 5th orbit (E_1) = (- 2.18 x 10^{-18} J) / 5^2
now find the difference in energies $E_5 - E_1$(Ans 2.09 x 10^{-18} J)

PASSAGE 2
Due to the Pauli exclusion principle, two electrons cannot share the same set of quantum numbers within the same system; therefore, there is room for only two electrons in each spatial orbital. One of these electrons must have, (for some chosen direction *z*) $m_s = \frac{1}{2}$, and the other must have $m_s = -\frac{1}{2}$.

Hund's first rule states that the lowest energy atomic state is the one that maximizes the total spin quantum number for the electrons in the open subshell. The orbitals of the subshell are each occupied singly with electrons of parallel spin before double occupation occurs.

Two different physical explanations have been given for the increased stability of high multiplicity states. In the early days of quantum mechanics, it was proposed that electrons in different orbitals are further apart, so that electron–electron repulsion energy is reduced. However, accurate quantum-mechanical calculations (starting in the 1970s) have shown that the reason is that the electrons in singly occupied orbitals are less effectively screened or shielded from the nucleus, so that such orbitals contract and electron–nucleus attraction energy becomes greater in magnitude (or decreases algebraically).

Q.1)How does Hund's rule relates to electron spins and orbital degeneracy?
Q.2) How filling of electrons takes place in degenerate orbitals?
Q.3)Write the electronic configuration of Phosphorous(Z=15)and sulphur (Z=16)elements.
Q.4)An atomic orbital has n = 3. What are the possible values of **l** and m_l ?
Ans.) For n = 3; l = 0, 1 and 2.
For l = 0 ; m_l = 0
For l = 1; m_l = +1, 0, -1
For l = 2 ; m_l = +2, +1,0, +1, + 2

SECTION - E (5 MARKS)

Q.1) a.) Calculate the total number of angular nodes and radial nodes present in the 3p orbital.

Hint : angular node = azimuthal quantum number

Radial node (n- l -1)

b.)What is the maximum number of emission lines when the excited electron of ahydrogen atom in n = 6 drops to the ground state?

Hint :The maximum no. of emission lines = [n(n–1)] /2

= [6(6–1)] / 2 =3 × 5 = 15

Q.2 a.)In Rutherford experiment, generally the thin foil of heavy atoms like gold, platinum etc. have been used to be bombarded by the α- particles. If a thin foil of light atoms like aluminium etc. is used, what difference would be observed from the above results?

Hint :**the obstruction offered to the path of the fast moving α-particles would be comparatively quite less. As a result, the number of α-particles deflected will be quite less and the particles which are deflected back will be negligible.**

b.)Arrange the following type of radiations in increasing order of wavelength:

(a) Radiation from microwave oven RA (b) Amber light from traffic signal

(c) Radiation from FM radio (d) Cosmic rays from outer space and

(e) X-rays

Hint :Cosmic rays < X-rays < radiation from microwave oven < amber light from traffic signal < radiation from FM radio

****

CHAPTER 3 CLASSIFICATION OF ELEMENTS AND PERIODOCITY IN PROPERTIES (6 MARKS)

Significance of classification, brief history of the development of periodic table, 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, valiancy, Nomenclature of elements with atomic number greater than 100.

Classification of elements: The arrangement of elements into different groups on the basis of similarties in their properties is called classification of elements.

Genesis of Periodic Classification:

1. Dobereiner'Triad's: Here elements were arranged in increasing order of their atomic masses into group of three elements . This is called Law of Triads.

Dobereiner's Triads : In the given table atomic mass of middle element is approx. equal to the average of atomic masses of other two elements.

Element	Atomic weight	Element	Atomic weight	Element	Atomic weight
Li	7	**Ca**	40	**Cl**	35.5
Na	23	**Sr**	88	**Br**	80
K	39	**Ba**	137	**I**	127

2.Newland's Octave's: Here elements were arranged in increasing order of their atomic masses into group of eight elements like notes of music.

sa	re	ga	ma	pa	da	ni
H	Ll	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Tl	Mn	Fe
Co and Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce and La	Zr	-	-

- **Mandeleev's Periodic Law**:- The properties of the elements are the periodic function of their atomic masses.

  Merits:

  1.Spaces were left vacant to accommodate the elements to be discovered in future.

  2.It could predict the properties of elements which helped in discovery of new elements.

  3.Inert gas elements discovered later could be placed in separate group without disturbing the table.

  Demerits:

  1.Some elements were not arranged in order of their increasing atomic masses. Co placed before Ni .

  2. Position of Hydrogen is not clear. It shows properties similar to both metal as well as non- metals.

  3.The position of isotopes of elements is not clear.

- **Modern Periodic Law**: The physical and chemical properties of elements are the periodic functions of their atomic numbers.

  Division of periodic table into four blocks : s-, p-, d- and f- blocks.

  MAIN GROUP ELEMENTS/ REPRESENTATIVE ELEMENTS:

  The s- and p- block elements are called main group elements or representative elements.

- **s- block elements:**

  Group-1 (Alkali metals) and Group-2 elements (Alkaline earth metals)

  1.In this block elements, last electron enters s- orbital.

  2.Lies on extreme left of periodic table.

  3.Valence shell electronic configuration varies from ns^1 to ns^2.

  4. Electropositive in nature.

  5.Exhibihit +1/+2 valency / oxidation state.

  6. Its' basic oxides and hydroxides are basic in nature.

  7. Impart colour to the flame .

  8.They have low ionization potential.

  9. They are good reducing agent. 10.Solid at room temperature (Cs is liquid at 35 ^{0}C)

- **p- Block elements:**

  Group 13 to 18:

  1. In this block elements, last electron enters the p-orbital.

  2. The p-block elements lie on the extreme right of the periodic table.

  3. Valence shell electronic configuration of these elements varies from $ns^2\ np^{1-6}$.

  4. p-block elements are some non-metals, metalloids and inert gases.

  5. The valency of these block elements varies from +3, ±4, -3, -2, -1 & Zero.

  6. They form acidic oxides.7. They have high ionization potentials.

  8. They are solids/liquids/gases at room temperature (Br is liquid).

- **d- block elements (Transition elements) :**

  Group 3 to 12 :

  1.In these block elements, the last electron enters the d-orbital.

  2.The d-block elements lie between s-block and p-block in the periodic table.

  3.Valence shell electronic configuration of these elements varies from $(n-1)d^{1-10}ns^{1-2}$.

  4. d-block elements are transition metals.

  5.Many of their compounds are colored.

  6.They readily form complexes by acting as Lewis acids.

  7.Most of them and their compounds show paramagnetic and ferromagnetic Behavior.

  8. Most of them act as good catalysts.

- f-**Block elements (Inner- transition elements)**

  1.In this block elements, last electron enters the f-orbital.

  2.The elements belonging to this block are lanthanides and actinides.

  3.Valence shell electronic configuration varies from $(n-2)f^{1-14}\ (n-1)d^{1-10}\ ns^{1-2}$.

  4. f-block elements are inner-transition metals.

  5.There are two series in the f-block i.e., 4f and 5f. **6.** All the actinides are radioactive.

  7.These are highly electro-positive and show +3, +4, +5, +6 oxidation state

- **Noble Gases**: The gaseous elements of group 18 are called noble gases. The general outermost electronic configuration of noble gases (except He) is $ns^2\ np^6$.

  'He' exceptionally has $1s^2$ configuration. Thus the outermost shell of noble gases is completely filled.

- **PERIODICITY:** The repetition of similar properties after regular intervals is called periodicity.

- **Cause of Periodicity**: The properties of elements are the periodic repetition of similar electronic configuration of elements as the atomic number increases.

- **ATOMIC PROPERTIES**: The physical characteristics of the atom of an element are called atomic properties. The properties such as atomic radius, ionic radius, ionisation energy, electro-negativity, electron affinity and valence etc., called atomic properties.

- **ATOMIC RADIUS-** The distance from the centre of the nucleus to the outermost shell of the electrons in the atom of any element is called its atomic radius.
- **Periodicity**- (a) **In period-**Atomic radius of elements decreases from left to right in a period.
  In Group- Atomic radius of elements increases on moving top to bottom in a group.
- **COVALENT RADIUS-** Half the inter-nuclear distance between two similar atoms of any element which are covalently bonded to each other by a single covalent bond is called covalent radius.
- **VAN DER WAALS' RADIUS:** Half the inter-nuclear separation between two similar adjacent atoms belonging to the two neighbouring molecules of the same substance in the solid state is called the van der waals'radius of that atom.
- **METALLIC RADIUS:** Half the distance between the nuclei of the two adjacent metal atoms in a close packed lattice of the metal is called its metallic radius.
  Van der Waals'radius > Metallic radius > Covalent radius
- **IONIC RADIUS:** The effective distance from the centre of the nucleus of anion up to which it has an influence on its electron cloud is called its ionic radius.
  A cation is smaller but the anion is larger than the parent atom.
  In case of **iso-electronic** species, the cation with greater positive charge has smaller radius but anion with greater negative charge has the larger radii.

** **Atom and ions which contain same no. of electron but different magnitude of nuclear charge are called iso- electronic species. For example : O^{2-}, F^- , Na^+ and Mg^{2+}**

****cation with the greater positive charge will have a smaller radius because of the greater attraction of the electrons to the nucleus. Anion with the greater negative charge will have the larger radius.**

- **IONISATION ENTHALPY:** The ionisation enthalpy is the molar enthalpy change accompanying the removal of an electron from a gaseous phase atom or
  ion in its ground state. Thus enthalpy change for the reaction; $M_{(g)} \rightarrow M^+_{(g)} + e^-$
  is the ionisation enthalpy of the element M. Like ionisation energies for successive ionisation, the successive ionisation enthalpy may also be named as
  2^{nd}ionisation enthalpy (Δ_iH_2), third ionisation enthalpy (Δ_rH_3) etc. The term ionisation enthalpy is taken for the first ionisation enthalpy.(Δ_rH_1) is expressed in kg mol^{-1}or in eV.
- **Periodicity:**
  Generally the ionisation enthalpies follow the order (there are few exceptions):
  $(\Delta_rH_1) < (\Delta_rH_2) < (\Delta_rH_3)$
  The ionisation enthalpy decreases on moving top to bottom in a group.
  The ionisation enthalpy increases on moving from left to right in a period.

Screening Effect or shielding effect: the phenomenon where inner-shell electrons reduce the effective nuclear charge felt by the outer-shell electrons.

** Atoms with a strong shielding effect have lower ionization energies because it is easier to remove an outer electron.

***Ionisation enthalpy of boron is slightly less than beryllium**
Reason: Due to completely filled 2s orbital in Be.
*** Ionisation enthalpy of oxygen is less than nitrogen.**
Reason: Due to half filled 2p- orbital in nitrogen.

- **ELECTRON GAIN ENTHALPY:** The electron gain enthalpy (($\Delta_{eg}H$) is the molar enthalpy change when an isolated gaseous atom or ion in its ground state adds an electron to form the corresponding anion thus the enthalpy change for the reaction;

$$X_{(g)} + e^- \rightarrow X^-_{(g)}$$

is called the electron gain enthalpy (Δ_{eg} H) of the element X. The Δ_{eg} H may be positive or negative.

The successive values for the addition of second, third etc. Electron, these are called second, third etc. electron gain enthalpies.

- **Periodicity:**

In period- The electron gain enthalpy increases from left to right in a period.
In group- The electron gain enthalpy decreases from top to bottom in a group.

- **ELECTRONEGATIVITY:** "The relative tendency of an atom in a molecule to attract the shared pair of electrons towards itself is termed as its electro-negativity."
- **Periodicity:**

In period- The electro-negativity increases from left to right in a period.
In group- The electro-negativity decreases from top to bottom in a group.
Fluorine has highest electronegativity value of 4.

- **VALENCE ELECTRONS:** The electrons present in outermost shell are called as valence electron. Because the electrons in the outermost shell determine the valency of an element.
- **VALENCY OF AN ELEMENT:** The number of hydrogen or halogen atom or double the number of oxygen atom, which combines with one atom of the element is taken as its valency. According to the electronic concept of valency,

"The number of electrons which an atom loses or gains or shares with other atom to attain the noble gas configuration is termed as its valency."

- **Periodicity:**

In period- The valency first increases then decreases from left to right in a period.
In group- The valency remains constant from top to bottom in a group.

- **ELECTROPOSITIVE OR METALLIC CHARACTER:** The tendency of an element to lose electrons and forms positive ions (cations) is called electropositive or metallic character. The elements having lower ionisation energies have higher tendency to lose electrons, thus they are electropositive or metallic in their behaviour.

Alkali metals are the most highly electropositive elements.

- **Periodicity:** In period- The electropositive or metallic characters decreases from left to right in a period.
In group- The electropositive or metallic characters increases from top to bottom in a group.
- **ELECTRO-NEGATIVE OR NON- METALLIC CHARACTERS:** the tendency of an element to accept electrons to form an anion is called its non- metallic or electronegative character. The elements having high electro-negativity have higher tendency to gain electrons and forms anion. So, the elements in the upper right hand portion of the periodic table are electro-negative or non-metallic in nature.
- **Periodicity:**

In period- The electro-negative or non- metallic characters increases from left to right in a period.
In group- The electro-negative or non-metallic characters decreases from top to bottom in a group.

- **REACTIVITY OF METALS:**
- **Periodicity:**

In period- The tendency of an element to lose electrons decreases in a period. So the reactivity of metals decreases from left to right in a period.

In group- The tendency of an element to lose electrons increases in a period. So the reactivity of metals increases from top to bottom in a group.

- **REACTIVITY OF NON- METALS:**

In period- The tendency of an element to gain electrons increases in a period. So the reactivity of non-metals increases from left to right in a period.

In group- The tendency of an element to gain electrons decreases in a group. So the reactivity of non-metals increases from top to bottom in a group.

- **SOLUBILITY OF ALKALI METALS CARBONATES AND BICARBONATES:**

PERIODICITY IN GROUP: The solubility of alkali metal carbonates and bicarbonates in water increases down the group (From Lithium to Caesium).

- **SOLUBILITY OF ALKALINE EARTH METAL HYDROXIDES AND SULPHATES:**

PERIODICITY IN GROUP: The solubility of alkaline earth metal hydroxide and sulphates in water increases down the group (From Beryllium to Barium).

- **BASIC STRENGTH OF ALKALINE EARTH METAL HYDROXIDES:**

PERIODICITY IN GROUP: The basic strength of alkaline earth metal hydroxide in water increases down the group (From Beryllium to Barium), i.e.,

$Be(OH)_2 < Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$

Basic strength increases

- **THERMAL STABILITY OF CARBONATES OF ALKALI AND ALKALINE EARTH METALS:**

Except lithium carbonate, ($LiCO_3$), the carbonates of all other alkali metals are stable towards heat, i.e., carbonates of alkali metals (except $LiCO_3$) do not decompose on heating. $LiCO_3$ decomposes on heating to give lithium oxide .

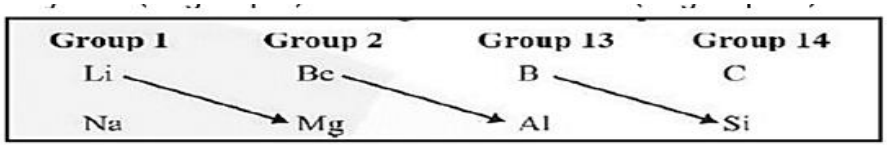
The carbonates of alkaline earth metals are relatively less stable. On heating,

they decompose to give corresponding oxide and CO_2 gas. The decomposition temperature for alkaline earth metal carbonates increases as we go down the group.

- **Anomalous Properties of Second Period Elements**

Their anomalous behaviour is attributed to their small size, large charge/radius ratio, high electro negativity, non- availability of d- orbitals in their valence shell. The first member of each group of p-Block elements displays greater ability to form p-p multiple bonds to itself (e.g. C=C, C≡C O=O, N≡N) and to other second period elements (e.g. C=O, C≡N, N=O) compared to subsequent member of the group.

DIAGONAL RELATIONSHIP



- It has been observed that some elements of the second period show similarities in properties with the elements of the third period placed diagonally to each other, though belonging to different groups. This similarity in properties of elements placed diagonally to each other is called diagonal relationship. • This is because diagonally situated elements have almost same size, ionization enthalpy, electronegativity etc.

For example- lithium (of group 1) resembles magnesium (of group 2) and beryllium (of group 2) resembles aluminium (of group 13) and so as.

Basic oxides: Na_2O **Acidic oxides**: Cl_2O_7 **Neutral oxides**: CO, NO, N_2O

Amphoteric oxides: Al_2O_3, As_2O_3

Unit-3: classification of elements and periodicity in properties

1. INTRODUCTION

A systematic arrangement of elements in the Periodic Table helps us to understand their properties and the periodic trends.

2. CLASSIFICATION OF ELEMENTS

2.1 Basis of Classification

- Atomic number
- Electronic configuration
- Recurrence of properties

2.2 Early Attempts

- Dobereiner's Triads
- Newlands' Law of Octaves
- Mendeleev's Periodic Table

2.3 Modern Periodic Table (Long Form)

- Based on increasing atomic number
- 7 periods (rows) and 18 groups (columns)
- Elements in a group have similar properties due to same valence shell electronic configuration

2.4 Classification of Elements

2.4.1 On the basis of electronic configuration

- s-block elements
- p-block elements
- d-block elements
- f-block elements

2.4.2 On the basis of position in the Periodic Table

- Representative elements (Groups 1, 2 and 13–18)
- Transition elements (Groups 3–12)
- Inner transition elements (f-block)

2.4.3 On the basis of nature

- Metals
- Non-metals
- Metalloids

2.5 Significance of Classification

- Helps in the systematic study of elements
- Helps in predicting properties of elements
- Helps in discovering new elements

3. PERIODICITY IN PROPERTIES

The properties of elements show a periodic variation with their atomic numbers.

3.1 Cause of Periodicity

Periodic variation is due to the periodic recurrence of electronic configurabion (especially valence electrons) of elements.

3.2 Periodic Trends in Properties

3.2.1 Atomic Radius (Size)

Decrease across a period (left → right)
Increase down a group (top ↓ down)

3.2.2 Ionization Enthalpy

Increase across a period (left → right)
Decrease down a group (top ↓ down)

3.2.3 Electron Affinity

Generally increase across a period (left → right)
Decrease down a group (top ↓ down)

3.2.4 Electronegativity

Increase across a period (left → right)
Decrease down a group (top ↓ down)

3.2.5 Metallic and Non-metallic Character

Metallic character decreases across a period and increases down a group.
Non-metallic character increases across a period and decreases down a group.

3.2.6 Reactivity

- Metals: Reactivity generally increases down a group.
- Non-metals: Reactivity generally increases up a group and across a period.

3.3 Anomalous Behaviour

Some elements show deviation from general trends due to factors like half-filled or fully filled subshells, high ionization enthalpy, etc. (e.g., Be, N, O, F)

4. INTERRELATION

Classification of elements in the Periodic Table is the basis for understanding the periodicity in properties. Periodic trends help in predicting the properties of elements and their compounds.

5. IMPORTANCE

- Helps in understanding the relationship between structure and properties
- Helps in predicting properties of known elements
- Helps in the discovery of new elements and their compounds

6. SUMMARY

The Periodic Table is a powerful tool for the classification of elements.
The periodicity in properties arises due to the periodic recurrence of electronic configuration, which helps in understanding and predicting the behaviour of elements.

Quesiton Bank

Section- A (1 Mark)

1. Which one of the following is correct order of ionization enthalpy:
(a) $Na^{+} > Mg^{+2} > Ne$ (b) $Na^{+} > Ne > Mg^{+2}$
(c) $Mg^{+2} > Na^{+} > Ne$ (d) $Ne > Na^{+} > Mg^{+2}$

2. As per the IUPAC element with atomic no 119 would be named as :
(a) Ununseptium (b) Ununennium (c) unniloctium(d) unnilseptium

3. . Electronic configuration $Ar[4s^2 3d^7]$ Element will belong to:
(a) Group 7 period 3 (b) Group 9 period 3
(c) Group 7 period 4 (d) Group 9 period 4

4. Periodicity in the properties of the elements depend on :
(a) No of electrons in neutral atom (b) No. of neutrons
(c) Sum of no. of protons and neutrons (d) Ratio of no. of neutrons to no of protons

5. Elements known as Eka Aluminium and Eka Silicon would be :
(a) Aluminium and Boron (b) Germanium and Gallium
(c) Gallium and Germanium (d) Boron and Aluminium

6.Second ionization enthalpy is always greater than the first ionisation enthalpy because of :
(a) Increase in no of electrons (b) Decrease in effective nuclear charge
(c) Increase in size (d) Increase in effective nuclear charge

7. As per the Modern Periodic table reason for the periodicity is:
(a) Similar electronic configuration (b) Similar ionic size
(c) Same no of neutrons (d) Same neutron/proton ratio

8.Element with the following electronic configurations of an atom has the lowest ionisation enthalpy?
(a) $1s^2\ 2s^2\ 2p^3$ (b) $1s^2\ 2s^2\ 2p^6\ 3s^1$
(c) $1s^2\ 2s^2\ 2p^6$ (d) $1s^2\ 2s^2\ 2p^5$

9. Elements in the same group have:
(a) Same no. of protons (b) Same no. of valence electrons
(c) Same atomic no. (d) Same physical state

10.Element with the most metallic character will be :
(a) Na (b)Mg (c) Al (d) K

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 each question.
(a) **Assertion** is correct, reason is correct; reason is a correct explanation for **assertion**.
(b) **Assertion** is correct, reason is correct; reason is not a correct explanation for **assertion**
(c) **Assertion** is correct, reason is incorrect
(d) **Assertion** is incorrect, reason is correct.

11) **Assertion**- Electron gain enthalpy of Fluorine is more negative than that of Chlorine
Reason- Size of Fluorine atom is very small.

12) **Assertion**- He has highest ionization potential in the periodic table
Reason- He is the smallest element in the periodic table.

13) **Assertion**- A cation is always smaller than the parent atom.
Reason- Cation is formed by the loss of electron/s.

14) **Assertion** – Phosphorus belongs to 15th group and 3rd period in the modern periodic table.

Reason- Group no is decided by the no of shells and the period no. is decided by the no. of valence electrons.

15) **Assertion**- Fluorine shows -1 oxidation state .

Reason- Fluorine is the most electronegative element and it does not have d subshell.

KEY for MCQ

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C	B	D	A	C	D	A	B	B	D	D	C	A	C	A

Section- B[02 Marks]

1. In terms of period and group where would you locate the element with Z=114

[Hint: Period 7^{th} and Group 14^{th}]

2. The species having same no. of electrons are known as ? Name the Noble gas species which are isoelectronic with the following ionic species: (i) F- (ii) K+

[Hint: (i) Ne (ii)Ar]

3. Account the reason that Cations are smaller and anions are larger in radii than their parent atoms.

[Hint: Cation having higher effective nuclear charge , Anions having lesser effective nuclear charge]

4. Element having more negative electron gain enthalpy would be :

(i)O or F (ii) F or Cl

[Hint: (i) F (ii) Cl

5. Predict the elements which have been named by:

(i) Lawrence Barkley laboratory (ii) Seaborg's group

[Hint; Lr &Bk ,Sg]

Section- C [03 Marks]

1. Compare the Electron gain enthalpy and Electronegativity, Name the element with highest electron gain enthalpy and highest electronegativity.

[Hint: highest electron gain enthalpy element=Cl, Highest Electronegativity element=F]

2. How would you expect the first ionization enthalpies for two isotopes of the same element to be the same or different. Justify your answer

[Hint: First ionization enthalpy should be same as isotopes have same no,.of electrons]

3. Accounts for the following:

(i) F is more reactive than Cl though having less negative electron gain enthalpy

[Hint: low bond dissociation enthalpy of Fluorine make it more reactive]

(ii) First ionisation enthalpy of Na is lower but second ionisation enthalpy is higher as compared to the case of Mg. [Hint: based on electronic configuration in first case it has $3S^1$ but in second case more stable $2P^6$]

(iii) d block elements are called Transitional elements.

[Hint; elements are present in between s- block and p- block elements and they have partially filled d orbital in which electronic transitions may take place]

4. Predict the formula of the stable binary compounds that would be formed by the combination of the following pairs of elements.

(a) Lithium and oxygen (b) Magnisiumnd Nitrogen(c) Aluminium and iodine

(d) Silicon and Oxygen (e) Phosphorus and fluorine

(f) Element with atomic no. 71 and atomic no. 9

[Hint: (a) Li_2O (b) Mg_3N_2 (c) AlI_3 (d) SiO_2 (e) PF_3 or PF_5 (b) Magnesium and nitrogen (d) Silicon and oxygen (f) Element 71 and fluorine (f) The element with the atomic number 71 is Lutetium (Lu). It has valency 3.

Hence LuF_3]

5.Give the name of property in which Li resemble with Mg, Also assign the reason

[Hint: as per the text]

Section- D CASE BASED STUDY QUESTION [04 marks]

1. Read the passage carefully and answer the questions followed.

The s-Block Elements The elements of Group 1 (alkali metals) and Group 2 (alkaline earth metals) which have ns1and ns^2 outermost electronic configuration belong to the s-Block Elements. They are all reactive metals with low ionization enthalpies. They lose the outermost electron(s) readily to form 1+ ion (in the case of alkali metals) or 2+ ion (in the case of alkaline earth metals). The metallic character and the reactivity increase as we go down the group. Because of high reactivity they are never found pure in nature. The noble gases thus exhibit very low chemical reactivity. Preceding the noble gas family are two chemically important groups of non-metals. They are the halogens (Group 17) and the chalcogens (Group 16).The non-metallic character increases as we move from left to right across a period and metallic character increases as we go down. And the Basic strength of hydroxides also increases .

Account the reason for the following:

(i) group 1 elements known as Alkali metals and group 2 elements Alkaline earth metals .

[Hint: Their oxides and hydroxides are basic in nature]

(ii) 16^{th} elements are known as as Chalcogens and group 17^{th} elements as Halogens.

[Hint: Chalcogens means ore forming, Halogen means Sea salt producers]

(ii) Nature of chlorides of Group one elements is ionic

[Hint:due to their lower ionisation enthalpy they form cations easily]

(iv) Most basic Hydroxide of alkaline earth metals is $Ba(OH)_2$

[Hint: down the group atomic radius increases so bond dissociation enthalpy decreases]

Long Answer type questions [05 Marks]

1. The first ($\Delta_i H1$) and the second ($\Delta_i H$) ionization enthalpies (in kJ mol^{-1}) andthe ($\Delta_{eg} H$) electron gain enthalpy (in kJ mol^{-1}) of a few elements are given below:

Elements	H_{IE}		H_{eg}
I	520	7300	–60
II	419	3051	–48
III	1681	3374	–328
IV	1008	1846	–295
V	2372	5251	+48
VI	738	1451	–40

Name the above elements likely to be :

(a) the least reactive element. (b) the most reactive metal.

(c) the most reactive non-metal. (d) the least reactive non-metal.

(e) the metal which can form a stable binary halide of the formula MX_2, (X=halogen).

[**Hint**:

(a) Element V is likely to be the least reactive element. This is because it has thehighest first ionization enthalpy (Δ_iH_1) and a positive electron gain enthalpy ($\Delta_{eg}H$).

(**b**) Element II is likely to be the most reactive metal as it has the lowest first ionization enthalpy (Δ_iH_1) and a low negative electron gain enthalpy ($\Delta_{eg}H$).

(**c**) Element III is likely to be the most reactive non–metal as it has a high first ionization enthalpy (Δ_iH_1) and the highest negative electron gain enthalpy ($\Delta_{eg}H$).

(d) Element V is likely to be the least reactive non–metal since it has a very high first ionization enthalpy (Δ_iH_2) and a positive electron gain enthalpy ($\Delta_{eg}H$).

(**e**) Element VI has a low negative electron gain enthalpy ($\Delta_{eg}H$). Thus, it is a metal. Further, it has the lowest second ionization enthalpy (Δ_iH_2). Hence, it can form a stable binary halide of the formula MX_2(X=halogen).

2.(a) What could be the reason for not considering Zn, Cd and Hg as transitional elements.

[Hint; parent atom or their cations having fully filled d -orbital]

(b) Predict the first element and group no. for the following as per the periodic able

i. Identify the element with five electrons in the outer sub-shell.
ii. Identify an element that would tend to lose two electrons.
iii. Identify an element that would tend to gain two electrons

[**Hin**t: Cl(17^{th} group),Mg(2^{nd} group), O (16^{th} group)

****

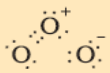
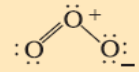
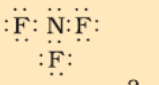
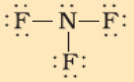
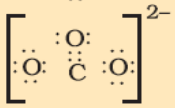
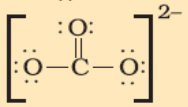
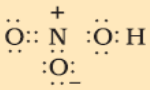
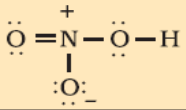
UNIT -4: CHEMICAL BONDING AND MOLECULAR STRUCTURE (7 Marks)

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.

KEY CONCEPTS-

Chemical bonding refers to the attractive force that holds various constituents together in a molecule. There are three types of chemical bonds:
(i) Ionic Bond: Involves a transfer of electrons from one atom to another.
(ii) Covalent Bond: Indicates the sharing of electrons between atoms.
(iii) Coordinate Bond: Formed when one or more electrons are completely transferred from one atom to another.

Kossel-Lewis Approach to Chemical Bonding - *Lewis Symbols:*

Molecule/Ion	Lewis Representation	
H_2	H : H*	H – H
O_2	:Ö::Ö:	:Ö=Ö:
O_3		
NF_3		
CO_3^{2-}		
HNO_3		

Formal Charge

The formal charge of an atom in a polyatomic molecule or ion may be defined as the difference between the number of valence electrons of that atom in an isolated or free state and the number of electrons assigned to that atom in the Lewis structure.

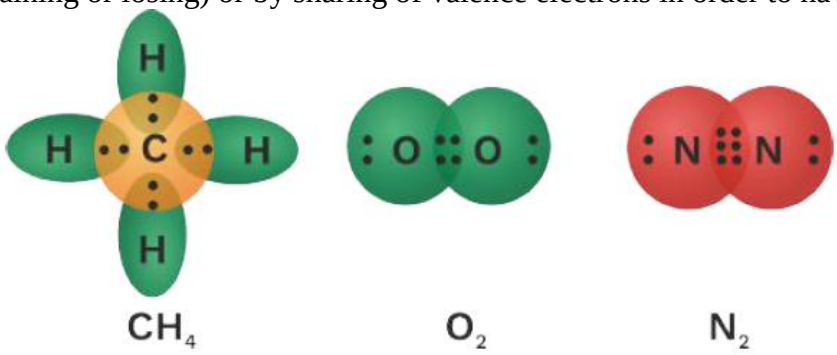
Formal charge (F.C.) on an atom in a Lewis structure =

[total number of valence electrons in the free atom] - [total number of nonbonding (lone pair) electrons] — (1/2) [total number of bonding (shared) electrons]

Ex.

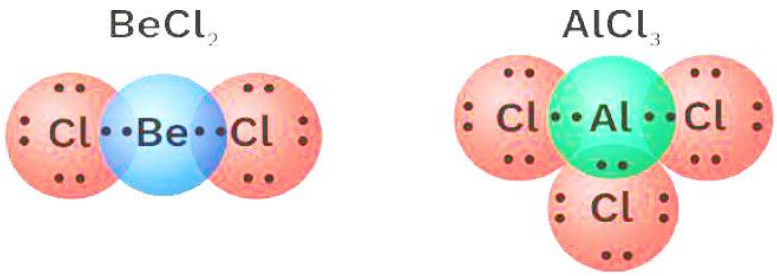
Molecule / Ion	Lewis Structure	Formal Charge Calculation	Formal Charge
NH_4^+ (Ammonium ion)	H attached to central N with 4 single bonds	FC on N = 5 − 0 − 8/2 = 5 − 4 = +1	N = +1, H = 0
CO_3^{2-} (Carbonate ion)	Central C bonded to 3 O atoms (one double bond, two single bonds)	FC on C = 4 − 0 − 8/2 = 0 FC on double bonded O = 6 − 4 − 4/2 = 0 FC on single bonded O = 6 − 6 − 2/2 = −1	C = 0, two O = −1 each, one O = 0
NO_3^- (Nitrate ion)	Central N bonded to 3 O atoms (one double bond, two single bonds)	FC on N = 5 − 0 − 8/2 = +1 FC on double bonded O = 6 − 4 − 4/2 = 0 FC on single bonded O = 6 − 6 − 2/2 = −1	N = +1, two O = −1 each, one O = 0

Octet Rule- atoms can combine either by transfer of valence electrons from one atom to another (gaining or losing) or by sharing of valence electrons in order to have an octet in their valence shells



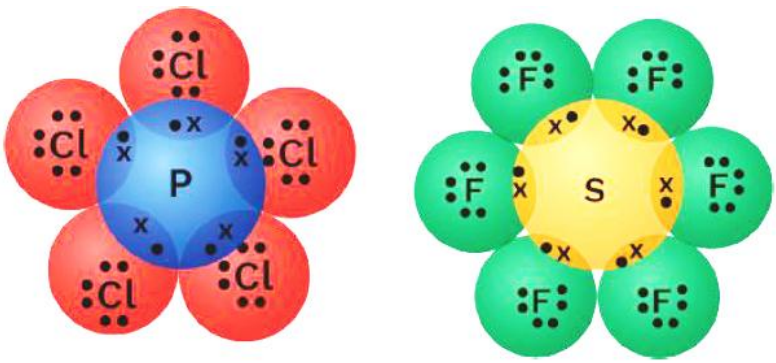
Limitations of the Octet Rule

(i) ***The incomplete octet of the central atom***



(ii) ***Odd-electron molecules***

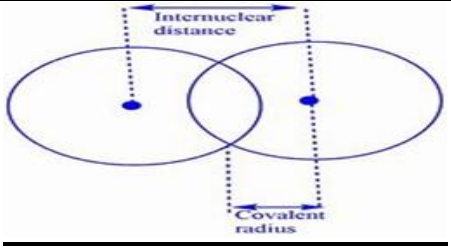
(iii) ***The expanded octet***



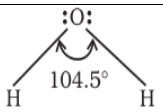
(iv) octet rule is based upon the chemical inertness of noble gases. However, some noble gases (for example xenon and krypton) also combine with oxygen and fluorine to form a number of compounds like XeF_2, KrF_2, $XeOF_2$ etc.
(v) This theory does not account for the shape of molecules.
(vi) It does not explain the relative stability of the molecules being totally silent about the energy of a molecule.

Bond Parameters

Bond Length- The covalent radius is measured approximately as the radius of an atom's core which is in contact with the core of an adjacent atom in a bonded situation

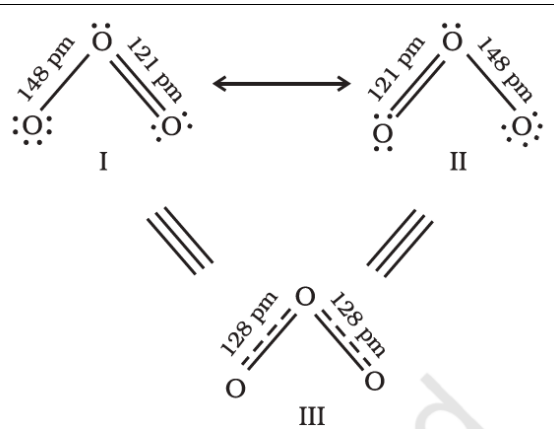


Bond Angle- The angle between the orbitals containing bonding electron pairs around the central atom in a molecule/complex ion.



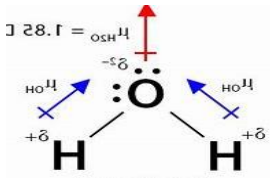
Bond Order- the number of bonds between the two atoms in a molecule. Isoelectronic molecules and ions have identical bond orders; for example, F_2 and O_2^{2-} have bond order 1. N_2, CO and NO^+ have bond order 3.

Resonance-, a number of structures with similar energy, positions of nuclei, bonding and non- bonding pairs of electrons are taken as the canonical structures of the hybrid which describes the molecule accurately

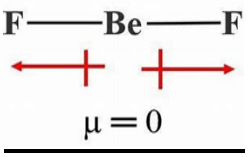


Dipole moment (μ) = charge (q) × distance of separation (d) Unit: Debye units (D).

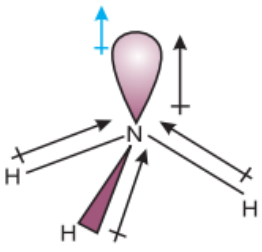
For water



For BeF_2

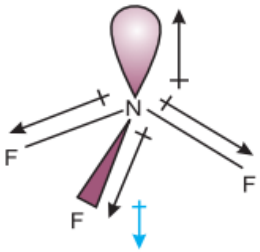


For NH_3



Resultant dipole moment in $NH_3 = 4.90 \times 10^{-30}$ C m

For NF_3



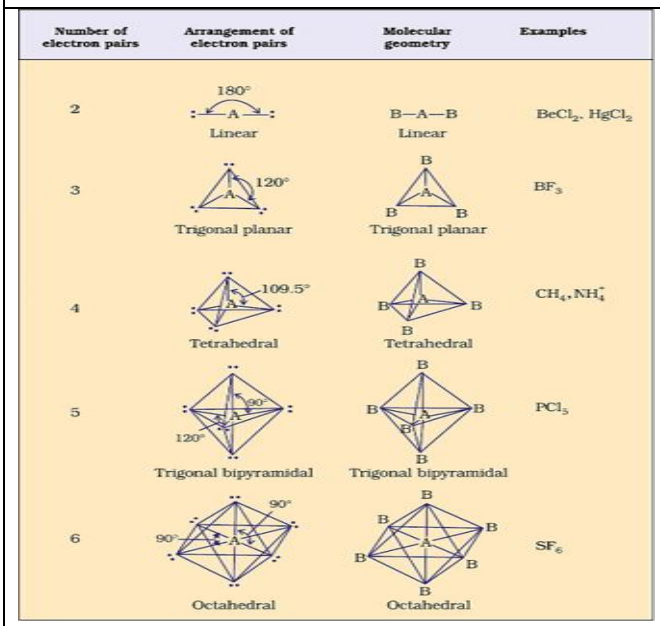
Resultant dipole moment in $NF_3 = 0.80 \times 10^{-30}$ C m

Valence Shell Electron Pair Repulsion (VSEPR) Theory

(i) The shape of a molecule depends on the number of bonded and lone electron pairs around the central atom.
(ii) Electron pairs repel each other because they are negatively charged. They arrange themselves as far apart as possible to minimize repulsion.
(iii) The valence shell is considered as a sphere with electron pairs placed at maximum distance.
(iv)A multiple bond is treated as a single electron pair in determining shape.
(v) VSEPR theory can be applied to any one of the resonance structures of a molecule.
(vi) Order of repulsion:
Lone pair–Lone pair > Lone pair–Bond pair > Bond pair–Bond pair.

The Valence Shell Electron Pair Repulsion (VSEPR) Theory

Geometry of Molecules in which the Central Atom has No Lone Pair of Electrons



Shape (geometry) of Some Simple Molecules/Ions with Central Ions having One or More Lone Pairs of Electrons(E)

Number of electron Pair	Arrangement of electron pairs	Molecular geometry	Hybridization	Example
2	180° Linear	B—A—B Linear	sp	$BeCl_2$, $HgCl_2$
3	120° Trigonal planar	Trigonal planar (AB_3)	sp^2	BF_3
4	109.5° Trigonal bipyramidal	Tetrahedral (AB_4)	sp^3	CH_4, NH_4^+
5	90°, 120° Trigonal bipyramidal	Trigonal bipyramidal (AB_5)	sp^3d	PCl_5
6	90°, 90° Octahedral	Octahedral (AB_6)	sp^3d^2	SF_6

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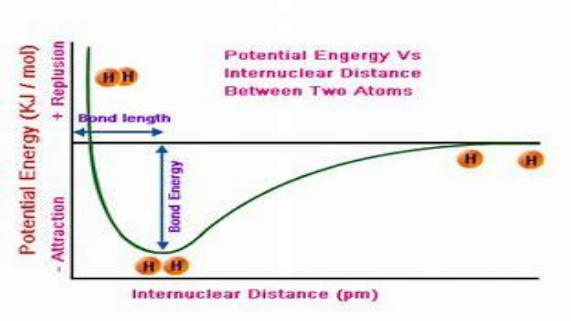
VALENCE BOND THEORY



- Consider two hydrogen atoms A and B approaching each other having nuclei N_A and N_B and electrons present in them are represented by e_A and e_B

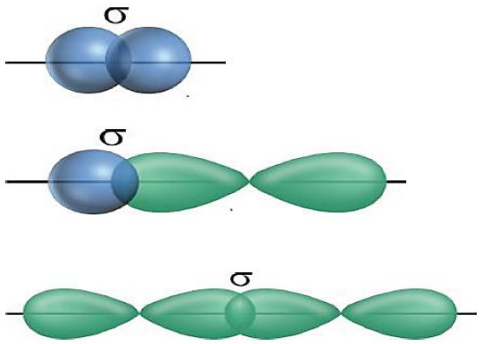
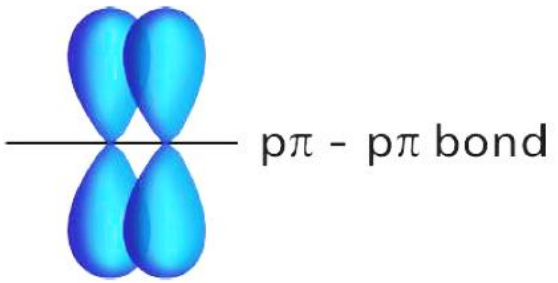
PARTICIPANTS: Each hydrogen atom has one proton (in the nucleus) and one electron So, when two hydrogen atoms approach each other, these are the main interactions:

1. Attractive Forces: Electron-Proton Attraction (between different atoms): (i) The electron of one atom is attracted to the proton (nucleus) of the other atom. (ii)This is the key attractive force that leads to bond formation.	**2. Repulsive Forces:** Electron-Electron Repulsion: (i) The electrons of the two atoms repel each other because they are both negatively charged. (ii) Proton-Proton Repulsion: The nuclei (protons) of the two atoms repel each other due to their positive charges.

