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FEDERAL PUBLIC SERVICE COMMISSION

By
ZAHID IQBAL CHEEMA
Chemistry Professor (HED)

TEST SYLLABUS

PART 1

- Vocabulary, Grammar
- Usage & Sentence Structuring

PART 2
(MASTERS LEVEL)

- Nature, Properties & States of Matter
- Electronic Structure
- Chemical Kinetics & Radioactivity
- Reaction, Mechanism (electrophilic & nucleophilic substitution & addition reaction)
- Inorganic Chemistry
- Thermodynamics
- Synthetic & Polymer Chemistry
- Chemical Bonding
- Electrochemistry

PART 3

- Teaching Techniques & Methodology
- Classroom Management & Discipline
- Testing & Evaluation
- Knowledge of Bloom's Taxonomy
- Educational Psychology
- Educational Guidance & Counselling
- Education System in Pakistan

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- SENIOR ELEMENTARY SCHOOL TEACHER
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The Gaseous State

Introduction to States of Matter

Matter exists primarily in four states: **Solid, Liquid, Gas, and Plasma**.

Solids: Have a definite shape and volume. Particles are tightly packed in a fixed, orderly arrangement and can only vibrate.

Liquids: Have a definite volume but no definite shape; they take the shape of their container. Particles are close together but can move past one another (flow).

Gases: Have no definite shape or volume. They expand spontaneously to fill their container. Particles are far apart, move rapidly and randomly, and have high kinetic energy.

Plasma: A fourth state of matter consisting of an ionized gas with positive ions and free electrons. It is macroscopically neutral and responds strongly to electromagnetic fields

Example of plasma

(Stars, neon signs).

The gaseous state is the simplest to study and model mathematically due to the minimal intermolecular forces and large separations between molecules.

General Properties and Characteristics of Gases

Gases exhibit unique properties due to the large spaces between their molecules and their high kinetic energy.

Expansibility: Gases expand indefinitely to fill the entire volume of their container.

Compressibility: Gases can be easily compressed into a smaller volume by applying pressure due to the large amount of space between molecules (e.g., LPG, CNG).

Diffusibility: Gases mix spontaneously and rapidly with each other to form a homogeneous mixture.

Diffusion: The spontaneous intermingling and mixing of gas molecules (e.g., the smell of perfume spreading in a room).

Effusion: The process by which gas molecules escape from a container through a tiny hole or porous plug into a vacuum or region of lower pressure without collisions.

Exertion of Pressure: Gas molecules constantly collide with the walls of their container, exerting pressure. This pressure is due to the force of these numerous collisions per unit area and is exerted uniformly in all directions.

Low Density: Densities are much lower than those of liquids and solids because molecules are widely spaced.

Parameters (State Variables) of a Gas

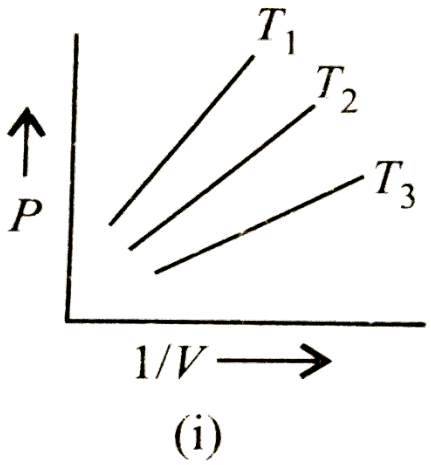
A gas sample is completely described by four measurable properties:

Pressure (P):

The force exerted by gas molecules per unit area of the container wall.

SI Unit: Pascal (Pa).

Common Units: atmosphere (atm), millimeter of mercury (mm Hg), torr, bar.



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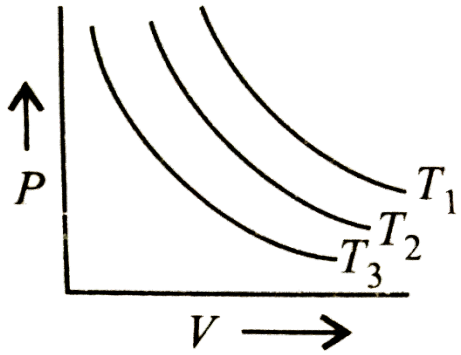

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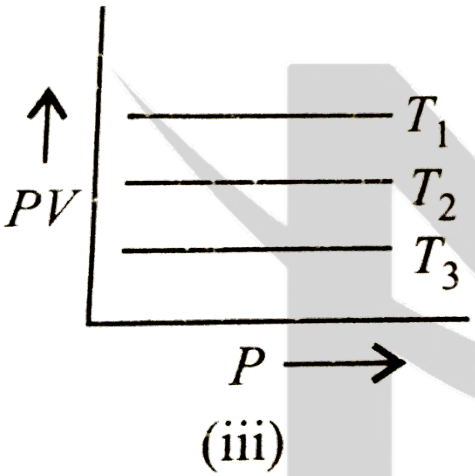

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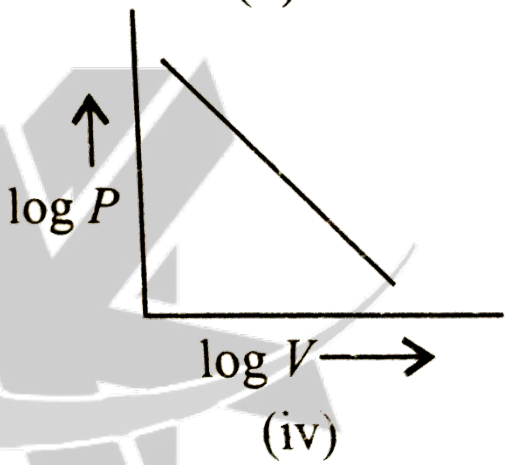

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Charles's Law (Volume-Temperature Relationship)

Statement: For a fixed amount of gas at constant pressure, the volume of the gas is directly proportional to its absolute temperature (Kelvin).

Mathematical Expression: $V \propto T$ (constant n, P) or $\mathbf{V/T = k}$ or $\mathbf{V_1/T_1 = V_2/T_2}$

Explanation (KMT): Increasing temperature increases molecular speed. Molecules hit the walls more frequently and with greater force. To keep pressure constant, the volume must increase.

Absolute Zero: This is absolute zero (0 K). Absolute zero is theoretically approached but not attained; extrapolation of ideal gas V–T gives **−273.15 °C.**

- At 0 K (idealized limit**), translational kinetic energy** approaches zero."

Topic-Wise One-Liners: The Gaseous State

1. Introduction to States of Matter

1. Matter primarily exists in four states: **Solid, Liquid, Gas, and Plasma**.
2. **Solids** have a definite shape and volume with particles in a fixed, orderly arrangement.
3. **Liquids** have a definite volume but no definite shape, taking the shape of their container.
4. **Gases** have no definite shape or volume, expanding spontaneously to fill their container.
5. **Plasma** is an ionized gas consisting of positive ions and free electrons, found in stars and neon signs.
6. The **gaseous state** is the simplest to study mathematically due to minimal intermolecular forces.

2. General Properties of Gases

7. **Expansibility** is the property of gases to expand indefinitely and fill the entire volume of their container.
8. **Compressibility** allows gases to be easily reduced in volume by applying pressure (e.g., LPG, CNG).
9. **Diffusibility** is the spontaneous and rapid mixing of gases to form a homogeneous mixture.
10. **Diffusion** is the intermingling of gas molecules (e.g., perfume smell spreading in a room).
11. **Effusion** is the escape of gas molecules through a tiny hole into a vacuum without collisions.
12. Gases exert **pressure** due to constant collisions of molecules with the container walls.
13. Gases have **low density** because their molecules are widely spaced.

3. Parameters (State Variables) of a Gas

14. A gas sample is described by four parameters: **Pressure (P), Volume (V), Temperature(T), and Amount (n)**.
15. The **SI unit of pressure** is Pascal (Pa); common units include atm, mm Hg, torr, and bar.
16. **Standard conversions**: 1 atm = 760 mm Hg = 760 torr = 1.013×10^5 Pa = 1.013 bar.
17. Pressure is measured by a **manometer** for gas samples and a **barometer** for atmospheric pressure.
18. The **SI unit of volume** is cubic metre (m^3); common units are litre (L) and millilitre (mL).
19. The **SI unit of temperature** for gas laws is **Kelvin (K)**, where K = °C + 273.15.
20. The **amount of gas (n)** is expressed in moles, calculated as n = mass (m) / Molar mass (M).

4. The Gas Laws

21. **Boyle's Law**: For a fixed mass of gas at constant temperature, volume is inversely proportional to pressure ($V \propto 1/P$ or $P_1V_1 = P_2V_2$).
22. A plot of **P vs. V** at constant temperature is a hyperbola called an **isotherm**.
23. **Charles's Law**: For a fixed mass of gas at constant pressure, volume is directly proportional to its absolute temperature ($V \propto T$ or $V_1/T_1 = V_2/T_2$).
24. **Absolute Zero (0 K or -273.15 °C)** is the temperature where the volume of an ideal gas becomes zero.

72. **Critical Volume (V_c)** is the volume occupied by one mole of the gas at its Tc and Pc.
73. Relations with van der Waals constants: $V_c = 3b$, $P_c = a / 27b^2$, $T_c = 8a / (27Rb)$.
74. The **Joule-Thomson effect** is the cooling of a gas when it expands adiabatically from high to low pressure.
75. **Linde's method** for liquefying air uses the Joule-Thomson effect.

Practice MCQs

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1. According to Boyle's law, for a fixed amount of gas at constant temperature, the volume is:
A) directly proportional to its pressure
B) inversely proportional to its pressure
C) directly proportional to the square of its pressure
D) independent of its pressure
Answer: inversely proportional to its pressure

2. Mathematically, Charles's law can be represented as:
A) $V \propto P$
B) $V \propto 1/T$
C) $V \propto T$
D) $P \propto T$
Answer: $V \propto T$

3. The value of the universal gas constant R in litre-atm K^{-1} mol^{-1} is:
A) 8.314
B) 0.0821
C) 1.987
D) 62.364
Answer: 0.0821

4. At Standard Temperature and Pressure (STP), one mole of any ideal gas occupies a volume of:
A) 20.0 L
B) 22.4 L
C) 24.8 L
D) 25.0 L
Answer: 22.4 L

5. Dalton's law of partial pressures states that the total pressure of a mixture of non-reacting gases is equal to the:
A) average of the partial pressures
B) product of the partial pressures
C) sum of the partial pressures
D) difference of the partial pressures
Answer: sum of the partial pressures

6. Graham's law of diffusion states that the rate of diffusion of a gas is inversely proportional to the:
A) square of its density
B) square root of its molar mass
C) square of its molar mass
D) square root of its density
Answer: square root of its molar mass

7. According to the kinetic molecular theory, the average kinetic energy of gas molecules is directly proportional to the:
A) square of the absolute temperature
B) square root of the absolute temperature
C) absolute temperature
D) pressure of the gas
Answer: absolute temperature

8. The root mean square velocity (u) of a gas molecule is given by:
A) $\sqrt{(2RT/M)}$
B) $\sqrt{(3RT/M)}$
C) $\sqrt{(8RT/\pi M)}$
D) $\sqrt{(RT/M)}$
Answer: $\sqrt{(3RT/M)}$

9. The compressibility factor (Z) for an ideal gas is always:
A) 0
B) 1
C) less than 1

D) greater than 1
Answer: 1

10. The van der Waals constant 'a' accounts for:
A) the finite volume of gas molecules
B) the universal gas constant
C) intermolecular attractive forces
D) the temperature of the gas
Answer: intermolecular attractive forces

11. The critical temperature of a gas is defined as the temperature:
A) at which it solidifies
B) above which it cannot be liquefied
C) at which it becomes ideal
D) below which it cannot exist as a liquid
Answer: above which it cannot be liquefied

12. The plasma state of matter is characterized by the presence of:
A) only neutral atoms
B) positive ions and free electrons
C) molecules in fixed positions
D) only negative ions
Answer: positive ions and free electrons

13. The SI unit for the viscosity of a liquid is:
A) Poise
B) Pascal Second (Pa.s)
C) Dyne
D) Newton
Answer: Pascal Second (Pa.s)

14. Surface tension is defined as the force acting:
A) per unit volume
B) per unit area
C) at right angles to a unit length of the liquid surface
D) parallel to the liquid surface
Answer: at right angles to a unit length of the liquid surface

15. The molar heat of vaporization for water is approximately:
A) 6.02 kJ/mole
B) 40.7 kJ/mole
C) 80.0 kJ/mole
D) 100.0 kJ/mole
Answer: 40.7 kJ/mole

16. Liquid crystals are an intermediate phase between:
A) solid and gas
B) liquid and gas
C) solid crystal and clear liquid
D) amorphous and crystalline solid
Answer: solid crystal and clear liquid

17. Which of the following has the highest surface tension at room temperature?
A) Methanol
B) Ethanol
C) Water
D) Hexane
Answer: Water

18. The phenomenon where a liquid turns into vapour at its surface at any temperature is called:
A) boiling
B) condensation
C) evaporation
D) sublimation
Answer: evaporation

19. The boiling point of a liquid is the temperature at which its vapour pressure becomes equal to the:
A) critical pressure
B) atmospheric pressure
C) vapor pressure of water
D) internal pressure of the container
Answer: atmospheric pressure

20. The property of a liquid that measures its resistance to flow is called:
A) surface tension
B) viscosity
C) compressibility
D) diffusibility
Answer: viscosity

21. Hydrogen bonding in water is responsible for its:
A) low boiling point
B) high vapour pressure

States of matter - liquids and solids

Kinetic Molecular Theory of Liquids and Solids

Postulates for Liquids

Composition and Proximity: A liquid consists of atoms, ions, or molecules that are in close contact with one another, resulting in negligible empty space between them.

Motion: The particles are in constant, random motion. However, this motion is restricted by the close packing; they cannot move freely but can slide past one another, which is why liquids can flow.

Intermolecular Forces: The attractive forces between liquid molecules are stronger than those in gases but significantly weaker than those in solids. These forces are insufficient to hold the particles in fixed positions.

Kinetic Energy: The average kinetic energy of the liquid molecules is directly proportional to the absolute temperature. At a given temperature, the average kinetic energy of the liquid molecules is equal to that of its vapour molecules.

Postulates for Solids

Composition and Packing: Solids are composed of atoms, ions, or molecules that are closely packed together in a fixed, orderly arrangement.

Intermolecular Forces: The particles are held together by very strong intermolecular (or ionic/covalent/metallic) forces of attraction.

Rigidity and Motion: Solids are rigid and possess a definite shape because their particles are locked in place and cannot translate or rotate. They can only vibrate about their mean positions.

Order and Arrangement: The particles in solids exhibit a high degree of long-range order, arranged in regular, three-dimensional patterns called a crystal lattice (for crystalline solids).

Compressibility and Density: There is very little empty space between particles, making solids virtually incompressible. This close packing results in high density.

Intermolecular Forces

Intermolecular forces are the attractive forces *between* molecules. They are much weaker than intramolecular forces (covalent, ionic bonds) that hold atoms together *within* a molecule. Collectively, these weak forces are known as **Van der Waals forces** Van der Waals forces (in the standard/IUPAC sense) include dipole–dipole, dipole-induced dipole, and London dispersion forces,hydrogen bonding is usually discussed separately as a special, stronger, directional interaction..

Types of Intermolecular Forces

A. Dipole-Dipole Forces

Definition: These are the attractive forces between the positive end (δ+) of one polar molecule and the negative end (δ-) of another polar molecule.

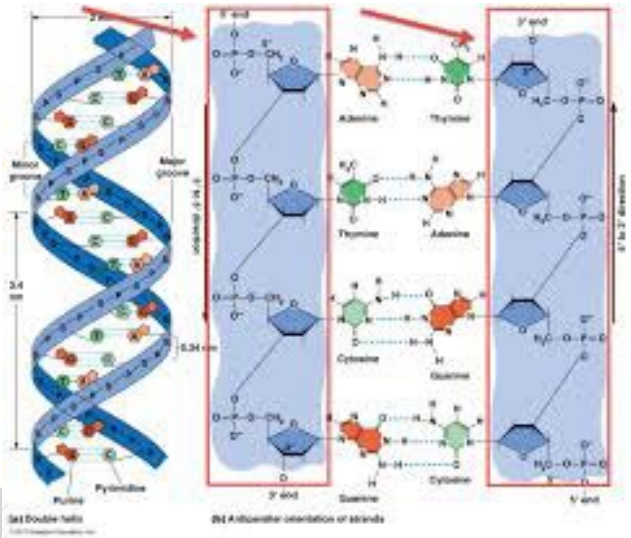
Explanation: In polar molecules (e.g., HCl, HBr, $CHCl_3$), a permanent dipole exists due to the difference in electronegativity between bonded atoms. These molecular dipoles align so that opposite charges attract.

Strength: They are approximately 1% as strong as a covalent bond (0.5 - 2 kcal/mol) and are effective only at short distances.

Effect on Properties: Stronger dipole-dipole forces lead to higher melting points, boiling points, and heats of vaporisation.

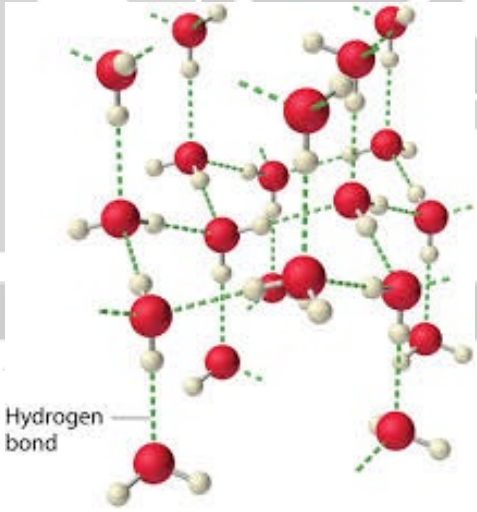
B. Hydrogen Bonding

DNA: The double-helix structure is held together by hydrogen bonds between complementary nitrogenous bases (A-T, G-C).



- **Structure of Ice:** In ice, water molecules form an open, tetrahedral, cage-like structure due to extensive hydrogen bonding, creating empty spaces. This makes ice less dense than liquid water, causing it to float.

Structure of ice



Other Applications: Cleaning action of soaps and detergents (by reducing surface tension), adhesive action of paints and dyes, and the viscous, sticky nature of substances like glue and honey.

Physical Properties of Liquids

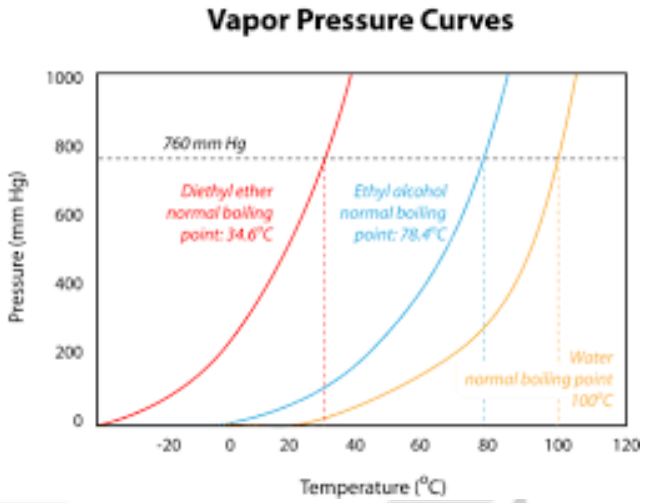
Evaporation

Definition: The spontaneous change of a liquid into its vapour at the surface of the liquid, occurring at any temperature below the boiling point.

Kinetic Molecular Explanation: Molecules in a liquid have a distribution of kinetic energies. The high-energy molecules near the surface can overcome intermolecular forces and escape into the vapour phase.

Cooling Effect: Evaporation causes cooling because when the most energetic molecules leave, the average kinetic energy (and thus temperature) of the remaining liquid decreases.

Manometer instrumentation



[Graph: Vapor Pressure vs. Temperature]

Boiling Point

Definition: The temperature at which the vapour pressure of a liquid becomes equal to the external (atmospheric) pressure. At this point, bubbles of vapour form throughout the liquid.

Explanation: The kinetic energy of the molecules becomes sufficient to overcome intermolecular forces throughout the bulk liquid, causing it to vaporize. The temperature remains constant until all liquid has vaporized.

Molar Heat of Vaporization (ΔH_{vap}): The amount of heat required to vaporize one mole of a liquid at its boiling point. For water, $\Delta H_{vap} = 40.7$ kJ/mol.

Dependence on Pressure:

Lower External Pressure = Lower Boiling Point. (e.g., water boils below 100°C on high mountains).

Higher External Pressure = Higher Boiling Point. (e.g., in a pressure cooker, water boils above 100°C, cooking food faster).

Normal Boiling Point: The boiling point at a standard pressure of 1 atm (760 torr).

Vacuum Distillation: A technique where distillation is carried out under reduced pressure to lower the boiling point and prevent decomposition of heat-sensitive liquids (e.g., purification of glycerin).

Viscosity

Definition: Viscosity (η) is a measure of a liquid's internal resistance to flow. It arises from internal friction between layers of molecules as they slide past one another.

Explanation: When a liquid flows, layers near the container walls move slower than layers in the center. This velocity gradient (dv/dx) leads to frictional resistance. According to Newton's law, $F = \eta A (dv/dx)$, where η is the coefficient of viscosity.

Units: The SI unit is Pascal-second (Pa.s) or kg m^{-1} s^{-1}. The CGS unit is Poise (P), where 1 Pa.s = 10 P. Fluidity (φ) is the reciprocal of viscosity ($\varphi = 1/\eta$).

Factors Affecting Viscosity:

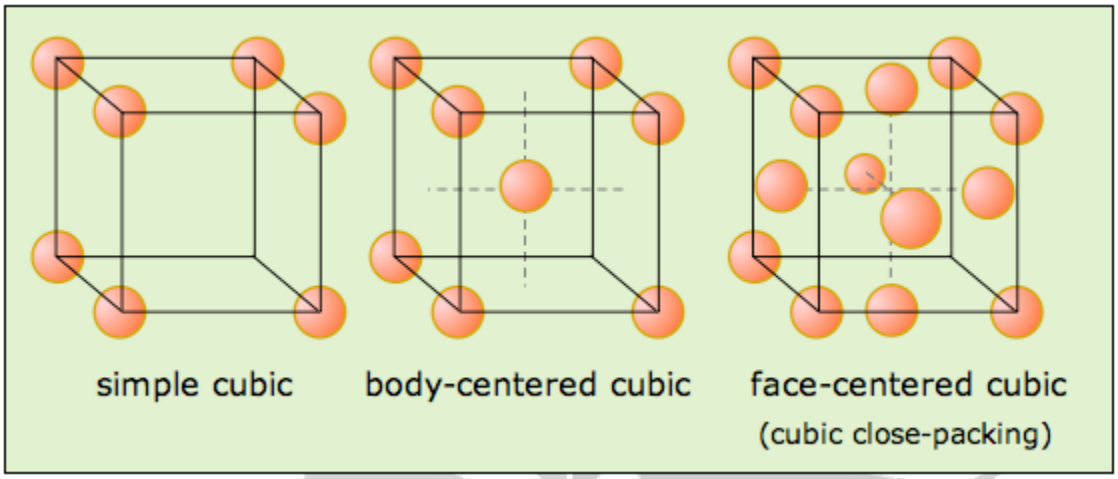
Intermolecular Forces: Stronger forces lead to higher viscosity (e.g., honey has high viscosity due to hydrogen bonding and large molecular size).

Molecular Size and Shape: Large, irregular molecules that can tangle have higher viscosities.

Hexagonal	a = b ≠ c	α = β = 90°, γ = 120°	Graphite, ZnO, Ice
Rhombohedral	a = b = c	α = β = γ ≠ 90°	Calcite ($CaCO_3$), $NaNO_3$, Cinnabar

Cubic Unit Cells

1. **Simple Cubic (SC):** Lattice points only at the corners. Atoms/unit cell = 1. Coordination Number = 6.
2. **Body-Centered Cubic (BCC):** One lattice point at the center of the cube. Atoms/unit cell = 2. Coordination Number = 8. (e.g., Fe, Na, W).
3. **Face-Centered Cubic (FCC):** One lattice point at the center of each face. Atoms/unit cell = 4. Coordination Number = 12. (e.g., Cu, Ag, Au, Al, NaCl).



(Three cubes side-by-side. SC: Spheres only at corners.
BCC: Spheres at corners and one in the center.
FCC: Spheres at corners and one in the center of each face.)

Calculation of Density of a Crystal

The density (ρ) can be calculated from unit cell properties:

ρ = (Mass of unit cell) / (Volume of unit cell) = (Z × M) / (N_A × a^3)

Where: Z = number of atoms per unit cell, M = molar mass (g/mol), N_A = Avogadro's number, a = edge length of the unit cell (cm).

X-Ray Crystallography and Bragg's Law

Principle: X-rays have wavelengths comparable to interatomic distances, so crystals act as diffraction gratings.

Bragg's Law: The condition for constructive interference is given by: **$n\lambda = 2d \sin\theta$**

Where: n = order of reflection, λ = wavelength of X-rays, d = interplanar spacing, θ = glancing angle.