Net Result: Balance of Forces-

At larger distances, attractive forces dominate, pulling the atoms together. As the atoms get closer, repulsive forces become significant at a certain optimal distance (~0.74 Å), the attraction and repulsion balance, forming a stable covalent bond.
This is the bond length of H_2.
The system reaches minimum potential energy, making the molecule stable

Types of Overlapping and Nature of Covalent Bonds

(i) Sigma (σ bond):	**(ii) pi (π bond):**
(a) Sigma bond is formed by the end to end (head-on) overlap of bonding orbitals along the inter-nuclear axis (b)The extent of overlap is more so, sigma bond is a strong bond. (c) It is the strongest covalent bond 	(a) π bond is formed by the atomic orbitals when they overlap in such a way that their axes remain parallel to each other and perpendicular to the inter-nuclear axis. (b) The orbital formed is due to lateral overlapping or side wise overlapping. The extent of overlap is less, so pi bond is a weak bond. (c) It is weaker than a sigma bond 

HYBRIDIZATION

The process of intermixing the orbitals of slightly different energies so as to redistribute their energies, resulting in the formation of new set of orbitals of equivalent energies and shape.
Conditions for Hybridization:

- Orbitals should have almost equal energy.
- Promotion of electrons may occur to achieve hybridization.
- Number of hybrid orbitals = number of atomic orbitals mixed.
- It involves only valence shell orbitals.

Important Notes:

- Only sigma bonds are considered for hybridization (π-bonds are not).
- d-orbital participation occurs only in elements of period 3 or higher.
- Hybridization helps explain molecular shape (VSEPR theory).

Steps to Determine Hybridization:

1.Count sigma bonds formed by the atom.

2. Add lone pairs on the atom.

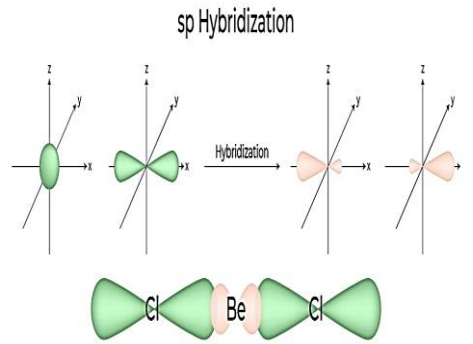
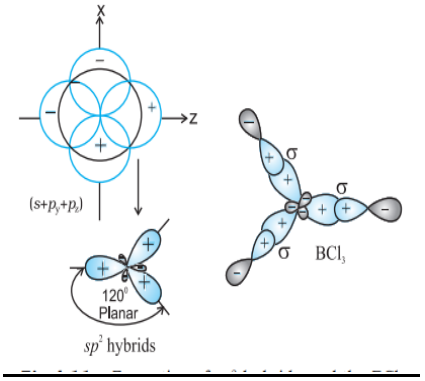
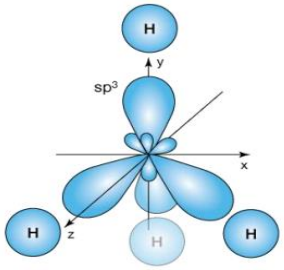
3. Total = Number of hybrid orbitals = Type of hybridization.

Example: In NH_3

Sigma bonds = 3 (with H)

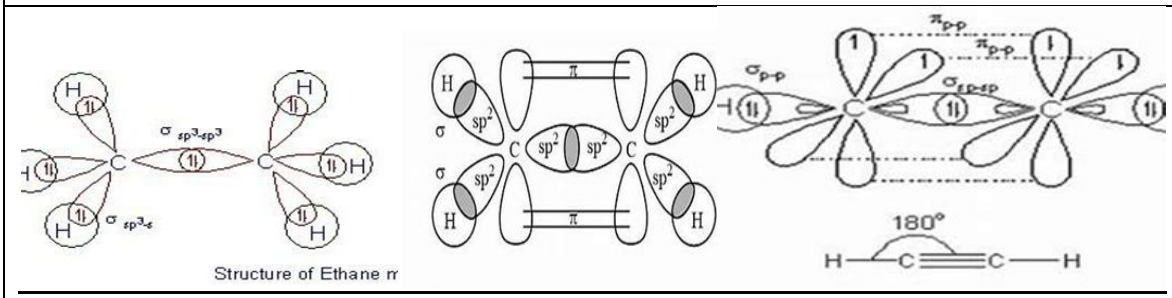
Lone pairs = 1

Total = 4 → sp^3 hybridization

sp HYBRIDIZATION	sp^2 HYBRIDISATION	sp^3 HYBRIDISATION:
		
➢ Each of the hybrid orbitals formed has 50% s-character and 50%, p-character. ➢ This type of hybridisation is also known as diagonal hybridisation having linear structure & bond angle = 180° ➢ Example: $BeCl_2$, BeF_2, C_2H_2etc	➢ In this type, one s and two p-orbitals hybridise to form three equivalent sp2 hybrid orbitals in the same plane making an angle of 120° & trigonal planar shape. ➢ Each of the hybrid orbitals formed has 33.3 % s-character and 66.7 %, p-character.	➢ Each orbital has 25% s-character and 75% p-character. With tetrahedral structure & bond angle 109.5° The four sp3 orbitals are directed towards four corners of the tetrahedron. ➢ A compound having sp3 hybridisation is CH_4, CCl_4, NH_4+ etc.

EXAMPLES –(HYBRIDIZATION)

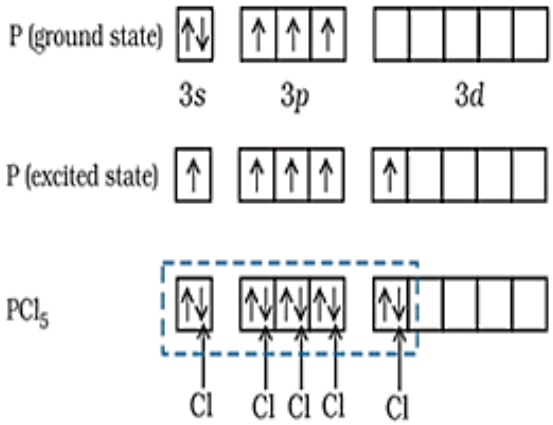
sp^3Hybridisation in C_2H_6 molecule sp^2 Hybridisation in C_2H_4 and sp Hybridisationin C_2H_2

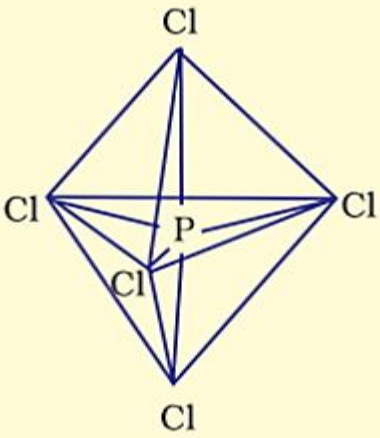


Hybridisation of Elements involving d Orbitals

Hybridization	Orbitals Involved	Geometry	No. of Electron Domains / Regions	Example Compounds
sp^3d	1=one s+ three p + one d	Trigonal bipyramidal	5	PCl_5, SF_4
sp^3d^2	One s+ Three p, + two d	Octahedral	6	SF_6, $[Fe(CN)_6]^{3-}$
dsp^2	One d+ one s + two p	Square planar	4	$[Ni(CN)_4]^{2-}$, $[PtCl_4]^{2-}$
d^2sp^3	Two d+ one s +three p	Octahedral (inner orbital)	6	$[Co(NH_3)_6]^{3+}$, $[Fe(CN)_6]^{4-}$

Formation of PCl_5 (sp^3d hybridisation)





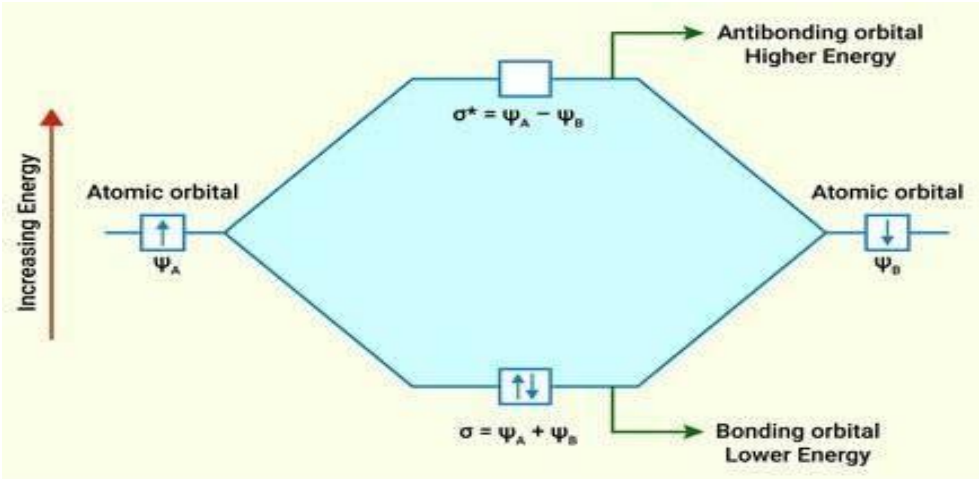
Molecular Orbital Theory

(i) Molecular orbitals (MOs) are formed when atomic orbitals combine.
(ii) Molecular orbitals are different from atomic orbitals.
(iii) Electrons in a molecule move under the influence of all the nuclei present in the molecule.
(iii) Molecular orbitals have different energy levels, just like atomic orbitals.
(iv) The shape of a molecular orbital depends on the atomic orbitals forming it.
(vi) Molecular orbitals are filled in increasing order of energy.
(vii) Number of molecular orbitals formed = Number of atomic orbitals combined.
(viii) Electrons fill molecular orbitals according to: Aufbau Principle, Hund's Rule Pauli Exclusion Principle.

Formation of Molecular Orbitals Linear Combination of Atomic Orbitals (LCAO)-

The molecular orbitals are formed by LCAO (Linear combination of atomic orbitals) method, i.e., by addition or subtraction of wave functions of individual atoms,

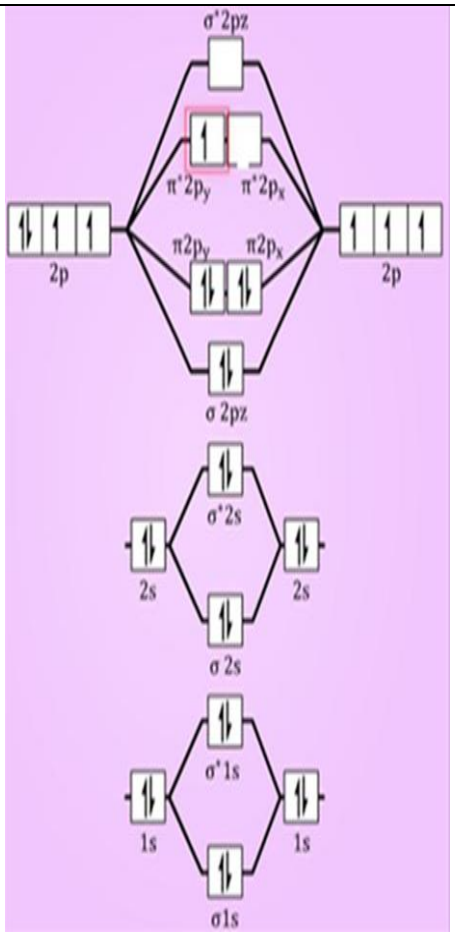
- Mathematically, the formation of molecular orbitals -ψMO = ψA + ψB ,Therefore, the two molecular orbitals σ(bonding MO) and σ* (antibonding MO)are formed as:
- σ = ψA + Ψb , σ* = ψA – ψB



- Molecular orbitals of lower energy is known as bonding molecular orbital and that of higher energy is known as antibonding molecular orbital.
- Aufbau Principle, Hund's Rule and Pauli Exclusion Principle are all applicable for molecular orbitals.

Types of Molecular Orbital		
Bonding Molecular Orbitals (σ and π)	**Antibonding Molecular Orbitals (σ and π)****	**Non-Bonding Molecular Orbitals**
*Definition: Formed by constructive interference (in-phase combination) of atomic orbitals. *Properties: Lower energy than the original atomic orbitals. Electron density is concentrated between the nuclei. Stabilizes the molecule. *Types: σ (sigma) bond: Head-on overlap (e.g., s-s, s-p, or p-p along the inter-nuclear axis). π (pi) bond: Side-on overlap of p orbitals perpendicular to the inter-nuclear axis.	*Definition: Formed by destructive interference (out-of-phase combination) of atomic orbitals. *Properties: Higher energy than the original atomic orbitals. Has a node between nuclei (zero electron density). Destabilizes the molecule. *Types: σ* (sigma star): From out-of-phase head-on overlap. π* (pi star): From out-of-phase side-on overlap.	➢ Definition: Orbitals that do not overlap with other atomic orbitals. ➢ Properties: No bonding or antibonding character. Energy is similar to that of the original atomic orbital. Often associated with lone pairs (e.g., in H_2O, NH_3

- The increasing order of energies of various molecular orbitals for O_2 and F_2 is given below: σ 1s <σ* 1s <σ 2s < σ* 2s <σ $2p_z$ < (π $2p_x$ =π $2p_y$) < (π*$2p_x$ = π* $2p_y$) <σ* $2p_z$
- for molecules such as B_2, C_2, N_2, etc. the increasing order of energies of various molecular orbitals is σ1s < σ*1s < σ2s < σ*2s < (π 2 p_x = π 2 p_y) <σ $2p_z$ < (π*$2p_x$ =π*$2p_y$) <σ*$2p_z$
- Electronic Configuration and Molecular Behavior-
- **Stability of Molecules**: If N_b is the number of electrons occupying bonding orbitals and N_a the number occupying the antibonding orbitals, then
- (i) the molecule is stable if N_b is greater than N_a, and
- (ii) the molecule is unstable if N_b is less than N_a

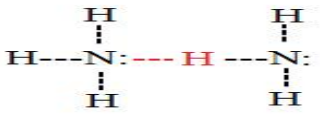
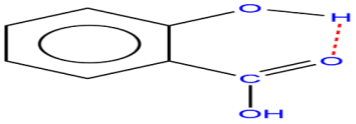
Bond order	**Nature of the bond**	
-Bond order (b.o.) = ½ (N_b–N_a) -A positive bond order (i.e., N_b> N_a) means a stable molecule while a negative (i.e., N_b= N_a) bond order means an unstable molecule.	➢ Integral bond order values of 1, 2 or 3 correspond to single, double or triple bonds respectively **Bond-length** The bond length decreases as bond order increases. **Magnetic nature** If all the molecular orbitals in a molecule are doubly occupied, the substance is diamagnetic (repelled by magnetic field). However, if one or more molecular orbitals are singly occupied it is paramagnetic (attracted by magnetic field)	

BONDING IN SOME HOMONUCLEAR DIATOMIC MOLECULES	
Hydrogen Molecule (H_2) Atomic configuration: $1s^1$ for each H atom. Total electrons in H_2=2 Bonding: Combination of two 1s atomic orbitals forms: One bonding molecular orbital (σ1s) One antibonding molecular orbital (σ*1s) Electron configuration: $(\sigma 1s)^2$ Bond order = ½ (2 - 0) =1 Bond type: Single covalent bond	**Helium (He)** Atomic number of He = 2 → $1s^2$ Total electrons in He_2 = 2 × 2 = 4 electrons Molecular orbital (MO) configuration: $(\sigma 1s)^2$ $(\sigma^* 1s)^2$ Bonding electrons = 2 (σ1s) Antibonding electrons = 2 (σ*1s) Bond order = $(N_b - N_a)/2 = (2 - 2)/2 = 0$ Conclusion: He_2 does not exist (unstable), because bond order is zero

Nitrogen (N_2)	**Oxygen Molecule (O_2)**
• Atomic number of C = 7 → $1s^2\ 2s^2\ 2p3$ • Total electrons in N_2 = 2 × 7 = 14 electrons • MO configuration (up to Nitrogen): $(\sigma 1s)^2\ (\sigma^*1s)^2\ (\sigma 2s)^2\ (\sigma^*2s)^2\ (\pi 2px)2(\pi 2py)2\ (\sigma 2pz)^2$ Bonding electrons: 2(σ1s), 2 (σ2s), 6(π2px, π2py, σ2pz) so total = 10 Antibonding electrons: 2 (σ*1s) = 2 (σ*2s) so total =4 Bond order =(Nb -Na)/2 (10 – 4)/2 = 3 • Conclusion: N_2 has a triple bond, and it's diamagnetic due to all paired electrons.	Atomic configuration: $1s^2\ 2s^2\ 2p^4$ for each O atom MO Electron configuration (total 16 e^-): $(\sigma 1s)^2\ (\sigma^*1s)^2\ (\sigma 2s)^2\ (\sigma^*2s)^2\ (\sigma 2p_z)^2\ (\pi 2p_x)^2\ (\pi 2p_y)^2(\pi^*2p_x)^1\ (\pi^*2p_y)^1$ Bond order = ½ (10 bonding - 6 antibonding) = 2 Bond type: Double bond Special feature: Paramagnetic due to two unpaired electrons in π* orbitals.

HYDROGEN BONDING:

Hydrogen bonding is a type of attractive interaction between a hydrogen atom covalently bonded to a highly electronegative atom (like F, O, or N) and another electronegative atom.

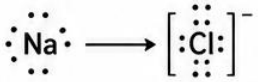
Intermolecular Hydrogen Bonding:	**Intramolecular Hydrogen Bonding:**
Occurs between molecules. Common in water (H_2O), where hydrogen bonds form between different water molecules. Responsible for properties like high boiling point and surface tension of water. Example: Water (H_2O), ethanol (C_2H_5OH), ammonia (NH_3). 	Occurs within the same molecule between two functional groups. Often seen in organic compounds like ortho-nitrophenol. Can affect the physical and chemical properties such as boiling point and solubility. Example: Ortho-nitrophenol, salicylic acid.  Salicylic acid

CHEMICAL BONDING AND MOLECULAR STRUCTURE

FLOWCHART

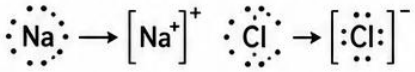
1 KOSSEL – LEWIS APPROACH

- Octet Rule
- Lewis Symbols
- Formation of Bonds
  - Ionic Bond
  - Covalent Bond
- Limitations of Octet Rule



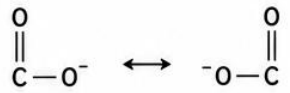
2 IONIC (ELECTROVALENT) BOND

- Formation by Electron Transfer
- Lattice Enthalpy
- Factors Affecting Ionic Bond
  - Ionisation Enthalpy
  - Electron Gain Enthalpy
  - Lattice Energy
- Properties of Ionic Compounds



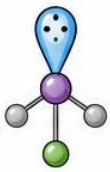
3 COVALENT BOND

- Single, Double, Triple Bond
- Bond Length
- Bond Enthalpy
- Bond Angle
- Resonance



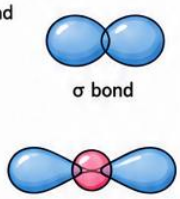
4 VSEPR THEORY

- Shape Prediction
- Lone Pair – Bond Pair Repulsion
- Molecular Shapes
  - Linear
  - Trigonal Planar
  - Tetrahedral
  - Trigonal Bipyramidal
  - Octahedral



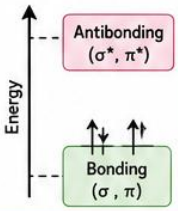
5 VALENCE BOND THEORY

- Orbital Overlapping
- Sigma (σ) Bond
- Pi (π) Bond
- Hybridisation
  - sp
  - sp^2
  - sp^3
  - sp^3d
  - sp^3d^2



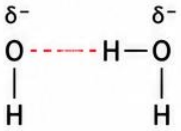
6 MOLECULAR ORBITAL THEORY

- Bonding Molecular Orbital (lower energy)
- Antibonding Molecular Orbital (higher energy)
- Bond Order $(B.O. = \frac{N_b - N_a}{2})$
- Magnetic Nature (Diamagnetic / Paramagnetic)



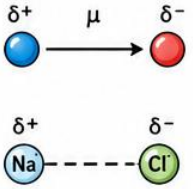
7 HYDROGEN BONDING

- Intermolecular Hydrogen Bonding
- Intramolecular Hydrogen Bonding
- Importance in Physical Properties (e.g., bp, mp, solubility)



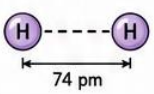
8 IMPORTANT CONCEPTS

- Dipole Moment ($\mu = q \times r$)
- Polar and Non-polar Molecules
- Fajan's Rule
- Partial Ionic Character



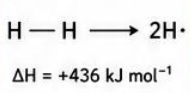
Bond Length

Distance between nuclei of bonded atoms in a molecule.



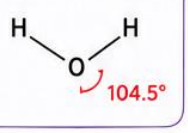
Bond Enthalpy

Energy required to break one mole of bonds in gaseous state.



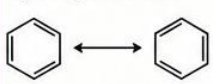
Bond Angle

Angle between two bonds in a molecule.



Resonance

When a molecule/cation cannot be represented by a single structure.



Octet Rule Limitations

Incomplete octet: $BeCl_2$, BF_3

Expanded octet: PCl_5, SF_6

Odd electron species: NO, NO_2

QUESITON BANK
SECTION-A (1 MARKS)

Q1**.** The outer orbitals of C in ethene molecule can be considered to be hybridized to give three equivalent sp^2 orbitals. The total number of sigma (s) and pi (p) bonds in ethene molecule is

(a) 1 sigma (s) and 2 pi (p) bonds (b) 3 sigma (s) and 2 pi (p) bonds

(c) 4 sigma (s) and 1 pi (p) bonds (d) 5 sigma (s) and 1 pi (p) bonds.

Q2.The correct order of hybridization of the central atom in the following species: NH_3, $[PtCl_4]^{2-}$, PCl_5 and BCl_3 is

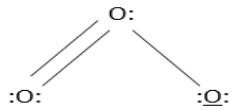
(a) dsp^2, dsp^3, sp^2 and sp^3 (b) sp^3, dsp^2, sp^3d, sp^2

(c) dsp^2, sp^2, sp^3, dsp^3 (d) dsp^2, sp^3, sp^2, dsp^3

Q3.Which one of the following arrangements of molecules is correct on the basis of their dipole moments?

(a) $BF_3 > NF_3 > NH_3$ (b) $NF_3 > BF_3 > NH_3$(c) $NH_3 > BF_3 > NF_3$ (d) $NH_3 > NF_3 > BF_3$

Q4.Calculate the formal charge of the middle atom in the ozone molecule.



(a) 1 (b) -1 (c) 0 (d) -2

Q5. Polarity in a molecule and hence the dipole moment depends primarily on electronegativity of the constituent atoms and shape of a molecule. Which of the following has the highest dipole moment?

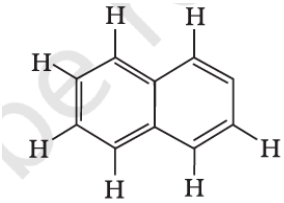
(a) CO_2

(b) HI

(c) H_2O

(d) SO_2

Q6. Number of π bonds and σ bonds in the following structure is–



(a) 6, 19

(b) 4, 20

(c) 5, 19

(d) 5, 20

Q7.Using VSEPR theory, predict the species which has square pyramidal shape

(a) $SnCl_2$ (b) CCl_4 (c) SO_3 (d) BrF_5

Q8. Sp^3d^2 hybridization is present in $[Co(NH_3)_6]^{3+}$, Find its geometry.

(a) tetrahedral geometry (b)square planar geometry (c)tetragonal geometry (d)octahedral geometry

Q9.The charge/size ratio of a cation determines its polarizing power. Which one of the following sequences represents the increasing order of the polarizing order of the polarizing power of the cationic species, K^+, Ca^{++}, Mg^{2+}, Be^{2+}?

(a) $Ca^{2+} < Mg^{2+} < Be^{+} < K^{+}$ (b) $Mg^{2+} < Be^{2+} < K^{+} < Ca^{2+}$

(c) $Be^{2+} < K^{+} < Ca^{2+} < Mg^{2+}$ (d) $K^{+} < Ca^{2+} < Mg^{2+} < Be^{2}$

Q10.Which of the following statements explains why silicon dioxide has a high melting point?

(a) It has a giant ionic structure with strong electrostatic attraction between ions.

(b)It has a giant covalent structure with strong covalent bonds between atoms.

(c)It has a simple molecular structure with weak forces between molecules.
(d) It has a giant metallic structure with a strong attraction between positive ions and the sea of electron

In these questions (Q11-Q15), a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

(c) Assertion is correct statement but reason is wrong statement.

(d) Assertion is wrong statement but reason is correct statement.

Q11. Assertion (A): A molecule of ammonia has a pyramidal shape**.**
Reason (R): The nitrogen atom in ammonia is sp^3 hybridized and has a lone pair of electrons.
Q12.Assertion (A): CO_2 is a linear molecule.
Reason (R**):** The central atom in CO_2 undergoes sp^3 hybridization.
Q13. Assertion : Lone pair-lone pair repulsive interactions are greater than lone pair -bond pair and bond pair-bond pair interactions.
Reason : The space occupied by lone pair electrons is more as compared to bond pair electrons.
Q14.Assertion : The lesser the lattice enthalpy more stable is the ionic compound.
Reason : The lattice enthalpy is greater, for ions of highest charge and smaller radii
Q15.Assertion: The dipole moment helps to predict whether a molecule is polar or non polar.
Reason: The dipole moment helps to predict the geometry of molecules –

Answer key

SECTION- B (2 MARKS)

Q1.(a)o-nitrophenol is steam volatile while p-nitrophenol is not. Why?
Hint-hydrogen bonding.
(b)Which out of CH_3F and CH_3Cl has a higher dipole moment and why?
Hint-Dipole Moment (μ) = Charge (Q) × distance of separation (r). so CH_3Cl
Q2.In the molecule NH_3, the bond angles are 107° instead of 109.5°. Analyze this deviation in light of Valence Bond Theory and electron pair repulsion.
Hint-refer valence bond theory and VSEPR theory .
Q3. If a new molecule with the formula AX_2E_3 were discovered, how would you use VSEPR theory to determine its 3D geometry? What challenges might arise in modeling such a molecule?
Hint-refer VSEPR theory
Q4The bond length in HCl is 1.27 Å and its dipole moment is 1.03 D. Calculate the percentage ionic character.
Ans. Percentage ionic character= theoretical value of dipole moment / observed dipole moment ×100=16.83%
Q5Can a molecule be polar even if it has only non-polar bonds? Justify your answer with an example or counterexample.
Hint-refer dipole moment

QUESTION NO	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	13	Q14	Q15
ANSWER	d	b	d	a	c	c	d	d	d	b	a	c	a	d	b

SECTION- C(3 MARKS)

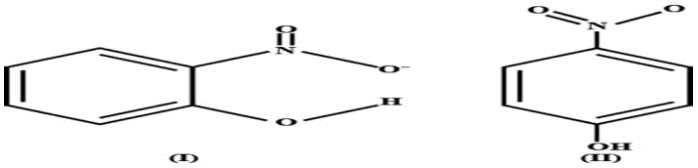
Q1(a) Why are resonance structures necessary to describe the bonding in molecules like benzene, carbonate ion, or nitrate ion?

Hint-a single Lewis structure fails to explain the bonding in a molecule/polyatomic ion due to the presence of partial charges and fractional bonds in it

(b) Given two molecules—SF_6 and NH_3—evaluate which one better conforms to the octet rule and justify your answer.

Hint-refer octet rule

(c) Which of the two compounds will have intermolecular hydrogen bonding and which compound is expected to show intramolecular hydrogen bonding



Hint-I)IntramolecularII)intermolecular hydrogen bonding.

Q2.Elements X, Y and Z have 4, 5 and 7 valence electrons respectively,

(a) Write the molecular formula of the compounds formed by these elements individually with hydrogen,

HINT-Formula: XH_4,YH_3,ZH,Dipole moment depends on:Polarity of the bond (electronegativity difference)Molecular geometry

(b) Which of these compounds will have the highest dipole moment?

Q3. Give reasons for the following: ‘

(a) Covalent bonds are directional bonds while ionic bonds are non- directional.

HINT-orientation of a covalent bond depend on the direction of the overlapping atomic orbitals

(b) Water molecule has bent structure whereas carbon dioxide molecule is linear.

Hint-refer dipole moment

(c) Ethyne molecule is linear.

Hint-hybridization and overlapping of orbitals

Q4suppose a new compound XY_3 is discovered. It has a trigonal planar structure and all X–Y bond lengths are equal. What can you infer about:

a)The hybridization of X?

Ans -The central atom X is sp^2 hybridized.

b)The presence or absence of lone pairs on X?

ans-X has no lone pairs

c)The bond type and polarity?

Ans-covalent,Bond polarity: Each X–Y bond is polar (if $X \neq Y$), but the overall molecule is nonpolar due to symmetry

Q5a)Why does the bond order of O_2^- decrease compared to O_2? What does this imply about the stability and bond length of O_2^-?

Hint: Use Molecular Orbital Theory

b) Can a molecule with an odd number of electrons ever be diamagnetic? Explain why or why not.

Hint- It will always be paramagnetic.

c)If molecular orbitals are created by combining five atomic orbitals from atom A and five atomic orbitals from atom B combine, how many molecular orbitals will result?

Hint-refer Molecular Orbital Theory

SECTION – D CASE STUDY BASED QUESTIONS (4 MARKS)

Read the passage carefully and answer the questions.

Q1.A chemistry lab investigates the physical properties (melting point, solubility in water, and electrical conductivity) of three substances: sodium chloride (NaCl), glucose ($C_6H_{12}O_6$), and magnesium oxide (MgO). They observe that:

- NaCl and MgO conduct electricity in molten form but not as solids.
- Glucose does not conduct electricity in any form.
- NaCl and MgO have high melting points, while glucose melts at a lower temperature.

They conclude that NaCl and MgO are ionic compounds, while glucose is covalent.

i)An ionic bond is formed between _____

(a) two metal atoms (b) one metal atom and one non-metal atom

(c) two non-metal atoms (d) one metal atom and one metalloid atom

Ans-(b)

ii)Why does glucose not conduct electricity in any state?

Hint-no free ions

iii)Compare the melting points of MgO and NaCl. Why is MgO's melting point higher?

Hint-charge on ions

iv)How does temperature affect the conductivity of ionic and covalent compounds?

Hint-*For ionic compounds: Higher temperature increases ion mobility, thus conductivity increases. For covalent compounds: Unless they ionize at higher temperatures, their conductivity remains low.*

Q2A group of students is analyzing the bonding in ethene (C_2H_4), ethyne (C_2H_2), and methane (CH_4) using the concept of hybridization. They discover:

- In methane, carbon forms four sigma bonds using sp^3 hybrid orbitals.
- In ethene, carbon forms three sigma bonds using sp^2 hybrid orbitals, and a π bond using unhybridized p-orbitals.
- In ethyne, carbon uses sp hybrid orbitals and forms two π bonds due to two unhybridized p-orbitals.

i)How does hybridization affect the acidity of terminal alkynes?

Hint-percentage character.

ii)Compare the bond angles in CH_4, C_2H_4, and C_2H_2 and explain the reasons.

Hint-consider hybridization and electron pair repulsion.

iii)Why is ethyne a linear molecule while ethene is planar?

Hint-refer hybridization

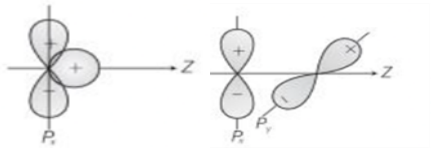
iv)In the compound HCN, identify the hybridization of carbon and explain your reasoning.

Hint-Carbon hybridization in HCN: sp

Reason: Carbon forms two sigma bonds (one with H, one with N) → 2 regions of electron density → sp hybridized.

SECTION - E (5 MARKS)

Q1) a) Why does type of overlap given in the following figure does not result in bond formation



Hint-refer VBT and Hybridization

b) Account for the following: (i) Water is a liquid while H_2S is a gas

Hint-hydrogen bonding

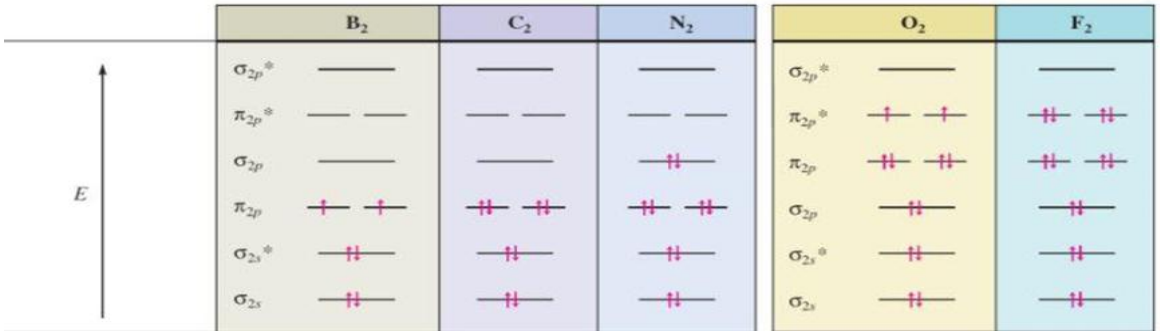
(ii) NH_3 has higher boiling point than PH_3.

Hint-hydrogen bonding

c) Why are the axial bonds longer a compared to equatorial bonds?

Hint-Stronger repulsion from equatorial bonds

Q2. Table shows the molecular orbital occupancy and molecular properties for B_2, C_2, N_2, O_2, F_2,Observe this figure and answer the questions based on this diagram and related studied concepts. MO occupancy and molecular properties for B_2 through N_2



Molecule	MO Configuration (valence electrons only)	Bond Order	Magnetic Behavior
B_2	$(\sigma 2s)^2 (\sigma^* 2s)^2 (\pi 2p)^2$	1	Paramagnetic (2 unpaired e^-)
C_2	$(\sigma 2s)^2 (\sigma^* 2s)^2 (\pi 2p)^4$	2	Diamagnetic (all paired)
N_2	$(\sigma 2s)^2 (\sigma^* 2s)^2 (\pi 2p)^4 (\sigma 2p)^2$	3	Diamagnetic
O_2	$(\sigma 2s)^2 (\sigma 2s)^2 (\sigma 2p)^2 (\pi 2p)^4 (\pi 2p)^2$	2	Paramagnetic (2 unpaired e^-)
F_2	$(\sigma 2s)^2 (\sigma 2s)^2 (\sigma 2p)^2 (\pi 2p)^4 (\pi 2p)^4$	1	Diamagnetic

a)Why is Ne_2 not formed according to M.O. theory?

Hint-bond order

b) Arrange B_2, C_2, N_2, O_2, F_2 in increasing order of bond length.

Hint-bond order

(c) On the basis of fig and table given above, Why F_2 diamagnetic where as O_2 paramagnetic?

Hint -unpaired electron ,refer molecular orbital theory

d) Consider the table given above and answer ,Why does bond enthalpy of N_2 is higher than O_2?

Hint-triple bond

e) Why is F_2 more reactive than O_2 ?

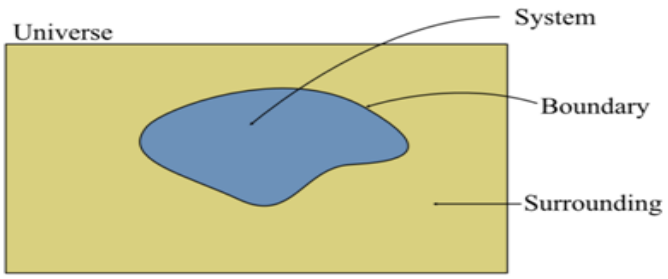
Hint-**higher electronegativity.**

UNIT – 5 THERMODYNAMICS (9 Marks)

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 ΔU and ΔH, 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)

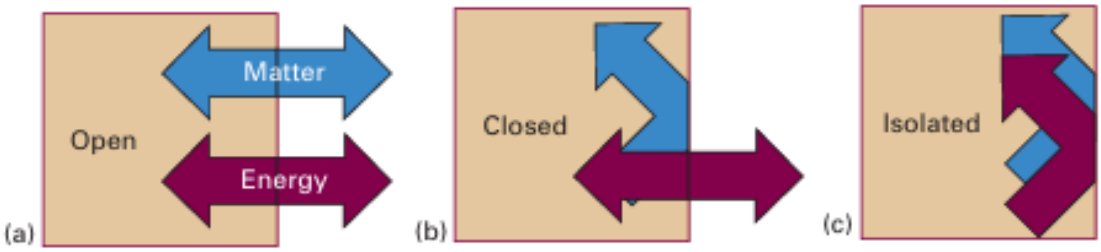
The branch of chemistry which deals with study of exchange of energy entropy and spontaneity of chemical process of the system i.e. known as thermodynamics.

- **System** refers to the specific part of the universe that is under observation or study.
- **Surroundings** include everything in the universe **outside the system**.
- **Boundary** is the real or imaginary surface that separates the **system** from its **surroundings**.
- universe = system + surroundings



TYPES OF THE SYSTEM

(i) Open system: Energy and matter both can be exchanged with the surroundings.
(ii) Closed system: Only energy can be exchanged with the surroundings but not matter
(iii) Isolated system: Neither energy nor matter can be exchanged with the surroundings.



STATE OF SYSTEM

State functions or State variables	Path Functions
(a) Thermodynamic variables whose value depends only on the initial and final states of the system.	(a) Thermodynamic variables whose value depends upon the path followed by system.
(b) Example: Temperature, pressure, volume, density, enthalpy, internal energy, entropy, gibbs free energy etc.	(b) Example: work(w) and heat(q)

THERMODYNAMIC PROPERTIES

Extensive Properties	Intensive Properties
(i) Property whose value depends on the quantity or size of matter present in the system.	(i) Properties which do not depend on the quantity or size of matter present.
(ii) Example: mass, volume, internal energy, enthalpy, heat capacity, etc.	(ii) Example temperature, density, pressure, molar volume, molar heat capacity, molar enthalpy etc.

Note: Molar property like molar volume, molar heat capacity, molar enthalpy is an intensive property because a molar property is an extensive property (like heat capacity or volume) divided by the number of moles, making it independent of the amount of substance present.

THERMODYNAMIC PROCESS

Process	Condition
Isothermal process	Temperature remains constant, i.e. ($\Delta T=0$).
Isochoric process	Volume remains constant, i.e. ($\Delta V=0$).
Isobaric process	Pressure remains constant, i.e. (Δp)= 0.
Adiabatic process	Heat is not exchanged by system with the surroundings, i.e. q=0
Endothermic Process	energy is acquired from its surroundings as heat.
Exothermic process	releases energy as heat into its surroundings.

INTERNAL ENERGY, WORK AND HEAT-:

- **Internal energy(U):** (i) The total energy contained within a substance.
  It is a sum of all types of energies like vibrational energy, translational energy, etc.
- (ii) Absolute internal energy is indeterminable, but its change is measurable, determined by
  $\Delta U = U_f - U_i$ .Measured in Joule
- **Work(w):** It is an ordered forces of energy transfer due to the action of macroscopic forces.
  Unit is Joule.
- Heat(q): Exchange of energy, which is a result of temperature difference is called heat. Unit is Joule.

FIRST LAW OF THERMODYNAMICS

- -Energy can neither be created nor destroyed.It can be transformed from one form to another.
- -The energy of an isolated system is always constant.
- **Expression: $\Delta U = q + W$**
- **Sign Convention**:
-

(i) q is positive = heat is supplied to the system
(ii) q is negative = heat is lost by the system
(iii) W is positive = work done on the system
(iv) W is negative = work done by the system
(v) U is positive = Heat absorb by the system
(vi) U is negative = Heat release by the system

EXPRESSIONS FOR WORK DONE UNDER VARIOUS CONDITIONS	
(a) Work done against constant pressure p under isothermal irreversible change	$w = -p_{ext}(V_f - V_i)$ **$W = - P_{ex} X \Delta V$**
(b) Work done in reversible expansion under isothermal conditions.	$q = w = -2.303nRT\log\frac{V_f}{V_i}$
(c) Expansion of a gas in vacuum ($p_{ex} = 0$) is called free expansion.(process is Reversible / Irreversible)	w = zero, from equation $w = -p_{ext}(V_f - V_i)$; $\Delta U = q$ at constant V
(d) For adiabatic change,	$q = 0$; $\Delta U = w_{ad}$
(e) Work done at constant volume($\Delta V = 0$)	$w = 0$; $\Delta U = q_v$

ENTHALPY:

- The sum of the energy stored in the system and the ability of the system to do work. Expression:
- $H = U + pV$
- During a process we can estimate the change in enthalpy as $\Delta H = \Delta U + p\Delta V$
  For ideal gas equation, $P\Delta V = \Delta n_g RT$; $\Delta H = \Delta U + \Delta n_g RT$
- Sign Convention: (i) ΔH is negative for exothermic reactions; (ii) ΔH is positive for endothermic reactions.
- Enthalpy is measured in k J / Mol

HEAT CAPACITY

- The amount of heat required to raise the temperature of a system by 1°C.
- Formula: $q = C \times \Delta T$; Here, C is heat capacity.
- It is the extensive property
- **Molar Heat Capacity:** It is the heat capacity of 1 mole of substance of the system.
- It is the Intensive property
- Specific **Heat Capacity:** (i) It is the heat capacity of 1 g of substance of the system to increase 1^0C temperature. (ii) Formula: $q = c \times \mathbf{m} \times \Delta T$;
  (Here, c is specific heat capacity, m is mass of substance, and ΔT is temperature change)
- At constant volume, the heat capacity, C is denoted by C_v and at constant pressure, this is denoted by C_p.
- **Relation between Cp and Cv -:**

At constant volume as $q_v = C_v\Delta T = \Delta U$

At constant pressure as $q_p = Cp\Delta T = \Delta H$

For a mole of an ideal gas, $\Delta H = \Delta U + \Delta(pV)$
$= \Delta U + \Delta(RT)$
$= \Delta U + R\Delta T$

From $\Delta H = \Delta U + R\Delta T$ ----------(1)

On putting the values of ΔH and ΔU, we have

$$C_p\Delta T = C_V\Delta T + R\Delta T$$
$$C_p = C_V + R$$
$$C_p - C_V = R \qquad (5.13)$$

- **Relationship between C_p and C_v for 1 mol of an Ideal Gas is $Cp - C_v = R$**

THERMOCHEMISTRY

- Enthalpy of Reaction ($\Delta_r H$): The enthalpy change is occurred when 1 mol of reactant is converted into product is called Enthalpy of Reaction .
- The enthalpy change of a chemical reaction is given by:
- $\Delta_r H$ = (sum of enthalpies of products) – (sum of enthalpies of reactants)

$$\Delta_r H = \Sigma a_i H_{products} - \Sigma b_i H_{reactants}$$

Here, $\sum$ (sigma) is used for summation and a_i and b_i are the stoichiometric coefficient of balanced chemical equation.