Practice MCQs – States of Matter

1. According to Boyle's law, for a fixed amount of gas at constant temperature, the volume is:
A) directly proportional to its pressure
B) inversely proportional to its pressure
C) directly proportional to the square of its pressure
D) independent of its pressure
Answer: inversely proportional to its pressure

2. Mathematically, Charles's law can be represented as:
A) $V \propto P$
B) $V \propto 1/T$
C) $V \propto T$
D) $P \propto T$
Answer: $V \propto T$

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A) average of the partial pressures
B) product of the partial pressures
C) sum of the partial pressures
D) difference of the partial pressures
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C) square of its molar mass
D) square root of its density
Answer: square root of its molar mass

7. According to the kinetic molecular theory, the average kinetic energy of gas molecules is directly proportional to the:
A) square of the absolute temperature
B) square root of the absolute temperature
C) absolute temperature
D) pressure of the gas
Answer: absolute temperature

8. The root mean square velocity (u) of a gas molecule is given by:
A) $\sqrt{(2RT/M)}$
B) $\sqrt{(3RT/M)}$
C) $\sqrt{(8RT/\pi M)}$
D) $\sqrt{(RT/M)}$
Answer: $\sqrt{(3RT/M)}$

9. The compressibility factor (Z) for an ideal gas is always:
A) 0
B) 1
C) less than 1
D) greater than 1
Answer: 1

10. The van der Waals constant 'a' accounts for:
A) the finite volume of gas molecules
B) the universal gas constant
C) intermolecular attractive forces
D) the temperature of the gas
Answer: intermolecular attractive forces

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A) at which it solidifies
B) above which it cannot be liquefied
C) at which it becomes ideal
D) below which it cannot exist as a liquid
Answer: above which it cannot be liquefied

12. The plasma state of matter is characterized by the presence of:
A) only neutral atoms
B) positive ions and free electrons
C) molecules in fixed positions
D) only negative ions
Answer: positive ions and free electrons

13. The SI unit for the viscosity of a liquid is:
A) Poise

Atomic Structure

Historical Development of the Atomic Theory

Early Greek Philosophers and the Concept of the Atom

Leucippus (500 B.C): First proposed that matter is composed of indivisible particles. He is known as the father of atomic philosophy.

Democritus (430 B.C): A student of Leucippus, he named these fundamental particles "atomos," meaning "uncuttable" or "indivisible."

He theorized that different properties of matter (e.g., sour taste, white color) arose from the different shapes and sizes of these atoms.

He believed changes in matter were due to the combination and separation of atoms.

Dalton's Atomic Theory (1808)

John Dalton converted the philosophical idea of the atom into a scientific theory based on experimental evidence.

Main Postulates:

- Matter is composed of indivisible atoms.
- Atoms of the same element are identical in mass and properties. Compounds are formed by the combination of atoms of different elements in simple whole-number ratios.
- Chemical reactions involve the rearrangement of atoms.
- **Significance:** This theory laid the experimental foundation for modern chemistry.

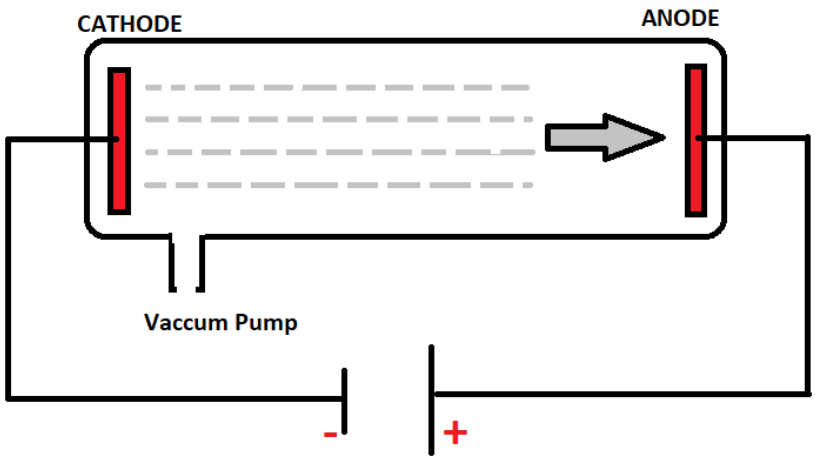
Discovery of Subatomic Particles

The indivisibility of the atom was challenged by the discovery of subatomic particles.

Discovery of the Electron (Cathode Rays)

Experiment: Sir William Crookes and J.J. Thomson used a **gas discharge tube** at low pressure (~0.01 mm Hg) with a high voltage (5000-10,000 V).

Observations: Rays originated from the cathode (negative electrode) and traveled towards the anode, causing fluorescence on the glass wall opposite the cathode.



These were named **cathode rays**.

Properties of Cathode Rays (J.J. Thomson's Conclusions):

Travel in straight lines from the cathode, casting sharp shadows.

Are negatively charged (deflected towards the positive plate in an electric field).

Are deflected by a magnetic field.

Possess momentum and kinetic energy (can rotate a paddle wheel).

Their e/m (charge-to-mass ratio) is constant (**1.7588×10^{11} C/kg**), regardless of the gas or electrode material in the tube.

Can produce X-rays upon striking a metal anode.

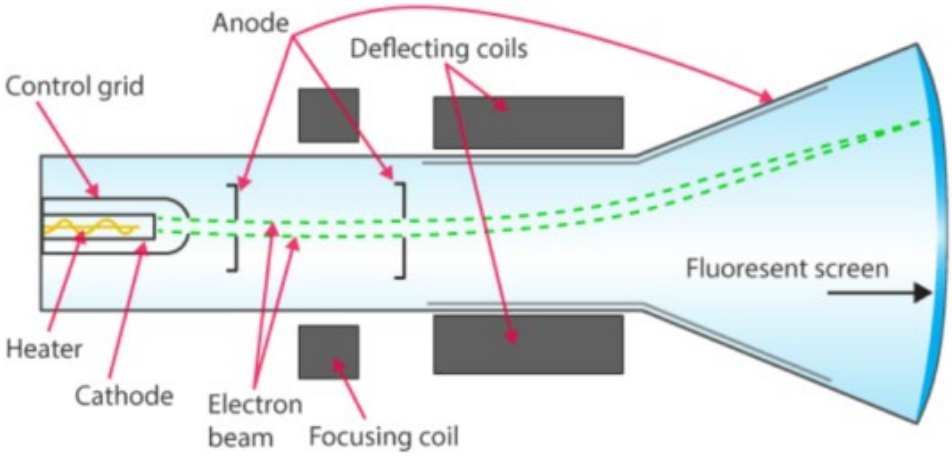
Conclusion (J.J. Thomson): Cathode rays are streams of negatively charged particles, which were later named **electrons** by Stoney. All atoms contain electrons.

Discovery of the Proton (Positive Rays / Canal Rays)

Experiment: Eugene Goldstein (1886) used a perforated cathode in a discharge tube.

Observations: Along with cathode rays moving away from the cathode, new rays were observed moving *towards* the cathode and passing through its holes (canals). These were called **canal rays** or **positive rays**.

Reason for Production: High-speed electrons (cathode rays) collide with gas molecules, knocking out electrons and creating positive ions **$M + e^- \text{ (high-speed)} \rightarrow M^+ + e^- \text{ (slow)} + e^- \text{ (knocked-out)}$** these positive ions are attracted to the cathode.



Properties of Positive Rays:

Travel in straight lines.

Are positively charged (deflected towards the negative plate in an electric field).

Are deflected by a magnetic field in the opposite direction to electrons.

The e/m value depends on the nature of the gas in the tube.

The maximum e/m value is observed when hydrogen gas is used. This lightest positive particle was named the **proton**.

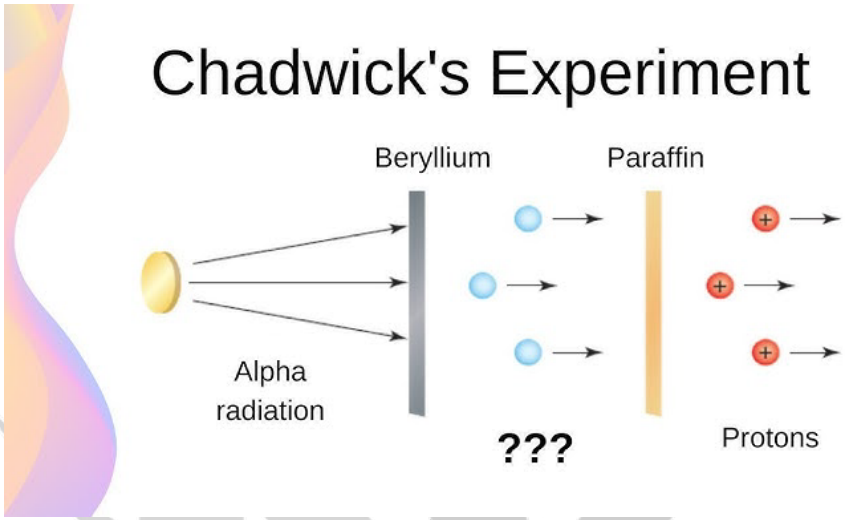
Discovery of the Neutron

Experiment: James Chadwick (1932) bombarded a beryllium ($^{9}_{4}Be$) target with alpha (α) particles from polonium.

Observations: Highly penetrating, electrically neutral radiation was produced. These particles could knock out protons from paraffin wax.

Nuclear Reaction: ${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$

Conclusion: The neutral particle, named the **neutron**, was a fundamental constituent of the atomic nucleus.



Properties of Fundamental Particles

Particle	Symbol	Relative Charge	Absolute Charge (Coulomb)	Mass (kg)	Relative Mass (amu)
Electron	e^- or ${}^{0}_{-1}e$	-1	-1.6022×10^{-19}	9.1095×10^{-31}	0.00055
Proton	p^+ or ${}^{1}_{1}H$	+1	$+1.6022 \times 10^{-19}$	1.6726×10^{-27}	1.0073
Neutron	n or ${}^{1}_{0}n$	0	0	1.6749×10^{-27}	1.0087

A proton is approximately **1836 times** heavier than an electron.

A neutron is slightly heavier than a proton.

Measurement of Electron's Charge (Millikan's Oil Drop Experiment)

Procedure: Robert Millikan (1909) observed charged oil droplets in a chamber with adjustable electric fields.

Principle: By balancing the gravitational force (mg) and the electrostatic force (Ee), he calculated the charge on the droplets.

Finding: The charge on the droplets was always an integral multiple of $(1.59\times10^{-19}$ which is close to modern value of 1.6022×10^{-19} C, which is the **charge of a single electron**.

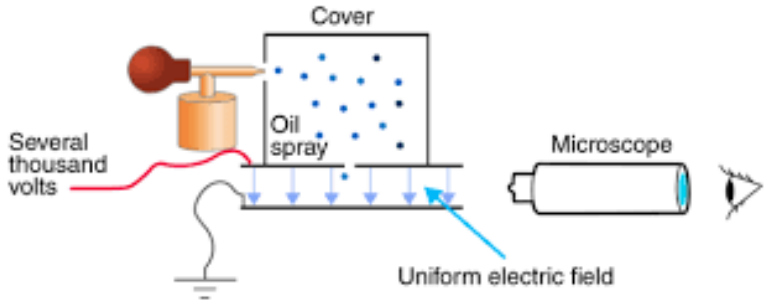


Figure: Mullikan Oil Droplet Method

Atomic Models

Rutherford's Nuclear Model (1911)

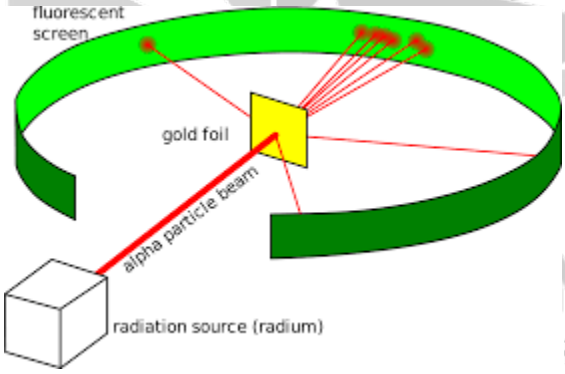
Experiment: Bombarded a thin gold foil with alpha (α) particles.

Observations:

Most α-particles passed through undeflected.

A few were deflected at small angles.

A very small number (1 in 20,000) were deflected backwards.



Conclusions:

The atom is mostly empty space.

It has a small, dense, positively charged core called the **nucleus**, where most of the mass is concentrated.

Electrons revolve around the nucleus.

Defects:

According to classical electromagnetic theory, a revolving electron should continuously lose energy and spiral into the nucleus, causing the atom to collapse. This model could not explain the **stability of the atom**

Planck's Quantum Theory (1900) and Einstein's Photoelectric Effect (1905)

Postulates:

Energy is emitted or absorbed by a body not continuously, but in discrete packets called **quanta** (or **photons** for light).

The energy of a quantum is directly proportional to its frequency: $E = h\nu$, where h is **Planck's constant** (6.626×10^{-34} Js), And according to **Einstein energy can be represented as**

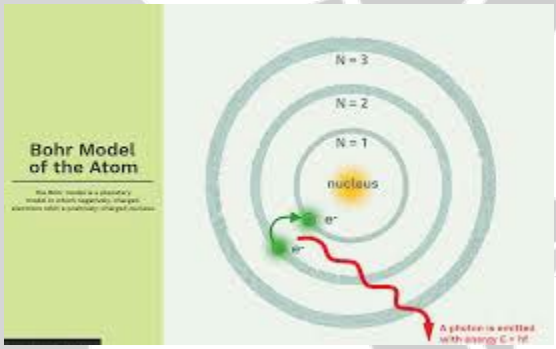
$\frac{1}{2}mv^2 = h\nu - h\nu_0$ (or $h\nu - \varphi$)

Bohr's Model of the Atom (1913)

Niels Bohr combined Rutherford's model with Planck's quantum theory to explain the hydrogen spectrum.

Postulates:

1. Electrons revolve around the nucleus in specific, stable orbits called **stationary orbits** or **shells** without radiating energy.
2. Each orbit is associated with a definite energy. The energy of an electron remains constant in a stationary orbit.
3. Electrons can only jump from one orbit to another. Energy is **absorbed** when an electron jumps to a higher orbit ($E_2 > E_1$) and **emitted** when it falls to a lower orbit ($E_1 < E_2$). The energy difference is given by $\Delta E = E_2 - E_1 = h\nu$.
4. The angular momentum of an electron in a stationary orbit is quantized and is an integral multiple of $h/2\pi$: $mvr = n\hbar$ or $mvr = nh/2\pi$, where n is the principal quantum number ($n = 1, 2, 3.,$).



Derivation of Radius of the nth Orbit

By equating Coulomb's force of attraction to the centrifugal force and using the quantization of angular momentum, the radius for a hydrogen-like atom (one electron) is derived as:

$r_n = (\varepsilon_0 n^2 h^2) / (\pi Z e^2 m)$

For hydrogen ($Z=1$), this simplifies to:

$r_n = 0.529$ Å $\times$ (n^2/Z) (Bohr Radius)

Conclusion: The radius is directly proportional to the square of the principal quantum number, n^2.

Derivation of Energy of the Electron in the nth Orbit

The total energy (E) is the sum of kinetic (K.E.) and potential (P.E.) energy.

E_n = K.E. + P.E. = $- (Z^2 e^4 m) / (8 \varepsilon_0^2 n^2 h^2)$

For hydrogen ($Z=1$):

In Joules/atom: $E_n = -2.18 \times 10^{-18} / n^2$ J/atom

In kJ/mol: $E_n = -1312 / n^2$ kJ/mol

Conclusion: Energy is negative, indicating the electron is bound to the nucleus. Higher orbits (n) have higher (less negative) energy.

Energy Difference and Hydrogen Spectrum

When an electron jumps from a higher energy level n_2 to a lower level n_1, the energy difference is:

$\Delta E = E_2 - E_1 = 2.18 \times 10^{-18} [1/n_1^2 - 1/n_2^2]$ J/atom

According to Planck's theory, $\Delta E = h\nu = hc/\lambda$.

Therefore, the wave number ($\tilde{\nu} = 1/\lambda$) of the emitted photon is:

$\tilde{\nu} = 1/\lambda = R_H [1/n_1^2 - 1/n_2^2]$ m^{-1}

where R_H is the Rydberg constant (1.09678×10^7 m^{-1}).

Spectral Series of Hydrogen:

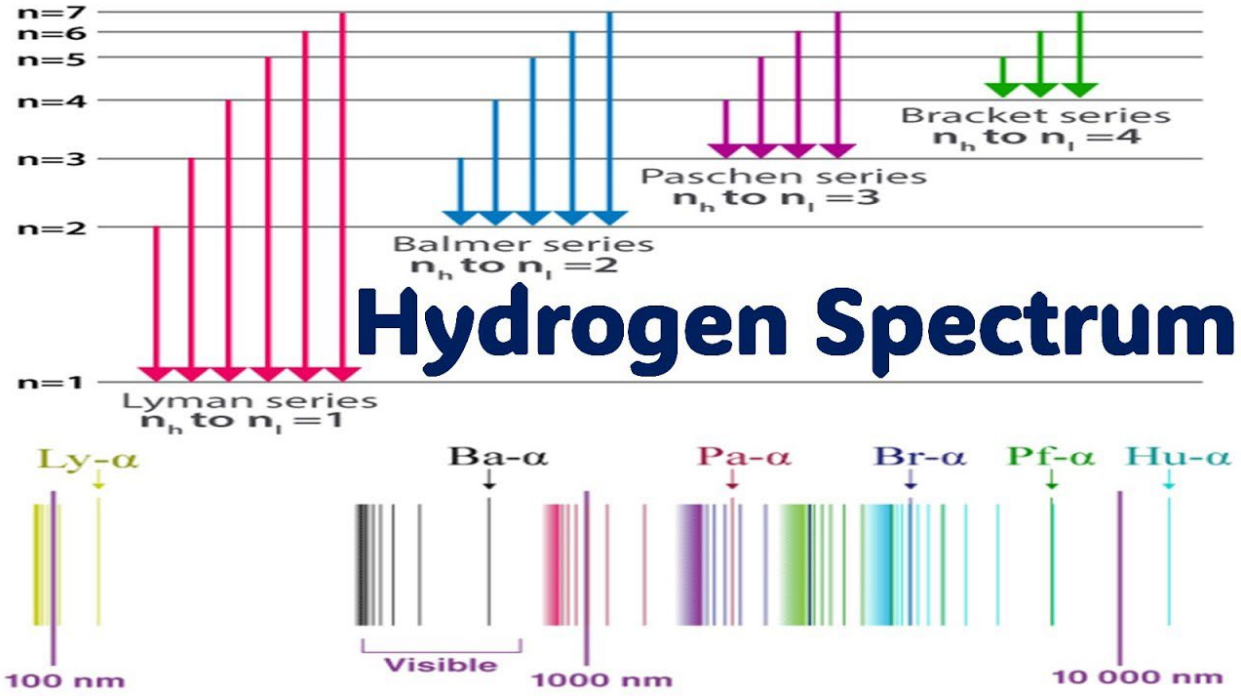
Lyman Series: n_1=1, n_2=2, 3, 4... (Ultraviolet region)

Balmer Series: n_1=2, n_2=3, 4, 5... (Visible region)

Paschen Series: n_1=3, n_2=4, 5, 6... (Infrared region)

Brackett Series: n_1=4, n_2=5, 6, 7... (Infrared region)

Pfund Series: n_1=5, n_2=6, 7, 8... (Infrared region)



Defects of Bohr's Model

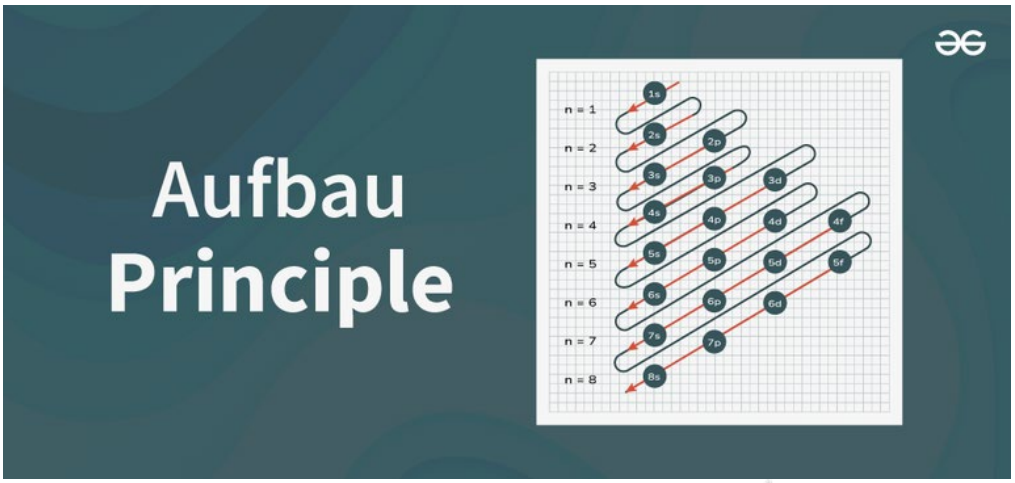
1. It could not explain the spectra of atoms with more than one electron (multi-electron atoms).
2. It failed to explain the **fine structure** of spectral lines (splitting of lines under high resolution).
3. It could not explain the **Zeeman effect** (splitting of spectral lines in a magnetic field) and the **Stark effect** (splitting in an electric field).
4. It violated Heisenberg's Uncertainty Principle by defining precise orbits for electrons.

Quantum Mechanical Model of the Atom

Wave-Particle Duality

De Broglie's Hypothesis (1924): Louis de Broglie proposed that all moving particles have a dual character: they exhibit both particle and wave nature.

Order of filling: 1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p



Pauli's Exclusion Principle

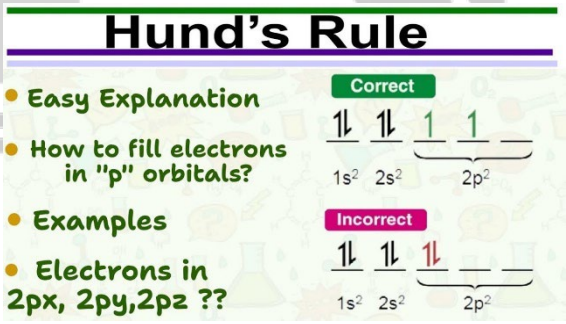
No two electrons in an atom can have the same set of all four quantum numbers.

Consequence: An orbital can hold a maximum of **two electrons**, and they must have opposite spins.

Hund's Rule of Maximum Multiplicity

Electron pairing in degenerate orbitals (orbitals of the same energy, like p_x, p_y, p_z) starts only after each orbital in the subshell is singly occupied. All unpaired electrons in a subshell will have parallel spins.

Example: For a p^3 configuration, the electrons will occupy all three p-orbitals singly with parallel spins, rather than pairing up in fewer orbitals.



X-Rays and Atomic Number

Production and Properties of X-Rays

Discovery: W.C. Roentgen (1895).

Production: Produced when high-energy electrons (cathode rays) strike a heavy metal target (anode) in an X-ray tube.

Properties:

Electromagnetic radiation with very short wavelengths (0.1 Å - 100 Å).

Travel in straight lines.

Not deflected by electric or magnetic fields.

Highly penetrating.Can ionize gases and affect photographic plates.

Types of X-Ray Spectra

1. **Continuous Spectrum:** Produced when high-speed electrons are decelerated by the nucleus of the target atom. It contains a continuous range of wavelengths.
2. **Characteristic Spectrum:** Produced when an incoming electron ejects an inner-shell electron from the target atom. An electron from a higher shell falls to fill the vacancy, emitting an X-ray photon of specific energy. These are labeled as K-series, L-series, etc.

Moseley's Law (1913)

Henry Moseley studied the characteristic X-rays of various elements and established a fundamental relationship.

- **Law:** The square root of the frequency (ν) of a characteristic X-ray line is directly proportional to the atomic number (Z) of the element.

  $\sqrt{\nu} = a (Z - b)$

  where a and b are constants ($b = 1$ for the K-series).
- **Significance:**
  - Proved that the **atomic number (Z)**, not the atomic mass, is the fundamental property of an element.
  - Corrected the positions of elements in the periodic table (e.g., Co and Ni).
  - Helped in the discovery of new elements.

Topic-wise One-Liners on Atomic Structure

Historical Development & Subatomic Particles

1. **Democritus** named the fundamental, indivisible particle of matter **"atomos"**.
2. **John Dalton** established the first scientific atomic theory based on experimental evidence.
3. **J.J. Thomson** discovered the **electron** through his cathode ray tube experiment.
4. The **charge-to-mass ratio (e/m)** of electrons is constant, proving they are a universal constituent of all atoms.
5. **R.A. Millikan**, via his oil-drop experiment, determined the **charge of a single electron**.
6. **E. Goldstein** discovered the **proton** by observing positive rays or canal rays.
7. The **e/m ratio for positive rays** depends on the nature of the gas in the discharge tube.
8. **James Chadwick** discovered the **neutron** by bombarding beryllium with alpha particles.
9. A **proton** is approximately **1836 times heavier** than an electron.
10. The absolute charge of an electron is **-1.602×10^{-19} Coulomb**.

2. Atomic Models

11. **J.J. Thomson's "Plum Pudding Model"** described the atom as a sphere of positive charge with electrons embedded in it.
12. **Rutherford's alpha-particle scattering experiment** led to the proposal of the **nuclear model** of the atom.
13. Rutherford's model concluded that the atom is mostly **empty space** with a small, dense, positively charged **nucleus**.
14. A major defect of Rutherford's model was its inability to explain the **stability of the atom**.
15. **Niels Bohr** combined Rutherford's model with **Planck's quantum theory** to explain the hydrogen spectrum.
16. Bohr's first postulate states that electrons revolve in certain **stationary orbits** without radiating energy.
17. Bohr's model introduced the **quantization of angular momentum**: **$mvr=nh/2\pi$**
18. The radius of the nth orbit in a hydrogen atom is given by **$r=0.529\ n^2 / z$**
19. The energy of an electron in the nth orbit is given by **$E_n=-13.6\ Z^2/n^2$ eV/atom.**
20. The total energy of an electron in a Bohr orbit is **negative**, indicating it is bound to the nucleus.
21. Bohr's model successfully derived the **Rydberg formula** for the hydrogen spectrum.
22. Bohr's model could not explain the **Zeeman effect** (splitting of spectral lines in a magnetic field).
23. Bohr's model violated the **Heisenberg Uncertainty Principle**.

3. Quantum Theory & Spectra

24. **Max Planck** proposed that energy is emitted or absorbed in discrete packets called **quanta**.
25. The energy of a quantum is given by $E=h\nu$, where h is **Planck's constant**.
26. **Albert Einstein** explained the **photoelectric effect** by proposing that light consists of particles called **photons**.
27. In the photoelectric effect, electrons are ejected only if the incident light's frequency is above a certain **threshold frequency**.
28. The hydrogen spectrum consists of several series, including **Lyman (UV)**, **Balmer (Visible)**, and **Paschen (IR)**.
29. The **Rydberg constant** for wavenumber is approximately **109,677 cm^{-1}**.

Practice MCQs

1. According to Bohr's model, the specific permitted circular orbits are referred to as:
A) elliptical paths
B) stationary energy levels
C) quantum jumps
D) magnetic fields
Answer: stationary energy levels

2. The correct relationship between wavelength, frequency, and speed of an electromagnetic wave is:
A) $c = \nu + \lambda$
B) $c = \nu\lambda$
C) $\nu = c\lambda$
D) $\lambda = c/\nu^2$
Answer: $c = \nu\lambda$

3. In the Balmer equation $1/\lambda = R(1/2^2 - 1/n^2)$, the constant R is known as:
A) Planck's constant
B) Rydberg constant
C) Avogadro's number
D) Bohr radius
Answer: Rydberg constant

4. According to the quantum theory of radiation, energy is emitted or absorbed in discrete units called:
A) waves
B) quanta or photons
C) frequencies
D) orbitals
Answer: quanta or photons

5. The kinetic energy of photoelectrons is given by the equation:
A) $1/2mv^2 = h\nu + h\nu_0$
B) $1/2mv^2 = h\nu_0 - h\nu$
C) $1/2mv^2 = h\nu - h\nu_0$
D) $1/2mv^2 = h\nu_0$
Answer: $1/2mv^2 = h\nu - h\nu_0$

6. The Compton effect demonstrated that X-rays exhibit particle-like behavior because they can:
A) be diffracted
B) be refracted
C) knock out electrons from a surface
D) produce continuous spectra
Answer: knock out electrons from a surface

7. The radius of the nth orbit in the hydrogen atom according to Bohr's model is given by:
A) $r = n \times 0.529 \times 10^{-8}$ cm
B) $r = n^2 \times 0.529 \times 10^{-8}$ cm
C) $r = 0.529 \times 10^{-8}$ cm
D) $r = 0.529 \times 10^{-10}$ cm
Answer: $r = n^2 \times 0.529 \times 10^{-8}$ cm

8. The energy of an electron in the nth orbit of a hydrogen atom is:
A) directly proportional to n^2
B) directly proportional to n
C) inversely proportional to n^2
D) inversely proportional to n
Answer: inversely proportional to n^2

9. The spectral series of hydrogen that lies in the infrared region is the:
A) Lyman series
B) Balmer series
C) Paschen series
D) Pfund series
Answer: Paschen series

10. A significant shortcoming of the Bohr model was its inability to explain:
A) the hydrogen spectrum
B) the stability of the hydrogen atom
C) the spectra of atoms with more than one electron
D) the quantization of angular momentum
Answer: the spectra of atoms with more than one electron

11. According to Sommerfeld's modification of the Bohr model, electron orbits could be:
A) only circular
B) only elliptical
C) both circular and elliptical
D) parabolic
Answer: both circular and elliptical

12. The maximum number of electrons that can be accommodated in an orbit designated by principal quantum number n is:
A) 2n
B) n^2
C) $2n^2$

Chemical Bonding and Molecular Structure

Introduction to Chemical Bonds

Definition:

A **chemical bond** *is defined as the attractive force that holds two or more atoms together in a stable molecule or ion.*

This force results from the electrostatic interactions between the electrons and nuclei of the combining atoms. A **chemical bond** represents the fundamental force responsible for the cohesion of atoms and ions, leading to the formation of the vast array of chemical compounds known to science. This force of attraction, which operates between the constituent particles, is the direct consequence of chemical combination. The overarching goal of chemical bonding theory is to elucidate the mechanisms by which these bonds form, the forces that govern their stability, and the three-dimensional architectures of the resulting molecules.

Why bonds Formation Occur?

A particularly illuminating case is that of the noble gases: helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn). These elements exhibit a profound chemical inertness under standard conditions. Their electronic configurations are characterized by completely filled valence shells: helium possesses the stable duplet configuration $\mathbf{1}s^2$, while the others conform to the general pattern $\mathbf{n}s\mathbf{2}np\mathbf{6}$, signifying a complete octet of electrons in their outermost principal quantum level. This electronic arrangement confers exceptional stability, rendering these gases largely unreactive. Indeed, a noble gas does not react with another noble gas.

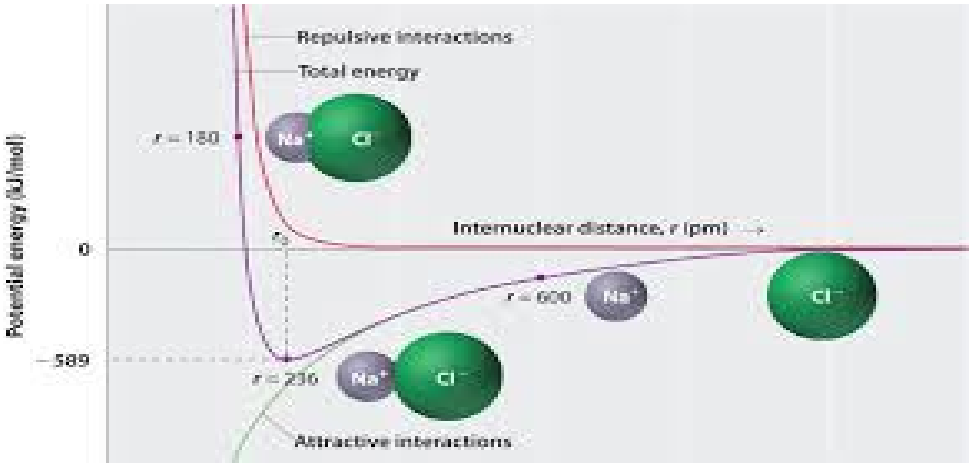
ENERGETICS OF BOND FORMATION

A very fine example of Energy involved during bond **formation is H_2.**When two isolated hydrogen atoms, each with its single 1s electron, are infinitely separated, the potential energy of the system is arbitrarily set to zero. As these atoms begin to approach each other under the influence of mutual attraction, several forces come into play simultaneously. **Attractive forces** arise between the nucleus of one atom and the electron of the other, and vice-versa. These forces tend to pull the atoms closer together. Concurrently, **repulsive forces** emerge: repulsion between the two positively charged nuclei and repulsion between the two negatively charged electrons. These forces tend to push the atoms apart.

The net potential energy of the two-atom system is the balance of these attractive and repulsive interactions. Initially, as the internuclear distance decreases from infinity, the magnitude of the attractive forces increases more rapidly than that of the repulsive forces. Consequently, the net force is attractive, and the **potential energy of the system decreases** as the atoms approach.

For the hydrogen molecule, this minimum occurs at an internuclear distance of **74 picometers (pm)**. This specific distance is known as the **bond length**, **bond distance**, or **equilibrium bond distance**. It represents a "**compromise distance**" where the attractive and repulsive forces are balanced, resulting in the lowest possible potential energy for the H_2 molecule.

The depth of this potential energy well, measured from the zero-energy reference of separated atoms, quantifies the strength of the bond. For H_2, the energy released when one mole of H_2 molecules is formed from its constituent atoms is **436.45 kilojoules per mole (kJ mol^{-1})**. This quantity is termed the **bond formation energy** or, more commonly, the **bond dissociation energy (D)**.



Fundamental Goal of Bond Formation:

Atoms form chemical bonds to achieve a lower energy state, thereby increasing their stability compared to their isolated forms. A stable chemical bond is formed only when the total energy of the system decreases as the atoms approach each other. The **Octet Rule** posits that during chemical bond formation, atoms tend to gain, lose, or share electrons in such a manner that each atom attains a maximum of eight electrons in its valence shell, mirroring the electronic configuration of noble gases (except helium). This rule provides a powerful, albeit simplified, framework for predicting the stoichiometry of a vast number of compounds.

Consider the following illustrative examples:

Lithium (Li): Configuration $\mathbf{1s^2 2s^1}$. By losing its single valence electron, it forms the Li+ ion, achieving the stable helium configuration 1s2

Magnesium (Mg): Configuration $\mathbf{1s^2,2s^2,2p^6 3s^2}$ Loss of two electrons yields Mg^{2+}, attaining the neon configuration $\mathbf{1s^2,2s^2,2p^6}$.

Fluorine (F): Configuration $\mathbf{1s^2,2s^2,2p^5}$. Gaining one electron forms the F^- ion, achieving the neon octet.

The driving force for bond formation is thus the attainment of a more stable, lower-energy electronic configuration. However, the pathway to this stability—whether by complete electron transfer or by mutual sharing—depends on the specific properties of the interacting atoms, such as their ionization energies, electron affinities, and electronegativity. In some reactions, an atom may exhibit an *apparent* ambiguity in its tendency.

For instance, in the formation of sodium hydride **(NaH),** hydrogen acts as an electron acceptor, forming H−. Conversely, in hydrogen fluoride (HF), the hydrogen atom, while still bonded, donates the major share of its electron density to the highly electronegative fluorine. These behaviors are not contradictions but rather reflections of the relative energies involved in different chemical contexts.

Limitations and Exceptions to the Octet Rule:

Incomplete Octet: Some molecules have less than 8 electrons around the central atom (e.g., $BeCl_2$ has 4, BF_3 has 6).

Odd-Electron Molecules (Free Radicals): Molecules with an odd number of valence electrons cannot pair all electrons (e.g., NO, NO_2).

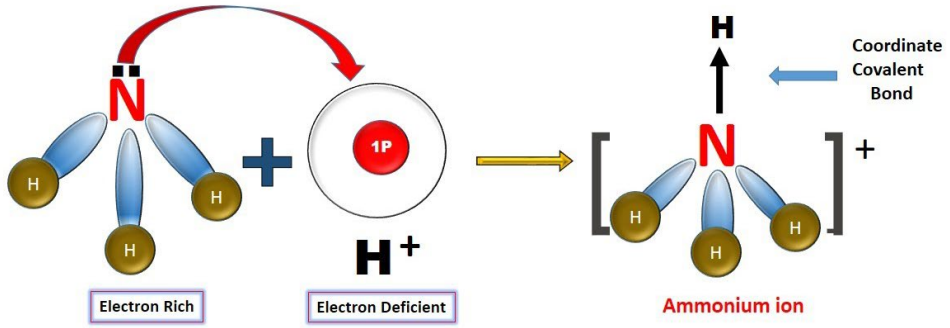
Expanded Octet (Super-Octet): Central atoms from the 3rd period and beyond can accommodate more than 8 electrons by utilizing empty d-orbitals **(e.g., PCl_5 with 10 electrons, SF_6 with 12 electrons).**

Isomerism: Exhibit stereoisomerism due to the rigid and directional nature of the covalent bond.
Reaction Speed: Molecular reactions are generally slow.

Coordinate Covalent (Dative) Bond

Definition:

A coordinate covalent bond is a special type of covalent bond where **both electrons of the shared pair are contributed by a single atom** (the donor). Once formed, it is identical in properties to a regular covalent bond.



Formation:

It is formed between an atom with a **lone pair of electrons** (donor) and an atom with a **vacant orbital** (acceptor).

Example: Formation of Ammonium ion (NH_4^+)

NH_3 has a lone pair on Nitrogen.

H^+ has a vacant 1s orbital.

$NH_3 + H^+ \rightarrow NH_4^+$ (The N→H bond is a coordinate bond).

Point to remember

Percentage of coordinate covalent bond and covalent bond (H_3O^+ Percentage of Coordinate covalent bond is 33% ,in Ammonium ion its 25 %)

Other Examples:

Hydronium ion (H_3O^+)

Ozone (O_3)

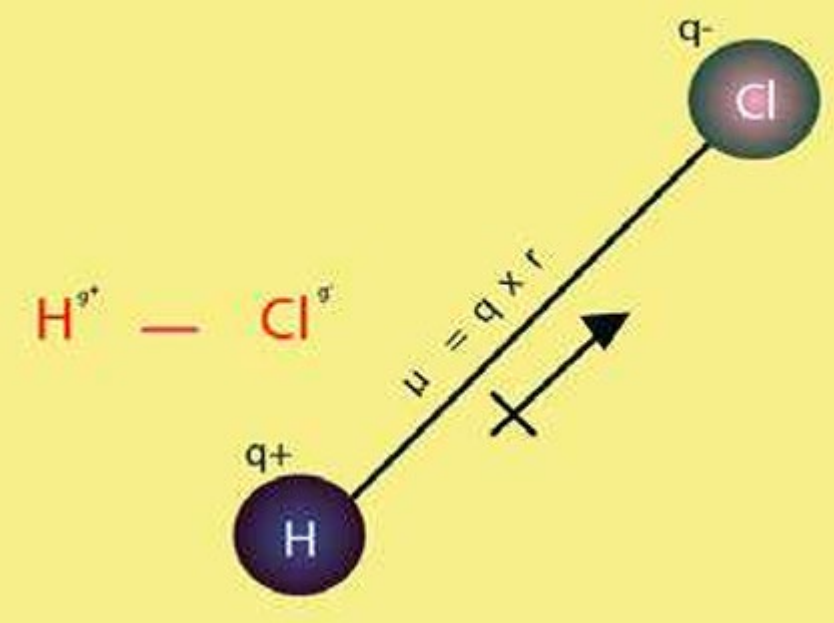
Aluminum chloride dimer (**Al_2Cl_6** which is an example of **Dimeric halides)**

Dipole Moment

It is a quantitative measure of the polarity of a molecule. It is defined as the product of the magnitude of the charge (q) and the distance (r) between the charges.

Definition: For a system of two charges +q and -q separated by a distance r*r*, the dipole moment is a vector quantity defined as:

$\mu = q \times r$



where ris the displacement vector pointing from the negative to the positive charge. In chemistry, for a bond $A\delta^+—B\delta^-$, it points from δ^+ to δ^-.

Units: The SI unit is the **coulomb-meter (C m).** The more common unit is the **Debye (D)**, where $1D=3.336\times10-30$ C m.

For a Diatomic Molecule: The dipole moment is the **bond dipole moment**. Examples: HF (1.91 D), HCl (1.08 D), HBr (0.82 D), HI (0.44 D). The decrease reflects decreasing polarity.

For Polyatomic Molecules: The molecular dipole moment is the **vector sum** of all individual bond dipole moments (and lone pair moments). It depends on both bond polarity and molecular geometry.

Symmetrical Molecules: If the geometry is such that the bond dipoles cancel each other, the molecule is **nonpolar** ($\mu = 0$).

CO_2 (linear): Two equal C=O dipoles point in opposite directions → cancel. $\mu = 0$.

BF_3 (trigonal planar): Three B-F dipoles cancel at 120° → $\mu = 0$.

CCl_4, CH_4(tetrahedral): Four bond dipoles cancel → $\mu = 0$.

SF6 (octahedral): $\mu = 0$.

Asymmetrical Molecules: If the bond dipoles do not cancel, the molecule has a net dipole moment (**polar molecule**).

H_2O (bent): Two O-H dipoles do not cancel → $\mu = 1.85$ D.

NH_3 (trigonal pyramidal): Three N-H dipoles do not cancel → $\mu = 1.47$ D.

CH_3Cl (tetrahedral but not symmetric due to different substituents): The C-Cl dipole is not cancelled by the three C-H dipoles → $\mu = 1.87$ D.

SO_2 (bent): $\mu = 1.63$ D.

Applications of Dipole Moment

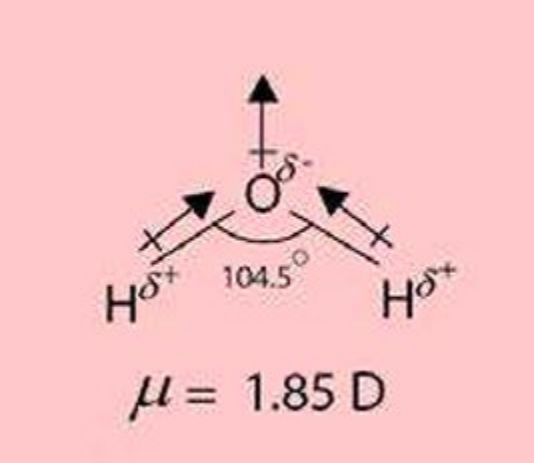
1. **Determining Percentage Ionic Character:**

   $\%\text{Ionic Character}=\mu_{\textbf{observed}} / \mu_{\textbf{ionic}} \times 100$

   Where *i*onicis the dipole moment calculated assuming complete electron transfer **(q=1.602×10−19 C)** and the experimental **bond length (r).**

Example for HF:
%Ionic Character=(1.91/4.40)×100=43.4%
Where 1.91 is observed dipole moment
And 4.40 is ionic dipole moment

2. **Determining Molecular Geometry:**
3. The measured dipole moment can distinguish between possible geometries.
   CO_2has μ = 0, confirming a **linear** structure (a bent structure would have μ > 0).
   H_2O has μ = 1.85 D, confirming a **bent** structure (a linear structure would have μ = 0).



BF_3 has μ = 0, confirming a **trigonal planar** structure (a pyramidal shape would have μ > 0).

For H_2S and SO_2, which are polar molecules, dipole moment is not zero**.**

Valence Shell Electron Pair Repulsion (VSEPR) Theory

Basic Principle:

The VSEPR theory states that **electron pairs (both bonding and lone pairs) in the valence shell of a central atom repel each other** and arrange themselves in space to be as far apart as possible. This arrangement of electron pairs determines the electron-pair geometry, while the positions of the atoms define the molecular geometry.

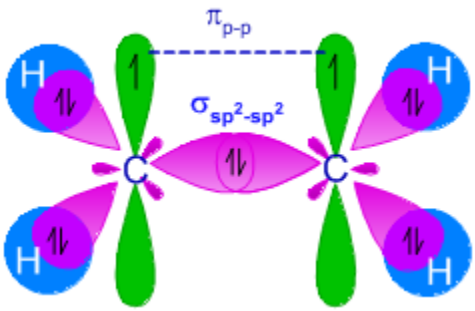
Order of Repulsion:

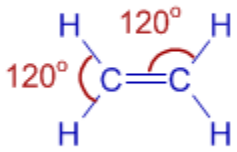
Lone pair-Lone pair (lp-lp) > Lone pair-Bond pair (lp-bp) > Bond pair-Bond pair (bp-bp)

Steps to Predict Molecular Shape:

1. Draw the Lewis structure of the molecule/ion.
2. Count the total number of electron pairs around the central atom (bonding pairs + lone pairs).

Example: BF_3, $H_2C=CH_2$ (in C=C, one σ and one π bond).





- **Example: Boron Trifluoride (BF3)**

B (ground state): $1s^2$, 2s2, $2px^1$. Only one unpaired electron.
Promotion & Hybridization: Electron promoted from 2s to 2py. The 2s, 2px, and 2py orbitals hybridize to form three sp^2 orbitals in a trigonal plane. Each sp^2 orbital overlaps with a p orbital of F, forming three B-F σ bonds. The molecule is trigonal planar.

- **Example: Ethene (C2H4)**

Each C atom undergoes sp^2 hybridization. Three sp^2 orbitals form σ bonds: two with H atoms and one with the other C atom. The unhybridized p orbitals on the two C atoms are parallel. They overlap sideways to form a ***π* bond**. Thus, the C=C double bond is one σ bond (sp^2-sp^2 overlap) and one π bond (p-p sideways overlap). The molecule is planar with H-C-H and H-C-C angles close to 120°.

sp^3 Hybridization:

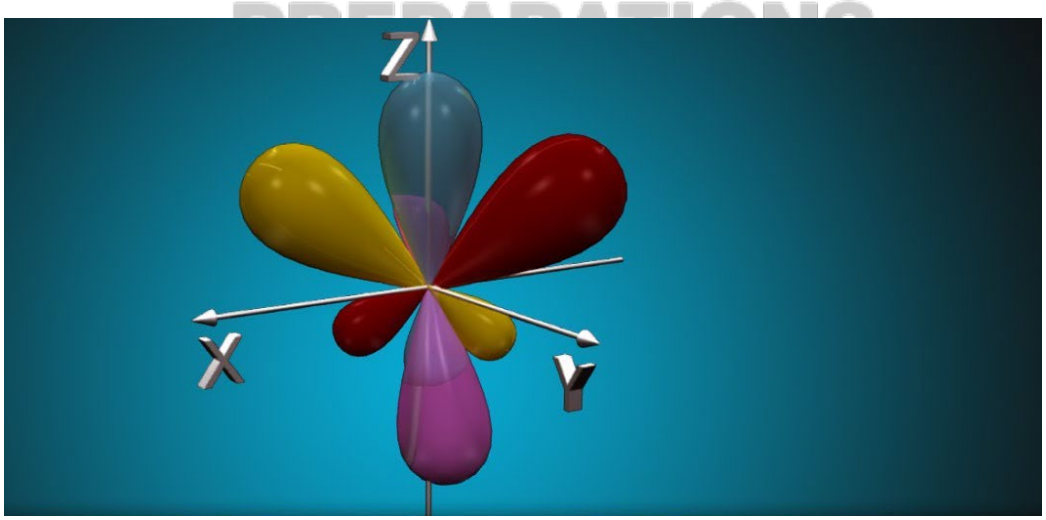
Orbitals Mixed: One s + three p orbitals.

Number of Hybrid Orbitals: 4 sp^3 orbitals.

Geometry: Tetrahedral.

Bond Angle: 109.5°.

Example: CH_4 (tetrahedral), NH_3 (pyramidal), H_2O (bent).



Practice MCQs

. Which overlapping may lead to Pi bond formation?
A) p-p in fluorine
B) s-p in hydrogen fluoride
C) sp^2-sp^2 in benzene
D) None
Correct Answer: D) None

2. Ionic bond with greater ionic character is mostly formed between elements of?
A) IA and IIA
B) IA and VIIA
C) IA and VIA
D) IIA and VIIA
Correct Answer: B) IA and VIIA

3. Bonds in calcium carbide between carbon atoms are?
A) Two pi
B) One sigma and one pi
C) One sigma and two pi
D) Ionic (no sigma, no pi)
Correct Answer: C) One sigma and two pi

4. Indicate the parameter which affects atomic radii in a period?
A) Number of shells
B) Nuclear charge
C) Shielding effect
D) Number of orbitals
Correct Answer: B) Nuclear charge

5. A cation is smaller in size than the parent atom because of?
A) Greater effective nuclear charge and lesser shielding effect
B) Greater effective nuclear charge and greater shielding effect
C) Lesser effective nuclear charge and lesser shielding effect
D) Lesser effective nuclear charge and greater shielding effect
Correct Answer: A) Greater effective nuclear charge and lesser shielding effect

6. Indicate the incorrect order of atomic/ionic radii?
A) $Na > Na^+$
B) $O^{2-} < O^-$
C) $Cl^- > Cl$
D) $Mg^{2+} < Mg$
Correct Answer: B) $O^{2-} < O^-$

7. Ionization energy of an element in a period increases due to?
A) Successive addition of electron shell
B) Successive increase of nuclear charge
C) Successive increase of effective nuclear charge
D) Both b and c
Correct Answer: D) Both b and c

8. In the formation of a compound AB, an electron is transferred from atom A to atom B, then?
A) A is divalent
B) B is oxidized and A is reduced
C) The compound AB is covalent
D) The compound AB is electrovalent
Correct Answer: D) The compound AB is electrovalent

9. In an ethylene molecule, the sigma bond is formed by _____ overlapping?
A) sp^3-sp^3
B) sp^2-sp^2
C) sp^3-sp
D) sp-sp^3
Correct Answer: B) sp^2-sp^2

10. Which of the following has the highest bond energy?
A) H–H bond in H_2
B) C–H in CH_4
C) N≡N bond in N_2
D) O=O bond in O_2
Correct Answer: C) N≡N bond in N_2

11. In which of the following molecules are triple covalent bonds present?
A) CH_4

Chemical Kinetics

Chemical Kinetics is the branch of chemistry that deals with the rates (or speeds) of chemical reactions, the factors affecting these rates, and the mechanisms by which reactions occur.

Rate of a Chemical Reaction

The rate of a reaction is defined as the change in the concentration of any reactant or product per unit time.

Explanation

During the course of a chemical transformation, reactant species are consumed as product species are generated. This process is quantitatively described by the continuous change in the concentrations of the involved substances. Specifically, the concentration of reactants exhibits a monotonic decrease, while the concentration of products shows a corresponding increase over time. This dynamic can be represented graphically. Consider an irreversible elementary reaction where a single reactant A is converted into a single product B: $A \rightarrow B$. A plot of concentration versus time for such a system yields characteristic curves. The concentration of A, [A], will be represented by a downward-sloping curve that originates at the initial concentration, $[A]_0$, and asymptotically approaches zero. Conversely, the concentration of B, [B], will be represented by a rising curve that originates at zero and asymptotically approaches $[A]_0$ as the reaction goes to completion.