- Standard enthalpy of reaction: The standard enthalpy of reaction is the enthalpy change for a reaction in their standard states (At 298 K temperature and 1 bar pressure)

Enthalpy Changes during Phase Transformations

Enthalpy of fusion($\Delta_{fu}H^o$)	Standard enthalpy of vaporization ($\Delta_{vap}H^o$)	Standard enthalpy of sublimation, $\Delta_{sub}H^o$
Enthalpy change is occurred when melting of one mole of a solid substance in standard state.	Enthalpy change is occurred when vaporization of one mole of a liquid at constant temperature and under standard pressure (1bar).	Enthalpy change is occurred when one mole of a solid substance sublimes at a constant temperature and under standard pressure (1bar).

- Standard Enthalpy of Formation(Δ_fH^o): The enthalpy change is occored for the formation of one mole of a compound from its elements in the standard states.
- **Relation between ΔrH^0 and (Δ_fH^0):**

$$\Delta_r H^\ominus = 2\Delta_f H^\ominus$$

e.g. Given N2 (g) + 3H2 (g) → 2NH3 (g) . $\Delta rH^0 = -92.4$ kJ mol^{-1} .
What is the standard enthalpy of formation of NH3 gas?

Ans- $\Delta_r H^\ominus = 2\Delta_f H^\ominus$

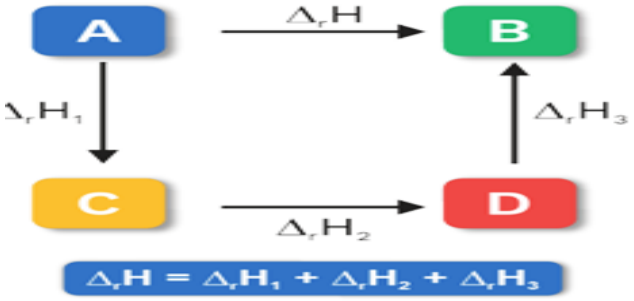
-92.4 = 2 X Δ_fH^0

Δ_fH^0= - 92.4 / 2 = -46.2 kJ mol^{-1} .

Elements	Reference state
C	C(graphite)
S	S_8(rhombic)
P	P_4 (white)
O	O_2(g)
H	H_2(g)
Br	Br_2(l)
Metal	M (s)(except Hg(l))

Hess's Law of Constant Heat Summation

According to this Law -If a reaction takes place in several steps directly or indirectly , then its standard reaction enthalpy is the sum of the standard enthalpies of the steps reactions in which the heat is released or absorbed.



- The value of Δ_rH^o corresponds to the moles in the equation and is expressed in kJ mol^{-1}.

For example: $C(s) + 1/2O_2(g) \rightarrow CO(g)$ $\Delta_rH^0 = -110.5$ kJmol^{-1} .....(1)

$CO(g) + 1/2O_2(g) \rightarrow CO_2(g)$ $\Delta_rH^0 = -283.0$ kJmol^{-1} .....(2)

Combine equation 1 and 2

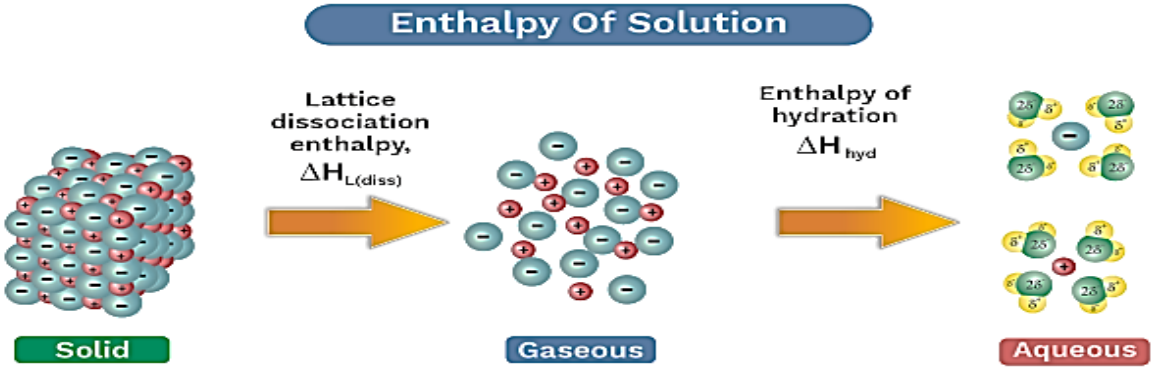
$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta_rH^0 = -393.5$ kJmol^{-1}

[Total Enthalpy of Reaction = Sum of Enthalpies of steps Reaction]

[-393.5 kJ mol^{-1} = (-110.5 + -283.0) kJ mol^{-1}]

ENTHALPIES FOR DIFFERENT TYPES OF REACTIONS

Enthalpy of Combustion (Δ_cH^o)	Enthalpy ofAtomization(Δ_aH^o)	Enthalpy of Solution ($\Delta_{sol}H^o$)
(i) It is the enthalpy change taking place when one mole of a compound undergoes complete combustion in the presence of oxygen . (ii) Exothermic in nature	(i) It is the enthalpy change taking place on breaking one mole of bonds between the atoms in any compound completely to obtain atoms in the gas phase.	(i) It is the enthalpy change taking place when one mole of substance dissolves in a specified amount of solvent. (ii) $\Delta_{sol}H^o = \Delta_{lattice}H^o + (\Delta_{hyd}H^o)$

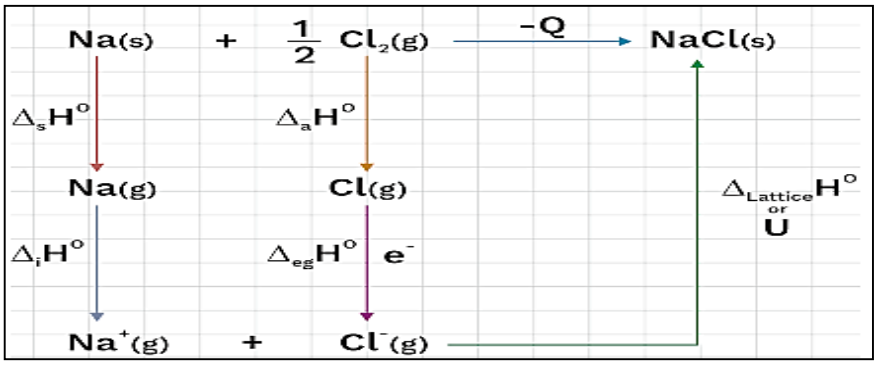


- **Enthalpy of dilution**: It is the enthalpy change associated with the addition of a specified amount of solute to the specified amount of solvent at a constant temperature and pressure.
- **Bond Enthalpy ($\Delta_{bond}H^o$)**
  Enthalpy is required to break a bond and energy is released when bond is formed.

$$\Delta_rH = \sum bondenthapies_{reactants} - \sum bondenthapies_{products}$$

- **Lattice Enthalpy**:

- The lattice enthalpy is the enthalpy change which occurs when one mole of an ionic compound dissociates into its ions in gaseous state.
  e.g. NaCl (s) -------> Na^+ (g) + Cl^-(g) $\Delta_{lattice}H^0 = +788$ kJ mol^{-1}
- Since it is not possible to determine lattice enthalpies directly through experiments, an indirect method is used by constructing an enthalpy diagram known as the Born-Haber cycle.



Total energies involved in the above five steps

$$= \Delta_sH^\circ + \frac{1}{2}\Delta_aH^\circ + \Delta_iH^\circ - \Delta_{eg}H^\circ + U$$

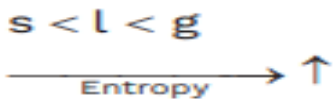
SPONTANEOUS PROCESS:

- A process which can take place by itself or has a tendency to take place is called spontaneous process.
- It cannot be reversed.

- All natural processes are spontaneous process and Irreversible.

ENTROPY

- Degree of the randomness or disorderness of the system is known as entropy.
- The unit of entropy is J/Kmol.
- Entropy change for a system is given by $\Delta S = \frac{q_{rev}}{T}$



- **Entropy Criterion Entropy Criterion of Spontaneous Process :**
  The total entropy change (ΔS_{total}) for a spontaneous process is given by

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

- At equilibrium position (ΔS_{total}) is 0.
  Note: For isothermal expansion of an ideal gas: **ΔU = 0** for both reversible and irreversible processes. But ΔS_{total} is not zero for irreversible process. ΔU does not discriminate between reversible and irreversible process, whereas ΔS does.

Entropy and Second Law of Thermodynamics:

- The entropy of the universe is always increasing in the course of every spontaneous or natural change.
  Absolute Entropy and Third Law of Thermodynamics-: According to this law The entropy of any pure crystalline substance approaches zero as the temperature approaches absolute zero. -Entropy of solutions and super cooled liquids is not zero at 0 K.

GIBBS ENERGY (G) OR GIBBS FREE ENERGY

- It is the energy available in a system that can be converted into maximum work done under the condition of constant temperature and pressure .
- Gibbs Energy G is an extensive property and a state function.
- Gibbs Helmholtz Equation- Gibbs free Energy/function G = H – TS
  The change in Gibbs energy for the system $\Delta G = \Delta H - T\Delta S$
- The formula is **ΔG° = ΔH° – TΔS°**

Gibbs energy criterion of spontaneity
ΔG > 0, process is non-spontaneous
ΔG< 0, process is spontaneous
ΔG= 0,process is in equilibrium state.

- **Effect of Temperature on Spontaneity**:

$\Delta_r H^\ominus$	$\Delta_r S^\ominus$	$\Delta_r G^\ominus$	Description*
–	+	–	Reaction spontaneous at all temperatures
–	–	– (at low T)	Reaction spontaneous at low temperature
–	–	+ (at high T)	Reaction nonspontaneous at high temperature
+	+	+ (at low T)	Reaction nonspontaneous at low temperature
+	+	– (at high T)	Reaction spontaneous at high temperature
+	–	+ (at all T)	Reaction nonspontaneous at all temperatures

GIBBS ENERGY CHANGE AND EQUILIBRIUM

- **ΔG = ΔG° + 2.303 RT log Q**

  At equilibrium, ΔG value is zero. The above formula is rewritten as follows:

  ΔG°= -2.303 RT log K

Unit-5: Thermodynamics

THERMODYNAMICS

Study of energy changes that occur in chemical and physical processes.

1. THERMODYNAMIC SYSTEM AND SURROUNDINGS

- **System:** Part of the universe under study.
- **Surroundings:** Everything outside the system.
- **Types of systems:**
  (i) Open system
  (ii) Closed system
  (iii) Isolated system

2. STATE FUNCTIONS

Properties that depend only on the state of the system and not on the path followed.

Examples: P, V, T, U, H, S

Δ (state function) depends only on initial and final state, not on the path.

3. THERMODYNAMIC EQUILIBRIUM

A state in which macroscopic properties of the system do not change with time.

Types of equilibrium:

(i) Thermal equilibrium
(ii) Mechanical equilibrium
(iii) Chemical equilibrium

4. THERMODYNAMIC PROCESSES

Change in the state of a system from one equilibrium state to another.

Types:

(i) Reversible process
(ii) Irreversible process

5. WORK (w) AND HEAT (q)

Work (w): Energy transfer when a force causes displacement.

- $w = -P_{ext}\,\Delta V$

Heat (q): Energy transfer due to temperature difference.

- Heat is positive when absorbed by the system.

6. FIRST LAW OF THERMODYNAMICS

Law of conservation of energy.

$$\Delta U = q + w$$

where,
ΔU = change in internal energy
q = heat
w = work done on the system
(ΔU is a state function)

7. INTERNAL ENERGY (U)

Total energy possessed by the system due to the motion and position of its particles.

It is a state function.

For an ideal gas, U depends only on temperature.

8. ENTHALPY (H)

Another state function defined as:

$$H = U + PV$$

$$\Delta H = \Delta U + \Delta(PV)$$

At constant pressure,
$\Delta H = q_p$ (heat at constant pressure)

9. SPONTANEITY OF PROCESSES

Spontaneous processes occur naturally without external aid.

Criterion: Changes in the universe.

$\Delta G < 0$ → spontaneous
$\Delta G = 0$ → equilibrium
$\Delta G > 0$ → non-spontaneous

10. ENTROPY (S)

A measure of randomness (or disorder) in a system.

- For a spontaneous process of an isolated system,
  $\Delta S_{universe} > 0$
- For a reversible process,
  $\Delta S_{universe} = 0$

11. GIBBS FREE ENERGY (G)

Defined as:

$$G = H - TS$$

At constant temperature and pressure:

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

Spontaneity is determined by ΔG.

12. APPLICATIONS

- Feasibility of processes
- Direction of spontaneous change
- Chemical equilibrium
- Electrochemical cells
- Stability of substances

INTERLINKAGE SUMMARY

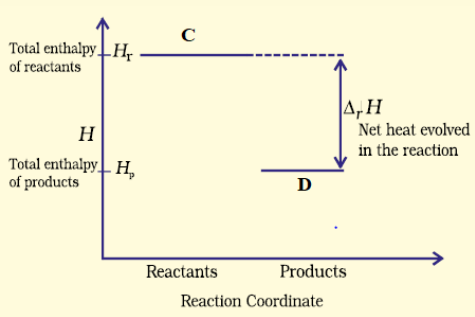
Thermodynamics begins with defining the system and its state, explains how energy is exchanged as heat and work (First Law), introduces state functions (U, H, S, G) and uses them to predict the spontaneity and feasibility of natural and chemical processes.

SECTION - A (1 MARKS)

1. If the volume of an ideal gas is increased isothermally then its internal energy will be:
(a) Increases (b) Decreases
(c) Decreases Remains constant (d) Cannot be determined

2. Which of the following options correctly represents the relationship between C_p and C_V for one mole of an ideal gas?
(a) $C_p=RC_v$ (b) $C_v=RC_p$ (c) $C_p + C_v = R$ (d) $C_p-C_v=R$

3. Consider the following diagram for a reaction C → D.



(a) Exothermic (b) Endothermic (c) At Equilibrium (d) None of these

4. The work done when three moles of an ideal gas undergo spontaneous expansion from 2 L to 5 L into a vacuum will be,
(a) 5 Joules (b) zero (c) -6 Joules (d) 9 Joule

5. $N_2 + 3H_2 \rightarrow 2NH_3$; $\Delta_rH^\circ = -94.4$ kJ mol^{-1}. The standard enthalpy of formation of NH_3 gas using the given reaction will be:
(a) -94.4 J mol^{-1} (b) -47.2 kJ mol^{-1} (c) 47.2 kJ mol^{-1} (d) 94.4 J mol^{-1}

6. The lattice energy and enthalpy of the solution of NaCl are 788 kJ mol^{-1} and 4 kJ mol^{-1} , respectively. Calculate the hydration enthalpy of NaCl.
(a) –784 kJ mol^{-1} (b) 784 kJ mol^{-1} (c) -792 kJ mol^{-1} (d) 792 kJ mol^{-1}

7. The entropy change (ΔS) associated with the fusion of one mole of a solid at its melting point of 27°C will be: (Given: Enthalpy of fusion is 2930 J mol^{-1})
(a) 9.77 $JK^{-1}mol^{-1}$ (b) 19.73 $JK^{-1}mol^{-1}$ (c) 2930 $JK^{-1}mol^{-1}$ (d) 108.5 $JK^{-1}mol^{-1}$

8. Match the terms in List I with their corresponding descriptions in List II:

List I	**List II**
A. Adiabatic process	I. At constant temperature
B. Isolated system	II. No transfer of heat
C. Isothermal change	III. Heat
D. Path function	IV. No exchange of energy and matter

(a) A-II, B-III, C-I, D-IV (b) A-II, B-IV, C-II, D-III
(c) A-IV, B-I, C-II, D-III (d) A-IV, B-III, C-II, D-I

9. Predict which of the following reactions has a negative entropy change:
I: $NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$
II: Temperature of a crystalline solid is raised from 0 K to 115 K.
(a). Only (II) (b). Only (I)(c). (I) and (II) (d). None above of these

10. What are the signs of ΔH and ΔS for a reaction that is spontaneous only at low temperatures?
(a) ΔH is positive, ΔS is positive. (b) ΔH is positive, ΔS is negative.
(c) ΔH is negative, ΔS is negative. (d) ΔH is negative, ΔS is positive.

ASSERTION REASON TYPE QUESTIONS(1MARKS)

These questions are based on Assertion-Reason and write the correct option from the following four options given:
(a) Both A and R are correct and R is the correct explanation of A.
(b) Both A and R are correct but R is not the correct explanation of A.
(c) A is correct and R is not correct.
(d) A is not correct but R is correct
11. **Assertion (A):**Variables like P, V, and T are called state functions.
Reason(R): Their values depend solely on the system's state, not its path.
12. Assertion(A): Absolute values of the internal energy of substances cannot be determined.
Reason(R): It is impossible to determine the exact values of constituent energies of the substances.
13. Assertion(A): A reaction with negative enthalpy change (ΔH < 0) and negative entropy change (ΔS < 0) is always spontaneous.
Reason(R): At high temperatures, the value of TΔS becomes large enough to make ΔG negative, even if ΔH is positive.
14. Assertion(A): During an adiabatic process, heat energy is not exchanged between the system and its surroundings.
Reason(R): The temperature of a gas increases when it undergoes an adiabatic expansion
15. Assertion (A): The bomb calorimeter is used to measure the energy change of a reaction at constant pressure.
Reason(R): In bomb calorimeter, the heat from the reaction is absorbed by the surrounding water, causing a temperature change.

Answer key-

Question no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	(b)	(d)	(a)	(b)	(b)	(a)	(d)	(b)	(b)	(c)	(a)	(a)	(d)	(c)	(d)

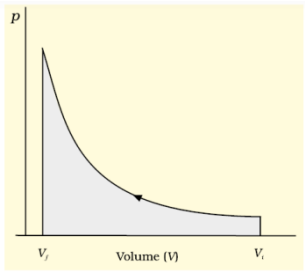
SECTION- B (2MARKS)

1. Consider the reaction given below,
$OF_2 + H_2O \rightarrow O_2 + 2HF$
Calculate the ΔH (enthalpy change) for the reaction
(Given the bond energies of O−F, O−H, H−F and O=O as 44, 111, 135, and 119 kcal mol^{-1}, respectively)
(Hint: -79 kcal)
2. An ideal gas is allowed to expand form 1 L to 10 L against a constant external pressure of 1 bar. Calculate the work done in Joule.
(Hint: -900 J)
3. Derive the relationship between ΔH and ΔU for an ideal gas.
4. State the third law of thermodynamic.
5. What is meant by enthalpy of atomization and enthalpy of dilution?
6. Enthalpies of formation of CO(g), CO2 (g), N2 O(g) and N2 O4 (g) are –110, – 393, 81 and

9.7 kJ mol–1 respectively. Find the value of ΔrH for the reaction:

(Hint: $\Delta_r H$ = (sum of enthalpies of products) – (sum of enthalpies of reactants)

SECTION –C (3 MARKS)

1. (a) 

Refer to the two P–V graphs in the image:

(i) Does this graph illustrate a reversible process or an irreversible process?

(ii) What does the area under the curve represent?

(b) Change in internal energy is a state function while work is not, why?

2. The standard enthalpy and standard entropy change for the oxidation of NH_3 at 298 K, are -220 kJ mol^{-1} and -150 J Mol^{-1} K^{-1} respectively. Calculate the standard Gibbs energy change for the same reaction at 300 K and also tell reaction is spontaneous or not.

(Hint: Use formula $\Delta G = \Delta H - T\Delta S$; Answer: 175.3 kJ

3. For the reaction at 25 ^oC

$NH_3(g) \rightarrow \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$; ΔH^o = 11.04 kcal

Calculate the value of $\Delta U^o$of the reaction at the given temperature.

(Hint: Use formula $\Delta H = \Delta U + \Delta n_g RT$; Answer: 10.44 kcal)

4. (a) Explain why the standard molar enthalpy of formation of $Cl_2(g)$ is zero at 298 K, while that of $H_2O(g)$ is not.

(Hint: Elements in their most stable (standard) states has zero standard molar enthalpy 1of formation)

(b) State the First Law of Thermodynamics and provide its mathematical expression.

5. (a) Calculate the number of kJ of heat necessary to raise the temperature of 60.0 g of aluminium from 35°C to 55°C. Molar heat capacity of Al is 24 J mol^{-1} K^{-1}. S

(Hint: Use formula, q = c × **m** × ΔT; Answer: 1.07 kJ)

SECTION – D CASE BASED QUESTIONS (4 MARKS)

1. Read the following passages and answer the questions that follow:

Most chemical reactions occur in open or closed systems, not isolated ones. In such conditions, the **total entropy change** ΔS_{total}helps determine spontaneity, but **enthalpy (ΔH)** also plays a significant role. To combine both entropy and enthalpy considerations, a thermodynamic quantity known as **Gibbs free energy (G)** is defined as: **G = H – TS**. For a process at constant temperature, the change in Gibbs free energy is: **ΔG = ΔH – TΔS.**

This equation helps predict spontaneity: If **ΔG < 0**, the process is **spontaneous**. If **ΔG > 0**, the process is **non-spontaneous**. If **ΔG = 0**, the system is at **equilibrium.**

(i) A reaction has ΔH = +30 kJ/mol and ΔS = +100 J/mol·K. At what minimum temperature will the reaction become spontaneous?

(a) 100 K (b) 200 K (c) 300 K (d) 400 K

(Hint: Use formula **ΔG = ΔH – TΔS by taking ΔG value zero. Answer:** 400 K)

(ii) State the conditions for the change in internal energy (ΔU) and total entropy change (ΔS_{total}) during an irreversible isothermal expansion of an ideal gas.

(iii) Two reactions have the same ΔH, but one is spontaneous while the other is not. Explain how entropy change and temperature influence this behavior.
(Hint: For spontaneous reaction **TΔS > ΔH)**

2. Read the following passages and answer the questions that follow:

In thermodynamics, the change in internal energy (ΔU) and enthalpy (ΔH) are essential concepts for understanding heat flow during chemical reactions. When a reaction occurs at constant volume, the heat absorbed or evolved is equal to the change in internal energy ($\Delta U = q_v$). However, most chemical reactions occur at constant pressure, where the heat absorbed is equal to the enthalpy change ($\Delta H = q_p$). For an ideal gas, the relationship between ΔH and ΔU is given by the equation:

$\Delta H = \Delta U + \Delta n_g RT$; where Δn_g is the change in number of moles of gaseous products and reactants, **R** is the gas constant, and **T** is the temperature in Kelvin.

(i) The maximum value of (ΔH−ΔU) at 27°C among the following reactions is:

(a) $H_2(g)+Cl_2(g)\longrightarrow 2HCl(g)$ (b) $PCl_5(g)\longrightarrow PCl_3(g)+Cl_2(g)$

(c) $N_2O_4(g)\longrightarrow 2NO_2(g)$ (d) $NH_4HS(s)\longrightarrow NH_3(g)+H_2S(g)$

(Hint: Calculate the value of $\Delta n_g RT$; Answer: (d))

(ii) Chemical reactions in industries are often carried out at constant pressure. In such conditions, explain why enthalpy (ΔH) is preferred over internal energy (ΔU) to measure heat changes in reactions.

(iii) A system undergoes a change where ΔU = 1000 J and it expands against a constant external pressure, doing 300 J of work. Calculate the change in enthalpy (ΔH)?

SECTION –E (5 MARKS)

1. (a) Use the information in the table to calculate the enthalpy of this reaction

$C_2H_6(g) + \frac{7}{2}O_2(g)\rightarrow 2CO_2(g) + 3H_2O(l)$

Reactions	ΔH_f^o kJ / mol
$2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$	-84.7
$C(s) + O_2(g) \rightarrow CO_2(g)$	-393.5
$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$	-285.8

(Hint: Use Hess Law; Answer: -

(b) Will the heat released in the following two reactions be equal? Give reasons in support of your answer.

$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(g)$

$H_2(g) + \frac{1}{2} O_2(g)\rightarrow H_2O(l)$

(Hint: The heat released in a reaction depends on the reactants, products and the physical states.)

2. (a)**14 g of N_2 gas is expanded reversibly and isothermally at a constant temperature of 300 K from 5 dm^3 to 25 dm^3. Calculate the values of ΔU, ΔH, w, and** q.

(Hint: $w = -2.303nRT\log\frac{V_f}{V_i}$, and ΔU = q + w; Answer: w = −2006.9 J)

(b) Given that the equilibrium constant (K) for a reaction is 20 at a certain temperature, calculate the standard Gibbs free energy change (ΔG°) for the reaction.

(Given: R = 8.314J.$K^{-1}$$mol^{-1}$ and T = 300K)

(Hint: Use Formula: $\Delta G° = -2.303RT\log K$; Answer: -7.47 kJ/mol)

UNIT 6 :EQUILIBRIUM (7 Marks)

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, hydrolysis of salts (elementary idea), buffer solution, Henderson Equation, solubility product, common ion effect (with illustrative examples).

Equilibrium is the state of a reversible process where the forward and backward reactions occur at the same rate.

Rate of Forward Reaction = Rate of backward reaction

At equilibrium there is no change in concentration, temperature, pressure or observable and measurable properties of reactants and products.

Type of Equilibrium –

A. **Equilibrium involve in Physical process.**

Process	**Conclusion**
Liquid ⇌Vapour H_2O (l) ⇌H_2O (g)	p_{H2O} constant at given temperature
Solid⇌Liquid H_2O (s) ⇌ H_2O (l)	Melting point is fixed at constant pressure
Solute(s) ⇌Solute (solution) Sugar(s) ⇌ Sugar (solution)	Concentration of solute in solution is constantat a given temperature
Gas(g) ⇌Gas (aq) CO_2(g) ⇌CO_2(aq)	[gas(aq)]/[gas(g)] is constant at a given temperature [CO_2(aq)]/[CO_2(g)] is constant at a given temperature

General Characteristics of Equilibria Involving Physical Processes-

(i) Equilibrium is possible only in a closed system at a given temperature.

(ii) Both the opposing processes occur at the same rate and there is a dynamic but stable condition.

(iii) All measurable properties of the system remain constant.

(iv)When equilibrium is attained for a physical process, it is characterized by constant value of one of its parameters at a given temperature.

(v) The magnitude of such quantities at any stage indicates the extent to which the physical process has proceeded before reaching equilibrium.

B. .**Equilibrium in Chemical Processes -Equilibrium involve in Chemical process.**

1. $H_2(g)+I_2(g) \rightleftharpoons 2HI(g)$

2. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

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

Characteristics of Equilibria Involving Chemical Processes-

(i) The concentration of each of the reactants and the products becomes constant at equilibrium.

(ii) The rate of forward reaction becomes equal to the rate of backward reaction at equilibrium and hence equilibrium is dynamic in nature.

(iii) None of the products is allowed to escape out or separate out as a solid then only chemical equilibrium can be established.

Law of Mass Action - Proposed by Guldberg and Waage so also known as Guldberg - Waage Law it state that:- ***The rate of a chemical reaction is directly proportional to the product of the active masses (concentrations) of the reactants, each raised to the power of their stoichiometric coefficients in the balanced chemical equation***.

Consider a reaction where aA + bB → cC + dD, Where a, b, c, and d are stoichiometric coefficients and A, B, C, and D are the reactants and products. According to the law of mass action.

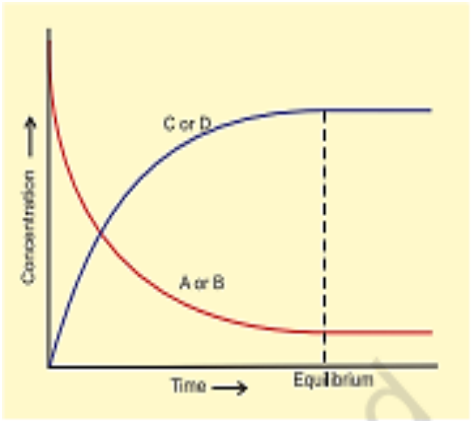
Rate of reaction = $k[A]^a[B]^b$, where k is the rate constant.

Law of Chemical Equilibrium –

At a constant temperature, the rate of a chemical reaction is directly proportional to the product of the molar concentrations of the reactants each raised to a power equal to the corresponding stoichiometric coefficients as represented by the balanced chemical equation. Let us consider the reaction, aA + bB ⇌ cC + dD

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

Where [A], [B], [C], [D] are equilibrium concentrations.



Where K_C is the Equilibrium Constant

- The value of K_c at a particular temperature is constant for a given reaction.
- If $K_c > 1$, products are favoured at equilibrium.
- If $K_c < 1$, reactants are favoured at equilibrium.
- If $K_c = 1$, reactants and products are present in comparable amounts.

Characteristics of Equilibrium Constant:

(i)The value of the equilibrium constant for a particular reaction is always constant depending only upon the temperature of the reaction and is independent of the concentrations of the reactants with which we start or the direction from which the equilibrium approached.

(ii) The value of equilibrium constant in inversed when the reaction is reversed.

(iii) The equilibrium constant for the new equation is square root of K. (i.e, K), when the equation is divided by 2.

(iii) The equilibrium constant for new equation is the square of K (i.e, 2 K), when the equation is multiplied by 2.

(iv) By the addition of catalyst to the reaction will not affect the value of the equilibrium.

Relations between Equilibrium Constants for a General Reaction and its Multiples

Chemical equation	Equilibrium constant
a A + b B ⇌ c C + d D	K_c
c C + d D ⇌ a A + b B	$K_c' = (1/K_c)$
na A + nb B ⇌ ncC + ndD	$K_c'' = (K_c^n)$

Difference between K_p and K_c-

K_p	K_c
This equilibrium constant is for the pressure ratio of products and reactants.	It is defined as the ratio of the concentrations of products and reactants.
This constant is only applicable to gaseous mixtures.	This constant can be applied to both gaseous and liquid reactions.
It is defined by pressure units.	It is defined by concentration units.

Homogeneous and Heterogeneous Equilibrium

Homogeneous Equilibrium: All reactants and products are in the same phase.

Example: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

Heterogeneous Equilibrium: Reactants and products are in different phases.

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

Relationship between equilibrium constants K_p and K_c

This relation between Kc and Kp can be defined using the equation:

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

K_p denotes the pressure equilibrium constant, Kc denotes the concentration equilibrium constant, R is the universal gas constant (8.314 Jmol-1K-1), T is the temperature, and n is the difference between total moles of gas products and total moles of gas reactants.

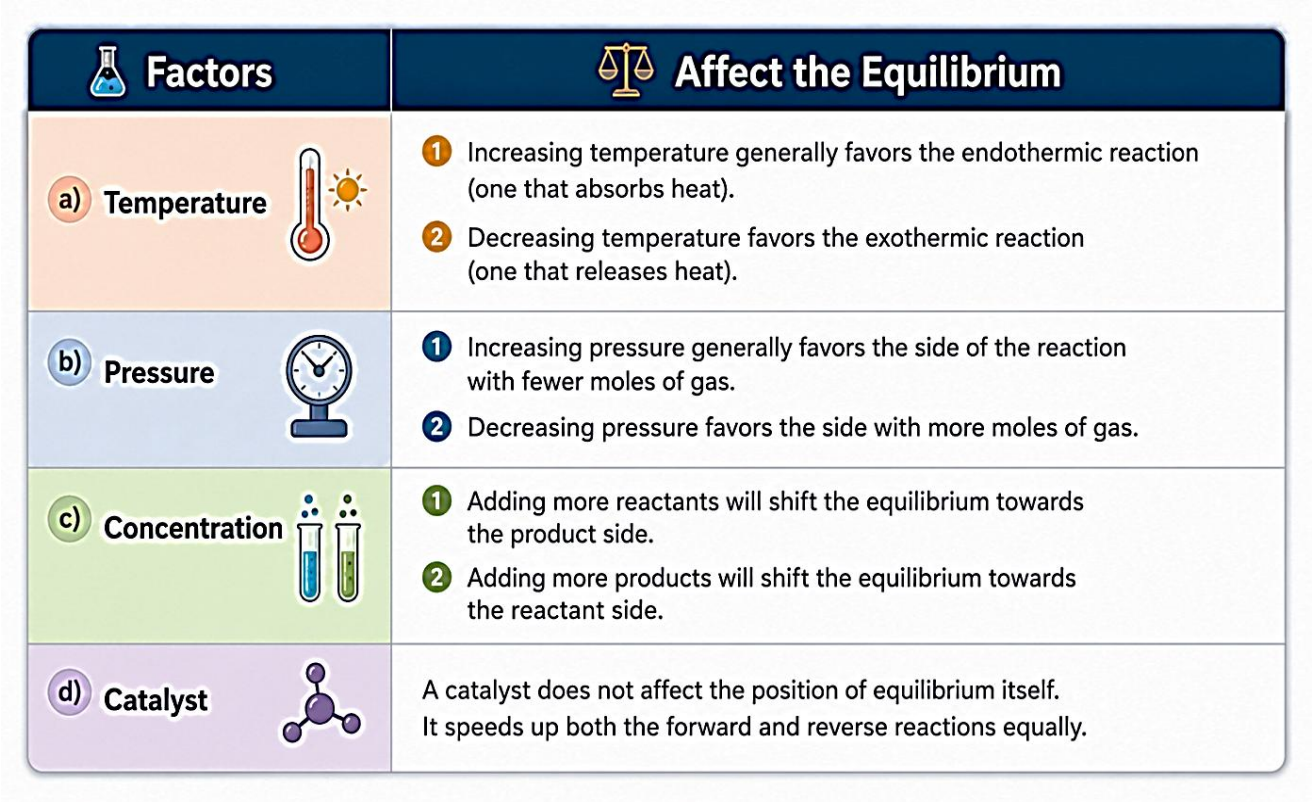
Predicting the direction of reaction in an equilibria:

$Q_c > K_c$	Backward
$Q_c < K_c$	Forward
$Q_c = K_c$	No change

Le Chatelier's principle.

It states that a change in any of the factors that determine the equilibrium conditions of a system will cause the system to change in such a manner so as to reduce or to counteract the effect of the change. This is applicable to all physical and chemical equilibria.

Factors That Affect Equilibrium

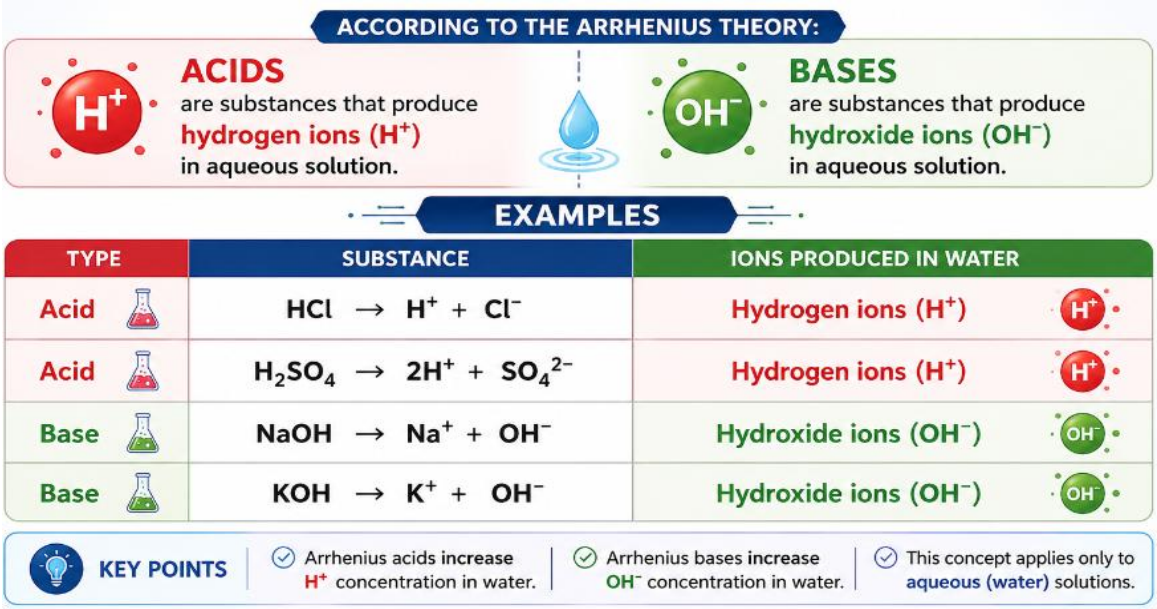


Ionic Equilibrium - An equilibrium involving ions is called ionic equilibrium. This equilibrium between unionized molecules and the ions is represented by 'reversible arrows'. For example:

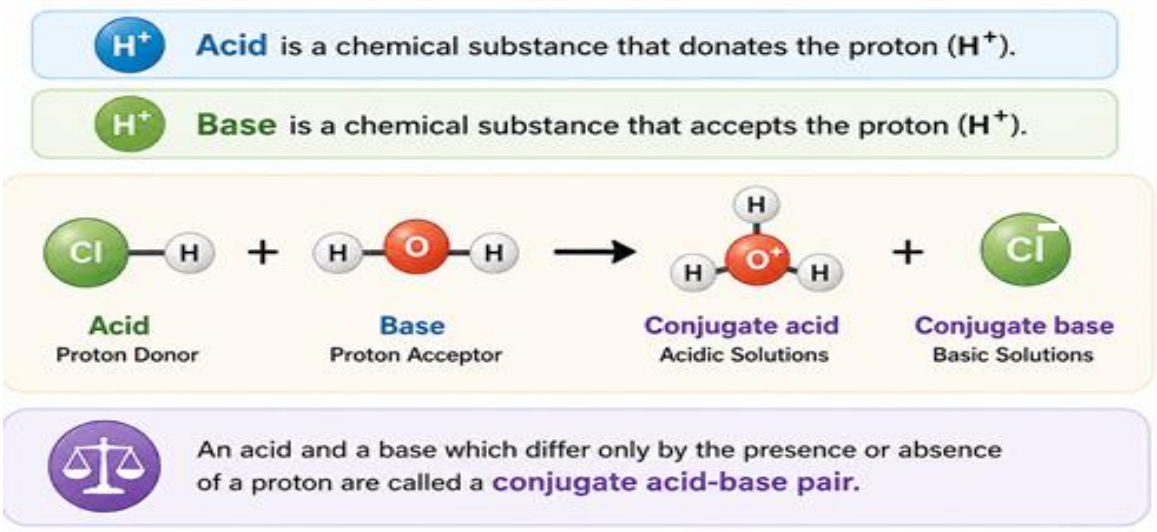
$CH_3COOH(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$

Acid Base theory -

Arrhenius Concept of Acids and Bases:

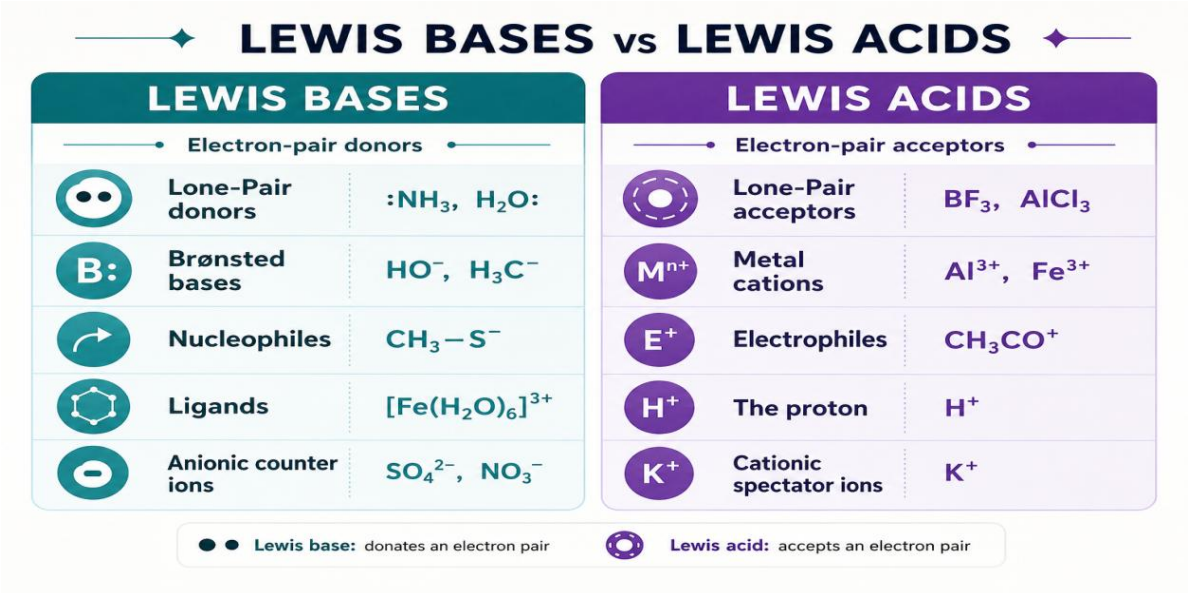


Bronsted Lowry Theory:



Lewis Theory: Lewis Acid is a species which accepts electron pair.