The slope of these concentration-time curves at any given instant is of paramount importance. At the very inception of the reaction (t=0), the slope of the curve for the reactant is at its steepest negative value, indicating the most rapid rate of consumption. Correspondingly, the slope for the product curve is at its steepest positive value, indicating the most rapid rate of formation. As the reaction progresses, these slopes become progressively less steep, demonstrating that the rate of the reaction is not constant but diminishes with time. This deceleration occurs because the frequency of successful molecular collisions decreases as the reactant concentration is depleted. Ultimately, the curve for the reactant will, in principle, intersect the time axis (concentration = 0), signifying the point of complete reaction, though for practical purposes, reactions may be considered complete when the concentration change becomes immeasurably small.

Mathematical Expression:

For a general reaction: $aA + bB \rightarrow cC + dD$

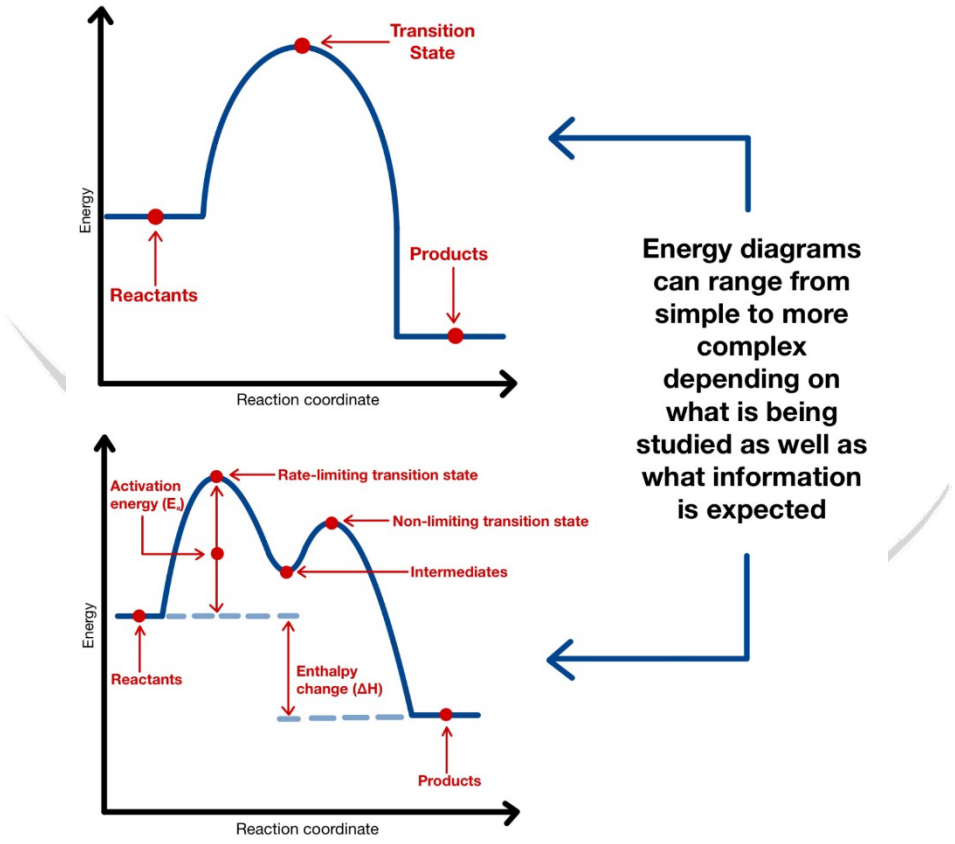
$$\text{Rate} = -\frac{1}{a}\frac{\Delta[A]}{\Delta t} = -\frac{1}{b}\frac{\Delta[B]}{\Delta t} = +\frac{1}{c}\frac{\Delta[C]}{\Delta t} = +\frac{1}{d}\frac{\Delta[D]}{\Delta t}$$

The negative sign for reactants indicates a decrease in concentration, while the positive sign for products indicates an increase.

Units: The unit of reaction rate is typically moles per cubic decimeter per second ($mol\ dm^{-3}\ s^{-1}$).

Activation Energy (E_a): The minimum amount of energy that colliding particles must possess for a reaction to occur. It is the energy barrier that must be overcome for reactants to transform into products.

Activated Complex (or Transition State): A temporary, high-energy, unstable species formed during the conversion of reactants to products. It has partial bonds and is the state of maximum potential energy in the reaction pathway.



Potential Energy Diagrams:

This diagram illustrate the energy changes during a reaction.

Exothermic Reaction: Products are at a lower energy level than reactants (ΔH is negative).

Endothermic Reaction: Products are at a higher energy level than reactants (ΔH is positive).

In both cases, the peak of the curve represents the activated complex, and the difference in energy between the reactants and this peak is the activation energy (E_a).

Factors Affecting Rate of Reaction

Nature of Reactants: Ionic reactions are generally much faster than covalent reactions because they involve simple ion exchange, while covalent reactions require bond breaking and forming.

Concentration of Reactants: According to the rate law, an increase in reactant concentration increases the reaction rate (except for zero-order reactions) because it increases the frequency of effective collisions.

ate ∝ Z·p·$e^{(-E_a/RT)}$ (Boltzmann fraction)where:

Z = Collision Frequency

p = Steric Factor (probability of correct orientation)

f = Fraction of molecules with energy ≥ E_a

Limitations of Collision Theory:

Applies mainly to simple gaseous reactions.

No method to calculate the steric factor (p) theoretically.

Ignores the contribution of vibrational and rotational energy.

Does not explain the cleavage and formation of bonds.

Transition State Theory (Activated Complex Theory)

This theory proposes that during a collision, reactant molecules form a short-lived, high-energy **activated complex** or **transition state**, which then decomposes to form products.

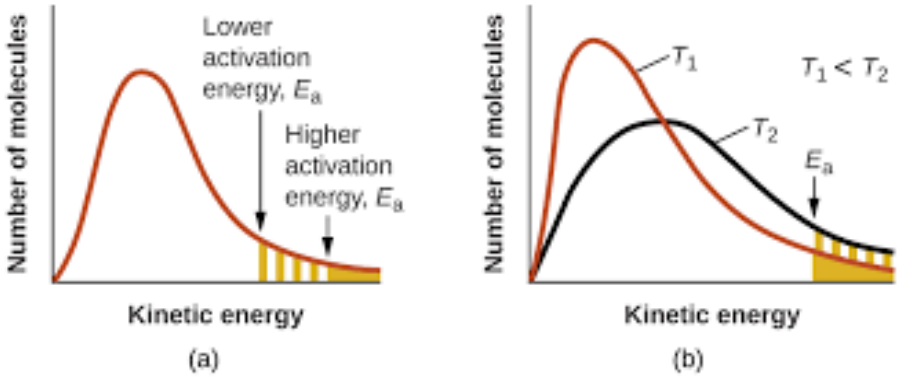
A + B–C ⇌ [A---B---C]‡ → A–B + C

(Reactants) (Activated Complex) (Products)

The double dagger (‡) denotes the transition state.

Effect of Temperature on Reaction Rate

The rate of most chemical reactions increases with temperature. A rough rule is that the rate doubles for every 10°C rise in temperature.



Arrhenius Equation

The Arrhenius equation gives the quantitative relationship between the rate constant (k), temperature (T), and activation energy (E_a).

$k = A\, e^{(-E_a/RT)}$

k = rate constant

A = Arrhenius constant or frequency factor (related to collision frequency and orientation)

E_a = Activation Energy (in J mol^{-1})

R = Universal Gas Constant (8.314 J mol^{-1} K^{-1})

T = Temperature in Kelvin

The logarithmic form is more useful for calculating E_a:

$\ln k = \ln A^{-} (E_a / RT)$ or $\log k = \log A^{-(E_a / 2.303RT)}$

Practice MCQs

Q1. The branch of chemistry dealing with reaction rates and mechanisms is called:
A) Thermodynamics
B) Electrochemistry
C) Chemical Kinetics
D) Stereochemistry
Correct Answer: C) Chemical Kinetics

Q2. For the reaction $2N_2O_5\ (g) \rightarrow 4NO_2\ (g) + O_2\ (g)$, if the rate of formation of O_2 is 2.5×10^{-4} mol L^{-1} s^{-1}, the rate of disappearance of N_2O_5 is:
A) 2.5×10^{-4} mol L^{-1} s^{-1}
B) 5.0×10^{-4} mol L^{-1} s^{-1}
C) 1.25×10^{-4} mol L^{-1} s^{-1}
D) 1.0×10^{-3} mol L^{-1} s^{-1}
Correct Answer: B) 5.0×10^{-4} mol L^{-1} s^{-1}

Q3. The unit of the rate constant for a zero order reaction is:
A) s^{-1}
B) L mol^{-1} s^{-1}
C) mol L^{-1} s^{-1}
D) L^2 mol^{-2} s^{-1}
Correct Answer: C) mol L^{-1} s^{-1}

Q4. For a first order reaction, the half-life is 20 minutes. The time required for the concentration to drop from 1.0 M to 0.125 M is:
A) 20 min
B) 40 min
C) 60 min
D) 80 min
Correct Answer: C) 60 min

Q5. A plot of ln[A] versus time gives a straight line with a negative slope. The order of the reaction is:
A) Zero
B) First
C) Second
D) Third
Correct Answer: B) First

Q6. The hydrolysis of ethyl acetate in the presence of a large excess of water is an example of:
A) Zero order reaction
B) First order reaction
C) Pseudo-first order reaction
D) Second order reaction
Correct Answer: C) Pseudo-first order reaction

Q7. The molecularity of the elementary step $2NO + O_2 \rightarrow 2NO_2$ is:
A) 1
B) 2
C) 3
D) 4
Correct Answer: C) 3

Q8. Which of the following is TRUE for order and molecularity?
A) Both are always the same
B) Order can be fractional, molecularity cannot
C) Molecularity is experimental, order is theoretical
D) They are identical for complex reactions
Correct Answer: B) Order can be fractional, molecularity cannot

Q9. The rate law for a reaction is found to be Rate = $k\ [A]^1[B]^{1/2}$. The overall order of the reaction is:
A) 1
B) 1.5
C) 2
D) 2.5
Correct Answer: B) 1.5

Q10. In the decomposition of H_2O_2, the volume of O_2 evolved is measured. If $V\infty$ is the final volume and V~t~ is the volume at time t, for a first order reaction:
A) $k = (2.303/t) \log(V\infty/Vt)$
B) $k = (2.303/t) \log(V\infty/(V\infty - Vt))$
C) $k = (1/t)\ (Vt/(V\infty - Vt))$

Electrochemistry

Introduction to Electrochemistry

Electrochemistry is the branch of chemistry that deals with the interconversion of chemical energy and electrical energy. This involves two main types of processes:

Production of Electricity from Chemical Reactions: This occurs in **Galvanic or Voltaic Cells** (like batteries), where a spontaneous redox reaction generates an electric current.

Use of Electricity to Drive Chemical Reactions: This occurs in **Electrolytic Cells**, where an external electric current is used to force a non-spontaneous chemical reaction to occur, a process known as **electrolysis**.

A fundamental requirement for these processes is the presence of an **electrolyte**—a substance that in solution or molten state conducts electricity by the movement of ions.

Oxidation and Reduction (Redox Reactions)

Basic Concepts

The concepts of oxidation and reduction are central to electrochemistry. Historically, these terms were defined in relation to oxygen and hydrogen transfer. Oxidation was described as the gain of oxygen or the loss of hydrogen by a substance. Reduction was conversely defined as the loss of oxygen or the gain of hydrogen. While these definitions are still useful for certain reactions, the modern, more comprehensive understanding is based on electron transfer.

Classical Concept:

Oxidation: Addition of oxygen or removal of hydrogen.

$2SO_2+O_2 \rightarrow 2SO_3$ (Oxidation of SO_2)

Reduction: Removal of oxygen or addition of hydrogen.

$H_2+Cl_2 \rightarrow 2HCl$ (Reduction of Cl_2)

Electron Transfer Concept (Modern Concept):

It defines oxidation and reduction in terms of electrons. Oxidation is the loss of electrons by a species, resulting in an increase in its oxidation state. Reduction is the gain of electrons, leading to a decrease in oxidation state. Crucially, these processes occur simultaneously in what is known as a **redox reaction**; one species is oxidized (the reducing agent) while another is reduced (the oxidizing agent). The electrons lost by the oxidized species are directly gained by the reduced species. This electron-transfer framework provides a universal language for analyzing reactions in aqueous solution, molten salts, and even in solid-state chemistry.

Redox Reaction: A reaction in which oxidation and reduction occur simultaneously.

Oxidation State (Oxidation Number)

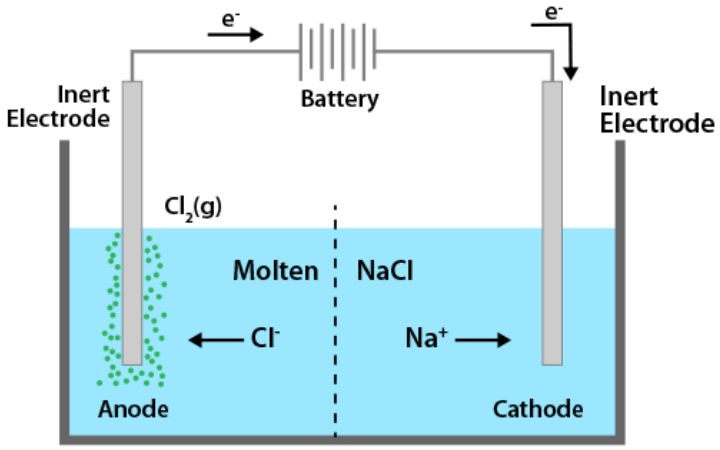
The oxidation number (or oxidation state) is a conceptual tool used to keep track of electron transfer in redox reactions. It is defined as the **apparent charge an atom** would carry if all its bonds to different atoms were considered 100% ionic, disregarding covalent character. Assigning oxidation numbers follows a set of well-established rules, which are essential for balancing redox equations and identifying oxidizing and reducing agents.

Rules for Assigning Oxidation Numbers:

The oxidation number of an atom in a **free element** is **0** (e.g. O_2, Zinc)

The oxidation number of a **monatomic ion** is equal to its **charge** like **Na^+**

Thus, electrolysis decomposes hydrochloric acid into its constituent elements.



Applications of Electrolysis

Applications of Electrolysis

The principles of electrolysis have vast industrial and technological applications:

1. **Electroplating:** The process of depositing a thin, coherent layer of a superior metal (e.g., Cr, Ni, Ag, Au) onto an inferior metal object. The object to be plated is made the cathode, a strip of the plating metal is the anode, and a solution of a salt of the plating metal serves as the electrolyte. This is used for decoration, corrosion resistance, and improving surface properties.
2. **Purification of Metals:** Impure metals can be refined electrolytically. For copper, a thick slab of impure copper is made the anode, a thin sheet of pure copper is the cathode, and acidified copper (II) sulphate is the electrolyte. On passing current, copper from the anode dissolves ($Cu \rightarrow Cu^{2+} + 2e^-$), and pure copper deposits on the cathode ($Cu^{2+} + 2e^- \rightarrow Cu$). Impurities either dissolve into the solution or fall to the bottom as "anode mud," which often contains valuable metals like gold and silver.
3. **Extraction of Metals:** Highly reactive metals that cannot be reduced by carbon (e.g., Na, K, Mg, Al) are extracted from their molten ores or salts via electrolysis. For example, **aluminium** is extracted from purified alumina (Al_2O_3) dissolved in molten **cryolite (Na_3AlF_6)** via the **Hall-Héroult process.**
4. **Manufacture of Chemicals:** Several important industrial chemicals are produced electrolytically.
5. **Chlor-alkali industry:** Electrolysis of concentrated brine (NaCl solution) produces chlorine gas at the anode, hydrogen gas at the cathode, and sodium hydroxide (NaOH) in the solution.
6. **Heavy water (D_2O):** Can be produced by the prolonged electrolysis of water, as H_2 is evolved slightly faster than D_2 (from HDO), enriching the remaining water in deuterium.
7. **Anodizing:** A process to increase the thickness of the natural oxide layer on the surface of metals like aluminium. The metal is made the anode in an electrolytic bath (e.g., sulfuric acid). Oxygen generated at the anode reacts with the metal to form a durable, corrosion-resistant oxide coating that can also be dyed.

Electrical Conductance of Electrolytic Solutions

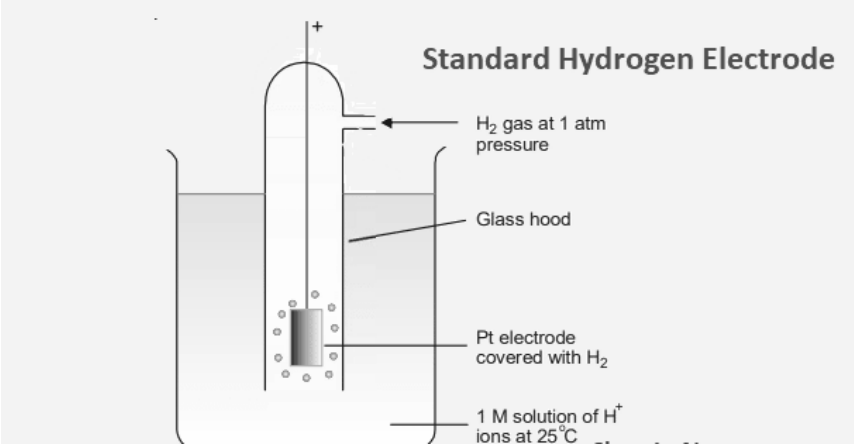
Key Definitions and Units

Resistance (R): Opposition to current flow. Unit: **Ohm (Ω)**.

Conductance (G): Reciprocal of resistance. G=1/R. Unit: **Siemens (S) or Ohm−1**

The standard electrode potential of SHE is **arbitrarily assigned a value of 0.00 V**

Half-reactions:



When SHE acts as anode: $H_2\ (g) \rightarrow 2H\ (aq)^+ + 2e^-\ (E_{Ox} = 0)$

When SHE acts as cathode: $2H\ (aq)^+ + 2e^- \rightarrow H_2\ (g)\ (E_{red} = 0)$

Standard Electrode Potential (E^o)

The potential of an electrode when it is in contact with a 1M solution of its ions at 298 K and 1 atm pressure, measured relative to the SHE.

Measurement of Electrode Potential

The electrode whose potential is to be measured is connected to the SHE to form a galvanic cell. The potential difference measured by the voltmeter gives the standard electrode potential of that electrode directly.

Example: For a Zn electrode, $E_{red} = -0.76V$ this means Zn has a lower tendency to gain electrons (be reduced) compared to hydrogen.

Electrochemical Series (ECS)

The Electrochemical Series is an arrangement of elements in the **order of increasing standard reduction potentials**.

Key Features and Applications

1. **Predicting the Direction of Redox Reactions:** A redox reaction is spontaneous (produces a positive EMF in a galvanic cell) if the species with the **higher (more positive) reduction potential** is reduced, and the species with the **lower (more negative) reduction potential** is oxidized. For example, Zn ($E° = -0.76$ V) reduces Cu^{2+} ($E° = +0.34$ V) spontaneously: $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$.
2. **Relative Strengths of Oxidizing and Reducing Agents:** Li^+/Li ($E° = -3.04$ V) is a very weak oxidizing agent but Li metal is the strongest reducing agent in aqueous solution. F_2/F^- ($E° = +2.87$ V) is the strongest oxidizing agent.
3. **Displacement Reactions:** A metal higher in the series (more negative E°) can displace a metal lower in the series from its salt solution. Zn displaces Cu from $CuSO_4$, but Cu cannot displace Zn from $ZnSO_4$.
4. **Displacement of Hydrogen from Acids:** Metals with negative reduction potentials (above hydrogen in the series, $E° < 0$) can displace H_2 from dilute acids (H^+ is reduced to H_2). Metals with positive potentials (below hydrogen) cannot.

5. **Predicting Feasibility of Corrosion:** Metals with negative E° values (like Fe, Zn) are thermodynamically prone to oxidation (corrosion) in the presence of air and moisture. Noble metals with positive E° (like Au, Pt) are resistant.
6. **Calculation of Standard EMF of a Cell:** For a galvanic cell, the standard EMF ($E°_{cell}$) is given by: $\mathbf{E°_{cell} = E°_{Cathode} - E°_{Anode}}$ where $E°_{cathode}$ is the reduction potential of the cathode half-cell and $E°_{anode}$ is the reduction potential of the anode half-cell. Since oxidation occurs at the anode, if using reduction potentials, $E°_{anode}$ is the reduction potential of the species being oxidized. For the Daniell cell: $E°_{cell}$ = $E°(Cu^{2+}/Cu) - E°(Zn^{2+}/Zn) = 0.34 - (-0.76) = \mathbf{+1.10\ V}$.

Cell Potential and Nernst Equation

Cell Potential (EMF, E°cell)

The potential difference between the two electrodes of a galvanic cell under standard conditions (1 M concentration, 1 atm pressure, 298 K) when no current is flowing.

Formula: E°cell = E°cathode − E°anode

Spontaneity: A **positive E°cell** indicates a spontaneous reaction.

Example: Calculating E°cell for a Zn-Cu Cell

Given: $E°(Zn^{2+}/Zn) = -0.76$ V; $E°(Cu^{2+}/Cu) = +0.34$ V

$E°cell = E°(Cu^{2+}/Cu) - E°(Zn^{2+}/Zn) = 0.34\ V - (-0.76\ V) = \mathbf{1.10\ V}$

Cell Representation (Cell Notation)

Anode (oxidation) is written on the **left**.

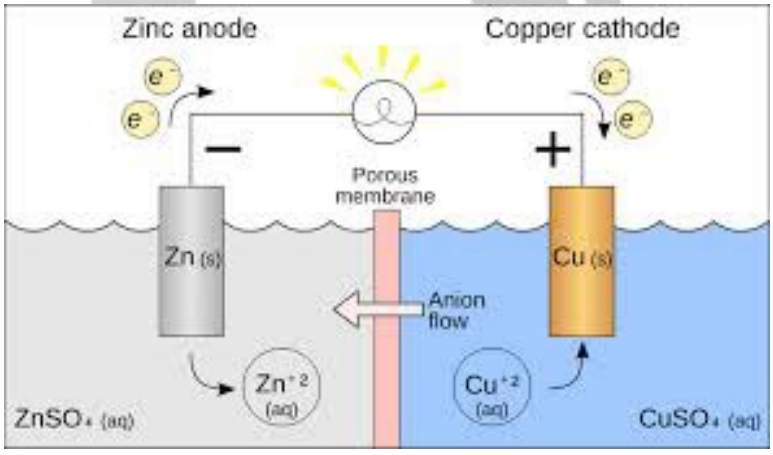
Cathode (reduction) is written on the **right**.

| represents a phase boundary (e.g., between solid electrode and ion solution).

|| represents the salt bridge.

Example (Daniel Cell): $Zn(s) | Zn^{2+}(1\ M) || Cu^{2+}(1\ M) | Cu(s)$

Nernst Equation



Nernst Equation

Relates the cell potential under non-standard conditions to the standard potential and the reaction quotient (Q).

For a general half-reaction: $aA + ne^- \rightleftharpoons bB$

General Form: $E = E° - (RT / nF) \ln (Q)$

Topic-wise One-Liner Statements: Electrochemistry

1. Introduction to Electrochemistry

1. **Electrochemistry** is the branch of chemistry dealing with the interconversion of electrical energy and chemical energy.
2. An **electrolytic cell** uses electrical energy to drive a non-spontaneous chemical reaction (electrolysis).
3. A **galvanic** or **voltaic cell** converts chemical energy from a spontaneous reaction into electrical energy.

2. Oxidation and Reduction (Redox)

4. **Oxidation** is defined as the loss of electrons or an increase in oxidation number.
5. **Reduction** is defined as the gain of electrons or a decrease in oxidation number.
6. An **oxidizing agent** accepts electrons and gets reduced during a reaction.
7. A **reducing agent** donates electrons and gets oxidized during a reaction.
8. In the classical concept, oxidation is the addition of oxygen or removal of hydrogen.
9. In the classical concept, reduction is the removal of oxygen or addition of hydrogen.

3. Oxidation State (Oxidation Number)

10. The **oxidation number** is the apparent charge an atom would have if all bonds were 100% ionic.
11. The oxidation number of a free element (e.g., Na, O_2, Cl_2) is always zero.
12. The oxidation number of hydrogen is +1, except in metal hydrides (e.g., NaH, CaH_2) where it is -1.
13. The oxidation number of oxygen is -2, except in peroxides (e.g., H_2O_2) where it is -1, and in OF_2 where it is +2.
14. The algebraic sum of oxidation numbers of all atoms in a neutral molecule is zero.
15. The algebraic sum of oxidation numbers of all atoms in a polyatomic ion is equal to the charge on the ion.
16. In $K_2Cr_2O_7$, the oxidation number of Cr is +6.
17. In H_2SO_4, the oxidation number of S is +6.