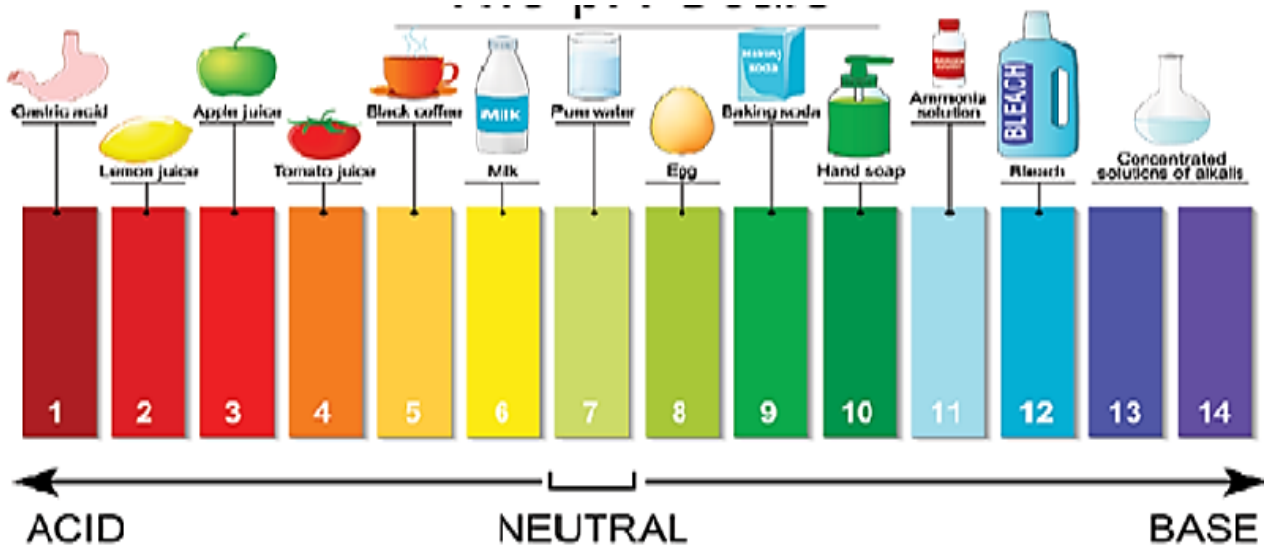
Lewis Base is a species which donates an electron pair.



pH and pH scale:

Hydronium ion concentration in molarity is more conveniently expressed on a logarithmic scale known as the pH scale. The pH of the solution is defined as the negative logarithm to base 10 of the activity of hydrogen ion.

pH= -log [H^+]



Acidic: $[H_3O^+] > 10^{-7}$, pH < 7

Neutral: $[H_3O^+] = 10^{-7}$, pH = 7

Basic: $[H_3O^+] < 10^{-7}$, pH > 7

This has been extended to other quantities;

p^{OH}= -log [OH^-] ,

pK_a= -log [K_a] ,

pK_b= -log [K_b] ,

pK_w= -log [K_w]

Ionization of water: Self ionization of water:-

$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

Acid base conjugate acid conjugate base

$Kw = [H_3O^+][OH^-] = (1 \times 10^{-7})^2 = 1 \times 10^{-14}$

For the ionization of water, $pH + pOH = pK_w$, equation is always satisfied.

Hydrolysis of Salts: Hydrolysis is the reaction of salt with water.

Types

1. Salt of strong acid + strong base ⇒ Neutral solution (No hydrolysis)
2. Salt of strong acid + weak base ⇒ Acidic solution
3. Salt of weak acid + strong base ⇒ Basic solution
4. Salt of weak acid + weak base ⇒ Acidic or basic (Depends on strengths)

Common ion effect-When a common ion is added to a solution containing a weak electrolyte in equilibrium with its ions, the equilibrium shifts to the left, favoring the undissociated form of the weak electrolyte.

$NH_4OH \rightleftharpoons NH_4^+ + OH^-$

$NH_4Cl \longrightarrow NH_4^+ + Cl^-$

Common ion

Buffer solution: The solutions which resist change in pH on dilution or with the addition of small amounts of acid or alkali are called Buffer Solutions.
Two types-Acidic buffer solution and Basic buffer solution

Some Examples of Buffer Composition

CH_3CO_2H / $CH_3CO_2^-$	NH_4Cl / NH_3
Acetate buffer	Ammonium buffer
HF / F^-	$H_2PO_4^-$ / HPO_4^{2-}
Fluoride buffer	Phosphate buffer

Solubility Product-It represents the product of the concentrations of the ions in a saturated solution, each raised to the power of its stoichiometric coefficient in the dissolution equation.It is denoted by $K_{sp.}$
For the dissolution of AgCl(s) into Ag+(aq) and Cl-(aq):

$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-_{(aq)}$

If the solubility (S) of AgCl is 's',
then $[Ag^+] = [Cl^-] = s$.
$Ksp = [Ag^+][Cl^-] = s \times s = s^2$
Therefore, **$S = \sqrt{Ksp}$** .

Difference between solubility and solubility product.

Solubility	Solubility Product
1.At a definite temperature solubility is defined as the concentration of a substance as solute in its saturated solution.	At a definite temperature solubility product of a sparingly soluble salt is define as the product of the molar concentration of its ions each raised to the power equal to the number of ions present in the balanced equation representing the dissociation of molecule of the salt or electrolyte.
2. Applicable to both organic and inorganic solute.	It is applicable in case of electrolyte only.
3.Its magnitude change due to common ion effect or complex formation.	At a given temperature it has a fixed magnitude and dose not affected by common ion effect.

CLASS XI CHEMISTRY (NCERT) – EQUILIBRIUM
FLOW CHART OF TOPICS

EQUILIBRIUM
A dynamic state in a reversible reaction in which the rate of the forward reaction is equal to the rate of the reverse reaction. (No net change in concentrations with time)

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

1. REVERSIBLE REACTIONS
- Forward and reverse reactions occur simultaneously
- Notations: $\rightleftharpoons$
- Examples (NCERT):

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

2. DYNAMIC NATURE OF EQUILIBRIUM
- At equilibrium: $\text{Rate}_{\text{forward}} = \text{Rate}_{\text{reverse}}$
- Occurs in closed system
- Macroscopic properties remain constant
- Equilibrium is dynamic, not static

3. LAW OF CHEMICAL EQUILIBRIUM
At a given temperature, the ratio of the product of equilibrium concentrations (of products) to the product of equilibrium concentrations (of reactants), each raised to their stoichiometric powers, is constant.

4. EQUILIBRIUM CONSTANT (K_c)
- For $aA + bB \rightleftharpoons cC + dD$

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

- Based on molar concentrations (in mol L^{-1})
- K_c is constant at a given temperature
- Does not depend on initial concentrations
- Pure solids and liquids are not included in K_c expression

5. EXPRESSION OF EQUILIBRIUM CONSTANT (K_c) FOR DIFFERENT CASES
- **Homogeneous equilibria** (all reactants and products in same phase)
- **Heterogeneous equilibria** (involving more than one phase)
- **Ionic equilibria in solutions**
- K_c written in terms of concentrations of species in the same phase
- K_c is dimensionless

6. RELATION BETWEEN K_c AND K_p
- For gaseous equilibria:

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

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

where, $\Delta n = (c + d) - (a + b)$

- R = gas constant, T = temperature (K)
- If $\Delta n = 0$, then $K_p = K_c$
- If only solids/liquids are involved, $K_p = K_c = 1$

7. FACTORS AFFECTING EQUILIBRIUM (LE CHATELIER'S PRINCIPLE)
If a system at equilibrium is subjected to a change, the equilibrium shifts in the direction that opposes the change.

1. **Change in Concentration**
   - Add reactant: shifts forward
   - Add product: shifts backward
   - Remove reactant: shifts backward
   - Remove product: shifts forward
2. **Change in Pressure / Volume** (Only for Gaseous Systems)
   - **Increase pressure** (decrease volume): shifts towards side with less number of moles of gas
   - **Decrease pressure** (increase volume): shifts towards side with more number of moles of gas
   - No effect if number of moles of gas are same
3. **Change in Temperature**
   - Increase temperature:
     - Favors endothermic direction
     - Opposes exothermic direction
   - Decrease temperature: opposite effect
4. **Catalyst**
   - Does not change position of equilibrium
   - Only helps in attaining equilibrium faster

8. IMPORTANT TERMS
- Equilibrium mixture / Equilibrium state
- Equilibrium constant (K_c, K_p)
- Dynamic equilibrium
- Homogeneous and Heterogeneous equilibrium
- Dissociation, Dimerisation, Association
- Degree of dissociation (α)
- Extent of reaction
- Surrogate reactions

9. APPLICATIONS OF EQUILIBRIUM
- In the formation of ammonia (Haber's process)

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

(High pressure, moderate temperature, Fe catalyst)

- In the Contact process for H_2SO_4

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(V_2O_5 catalyst)

- In the extraction of iodide from aqueous solutions

$$I_2(s) + I^-(aq) \rightleftharpoons I_3^-(aq)$$

- In the ions in solution (acid dissociation, base dissociation, solubility of sparingly soluble salts)

10. IONIC EQUILIBRIUM (ACIDS, BASES AND SALTS)
A. Acid–Base Equilibria
- Ostwald's dilution law for weak acids:

$$K_a = \frac{C\alpha^2}{1-\alpha}$$ (C = initial concentration, α = degree of dissociation)

- For weak bases:

$$K_b = \frac{C\alpha^2}{1-\alpha}$$

- $K_w = K_a \times K_b = 1.0 \times 10^{-14}$ (at 298 K)

B. Solubility Equilibria
- For sparingly soluble salt: $AB(s) \rightleftharpoons A^+(aq) + B^-(aq)$

$$K_{sp} = [A^+][B^-]$$

- Solubility product is constant at a given temperature
- Effect of common ion, pH, complex formation on solubility

C. Buffer Solutions
- Mixture of weak acid and its salt / weak base and its salt
- Resist change in pH on adding small amounts of acid/base
- Henderson – Hasselbalch equation:

For acidic buffer: $pH = pK_a + \log\frac{[salt]}{[acid]}$

For basic buffer: $pOH = pK_b + \log\frac{[salt]}{[base]}$

11. SOLVED NUMERICALS
- Calculation of K_c and K_p
- Relation between K_c and K_p
- Equilibrium concentrations using ICE table
- Effect of concentration, pressure, volume, temperature
- Degree of dissociation (α) and K_a, K_b calculations
- Solubility product (K_{sp}) problems
- pH of buffer solutions

HOW THE TOPICS ARE INTERLINKED
1. provides the foundation (reversible reactions) for 2 (dynamic nature) and leads to 3 (law).
2. explains the state described in 3.
3. gives the basis for 4, 5 and 6.
4. and 5 build the concept and application of equilibrium constant.
6. connects concentration-based and pressure-based equilibria.
7. uses Le Chatelier's principle to predict shifts in equilibrium.
8. defines essential terms used across all topics.
9. shows real-life applications of equilibrium principles.
10. applies equilibrium concepts to acids, bases and salts in solution.
11. Involves numerical application of all concepts.

KEY FORMULAE (QUICK RECALL)
- $K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$
- $K_p = K_c\,(RT)^{\Delta n}$
- Δn = (moles of gaseous products) – (moles of gaseous reactants)
- $K_a = \frac{C\alpha^2}{1-\alpha}$, $K_b = \frac{C\alpha^2}{1-\alpha}$
- $K_w = 1.0 \times 10^{-14}$ (at 298 K)
- $K_{sp} = [A^+][B^-]$

SYLLABUS COVERED (NCERT)
This flow chart covers all CBSE Class XI topics from the Equilibrium chapter.

(Reversible Reactions, Dynamic Equilibrium, Law of Chemical Equilibrium, Equilibrium Constant (K_c, K_p), Factors Affecting Equilibrium (Le Chatelier's Principle), Ionic Equilibrium – Acids, Bases and Salts, pH & Buffers, Applications and Numerical Problems)

LEGEND (FLOW INDICATION)
- Foundation / Introduction
- Builds / Explains
- Core Concept
- Supports / Related To
- Application / Outcome
- Leads To / Used In
- Interlinking

QUESTION BANK

SECTION - A (1 MARK EACH)

1- Le Chatelier's principle is applicable to:

(a) only homogeneous chemical reversible reactions

(b) only heterogeneous chemical reversible reactions

(c) only physical equilibria

(d) all systems, chemical or physical in equilibrium.

2-When NH_4Cl is added to NH_4OH solution the dissociation of ammonium hydroxide is reduced. It is due to:

(a) common ion effect (b) hydrolysis (c) oxidation (d) reduction

3- The pH of a solution of hydrochloric acid is 4.The molarity of the solution is:

(a) 4.0 (b) 0.4 (c) 0.0001 (d) 0.04

4- What does it indicate having a higher equilibrium constant?

(a) reaction occurs faster

(b) rate of backward reaction is faster

(c) both the backward and forward reactions are equal

(d) reaction may be slower than usual

5- The equilibrium constant of a reaction is 20 units and the equilibrium constant of other reaction is 30 units when both the reactions are added up together then the equilibrium constant of the resultant reaction is given by

(a) 20 units (b) 600 units (c) 50 units (d) 10 units

6- What is the equilibrium constant of the following reaction:

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

(a) $[NO][H_2O]/[NH_3][O_2]$ (b) $[C]^c[D]^d/[A]^a[B]^b$

(c) $[NO\}^4[H_2]^6/NH_3]4[O_2]^5$ (d) $[NO]^4[H_2O]^6/[NH_3]^4[O_2]^5$

7- Consider the following equilibrium in a closed container: **N_2O_4 (g) $2NO_2$ (g)**. At a fixed temperature, the volume of the reaction container is halved. For this change, which of the following statements hold true regarding the equilibrium constant (Kp) and degree of dissociation (α)?

(a) Neither Kp nor α changes (b) Both Kp and α change

(c) Kp changes but α does not change (d) Kp does not change but α changes.

8- We know that the relationship between Kc and Kp is $Kp = Kc\,(RT)^{\Delta n}$ What would be the value of Δn for the reaction $NH_4Cl\,(s) \Leftrightarrow NH_3\,(g) + HCl\,(g)$

(a) 1 (b) 0.5 (c)1.5 (d) 2

9- Acidity of BF_3 can be explained on the basis of which of the following concepts?

(a) Arrhenius concept (b) Bronsted Lowry concept

(c) Lewis concept (d) Bronsted Lowry as well as Lewis concept.

10- A reversible reaction, two substances are in equilibrium. If the concentration of each one is doubled the equilibrium constant will be

(a) Reduce to half its original value. (b) Reduced to one fourth of its original value.

(c) Doubled. (d) Constant.

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.

a) Both A and R are true and R is correct explanation of A.

b) Both A and R are true but R is not correct explanation of A.

c) A is true but R is false.

d) A is False but R is true.

11-Assertion: (A) For any chemical reaction at a particular temperature, the equilibrium constant is fixed and is a characteristic property.

Reason: (R) Equilibrium constant is independent of temperature.

12- Assertion: (A) :Kp can be less than, greater than or equal to Kc.

Reason: (R): Relation between Kp and Kc depends on the change in number of moles of gaseous reactants and products (Δn).

13- Assertion: (A) :The endothermic reactions are favoured at lower temperatures and the exothermic reactions are favoured at a higher temperature.

Reason: (R): when a system in equilibrium is disturbed by changing the temperature, it will tend to adjust itself so as to effect of change.

14- Assertion: (A) :If water is heated to 59°C, the pH will increase.

Reason: (R): K_w increases with an increase in temperature.

15.Assertion: (A) :Buffer system of carbonic acid and sodium bicarbonate is used for the precipitation of hydroxides of third group elements.

Reason: (R):It maintains the pH to a constant value, about 7.4.

ANSWERS KEY

Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ans	**d**	**a**	**c**	**c**	**B**	**d**	**d**	**d**	**c**	**d**	**c**	**a**	**d**	**d**	**d**

SECTION – B (2 MARKS)

1. Calculate the hydrogen ion concentration for the following biological fluids which have pH as given below.

(I) For Human saliva, 6.4 (II) For Human stomach fluid, 1.2

Answer Key-(I) For Human saliva, 6.4, pH = 6.4

6.4 = – log $[H^+]$,$[H^+]$ = 3.98 x 10-7

(II) For Human stomach fluid, 1.2, pH =1.2

1.2 = – log $[H^+]$, $[H^+]$ = 0.063

2. On the basis of the given equation pH= – log $[H^+]$, the pH of the given10^{-8}mol/dm^3 solution for HCI should be 8. But, it is observed as less than 7.0. Justify the reason.

Answer Key-The water concentration could not be neglected as the solution is very dilute.

From Acid $[H_3O^+] = 10^{-8} + 10^{-7}$ M, From Water $[H_3O+] = 10^{-8}$ (1 + 10) ,

Total = $[H_3O^+] = 11 \text{ X } 10^{-8}$ M

pH = – log $[H_3O^+]$

pH = – log $^{11} \text{ X } 10^{-8}$ M = pH = 6.96 (pH would be less than 7.0.)

3.For the following equilibrium, $K_c = 6.3 \times 10^{14}$ at 1000K .Both the forward and backward reactions in the equilibrium are elementary bimolecular reactions. What is Kc, for the backward reaction?

Answer Key- The value of equilibrium constant in inversed when the reaction is reversed.

4. What will be the effect on equilibrium when Δn is negative and pressure is decreased?

Answer Key – According to Le Chatelier's principle Reaction will shift in backward direction.

5.Find the K_c for the following reaction in state of equilibrium?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Given: $[SO_2] = 0.6$ M; $[O_2] = 0.82$ M; and $[SO_3] = 1.90$ M

SECTION- C (3 MARKS)

1.The sparingly soluble salt gets precipitated only if the product of the concentration of the ions in the given solution (Ksp) becomes greater than the solubility product. When the solubility of $BaSO_4$ in water is 8 × 10-4 mol dm^{-3}, calculate the solubility in
0.01 mol dm^{-3} of H_2SO_4.

Answer Key - Given that the standard solubility of $BaSO_4$ in water is 8×10^{-4} g/L
dissociation of $BaSO_4$ would be- $BaSO_4 \rightleftharpoons Ba^{2+} + SO_4^{2-}$
(S' is the solubility of the Ba^{2+} in 0.01 of HCl) ,S<<< 0.01, thus it could be neglected and We already know that $K_{sp} = S^2$
$Ksp = (8\times10\text{-}8)^2 = 64\times10^{-8}$ Then, Ksp= (S') (0.01)
S' = 64.8×10-8/0.01 = 6.4×10^{-5}
Thus, the solubility of $BaSO_4$ in the given 0.01 mol dm^{-3} of H_2SO_4 is 6.4×10^{-5}

2.What is meant by conjugate acid-base pair? Find the conjugate acid/base for the following species: HNO_2, CH^-, $HClO_4$, OH^-, CO_3^{2-}, S^{2-}

Answer key - An acid-base pair which differs by a proton only (HA———> A^- + H^+) is known as conjugate acid-base pair.

3.The compound BF_3 does not have a proton; however, it still acts as an acid and reacts with NH_3. Why is it so? What type of bond can be formed between the two?

4. What happens to the magnitude of the equilibrium constant if the forward response rate is doubled, given $K = k_f/k_r$? What happens if the reverse reaction rate for the total reaction is reduced by a factor of three?

Answer key: $K = k_f/k_r$,
$K' = 2(k_f/k_r) = 2K$.

5. How can you predict the following stages of a reaction by comparing the value of Kc and Qc?
(i) Net reaction proceeds in the forward direction.
(ii) Net reaction proceeds in the backward direction.
(iii)No net reaction occurs.

SECTION- D Case Study Based question (Four marks)

1.Reactants and products coexist at equilibrium, so that the conversion of reactant to products is always less than 100%. Equilibrium reaction may involve the decomposition of a covalent (nonpolar) reactant or ionization of ionic compound into their ions in polar solvents. Ostwald dilution law is the application of the law of mass action to the weak electrolytes in solution. A binary electrolyte AB which dissociates into A+ and B– ions i.e.

$$AB \rightleftharpoons A^+ + B^-$$

for every weak electrolyte, Since α <<1 (1 – α) = 1

$$K = C\,\alpha^2 \Rightarrow \alpha = \sqrt{\frac{K}{C}} \Rightarrow \alpha = \sqrt{KV}\,.$$

(i) A monobasic weak acid solution has a molarity of 0.005 M and pH of 5. What is its percentage ionization in this solution?

(a) 2.0 (b) 0.2 (c) 0.5 (d) 0.25

(ii) Calculate ionisation constant for pyridinium hydrogen chloride.

(Given that H+ ion concentration is 3.6×10^{-4} M and its concentration is 0.02 M.)

(a) 6.48×10^{-2} (b) 6×10^{-6} (c) 1.5×10^{-9} (d) 12×10^{-3}

(iii)The behaviour of weak electrolytes in aqueous solution has been studied by Ostwald. Give the law referring this behaviour.

Answer Key- (i) b (ii) c (iii) Ostwald's dilution law.

2 - According to Arrhenius theory, acids are substances that dissociate in water to give hydrogen ions H+ (aq) and bases are substances that produce hydroxyl ions OH– (aq). The ionization of an acid HX (aq) can be represented by the following equations:

HX (aq) → H+ (aq) + X – (aq)

or

$HX(aq) + H_2O(l) \rightarrow H_3O^+(aq) + X^-(aq)$

Similarly, a base molecule like MOH ionizes in aqueous solution according to the equation:

MOH(aq) → M+ (aq) + OH–(aq)

Bronsted acids are proton donors whereas Bronsted bases are proton acceptors. Acids on donating proton form conjugate bases whereas bases form conjugate acids after accepting proton. Buffer solution is a solution whose pH does not change. By adding small amount of H+ or OH-.The decrease in concentration of the ion by adding other ion as common ion is called common ion effect. Ksp (solubility product) is product of molar concentrations of ions raised to power no. of ions per formula of ions per formula of the compound in sparingly soluble salt.

Precipitation occurs only if ionic product exceeds solubility product. Solubility of salt decreases in presence of common ion. Kw the ionic product of water is $1x10^{-14}$ at 298 k. K_w increases with increase in temperature.

pH is $-\log[H_3O+]$

where $[H_3O+]=C\alpha$ in monoprotic acid, is molar conc., α is degree of ionisation.

(a) What will be the conjugate base of

(i) H_2SO_4 (ii) HCO_3^-?

(b) What will be the conjugate acid of

(i) NH_2^- (ii) NH_3

(c) The conc. of H_3O^+ is $4x\ 10^{-4}$. Find its pH.

(d) K_b for NH3 is1.80×10^{-5}, what will be Ka? [Kw is $1\ x10^{-14}$]

Answer key- (a) (i)HSO_4^- (ii) CO_3^{2-}

(b) (i)NH_3 ii) NH_4^+ (c) 3.398 d)$5.5x10^{-10}$

SECTION-E (5 MARKS)

1. A(i) The ratio of the product of molar concentration of products to the product of molar concentration of reactants at any stage of the reaction**?**

(ii) a mixture containing weak base and its salt with a strong acid is called and give its example**?**

B.Which of the following reactions will get affected by increase in pressure ? Also mention whether the change will cause the reaction to go to the right or left direction.

(i) $CH_4(g) + 2S_2(g) \rightleftharpoons CS_2(g) + 2H_2S(g)$

(ii) $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$

(iii) $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$

(iv) $C_2H_4(g) + H_2(g) \rightleftharpoons C_2H_6(g)$

(v) $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$

(vi) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

Answer key – A (i) reaction quotient.

(ii) Basic beffer e.g., $NH_4Cl + NH_4OH$

B. Only those reactions will be affected by increasing the pressure in which the number of moles of the gaseous reactants and products are different ($n_p \neq n_r$) (gaseous).

2(i)Describe a situation where you had to apply the Law of Mass Action to solve a problem in a laboratory or academic setting. What was the challenge, how did you apply the principle, and what was the outcome?

(ii) A solution of NH_4Cl in water shows pH less than 7.why?

(iii)What is the effect of increasing pressure in the given reactions? Give reasons.

(a)$PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$

(b)$N_2(g)+O_2(g) \rightarrow 2NO(g)$

(iv) Which of the following are lewis acids?

H_2O, BF_3, H^+, NH_4^+

Answer Key-(i) **Situation:** During a chemistry lab in my second year, we were tasked with determining the equilibrium constant (Kc) for the esterification of ethanoic acid with ethanol.

Task: The challenge was that the reaction didn't go to completion, and we needed to apply the Law of Mass Action to calculate Kc using the equilibrium concentrations.

Action: I prepared the solution, allowed the system to reach equilibrium, and used titration to determine the concentration of ethanoic acid remaining. Using initial concentrations and the changes during the reaction, I applied the Law of Mass Action.

Rate of reaction = $k[A]^a[B]^b$, where k is the rate constant

(ii) NH_4Cl is salt of weak base NH_4OH and strong acid HCl, therefore H^+ ions are more than OH^- ions thus, pH is less than 7.

(iii) (a)The equilibrium will shift in backward reaction because number of moles of products are more than reactants $\Delta n>0$.

(b)No effect because number of moles of reactants and products are equal, i.e., $\Delta n=0$.

(iv) BF_3, H^+

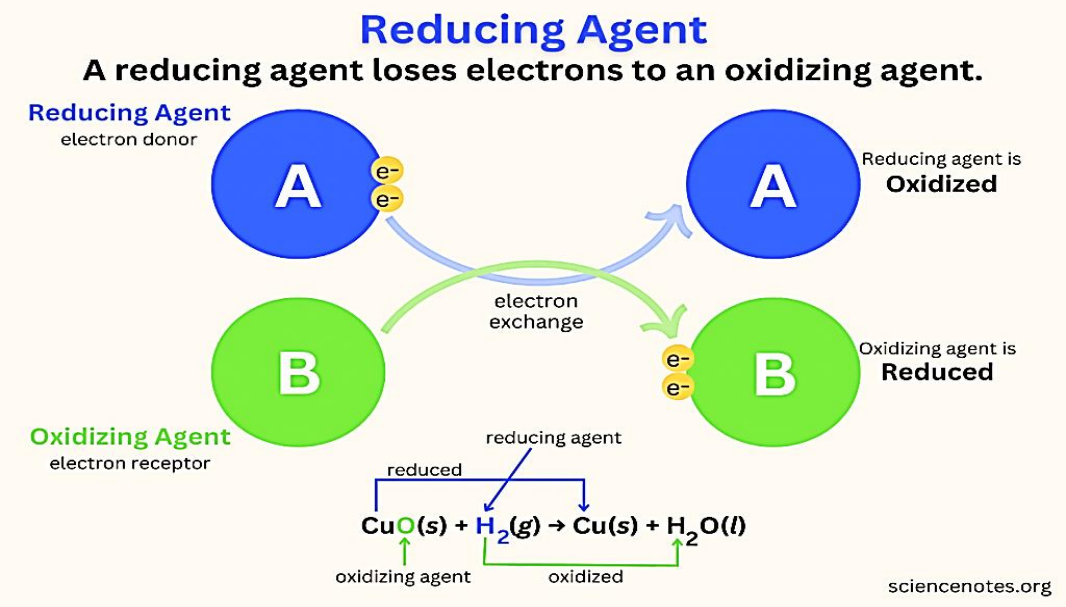
UNIT 7: Redox reactions (4 Marks)

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.

- **A redox reaction is a chemical reaction in which oxidation and reduction occur simultaneously.**

Oxidation	Reduction
• Addition of oxygen or an electronegative elements	• Removal of oxygen or an electronegative elements
• Removal of hydrogen or an electropositive elements	• Addition of hydrogen or an electropositive element
• Loss of electron(s) by any species.	• Gain of electron(s) by any species.

- Oxidising agent: A reagent which can increase the oxidation number of an element in a given substance. These reagents are also called as oxidants .
- Reducing agent: A reagent which lowers the oxidation number of an element in a given substance. These reagents are also called as reductants.



Mnemonics

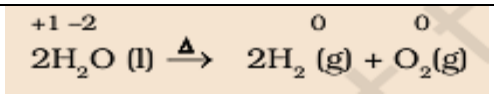
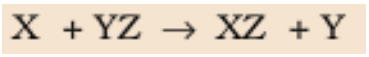
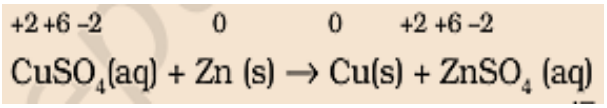
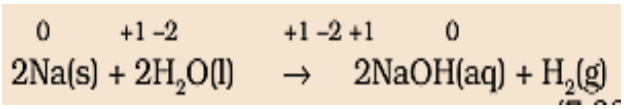
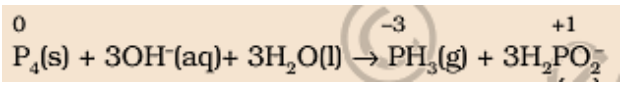
OIL RIG: Oxidation is loss of electrons; reduction is gain of electrons

LEO (the lion) says GER: Loss of electrons is oxidation; gain of electrons is reduction

LEORA says GEROA: This is similar to LEO says GER, except it includes reducing agent and oxidizing agent. The loss of electrons is oxidation (reducing agent), while the gain of electrons is reduction (oxidizing agent).

Types of Redox Reactions

Type	Example
Combination Reactions: Chemical reactions in which two or more substances (elements or compounds) combine to form a single substance	$\overset{0}{C}(s) + \overset{0}{O_2}(g) \xrightarrow{\Delta} \overset{+4\ -2}{CO_2}(g)$

Decomposition Reactions: Chemical reactions in which a compound break up into two or more simple substances	
Displacement Reactions: Reaction in which one ion(or atom) in a compound is replaced by an ion (or atom) of other element	
Metal Displacement Reactions: Reactions in which a metal in a compound is displaced by another metal in the uncombined state	
Non-metal Displacement Reactions: Such reactions are mainly hydrogen displacement or oxygen displacement reactions	
Disproportionation Reactions: Reactions in which an element in one oxidation state is simultaneously oxidized and reduced	

Stock Notation

Given by German chemist, Alfred Stock. In Stock notation, the oxidation state of a metal is written in Roman numerals inside brackets after the metal name or symbol.

Ex. $FeCl_3$ - Iron (III) chloride, PbO_2 - Lead (IV) oxide

Balancing of Redox Reactions

(a) Oxidation Number Method:	**(b) Half Reaction Method or Ion – electron method:**
(i) Write the skeletal redox reaction for all reactants and products of the reaction.	(i) Find the elements whose oxidation numbers are changed. Identify the substance that acts as an oxidizing agent and reducing agent.
(ii) Indicate the oxidation number of all the atoms in each compound above the symbol of element.	(ii) Separate the complete equation into oxidation half reaction and reduction half reaction.
(iii) Identify the element/elements which undergo change in oxidation numbers.	(iii) Balance the half equations by following steps.
(iv) Calculate the increase or decrease in oxidation number per atom.	(iv) Add the two balanced equations. Multiply one or both half equations by suitable numbers so that on adding two equations the electrons are balanced.
(v) Equate the increase in oxidation number with decrease in oxidation number on the reactant side by multiplying formula of oxidizing agent and reducing agents with suitable coefficients	(v)Balance all atoms other than H and O .
(vii) Finally balance hydrogen and oxygen. For balancing oxygen atoms add water molecules to the side deficient in it. Balancing of hydrogen atoms depend upon the medium .	(vii) Balance the half equation so that both sides get the same charge .
(viii) Finally balance the equation by cancelling common species present on both sides of the equation.	(viii) Add water molecules to complete the balancing of the equation.

Ex. Balance the following ionic equation

$Cr_2O_7^{2-}(aq) + SO_3^{2-}(aq) \rightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$ (acidic medium)

Method :1 Oxidation Number Method

The Given ionic equation is:

$Cr_2O_7^{2-}(aq) + SO_3^{2-}(aq) \rightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$

Step 1: Assign oxidation numbers for Cr and S

+6 –2 +4 –2 +3 +6-2

$Cr_2O_7^{2-}(aq) + SO_3^{2-}(aq) \rightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$

Step 2: Calculate the increase and decrease of oxidation number, and make them equal:

$Cr_2O_7^{2-}(aq) + 3SO_3^{2-}(aq) \longrightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$

STEP 3: Balance all atoms except H and O

$Cr_2O_7^{2-}(aq) + 3SO_3^{2-}(aq) \rightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq)$

Step 4: Balance the oxygen atom by adding water molecules

$Cr_2O_7^{2-}(aq) + 3SO_3^{2-}(aq) \longrightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + 4H_2O(l)$

Step 5: Balance the charge by adding H^+as the reaction occurs in the acidic medium,

$Cr_2O_7^{2-}(aq) + 3SO_3^{2-}(aq)\ 8H^+ \rightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + 4H_2O(l)$

METHOD: 2 Half Reaction Method(or) Ion Electron Method

In this method, the two half equations are balanced separately and then added together to give balanced equation.

Ex : Balance the following ionic equation

$MnO_4^-(aq) + I^-(aq) \longrightarrow MnO_2(s) + I_2(s)$ (basic medium)

Given ionic equation is:

$MnO_4^-(aq) + I^-(aq) \longrightarrow MnO_2(s) + I_2(s)$

Step 1: Write the two half-reactions:

Oxidation half reaction :

$-I \qquad\qquad 0$

$I^-_{(aq)} \longrightarrow I_2(s)$

Reduction half reaction :

$+7 \qquad\qquad +4$

$MnO_4^-(aq) \longrightarrow MnO_2(s)$

Step 2: To balance the I atoms in the oxidation half reaction, we rewrite it as:

$2I^-(aq) \longrightarrow I_2(s)$

Step 3: To balance the O atoms in the reduction half reaction, we add two water molecules on the right:

$MnO_4^-(aq) \longrightarrow MnO_2(s) + 2H_2O(l)$

Step 4:To balance the H atoms, we add four H^+ ions on the left:

$MnO_4^-(aq) + 4H^+(aq) \longrightarrow MnO_2(s) + 2H_2O(l)$

As the reaction takes place in a basic solution, therefore, for four H+ ions, we add four OH– ions to both sides of the equation:

$MnO_4(aq) + 4H^+(aq) + 4OH^-(aq) \longrightarrow MnO_2(s) + 2H_2O(l) + 4OH^-(aq)$

Replacing the H+ and OH– ions with water, the resultant equation is:

$$MnO_4\ (aq) + 2H_2O\ (l) \longrightarrow MnO_2\ (s) + 4\ OH^-\ (aq)$$

Step 5 : In this step we balance the charges of the two half-reactions by adding electrons in the manner depicted as:

$$2I^-\ (aq) \rightarrow I_2\ (s) + 2e^-$$

$$MnO_4^-(aq) + 2H_2O(l) + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$$

Now to equalise the number of electrons, we multiply the oxidation half-reaction by 3 and the reduction half-reaction by 2.

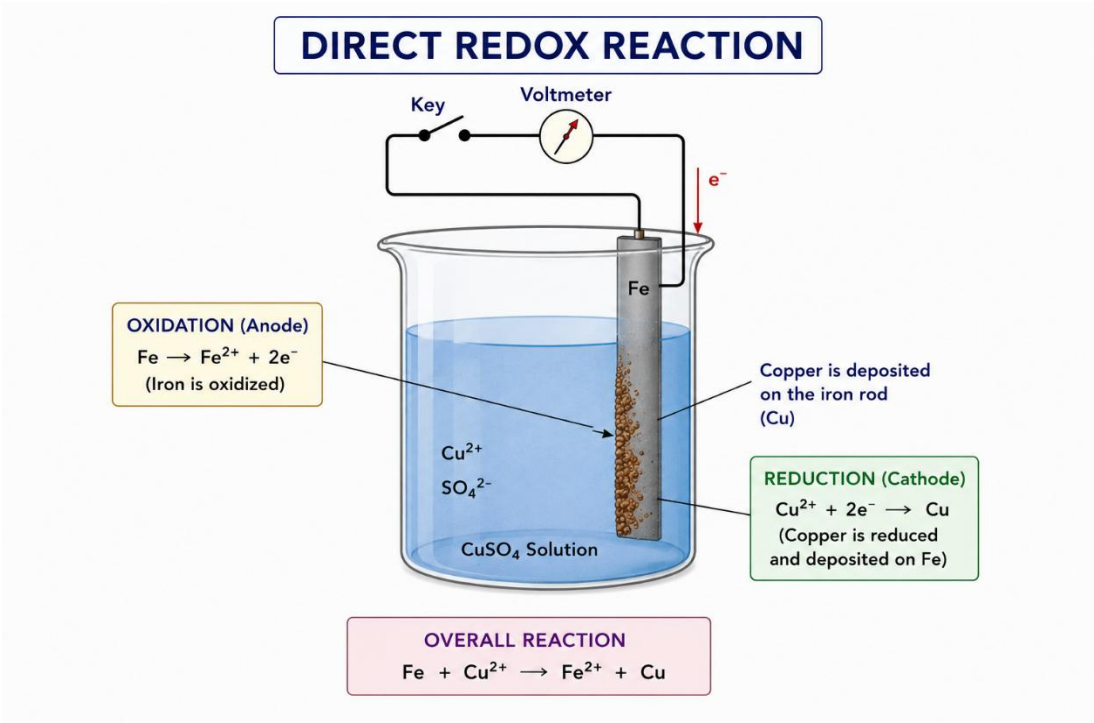
$$6I^-(aq) \longrightarrow 3I_2\ (s) + 6e^-$$

$$2\ MnO_4^-(aq) + 4H_2O\ (l) + 6e^- \longrightarrow 2MnO_2(s) + 8OH^-(aq)$$

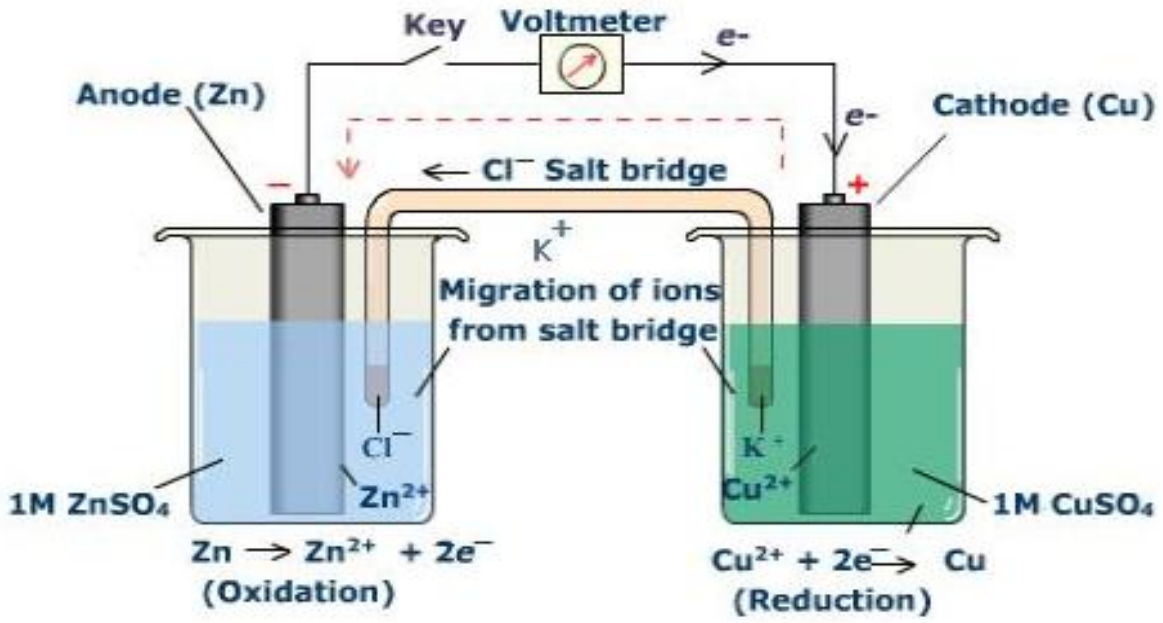
Step 6: Add two half-reactions to obtain the net reactions after cancelling electrons on both sides.

$$6I^-(aq) + 2MnO_4^-(aq) + 4H_2O(l) \longrightarrow 3I_2(s) + 2MnO_2(s) + 8\ OH^-(aq)$$

- **Electrochemical cell is a device that converts chemical energy produced in a redox reaction into electrical energy. These cells are also called Galvanic cells or Voltaic cells .**
- **Direct redox reaction: Redox reactions in which reduction and oxidation occurs in same solution (i.e. same reaction vessel). In these reactions transference of electrons is limited to very small distance.**



- **Indirect redox reactions: Redox reactions in which oxidation and reduction reactions take place in different reactions vessels and thus transfer of electrons from one species to another does not take place directly.**



Functions of salt bridge

1. The electrical circuit is completed with a salt bridge.

2. Salt bridge also maintains the electrical neutrality of the two half cells.

- **Electrode potential**: The potential difference between a metal electrode and its solution. It shows the tendency of an electrode to gain or lose electrons.
- **Oxidation potential**: Tendency of an electrode to lose electrons (oxidation).
- **Reduction potential**: Tendency of an electrode to gain electrons (reduction).
- In electrochemistry, electrode potentials are usually written as reduction potentials.
- An electrode with higher reduction potential has a greater tendency to gain electrons.
- ***The standard electrode potential of the hydrogen electrode is taken as 0.00 V.***
- **Redox couple**: The oxidized and reduced forms of a substance involved in a redox reaction.
- **EMF (Cell potential)**: Difference between the electrode potentials of two electrodes in a cell.

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

- Negative E° → stronger reducing agent than H^+/H_2.
- Positive E° → weaker reducing agent than H^+/H_2.

REDOX REACTIONS
FLOWCHART

1. WHAT ARE REDOX REACTIONS?
Reactions in which oxidation and reduction take place simultaneously are called Redox Reactions.