4. Balancing Redox Reactions

18. The **Oxidation Number Method** balances redox reactions by equating the total increase and decrease in oxidation numbers.
19. The **Ion-Electron (Half-Reaction) Method** splits the reaction into oxidation and reduction half-reactions, which are balanced separately before combining.
20. In the half-reaction method for acidic medium, O atoms are balanced by adding H_2O and H atoms are balanced by adding H^+ ions.
21. In the half-reaction method for basic medium, O atoms are balanced by adding H_2O, and H atoms are balanced by adding OH^- ions.

5. Electrolytes and Electrolytic Conduction

22. An **electrolyte** is a substance that in solution or molten state conducts electricity by the movement of ions.
23. A **strong electrolyte** is completely ionized in solution (e.g., NaCl, H_2SO_4, NaOH).
24. A **weak electrolyte** is partially ionized in solution (e.g., CH_3COOH, NH_4OH).
25. **Electrolysis** is the process of chemical decomposition of an electrolyte by the passage of electric

Practice MCQs

1. Weak electrolyte in solution is:
A) completely ionized
B) slightly ionized
C) never ionized
D) destroyed
Correct Answer: B) slightly ionized

2. Which one of the following is a strong electrolyte in solution?
A) Ammonium hydroxide
B) Carbonic acid
C) Potassium iodide
D) Acetic acid
Correct Answer: C) Potassium iodide

3. In an electrolytic cell, the cathode has a charge:
A) Positive
B) Negative
C) Neutral
D) Zero
Correct Answer: B) Negative

4. The oxidation number of Cl in $HClO_3$ is:
A) -1
B) +1
C) +3
D) +5
Correct Answer: D) +5

5. The oxidation number of magnesium in $MgCO_3$ is:
A) +3
B) +2
C) +1
D) -1
Correct Answer: B) +2

6. Which one of the following is a reduction reaction?
A) $Br_2 \rightarrow 2Br^-$
B) $Fe^{2+} \rightarrow Fe^{3+}$
C) $Zn \rightarrow Zn^{2+}$
D) $Sn^{2+} \rightarrow Sn^{4+}$
Correct Answer: A) $Br_2 \rightarrow 2Br^-$

7. A cell in which a non-spontaneous redox reaction is carried out by passing an electric current is a/an:
A) Galvanic cell
B) Voltaic cell
C) Daniell cell
D) Electrolytic cell
Correct Answer: D) Electrolytic cell

8. Zinc rod acts as anode in the Daniell cell but acts as cathode when coupled with aluminum electrode, this is because the standard reduction potential of:
A) Zn > Al
B) Zn < Al
C) Zn = Al
D) None of these
Correct Answer: A) Zn > Al

9. Electrolysis is a process in which the 'cations' and 'anions' liberated from electrolyte are:
A) hydrated
B) hydrolyzed
C) discharged
D) vaporized
Correct Answer: C) discharged

10. A cell which produces electric current by a redox reaction is called a/an:
A) Voltaic cell
B) Electrolytic cell
C) Half-cell
D) Standard cell
Correct Answer: A) Voltaic cell

11. The lead storage battery is a/an:
A) Down cell
B) Voltaic cell
C) Dry cell
D) Electrolytic cell
Correct Answer: B) Voltaic cell

12. The electrode potential of the standard hydrogen electrode is chosen as:
A) 0 V

Thermochemistry

Thermochemistry

Thermochemistry is dedicated to the quantitative study of thermal energy changes—specifically, heat transfers—that accompany chemical reactions and physical transformations. This field represents a direct application of the First Law of Thermodynamics to chemical processes, focusing on the energy inherently stored within substances, termed internal energy, and the energy exchanged with the surroundings as heat during reactions.

Fundamental principle

All chemical transformations involve the breaking of existing chemical bonds in the reactants, a process requiring an input of energy, and the formation of new bonds in the products, a process that releases energy. The net thermal effect observed—the heat of reaction—is the arithmetic difference between the total energy required for bond dissociation and the total energy liberated upon bond formation.

Heat

It is energy transferred due to temperature difference;

Temperature

It is average kinetic energy"

.**Energy Changes in Reactions:** During a chemical reaction, bonds in the reactants are broken (requiring energy) and new bonds in the products are formed (releasing energy). The net heat change of the reaction is the difference between these two energy values.

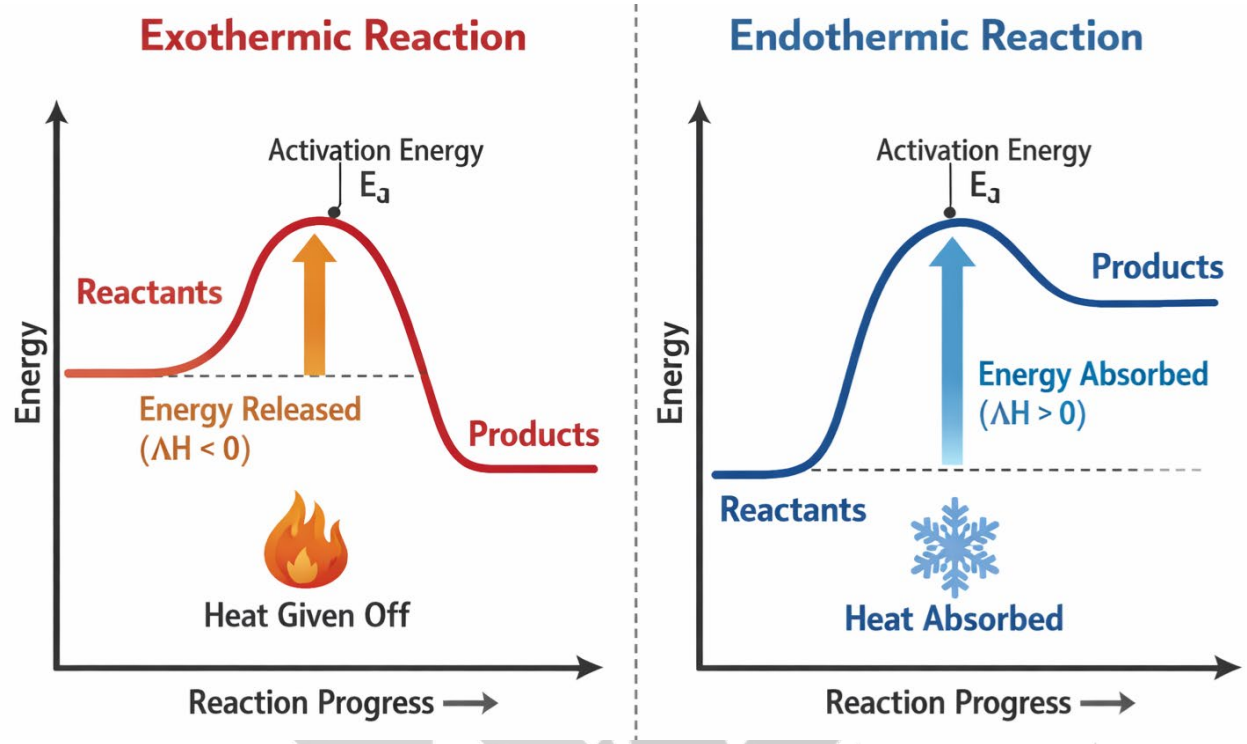
Sign Convention: The heat change of a reaction is denoted by **ΔH** (enthalpy change).

By convention:

ΔH = Negative (–ve): Exothermic Reaction. In such reactions, the system releases thermal energy to its surroundings. This is characteristic of processes like combustion, where the enthalpy of the products is lower than that of the reactants; the surplus energy manifests as heat, often accompanied by an increase in the temperature of the surroundings.

ΔH = Positive (+ve): Endothermic Reaction. Here, the system absorbs thermal energy from its surroundings. The enthalpy of the products is higher than that of the reactants, and the requisite energy is drawn from the environment, typically resulting in a cooling effect. A quintessential biological example is photosynthesis, where light energy is ultimately converted and stored as chemical energy within glucose molecules.

Photosynthesis: $6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$; $\Delta H = +2800$ kJ/mol (endothermic)"



Key Thermodynamic Concepts

System, Surroundings, and Boundary

System: The specific part of the universe under study (e.g., reactants in a beaker).

Surroundings: Everything else in the universe outside the system.

Boundary: The real or imaginary surface that separates the system from the surroundings.

State and State Functions

The **state of a system** is its condition as described by a set of macroscopic, measurable properties such as temperature (T), pressure (P), volume (V), internal energy (E), and composition (e.g., number of moles, n). When these properties have definite, unchanging values, the system is said to be in a definite state.

State function

(or state property) is a property whose value depends exclusively on the current, equilibrium state of the system, and not on the history or the specific path by which that state was achieved. The **change** in a state function (denoted by Δ, as in ΔV or ΔE) is determined solely by the values in the initial and final states **(Δ = Final State – Initial State).**

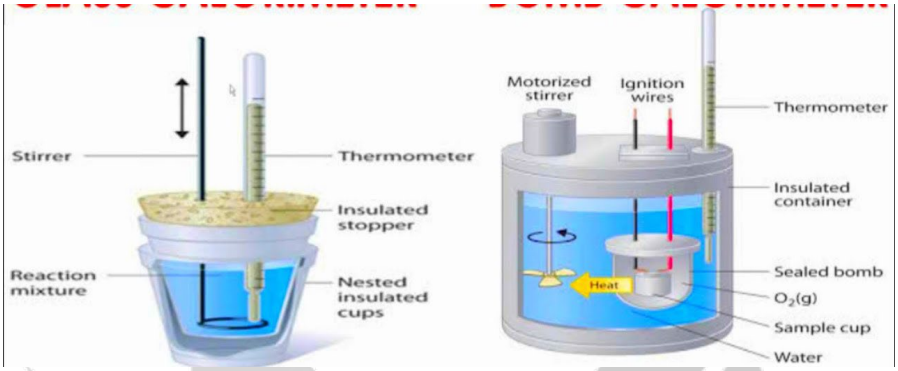
Common examples of state functions include **internal energy (E), enthalpy (H), pressure (P), volume (V), temperature (T), entropy (S), and Gibbs free energy (G).** These are path-independent.

In contrast, **heat (q)** and **work (w)** are **path functions**. Their magnitudes depend critically on the specific sequence of intermediate states traversed during a process. For instance, the work done in expanding a gas depends on whether the expansion occurs against a constant external pressure, reversibly, or in a series of steps; different paths yielding the same final volume will involve different amounts of work.

Consequently, while we can discuss changes in state functions (ΔE, ΔH), it is incorrect to refer to "change

the **change in internal energy (ΔE)** for the combustion reaction. To find the standard enthalpy of combustion (ΔH°c), one must then apply the correction ΔH = ΔE + Δn(g)RT.where **R = 8.314 J/mol·K = 0.0821 L·atm/mol·K = 1.987 cal/mol·K = 0.008314 kJ/mol·K**

At constant volume, q_v = **ΔE.(At constant volume, q_v = ΔE** only **if no non-PV work**)



Hess's Law of Constant Heat Summation

This is a fundamental law in thermochemistry, stated as:

The total enthalpy change for a reaction is the same, regardless of the number of steps in which the reaction is carried out, provided the initial and final conditions are the same.

In other words, enthalpy is a state function, so the pathway is irrelevant.

Applications:

Calculation of enthalpies of formation for compounds that cannot be synthesized directly from their elements (e.g., CO).

Determination of enthalpy changes for reactions that are slow or have side reactions.

Calculation of lattice energy and electron affinity via the Born-Haber cycle.

Methodology: Thermochemical equations can be treated algebraically—they can be added, subtracted, reversed (sign of ΔH changes), or multiplied by a coefficient (ΔH is multiplied by the same coefficient).

Example: Calculation of ΔH°*f* for CO (g)

Given:

1. $C(graphite) + O_2(g) \rightarrow CO_2(g)$ | $\Delta H_1 = -393.5$ kJ mol^{-1}
2. $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$ | $\Delta H_2 = -283.0$ kJ mol^{-1}

Target Equation: $C(graphite) + \frac{1}{2} O_2(g) \rightarrow CO(g)$ | $\Delta H_3 = ?$

Subtracting equation (2) from equation (1) gives the target equation.

Therefore, $\Delta H_3 = \Delta H_1 - \Delta H_2 = (-393.5) - (-283.0) =$ **-110.5 kJ mol^{-1}**

Remember (When reversing an equation, ΔH changes sign. When multiplying equation by n, multiply ΔH by n)

The Born-Haber Cycle

The Born-Haber cycle is a specific application of Hess's Law used to calculate the **Lattice Energy** of an ionic compound, which cannot be measured directly.

Lattice Energy ($\Delta H°_{latt}$): The enthalpy change when one mole of an ionic crystal is formed from its constituent gaseous ions. It is a measure of the stability of the ionic lattice.

Table of Spontaneity in Thermochemistry				
ΔH (Enthalpy)	ΔS (Entropy)	ΔG (Gibbs Free Energy)	Spontaneity	
– (Negative)	+ (Positive)	ΔG < 0 Negative Spontaneous	Always Spontaneous	
– (Negative)	– (Negative)	ΔG < 0 at Low T Spontaneous at Low Temp	Spontaneous at Low Temp	Spontaneous at Low Temperatures
+ (Positive)	+ (Positive)	ΔG < 0 at High T Spontaneous at High Temp	Spontaneous at High Temp	Spontaneous at High Temperatures
+ (Positive)	– (Negative)	ΔG > 0 Positive Non-Spontaneous	Never Spontaneous	

Important Note: While many spontaneous processes are exothermic, this is not always true. Endothermic processes can also be spontaneous (e.g., dissolving of NH_4Cl in water). Spontaneity is governed by both **enthalpy (ΔH)** and **entropy (ΔS)**, a measure of disorder, as described by the Gibbs free energy equation: **ΔG = ΔH – TΔS**. A negative ΔG indicates a spontaneous process.

Topic-Wise One-Liners: Thermochemistry

Introduction to Thermochemistry

1. **Thermochemistry** is the study of heat energy changes accompanying chemical reactions and physical transformations.
2. An **exothermic** reaction releases heat to the surroundings, indicated by a **negative ΔH**.
3. An **endothermic** reaction absorbs heat from the surroundings, indicated by a **positive ΔH**.
4. **Energy** is defined as the capacity to do work.
5. The **Electron Volt (eV)** is the smaller unit of energy, used for sub-atomic particles.
6. The SI unit of energy is the **Joule (J)**.
7. One calorie is equal to **4.184 Joules**.
8. The bigger practical unit of energy is the **Kilowatt-hour (KWH)**, which equals 3.6 million Joules.

Systems and Surroundings

9. A **system** is the specific part of the universe under observation.
10. The **surroundings** comprise everything else in the universe outside the system.
11. The **boundary** is the real or imaginary surface separating the system from its surroundings.
12. An **open system** can exchange both matter and energy with its surroundings.
13. A **closed system** can exchange energy but not matter with its surroundings.
14. An **isolated system** can exchange neither matter nor energy with its surroundings.
15. The human body is an example of an **open system**.

State Functions and Path Functions

16. A **state function** is a property whose value depends only on the current state of the system, not the path taken to reach that state.
17. Examples of state functions are **Internal Energy (E), Enthalpy (H), Pressure (P), Volume (V), and Temperature (T)**.
18. **Heat (q)** and **Work (w)** are path functions, as their values depend on the path taken.
19. **Intensive properties** do not depend on the quantity of matter (e.g., Temperature, Density).
20. **Extensive properties** depend on the quantity of matter (e.g., Mass, Volume, Internal Energy).

First Law of Thermodynamics

21. The **First Law of Thermodynamics** states that energy cannot be created or destroyed, only converted from one form to another (Law of Conservation of Energy).
22. The mathematical expression of the first law is **ΔE = q + w**, where ΔE is the change in internal energy, q is heat, and w is work.
23. The sign convention states that **heat absorbed by the system (q) is positive**, and **heat released by the system (q) is negative**.
24. The sign convention states that **work done on the system (w) is positive**, and **work done by the system (w) is negative**.
25. For expansion against a constant external pressure, work is calculated as **w = -PΔV**.
26. A limitation of the first law is that it does not indicate the **direction** of a process.

Enthalpy (H)

27. **Enthalpy (H)** is a state function defined as **H = E + PV**.
28. The change in enthalpy (**ΔH**) is equal to the heat absorbed or released at **constant pressure (q_p)**.
29. For reactions involving gases, the relationship between ΔH and ΔE is **ΔH = ΔE + ΔnRT**, where **Δn** is

Practice MCQs

1. Which of the following is always true for an exothermic reaction?
A) ΔH is positive
B) ΔH is negative
C) ΔS is positive
D) ΔG is negative
Answer: ΔH is negative

2. The branch of chemistry that deals with the energy changes in chemical reactions is called:
A) Electrochemistry
B) Thermochemistry
C) Chemical Kinetics
D) Stoichiometry
Answer: Thermochemistry

3. Which one of the following is an extensive property?
A) Temperature
B) Density
C) Internal Energy
D) Specific Heat
Answer: Internal Energy

4. In an isolated system, what can be exchanged with the surroundings?
A) Matter only
B) Energy only
C) Both matter and energy
D) Neither matter nor energy
Answer: Neither matter nor energy

5. A state function is:
A) Heat (q)
B) Work (w)
C) Enthalpy (H)
D) Both q and w
Answer: Enthalpy (H)

6. According to the first law of thermodynamics, the equation for the change in internal energy (ΔE) is:
A) ΔE = q – w
B) ΔE = q / w
C) ΔE = q + w
D) ΔE = w – q
Answer: ΔE = q + w

7. For a system that absorbs heat and does work on the surroundings, the signs of q and w are respectively:
A) Negative, Negative
B) Positive, Positive
C) Positive, Negative
D) Negative, Positive
Answer: Positive, Negative

8. The work done by a system during an expansion against a constant external pressure is given by:
A) w = PΔV
B) w = –PΔV
C) w = ΔV/P
D) w = –ΔV/P
Answer: w = –PΔV

9. Enthalpy (H) is defined as:
A) E – PV
B) E / PV
C) E + PV
D) PV – E
Answer: E + PV

10. The heat change at constant pressure (q_p) is equal to:
A) ΔE
B) ΔH
C) ΔG
D) w
Answer: ΔH

11. For the reaction where the number of moles of gas decreases (Δn < 0), which relationship is correct?
A) ΔH = ΔE
B) ΔH > ΔE
C) ΔH < ΔE
D) ΔH = 0
Answer: ΔH < ΔE

Radio and Nuclear Chemistry

Introduction to Radioactivity

Radioactivity is defined as the spontaneous disintegration of an unstable atomic nucleus, accompanied by the emission of penetrating radiation such as alpha particles, beta particles, and gamma rays. This process is independent of external factors such as temperature, pressure, or chemical combination and depends solely on the internal instability of the nucleus. **Radioactive elements** are those whose nuclei are unstable and undergo spontaneous decay to achieve a more stable configuration. Examples include Uranium (U), Radium (Ra), Polonium (Po), and Thorium (Th).

The historical background of radioactivity begins with **Wilhelm Roentgen's** discovery of X-rays in 1895, which are high-energy electromagnetic waves. This sparked interest in "invisible rays." In 1896, **Henri Becquerel** accidentally discovered that uranium salts emitted invisible, penetrating rays capable of darkening a photographic plate without any external energy source; this was the first observation of natural radioactivity. In 1898, **Marie and Pierre Curie** coined the term "radioactivity" and discovered two new, highly radioactive elements: Polonium and Radium. Finally, in 1899, **Ernest Rutherford** identified and named the three types of radiation based on their penetrating power and charge: **Alpha (α), Beta (β), and Gamma (γ)**. These discoveries fundamentally changed the understanding of the atom, revealing that it was not indivisible and that the nucleus could undergo transformations.

Types and Properties of Radiations

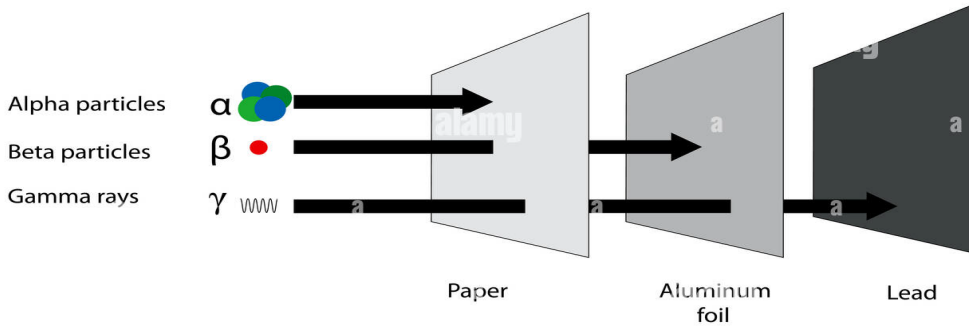
Rutherford's experiment of passing radiation through an electric field allowed classification based on their deflection. The properties of the three main types of radiation are distinct and critical to understanding their behavior and applications.

Alpha (α) Rays consist of streams of helium nuclei ($^{4}_{2}He^{2+}$). They carry a charge of +2 and have a mass of approximately 4 atomic mass units (amu). Alpha particle speed depends on kinetic energy; typically a **few % to 10% of c** (order of magnitude).". Due to their high mass and charge, they possess very high ionizing power but very low penetrating power; they can be stopped by a sheet of paper, skin, or a few centimeters of air. In an electric or magnetic field, alpha particles are deflected toward the negative plate.

Beta (β) Rays are streams of fast-moving electrons . They carry a charge of -1 and have a negligible mass (about 1/1837 amu). Their velocity can reach up to 90% of the speed of light. Beta penetration is **moderate**; stopped by a few mm of Al/plastic; range in air is **energy-dependent**. Their ionizing power is moderate, roughly one-hundredth that of alpha particles. In an electric field, they are deflected toward the positive plate.

Gamma (γ) Rays are high-energy electromagnetic radiation (photons). They are neutral, massless, and travel at the speed of light. Gamma rays have very high penetrating power, requiring thick lead or concrete shielding to attenuate them. Their ionizing power is very low, making them weak ionizers. They are not deflected by electric or magnetic fields.

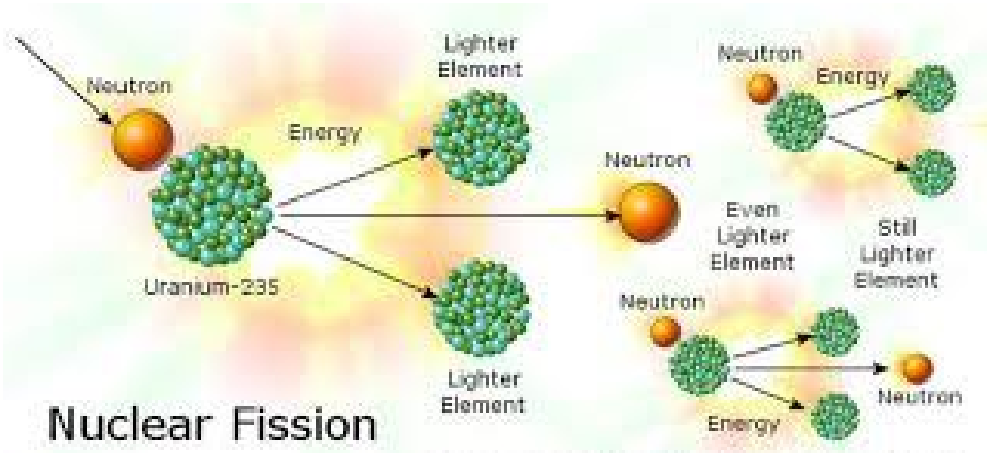
Radioactivity Penetration Range



Key comparative points to remember are: The order of **ionizing power** is **α > β > γ**, and the order of **penetrating power** is **α < β < γ**.

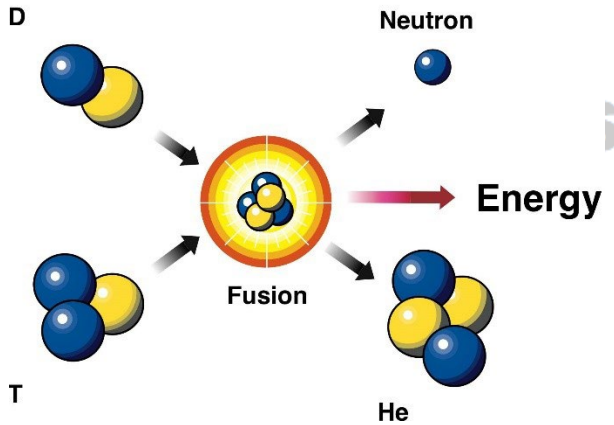
Property	Alpha (α) Rays	Beta (β) Rays	Gamma (γ) Rays
Nature & Identity	Streams of Helium nuclei	Streams of fast-moving electrons (Beta-minus (β^-) rays are streams of fast-moving electrons; beta-plus (β^+) rays are streams of positrons)	High-energy electromagnetic radiation (photons)
Charge	+2	-1	0 (Neutral)
Mass	4 amu (approx.)	1/1837 amu (negligible)	0 (massless)
Velocity	$1/10^{th}$ of speed of light	90% the speed of light **Exact is (0.3 to 0.99c)**	Speed of light
Penetrating Power	Very Low (stopped by paper, skin, or a few cm of air)	Moderate (stopped by a few mm of Aluminum or 1m of air)	Very High (requires thick lead or concrete to attenuate)
Ionizing Power	Very High (intense ionizers due to high mass and charge)	Moderate (about $1/100^{th}$ of that of α-particles)	Very Low (weak ionizers)

Nuclear Fusion



Nuclear Fusion is the process in which two or more light atomic nuclei combine to form a single, heavier nucleus, releasing an enormous amount of energy. This process requires extremely high temperatures (millions of degrees Celsius) to overcome the electrostatic repulsion between the positively charged nuclei, hence it is termed a **thermonuclear reaction**. At these temperatures, matter exists in the plasma state.

The Sun's energy is produced primarily by the proton-proton chain (99%) with a small contribution from the CNO cycle (1%). For more massive stars, the CNO cycle dominates. A **Hydrogen Bomb (H-Bomb)** is an uncontrolled fusion device that uses a fission bomb as a trigger to achieve the necessary temperature and pressure for fusion of hydrogen isotopes like deuterium and tritium.



Fusion as a Future Energy Source Deuterium is abundant, **but tritium (required for D-T fusion**) is radioactive with a 12.3-year half-life and must be bred from lithium in the reactor blanket, higher energy yield per gram, and less long-lived radioactive waste compared to fission. However, major challenges remain in achieving and confining plasma at the required temperatures and pressures.

Artificial Radioactivity and Nuclear Isomerism

Artificial (Induced) Radioactivity refers to the phenomenon where stable nuclei are transformed into radioactive isotopes by bombarding them with high-energy particles like protons, neutrons, or alpha

Rayleigh-Jeans law, The Rayleigh-Jeans law accurately predicted black-body radiation at long wavelengths **but failed catastrophically** at short wavelengths (ultraviolet catastrophe), predicting infinite energy density. a problem known as the **ultraviolet catastrophe**. **Max Planck** resolved this in 1900 by proposing that energy is quantized, existing only in discrete amounts given by **E = nhν**, where n is an integer and h is Planck's constant. This led to the Planck distribution formula.

The **Photoelectric Effect**, where electrons are ejected from a metal surface by light, also defied classical explanation. Key observations were that ejection occurred only above a threshold frequency, and the kinetic energy of ejected electrons depended on frequency, not intensity.

Albert Einstein explained this in 1905 by proposing that light consists of particles called **photons**, each with energy **hν**. The kinetic energy of an ejected electron is given by $\frac{1}{2}m_e v^2 = h\nu - \Phi$, where Φ is the work function of the metal.

Wave-Particle Duality emerged as a central concept. **Louis de Broglie** hypothesized that particles could exhibit wave-like properties, with a wavelength given by $\lambda = h / p$, where p is momentum. The **Davisson-Germer experiment**, which demonstrated electron diffraction, confirmed the wave nature of particles.

In quantum mechanics, the state of a system is described by a **wavefunction, ψ**. The **time-independent Schrödinger equation** is the fundamental equation: $-\hbar^2/2m\,(d^2\psi/dx^2) + V(x)\psi = E\psi$, where V(x) is the potential energy, and E is the total energy.

According to the **Born Interpretation**, the square of the wave function's modulus, $|\psi|^2$, represents the **probability density** of finding a particle at a given point. The wavefunction itself is the probability amplitude.

The **Heisenberg Uncertainty Principle**, formulated by Werner Heisenberg, states that certain pairs of complementary observables, like position (x) and momentum (p_x), cannot be measured simultaneously with arbitrary precision: $\Delta x\, \Delta p_x \geq \hbar/2$.

Topic-Wise One-Liner: Radio and Nuclear Chemistry

Introduction to Radioactivity

1. **Radioactivity** is the spontaneous disintegration of unstable atomic nuclei, accompanied by the emission of penetrating radiation.
2. The radioactive decay process is independent of external factors like temperature, pressure, or chemical bonding.
3. **Radioactive elements**, such as Uranium, Radium, Polonium, and Thorium, possess unstable nuclei that decay to achieve a more stable configuration.

Historical Background

4. **Wilhelm Roentgen** discovered **X-rays** in 1895, sparking interest in "invisible rays."
5. **Henri Becquerel** accidentally discovered **natural radioactivity** from uranium salts in 1896.
6. **Marie and Pierre Curie** coined the term "radioactivity" and discovered the elements **Polonium** and **Radium** in 1898.
7. **Ernest Rutherford** identified and named **Alpha (α), Beta (β), and Gamma (γ)** radiations in 1899.

Types and Properties of Radiations

8. **Alpha particles** are helium nuclei ($^4_2He^{2+}$) with a charge of +2 and a mass of approximately 4 amu.
9. **Beta particles** are fast-moving electrons ($^0_{-1}e$) with a charge of -1 and negligible mass.

Practice MCQs

1. What is the defining characteristic of radioactivity?
A) It requires high temperature to initiate
B) It involves the spontaneous disintegration of unstable nuclei
C) It only occurs in man-made elements
D) It is highly dependent on chemical bonding
Answer: It involves the spontaneous disintegration of unstable nuclei

2. Who accidentally discovered natural radioactivity?
A) Marie Curie
B) Wilhelm Roentgen
C) Henri Becquerel
D) Ernest Rutherford
Answer: Henri Becquerel

3. Which scientists coined the term "radioactivity"?
A) Marie and Pierre Curie
B) Henri Becquerel
C) Ernest Rutherford
D) Wilhelm Roentgen
Answer: Marie and Pierre Curie

4. What is the identity of an alpha particle?
A) A high-energy electron
B) A helium nucleus
C) A high-energy photon
D) A proton
Answer: A helium nucleus

5. Which type of radiation has the highest penetrating power?
A) Alpha rays
B) Beta rays
C) Gamma rays
D) X-rays
Answer: Gamma rays

6. Which type of radiation has the highest ionizing power?
A) Alpha rays
B) Beta rays
C) Gamma rays
D) Neutrons
Answer: Alpha rays

7. In an electric field, towards which plate are beta particles deflected?
A) Negative plate
B) Positive plate
C) They are not deflected
D) Perpendicular to the field
Answer: Positive plate

8. Which instrument uses a supersaturated vapor to make radiation paths visible?
A) Geiger-Muller Counter
B) Scintillation Counter
C) Cloud Chamber
D) Ionisation Chamber
Answer: Cloud Chamber

9. What is the principle behind a Film Badge used for radiation monitoring?
A) Gas ionization
B) Light scintillation
C) Film darkening
D) Electron avalanche
Answer: Film darkening

10. The rate of radioactive disintegration is proportional to:
A) The decay constant only
B) The time elapsed
C) The number of undecayed atoms present
D) The half-life of the substance
Answer: The number of undecayed atoms present

11. The mathematical expression for the radioactive decay law is:
A) $N = N_0 / t$
B) $N = N_0 \lambda t$
C) $N = N_0 e^{(-\lambda t)}$

Aromatic Compounds (Benzene)

Introduction to Aromatic Compounds

Definition: Aromatic compounds are a class of cyclic, planar, and conjugated organic compounds that exhibit exceptional stability due to the delocalization of π-electrons. The term "aromatic" originally referred to their pleasant fragrances but now is based on their specific chemical structure and stability.

Parent Molecule: Benzene (C_6H_6) is the fundamental and simplest aromatic hydrocarbon. All compounds that resemble benzene in chemical behavior, particularly their unusual stability, are classified as aromatic.

Historical Context:

Michael Faraday first isolated benzene in 1825 from the oily residue of London's illuminating gas.

Eilhardt Mitscherlich synthesized it in 1834 by heating benzoic acid with lime.

The name "**benzene**" is derived from "gum benzoin," a fragrant resin from which benzoic acid was obtained.

Health Warning: Benzene is a known carcinogen (causes leukemia) and should be handled with extreme care.

Nomenclature of Benzene Derivatives

The systematic process of naming benzene derivatives follows IUPAC rules, though many common names are retained.

Monosubstituted Benzenes: Compounds with one substituent on the benzene ring.

IUPAC System: Named by adding the substituent name as a prefix to "benzene."

Example: C_6H_5–Br is **Bromobenzene**; C_6H_5–NO_2 is **Nitrobenzene**.

Common Names: Some derivatives have widely accepted common names that are used in preference to systematic names.

C_6H_5–CH_3: **Toluene** (not Methylbenzene)

C_6H_5–OH: **Phenol** (not Hydroxybenzene)

C_6H_5–NH_2: **Aniline** (not Aminobenzene)

C_6H_5–CHO: **Benzaldehyde**

C_6H_5–COOH: **Benzoic Acid**

Disubstituted Benzenes

Compounds with two substituents. The relative positions are indicated by prefixes or numbers.

Ortho (o- or 1, 2): Substituents are on adjacent carbon atoms.

Meta (m- or 1, 3): Substituents are separated by one carbon atom.

Para (p- or 1, 4): Substituents are on opposite sides of the ring.

The Phenyl (C_6H_5–) and Benzyl (C_6H_5—CH_2–) Groups:

Phenyl Group (Ph- or φ-): The group derived from benzene by removing one hydrogen atom. It is used when the benzene ring is a substituent on a larger molecule.

Topic Wise One Liner: Aromatic Compounds

1. Aromatic compounds are cyclic, planar, conjugated, and obey Hückel's (4n+2) π-electron rule.
2. Benzene (C_6H_6) is the parent aromatic hydrocarbon with a delocalized π-cloud of 6 electrons.
3. The resonance energy of benzene is **152 kJ/mol**, explaining its exceptional stability.
4. Benzene primarily undergoes **Electrophilic Aromatic Substitution (EAS)** reactions to preserve its aromaticity.
5. The EAS mechanism involves the formation of a resonance-stabilized **arenium ion** intermediate.
6. Substituents on the ring are classified as **Activating/Deactivating** and **Ortho-Para/Meta Directing**.
7. **Ortho/Para directors** are generally electron-donating groups (except halogens).
8. **Meta directors** are strong electron-withdrawing groups.
9. The benzene ring is resistant to addition and oxidation, but alkyl side-chains can be oxidized to –COOH.

Aromatic Compounds & Electrophilic Aromatic Substitution: Detailed One-Liners

1. Introduction & History

10. **Aromatic compounds** are a class of cyclic, planar, and conjugated organic compounds that exhibit exceptional stability due to the delocalization of π-electrons.
11. **Benzene (C_6H_6)** is the simplest and parent aromatic hydrocarbon.
12. **Michael Faraday** first isolated benzene in 1825 from the oily residue of coal gas.
13. **Eilhardt Mitscherlich** synthesized benzene by heating benzoic acid with lime in 1834.
14. The name "benzene" is derived from "gum benzoin," a fragrant resin from which benzoic acid was obtained.
15. Benzene is a known **carcinogen** and can cause **leukemia and leukopenia.** (Benzene exposure is linked to **leukemia** and also **bone-marrow suppression** which can cause **leukopenia/aplastic anemia.)**

2. Nomenclature of Benzene Derivatives

7. **Monosubstituted benzenes** are named by adding the substituent as a prefix to "benzene" (e.g., C_6H_5–Br is Bromobenzene).
8. Common names for monosubstituted benzenes include **Toluene** (C_6H_5–CH_3), **Phenol** (C_6H_5–OH), **Aniline** (C_6H_5–NH_2), **Benzaldehyde** (C_6H_5–CHO), and **Benzoic acid** (C_6H_5–COOH).
9. For **disubstituted benzenes**, **ortho (o-)** denotes a 1, 2 relationship, **Meta (m-)** denotes a 1, 3 relationship, and **para (p-)** denotes a 1, 4 relationship.
10. If one substituent gives a special name (like -OH in phenol), the compound is named as a derivative of that parent, with the special group at position 1 (e.g., NO_2–C_6H_4–OH is **o**-Nitrophenol).
11. In **polysubstituted benzenes**, the ring is numbered to give the lowest possible set of locants to the substituents, which are listed in alphabetical order.
12. The **Phenyl group (Ph- or C_6H_5–)** is the group derived from benzene by removing one hydrogen

11. Spectroscopy of Aromatic Compounds

58. In IR spectroscopy, aromatic C–H stretching occurs near **3030 cm^{-1}**, and the ring itself shows absorptions between **1450 to 1600 cm^{-1}**.

59. In **^{1}H NMR**, aromatic protons are strongly deshielded by the **ring current** and absorb between **6.5 and 8.0 δ**.

60. Benzylic protons (H–C–C_6H_5) absorb between **2.3 and 3.0 δ**.

Practice MCQs

1. Which scientist first isolated benzene in 1825 from coal gas?
A) August Kekulé
B) Eilhardt Mitscherlich
C) Michael Faraday
D) Richard Willstätter
Answer: Michael Faraday

2. The synthesis of benzene by heating benzoic acid with lime was achieved by:
A) Faraday
B) Kekulé
C) Mitscherlich
D) Hückel
Answer: Mitscherlich

3. Benzene is known to be:
A) A strong base
B) A carcinogen
C) An aliphatic hydrocarbon
D) Highly saturated
Answer: A carcinogen

4. What is the common name for C_6H_5–CH_3?
A) Phenol
B) Aniline
C) Toluene
D) Benzaldehyde
Answer: Toluene

5. The compound C_6H_5–OH is commonly known as:
A) Toluene
B) Phenol
C) Aniline
D) Benzoic acid
Answer: Phenol

6. What is the IUPAC name for C_6H_5–NH_2?
A) Hydroxybenzene
B) Benzenamine
C) Methylbenzene
D) Nitrobenzene
Answer: Benzenamine

7. For disubstituted benzenes, the prefix "meta" indicates which positions?
A) 1,2
B) 1,3
C) 1,4
D) 1,5
Answer: 1,3

8. The group $C_6H_5CH_2$– is known as:
A) Phenyl
B) Benzyl
C) Phenoxide
D) Toluene
Answer: Benzyl

9. The phenyl group is represented as:
A) Bn–
B) Ph–
C) Tol–
D) Benz–
Answer: Ph–

10. Kekulé's structure of benzene failed to explain:
A) Planarity
B) Identical bond lengths
C) sp^2 hybridization
D) Resonance energy
Answer: Identical bond lengths

Carbonyl Compounds – Aldehydes, Ketones, and Carboxylic Acid Derivatives (Nu.Addition Reactions)

Introduction to Carbonyl Compounds

Definition: Carbonyl compounds are a major class of organic molecules characterized by the presence of a **carbonyl functional group**, which consists of a carbon atom doubly bonded to an oxygen atom (>C=O).

Significance: This group is highly reactive and is a key structural feature in many biological molecules (like sugars and metabolic intermediates) and industrial chemicals (like solvents, pharmaceuticals, and polymers).

Major Classes:

The nature of the atoms or groups attached to the carbonyl carbon determines the class of the compound and its reactivity.

Aldehydes (R-CHO): The carbonyl carbon is bonded to at least one hydrogen atom.

Ketones (R-CO-R'): The carbonyl carbon is bonded to two alkyl or aryl groups.

Carboxylic Acids (R-COOH): Carboxylic acids contain the carboxyl group (-COOH), where the carbonyl carbon is bonded to a hydroxyl group. The carboxyl group is a resonance hybrid, making it significantly more acidic than alcohols

Carboxylic Acid Derivatives:

Esters (R-COO-R')

Amides ($R-CONH_2$, R-CONHR, $R-CONR_2$)

Acyl Chlorides (R-COCl)

Acid Anhydrides (R-CO-O-CO-R')

Remember

Reducing sugars possess a free aldehyde group or a free hemiacetal/hemiketal group capable of reducing mild oxidizing agents (**Tollen's, Fehling's, Benedict's).** All monosaccharides (both aldoses and ketoses) are reducing because ketoses tautomerize to aldoses under basic conditions. **Disaccharides** are reducing if they have a free anomeric carbon (maltose, lactose) and non-reducing if both anomeric carbons are bonded (sucrose). It is the principal constituent of number of essential oils used as fragrances and flavours.

Aldehydes and Ketones

Nomenclature of Aldehydes

Aldehydes

IUPAC System

Rule: Select the longest continuous carbon chain containing the -CHO group.

Suffix: Replace the final "-e" of the parent alkane with "**-al**".

Numbering: The carbonyl carbon is always assigned number **1**. It is not necessary to specify its position in the name.

Examples:

HCHO: Methanal

CH_3CHO: Ethanal

For Cyclic Aldehydes

Topic Wise Liner on Carbonyl Compounds

1. Introduction to Carbonyl Compounds

1. Organic compounds containing the **carbonyl functional group** (>C=O) are called carbonyl compounds.
2. The carbonyl group consists of a carbon atom doubly bonded to an oxygen atom.
3. Major classes include **aldehydes**, **ketones**, **carboxylic acids**, and their **derivatives** (esters, amides, acyl chlorides, acid anhydrides).
4. In **aldehydes**, the carbonyl carbon is bonded to at least one hydrogen atom (R-CHO).
5. In **ketones**, the carbonyl carbon is bonded to two alkyl or aryl groups (R-CO-R').
6. Aldehydes are terminal functional groups and have no position isomerism.

2. Nomenclature

7. The IUPAC suffix for aldehydes is **-al**.
8. In IUPAC naming of aldehydes, the carbonyl carbon is always assigned number **1**.
9. For cyclic aldehydes where -CHO is attached to a ring, the suffix **-carbaldehyde** is used.
10. The IUPAC suffix for ketones is **-one**.
11. In ketones, the chain is numbered to give the carbonyl carbon the **lowest possible number**.
12. Common names for ketones are derived by naming the two alkyl groups followed by the word **"ketone"**.

3. Structure and Physical Properties

13. The carbonyl carbon is **sp^2-hybridized**, resulting in a **trigonal planar** geometry with bond angles of ~120°.
14. The C=O bond is **polar** due to the electronegativity difference between carbon and oxygen.
15. Carbonyl compounds have **higher boiling points** than alkanes of similar molecular weight due to **dipole-dipole interactions**.
16. They have **lower boiling points** than comparable alcohols because they **cannot form intermolecular hydrogen bonds** with each other.
17. Lower members (up to C_4) are **soluble in water** as the carbonyl oxygen can hydrogen bond with water.

4. Preparation of Aldehydes and Ketones

18. **Primary alcohols** undergo controlled oxidation to form **aldehydes** using reagents like **PCC** or **Dess-Martin Periodinane**.
19. **Secondary alcohols** are oxidized to **ketones** by common oxidizing agents like $K_2Cr_2O_7/H_2SO_4$.
20. **Ozonolysis of alkenes** followed by reduction with Zn/H_2O yields aldehydes and/or ketones.
21. **Hydration of terminal alkynes** (e.g., HC≡CH) produces **aldehydes**.
22. **Hydration of internal alkynes** produces **ketones**.
23. **Friedel-Crafts Acylation** of an aromatic ring with an acid chloride produces **aryl ketones**.
24. Formaldehyde is prepared industrially by the oxidation of **methanol vapors** over a catalyst like FeO/Mo_2O_3.
25. Acetaldehyde is prepared in the lab by the oxidation of **ethanol** with acidified $Na_2Cr_2O_7$.
26. Acetone is prepared by the **dry distillation of calcium acetate**.
27. Partial reduction of **esters** using **DIBAL-H** at low temperatures yields aldehydes.

Practice MCQs

1. The carbonyl functional group is characterized by which of the following?
A) C-O single bond
B) C≡O triple bond
C) C=O double bond
D) C-OH bond
Answer: C=O double bond

2. Which class of carbonyl compounds has the carbonyl carbon bonded to at least one hydrogen atom?
A) Ketones
B) Carboxylic acids
C) Aldehydes
D) Esters
Answer: Aldehydes

3. The IUPAC suffix for naming aldehydes is:
A) -one
B) -al
C) -oic acid
D) -ol
Answer: -al

4. In the IUPAC naming of aldehydes, the carbonyl carbon is assigned which number?
A) The lowest possible number
B) Number 1
C) Number 2
D) The highest possible number
Answer: Number 1

5. For cyclic aldehydes where the -CHO group is attached directly to a ring, the suffix used is:
A) -al
B) -aldehyde
C) -carbaldehyde
D) -cycloaldehyde
Answer: -carbaldehyde

6. The IUPAC suffix for ketones is:
A) -al
B) -one
C) -ene
D) -ol
Answer: -one

7. In ketones, the parent chain is numbered to give the carbonyl carbon:
A) The highest possible number
B) Number 1
C) The lowest possible number
D) Any arbitrary number
Answer: The lowest possible number

8. The hybridization state of the carbonyl carbon in aldehydes and ketones is:
A) sp
B) sp^2
C) sp^3
D) dsp^2
Answer: sp^2

9. The geometry around the carbonyl carbon is:
A) Linear
B) Tetrahedral
C) Trigonal planar
D) Octahedral
Answer: Trigonal planar

10. Carbonyl compounds have higher boiling points than comparable alkanes due to:
A) Hydrogen bonding between molecules
B) Dipole-dipole interactions
C) Covalent bonding
D) London dispersion forces only
Answer: Dipole-dipole interactions

11. Why do carbonyl compounds have lower boiling points than comparable alcohols?
A) They have higher molecular weight
B) They cannot form intermolecular hydrogen bonds with each other
C) They are less polar
D) They have weaker dipole-dipole interactions
Answer: They cannot form intermolecular hydrogen bonds with each other

12. Lower members of aldehydes and ketones (up to C_4) are soluble in water because:

Halogenoalkanes (Alkyl Halides) And SN Reactions

Introduction to Halogenoalkanes

Definition: Halogenoalkanes, also known as alkyl halides, are organic compounds in which one or more hydrogen atoms of an alkane have been replaced by halogen atoms (F, Cl, Br, I). Their general formula is **R-X**.

Or

Monohalo alkanes (R-X) are called alkyl halides.

It is a class of compounds where Halogen is bonded to the **carbon atom (typically sp^3-hybridized)** of an alkyl group via an σ(C–X) bond."

Halogenoarenes: These are compounds where a halogen is attached directly to an aromatic ring. Their general formula is **Ar-X** (where Ar is an aryl group, e.g., C_6H_5-).

Classification of Alkyl Halides

Alkyl halides are classified based on the carbon atom to which the halogen is bonded.

Primary (1°) Alkyl Halide: The halogen atom is attached to a carbon atom that is itself attached to only one other carbon atom.

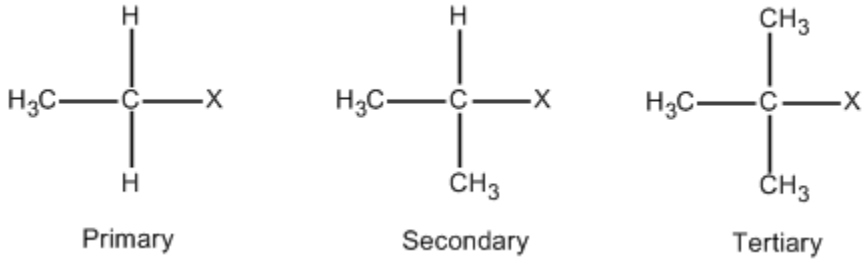
Examples: CH_3-Cl (Chloromethane), CH_3-CH_2-Br (Bromoethane).

Secondary (2°) Alkyl Halide: The halogen atom is attached to a carbon atom that is attached to two other carbon atoms.

Example: $(CH_3)_2CH$-Cl (2-Chloropropane or Isopropyl chloride).

Tertiary (3°) Alkyl Halide: The halogen atom is attached to a carbon atom that is attached to three other carbon atoms.

Example: $(CH_3)_3C$-Cl (2-Chloro-2-methylpropane or tert-Butyl chloride)



Remember

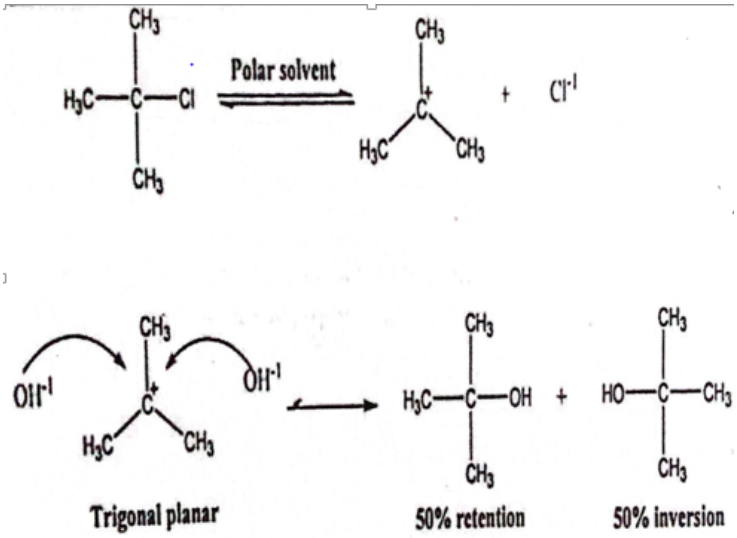
***α* – Carbon: Carbon to which functional group is directly attached.**

***α* –Hydrogen: hydrogen atoms attached to *α* –carbon atoms.**

Preparation of Halogenoalkanes and Halogenoarenes

From Alkanes (Free Radical Halogenation): Alkanes react with halogens (Cl_2 or Br_2) in the presence of UV light to form alkyl halides. This reaction proceeds via a free radical mechanism and often gives a mixture of mono- and poly-halogenated products.

The SN^1 Mechanism (Substitution Nucleophilic Unimolecular)



Mechanism: A **two-step** process.