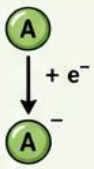
OXIDATION
- Addition of oxygen
- Removal of hydrogen
- Removal of electrons
- Increase in oxidation number

REDUCTION
- Addition of hydrogen
- Removal of oxygen
- Addition of electrons
- Decrease in oxidation number

2. CHANGES IN OXIDATION NUMBER
Increase in oxidation number ⟶ Oxidation
Decrease in oxidation number ⟶ Reduction

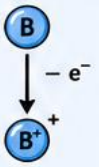
3. AGENTS INVOLVED IN REDOX REACTIONS

OXIDISING AGENT
- Accepts electrons
- Itself gets reduced
- Causes oxidation of other substance



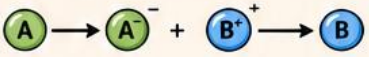
Example: $KMnO_4$, $K_2Cr_2O_7$, HNO_3, Cl_2, etc.

REDUCING AGENT
- Donates electrons
- Itself gets oxidised
- Causes reduction of other substance



Example: H_2, CO, H_2S, SO_2, Fe^{2+}, I^-, etc.

OXIDATION & REDUCTION ALWAYS OCCUR TOGETHER
One species is oxidised (loses e^-) while the other is reduced (gains e^-).



Oxidised Reduced

4. BALANCING REDOX REACTIONS

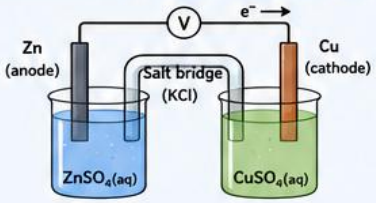
1. Assign oxidation numbers to all atoms.
2. Identify species oxidised and reduced.
3. Write oxidation and reduction half reactions.
4. Balance atoms other than H and O in each half reaction.
5. Balance H and O using H_2O, H^+ (acidic medium) or OH^- (basic medium).





5. TYPES OF REDOX REACTIONS
- Combination Reaction — $2Mg + O_2 \longrightarrow 2MgO$
- Decomposition Reaction — $2H_2O_2 \longrightarrow 2H_2O + O_2$
- Displacement Reaction — $Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$
- Disproportionation Reaction — $Cl_2 + 2OH^- \longrightarrow Cl^- + ClO^- + H_2O$

6. ELECTROCHEMICAL CELL



- Oxidation occurs at anode (negative electrode).
- Reduction occurs at cathode (positive electrode).
- Electrons flow from anode to cathode through external circuit.
- Salt bridge maintains electrical neutrality.

7. STANDARD REDUCTION POTENTIAL (E°)
- Measured under standard conditions: 1 M concentration, 1 bar pressure, 298 K temperature.
- Standard hydrogen electrode (SHE) is assigned E° = 0.00 V.
- More positive E° ⟶ greater tendency to get reduced.
- More negative E° ⟶ greater tendency to get oxidised.

STANDARD ELECTRODE POTENTIAL SERIES (Selected)

More negative E° (stronger reducing agents) ⟵ More positive E° (stronger oxidising agents)

E° (V)	−2.71	−0.76	−0.44	−0.13	0.00	+0.34	+0.80	+1.51
	Li^+/Li	Zn^{2+}/Zn	Fe^{2+}/Fe	Sn^{2+}/Sn	$2H^+/H_2$ (SHE)	Cu^{2+}/Cu	Ag^+/Ag	$F_2/2F^-$

8. STANDARD CELL POTENTIAL (E°_{cell})

$$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$$

If $E^\circ_{cell} > 0$ ⟶ Reaction is spontaneous.
If $E^\circ_{cell} < 0$ ⟶ Reaction is non-spontaneous.

Cathode (Reduction): Species with more positive E° value.

E°_{cell} = (+) − (−) = +ve

Spontaneous Reaction

Anode (Oxidation): Species with more negative E° value.

SECTION- A (1 mark each)

Q.1The oxidation number of Cr in $Cr(CO)_6$ is ————————

(a) 0 (b) +2 (c) -2 (d) +6

Q.2 Identify the reaction which is not a redox reaction?

(a) $2H_2 + O_2 \rightarrow 2H_2O$ (b) $CaCO_3 \rightarrow CaO + CO_2$

(c) $Na + H_2O \rightarrow NaOH + 1/2H_2$ (d) $MnCl_3 \rightarrow MnCl_2 + 1/2\ Cl_2$

Q.3 A standard hydrogen electrode has zero electrode potential because

(a) hydrogen is easiest to oxidize (b) the electrode potential is assumed to be zero

(c) hydrogen atom has only one electron (d) hydrogen is the lightest element

Q.4 How many electrons are transferred in the redox reaction:

$2MnO_4^- + 10I^- + 16H^+ \rightarrow 2Mn^{2+} + 5I_2 + 8H_2O$?

(a) 2 (b) 5 (c) 10 (d) 16

Q.5 "Which of the following rules used to determine the oxidation number of an element in a compound is incorrect?"

(a) The oxidation number of hydrogen is always +1.

(b) The algebraic sum of all the oxidation numbers in a compound is zero.

(c) An element in the free or the uncombine state bears oxidation number zero.

(d) In all its compounds, the oxidation number of fluorine is –1.

Q.6 The most powerful oxidising agent among the following is:

(a) H_2SO_4 (b) H_3BO_3 (c) HPO_3 (d) H_3PO_4

Q.7 Consider the following reaction:

$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

With reference to the above, which one of the following is the correct statement?

(a) Zn is reduced to Zn^{2+}ions (b) Zn is oxidised to Zn^{2+}ions

(c) Zn^{2+} ions are oxidised to Zn (d) Cu^{2+}ions are oxidized to Cu

Q.8 In the reaction:

$2Ag + 2H_2SO_4 \rightarrow Ag_2SO_4 + 2H_2O + SO_2$

Sulphuric acid acts as:

(a) Oxidising agent (b) Reducing agent

(c) Catalyst (d) Acid as well as oxidant

Q.9. The more positive the value of E°, the greater is the tendency of the species to get reduced. Using the standard electrode potential of redox couples given below find out which of the following is the strongest oxidising agent.

$E^{\ominus}$ values: $Fe^{3+}/Fe^{2+} = +0.77$; $I_2(s)/I^- = +0.54$;

$Cu^{2+}/Cu = +0.34$; $Ag^+/Ag = +0.80V$

(a) Fe^{+3} (b) $I_2(s)$ (c) Cu^{+2} (d) Ag^+

Q.10 Which of the following elements does not show disproportionation tendency?

(a) Br (b) F (c) Cl (d) I

Assertion-Reasoning

Given below are two statements labelled Assertion (A) and Reason (R)

Select the most appropriate answer from the options given below:

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

(c) Assertion is correct statement but reason is wrong statement.

(d) Assertion is wrong statement but reason is correct statement.

Q.11 Assertion: For every oxidation-reduction reaction oxidant and reductant must be different molecules or ions.
Reason: Oxidation and reduction always occur simultaneously.
Q.12 Assertion (A): $HgCl_2$ and $SnCl_2$ cannot stay together.
Reason (R): $HgCl_2$ is an oxidising agent but $SnCl_2$ is reducing agent.
Q.13 Assertion (A): Among halogens fluorine is the best oxidant.
Reason (R) : Fluorine is the most electronegative atom.
Q.14 Assertion(A): Zinc liberates hydrogen from a dilute solution of hydrochloric acid.
Reason(R): $E^0$of Zn is higher than that of H_2.
Q.15 Assertion: Elements with greater electron affinities are better oxidizing agents.
Reason: Oxidation is the gaining of electrons.

Answer Key:

Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10	Q.11	Q.12	Q.13	Q.14	Q.15
(a)	(b)	(d)	(c)	(a)	(a)	(b)	(d)	(d)	(b)	(d)	(a)	(b)	(c)	(c)

SECTION- B (2 marks each)

Q.1 MnO_4^{2-} undergoes a disproportionation reaction in an acidic medium but MnO_4^- does not. Give a reason.
(Hint: Oxidation number of Mn in MnO_4^{2-} is +6 and in MnO_4^- +7)
Q.2 "A student suggests storing copper sulphate solution in an iron container. Using your knowledge of metals and chemical reactions, explain whether this is appropriate or not."
(Hint: No, because Iron is more reactive than copper)
Q.3 "Using your understanding of redox reactions in an electrochemical cell, explain the direction in which electrons flow between the anode and cathode."
(Hint: Anode to cathode because electron density is more at anode due to loss of electron)
Q.4 Calculate the oxidation numbers of each sulphur atom in the following compounds:
(a) $Na_2S_2O_3$ (b) Na_2SO_4
(Hint: (a) +2 and (b) +6
Q.5 Show that F cannot undergo disproportionation reaction?
(Hint: F cannot show three different oxidation states)

SECTION –C (3 marks each)

Q.1 Depict the galvanic cell in which the reaction
$Zn_{(s)} + 2Ag^+_{(aq)}$ ----------> $Zn^{2+}_{(aq)} + 2Ag_{(s)}$ takes place. Further show :
(i) Which electrode is negatively charged.
(ii) The carriers of the current in the cell.
(iii) Individual reaction at each electrode.
(Hint : (i) Zn (ii) Ag to Zn electrode (iii) oxidation half reaction and reduction half reaction)
Q.2 Consider the elements: Cs, Ne, I and F
(a) Identify the element that exhibits only negative oxidation state.
(b) Identify the element that exhibits only positive oxidation state.
(c) Identify the element that exhibits both positive and negative oxidation states.
(d) Identify the element which exhibits neither the negative nor does the positive oxidation state.
(Hint :a –F b - Cs c- I d-Ne)
Q.3 Write the balanced chemical equation corresponding to the reaction. (In acidic medium)

$Cr_2O_7^{2-}{}_{(aq)} + Fe^{2+}{}_{(aq)} \rightarrow Cr^{3+}{}_{(aq)} + Fe^{3+}{}_{(aq)}$
(Hint : Balance the equation by following the steps)
Q.4 Balance the equation
$MnO_4^- + I^- \rightarrow Mn^{2+} + I_2 + H_2O$ by ion electron method in acidic medium
(Hint : Balance the equation by following the steps)
Q.5 "Why is a salt bridge used in an electrochemical cell? Explain its role and significance."
(Hint : To complete the circuitand to maintain the electrical neutrality of the solutions in the two half cells.)
Q6. Copper forms two oxides: Cu_2O and CuO. A student named them Copper oxide and Copper oxide respectively, which created confusion in the laboratory.
Answer the following questions:
(a) Write the Stock notation names of Cu_2O and CuO.
(b) What is the oxidation state of copper in each compound?
(c) Why is Stock notation important for transition metals?
(Hint: In Cu_2O: +1, in In CuO: +2)

SECTION – D CASE STUDY BASED QUESTIONS (4 MARKS)

Q.1 The idea of oxidation number has been invariably applied to define oxidation, reduction, oxidising agent (oxidant), reducing agent (reductant) and the redox reaction. To summarise, we may say that:
Oxidation: An increase in the oxidation number of the element in the given substance.
Reduction: A decrease in the oxidation number of the element in the given substance.
Oxidising agent: A reagent which can increase the oxidation number of an element in a given substance. These reagents are called as oxidants also.
Reducing agent: A reagent which lowers the oxidation number of an element in a given substance. These reagents are also called as reductants.
Redox reactions: Reactions which involve change in oxidation number of the interacting species.
1) In … an ion (or an atom) in a compound is replaced by an ion (or an atom) of another element.
(a) displacement reaction (b) decomposition reaction
(c) disproportionation reaction (d) combination reaction
2) … leads to the breakdown of a compound into two or more components at least one of which must be in the elemental state.
(a) displacement reaction (b) decomposition reaction
(c) disproportionation reaction (d) combination reaction
3) In …. an element in one oxidation state is simultaneously oxidised and reduced.
(a) displacement reaction (b) decomposition reaction
(c) disproportionation reaction (d) combination reaction
4) Reactions which involve change in oxidation number of the interacting species…
(a) Exothermic reaction (b) Endothermic reaction
(c) Neutralization reaction (d) Redox reaction
(Hint: (1) (a) , (2) (b) , (3) (c) , (4) (d))

Q.2Jiya conducted an experiment to study redox reactions. She placed a clean iron nail into a beaker containing blue copper(II) sulfate solution. After a few minutes, she noticed a reddish-brown coating forming on the nail and the blue color of the solution fading gradually. Curious, she decided to analyze the changes using her understanding of redox chemistry.

(a) Identify the type of chemical reaction occurred between iron and copper(II) sulfate?
(b) Identify which species is oxidized and which is reduced in this reaction.
(c) Write the balanced chemical equation for the reaction.
(d) Predict and justify what will happen if a copper strip is placed in iron(II) sulfate solution instead.
(Hint: (a) redox reaction and also a displacement reaction.

(b) Iron (Fe) is oxidized and Copper ions (Cu^{2+}) are reduced:

(c) $Fe_{(s)} + CuSO_{4\,(aq)} \rightarrow FeSO_{4\,(aq)} + Cu_{(s)}$

(d) Copper is less reactive than iron and cannot displace iron from iron(II) sulfate solution. Therefore, no reaction occurs when a copper strip is placed in $FeSO_4$)

SECTION – E (5 marks each)

Q.1 Identify the redox reactions out of the following reactions and identify the oxidising and reducing agents in them.

(i) $3\,HCl_{(aq)} + HNO_{3(aq)} \rightarrow Cl_{2(g)} + NOCl_{(g)} + 2H_2O_{(l)}$

(ii) $HgCl_{2(aq)} + 2KI_{(aq)} \rightarrow HgI_{2(s)} + 2KCl_{(aq)}$

(iii) $Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$

(iv) $PCl_{3(l)} + 3H_2O_{(l)} \rightarrow 3HCl(aq) + H_3PO_{4\,(aq)}$

(v) $4NH_3 + 3O_{2(g)} \rightarrow 2N_{2(g)} + 6H_2O_{(g)}$

(Hint: (i) HNO_3 (O.A.), HCl (R.A.),(ii)Not a redox reaction

(iii) Fe_2O_3(O.A.), CO(R.A.), (iv) not a redox reaction (v) O_2 (O.A.) ,NH_3(R.A.))

Q.2 (a)Why are redox reactions important in everyday life and industrial processes?

(b)On the basis of standard electrode potential values, suggest which of the following reactions would take place? (Consult the book for E^0 value).

(i) $Cu_{(s)} + Zn^{2+}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + Zn_{(s)}$

(ii) $Mg_{(s)} + Fe^{2+}_{(aq)} \longrightarrow Fe_{(s)} + Mg^{2+}_{(aq)}$

(iii) $Cd_{(s)} + Fe^{2+}_{(aq)} \longrightarrow Fe(s) + Cd^{2+}_{(aq)}$

(Hint: (a) In electrochemistry , (b) (i) and (iii) reaction is not feasible , (ii) is feasible)

****

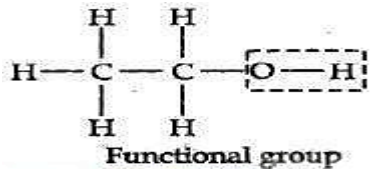
UNIT-8.ORGANIC CHEMISTRY-SOME BASIC PRINCIPLES AND TECHNIQUES (11 Marks)

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

Organic Chemistry

Organic chemistry is the branch of chemistry that deals with the study of hydrocarbons and their derivatives.

- **The Shapes of Carbon Compounds:** In organic or carbon compounds, s and p orbitals are involved in hybridisation. This leads to three types of hybridisation which are sp^3(in alkanes) – Tetrahedral in shape sp^2(in alkenes) – Planar structure sp(in alkynes) – Linear molecule
- **Functional Group:** The functional group are atom or group of atoms joined in a specific manner which determines the chemical properties of the organic compound. The examples are hydroxyl group (—OH), aldehyde group (—CHO) and carboxylic acid group (—COOH) etc.



Functional group

Homologous Series - A homologous series may be defined as a family of organic compounds having the same functional group, similar chemical properties and the successive members differ from each other in molecular formula by —CH_2 units.

The members of a homologous series can be represented by same general molecular for.

- **IUPAC (International Union of Pure and Applied Chemistry) -**

According to IUPAC system, the name of an organic compound contains three parts: (i) word root, (ii) suffix, (iii) prefix.

(i) Word root: Word root represents the number of carbon atoms present in the principal chain, which is the longest possible chain of carbon atoms.

For special word roots for

meth —— C_1
eth —— C_2
Prop —— C_3
but —— C_4

(ii) Suffix: Suffix are of two types, primary suffix, secondary suffix.

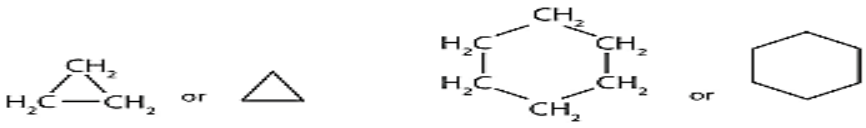
(a) Primary Suffix: It indicates the type of bond in the carbon atoms.

For example: Primary suffix ane for C–C bond
ene for C=C bond
yne for C≡C bond

(b) Secondary Suffix: Secondary suffix is used to represent the functional group.

(iii) Prefix: Prefix is a part of IUPAC name which appears before the word root. Prefix are of two types:

(a) Primary prefix: For example, primary prefix cyclo is used to differentiate cyclic compounds.



cyclopropane cyclohexane

(b) Secondary prefix: Some functional groups are considered as substituents and denoted by secondary prefixes.

For example:

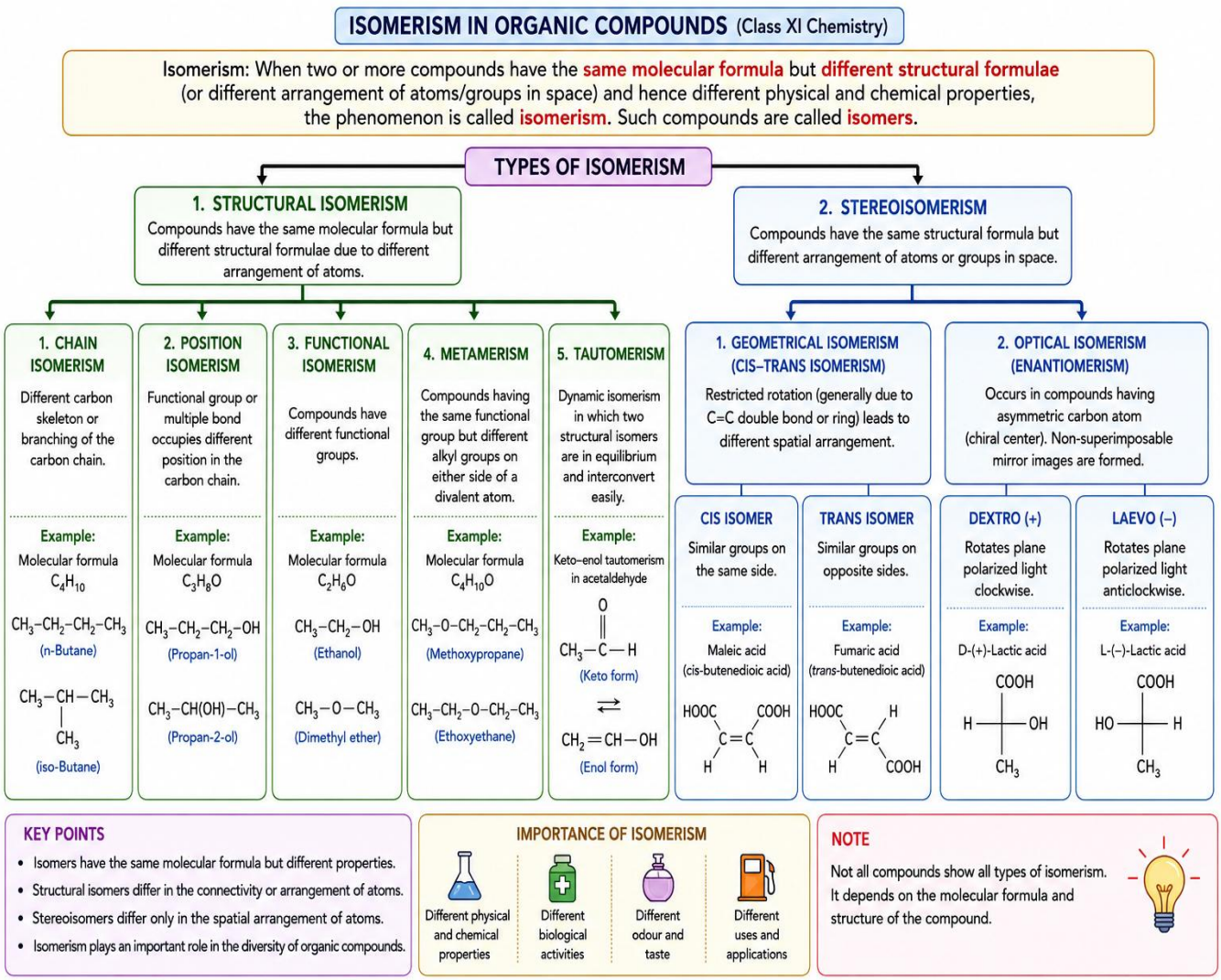
Substituted Group	Secondary prefix.
— F	Fluoro
— CH_3	Methyl
— OCH_3	Methoxy

Naming of Compounds Containing Functional Groups: The carbon chain containing the functional group is numbered so that the functional group gets the lowest possible number.

In polyfunctional compounds, the principal functional group is selected according to the order of priority, and the compound is named based on it.

$-COOH, -SO_3H, -COOR$ (R = alkyl group) $COCl, -CONH_2, COCl,$
$-CONH_2, -CN, -C{=}O, > -C{=}O, -OH, -NH_2 > C{=}C<, -C{\equiv}C-$

Isomerism :



Fundamental Concepts in Organic Reaction Mechanism

Fission of a covalent bond: A covalent bond can undergo Fission in two ways:

(i) By Homolytic Fission or Homolysis

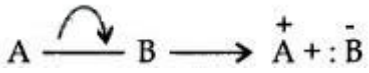
(ii) By Heterolytic Fission or Heterolysis

Homolytic Fission: In this process each of the atoms acquires one of the bonding electrons.

- $A\text{-}A \rightarrow A^{*}+A^{*}$

Heterolytic Fission: In this process one of atoms aquires both of the bonding electrons when the bond is broken.

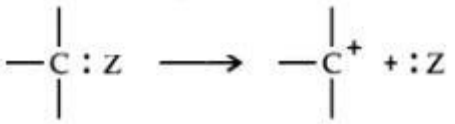
If B is more electronegative than A which thereby aquires both the bonding electrons and becomes negatively charged.



The products of heterolytic fission are ions.

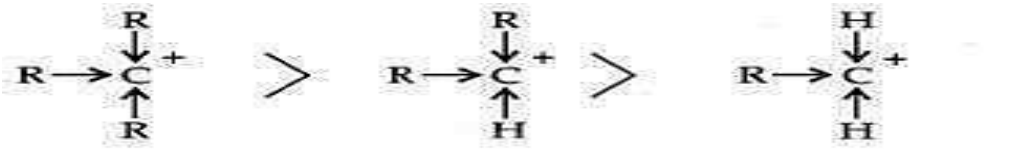
Reaction Intermediates: Heterolytic and homolytic bond fission results in the formation of short-lived fragments called reaction intermediates. Among the important reaction intermediates are carbonium ions, carbanions, carbon free radicals and carbenes.

Carbocations: Organic ions which contain a positively charged carbon atom are called carbonium ions or carbocations. They are formed by heterolytic bond fission.

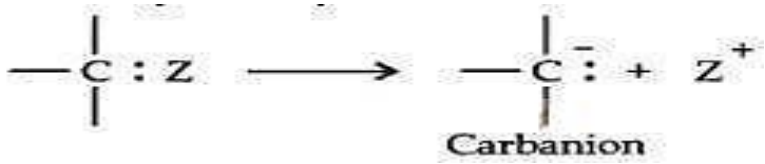


where Z is more electronegative than carbon.

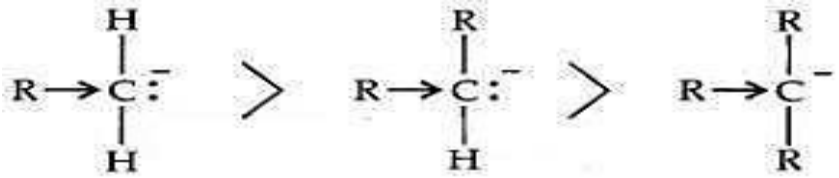
Tertiary carbonium ion is more stable than a secondary, which in turn is more stable than a primary because of +I effect associated with alkyl group.



***Carbanion:** Organic ion which contains a negatively charged carbon atom are called carbanions. They are also formed by hterolytic bond fission.



Where Z is less electronegative than carbon. A primary carbanion is more stable than a secondary, which in turn is more stable than a tertiary, because of +I effect associated with alkyl group.



Electrophile: It is positively charged or neutral species which is electron deficient, e.g., He^{-}, H_20^{+}, CH_3 , NH_4^{+}, $AICl_3$, $S0_3$, $CHCl_2$,CCI_3.

Nucleophile: It is negatively charged or neutral species with lone pair of electrons e.g., (HO^{-}), Cyanide (C = N), H_20: R_3N, R_2NH etc.

Electron Displacement Effects in Covalent Bonds: Electronic displacements in covalent bonds occurs due to the presence of an atom or group of different electronegativity or under the influence of some outside attaching group.

These lead to a number of effects which are as follows:

(i) Inductive effect

(ii) Elecromeric effect

(iii) Resonance or Mesomeric effect

(iv) Hyperconjugation effect.

Inductive Effect:

INDUCTIVE EFFECT (I–EFFECT)

The inductive effect involves σ (sigma) electrons.
In a covalent bond, electrons are not shared equally due to difference in electronegativity.
Thus, electrons are displaced towards the **more electronegative atom**, introducing **polarity** in the bond.

Example :

$\overset{\delta^+}{C} \text{——} \overset{\delta^-}{Cl}$

Chlorine is more electronegative than carbon, so electron density is pulled towards Cl.

TYPES OF INDUCTIVE EFFECT

1. POSITIVE INDUCTIVE EFFECT (+I EFFECT)

Atoms or groups which **donate electrons** towards a carbon atom are said to have **+I effect.**

Examples (Electron–donating groups)

$-CH_3$, $-C_2H_5$, $-C_3H_7$, $(-CH(CH_3)_2)$

(Alkyl groups)

Representation

$R \xrightarrow{+I} C \text{——} H$

Electron density is pushed towards carbon.

Effect : Increases electron density on carbon atom.

2. NEGATIVE INDUCTIVE EFFECT (–I EFFECT)

Atoms or groups which **draw electrons away** from a carbon atom are said to have **–I effect.**

Examples (Electron–withdrawing groups)

$-Cl$, $-OH$, $-NO_2$, $-CN$, $-COOH$, $-CHO$

Representation

$X \xleftarrow{-I} C \text{——} H$

Electron density is pulled away from carbon.

Effect : Decreases electron density on carbon atom.

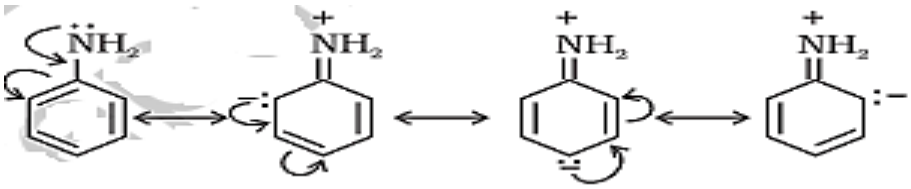
KEY POINTS

- Inductive effect operates through σ-bonds.
- It is a temporary effect and decreases with distance.
- Alkyl groups show +I effect while electronegative groups show –I effect.

Resonance Effect: The polarity produced in the molecule by the interaction of two π-bonds or between a π-bond and a lone pair of electrons present on an adjacent atom. There are two types of resonance or mesomeric effects designated as R or M effect.

Positive Resonance Effect (+R effect):

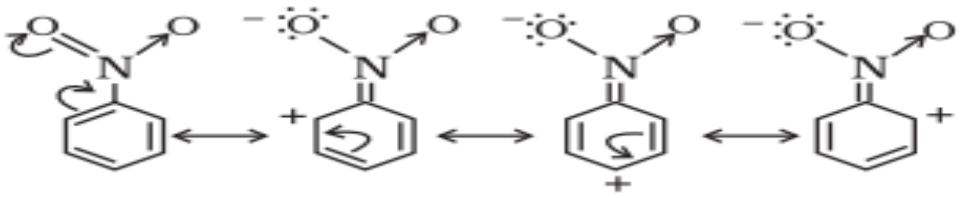
Those atoms which lose electrons towards a carbon atom are said to have a +M effect or +R effect.



For example:

—Cl, —Br, —I, —NH_2, —NR_2, —OH, —OCH_3

Negative Resonance Effect (-R effect): Those atoms or groups which draw electrons away from a carbon atom are said to have a -M effect or -R effect.



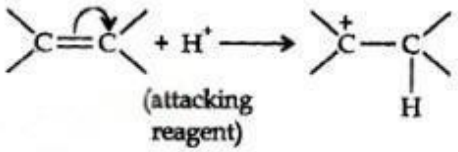
For example:-COOH,-CHO,-CN

Electromeric Effect (E Effect):

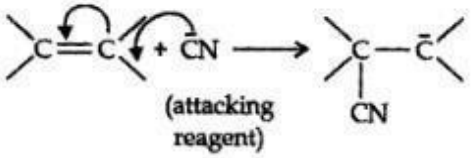
The electromeric effect refers to the polarity produced in a multiple bonded compound when it is attacked by a reagent when a double or a triple bond is exposed to an attack by an electrophile E^+ (a reagent) the two π electrons which from the π bond are completely transferred to one atom or the other. The electromeric effect is represented as:

It is represented by E and the shifting of the electrons is shown by a curved arrow (↷).
There are two distinct types of electromeric effect.

(*i*) **Positive Electromeric Effect (+E effect):** In this effect the π electrons of the multiple bond are transferred to that atom to which the reagent gets attached.

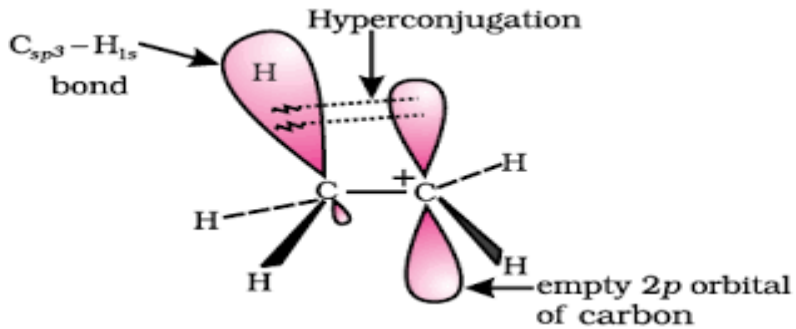


(*ii*) **Negative Electromeric Effect (–E effect):** In this effect the π electrons of the multiple bond are shifted to that atom to which the attacking reagent does not get attached.



Hyperconjugation or No Bond Resonance: Hyperconjugation is a stabilizing interaction that involves the delocalization of electrons from a sigma (σ) bond (usually C–H or C–C) to an adjacent empty or partially filled p-orbital or π-orbital. It's often used to explain the stability of carbocations, alkenes, and radicals.:.

This way of electron release by assuming no bond character in the adjacent C—H bond is called No-Bond Resonance or Hyperconjugation



METHODS OF PURIFICATION OF ORGANIC COMPOUNDS:

1**. Crystallization**

- **Principle**: Based on differences in solubility of the compound and impurities in a suitable solvent.
  Use: Purification of solid organic compounds

2. **Sublimation**

- **Principle**: Some solids can directly change to gas without becoming liquid (sublime).
- **Use**: For purifying solids that sublime (e.g., camphor, naphthalene).

3-Distillation

- **Principle**: Based on different boiling points.
  - **Use**: For liquid-liquid mixtures.
  - For separating volatile liquids from non-volatile impurities.
- **Types**:
- **Simple distillation** – large difference in boiling points (> 25°C).
- **Fractional distillation**–Small difference in boiling points (e.g., in petroleum refining)

4. **Distillation under Reduced Pressure** (Vacuum Distillation)

- **Use**: For compounds that decompose on heating.
- **Principle**: Boiling point of a liquid decreases under reduced pressure.

5. **Steam Distillation**

- **Use**: For temperature-sensitive organic compounds that are immiscible with water.
- **Principle**: Volatile compounds co-distill with steam at a lower temperature.
- **Example**: Extraction of essential oils

7. **Chromatography**

- **Principle**: Based on differential adsorption of compounds on an adsorbent.
- **Use**: For separation and purification of mixtures of compounds (especially colored compounds).

Types: **Paper Chromatography** **Column Chromatography** **Thin Layer Chromatography (TLC)** **Formula to calculate R_f value:** R_f =distance traveled by the compound/distance traveled by the solvent	$R_f = \frac{\text{Distance traveled by solute}}{\text{Distance traveled by solvent}}$

(Qualitative analysis)

Preparation of **Lassaigne's Extract**:

- **Fusion:**
  - A small piece of **dry sodium metal** is taken in a fusion tube.
  - The **organic compound** (dry, powdered form) is added.
  - The tube is heated strongly until the mixture melts and fuses. This helps sodium react with N, S, and halogens in the compound.
- **Quenching:**
  - The hot tube is plunged into **distilled water** in a beaker and broken.
  - The solution is **boiled for a few minutes** to ensure complete extraction of the ionic compounds.
- **Filtration** The mixture is filtered.

The clear filtrate is called the **Lassaigne's extract**.

Quantitative Analysis

Element	**Estimation Method**	**Formula**
Carbon	Carius Method	%C = (Mass of CO_2 × 12× 100) / (44 × Mass of sample)
Hydrogen	Carius Method	%H = (Mass of H_2O × 2 × 100) / (18 × Mass of sample)
Nitrogen	Kjeldahl Method	%N = (1.4 × Volume of acid × Normality) / Mass of sample
Nitrogen	Dumas method	%N=28×V(volume of N_2 at STP)×100/22.4×mass of sample
Sulphur	Carius Method	%S = (Mass of $BaSO_4$ × 32 × 100) / (233 × Mass of sample)
Chlorine	Carius Method	%Cl = (Mass of AgCl × 35.5 × 100) / (143.5 × Mass of sample

SECTION - A (1 mark question)

Q1. Select the compound that behaves not as a Electrophiles.
(a) BF_3 (b) NH_3 (c) $AlCl_3$ (d) H^+

Q2. Out of the following which one is the correct order of stability of carbocations?
(a) 1° > 2° > 3° (b) 2° > 3° > 1°
(c) 3° > 2° > 1° (d) 1° > 3° > 2°

Q3. Hyperconjugation involves interaction of:
(a) σ and π bonds (b) σ and p orbitals
(c) π and π orbitals (d) lone pair and π bond

Q4. Homolytic fission of a covalent bond results in:
(a) Carbocation and carbanion (b) Free radicals
(c)Two ions (d) Nucleophile and electrophile

Q5. The strongest acid among the following is:
(a) CH_3CH_2OH (b) CH_3COOH (c) HCOOH (d) $C_2H_5NH_2$

Q6. The hybridization of carbon in ethyne (C_2H_4) is:
(a)sp (b) sp^2
(c) sp^3 (d) dsp^2

Q7. The IUPAC name of CH_3CH_2COOH is:
(a) Propanoic acid (b)Ethanoic acid
(c) Butanoic acid (d) Acetic acid

Q8. Identify the true statement about mesomericeffect .
(a) It is a temporary effect (b) It operates through sigma bonds
(c) It involves delocalization of π electrons (d) It is due to electronegativity

Q9. Which is a planar molecule?
(a) Ethane (b) Ethene
(c) Cyclohexane (d) Propane

Q10. Which one of the following reactions does not belong to Lassaign'stest

(a) $Na + X \xrightarrow[\Delta]{} +NaX$ (b) $2CuO + C \xrightarrow[\Delta]{} 2Cu + CO_2$

(c) $Na + C + N \xrightarrow[\Delta]{} NaCN$ (d) $2Na + S \xrightarrow[\Delta]{} Na_2S$

Assertion and reason type question

(a) Assertion and reason both are correct statements and reason is the correct explanation for assertion.

(b) Assertion and reason both are correct statements but the reason is not a correct explanation for assertion.

(c) Assertion is a correct statement but the reason is the wrong statement.

(d) Assertion is a wrong statement but the reason is a correct statement

Q11.**Assertion (A):** Electron withdrawing groups show –I effect.
Reason (R): They decrease electron density on carbon atom.

Q12. Assertion (A): Resonance structures differ in the position of atoms.
Reason (R): Resonance involves delocalization of electrons.

Q13. Assertion (A): Electrophiles are electron-deficient species.
Reason (R): Electrophiles donate a pair of electrons to form a new bond.

Q14.**Assertion (A):** The angle between bonds in methane (CH_4) is 109.5°.
Reason (R): Methane has sp^2 hybridized carbon atom.

Q15.**Assertion (A):**Functional groups determine the chemical properties of organic compounds.
Reason (R): All organic compounds with the same functional group behave similarly.

Ans.:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	C	B	B	C	B	A	C	B	B	A	D	C	C	A

SECTION - B (2 MARKS)

Q1. Can you explain what a carbocation is? Explain its stability order.

Hint: Stability order: tertiary (3°) > secondary (2°) > primary (1°) > methyl.

Q2. State a technique commonly employed for purification of

a)A liquid that decomposes at its boiling point

b) Kerosene containing water.

Hint:a)Distillation under reduced pressure.

b)Separating funnel

Q3. 0.45 of an organic compound when analysed by combustion method, gave 1.10 g carbon dioxide and 0.30 g water. Calculate the percentage of carbon and hydrogen in it.

Hint:C%=12×mass of CO2/44×mass of organic compound

H%=2×mass of water/18×mass of organic compound

C%=66.67;H%=7.41%

Q4.. Which electron displacement effect explain the following correct orders of acidity of the carboxylic acids?

(a) $Cl_3CCOOH > Cl_2CHCOOH > ClCH_2COOH$

(b) $CH_3CH_2COOH > (CH_3)_2CHCOOH > (CH_3)_3CCOOH$

Hint:Inductive effect (-I and +I)

Q5.Identify the hybridized state of each C atom in the following compound

$CH_2 = CH – CN$

Hint: SP^2,SP^2,SP

SECTION – C (3 MARKS)

Q1. Explain the term ‘reaction intermediates’ and describe any two types along with examples.

Hint:Carbanion/ carbocation and free radical

Q2.Draw structures for the following IUPAC name

a)2-chloro 2-phenyl butane

b) 1,2 dibromo ethane

c)Propane 1,2,3carboxylic acid

Hint: a*) CH3-CH(Cl)-C(C6H5)-CH3*

b)Br-CH_2-CH_2-Br

c) COOH-CH_2-CH(COOH)-CH_2-COOH

Q3. 0.3 g of urea (NH_2CONH_2) was analyzed according to Kjeldahls method. After digestion, the released ammonia was absorbed in 40 mL of 0.1 MHCl.The excess of acid required 15 mL of 0.1 M NaOH solution for complete netralization. Calculate % nitrogen.

Hint: $M_1V_1=M_2V_2$ N%=1.4×volume of acid used×M/mass of organic compound

N%=11.67%

Q4. Account for the following:

a) Methyl amine is more basic than ammonia.

b) NH_4^+ is not considered an electrophile.

c) Benzene is more stable than expected from its structure.

Hint. a) +I effect

b) Absence of vacant orbitals.

c) Resonance energy

Q5. a) On what principle does chromatography work?

b) In a TLC experiment, a compound has an Rf value of 0.70 and the solvent front moved 9.0 cm. How far did the compound travel?

Hint:a) Refer summary

- b) **R_f =distance traveled by the compound/distance traveled by the solvent ;6.3cm**

SECTION - D(CASE BASED STUDY QUESTIONS)

Organic compounds contain carbon and hydrogen along with elements like oxygen, nitrogen, sulphur, and halogens. These compounds are purified by methods such as crystallization, sublimation, distillation, and chromatography. Detection of extra elements is carried out by Lassaigne's test. Organic reactions are influenced by electronic effects such as inductive effect and resonance effect.
Questions:

(i) Which purification method is used for compounds that directly convert from solid to vapour?
Answer: Sublimation

(ii) Name the test used for detection of nitrogen and sulphur in organic compounds.
Answer: Lassaigne's Test

(iii) What type of inductive effect is shown by alkyl groups?
Answer: +I Effect

(iv) Write one example each of:
(a) Electrophile (b) Nucleophile
Answer:
(a) Electrophile: H^+(b) Nuc leophile: OH^-

SECTION - E(5 MARKS)

Q1.(**i)** Explain the terms inductive and electromeric effects. Which electron displacement effect explain the following correct orders of acidity of the carboxylic acids?

(a) $Cl_3CCOOH > Cl_2CHCOOH > ClCH_2COOH$

(b) $CH_3CH_2COOH > (CH_3)_2CHCOOH > (CH_3)_3CCOOH$

Answer. (a) As the number of halogen atoms decreases, the overall -I- effect decreases and the acid strength decreases accordingly.

(b) As the number of alkyl groups increases, the +I-effect increases and the acid strength decreases accordingly.

(ii) Which of the two: $O_2NCH_2CH_2O^-$ or $CH_3CH_2O^-$ is expected to be more stable and why?

Answer: O_2N——<——- CH_2——<——- CH_2 —<——- O^- is more stable than CH_3——<——- CH_2——<——-O- because NO_2 group has -I-effect and hence it tends to disperse the -ve charge on the O-atom. In contrast, CH_3CH_2 has +I-effect. It, therefore, tends to intensify the -ve charge and hence destabilizes it

Q2(i).Give IUPAC names for following compounds:

a.$HO–CH_2–CH_2–COOH$ b.$CH_3–CHBr–CH_2–CH_3$ C. $CH_3–CH=CH–COOH$

(ii) Account for the following:

a) Toluene is o,p directing. b. Propene is more stable than ethene.