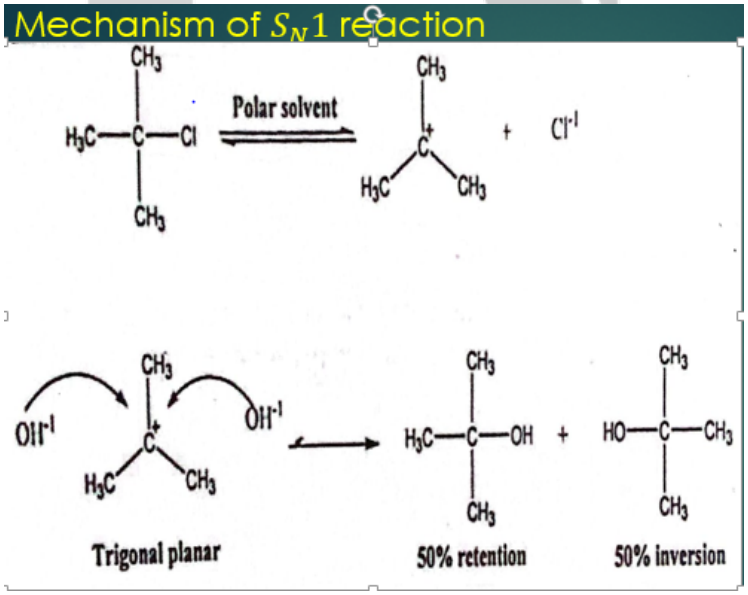
Slow, Rate-Limiting Step: Spontaneous dissociation of the alkyl halide to form a planar **carbocation intermediate**.

Fast Step: The nucleophile attacks the carbocation from either side to form the product.

Kinetics: First-order. Rate = k [R-X]

Stereochemistry: Results in **racemization** (a mixture of both enantiomers) because the planar carbocation is attacked equally from both faces. However, in practice, often a slight excess of inversion is observed due to "ion-pair" effects where the leaving group partially blocks one side.

Factors Affecting SN^1 Reactivity:

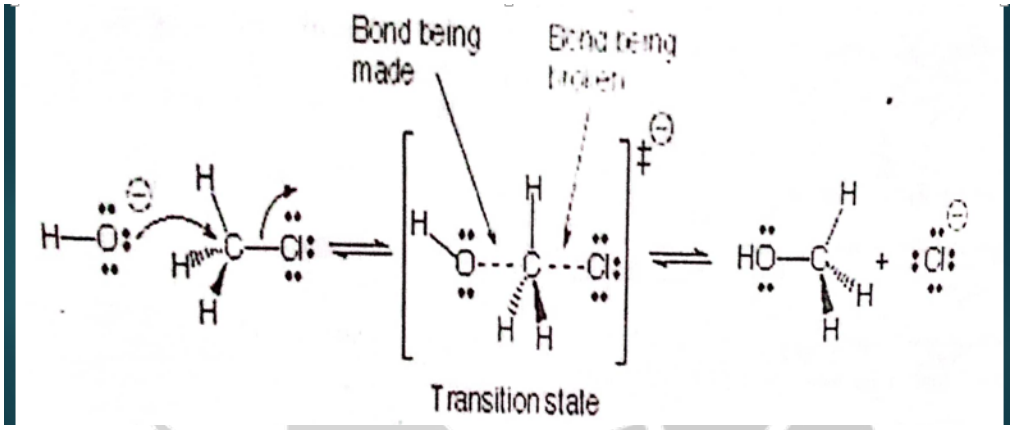


Substrate (Stability of the Carbocation): The rate depends on the stability of the carbocation formed. **Tertiary > Secondary >**

Primary > Methyl. Allylic and benzylic carbocations are exceptionally stable due to resonance and are highly reactive in SN1.

Leaving Group: Same as SN2; better leaving groups increase the rate.

Nucleophile: The nucleophile's strength **does not affect the rate** (as it's not involved in the rate-limiting step), but it must be non-basic to avoid elimination.



Solvent: Polar Protic solvents (e.g., H_2O, ROH) greatly increase the rate by stabilizing the transition state leading to the carbocation and by solvating the halide ion.

SN1 Rearrangements (Hydride and Alkyl Shift)

In **SN1 reactions**, the rate-determining step is the formation of a carbocation intermediate. Since carbocations can rearrange to form more stable carbocations, rearrangement is a common feature of SN1 reactions. Carbocation stability follows the order:

3° > 2° > 1° > methyl

Two major types of rearrangements are observed: **1,2-hydride shift** and **1,2-alkyl shift**.

1,2-Hydride Shift

A hydride ion (H^-) migrates from an adjacent carbon atom to the positively charged carbon, forming a more stable carbocation.

Example:

CH_3-CH_2-CH_2^+ → CH_3-CH^+-CH_3 (1,2-hydride shift from secondary to primary gives more stable secondary carbocation, After rearrangement, nucleophilic attack occurs:

$R^+ + Nu^- \rightarrow R–Nu$

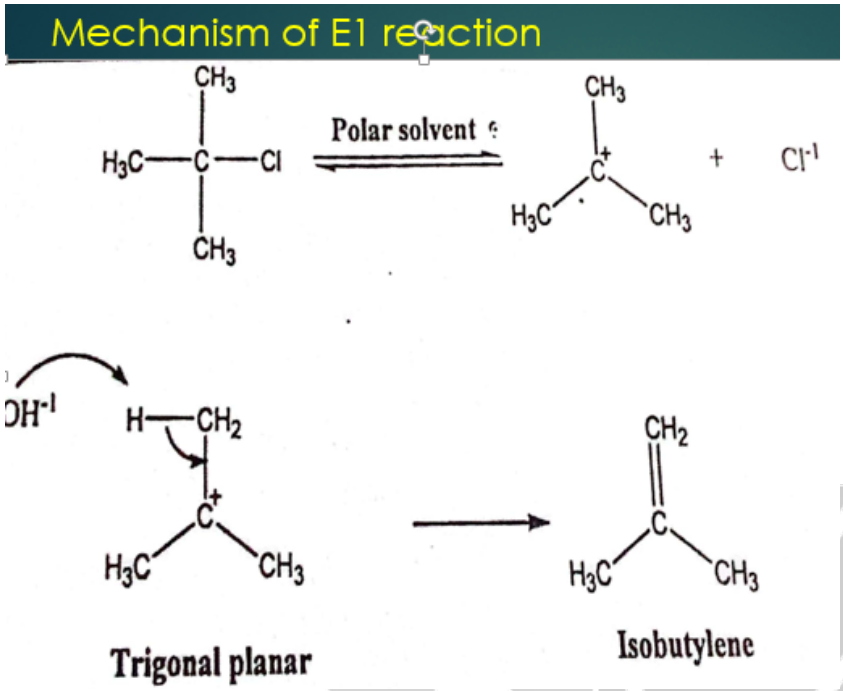
1,2-Alkyl Shift

CH_3-CH^+-CH_2-CH_3 → CH_3-C^+ (CH_3)-CH_3 (methyl shift from secondary to secondary gives more substituted tertiary carbocation)

General representation:

$R–C^+H–CH_3 \rightarrow R–CH–C^+H_2$

These rearrangements often lead to unexpected products and may alter the carbon skeleton, which makes this concept highly important in competitive examinations.



The E1cB Mechanism (Elimination, Unimolecular from the Conjugate Base)

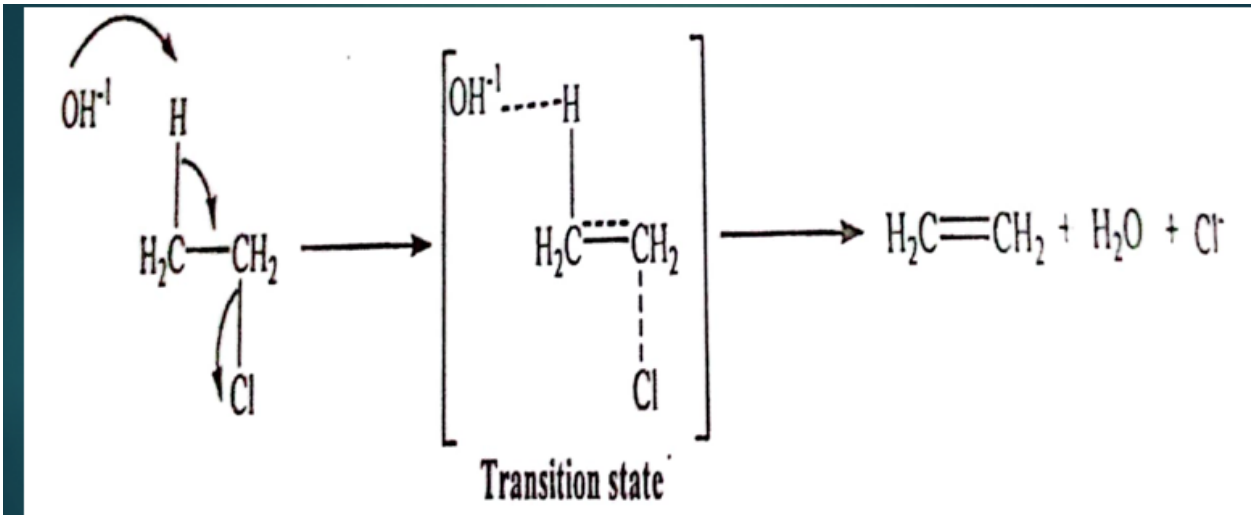
Mechanism: A **two-step** process common in poor leaving groups with an acidic β-hydrogen (e.g., adjacent to a carbonyl group).

Fast Step: A base abstracts a β-proton to form a **carbanion intermediate**.

Slow, Rate-Limiting Step: In E1cB, mechanism varies: if **carbanion formation** is rate-limiting → $E1cB_{rev}$,if **leaving group departure** is rate-limiting → $E1cB_{irrev}$

Kinetics: Complex, but often first-order in base.

This mechanism is predominant in biological systems.



Topic-wise One-Liners: Halogenoalkanes (Alkyl Halides) And SN Reactions

1. Introduction & Nomenclature of Alkyl Halides

1. **Halogenoalkanes** or **alkyl halides** are organic compounds with the general formula **R-X**, where a halogen atom (F, Cl, Br, I) replaces a hydrogen in an alkane.
2. **Halogenoarenes** have the general formula **Ar-X**, where the halogen is attached directly to an aromatic ring.
3. Alkyl halides are classified as **primary (1°)**, **secondary (2°)**, or **tertiary (3°)** based on the carbon atom to which the halogen is bonded.
4. In a **primary alkyl halide**, the halogen-bearing carbon is attached to only one other carbon atom.
5. In a **secondary alkyl halide**, the halogen-bearing carbon is attached to two other carbon atoms.
6. In a **tertiary alkyl halide**, the halogen-bearing carbon is attached to three other carbon atoms.
7. In IUPAC nomenclature, the parent chain is numbered to give the halogen the lowest possible locant.

2. Physical Properties & Structure of Alkyl Halides

8. Lower members like CH_3Cl and C_2H_5Cl are gases, while higher members are liquids or solids.
9. Alkyl halides are generally **insoluble in water** due to their inability to form hydrogen bonds.
10. Boiling points follow the order: **RI > RBr > RCl > RF** for the same alkyl group due to increasing molecular mass and van der Waals forces.
11. The **C-X bond is polar** because halogens are more electronegative than carbon, creating a δ^+ charge on carbon and a δ^- charge on halogen.
12. The **C-X bond strength** decreases down the group: **C-F > C-Cl > C-Br > C-I**.
13. The carbon atom in alkyl halides is **sp^3 hybridized** with a tetrahedral geometry.

3. Preparation of Alkyl Halides

14. Alkanes undergo **free radical halogenation** with Cl_2 or Br_2 in UV light to yield a mixture of alkyl halides.
15. Alkenes react with **hydrogen halides (HX)** via electrophilic addition, following **Markovnikov's rule**.
16. A common laboratory method involves the reaction of **alcohols with HX**; tertiary alcohols react the fastest.
17. **Thionyl chloride ($SOCl_2$)** converts alcohols to alkyl chlorides, producing gaseous SO_2 and HCl.
18. **Phosphorus trihalides (PBr_3, PCl_3)** are used to prepare alkyl bromides and chlorides from alcohols.
19. Halogenoarenes like chlorobenzene are prepared by the **electrophilic aromatic substitution** of benzene using Cl_2 and a Lewis acid catalyst (e.g., $FeCl_3$).

4. Nucleophilic Substitution Reactions (SN Reactions)

20. A **nucleophilic substitution reaction** involves a nucleophile (Nu^-) replacing a leaving group (X^-) in an alkyl halide.
21. The **substrate** is the alkyl halide (R-X) undergoing the reaction.
22. A **nucleophile** is an electron-rich species (e.g., HO^-, CN^-, NH_3) that attacks the electrophilic carbon.
23. A **leaving group** is the atom or group displaced from the substrate; the best leaving groups are

Practice MCQs

1. What is the general formula for alkyl halides?
A) R-OH
B) R-X
C) R-COOH
D) R-NH_2
Answer: R-X

2. In halogenoarenes, the halogen is attached to which type of carbon?
A) sp^3 hybridized carbon of an alkyl group
B) sp^2 hybridized carbon of an aromatic ring
C) sp hybridized carbon of an alkyne
D) Carbon of a carbonyl group
Answer: sp^2 hybridized carbon of an aromatic ring

3. A primary alkyl halide has the halogen attached to a carbon bonded to how many other carbon atoms?
A) One
B) Two
C) Three
D) Zero
Answer: One

4. Which of the following is a secondary alkyl halide?
A) CH_3CH_2Br
B) $(CH_3)_2CHCl$
C) $(CH_3)_3CBr$
D) CH_3Cl
Answer: $(CH_3)_2CHCl$

5. The α-carbon in an alkyl halide is defined as:
A) The carbon adjacent to the halogen
B) The carbon to which the functional group is directly attached
C) The carbon farthest from the halogen
D) The carbon bearing the most hydrogens
Answer: The carbon to which the functional group is directly attached

6. Which method is NOT typically used for preparing alkyl halides from alcohols?
A) Reaction with HX
B) Reaction with $SOCl_2$
C) Reaction with $KMnO_4$
D) Reaction with PBr_3
Answer: Reaction with $KMnO_4$

7. Halogenation of benzene to form chlorobenzene is an example of:
A) Nucleophilic aromatic substitution
B) Electrophilic aromatic substitution
C) Free radical substitution
D) Nucleophilic addition
Answer: Electrophilic aromatic substitution

8. For a given alkyl group, the boiling point order of alkyl halides is:
A) RF > RCl > RBr > RI
B) RI > RBr > RCl > RF
C) RCl > RBr > RI > RF
D) RBr > RI > RCl > RF
Answer: RI > RBr > RCl > RF

9. The carbon-halogen bond strength decreases in the order:
A) C-F > C-Cl > C-Br > C-I
B) C-I > C-Br > C-Cl > C-F
C) C-Cl > C-Br > C-F > C-I
D) C-Br > C-Cl > C-I > C-F
Answer: C-F > C-Cl > C-Br > C-I

10. A nucleophile is best described as:
A) An electron-deficient species
B) An electron-rich species that donates an electron pair
C) A species that accepts a proton
D) A strong acid
Answer: An electron-rich species that donates an electron pair

11. Which of the following is a strong nucleophile and a good leaving group?
A) OH^-
B) I^-
C) NH_2^-
D) F^-
Answer: I^-

12. The overall reactivity order of alkyl halides (for a particular alkyl group) towards

Industrial Chemistry & Synthetic Polymers

Introduction to Industrial Chemistry

Definition: Industrial chemistry is the branch of chemistry concerned with the chemical processing of raw materials into usable and profitable products. Industrial chemistry involves chemical processes at commercial scale (tonnage quantities) converting raw materials into products with economic value, including final consumer goods or intermediate chemicals.

Scope and Importance:

It is a highly diverse manufacturing sector that produces thousands of chemicals, which the public encounters as end-use products.

These products are valued for the specific effects or properties they provide, such as non-stick coatings or weed killers.

Chemical processing involves both chemical conversion (e.g., manufacturing sulphuric acid from sulphur) and physical operations (e.g., heat transfer, temperature control) to achieve high yields required by a competitive industry.

Importance of Chemical Industry in Pakistan's Economy

The chemical industry is a cornerstone of Pakistan's economic development and international trade.

Economic Contribution: It accounts for approximately **4.5% of total exports** and **12% of total imports**.

Industrial Role: It is a key enabler for **forward-oriented industries** (e.g., automobiles, textiles, leather goods, food and beverages) and **backward-oriented industries** (e.g., supplying surfactants to oil refineries).

Growth Factors: The sector has experienced rapid growth due to:

Rising domestic demand

Improved availability of raw materials

Supportive government policies

Increased foreign investment

Technological advancements

Enhanced regional integration

Raw Materials for Chemical Industries in Pakistan

Pakistan is endowed with a variety of raw materials that fuel its chemical sector.

A. Fossil Fuels & Minerals:

Coal, Natural Gas, and Oil

Salt, Limestone, Sulphur

Specialized minerals like Phosphates and Fluorides

Other mineral deposits: Copper, Gold, Chromite, Bauxite

Key Industrial Raw Materials:

Soapstone: A primary raw material; 85% is used in textiles, paper, soap, detergents, leather, and food industries.

Polyvinyl Chloride (PVC): Mainly used for producing pipes, fittings, cables, profiles, and footwear. Driven largely by the construction industry (70% of consumption). Also used in medical devices and packaging.

Polyesters:

Its Acid Hydrolysis Produces diol and dicarboxylic acid.

Its Alkaline Hydrolysis Produces diol and carboxylate salt.

Polyamides:

Its Acid Hydrolysis will Produces dicarboxylic acid and amine salt.

Its Alkaline Hydrolysis will Produces dicarboxylate salt and diamine.

Solutions for Recycling and Biodegradable Polymers

Recycling: The best solution. Plastics are identified by resin codes (e.g., 1-PET, 2-HDPE, 3-V, 4-LDPE, 5-PP, 6-PS), then shredded, washed, and melted for reuse.

Biodegradable Polymers: Designed to be broken down by microorganisms.

Examples: Polyglycolic Acid (PGA), Polylactic Acid (PLA), Polyhydroxybutyrate (PHB).

Use: PGA-PLA copolymers are used to make absorbable surgical sutures.

Key Differences between Polymerization Types

Feature	Addition Polymerization	Condensation Polymerization
Monomers	Unsaturated (e.g., alkenes)	Bifunctional (e.g., diol + diacid, diamine + diacid)
By-Product	None	Small molecule (e.g., H_2O, HCl, NH_3)
Growth Mechanism	Chain reaction (initiation, propagation, termination)	Stepwise reaction
Polymer Formula	Same as monomer's empirical formula	Different from monomer's empirical formula
Rate of Reaction	Fast	Slow
Molecular Mass	Increases rapidly	Increases slowly
Examples	Polyethene, PVC, Polystyrene	Nylon, Polyester, Polyurethane

Most Exam-Tested Polymers at a Glance

Polymer	Monomer(s)	Polymerization Type	Key Property	Major Application
LDPE	Ethylene	Free radical addition	Flexible, branched	Bags, films
HDPE	Ethylene	Coordination (Z-N/Phillips)	Rigid, linear	Bottles, pipes
PP	Propylene	Coordination (Z-N)	High Tm, stiff	Packaging, automotive
PVC	Vinyl chloride	Free radical addition	Versatile (rigid/flexible)	Pipes, profiles, medical

5. **Molecular Mass of Polymer** = Molecular Mass of repeating unit × DP.
6. **Repeating unit** is the smallest structural unit that regularly recurs along the polymer chain.
7. **Homopolymer** = one monomer type (e.g., PVC, polyethylene).
8. **Copolymer** = two or more different monomers.
9. **Copolymer types:** Random, Alternating, Block, Graft.
10. **Random copolymer:** Monomer distribution follows statistical pattern (e.g., commercial SBR).
11. **Alternating copolymer:** Strict A-B-A-B sequence (e.g., Nylon 6,6, Styrene-maleic anhydride).
12. **Block copolymer:** Long sequences of one monomer followed by another (e.g., SBS rubber, thermoplastic elastomers).
13. **Graft copolymer:** Branches of one monomer attached to backbone of another (e.g., ABS, HIPS).

SECTION 2: CLASSIFICATION BY SOURCE

14. **Natural polymers:** Produced by living organisms (cellulose, proteins, natural rubber, starch, nucleic acids).
15. **Synthetic polymers:** Man-made via chemical synthesis (polyethylene, nylon, PVC, polyester, Teflon).
16. **Semi-synthetic polymers:** Natural polymers chemically modified (cellulose acetate, rayon, vulcanized rubber).
17. **Biopolymers:** Produced by biological systems (distinct from biodegradable synthetics).

SECTION 3: CLASSIFICATION BY STRUCTURE

18. **Linear polymers:** Chains in straight lines; pack closely; high density, strength, crystallinity (HDPE, nylon, PET).
19. **Branched polymers:** Side chains extending from main chain; lower density, crystallinity (LDPE).
20. **Cross-linked polymers:** Chains interconnected by covalent bonds forming 3D network; insoluble, infusible (Bakelite, vulcanized rubber, epoxy resins).
21. **Network polymers:** Highly cross-linked 3D structures (thermosets).

SECTION 4: CLASSIFICATION BY THERMAL BEHAVIOR

22. **Thermoplastics:** Soften reversibly on heating, harden on cooling; held by intermolecular forces (HDPE, PVC, PS, PET, and PTFE).
23. **Thermosets:** Undergo irreversible chemical change on heating; form permanent cross-links; cannot be remelted (Bakelite, epoxy, melamine, urea-formaldehyde).
24. **Elastomers:** Amorphous polymers with Tg below room temperature; exhibit rubbery elasticity (natural rubber, SBR, neoprene, silicone).
25. **Fibers:** High tensile strength, high crystallinity, oriented chains (nylon, polyester, aramid).

SECTION 5: CLASSIFICATION BY POLYMERIZATION MECHANISM

26. **Addition (Chain-growth) Polymerization:** Monomers add without byproduct; requires unsaturated monomers.
27. **Condensation (Step-growth) Polymerization:** Bifunctional monomers react with elimination of small molecule (H_2O, HCl, NH_3, and CH_3OH).
28. **Chain-growth steps:** Initiation → Propagation → Termination.
29. **Step-growth characteristics:** Slow molecular weight increase; any two species can react; high conversion needed for high MW.

SECTION 6: ADDITION POLYMERIZATION TYPES

30. **Free Radical Polymerization:** Initiated by radicals from peroxides, azo compounds, or UV light.

2	HDPE	High-Density Polyethylene	Milk jugs, detergent bottles, pipes
3	V or PVC	Polyvinyl Chloride	Pipes, window frames, medical tubing
4	LDPE	Low-Density Polyethylene	Plastic bags, squeeze bottles, films
5	PP	Polypropylene	Food containers, bottle caps, automotive
6	PS	Polystyrene	Disposable cups, packaging, insulation
7	OTHER	Other (PC, ABS, Nylon, etc.)	Multi-layer, specialty plastics

Practice MCQs

1. Which type of polymerization involves the elimination of a small molecule like water or methanol?
A) Addition polymerization
B) Chain-growth polymerization
C) Condensation polymerization
D) Free-radical polymerization
Answer: Condensation polymerization

2. What is the main component used in the production of soda ash (sodium carbonate) via the Solvay process?
A) NaCl
B) $CaCO_3$
C) $NaHCO_3$
D) NH_3
Answer: NaCl

3. Which catalyst is used in the Ziegler-Natta polymerization of propylene?
A) BF_3/H_2O
B) $TiCl_4 + Al(C_2H_5)_3$
C) Butyllithium
D) Benzoyl peroxide
Answer: $TiCl_4 + Al(C_2H_5)_3$

4. What is the primary raw material for the production of PVC?
A) Ethylene
B) Acetylene
C) Vinyl chloride
D) Propylene
Answer: Vinyl chloride

5. Which type of copolymer has long blocks of one monomer alternating with blocks of another?
A) Random copolymer
B) Alternating copolymer
C) Block copolymer
D) Graft copolymer
Answer: Block copolymer

6. What is the repeating unit in polyvinyl acetate (PVA)?
A) $–CH_2–CHCl–$
B) $–CH_2–CH(OCOCH_3)–$
C) $–CH_2–CH(C_6H_5)–$
D) $–CH_2–CH(CN)–$
Answer: $–CH_2–CH(OCOCH_3)–$

7. Which of the following is a thermosetting polymer?
A) Polyethylene
B) Polystyrene
C) Bakelite
D) PVC
Answer: Bakelite

8. What is the main use of epoxy resins?
A) Food packaging
B) Adhesives and coatings
C) Plastic bottles

Periodic Classification of Elements and Atomic Structure

Historical Development of the Periodic Table

Early Attempts at Classification

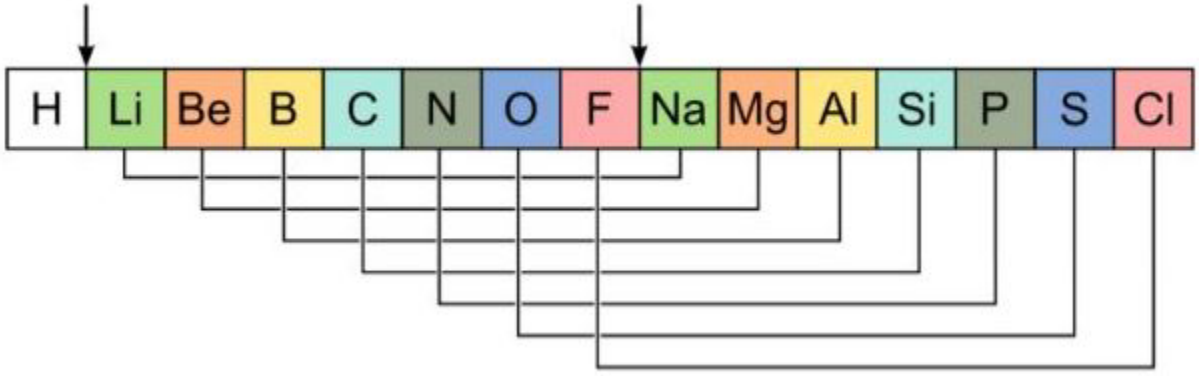
Al-Razi: Classified substances based on their physical and chemical properties.