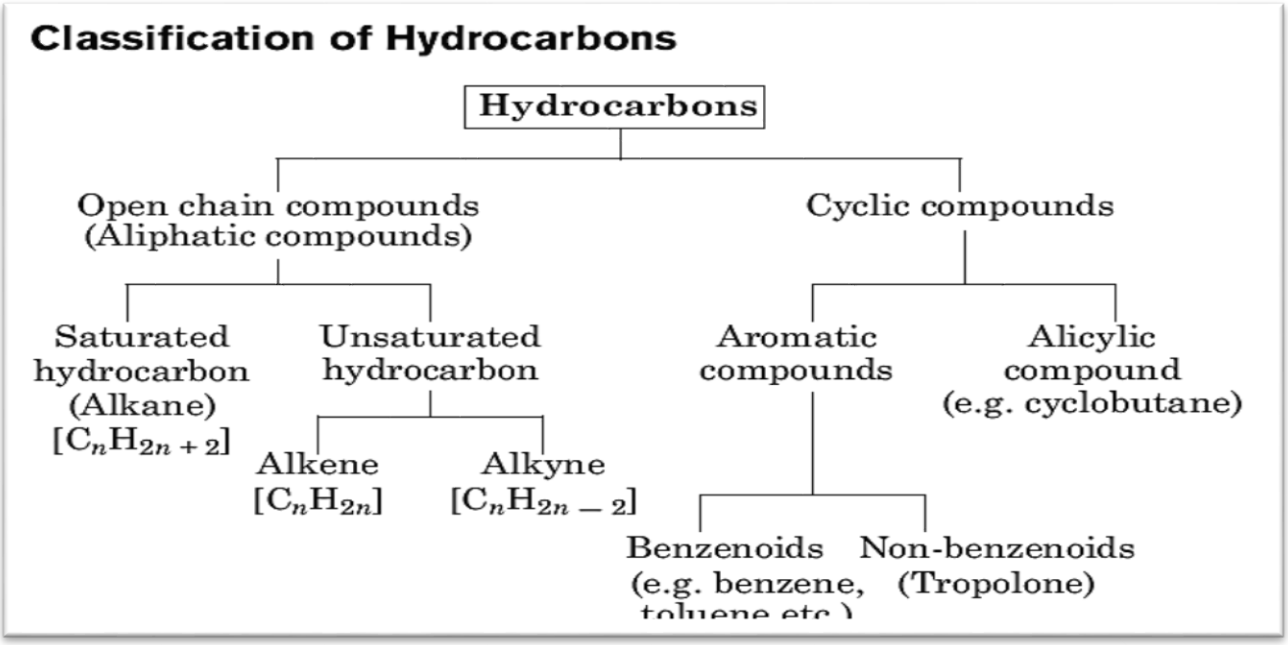
Hint (i) a)2-Hydroxypropanoic acid b) 2-Bromobutane c)But-2-enoic acid

(ii) a) hyperconjugation b)hyperconjugation

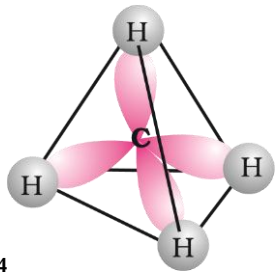
9. HYDROCARBONS (10 Marks)

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 (Markovnikov'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 mono substituted benzene, carcinogenicity and toxicity

The term '***Hydrocarbons***'means compounds of carbon and hydrogen only.



ALKANES-Hydrocarbons containing carbon-carbon single bonds.The general formula for alkane is C_nH_{2n+2}.



CH_4

Preparation of Alkanes

i. **From unsaturated hydrocarbons:**

This process of addition of dihydrogen is known as **hydrogenation** process.

$CH_2{=}CH_2 + H_2 \longrightarrow CH_3\text{-}CH_3$

$CH{\equiv}CH + 2H_2 \longrightarrow CH_3\text{-}CH_3$

ii. **From alkyl halides**

a) Reduction: $CH_3\text{-}Cl \xrightarrow{Zn/HCl} CH_4$

b) Wurtz reaction: $CH_3Br + 2Na + BrCH_3 \xrightarrow{Dry\ ether} CH_3\text{-}CH_3 + 2NaBr$

iii. From carboxylic acids

a) By decarboxylation of carboxylic acids:

$CH_3COONa + NaOH \xrightarrow{CaO,\ \Delta} CH_4 + Na_2CO_3$

b) Kolbe's electrolytic method:

$CH_3COONa + 2H_2O \longrightarrow CH_3\text{-}CH_3 + 2CO_2 + H_2 + NaOH$

Properties of Alkanes

Physical Properties

- C1 to C4 are gases, C5 to C17 are liquids and C18 or more are solids at 298 K.
- They all are colourless and odourless.
- Alkanes are generally insoluble in water or in polar solvents, but they are soluble in non-polar solvents like, ether, benzene, carbon tetrachloride etc.
- The boiling points of straight chain alkanes increase regularly with the increase of number of carbon atoms.

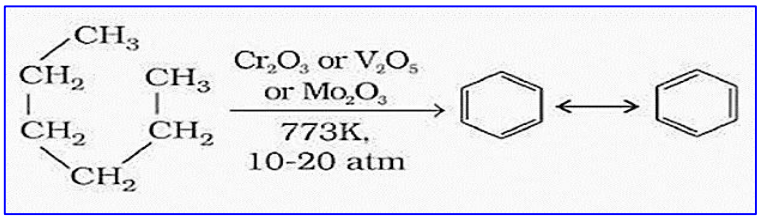
Chemical Properties

i. Halogenation reaction: $CH_4 + Cl_2 \xrightarrow{UV\ or\ high\ Temp} CH_3Cl + HCl$

ii. Combustion: $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

iii. Controlled oxidation: $2CH_4 + O_2 \longrightarrow \xrightarrow{Cu,523K/100atm} 2CH_3OH$

iv. Aromatization:



v. Reaction with steam: $CH_4 + H_2O \longrightarrow CO + 3H_2$

Conformations of ethane:

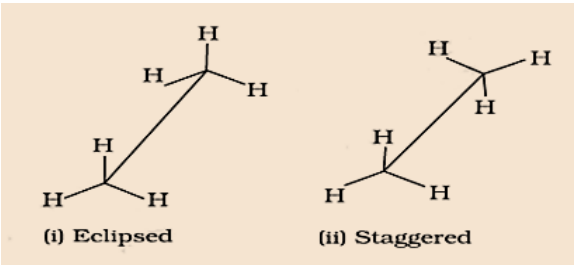
Eclipsed conformation: - conformation in which hydrogen atoms attached to two carbons are as closed together as possible is called eclipsed conformation and

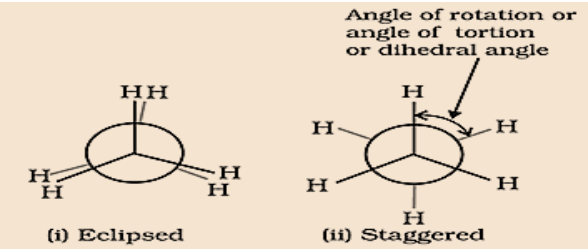
Staggered conformation: - conformation in which hydrogens are as far apart as possible is known as the staggered conformation.

Skew conformation:-Any other intermediate conformation is called a skew.

Projection of Eclipsed and Staggered Conformations of Ethane

Sawhorse Projection **Newman projections**





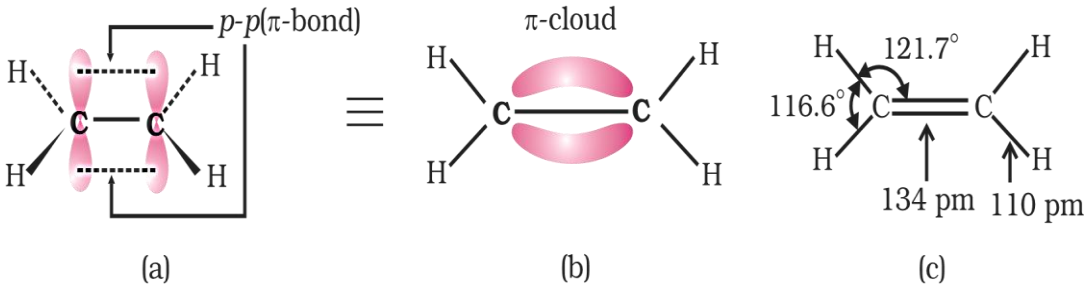
Relative stability of conformations

Staggered conformation is more stable than the eclipsed conformation.

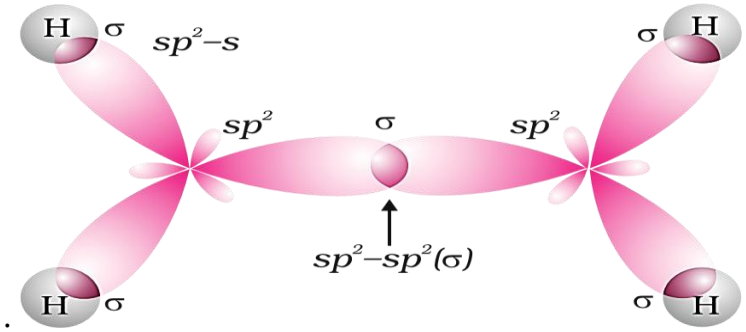
Order of stability:-

Staggered conformation > skew conformation > eclipsed conformation

ALKENES



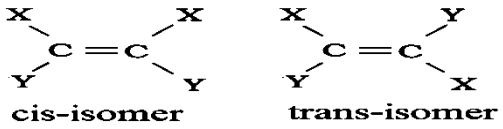
Alkenes are unsaturated hydrocarbons containing at least one carbon-carbon double bond with general formula C_nH_{2n}



Conditions for Geometrical isomerism in Alkenes

Each double bonded carbon atom should be attached with two different atoms or groups.

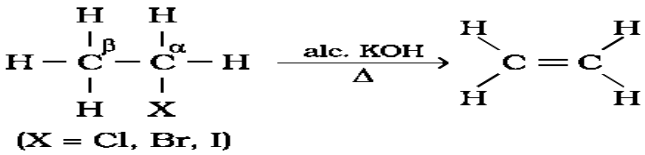
The geometrical isomers are also known as cis-trans isomers.



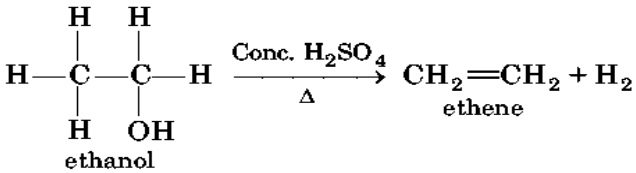
Preparation

i. From alkynes: $CH{\equiv}CH + H_2 \xrightarrow{Pd/C} CH_2{=}CH_2$

ii. From alkyl halides:



(iii) From alcohols by acidic dehydration:



Properties of Alkenes

Physical properties

- The first three members of alkenes are gases, the next fourteen are liquids and the higher ones are solids.
- Alkenes are colourless and odourless, insoluble in water but fairly soluble in non-polar solvents like benzene, petroleum ether.
- They show a regular increase in boiling point with increase in size.

Chemical properties

i. **Addition of dihydrogen:** $CH_2=CH_2 + H\text{-}H \xrightarrow{Ni\ or\ Pt\ or\ Pd} CH_3\text{-}CH_3$

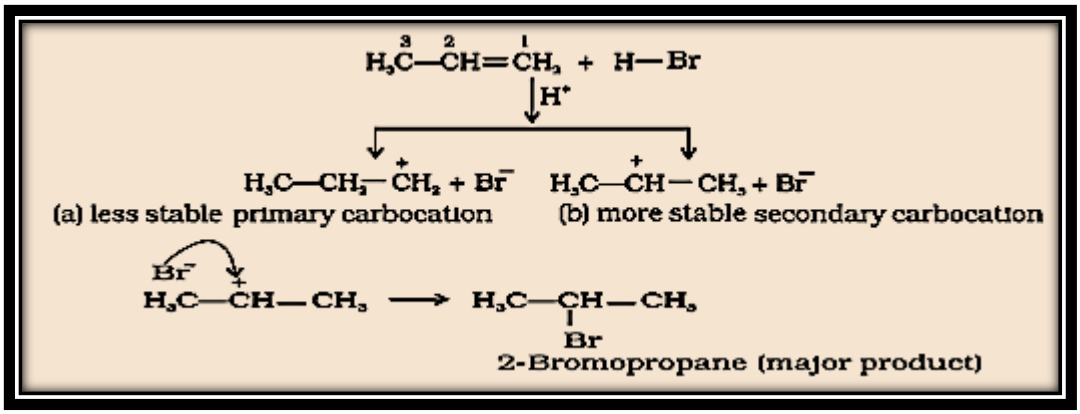
ii. **Addition of halogens:** $CH_2=CH_2 + Br\text{-}Br \xrightarrow{CCl4} Br\text{-}CH_2\text{-}CH_2\text{-}Br$

iii. **Addition of hydrogen halides:**

Markovnikov rule: According to the rule, the negative part of the addendum (adding molecule) adds to that carbon atom of the unsymmetrical alkene which is maximum substituted or which possesses lesser number of hydrogen atoms.

$CH_3CH=CH_2 + HBr \longrightarrow CH_3\text{-}CH(Br)\text{-}CH_3$

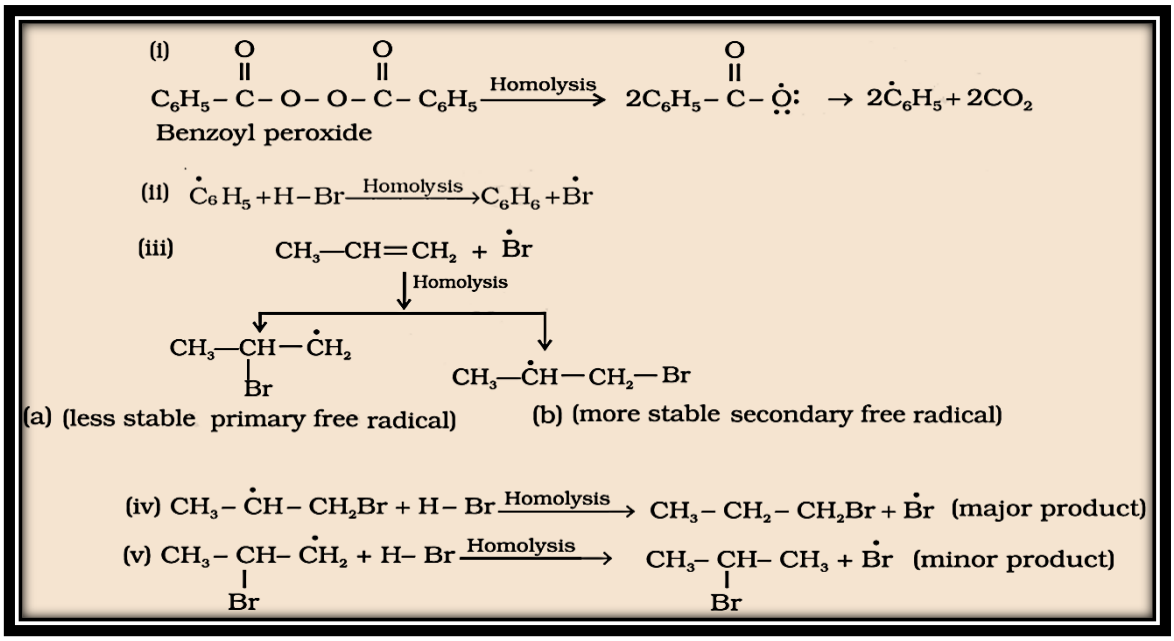
Mechanism of Addition according to Markovnikov Rule



Anti Markovnikov addition or Peroxide effect or Kharash effect: In the presence of peroxide, addition of HBr to unsymmetrical alkenes like propene takes place contrary to the Markovnikov rule. This happens only with HBr but not with HCl or HI. This reaction is known as peroxide or Kharash effect or addition reaction anti to Markovnikov rule.

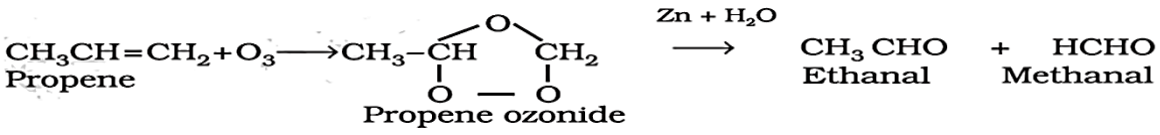
$CH_3CH=CH_2 + HBr \longrightarrow CH_3\text{-}CH_2\text{-}CH_2\text{-}Br$

Mechanism of Addition according to AntiMarkovnikov Rule



Ozonolysis :

Products are carbonyl compounds (aldehyde and /or ketone)



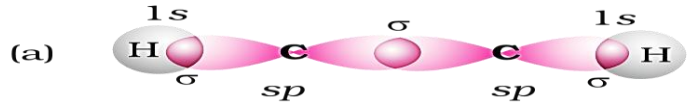
iv. Polymerisation:

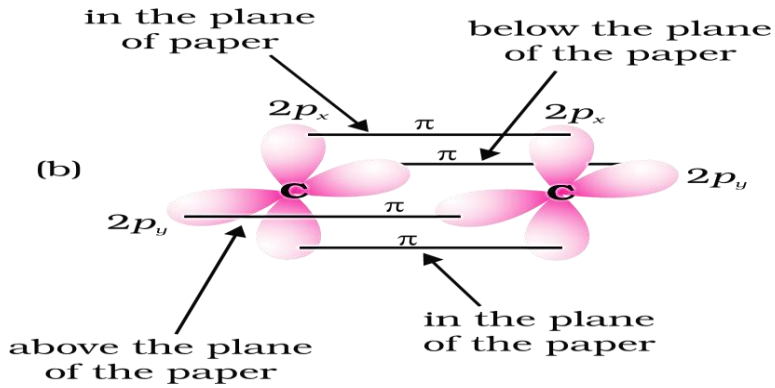
$$n(CH_2=CH_2) \xrightarrow[\text{Catalyst}]{\text{High temp./pressure}} -(CH_2-CH_2)-$$

Polythene

Alkynes

Alkynes are also unsaturated hydrocarbons with general formula C_nH_{2n-2}.





Nomenclature

Preparation

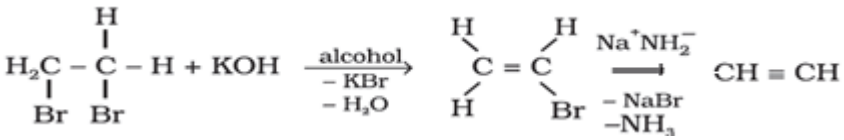
i. From calcium carbide:

$CaCO_3 \longrightarrow CaO + CO_2$

$CaO + 3C \longrightarrow CaC_2 + CO$

$CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 + C_2H_2$

ii. From vicinal dihalides:



Properties of Alkynes

Physical properties

- The first three members (acetylene, propyne and butynes) are gases, the next eight are liquids and higher ones are solids.
- Alkynes are weakly polar in nature and nearly insoluble in water. They are quite soluble in organic solvents like ethers, carbon tetrachloride and benzene.
- Their melting point, boiling point and density increase with increase in molar mass.

Chemical properties

Acidic character of alkynes

$$HC \equiv CH + Na \rightarrow HC \equiv C^-Na^+ + \tfrac{1}{2}H_2$$

Monosodium ethynide

$$HC \equiv C^-Na^+ + Na \rightarrow Na^+C^- \equiv C^-Na^+ + \tfrac{1}{2}H_2$$

Disodium ethynide

Order of acidic strength
i) $HC \equiv CH > H_2C=CH_2 > CH_3-CH_3$
ii) $HC \equiv CH > CH_3-C \equiv CH >> CH_3-C \equiv C-CH_3$

i. Addition of dihydrogen: $CH \equiv CH + H_2 \longrightarrow CH_2=CH_2 \longrightarrow CH_3\text{-}CH_3$

ii. Addition of halogens: $CH \equiv CH + Cl_2 \longrightarrow CH(Cl)=CH(Cl) \longrightarrow CH(Cl)_2\text{-}CH(Cl)_2$

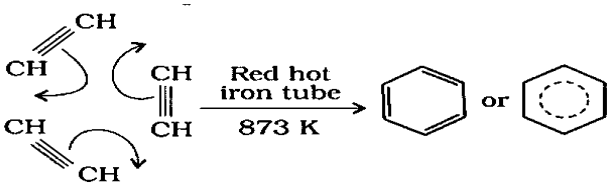
iii. Addition of hydrogen halides:

$$H\text{–}C\equiv C\text{–}H + H\text{–}Br \longrightarrow \underset{\text{Bromoethene}}{[CH_2=CH\text{–}Br]} \longrightarrow \underset{\text{1,1-Dibromoethane}}{CH(Br)_2\text{–}CH_3}$$

iv. Addition of water:

$$\underset{\text{Ethyne}}{HC\equiv CH} + H\text{–}OH \xrightarrow[333K]{Hg^{2+}/H^+} CH_2=C(OH)\text{–}H \xrightarrow{\text{Isomerisation}} \underset{\text{Ethanal}}{CH_3\text{–}C(=O)\text{–}H}$$

v. Polymerisation:



vi. Combustion: $2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$

Aromatic Hydrocarbon

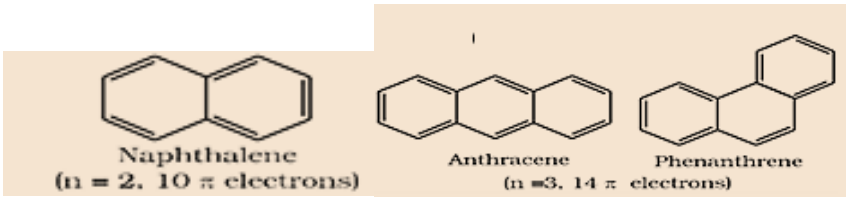
Aromatic hydrocarbons are also known as ‘arenes‘. Since most of them possess pleasant odour (Greek; aroma meaning pleasant smelling), the class of compounds are known as ‘aromatic compounds’.

Conditions of Aromaticity

(i) Planarity

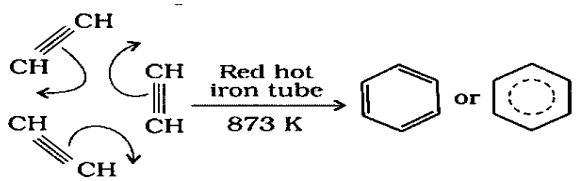
(ii) Complete delocalisation of the π electrons in the ring

(iii) Presence of (4n + 2) π electrons in the ring where n is an integer (n = 0, 1, 2 . . .). This is often referred to as **HückelRule**.Some examples of aromatic compounds are given below:

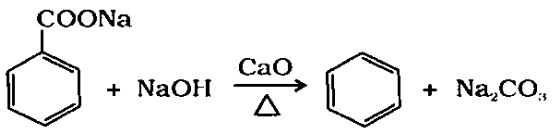


Preparation of Benzene

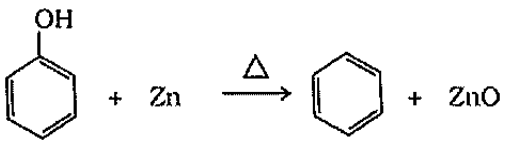
i. Cyclic polymerisation of ethyne:



ii. Decarboxylation of aromatic acids:



iii. Reduction of phenol:



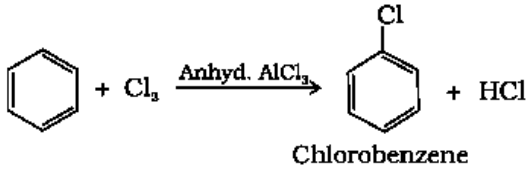
Properties of Benzene

Physical Properties

- Aromatic hydrocarbons are non-polar molecules and are usually colourless liquids or solids with a characteristic aroma. They burn with sooty flame.
- Aromatic compounds are insoluble in water but soluble in organic solvents such as alcohol and ether.

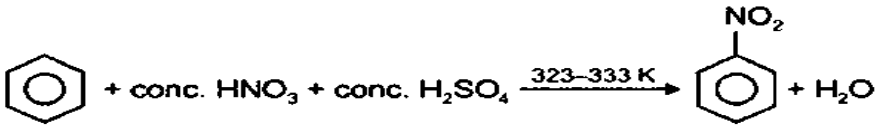
Chemical properties

i.Halogenation:

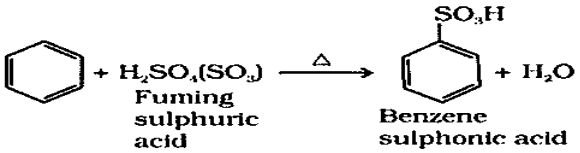


Chlorobenzene

ii. Nitration:

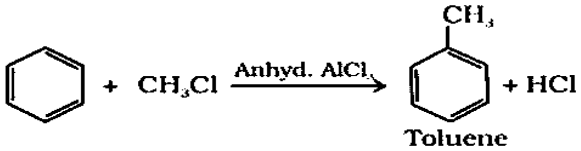


iii.Sulphonation:



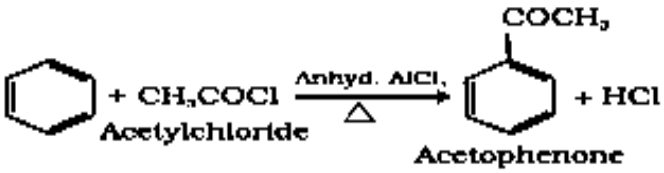
Benzene sulphonic acid

iv. Friedel-Crafts alkylation reaction:



Toluene

v.Friedel-Crafts acylation reaction:

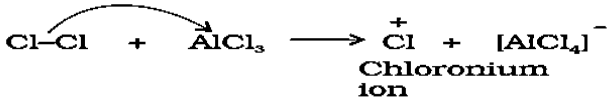


Acetophenone

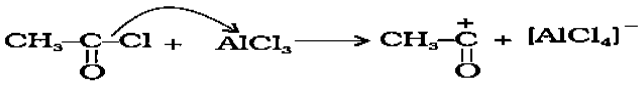
Mechanism of electrophilic substitution reactions:

These reactions are supposed to proceed via the following three steps:

(a) Generation of electrophile E⊕:

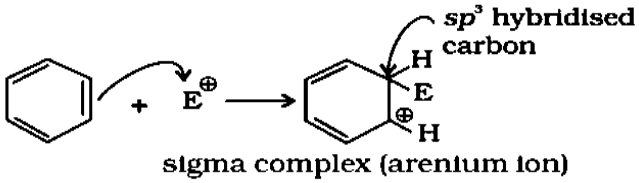


Chloronium ion



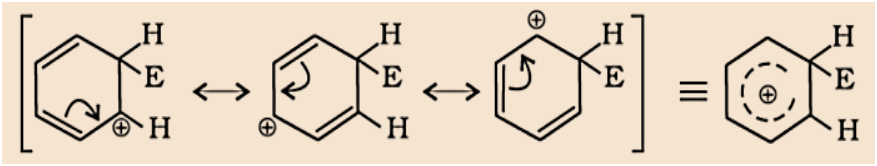
Acylium ion

(b) Formation of carbocation intermediate (arenium ion)

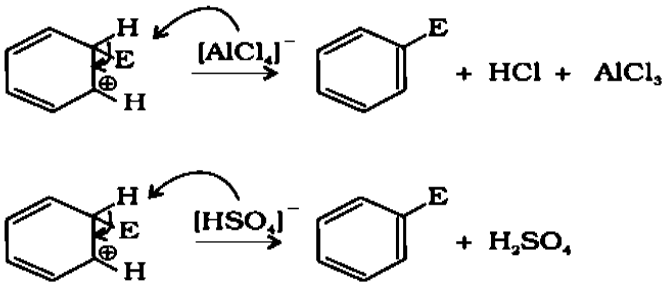


sigma complex (arenium ion)

The arenium ion gets stabilised by resonance:



(c) Removal of proton from the carbocation intermediate



Directive influence of a functional group in monosubstituted benzene

Ortho and para directing groups: (activating Groups)

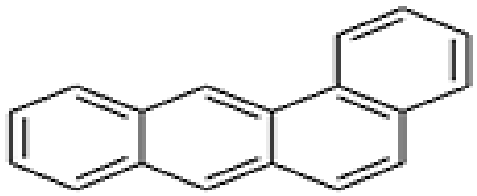
- The groups which direct the incoming group to *ortho*and*para*positions are called *ortho*and*para*directinggroups.Examples are $-\mathrm{OH}$, $-\mathrm{NH_2}$, $-\mathrm{NHR}$, $-\mathrm{NHCOCH_3}$, $-\mathrm{OCH_3}$, $-\mathrm{CH_3}$, $-\mathrm{C_2H_5}$ etc.
- In the case of aryl halides, halogens are moderately deactivating.

Meta directing group:-(Deactivating groups)

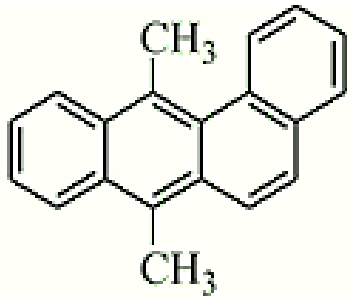
The groups which direct the incoming group to meta position are called meta directing groups. Some examples of meta directing groups are $-NO_2$, $-CN$, $-CHO$, $-COR$, $-COOH$, $-COOR$, $-SO_3H$ etc.

CARCINOGENICITY AND TOXICITY:

Benzene and polynuclear hydrocarbons containing more than two benzene rings fused together are toxic and said to possess cancer producing (carcinogenic) property. They enter into human body and undergo various biochemical reactions and finally damage DNA and cause cancer.

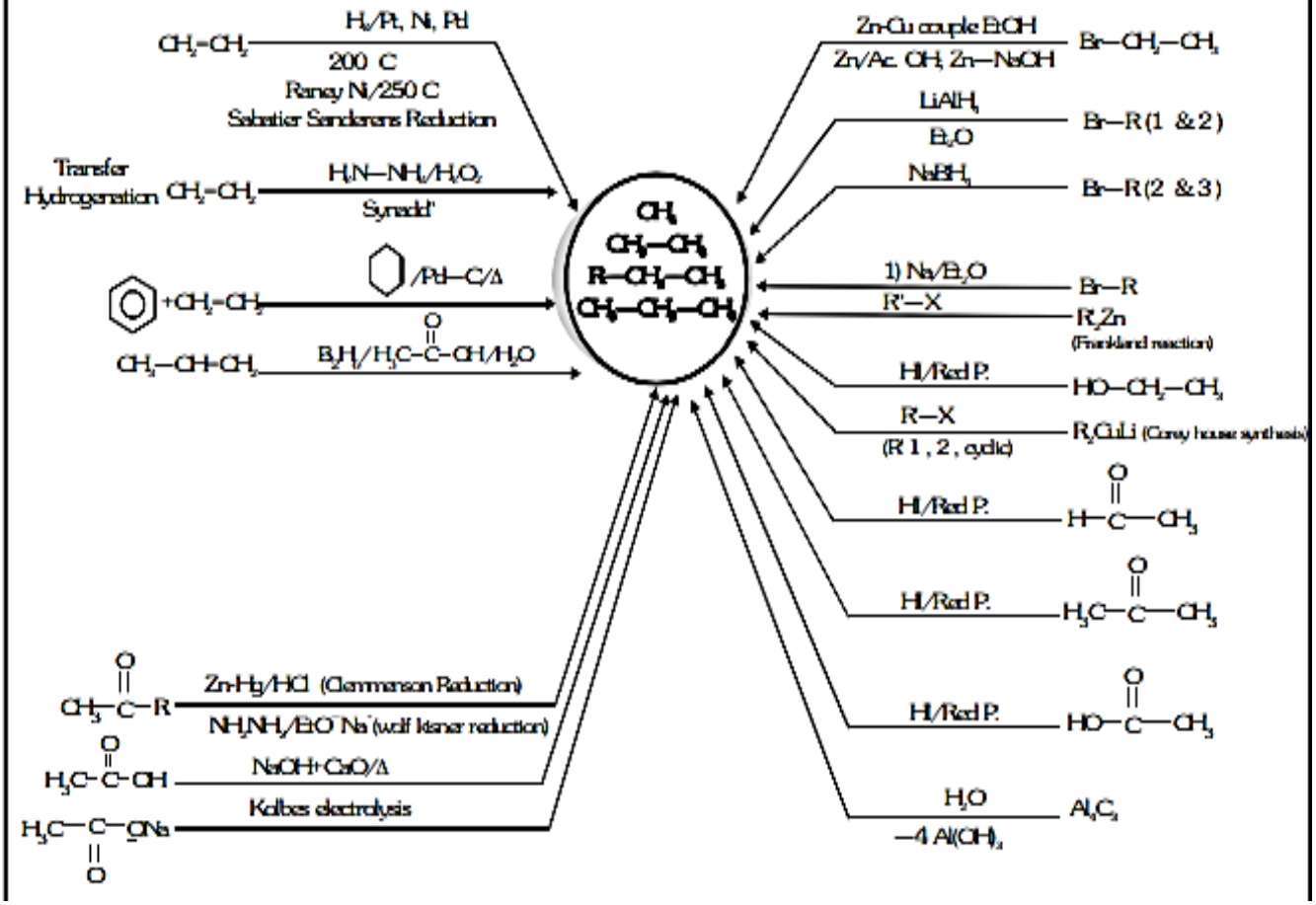


1,2-Benzanthracene

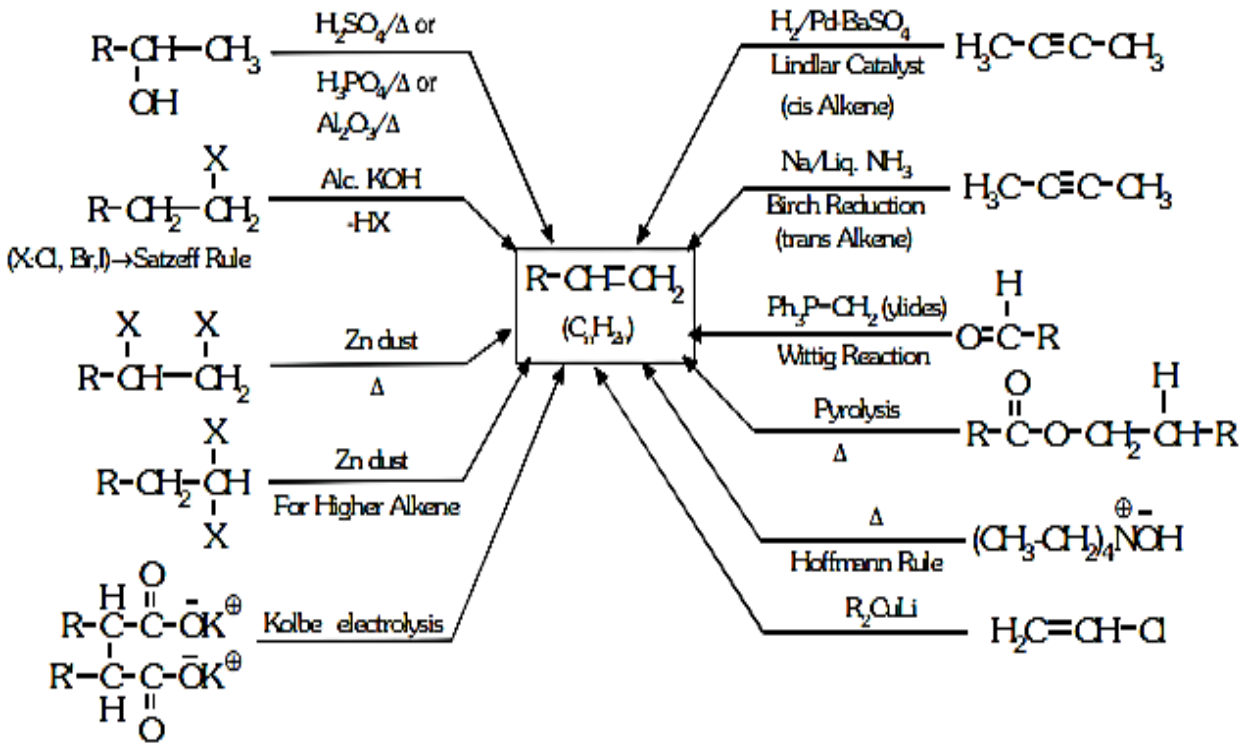


9,10-Dimethyl-1,2-benzanthracene

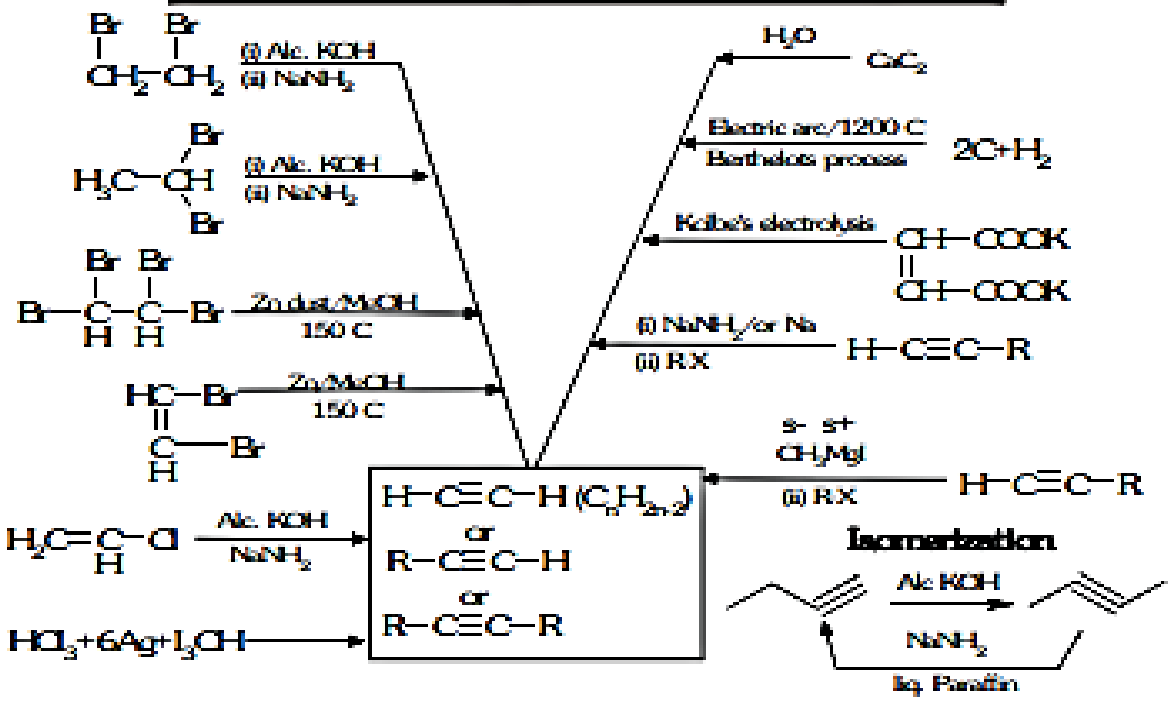
ALKANE

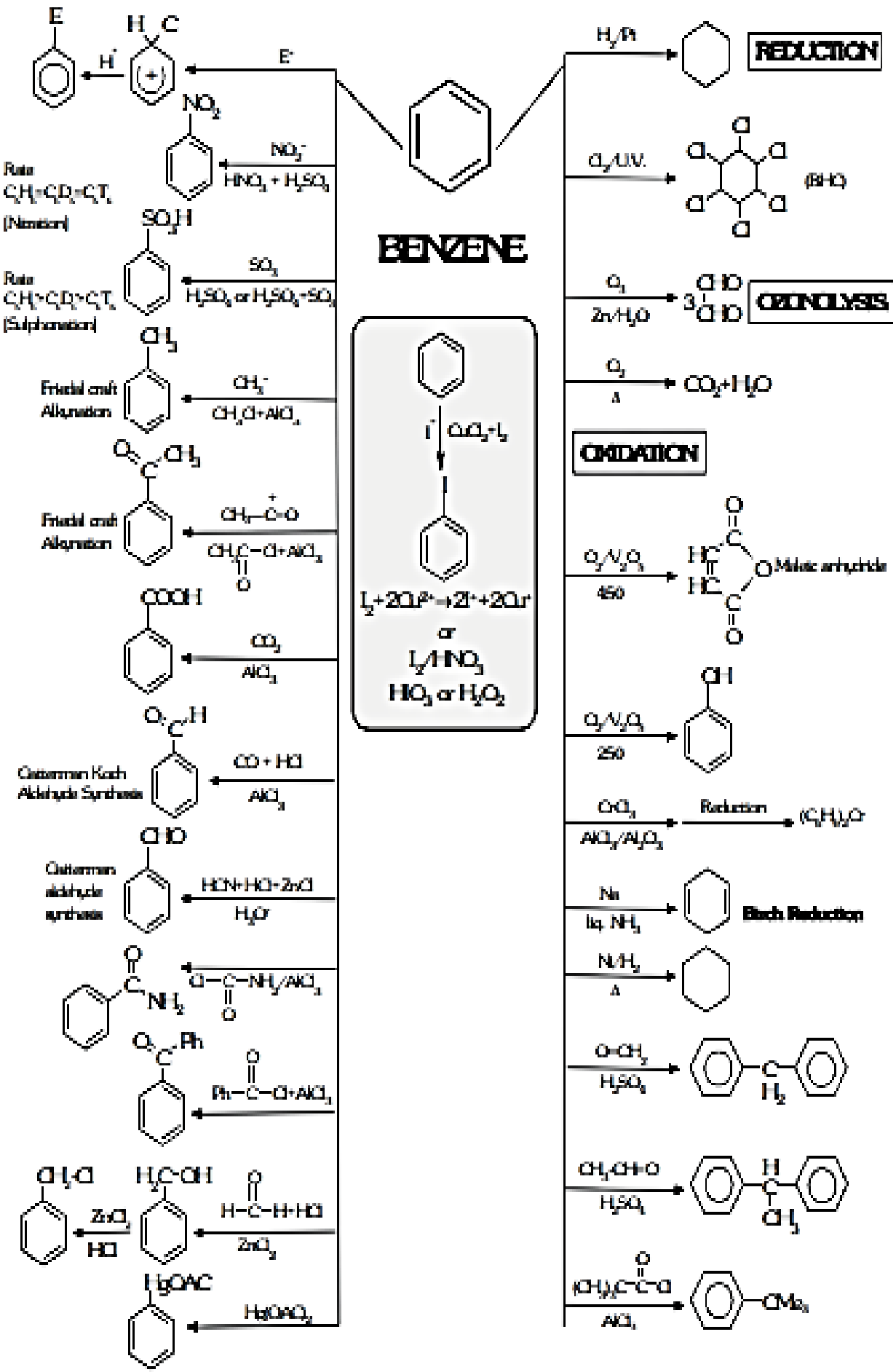


ALKENE



Nutshell Preparation of Alkyne




BENZENE
REDUCTION
OZONOLYSIS
OXIDATION
Rate
C6H6>C6D6>C6T6
(Nitration)
Rate
C6H6>C6D6>C6T6
(Sulphonation)
Friedel craft
Alkynation
Friedel craft
Alkynation
Gattermann Koch
Aldehyde Synthesis
Gattermann
aldehyde
synthesis
Maleic anhydride
Reduction
Birch Reduction

QUESTION BANK

SECTION – A (01 mark)

Q1. Which of the following hydrocarbon has highest boiling point?

(a) Isobutane (b) Butane (c) Neopentane (d) n-Hexane

Q2. Reaction of ethyne with Br_2 in CCI_4 gives:

(a) Bromoethane (b) 1, 2-Dibromoethane

(c) 1, 1-Dibromoethane (d) 1, 1, 2, 2-Tetrabromoethane

Q3. Ozonolysis of benzene followed its reaction with Zn/H_2O gives:

(a) HCHO (b) CHO-CHO (c) CH_3CHO (d) None of these

Q4. Phenol when distilled with zinc dust gives:

(a) Benzoic acid (b) Benzene (c) o– Nitrophenol (d) p – Nitrophenol

Q5. Which branched chain isomer of the hydrocarbon with molecular mass 72u gives only one isomer of monosubstituted alkyl halide?

(a) Tertiary butyl chloride (b) Neohexane (c) Neopentane (d) Isohexane

Q.6 The catalyst used in Friedel–Crafts reaction is

(a) Zn/HCl (b) Anhydrous Aluminium Chloride (c) Methyl Chloride (d) Copper

Q7.Isomerization of n-hexane on heating with anhydrous $AICI_3$ and HCl gas gives

a) 2-methylpentane b) 3-methylpentane c) 2-methylhexane

d) Mixture of 2-methylpentane and 3-methylpentane

Q8. Which of the following is an example of meta directing group?

a) -CHO b) $–NH_2$ c) $-OCH_3$ d) -NHR

Q9. Chlorination of alkanes in presence of diffused sunlight is an example of

(a) Free radical addition reaction (b) Free radical substitution reaction

(c) Nucleophilic substitution reaction (d) Nucleophilic addition reaction.

Q10. Which of the following statements is not correct?

(a) An aromatic molecule must be cyclic (b) An aromatic ring must be planar

(c) An aromatic ring must involve cyclic delocalization of $(4n + 2)$ π-electrons

(d) An aromatic ring must involve cyclic delocalization of $4n$ π-electrons

Assertion-Reason questions (01 Mark)

These questions are based on Assertion-Reason and write the correct option from the following four options given:

Option (A) if Both A and R are correct and R is the correct explanation of A.

Option (B) if Both A and R are correct but R is not the correct explanation of A.

Option(C) if A is correct and R is not correct.

Option (D) if A is not correct but R is correct

Q.11. Assertion: Acetylene is acidic in nature.

Reason: In Acetylene carbon is sphybridised.

Q.12. Assertion: Boiling point of alkanes increases with increase in molecular mass.

Reason: Van der Waal's forces increase with increase in molecular mass.

Q.13. Assertion: Benzene on heating with conc. H_2SO_4 and Conc HNO_3 gives nitrobenzene.

Reason: .Mixture of Conc H_2SO_4 and Conc HNO_3 produces electrophile SO_3

Q.14. Assertion: .Boiling point of Cis-But-2-ene is higher than Trans But-2-ene

Reason: Trans-But-2-ene is polar but Cis-but-2-ene is non-polar.

Q.15. Assertion (A): Addition of HBr to propene in presence of benzoyl peroxide produces 1-bromopropane as the major product.

Reason(R): Addition of HBr to propene in the presence of peroxide follows free radical chain mechanism.

ANSWERS:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
d)	d)	b)	b)	c)	b)	d)	a)	b)	d)	a)	a)	c)	c)	a)

Short Answer Type Questions (2 Marks)

Q1. Draw cis and trans isomers of hex-2-ene. Which isomer will have higher boiling point and why? (Hint: Cis isomer has higher boiling point because it is more polar.)

Q2. Draw the possible chain isomers of alkane with Molecular Formula C_5H_{12} and write their IUPAC names.

(Hint: IUPAC Names-Pentane, 2-Methyl Butane and 2,2- Dimethyl Propane)

Q3. Draw Newman projections of ethane for the eclipsed and staggered conformations of ethane. Which of these conformations is more stable and why?

(Hint: The staggered conformation is most stable because the hydrogens and bonding pairs of electrons are at maximum distance, thus causing minimum repulsion.)

Q4. An alkene 'A' on ozonolysis gives a mixture of ethanal and pentan-3- one. Write structure and IUPAC name of 'A'.

(Hint: 3-Ethyl Pent-2-ene)

Q5.Sodium salt of which acid is needed for the preparation of methane? Write chemical equation involved.

(Hint: Sodium Acetate CH_3COONa)

Short Answer Type Questions (3 Marks)

Q1. a) Out of benzene, m–dinitrobenzene and toluene which will undergo nitration most easily and why?

b) Draw resonating structures of chlorobenzene using arrow to show Resonance effect in it.

(Hint: Toluene will undergo nitration easily due to +R effect of Methyl group attached to benzene ring which increases electron density.)

Q2. Convert the following

a) Benzoic acid to benzene b) Ethane to butane c) Ethyne to acetaldehyde

(Hint: a) First reaction with NaOH and then use soda-lime decarboxylation

b) First Chlorination of ethane and then apply wurtz reaction

c) Addition of water in the presence of H_2SO_4 and $HgSO_4$)

Q3. a) How Huckel's rule is applied?

b) Out of cyclopentadiene and cyclopentadienyl anion which one is aromatic and why?

c) Which conditions are essentially required for a compound to be aromatic

(Hint: a) Huckel's Rule states that a Cyclic, Planar molecule is considered to be Aromatic if it has $(4n + 2)$ πElectrons

b) Cyclopentadienyl anion is aromatic because it has $(4n + 2)$ πElectrons, planarity and complete delocalisation of πElectrons

c) The molecule should follow Huckel rule, there should be Complete delocalization of π electrons, Molecule should be Planar)

Q4. Use the following terms by taking an example.

a) Markovnikov's Rule b) Wurtz Reaction c)Decarboxylation reaction

(Hint: a)Negative part of the addendum is attached to that double bonded carbon atom which has the least number of hydrogen atoms.

b) $CH_3Br + 2Na + BrCH_3 \xrightarrow{Dry\ ether} CH_3\text{-}CH_3 + 2NaBr$

c) $CH_3COONa + NaOH \xrightarrow{CaO,\ \Delta} CH_4 + Na_2CO_3$)

Q.5.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

(Hint: Addition of HBr to propene yields 2-bromopropane because the addition take place according to Markovnikov's rule through electrophilic addition, while in the presence of benzoyl peroxide, the addition take place against Markovnikov's rule through free radical addition)

Case Based Questions (04 Marks)

The following questions are case-based questions. Each question has an internal choice and carries 4 marks each.

Read the passage carefully and answer the questions that follow

Q1. Hydrocarbons are compounds of carbon and hydrogen only, obtained from coal and petroleum mainly which are major sources of energy. Hydrocarbons are classified as open chain, saturated (alkanes), unsaturated (alkenes and alkynes), cyclic (alicyclic) and aromatic based on structure. Alkanes show conformational isomerism due to free rotation along C-C bond leading to staggered and eclipsed conformations of ethane.

The repulsive interaction between the electron clouds, which affects stability of a conformation, is called torsional strain. Magnitude of torsional strain depends upon the angle of rotation about C–C bond. This angle is also called dihedral angle or torsional angle. Of all the conformations of ethane, the staggered form has the least torsional strain and the eclipsed form, the maximum torsional strain.

Alkenes show geometrical (cis-trans) isomerism due to restricted rotation around carbon-carbon double bond.

(a) Name the angle between hydrogens of different carbons of ethane (1 mark)

(b) Alkanes show conformational isomerism but alkenes do not .Why? (1 mark)

(c) Which conformation of ethane has less torsional strain and why? (2 marks)

OR

Why is trans but-2-ene has higher melting point than cis but-2-ene?

(Hint: a) dihedral angle

b) In alkenes there is no free rotation in Carbon-Carbon bond.

c) Staggered due to maximum dihedral angle.

OR

The molecule is symmetrical and hence packed well in the crystal lattice.)

Q2. Benzene is a key compound in organic chemistry and serves as a starting material for synthesizing various derivatives used in industries, such as dyes, plastics, and pharmaceuticals. Due to its aromatic nature, benzene undergoes electrophilic substitution reactions like nitration, sulphonation, halogenation, and Friedel-Crafts alkylation/acylation. These reactions involve the replacement of a hydrogen atom on the benzene ring with a functional group. The reactivity of benzene is influenced by the electron density in its pi system, which makes it susceptible to attack by electrophiles.

a) Name one electrophilic substitution reaction that benzene undergoes.(1 mark)

b) What is the role of a catalyst in the Friedel-Crafts alkylation of benzene?(1 mark)

c) Describe the mechanism of nitration of benzene.(2 marks)

Or

Benzene undergoes electrophilic substitution reactions easily and nucleophilic substitutions with difficulty. Why?

(Hint: a) Nitration, sulphonation, halogenation, and Friedel-Crafts alkylation/acylation (any one)

(b) The catalyst generates the electrophile.

(c) The generation of the nitronium ion (NO_2^+) as the electrophile, followed by its attack on the benzene ring forming a sigma complex (arenium ion).A proton is then lost from the sigma complex, restoring the aromatic ring and forming nitrobenzene
($C_6H_5NO_2$).

Or

Benzene is a planar molecule having delocalized electrons above and below the plane of the ring. Hence, it is electron-rich. As a result, it is highly attractive to electron-deficient species i.e., electrophiles but repels Nucleophiles (Electron rich species). Therefore, it undergoes electrophilic substitution reactions very easily.)

Long Answer Questions (05 Marks)

Q1. (i)Write chemical equation for lab preparation of ethene.

(ii) What happens (Give chemical equation involved in each case.)

a) whenethene is passed through Br_2 water

b) Propene reacts with HBr in the presence of peroxide

(iii) Convert : a. Ethyne to Benzene b. Benzene to Acetophenone

(Hint: (i) $CH_3\text{-}CH_2OH \xrightarrow{ConcH2SO4\ /Heat} C_2H_4 + H_2O$

(ii) a) Form colourless 1,2-dibromoethane.

b) Apply antiMarkownikov's rule

(iii) (a) $3C_2H_2 \xrightarrow{redhot\ iron\ tube\ /873K} C_6H_6$

(b) $C_6H_6 + CH_3COCl \xrightarrow{AnhydAlCl3} C_6H_5COCH_3 + HCl$)

Q2. (i) Give reason for following

a) Ethyne is more acidic than ethene

b) Nitration of Toluene give ortho and para nitro toluene but not m-Nitro toluene

(ii) Complete the following equation

$CH_3CH(Cl)\text{-}CH_2\text{-}CH_3 \xrightarrow{AlcKOH}$

(iii) Give a chemical test to distinguish the following pairs

(a)Ethene and Ethyne (b)Ethene and Ethane .

(Hint: (i) a) Inethyne, the hybridization of each carbon is sp which has 50 % s character.

(b) In Toluene, $-CH_3$ group causes +R effect and activates the benzene ring.

(ii) $CH_3CH{=}CH\text{-}CH_3$ (Major product) + HCl

(iii) (a) When ammonical Silver Nitrate ($AgNO_3$) is added to Ethyne then it gives white precipitate.

(a) Ethene will react with bromine water and will decolourise bromine water.

==========xxxxxxxxxxxxx----------

Class-XI : Google Form Link for Multiple Choice Practice Questions		
Name of Chapters	**Google Form Link**	**QR Code**
1.Some Basic Concepts of Chemistry	**https://docs.google.com/forms/d/e/1FAIpQLScngqQEKmPM64VzqwILV_vZQKw_kFTi-6s4GJFwcUcRa5rcEA/viewform?usp=publish-editor**	
2.Structure of Atom	**https://docs.google.com/forms/d/e/1FAIpQLSfpbLxpK181Zp7PPer683s_eEqbWTP7uzFMvcF8uJf-17AiFQ/viewform?usp=header**	
3.Classification of Elements and Periodicity in Properties	**https://docs.google.com/forms/d/e/1FAIpQLSfMgQLzc9oyW49lGeP0mNcrpucpab5qG61M4OfprapSRiO81w/viewform?usp=publish-editor**	
4.Chemical Bonding and Molecular Structure	**https://docs.google.com/forms/d/e/1FAIpQLSfokRU_kHZA9BIo_7VJl-L89R9sAX4JOSRcbCQasGBg7Vy5Ug/viewform?usp=dialog**	
5.Chemical Thermodynamics	**https://docs.google.com/forms/d/e/1FAIpQLSfY7_xVEh-f__IJ3e5ThICixZ6mhPKvH_O-ecZyCT5qwLVbBQ/viewform?usp=publish-editor**	

6.Equilibrium	**https://docs.google.com/forms/d/e/1FAIpQLSckEcQIRcEXeIG07LTBGsiFQ6_5A4cGLo72uXI8_aWNWXclAw/viewform?usp=publish-editor**	
7.Redox Reactions	**https://docs.google.com/forms/d/e/1FAIpQLSf1OQYDep0hID5GKMhxZryzH9DUQx1t6_mjHS4QnE_MMnYHkA/viewform?usp=dialog**	
8.Organic Chemistry: Some Basic Principles and Techniques	**https://docs.google.com/forms/d/e/1FAIpQLScZ3Y669cdT-b7RX6B20zqI4MAoY9J_qah7JbA_PW2zCzp-wA/viewform?usp=header**	
9.Hydrocarbons	**https://docs.google.com/forms/d/e/1FAIpQLSfBG2NADuwuXdanN7j2HPpsN7ZavriaXp-gF2m5Jqhlxb6LPA/viewform?usp=publish-editor**	

SAMPLE QUESTION PAPER :2026-27
CLASS-XI
SUBJECT- CHEMISTRY
SET-01

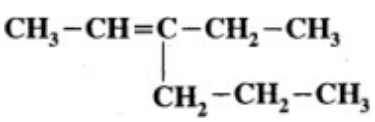
TIME: 3 hours **M.M.: 70**

General Instructions:

Read the following instructions carefully.

a) There are 33 questions in this question paper with internal choice.
b) SECTION A consists of 12 MCQ & 4 Assertion-Reasoning type questions carrying 1 mark each.
c) SECTION B consists of 5 very short answer questions carrying 2 marks each.
d) SECTION C consists of 7 short answer questions carrying 3 marks each.
e) SECTION D consists of 2 case- based questions carrying 4 marks each.
f) SECTION E consists of 3 long answer questions carrying 5 marks each.
g) All questions are compulsory.
h) Use of log tables and calculators is not allowed.

Q. No.	SECTION-A	Marks
1.	Two compounds of nitrogen and oxygen were analysed. In compound A, 14 g nitrogen combines with 16 g oxygen**.** In compound B, 14 g nitrogen combines with 32 g oxygen. Which law is best illustrated by this data? (a) Law of conservation of mass (b) Law of constant proportions (c) Law of multiple proportions (d) Avogadro's law	1
2.	If the uncertainty in the position of electron is zero, the uncertainty in its momentum would be- (a) Zero (b) Less than $h/4\pi$ (c) Greater than $h/4\pi$ (d) Infinite	1
3.	Number of angular nodes and radial nodes for 3p orbital is _____. (a) 1 & 1, respectively (b) 1 & 2, respectively (c) 2 & 1, respectively (d) 2 & 2, respectively	1
4.	Which of the following is an isoelectronic pair. (a) Na^+ & Na (b) O^{2-} & F^- (c) Mg^{2+} & Mg (d) Cl^- & Cl	1
5.	The symbol of an element with atomic number 112 as per IUPAC will be- (a) Uun (b) Ubn (c) Uub (d) Unb Or	1

	Which of the following orders is **incorrect**? (a) Ionization enthalpy: Li < Be > B (b) Atomic radius: C < N < O (c) Metallic character: Na > Mg > Al (d) Electronegativity: F > O > N	
6.	The group number, number of valence electrons, and valency of an element with the atomic number 15, respectively, are: (a) 16, 5 and 2 (b) 16, 6 and 3 (c) 15, 5 and 3 (d) 15, 6 and 2	1
7.	The solubility product of a sparingly soluble salt AX_2 is 3.2×10^{-11}. Its solubility (in mol L^{-1}) is: (a) 3.1×10^{-4} (b) 2×10^{-4} (c) 4×10^{-4} (d) 5.6×10^{-6}	1
8.	Values of standard reduction electrode potential of three metals X, Y and Z are -1.2V, +0.5V and -3.0V respectively. The reducing power of these metals will be in order: (a) X>Y>Z (b) Y>Z>X (c) Y>X>Z (d) Z>X>Y	1
9.	Chromatography is used to (a) Heat substances. (b) Separate components of a mixture. (c) Measure temperature. (d) Prepare solutions.	1
10.	Which of the following compounds will show cis-trans isomerism? (a) $(CH_3)_2C = CH2$ (c) $CH_2 = CBr_2$ (b) $CH_3\text{-}CH = CH - CH_3$ (d) $CH_3CH = CCl_2$	1
11.	Which of the following undergoes electrophilic substitution reaction easily. (a) Ethane (b) Ethene (c) Ethyne (d) Benzene	1
12.	The I.U.P.A.C. name of the following compound is  (a) 3-Ethyl-2-hexene (b) 3-Propyl-2-hexene (c) 3-Propyl-3-hexene (d) 4-Ethyl-4-hexene	
	In the following questions, [from Q.13 to Q.16] a statement of assertion	

	followed by a statement of reason is given. Choose the correct answer out of the following choices. **a) Assertion and reason both are correct statements and reason is correct explanation for assertion.** **b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.** **c) Assertion is correct statement but reason is wrong statement.** **d) Assertion is wrong statement but reason is correct statement.** **e) Both assertion and reason are wrong statements.**	
13.	**Assertion (A):** The configuration of Chromium is $3d^5\ 4s^1$ and not $3d^4\ 4s^{2.}$ **Reason (R):** Half-filled and fully filled subshells have extra stability due to symmetry and exchange energy. **Or** **Assertion (A):** The 19th electron in a potassium atom enters the 4s-orbital and not the 3d-orbital. **Reason (R):** According to the (n+l) rule, the 3d-orbital has a lower energy than the 4s-orbital.	1
14.	**Assertion:** The ionic radii follows the order: $I^- < I < I^+$. **Reason:** Smaller the value of z/e, larger the size of the species.	1
15.	**Assertion:** If water is heated to 59°C, the pH will increase. **Reason:** K_w increases with an increase in temperature.	1
16.	**Assertion:** Primary carbanions are more stable than tertiary carbanions. **Reason:** Alkyl group shows +I effect, which destabilizes carbanion.	1
	SECTION-B (VSQ)	
17.	How many atoms are present in 0.5 mole of O_2.	2
18.	(i) State Hund's rule of maximum multiplicity. (ii) Draw the structure of 'p'orbital.	1 x 2 = 2
19.	(i) Which has greater dipole moment: NH_3 or NF_3 and why? (ii) O-nitrophenol is steam volatile whereas p-nitrophenol is not. Give reason.	1 x 2 = 2
20.	(A) Predict in which of the following the entropy increases or decreases: (i) $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2(g)$ (ii) $2H\ (g) \rightarrow H_2(g)$ (B) Select which of the following are extensive properties: Temperature, internal energy, pressure, density and heat capacity. Give reason. **Or** Calculate the standard enthalpy of formation of CH_3OH from the following data: (i) $CH_3OH(l) + 3/2\ O_2\ (g) \text{———->} CO_2\ (g) + 2H_2O\ (l)$; $\Delta H^o = -726 kj\ mol^{-1}$ (ii) $C(s) + O_2\ (g) \text{————>} CO_2\ (g)$; $\Delta H^o = -393\ kj\ mol^{-1}$ (iii) $H_2(g) + ½\ 0_2(g) \text{————->} H_2O\ (l)$; $\Delta H^o = -286\ kj\ mol^{-1}$	1+1 2
21.	Arrange the following in the increasing order of stability: $(CH_3)_3C^+$, $CH_3CH_2CH_2^+$, $CH_3CH_2CH^+CH_3$, Give reason for your answer.	2
	SECTION-C (SAQ)	

22.	The quantum numbers of four electrons are given below. Arrange them in order of increasing energies. List if any of these combination(s) has/have the same energy. (i) $n = 4, l = 2, m_l = -2, m_s = -1/2$ (ii) $n = 3, l = 2, m_l = 1, m_s = +1/2$ (iii) $n = 4, l = 1, m_l = 0, m_s = +1/2$ (iv) $n = 3, l = 2, m_l = -2, m_s = -1/2$	0.5 x 4 + 1 = 3
23.	Give reason: (i) Atomic radius of Gallium smaller than Aluminium, despite being below it in the group. (ii) Electron gain enthalpy of F is less negative than Cl although F is more electronegative than Cl. (iii) The first ionization enthalpy of Na is lower than Mg but its second ionization enthalpy is higher than that of Mg?	1 x 3 = 3
24.	State the following (i) First law of Thermodynamics (ii) Specific Heat Capacity (iii) Adiabatic Process	1+1+1=3
25.	Balance the following redox reaction (either ion electron method or oxidation number method)- Fe^{2+} (aq.) + MnO_4^- (aq.) + H^+ → Fe^{3+}(aq.) + Mn^{2+} (aq.) + H_2O(l) [In acidic medium] Or P_4 + OH^- (aq.) → PH_3 + HPO_2^- [In basic medium]	3
26.	**(a)** Differentiate between electrophile and nucleophile . Give one example of each. (b) Draw the resonating structure of anyone of the following compounds. Phenol (C_6H_5OH) **or** Benzaldehyde (C_6H_5-CHO) Show the electron shift using curved-arrow notation.	2+1=3
27.	0.3780 g of an organic chloro compound gave 0.5740 g of silver chloride in Carius estimation. Calculate the percentage of chlorine present in the compound.	3
28.	(a) State "Huckel's rule of aromaticity". (b) Write the chemical reaction o**f** the following: (i) Nitration of benzene (ii) Friedel Craft acylation of benzene.	1 + 2
	SECTION-D (CBQ)	
29.	Read the following passage and answer the questions given below the passage: A chemical formula is a symbolic representation of one molecule of the substance which tells the number and kind of atoms of various elements present in its molecule. The determination of the formula of a substance involves first the determination of its "Empirical formula" and then the "Molecular formula". Empirical formula expresses the simplest whole number ratio of the atoms of constituent elements whereas molecular formula expresses the actual number of atoms of constituent elements present in one molecule of the compound. The chemical formula of different substances (i.e., reactants and products) are used to represent a chemical equation. Balanced chemical equation is very useful for theoretical calculation of amount of product from known amount of reactant or vice-versa. It also helps to calculate the percentage of different compounds present in a mixture or percentage purity of a compound or actual percent yield of a product etc. Knowing the concepts of molarity, normality etc., the calculations can be done for	

	reactions in solution also. In many reactions, generally involving two reactants, one of the reactants is completely consumed while some amount of the second reactant is left behind. The former is called limiting reagent while the latter is called excess reagent.	1
	(1) If 500 mL of a 6 M solution is diluted to 1500 mL, what will be the molarity of the solution obtained? (i) 1.5 M (ii) 1.0 M (iii) 2.0 M (iv) 1.6 M	1
	(2) In the reaction: $4X + 2Y + 3Z \rightarrow X_4 Y_2 Z_3$, what will be the number of moles of product formed starting from two mole of X, 0.5 mole of Y and 1.5 moles of Z? (i) 0.25 mol (ii) 0.5 mol (iii) 1.0 mol (iv) 0.20 mol	1
	(3) The empirical formula and molecular mass of a compound are C_2H_4O and 88 g respectively. What will be the molecular formula of the compound? (i) C_3H_6O (ii) C_2H_4O (iii) $C_6H_{12}O_3$ (iv) $C_4H_8O_2$	1
	(4) If the concentration of glucose ($C_6H_{12}O_6$) in blood is 0.9 g L-1 , what will be the molarity of glucose in blood? (i) 5 M (ii) 50 M (iii) 0.005 M (iv) 0.5 M	
30.	**<u>Read the following passage and answer the questions given below the passage:</u>** Spontaneous and Non spontaneous processes. Naturally, all processes have a tendency to occur in one direction under a given set of conditions. A spontaneous process is an irreversible process and it could only be reversed by some external agents. The entropy of any system is defined as the degree of randomness in it. Generally, the total entropy change is the essential parameter which defines the spontaneity of any process. Since most of the chemical reactions fall under the category of a closed system and open system; we can say there is a change in enthalpy too along with the change in entropy. Since, change in enthalpy also or decreases the randomness by affecting the molecular motions, entropy change alone cannot account for the spontaneity of such a process. Therefore, for explaining the spontaneity of a process we use the Gibbs energy change. Gibbs' energy is a state function and an extensive property. Reactions are favourable when they result in a decrease in enthalpy and an increase in entropy of the system. When both of these conditions are met, the reaction occurs naturally. A spontaneous reaction is a reaction that favour the formation of products at the conditions under which the reaction is occurring. A spontaneous process is capable of proceeding in a given direction without needing to be driven by an outside source of energy. An endothermic reaction (also called a non-spontaneous reaction) is a chemical reaction in which the standard change in free energy is positive and energy is absorbed. Based on above paragraph, answer the following questions by choosing correct option: **(i)** Give relationship between enthalpy change, entropy change and Gibb's free energy change. (ii) For a reaction ΔH and ΔS are positive. What is the condition that this reaction occurs spontaneously?	1 1

	(iii) Enthalpy & entropy changes of a reaction are 40.63 KJ mol^{-1} & 108.8 JK^{-1} mol^{-1} respectively. Predict the feasibility of the reaction at 27^0C. **OR** At 0^OC ice and water are in equilibrium and $\Delta H = 6.00$ kJ mol^{-1} for the process $H_2O(s) \rightarrow H_2O(l)$. What will be Δ S and ΔG for the conversion of ice to liquid water?	2
	SECTION-E (LAQ)	
31.	(a) Distinguish between sigma and pi bonds (any two points). Calculate number of sigma (σ) and pi (π) bonds in benzene. (b) Describe hybridisation in the case of PCl_5 and SF_6 according to VBT. The axial bonds are longer than the equatorial bonds in PCl_5 whereas in SF_6 both axial bonds and equatorial bonds have the same bond length. Explain. Or (a) Explain why CO_3^{2-} ion cannot be represented by a single Lewis structure. How can it be best represented? (b) Using the molecular orbital theory, compare the bond order, stability and magnetic character of O^{2+} and O^{2-} species.	1+1 1+1+1 1+1 ½ x 6 =3
32.	(a) A mixture of 2.0 mol of N_2 , 2.0 mol of H_2 and 8.0 mol of NH_3 is introduced into a 10 L reaction vessel at 500 K. At this temperature, the equilibrium constant, K_c for the reaction: N_2 (g) + 3 H_2(g) $\Leftrightarrow$ 2 NH_3 (g) is 1.7 x 10^2. Is the reaction mixture at equilibrium? If not, what is the direction of net reaction? (b) HI is stronger acid as compared to HF. Why? (c) Find the conjugate acid/base for the species: NH_4^+ and CO_3^{2-}. Or (a) Explain the following (i) Buffer solution (ii) Common ion effect (b) Mention at least three ways by which the concentration of SO_3 can be increased after the equilibrium is established in the following reaction: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ + Heat.	2 1 2 2 3
33.	(a) An alkene A on ozonolysis gives a mixture of propanal and pentan-3-one. Write the structural formula and IUPAC name of A. (b) Complete the following reactions: (i) $CH_3CH_2CH=CH_2$ + HBr (in the presence of organic peroxide) → ? (ii) $2CH_3CH_2Br$ + 2Na (in dry Ether) → ? (c)What happens when ethyne is passed through red hot iron tube at 873 K. Give chemical equation. Or **(a)** How t**he following conversions can be carried out** (i) Methane to ethane (ii) Ethyne to ethanal (a) Draw eclipsed and staggered Newman's projections of ethane. (b) What happens when benzene reacts with chlorine (excess) under ultra violet light. Give chemical reaction.	2 2 1 2 2 1

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SAMPLE QUESTION PAPER :2026-27

CLASS-XI

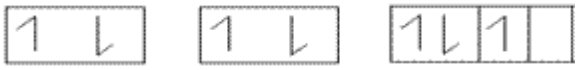
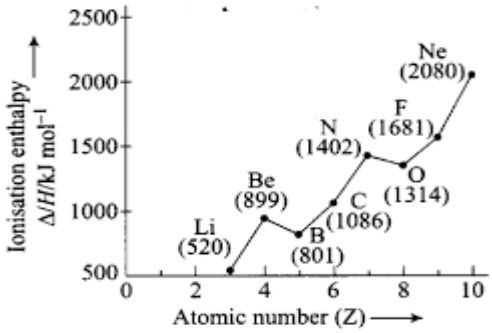
SUBJECT- CHEMISTRY

SET-02

TIME: 3 HOURS **M. MARKS: 70**

Q No	Section-A (16x1 = 16 marks)	Marks
1	Which of the following has the highest mass? a) 1 mole of O_2 b) 1 mole of H_2O c) 1 mole of CO_2 d) 1 mole of CH_4	**1**
2	If 4 g of dihydrogen reacts with 16 g of dioxygen to form water, what is the mass of water formed? (a) 32 g b) 36 g c) 18 g d) 20 g	**1**
3	**The Correct order of size of the given species?** **(a) I^+ > I^- > I** **(b) I^- > I^+ > I** **(c) I^- > I > I^+** **(d) I > I^+ > I^-**	**1**
4	**The type of hybridization in ammonia (NH_3) is:** a) sp b) sp^2 c) sp^3 d) sp^3d	**1**
5	If the concentration of a reactant is decreased in a system at equilibrium, the equilibrium will shift: a) To the left, favouring the reactants b) To the right, favouring the products c) No shift will occur d) The equilibrium will be disturbed and no shift will happen.	**1**
6	When a solution of sodium acetate is added to a solution of acetic acid, the ionization of acetic acid is suppressed. This phenomenon is an example of a) Le Chatelier's Principle b) Common Ion Effect c) Dynamic equilibrium d) Van't Hoff factor	**1**
7	What is the oxidation number of aluminium in $LiAlH_4$? a) +1 b) +3 c) -5 d) 0	**1**
8	What is the IUPAC name of **CH_3-O-CH_2CH_3?** a) Ethyl methyl ether b) Methoxyethane c) Methyl Ethyl ether d) Ethoxymethane	**1**
9	Which of the following is true for an **adiabatic** process? a) q=0 b) $\Delta S=0$ c) PV=constant d) T is constant	**1**
10	Which of the following statements is correct? a) $\Delta G>0$, the process is spontaneous. b) $\Delta G=0$, the system is at equilibrium. c) $\Delta G<0$, the process is non-spontaneous.	**1**

	d) ΔH>0, the process is always spontaneous.	
11	The addition of HCl to propene in presence of peroxide, the major product is: a) **1-Chloropropane** b) **2-Chloropropane** c) **Propane** d) **3-Chloropropane**	**1**
12	Which of the following statements is correct about the Wurtz reaction? a) It is used to prepare alkenes by the reaction of alkyl halides with sodium metal in ether. b) It is used to prepare alkanes by the reaction of alkyl halides with sodium metal in ether. c) It is used to prepare alcohols by the reaction of aldehydes with Grignard reagents. d) It is used to prepare alkynes by the reaction of alkyl halides with sodium metal.	**1**
13	**Assertion (A): The 4s orbital is filled before the 3d orbital.** **Reason (R): The energy of the 4s orbital is lower than that of the 3d orbital.** (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) Assertion is correct, but Reason is incorrect. (d) Assertion is incorrect, but Reason is correct.	**1**
14	**Assertion (A): The bond angle in the water molecule (H_2O) is 104.5°.** **Reason (R): The water molecule has two lone pairs of electrons on oxygen, which cause repulsion and reduce the bond angle.** (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) Assertion is correct, but Reason is incorrect. (d) Assertion is incorrect, but Reason is correct.	**1**
15	**Assertion (A): The IUPAC name of C_6H_5OH is Benzyl alcohol.** **Reason (R): The presence of an -OH group on a benzene ring is called phenol in IUPAC nomenclature.** (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) Assertion is correct, but Reason is incorrect. (d) Assertion is incorrect, but Reason is correct.	**1**
16	**Assertion (A): Lower alkanes (C1 to C4) exist as gases at room temperature.** **Reason (R): The boiling points of alkanes increase with an increase in molecular weight due to Van der Waals forces.** **(**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) Assertion is correct, but Reason is incorrect. (d) Assertion is incorrect, but Reason is correct.	**1**

	Section-B (5x2 = 10 marks)	
17	Write the main postulates of Dalton's atomic theory.	**2**
18	State Modern periodic law and Mendeleev's periodic law.	**2**
19	The pK_a of acetic acid and the pK_b of ammonium hydroxide are 4.76 and 4.75 respectively. Calculate the P^H of ammonium acetate solution. OR Calculate the P^H of 1 X 10^{-8} M HCl solution at 298 K assuming complete dissociation. (log 1.1 = 0.0414 log 10 =1)	**2**
20	Define Hyperconjugation and Inductive effect.	**2**
21	An alkene on ozonolysis gives ethanal only . Write the structure and IUPAC name of alkene.	**2**
	Section - C (7x3 = 21 marks)	
22	A compound contains 4.07 % hydrogen ,24.27% carbon and 71.65 % chlorine. Its molar mass is 99 g. What are Its empirical and molecular formulas? **Or** Chlorine is prepared in the laboratory by treating manganese dioxide (MnO_2) with aqueous hydrochloric acid according to the reaction: $4HCl\ (aq) + MnO_2(s) \rightarrow 2H_2O(l) + MnCl_2(aq) + Cl_2(g)$ How many grams of HCl react with 5.0 g of manganese dioxide? (Molar mass of Mn =55g/mol Cl=35.5 g/mol)	**3**
23	(a) Write the four quantum numbers for the unpaired electron of Chlorine atom (Cl , Z = 17). (b) Write Name & the rule due to which following electronic configuration for Nitrogen is not possible. 	**3**
24	Interpret the graph and answer the following.  a) Why is the first ionization energy of nitrogen more than that of oxygen? b) Arrange the following elements in increasing order indicated properties. i. Li, Be, B, C (First Ionisation Enthalpy) ii. Li, Be, B, C (Metallic Character)	**3 (1+2)**

25	.(a) Define entropy. (b) Predict in the following process, entropy increases/decreases: H_2 (g) → 2H(g) $2NaHCO_3$ (s) → Na_2CO_3 (s) + CO_2 (g)+ H_2O (g)	**3**
26	a) Write the conjugate acid and conjugate base of ammonia. b) Derive the relationship $K_p = K_c (RT)^{\Delta n}$	**3** **(1+2)**
27	Permanganate ion reacts with bromide ion in basic medium to give manganese dioxide and bromate ion. Write the balanced ionic equation for the reaction.	**3**
28	a) Why is an isomeric tertiary carbocation more stable than a primary carbocation? b) Out of formic acid and acetic acid which is more acidic & why? c) Why is But -2-ene more stable than But-1-ene?	**3**
	Section - D (2x4 = 8 marks) The following questions are case-based questions. With internal choice in one question of both case based study question and carries 4 (2+1+1) marks each.	
29	A student is tasked with determining the enthalpy of formation of methane $CH_4(g)$ using Hess's Law. To do this, the student gathers the following information about the enthalpy of combustion of methane, graphite (solid carbon), and hydrogen gas at 298 K: • Enthalpy of combustion of methane ($CH_4(g)$): –890 kJ/mol • Enthalpy of combustion of graphite (C): –393 kJ/mol • Enthalpy of combustion of hydrogen (H_2): –286 kJ/mol The student understands that the enthalpy of formation of a substance is the enthalpy change when one mole of the substance is formed from its elements in their standard states. In the case of methane, the elements are carbon (graphite) and hydrogen (H_2), and the formation reaction is: $C(s)+2H_2(g) \rightarrow CH_4(g)$ Using Hess's Law, which states that the total enthalpy change for a reaction is the sum of the enthalpy changes for the steps that lead to that reaction, the student reverses the combustion reactions of methane, graphite, and hydrogen to achieve the formation of methane from its elements. **Based on above paragraph answer the following.** (a) The enthalpy of combustion of methane, graphite and dihydrogen at 298 K are, –890 kJ mol^{-1} , –393 kJ mol^{-1}, and –286 kJ mol^{-1} respectively. Calculate the enthalpy of formation of $CH_4(g)$. **OR** For a reaction at 298 K 2 A + B →C ΔH = 400 kJ mol^{-1} and ΔS = 0.02 kJ K^{-1} mol^{-1}.At what temperature will the reaction become spontaneous considering ΔH and ΔS to be constant over the temperature range ? (b) Which of following has/have zero enthalpy under standard conditions? 1) $CH_4(g)$ 2)O_2 (g) 3)CO_2 (g) 4)H_2O (l) (c) State Hess's law of constant heat of summation.	**2** **1** **1**

30	In the field of organic chemistry, determining the elemental composition of compounds is crucial for understanding their structure and reactivity. Two well-known methods used for this purpose are the Carius method and the Dumas method. The Carius method is primarily used for determining the percentage of halogens (like chlorine, bromine, and iodine) in organic compounds. In this method, a known mass of the organic compound is placed in a sealed tube along with excess fuming nitric acid and sodium or potassium chlorate . The sealed tube is then heated. The halogen in the compound reacts with the chlorate to form a halogenated acid, which is then separated and analysed to determine the amount of halogen present in the sample. The amount of halogen is calculated based on the volume of the halogenated acid formed. The Dumas method, on the other hand, is a technique used for determining the nitrogen content in organic compounds. This method involves heating a known mass of the compound in a combustion tube with excess copper oxide (CuO) in the presence of oxygen. The nitrogen in the compound is oxidized to nitrogen gas (N_2), which is collected and measured. The volume of nitrogen gas obtained is then used to calculate the percentage of nitrogen in the compound. This method is particularly useful for determining nitrogen content in organic compounds such as proteins and amines. Both methods are widely used in qualitative analysis for determining the elemental composition of organic compounds. While the Carius method is specific to halogens, the Dumas method is commonly used for nitrogen, helping chemists in the analysis of complex organic molecules. **Based on above paragraph answer the following.**	**2**
	(a) In Carius method of estimation of halogen 0.15 g of an organic compound gave 0.12g of AgBr . Find out the percentage of bromine in the compound. **OR** 0.26 g of an organic compound gave 0.39 g of water and 0.245 g of carbon dioxide on combustion. Find out the percentage of C and H in the organic compound . (b) In the Dumas method for determining nitrogen content, the nitrogen in the organic compound is oxidized to which of the following gases? a) Ammonia b) Nitrogen dioxide c) Dioxygen d) Nitrogen gas (c) Which of the following element is not estimated by Carius method? (a) Sulphur (b)Nitrogen (c)Phosphorous (d)Halogen	**1** **1**
	Section - E (3x5 = 15 marks)	
31	a) Write four quantum numbers of 11^{th} electron of Na atom. b) Calculate number of radial nodes in 4s orbital. c) Calculate the wavelength of an electron moving with a velocity of 2.0×10^6 m/s. (Mass of electron = 9.11×10^{-31} kg, Planck's constant h = 6.626×10^{-34} Js). **OR** **a)** Write the electronic configuration of (a) Cu (Z=29) (b) Fe^{3+} (Z=26) **b)** Explain why Cu (Z = 29) and Cr (Z = 24) show anomalous electronic configurations. **c)** Using the quantum mechanical model, determine the total number of electrons that can be present in the following quantum states: a) n=3 l=1 b) n=4 l=2	**2** **1** **2** **2** **1** **2**
32	Calculate No. of sigma and pi bond in following: a) (i) $CH_2 = CH - CHO$ (ii) CH_3COOCH_3 b) Write the electronic configuration of F_2^+ based on MOT. c) Which out of NH_3 and NF_3 has higher dipole moment and why? d) Draw the shapes of sp, sp^2 hybrid orbitals.	**2** **1** **1** **1**

	OR a) Define the term bond order. Calculate the bond order of O_2 & O_2^+ . b) What is the hybrid state of : (i) S in SF_4 (ii) C in CO_2 ?, Also draw the geometry of each molecule according to VSEPR theory.	**3** **2**
33	Write all possible structures and IUPAC names of different structural isomers of alkenes corresponding to C_5H_{10} . **OR** (i) Convert a) Benzene to Cyclohexane b) Benzene to Toluene c) Benzene to Nitrobenzene (ii) Write chemical equations for combustion reaction of the following hydrocarbons: (a) Methane (b) Butane	**5**

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SAMPLE QUESTION PAPER :2026-27
CLASS-XI
SUBJECT- CHEMISTRY
SET-03

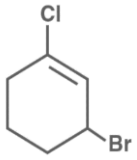
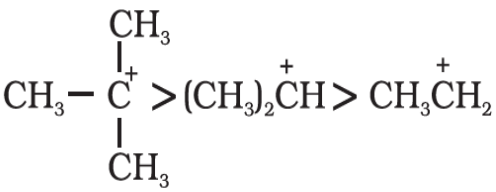
Max. Marks: 70 **Time: 3 Hours**

SECTION-A

Question 1 to 16 is multiple choice questions. Only one of the choices is correct. Select and write the correct choice as well as the answer to these questions.

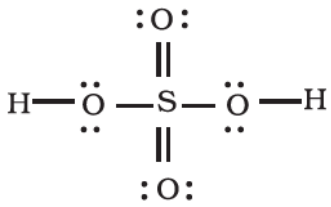
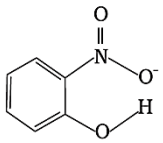
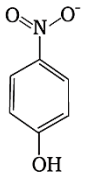
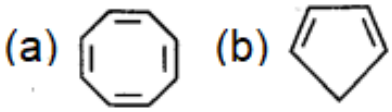
1	According to Modern periodic law physical and chemical propertoes of element are periodic function of their !) atomic masses 2) atomic number 3) both 4) none	**[1]**
2	But-1-ene and 2-methylprop-1-ene exhibit which type of isomerism? (a) Position isomerism (b) Functional isomerism (c) Chain isomerism (d) Metamerism	**[1]**
3	Maximum dipole moment possessing molecule is (a) CO_2 (b) BeH_2 (c) H_2O (d) BF_3	**[1]**
4	Given: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$; $\Delta rH^0 = -92.4$ kJ mol^{-1} The standard enthalpy of formation of NH_3 gas is (a) – 92.4 kJ mol^{-1} (b) – 46.2 kJ mol^{-1} (c) –184.8 kJ mol^{-1} (d) – 23.1 kJ mol^{-1}	**[1]**
5	The number of atoms present in one mole of an element is equal to Avogadro number. Which of the following element contains the lowest number of atoms? (a) 24 g He (b) 46 g Na (c) 0.40g Ca (d) 12 g Mg	**[1]**
6	Given the standard electrode potentials, $K^+/K = -2.93V$, $Ag^+/Ag = 0.80V$, $Hg^{2+}/Hg = 0.79V$, $Mg^{2+}/Mg = -2.37V$. $Cr^{3+}/Cr = -0.74V$ Which of the following represents the increasing order of reducing power of these metals? (a) K < Mg < Cr < Hg < Ag (b) Hg < Ag < Cr < Mg < K (c) Cr < Ag < Hg < Mg < K (d) Ag < Hg < Cr < Mg < K	**[1]**
7	The de-Broglie wavelength associated with a body of mass 1000 g moving with a velocity of 100 m s^{-1} is (Given: Planck's constant, h = 6.62 × 10^{-34} J s) (a) 6.62 x 10^{-39} m (b) 6.62x 10^{-36} m (c) 6.62 x 10^{39} m (d) 6.62x 10^{36} m	**[1]**
8	Among the following species, identify those that can function as Lewis acids: (i) H_2O (ii) BF_3 (iii) H^+ (iv) NH_3 Select the correct option: (a) (i) and (ii) (b) (ii) and (iv) (c) (ii) and (iii) (d) (i) and (iv)	**[1]**
9	Number of sigma and pi bonds present in benzene are (a) 12 & 3 respectively (b) 10 & 3 respectively (c) 9 & 3 respectively (d) 12 & 6 respectively	**[1]**
10	A hydrocarbon was found to contain 75% by mass of carbon and 25% by mass of hydrogen. The empirical formula of the compound is (a) CH_4 (b) C_2H_4 (c) C_3H_8 (d) C_2H_6	**[1]**
11	On the basis of thermochemical equations (i), (ii) and (iii), find out which of the algebraic relationships given in options (a) to (d) is correct. (i) C (graphite) + ½ O_2 (g) ⟶ CO (g); ΔrH = **x** kJ mol^{-1} (ii) CO (g) +½ O_2 (g) ⟶ CO_2 (g); ΔrH = **y** kJ mol^{-1}	**[1]**

	(iii) C (graphite) + O_2 (g) $\longrightarrow$ CO_2 (g); $\Delta rH = \mathbf{z}$ kJ mol^{-1} (a) z = x + y (b) x = y + z (c) y = x + z (d) y = 2z – x	
12	The equilibrium $CaO(s) + CO_2(g) \rightleftharpoons CaCO_3(s)$ when subjected to a decrease in pressure will: (a) Shift towards right (b) Shift towards left (c) Show no effect on equilibrium (d) Increase the number of moles of solid products	**[1]**
13	Given below are two statements labelled as Assertion (A) and Reason (R) **Assertion (A):** The net dipole moment of NF_3 is lesser than that of NH_3. **Reason (R):** NF_3 has no lone pair on nitrogen, while NH_3 has a lone pair. Select the most appropriate answer from the options given below: (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true but R is not the correct explanation of A. (c) A is true but R is false. (d) A is false but R is true.	**[1]**
14	Given below are two statements labelled as Assertion (A) and Reason (R) **Assertion (A):** Aniline is purified from an aniline–water mixture by simple distillation. **Reason (R):** Aniline is immiscible with water. Select the most appropriate answer from the options given below: (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true but R is not the correct explanation of A. (c) A is true but R is false. (d) A is false but R is true.	**[1]**
15	Given below are two statements labelled as Assertion (A) and Reason (R) **Assertion (A):** Isobars have the same mass number but belong to different elements. **Reason (R):** Isobars have the same number of neutrons. Select the most appropriate answer from the options given below: (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true but R is not the correct explanation of A. (c) A is true but R is false. (d) A is false but R is true.	**[1]**
16	Given below are two statements labelled as Assertion (A) and Reason (R) **Assertion (A):** The empirical mass of ethene is half of its molecular mass. **Reason (R):** The empirical formula represents the simplest whole number ratio of various atoms present in a compound.	**[1]**
	SECTION B	
Question No. 17 to 21 are very short answer questions carrying 2 marks each.		
17	(i) Considering the atomic number and position in the periodic table, arrange the following elements in the increasing order of non-metallic character: N, P, O and S (ii) In terms of period and group where would you locate the element with atomic number (Z) =114?	**[2]**
18	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: $2N_2(g) + O_2(g) \longrightarrow 2N_2O(g)$ Which law is being obeyed in this experiment? Write the statement of the law.	**[2]**

19	**Attempt either option A or B** **A. Answer the following:** (i) The concentration of hydrogen ion in a sample of soft drink is 3.8×10^{-3}M. what is its pH (ii) Predict if the solution of the following salts are neutral, acidic or basic: (a) CH_3-COONa **Or** **B. Answer the following:** (i) The species HSO_3^- can act both as Bronsted acid and Bronsted base. Write its corresponding conjugate acid and conjugate base. (ii) What are buffer solutions?	**[2]**
20	(i) Draw Sawhorse projections of ethane. (ii) Give the correct order of acidity for the following carboxylic acids (For electron displacement effect) $Cl_2CHCOOH$, $ClCH_2COOH$,Cl_3CCOOH	**[2]**
21	Calculate the entropy change in surroundings when 1.00 mol of $H_2O(l)$ is formed under standard conditions. $\Delta_f H^\theta = -286$ kJ mol^{-1}.	**[2]**
	SECTION C **Question No. 22 to 28 are short answer questions, carrying 3 marks each.**	
22	What is limiting reagent? Zinc and hydrochloric acid react according to the reaction: $Zn + 2HCl \rightarrow ZnCl_2 + H_2$ If 0.30 mol of Zn are added to hydrochloric acid containing 0.52 mol of HCl, how many moles of H_2 are produced? **Or** The mass percent of nitric acid in an aqueous solution is 69%. Determine its molality. What will be the effect on its molality if the temperature of the solution is increased by 10°C?	**[3]**
23	(i) Identify the reagents shown in bold in the following equation as nucleophile or electrophile: $CH_3COOH + \mathbf{OH^-} \rightarrow CH_3COO^- + H_2O$ (ii) Write the IUPAC name of following compound:  (iii) The order of stability of the following ionic species is given below. Explain the reason for this order of stability. 	**[3]**
24	Using the ion–electron method, balance the following reaction in acidic medium and state the oxidising agent and reducing agent involved. $MnO_4^-{}_{(aq)} + Fe^{2+}{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + Fe^{3+}{}_{(aq)}$	**[3]**

25	(i) In the Balmer series of hydrogen, identify the initial and final energy levels for the transition that produces the longest wavelength. (ii) Yellow light emitted from a sodium lamp has a wavelength of 580 nm. Calculate the frequency and wavenumber of the yellow light.	**[1]** **[2]**
26	The value of Kc for the reaction 2HI (g) $\rightleftharpoons$ H_2 (g) + I_2 (g) is 1×10^{-4}. At a given time, the composition of reaction mixture is [HI] = 2×10^{-5} M, [H_2] = 1×10^{-5} M and [I_2] = 1×10^{-5} M. (i) In which direction will the reaction proceed? (ii) What is Kc for the reverse reaction?	**[3]**
27	(a) Why is Ga smaller in size than Al? (b) Give reason for the following (i) F has lower electron gain enthalpy than Cl. (ii) Ionization enthalpy of N is higher than O.	**[3]**
28	(i) Predict the product of the following reaction: $CH_3C{\equiv}CH + H_2 \xrightarrow{Pd/C}$ (ii) Draw the Cis and Trans isomers of but-2-ene and identify the isomer which has higher boiling point.	**[1]** **[2]**
	SECTION D **Question No. 29 & 30 are case-based/data -based questions carrying 4 marks each.**	
29	The set of numbers used to describe the position and energy of the electron in an atom are called quantum numbers. There are four quantum numbers, namely, principal (n), azimuthal (l), magnetic (m_l) and spin quantum numbers (m_s). With the help of quantum numbers electronic configuration may be assessed. Quantum numbers can be used to completely describe all the attributes of a given electron belonging to an atom, The arrangement of the orbitals is based upon the energy based on the (n + l) value. The lower the value of the (n + l), the lower energy found. For orbitals with equal values of (n + l), the orbital with the lower value of n will have the lower energy. **Answer the following questions:** (i) The atomic number of potassium is 19. Based on its electronic configuration, write the values of the four quantum numbers for its valence electron. (ii) Name and state the principle that determines the sequence in which electrons occupy orbitals of different energies. **Attempt either (iii) or (iv)** (iii) The electrons, identified by quantum numbers n and l, (i) n = 4, l = 1, (ii) n = 4, l = 0, (iii) n = 3, l = 2, and (iv) n = 3, l = 1 can be placed in order of increasing energy, from the lowest to highest, as (a) (iv) < (ii) < (iii) < (i) (b) (ii) < (iv) < (i) < (iii) (c) (i) < (iii) < (ii) < (iv) (d) (iii) < (i) < (iv) < (ii) **Or** (iv) Which of the following orbitals has the highest energy? Give reason. 7s, 5d, 5f, 6s, 6p	**[2]** **[1]** **[1]**

30	After purification, organic compounds can be analyzed to determine the elements present and their quantities. Nitrogen, sulphur, halogens, and phosphorus are detected using Lassaigne's test. Carbon and hydrogen are estimated by measuring the amounts of carbon dioxide (CO_2) and water (H_2O) produced on combustion. Nitrogen can be quantified using Dumas or Kjeldahl's method, while halogens are determined by the Carius method. Sulphur and phosphorus are estimated by converting them into sulphuric acid and phosphoric acid, respectively. **Answer the following questions:** Attempt either **(i) or (ii)** (i) Name the method used for the quantitative estimation of nitrogen in nitrobenzene. **Or** (ii) A violet colour with sodium nitroprusside in Lassaigne's extract indicates the presence of which element? (iii) Why is an organic compound fused with metallic sodium in Lassaigne's test before testing for nitrogen, sulphur, and halogens? (iv) In Carius method of estimation of halogen, 0.15 g of an organic compound gave 0.12 g of AgBr. Find out the percentage of bromine in the compound. (Atomic mass of Ag =108, Br = 80)	**[1]** **[1]** **[2]**
	SECTION E **Question No. 31 to 33 are long answer type questions carrying 5 marks each.**	
31	**Attempt either A or B** **A. Answer the following questions:** (i) Express the change in internal energy of a system when 'w' amount of work is done on the system and 'q' amount of heat is supplied by the system. What type of system would it be? (ii) Out of mass and density which is an intensive property and why? (iii) For a reaction at 298 K $2X + Y \rightarrow Z$; $\Delta H = 400$ kJ mol^{-1} and $\Delta S = 200$ J K^{-1} mol^{-1}. At what temperature will the reaction become spontaneous considering ΔH and ΔS to be constant over the temperature range? **Or** B. **Answer the following questions:** (i) For the reaction; $2H(g) \rightarrow H_2(g)$; what will be the signs of ΔH and ΔS? (ii) Identify the path functions out of the following: enthalpy, entropy, heat, temperature, work, free energy. (iii) The reaction of cyanamide, $NH_2CN(s)$ with dioxygen was carried out in a bomb calorimeter and ΔU was found to be -742.7 KJ mol^{-1} at 298 K. Calculate the enthalpy change for the reaction at 298 K. $NH_2CN(s) + 3/2O_2(g) \rightarrow N_2(g) + CO_2(g) + H_2O(l)$.	**[1]** **[1]** **[3]** **[1]** **[1]** **[3]**
32	**Attempt either A or B** **A. Answer the following questions:** (i) Draw the resonance structures for nitrite ion (NO_2^-). (ii) Mention the hybridisation in the case of SF_6. (iii) Arrange the bonds in order of increasing ionic character in the molecules: LiF, K_2O, N_2, SO_2 and ClF_3 (iv) Which of the following molecules are linear?	**[5]**

	XeF_2 , H_2O, $BeCl_2$, $CH_2=CH_2$ (v) Calculate the formal charge on the S-atom in the following Lewis structure of H_2SO_4:  **Or** **B. Answer the following questions:** (i) Given below are the structures of two compounds. Identify the compound that shows intramolecular hydrogen bonding and justify your answer.  (I)  (II) (iii) Using VSEPR theory, deduce the shape of BrF_5. (iii) State which of the following oxygen species is/ are diamagnetic: O_2, O_2^+, O_2^- (superoxide), and O_2^{2-} (peroxide) (iv) Why are the axial bonds in the PCl_5 longer than the equatorial bonds? (v) What is the total number of sigma and pi bonds in C_2H_2 molecule?	**[5]**
33	**Attempt either A or B** **A. Answer the following questions:** (i) Write the structure of the products obtained by the ozonolysis of 1-Phenylbut-1-ene. (ii) Draw cis and trans isomers of the following compound: $CH_3CH = CHCH_3$ (iii) What is Kharash effect? Explain the addition of HBr to propene with the help of a suitable mechanism. **Or** **B. Answer the following questions:** (i) State whether the following systems are aromatic or not. Give reason for your answer.  (ii) Which sodium salt of a carboxylic acid is used for the preparation of ethane by decarboxylation? Write the chemical equation involved. (iii) How are the following conversions carried out? (a) Hexane to benzene (b) Benzene to m-chloronitrobenzene.	**[1]** **[1]** **[3]** **[1]** **[2]** **[2]**

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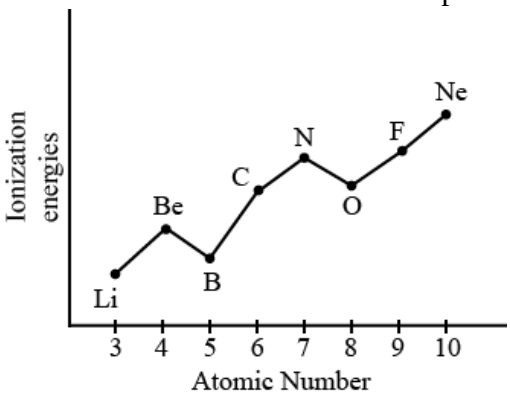
SAMPLE QUESTION PAPER :2026-27
CLASS-XI
SUBJECT- CHEMISTRY
SET-04

Max. Time:-3 Hours Max.Marks:-70

SECTION A

The following questions are multiple-choice questions with one correct answer. Each question carries 1 mark. There is no internal choice in this section.

1.	The number of moles present in 7.2 gm of carbon is: a. 2 b. 0.5 c. 0.6 d.1	1
2.	The number of significant figures in 7.04×10^{32} is : a. 23 b. 26 c. 3 d. 4	1
3	Which of the following statements does not form a part of Bohr's model of hydrogen atom: a. Energy of the electrons in the orbit is quantized. b. The electron in the orbit nearest the nucleus has the lowest energy c. Electron revolves in different orbits around the nucleus. d. The position and velocity of the electrons in the orbit cannot be measured simultaneously.	1
4.	Which one of the following Heterocyclic aromatic compound contain Nitrogen ? (a) Thiophene (b) Pyridine (c) Furan (d) Toluene	1
5.	The following graph shows the variation of first ionization enthalpy with the atomic number of elements of the second period (Li- Ne).  The higher first ionization enthalpy of nitrogen compared to oxygen is due to a. High electronegativity of nitrogen. b. Smaller atomic radii of nitogen. c. Stable half filled electronic configuration of nitrogen. d. Higher nuclear charge of nitrogen	1
6	In which of the following octet rule is not followed? a. NO b. CH_4 c. NH_3 d. CO_2	1
7	In a reversible process the system absorbs 600kJ heat and performs 250kJ work on the surroundings. What is the increase in the internal energy of the system? a. 850kJ b. 600kJ c. 350kJ d. 250kJ	1
8	Which one of the following alkane can not be prepared by Wurtz reaction? (a) Butane (b) Propane (c) Ethane (d) Hexane	1
9	White P_4 reacts with caustic soda, the products are PH_3 and NaH_2PO_2. The reaction is an example of: (a) Oxidation b. Reduction c. Disproportionation d. Neutralization	1
10	If Qc > Kc, the reaction proceeds in the :	1

	a. forward reaction b. backward reaction c. at equilibrium d) none	
11	Solubility of an MX_2 type electrolyte is 0.5×10^{-4} mol/L, then Ksp of the electrolyte is : a. 5×10^{-12} b. 25×10^{-10} c. 1×10^{-13} d. 5×10^{-13}	1
12	During lassaigne's test the elements sulphur and nitrogen present in an organic compound change into: a. Na_2S and NaCN b. Na_2SO_4 and NaCN c. Na_2S and NaCNO d. NaCN and NaCNO	1
13	Given below are two statements labelled as Assertion (A) and Reason (R) Select the most appropriate answer from the options given below: Assertion (A): The position of an electron can be determined exactly with the help of an electron microscope. Reason (R) : The product of uncertainty in the measurement of its momentum and the uncertainty in the measurement of the position can not be less than a finite limit. a. Both A and R are true, and R is the correct explanation of A b. Both A and R are true, but R is not the correct explanation of A. c. A is true, but R is false. d. A is false, but R is true.	1
14	Given below are two statements labelled as Assertion (A) and Reason (R) Assertion (A): Enthalpy of formation of graphite is zero but of diamond it is not zero. Reason (R) : Enthalpy of formation of the most stable allotrope is taken as zero. Select the most appropriate answer from the options given below: a. Both A and R are true, and R is the correct explanation of A b. Both A and R are true, but R is not the correct explanation of A. c. A is true, but R is false. d. A is false, but R is true.	1
15	Given below are two statements labelled as Assertion (A) and Reason (R) Assertion (A): Propanone and propanal are functional group isomerism Reason (R) : Functional group isomerism differ in the position of functional group or a substituent. Select the most appropriate answer from the options given below: a. Both A and R are true, and R is the correct explanation of A b. Both A and R are true, but R is not the correct explanation of A. c. A is true, but R is false. d. A is false, but R is true.	1
16	Given below are two statements labelled as Assertion (A) and Reason (R)Assertion (A): According to Mendeleev periodic properties of elements is a periodic function of their atomic number. Reason (R): Atomic number is equal to number of protons. Select the most appropriate answer from the options given below: a. Both A and R are true, and R is the correct explanation of A b. Both A and R are true, but R is not the correct explanation of A. c. A is true, but R is false. d. A is false, but R is true.	1

SECTION B

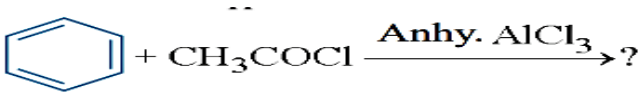
This section contains 5 questions with internal choice in two questions. The following questions are very short answer type and carry 2 marks each.

<table>
<tr><td>17</td><td>(i) Out of LiF and K_2O, which one has more ionic character and why ?
(ii) How many sigma and pi bonds are present in Propene?
OR
(i) Why does He_2 not exit?
(ii)
<table><tr><td>Species</td><td>N_2</td><td>O_2^{2--}</td><td>C_2</td></tr><tr><td>Bond Order</td><td>3</td><td>1</td><td>2</td></tr></table>Arrange the above species in the decreasing order of bond energy.</td><td>2*
1</td></tr>
<tr><td>18</td><td>Calculate the mass of methane required to produce 0.5 moles of CO_2(g) after complete combustion ?</td><td>2</td></tr>
<tr><td>19</td><td>The value of Kc for the reaction
$2A \rightleftharpoons B + C$ is $2x10^{-3}$. At a given time, the composition of reaction mixture is [A] = [B] = [C] = $3x\ 10^{-4}$ M. In which direction the reaction will proceed?</td><td>2</td></tr>
<tr><td>20</td><td>(i) Comment on the spontaneity of a process when ΔH is less than zero and $T\Delta S$ is greater than zero..
(ii) Enlist any two factors on which heat capacity (C) depends.</td><td>2*
1</td></tr>
<tr><td>21</td><td>(i) Which type of structural isomerism is shown between given pair of molecules? (a) $CH_3OC_3H_7$ and $C_2H_5OC_2H_5$ (ii CH_3COCH_3 and C_2H_5CHO
(ii) Arrange the following in decreasing order of acidic strength:
Cl_3CCOOH , $Cl_2CHCOOH$, $ClCH_2COOH$</td><td>2
*1</td></tr>
</table>

SECTION C

This section contains 7 questions with internal choice in two questions. The following questions are short answer type and carry 3 marks each

<table>
<tr><td>22</td><td>a) State Heisenberg`s uncertainty principle
b) If the velocity of the electron in Bohr's first orbit is $3.12 \times 10^6\ ms^{-1}$. Calculate the de Broglie wavelength associated with it.</td><td>1+
2</td></tr>
<tr><td>23</td><td>(a) Balance the following equations by ion-electron method :
P_4 (s) + OH^-(aq) $\rightarrow$ PH_3 (g) + $H_2PO_2^-$ (aq) (Basic medium)
OR
(a) MnO_4^- (aq) + SO_2 (g) $\rightarrow$ Mn^{2+} (aq) + HSO_4^- (aq) (Acidic medium)</td><td>3</td></tr>
<tr><td>24</td><td>What is the concentration of Glucose ($C_6H_{12}O_6$) in mol/L when its 25 g are dissolved in water to make a final volume up to 2L.</td><td>3</td></tr>
<tr><td>25</td><td>Observe tabular data given below and predict :
(i) Which one is having higher dipole moment ?
(ii)What is the cause of higher dipole of one species over other?
<table><tr><td>Species</td><td>NH_3</td><td>NF_3</td></tr><tr><td>Dipole moment</td><td>$4.90 * 10^{-30}$Cm</td><td>$0.80 * 10^{-30}$Cm</td></tr></table></td><td>3</td></tr>
<tr><td>26</td><td>a) Calculate the PH of a solution prepared by dissolving 0.3 g of Ca(OH)2 in water to give 500 mL of solution. (log of 625 = 2.79, log 10 = 1)
b) What will be the conjugate bases for the following Bronsted acids:
$HCOO^{---}$ and HCO_3^{--}</td><td>2+
1</td></tr>
<tr><td>27</td><td>a) Write the correct structure for the following compound having the IUPAC names of :
(i) 2-Amino-3-methylbutanoic acid (ii) Pent-4-en-2-ol</td><td>1+
2</td></tr>
</table>

	b) What in brief about no bond resonance ? OR a) Give reason why $C^+(CH_3)_3$ is more stable than $CH^+(CH_3)_2$ b) Write resonance structures of CH_2CHCHO and arrange contributing structures in decreasing order of stability.	
28	a)  b) Distinguish chemically butyne and but-2-yne. c) Give the products of ozonolysis of but-1-ene.	1+ 1+ 1

SECTION D

The following questions are case-based questions. Each question has an internal choice and carries 4 (1+1+2) marks each. Read the passage carefully and answer the questions that follow.

29	A quantitative measure of the tendency of an element to lose electron is given by its Ionization Enthalpy. It represents the energy required to remove an electron from an isolated gaseous atom (X) in its ground state. The ionization enthalpy is expressed in units of kJ mol–1. We can define the second ionization enthalpy as the energy required to remove the second most loosely bound electron. Energy is always required to remove electrons from an atom and hence ionization enthalpies are always positive. a. What is the basic difference between the term Ionization enthalpy and electron gain enthalpy. b. How ionization enthalpy related to screening effect. c. Explain why (i) Be has higher ionization enthalpy than B (ii) O has lower ionization enthalpy than N. OR What is the significance of the term isolated gaseous atom and ground state while defining the ionization enthalpy.	4
30	The elements present in organic compounds are carbon and hydrogen. In addition to these, they may also contain oxygen, nitrogen, sulphur, halogens and phosphorus. Nitrogen, sulphur, halogens and phosphorus present in an organic compound are detected by "Lassaigne's test". The elements present in the compound are converted from covalent form into the ionic form by fusing the compound with sodium metal. C, N, S and X come from organic compound. Cyanide, sulphide and halide of sodium so formed on sodium fusion are extracted from the fused mass by boiling it with distilled water. This extract is known as sodium fusion extract. a. if silver nitrate solution is added to chlorobenzene will there be formation of white ppt. b. Why diazonium salt do not show Lassaigne`s test. c. A student was given the compound $C_6H_4(NH_2)SO_3H$ for elemental analysis. While performing Lassaigne`s test for N, what colour will he get and why? (Or) Do you expect sodium cyanide to show positive Lassaigne`s test for N?	4

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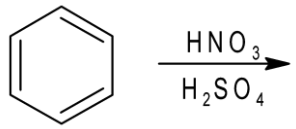
SECTION- E

The following questions are long answer type and carry 5 marks each. Two questions have an internal choice.

Q.31	Attempt either A or B : A. Answer the following questions: I. Calculate the energy associated with first orbit of He^+? II.What is the maximum number of emission lines when the excited electron Of a H atom in n = 5 drops to the ground state. III. Comment on the stability of half filled and completely filled subshells in the context of Cu. IV.Calculate the maximum number of electrons in the shell with principal quantum number 4. V. What are the nodal surfaces? OR B. Answer the following questions : I. What is the total numbers of orbitals associated with the principal quantum number n = 4 ? II.What will be the wavelength of a particle of mass 100 gram moving with a velocity of 10 m/ sec. ? III.Arrange the following orbitals in their decreasing order of energy: 6p, 7s, 4f, 3d IV.What are the two postulates of Bohr's model for hydrogen atom ? V.Which series of lines in the hydrogen spectrum appear in ultraviolet region of electromagnetic spectrum ?	5
Q.32	A. Answer the following questions: I.Standard enthalpy of formation is different from standard enthalpy of reaction. Comment. II. How temperature affect entropy of system ? III.For the reaction given below: $2P(g) + Q(g) \rightarrow 2R(g)$, $\Delta H^0 = 20.5$ kJ and $\Delta S^0 = -34.1$ J/K at $25\,^0C$. Calculate ΔG^0 for the reaction. IV. Give one example of closed system . V. Why solids and liquids do not suffer any significant volume change upon heating ? OR B. Answer the following questions: I.Name thermodynamic property whose value does not depend on quantity and size of matter and give one example. II.An ideal gas expands isothermally from 5 L to 8 L at $25\,^0C$ into vacuum at pressure of 10 atm.Calculate work done during the process. III.What is the significance of negative sign. in the expression irreversible work done. IV. How entropy changes when a given liquid crystallizes into a solid. V.Express the change in internal energy of a system when w amount of work is done by the system and q amount of heat is given to the system.	5

Q.33	a) Complete the following reactions: i)  ii) $(CH_3)_2C=CH_2 + HBr \xrightarrow{Peroxide}$ iii) $CH_3 - CH_2 - CH_2 - CH = CH_2 + Br_2 \rightarrow$ b) Explain the following name reactions i) Wurtz reaction ii) Decarboxylation reaction. OR a) Arrange the following in increasing order of the property as indicated: i) 2,2–Dimethylpropane, Pentane, 2-Methylbutane. (Boiling point) ii) Benzene, Toluene, Nitrobenzene. (Reactivity towards nitration) b) How do you convert : i) Acetylene → benzene. ii) Propene → Propanol iii) Acetic acid → Methane	5

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SAMPLE QUESTION PAPER :2026-27
CLASS-XI
SUBJECT- CHEMISTRY
SET-05

Time:3 Hours **M.M.-70**

Q. NO.	QUESTION	MARKS
	SECTION A **Questions no.1 to 16 are Multiple Choice type Questions, Carrying 1 mark each.**	
1.	The smallest ion among the following is (a) Na^+ (b) Al^{3+} (c) Mg^{2+} (d) Si^{4+}	1
2.	Considering entropy(S) thermodynamic parameters the criteria for the spontaneity of any process is: (a) $\triangle S$ system + $\triangle S$ surroundings > 0 (b) $\triangle S$ system – $\triangle S$ surroundings < 0 (c) $\triangle S$ system > 0 (d) $\triangle S$ surroundings > 0	1
3.	The number of significant figures in 6.02×10^{23} is ————. (a) 23 (b) 3 (c) 4 (d) 26	1
4.	Which of the following is not a redox reaction? (a) $CaCO_3 \rightarrow CaO + CO_2$ (b) $O_2 + 2H_2 \rightarrow 2H_2O$ (c) $Na + H_2O \rightarrow NaOH + ½\ H_2$ (d) $MnCl_3 \rightarrow MnCl_2 + ½\ Cl_2$	1
5.	A miscible mixture of benzene and chloroform can be separated by: (a) Sublimation (b) distillation (c) filtration (d) crystallisation	1
6.	The strong conjugate base is : (a) NO_3^{2-} (b) Cl^- (c) SO_4^{2-} (d) CH_3COO^-	1
7.	Isotopes of an element have ———— (a) Different chemical and physical properties (b) Similar chemical and physical properties (c) Similar chemical but different physical properties (d) Similar physical but different chemical properties	1
8.	The least random state of the water system is: (a) ice (b) liquid water (c) steam (d) randomness is same	1
9.	For the reversible reaction $N_2\ (g) + 3H_2(g) \leftrightharpoons 2NH_3 + Heat$ The equilibrium shifts in forward direction (a) by increasing the concentration of $NH_3(g)$ (b) by decreasing the pressure (c) by decreasing the concentration of N_2 and H_2 (d) by increasing pressure and decreasing temperature	1
10	Which of the following is an example of ortho and para directing group on benzene ring? a) $-SO_3H$ b) -COOR c) $-OCH_3$ d) –CN	1
11.	Which of the following molecules have trigonal planar geometry? (a) BF_3 (b) NH_3 (c) PCl_3 (d) IF_3	1
12.	Benzene reacts with CH_3Cl in the presence of anhydrous $AlCl_3$ to form (a) Chlorobenzene (b) Benzyl chloride (c) xylene (d) toluene	1
	For Questions number 13 to 16, two statements are given one labelled as Assertion (A) and the other labelled as Reason (R). Select the correct answer to these	

	questions from the codes (a), (b), (c) and (d) as given below. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A). (b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). (c) Assertion (A) is true, but Reason (R) is false. (d) Assertion (A) is false, but Reason (R) is true.	
13.	**Assertion (A)**: BF_3 molecule has zero dipole moment. **Reason (R)**: F is electronegative and B–F bonds are polar in nature.	1
14.	**Assertion (A)**: A spontaneous process is irreversible and can only be reversed by an external force. **Reason (R)**: A decrease in enthalpy is a factor that contributes to spontaneity.	1
15.	**Assertion (A):** Law of multiple proportions is applicable only if two elements combine to form two or more compounds. **Reason (R):** If mass of one of the elements is fixed, the masses of the other element are in a simple ratio to one another	1
16.	**Assertion (A):** Chain isomerism is observed in compounds containing four or more than four carbon atoms **Reason (R):** Only alkanes show chain isomerism	1
	SECTION B **This section contains 5 questions with internal choice in one question. The following questions are very short answer type and carry 2 marks each.**	
17.	For the reaction, $4Fe(s) + 3O_2(g) \square 2\ Fe_2O_3(s)$, the entropy change is -549.4 J K^{-1} mol^{-1} at 298 K. Inspite of the negative entropy change, why is the reaction spontaneous? Given ΔH^o = - 1648 kJ mol^{-1}.	2
18.	(a) What would be the name for the element with atomic number 104? (b) The first ionization enthalpy of oxygen is smaller compared to nitrogen. Give reason. **OR** (a) Write the general electronic configuration of d-block elements. (b) A group of ions are given below. Find one pair which is not Isoelectronic. Na^+, Al^{3+}, Ca^{2+}, Br^-, F^-	1 1 1 1
19.	$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ (a) Write down the expression for Kp. (b) What is the relation between Kp and Kc in the above reaction?	 1 1
20.	In a chemical reaction 6 g Hydrogen reacts with 40 g Oxygen to give water. (a) Identify the limiting reagent in this reaction. (b)Calculate the amount of H_2O produced.	 1 1
21.	Which of the two: $O_2NCH_2CH_2O^-$ or $CH_3CH_2O^-$ is expected to be more stable and why?	2
	SECTION C **This section contains 7 questions with internal choice in one question. The following questions are short answer type and carry 3 marks each.**	
22.	a) Give the relation between empirical formula and molecular formula. b) An organic compound has the following percentage composition C = 12.36%, H = 2.13%, Br = 85%. Its vapour density is 94. Find its molecular formula.	1 2
23.	(a) Which of the following set of quantum numbers are not allowed? i) n = 3, l = 3, m = -3, s = +½ ii) n = 2, l = 1, m = 0, s = -½	1

	iii) n = 1, l = 0, m = 0, s = +½ iv) n = 0, l = 0, m = 0, s = +½ (b) State Pauli's exclusion principle. (c) State Heisenberg's uncertainty principle.	1 1
24.	**(Attempt any three)** (a) Comment on the effect of increasing pressure in the reaction, $2SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g)$ (b) Write the conjugate acids for the following Bronsted bases: NH_3, $HCOO^-$ (c) Assuming complete dissociation, calculate the pH of 0.003 M HCl. (d) What are buffer solutions?	 1 1 1 1
25.	(a) Draw the structure of the molecule represented by the IUPAC name – pent-4-en-2-ol. (b) Arrange the following carbocation in the increasing order of their stability. CH_3-CH_2^+ , CH_3^+ , $(CH_3)_3C^+$, $(CH_3)_2CH^+$. (c) Draw the resonance structures for C_6H_5OH.	1 1 1
26.	(a) Assign oxidation number to the underlined elements in each of the following species: (i) $K_2\underline{Mn}O_4$ (ii)$Na\underline{B}H_4$ (b) Balance the following equation using oxidation number method (in acidic medium): $Cr_2O_7^{2-}(aq) + SO_3^{2-}(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$	½+½ 2
27.	(a) What are the necessary conditions for any system to be aromatic? (b) How will you convert benzene into acetophenone?	2 1
28.	Justify the following: (a) Ne has positive value for electron gain enthalpy. (b) The electron gain enthalpy of F is lower than that of Cl. (c) The size of Al^{3+} is lower than that of F.	 1 1 1
	SECTION D **The following questions are case-based questions. Each question has an internal choice in 2 marks questions and carries 4 (1+1+2) marks each.**	
29.	**Read the text carefully and answer the questions:** The phenomenon of the existence of two or more compounds possessing the same molecular formula but different properties is known as isomerism. Such compounds are called isomers. Compounds having the same molecular formula but different structures (manners in which atoms are linked) are classified as structural isomers. Structural isomers are classified as chain isomer, position isomer, functional group isomer. Meristematic arises due to different alkyl chains on either side of the functional group in the molecule and stereoisomerism and can be classified as geometrical and optical isomerism. Hyperconjugation is a general stabilising interaction. It involves delocalisation of σ electrons of the C-H bond of an alkyl group directly attached to an atom of an unsaturated system or to an atom with an unshared p orbital. This type of overlap stabilises the carbocation because electron density from the adjacent σ bond helps in dispersing the positive charge. (a) The molecular formula C_3H_8O represents which isomer? (b) What type of isomerism is shown by Methoxypropane and ethoxyethane? (c) What is hyperconjugation? Why it is a permanent effect? **OR** (c) What is chain isomerism. Write the names of chain isomers of pentene.	 1 1 2

30.	**Read the text carefully and answer the questions:** Thermodynamics involve energy changes in chemical reactions and other processes. Internal energy is total energy stored in a substance. We can specify absolute value of volume but not the absolute value of internal energy. We can measure only change in internal energy ($\triangle U$). Work done on the system is taken as positive and work done by the system is taken as negative. Heat (q) absorbed by the system is +ve and heat given out by system is negative. $\triangle U = q + w$ according to first law of thermodynamics. $\triangle H$ (enthalpy change) is measured at constant pressure, $\triangle U$ is measured at constant volume. $\triangle H$, $\triangle S$ (entropy change), $\triangle G$ (free energy change) and temperature help to decide spontaneity of the process. (a) Define First law of thermodynamics. (b) Predict the change in internal energy for an isolated system at constant volume. (c) In a process, 701 J of heat is absorbed by a system and 394 J of work is done by the system. What is the change in internal energy for the process? **OR** (c) Given that $\Delta H = 0$ for mixing of two gases. Explain whether the diffusion of these gases into each other in a closed container is a spontaneous process or not?	1+1+2
	SECTION E **The following questions are long answer types and carry 5 marks each. All questions have an internal choice.**	
31.	**(Attempt any five)** (a) How many unpaired electrons present in Cr^{3+} ? (Z = 24) (b) Write the electronic configuration of Copper (Z = 29) (c) Name the quantum number which gives the spatial orientation of an orbital with respect to standard set of co-ordinate axes. (d) How many radial nodes present in '4p' Orbital. (e) What is the maximum number of emission lines when the excited electron of an 'H' atom in n = 6 drops to the ground state? (f) What is the lowest value of n that allows 'g' orbitals to exist? (g) Write the expression for Bohr's radius in hydrogen atom.	5
32.	(a) Write the molecular orbital configuration of F_2 molecule. Find its bond order. (b) Give any two factors influencing the formation of an ionic bond. (c) Give the shape of the following species. i) NH_4^+ ii) $HgCl_2$ **OR** (a) He_2 cannot exist as stable molecule. Justify this statement based on bond order. (b) Which has higher boiling point – o-nitrophenol or p-nitrophenol? Give reason. (c) Give two examples of compounds having expanded octet.	2+2+1 2+2+1
33.	(a) Represent Sawhorse and Newman projection formulae of staggered and eclipsed conformations of ethane. (b) Compare the stabilities of staggered and eclipsed conformations. (c) Consider the reaction given below: $CH_3 – CH = CH_2 + HBr \rightarrow CH_3 – CHBr – CH_3 + CH_3 – CH_2 – CH_2Br$ i) Identify the major product obtained. ii) Explain the rule governing the formation of the major product. **OR**	2+1+2

	(a) How would you convert the following compounds into benzene? (i) Ethyne (ii) Ethene (b) $C_6H_6 + X \xrightarrow{\text{Anhyd. } AlCl_3} C_6H_5\text{-}CH_3 + HCl$ (i) Identify the reagent X. (ii) What is the name of the reaction? (c) Briefly describe Kharasch effect.	2+1+2

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Class-XI : Extra Practice Questions		
Name of UNIT	QUESTION BANK Link	QR Code
1.Some Basic Concepts of Chemistry	https://docs.google.com/document/d/1PzzfO007-D_fFRnF8ja1pdwCmdac4v5V/edit?usp=drive_link&ouid=110109177899496866646&rtpof=true&sd=true	
2.Structure of Atom	https://docs.google.com/document/d/1PLALuyjBjSidrmWlQ2uJjhNqy9lMcCmE/edit?usp=drive_link&ouid=105601752074736787498&rtpof=true&sd=true	
3.Classification of Elements and Periodicity in Properties	https://docs.google.com/document/d/1fn8yIZhuNm8uie_659aYxbz44EhKXUzv/edit?usp=drive_link&ouid=105601752074736787498&rtpof=true&sd=true	
4.Chemical Bonding and Molecular Structure	https://docs.google.com/document/d/1kg6_ZeKTxzFVkA6_ZxBFhqV9QN127Hgo/edit?usp=sharing&ouid=110109177899496866646&rtpof=true&sd=true	
5.Thermodynamics	https://docs.google.com/document/d/1LOmMS9of-0JlJlnVey5VpUSFp1Vrpu2S/edit?usp=drive_link&ouid=105601752074736787498&rtpof=true&sd=true	

6. Equilibrium	https://docs.google.com/document/d/1rP3Pdu7bk2hFWdy1DPn5J1-OKDzoIHiI/edit?usp=sharing&ouid=110109177899496866646&rtpof=true&sd=true	
7.Redox Reactions	https://docs.google.com/document/d/1O-BYwDO093LyF_s4Tf90R2BlQqcod0T4/edit?usp=sharing&ouid=110109177899496866646&rtpof=true&sd=true	
8.Organic Chemistry: Some basic Principles and Techniques	https://docs.google.com/document/d/1uAOlBDKuXTSyI6nQzizWedCVroG_Mgcs/edit?usp=drive_link&ouid=107228232524760083604&rtpof=true&sd=true	
9.Hydrocarbons	https://docs.google.com/document/d/1WCU6rf3xLrIwuoBQ2FpHR-1Gom3QdmPj/edit?usp=drive_link&ouid=110109177899496866646&rtpof=true&sd=true