Dobereiner's Triads (1829): Grouped elements into triads (groups of three) with similar properties. The atomic mass of the middle element was roughly the average of the other two.

Newlands' Law of Octaves (1864): Noted that when elements were arranged by increasing atomic mass, every eighth element had similar properties, like the octaves in music.

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

Table: Dobereiner's traids



Mendeleev's Periodic Table (1871)

Basis: Arranged elements in ascending order of their **atomic masses**.

Structure: Presented a regular table with vertical columns called **Groups** and horizontal rows called **Periods**.

Mendeleev's Periodic Law:

'The properties of elements are a periodic function of their atomic masses'.

Achievements:

Successfully predicted the existence and properties of undiscovered elements (e.g., Gallium, Germanium) by leaving gaps in his table.

The accuracy of these predictions led to the widespread acceptance of his periodic table.

Special Family Names

Group 1 (IA): Alkali Metals

Group 2 (IIA): Alkaline Earth Metals

Group 17 (VIIA): Halogens

Group 18 (VIIIA): Noble Gases

Metals, Non-Metals, and Metalloids

Metals: Located on the left-hand side and center of the table. They are lustrous, malleable, ductile, and good conductors of heat and electricity. They form cations and basic oxides.

Non-Metals: Located on the top right-hand side (above the stepped line). They are generally poor conductors and form anions and acidic oxides.

Metalloids (Semi-metals): Elements bordering the stepped line (e.g., B, Si, Ge, As, Sb, Te) that have properties intermediate between metals and non-metals.

Periodic Trends in Physical Properties

Atomic Size (Atomic Radius)

It has two types

(1) Covalent radius: half the distance between nuclei of two covalently bonded identical atoms.

(2) **Van der Waals radius**: for non-bonded atoms;

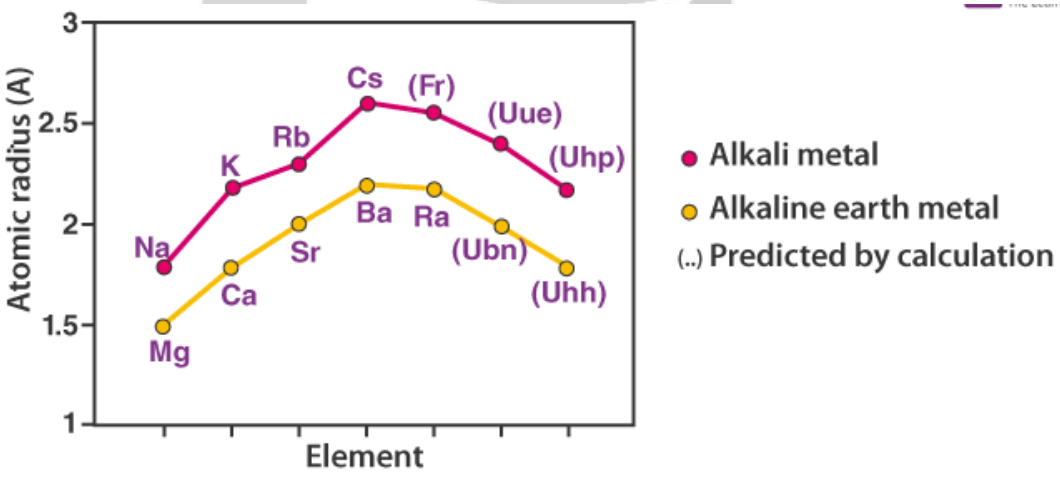
Trend Across a Period (Left to Right): Decreases.

Reason: Z_{eff} increases significantly, pulling the valence electrons closer to the nucleus. The shielding effect remains almost constant.

Trend Down a Group (Top to Bottom): Increases.

Reason: The principal quantum number n increases, adding a new electron shell farther from the nucleus. This outweighs the increase in Z_{eff}.

Ionic Radius



Cation than parent atoms because: (a) electron(s) removed from valence shell; (b) reduced electron-electron repulsion; (c) increased effective nuclear charge per remaining electron.

Anions: Larger than their parent atoms because the added electron(s) increase electron-electron repulsion, causing the electron cloud to expand.

Definition: The ability of an atom in a molecule to attract the shared pair of electrons towards itself.
Trend across a Period: Increases.
Trend down a Group: Decreases.
Application: Used to predict bond type.
ΔEN > 1.8: Ionic Bond
ΔEN 0.4 to 1.8: Polar Covalent Bond
ΔEN < 0.4: Non-Polar Covalent Bond

Metallic and Non-Metallic Character

Metallic Character: The tendency of an atom to lose electrons and form positive ions.
Trend across a Period: Decreases.
Trend down a Group: Increases.
Non-Metallic Character: The tendency of an atom to gain electrons and form negative ions.
Trend across a Period: Increases.
Trend down a Group: Decreases.

Melting and Boiling Points

Across a Period (s- and p-blocks): Increase to a maximum around Group 14 (due to strong covalent network bonding, e.g., Carbon as diamond) and then decrease sharply to the noble gases (which have weak London dispersion forces).
Down a Group (Metals, e.g., IA, IIA): Generally decrease due to weaker metallic bonding as atomic size increases.
Down a Group (Molecular Non-Metals, e.g., VIIA): Increase due to increasing molecular size and stronger London dispersion forces.

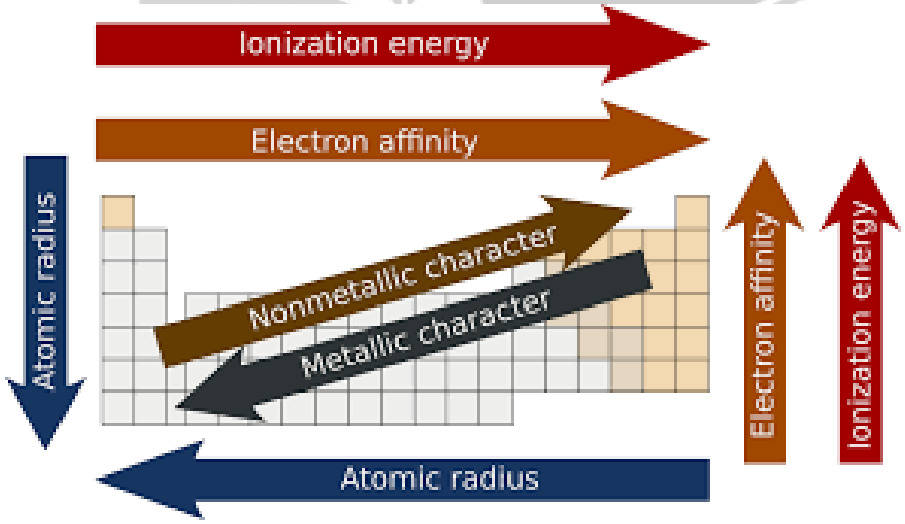


Fig. General trend In one frame

Periodicity in Compounds

Hydrides

Binary compounds of hydrogen.
Ionic (Saline) Hydrides: Formed by s-block elements except Be and partially except Mg (BeH_2 is covalent polymeric; MgH_2 is intermediate).

Topic-wise One-Liner on Periodic Classification of Elements & Atomic Structure

1. Historical Development of the Periodic Table

1. **Al-Razi** classified substances based on their physical and chemical properties.
2. **Dobereiner** grouped elements into **triads** where the atomic mass of the middle element was approximately the average of the other two.
3. **Newlands** proposed the **Law of Octaves**, stating that every eighth element had similar properties when arranged by atomic mass.
4. **Mendeleev** created the first successful periodic table based on **atomic masses**.
5. Mendeleev's **Periodic Law** states that the properties of elements are a periodic function of their atomic masses.
6. A major achievement of Mendeleev's table was the correct **prediction of the properties of undiscovered elements** like Gallium and Germanium.
7. The modern periodic table is based on **atomic number**, as established by **Henry Moseley**.
8. The **Modern Periodic Law** states that the properties of elements are a periodic function of their atomic numbers.
9. The modern table rectifies the position of **isotopes** as they have the same atomic number.
10. The **noble gases** (Group 18) were a new addition to the modern periodic table.

2. Structure of the Modern Periodic Table

11. **Groups** are the vertical columns in the periodic table, and elements in the same group have the same number of **valence electrons**.
12. **Periods** are the horizontal rows, and the period number signifies the **highest principal quantum number (n)**.
13. Based on the subshell being filled, elements are classified into **s, p, d, and f blocks**.
14. **s-block elements** have valence electrons in the s-orbital and include **Groups 1 and 2** (Alkali and Alkaline Earth Metals).
15. **p-block elements** have valence electrons in the p-orbital and include **Groups 13 to 18**.
16. **d-block elements** d-block elements (Groups 3-12) where differentiating electron enters d-orbital. Transition elements are d-block elements that form at least one ion with partially filled d-orbital. Group 12 (Zn, Cd, Hg) are not -Typical transition elements (full d^{10} in ground and common oxidation states)
17. **f-block elements** have valence electrons in the f-orbital and are called **Inner Transition Elements** (Lanthanides and Actinides).
18. **Group 1** elements are called **Alkali Metals**.
19. **Group 2** elements are called **Alkaline Earth Metals**.
20. **Group 17** elements are called **Halogens**.
21. **Group 18** elements are called **Noble Gases**.
22. **Metals** are located on the left and center of the table, are lustrous, malleable, and form **cations** and **basic oxides**.
23. **Non-metals** are located on the top right, are generally poor conductors, and form **anions** and **acidic oxides**.
24. **Metalloids** (e.g., B, Si, Ge) have properties intermediate between metals and non-metals.

Practice MCQs

1. Elements are arranged in the periodic table in order of increasing:
A) Atomic mass
B) Atomic number
C) Number of neutrons
D) Number of shells
Answer: Atomic number

2. The number of valence electrons in an element of group 13 is:
A) 1
B) 3
C) 5
D) 7
Answer: 3

3. Which period contains the element with electronic configuration 2,8,8,2?
A) 2
B) 3
C) 4
D) 5
Answer: 4

4. As we move from top to bottom in a group, the atomic radius generally:
A) Decreases
B) Increases
C) Remains constant
D) First decreases then increases
Answer: Increases

5. The screening effect increases down a group because of:
A) Increase in number of shells
B) Decrease in nuclear charge
C) Increase in valence electrons
D) Decrease in atomic size
Answer: Increase in number of shells

6. Which element has the highest melting point in period 2?
A) Lithium
B) Carbon
C) Nitrogen
D) Fluorine
Answer: Carbon

7. In period 3, the element with the highest melting point is:
A) Sodium
B) Magnesium
C) Aluminum
D) Silicon
Answer: Silicon

8. Which group elements are known as coinage metals?
A) IA
B) IIA
C) IB
D) VIIA
Answer: IB

9. The best conductor of electricity among the following is:
A) Sodium
B) Magnesium
C) Aluminum
D) Silicon
Answer: Aluminum

10. Which of the following has the smallest atomic radius?
A) Na^{+}
B) Mg^{2+}
C) Al^{3+}
D) Si^{4+}
Answer: Si^{4+}

11. Ionization energy is lowest for:
A) Alkali metals
B) Halogens
C) Noble gases
D) Transition metals
Answer: Alkali metals

12. Nitrogen has higher ionization energy than oxygen due to:
A) Smaller atomic size
B) Greater nuclear charge

S and P-Block Elements

Elements are classified into blocks based on the type of atomic orbital in which the valence electrons reside.

Block	Valence Orbital	General Electronic Configuration	Groups Included
s-Block	s-orbital	ns^{1-2}	IA (Alkali metals), IIA (Alkaline earth metals), and Helium
p-Block	p-orbital	$ns^2\ np^{1-6}$	IIIA to VIIIA (Noble gases), except Helium
d-Block	d-orbital	$ns^2\ (n-1)d^{1-10}$	Transition elements (Group IIIB to VIIIB, IB, IIB)
f-Block	f-orbital	$(n-2)f^{1-14}\ (n-1)\ d^{0-1}\ ns^2$	Lanthanides and Actinides

General Properties of S-Block Elements

. **Physical Properties**

Appearance: Soft, silvery-white, lustrous metals (except Lithium turns grey in air).

Density & Melting/Boiling Points: Density generally increases down the group, **although** irregularly (e.g., Mg > Ca) low melting, and boiling points (Alkali metals are softer than Alkaline Earth metals).

Conductivity: Excellent conductors of heat and electricity.

Flame Colors: Impart characteristic colors to flames **(e.g. Li: Red, Na: Yellow, K: Violet)**.

Chemical Properties

Valence Electrons: Have 1 (Group 1) or 2 (Group 2) electrons in their outermost *s*-orbital, with general configuration ***ns¹* or *ns²*.**

Ionization Energy: Very low ionization enthalpies, making them highly electropositive.

Reactivity: Highly reactive; reactivity increases down the group, typically stored in oil (except Be, Mg).

Ion Formation: Easily lose valence electrons to form +1 (Group 1) or +2 (Group 2) ions (cations).

Compound Nature: Form predominantly ionic compounds. Covalent character is observed in compounds of small cations with high charge density (e.g., $BeCl_2$ is covalent; LiCl, $MgCl_2$ show some covalent character)

Oxides: Form basic oxides and hydroxides (e.g., M_2O, MO), which react with water to form strong bases (alkalies).

Reducing Agents: Act as strong reducing agents.

Group IA: Alkali Metals

Elements: Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs), Francium (Fr).

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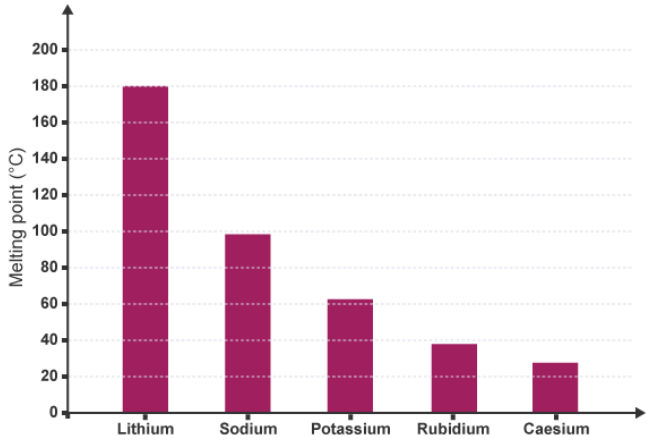


A trend of M.P of Alkali metals

Important Reactions of Alkali Metals

Reaction with Water: React violently to form metal hydroxides and hydrogen gas.

$2M+2H_2O \rightarrow 2MOH+H_2$

Reactivity order: Cs > Rb > K > Na > Li

Reaction with Oxygen: Form different types of oxides.

Lithium (Li): Normal oxide (Li_2O)

Sodium (Na): Peroxide (Na_2O_2

Potassium (K), Rubidium (Rb), Cesium (Cs): Superoxide (KO_2, RbO_2, CsO_2)

Stability of peroxides and superoxides increases down the group.

Reaction with Halogens: Form ionic halides (MX).

$2M+X_2 \rightarrow 2MX$

Reactivity order: Cs > Rb > K > Na > Li

Down the group: Ionic nature increases, lattice energy decreases, solubility in water increases.

Group IIA: Alkaline Earth Metals

General Configuration: ns_2

Elements: Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba), Radium (Ra).

Trends down the Group:

Increases: Atomic/ionic radius, electropositive character, reactivity, density, metallic character.

Decreases: Ionization energy, electronegativity, hydration energy, melting point (except irregularity), boiling point.

Topic-Wise One-Liners: s and p-Block Elements

1. The Periodic Table and Periodicity

1. The **Modern Periodic Table** is arranged based on increasing **atomic number**.
2. For s- and p-block elements, the **group number** In **A-group notation**, group number equals valence electrons; in modern IUPAC groups 13–18, valence electrons = (group no. − 10).”
3. The **period number** indicates the total number of **electron shells** in an atom.
4. **Valence electrons** are the electrons in the outermost shell and determine an element's chemical properties.
5. **Metals** typically have 1-3 valence electrons and tend to lose electrons to form **cations**.
6. **Non-metals** typically have 4-7 valence electrons and tend to gain electrons to form **anions**.
7. **Metalloids** (e.g., B, Si, Ge) exhibit properties of both metals and non-metals.
8. **Noble gases** have a completely filled valence shell and are chemically very unreactive.
9. Elements are classified into **s, p, d, and f blocks** based on the orbital where the valence electrons reside.
10. The general electronic configuration for the **s-block** is ns^{1-2}.
11. The general electronic configuration for the **p-block** is $ns^2\ np^{1-6}$.

2. Periodic Trends in Physical Properties

Trends Down a Group:

12. **Atomic/Ionic radius increases** down a group due to an increase in the number of electron shells.
13. **Ionization Energy (IE) decreases** down a group due to increased atomic size and the shielding effect.
14. **Electron Affinity (EA) decreases** down a group due to increased atomic size and shielding.
15. An exception to the EA trend is that **Chlorine has a higher electron affinity than Fluorine**.
16. **Electronegativity (EN) decreases** down a group.
17. **Metallic character increases** down a group.
18. **Electropositive character increases** down a group.

Trends Across a Period:

19. **Atomic radius decreases** across a period due to an increase in effective nuclear charge.
20. **Ionization Energy (IE) increases** across a period due to decreasing atomic radius.
21. An exception to the IE trend is that **Nitrogen has a higher IE than Oxygen** due to its stable half-filled p-subshell.
22. **Electron Affinity (EA) increases** across a period.
23. **Electronegativity (EN) increases** across a period.
24. **Metallic character decreases** across a period.
25. **Electropositive character decreases** across a period.

Melting & Boiling Points:

26. Across a period (e.g., Period 2 & 3), m.p. and b.p. **increase from Group IA to IVA** due to stronger bonding.
27. From Group VA to VIIIA, m.p. and b.p. **decrease sharply** as elements form small molecules with weak intermolecular forces.
28. Down a group of **metals**, m.p. and b.p. **decrease** due to weaker metallic bonding.
29. Down a group of **non-metals**, m.p. and b.p. **increase** due to stronger London dispersion forces.

Practice MCQs

1. Which one of the following is the least basic in nature?
A) NF_3
B) NCl_3
C) NBr_3
D) NI_3
Answer: NF_3

2. The oxide of nitrogen which causes hysterical laughter is:
A) N_2O_3
B) NO_2
C) N_2O
D) NO
Answer: N_2O

3. The basicity of orthophosphoric acid (H_3PO_4) is:
A) 1
B) 2
C) 3
D) 4
Answer: 3

4. Bone ash contains calcium phosphate approximately:
A) 40%
B) 50%
C) 70%
D) 80%
Answer: 80%

5. In the Contact Process, arsenic impurities are removed:
A) by prolong heating the gases
B) by treating with $Fe(OH)_3$
C) in the scrubbing tower
D) in the absorption tower
Answer: by treating with $Fe(OH)_3$

6. Which of the following acids possesses oxidizing and reducing properties?
A) HCl
B) HNO_2
C) HNO_3
D) H_2SO_4
Answer: HNO_2

7. Sugar becomes black when concentrated H_2SO_4 is added due to:
A) Hydrolysis
B) Hydration
C) Dehydration
D) Decolourization
Answer: Dehydration

8. SO_3 is not absorbed directly in water to form H_2SO_4 because:
A) The reaction does not go to completion
B) The reaction is quite slow
C) The reaction is highly exothermic
D) SO_3 is insoluble in water
Answer: The reaction is highly exothermic

9. Nitric acid behaves as an oxidizing agent in its reaction with:
A) Ammonia
B) Sodium hydroxide
C) Copper
D) Sodium carbonate
Answer: Copper

10. Which of the following oxyacids has reducing power?
A) H_3PO_3
B) H_3PO_4
C) $H_4P_2O_7$
D) All of these
Answer: H_3PO_3

11. Fuming nitric acid contains an excess of:
A) N_2O_5
B) NO_2
C) NO

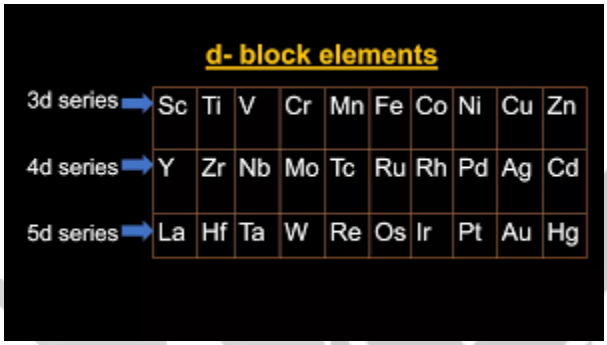
Transition Elements (d-Block) & Coordination Chemistry

Introduction to Transition Elements

Definition:

Transition elements are defined as those elements which have incompletely filled **d-orbitals** in their ground state or in any of their common oxidation states. The f-block elements (Lanthanides and Actinides) are often called **Inner Transition Elements** and have incompletely filled f-orbitals.

Location in the Periodic Table:



They are located in the central part of the periodic table, spanning **Groups 3 to 12**, positioned between the electropositive s-block metals and the electronegative p-block elements.

Electronic Configuration

General Valence Shell Configuration:

The general electronic configuration for d-block elements is **(n-1) d^{1-10} ns^{1-2}** with exceptions **(Cr, Cu, Mo, Ag, Au, Pd)**

First Transition Series (3d): Scandium (Sc, 21) to Zinc (Zn, 30)

Second Transition Series (4d): Yttrium (Y, 39) to Cadmium (Cd, 48)

Third Transition Series (5d): Lanthanum (La, 57), Hafnium (Hf, 72) to Mercury (Hg, 80)

Fourth Transition Series (6d): Actinium (Ac, 89), Rutherfordium (Rf, 104) onwards (incomplete and radioactive).

Exceptions to the Aufbau Principle:

Certain elements deviate from the expected order of filling to achieve extra stability.

1. **Chromium (Cr, 24):** Expected: [Ar] $3d^4$ $4s^2$ | **Actual: [Ar] $3d^5$ $4s^1$**
2. **Copper (Cu, 29):** Expected: [Ar] $3d^9$ $4s^2$ | **Actual: [Ar] $3d^{10}$ $4s^1$**
3. **Other Examples:** Molybdenum (Mo, 42), Silver (Ag, 47), and Gold (Au, 79) show similar behavior.

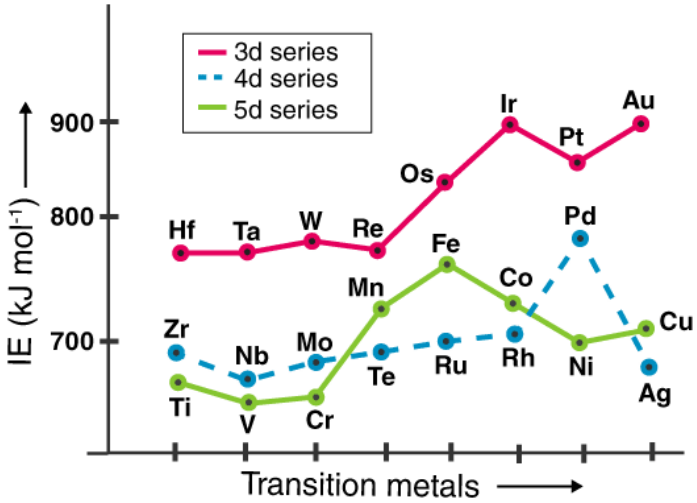
Reason for Exceptions: Atoms gain extra stability from a **half-filled (d^5)** or **fully filled (d^{10})** d-subshell. This configuration leads to symmetrical electron distribution and minimized electron-electron repulsion, making it more energetically favorable.

Classification: Typical vs. Non-Typical Transition Elements

Typical Transition Elements: Elements from Groups 4 to 11 (e.g., Ti, V, Cr, Mn, Fe, Co, Ni, Cu). They exhibit characteristic properties like variable oxidation states, colored ions, and catalytic activity.

The irregular trend is due to the varying stability of d^0, d^5, and d^{10} configurations.

Chemical Properties and Characteristics



Variable Oxidation States

Explanation: Transition elements show multiple oxidation states because the energy difference between the ns and (n-1)d orbitals is small. This allows electrons from both orbitals to be used in bonding.

Trends:

The **maximum oxidation state** increases from Sc to Mn, corresponding to the total number of 4s and 3d electrons (e.g., Mn shows +7 in $KMnO_4$).

After Mn (Group 7), the higher oxidation states become less stable due to the increasing nuclear charge, which holds the d-electrons more tightly. The +2 and +3 states become more common.

The **+2 oxidation state** is common for all elements (due to the loss of two 4s electrons), and its stability (ionic character) increases across the series.

The **+3 oxidation state** is common at the beginning of the series and for later elements in their complexes.

Examples:

Vanadium (V): +2 (violet), +3 (green), +4 (blue, as VO^{2+}), +5 (yellow, as VO_2^+)

Manganese (Mn): +2 (pale pink, most stable), +3, +4 (in MnO_2), +6 (green, in MnO_4^{2-}), +7 (purple, in MnO_4^-)

Iron (Fe): Fe^{2+} (pale green, high-spin), Fe^{3+} (yellow/brown, but pale violet in high-spin hexaaqua complexes; yellow/brown due to hydrolysis/chloride complexes)

Copper (Cu): +1 (Cuprous, colorless, diamagnetic), +2 (Cupric, blue, paramagnetic)

Transition element	Known oxidation states	Electron configuration	Orbital diagram (4s and 3d sub-levels only)
Sc	+3	[Ar] $4s^2\ 3d^1$	4s ↿⇂ 3d ↿ ☐ ☐ ☐ ☐
Ti	+2 +3 +4	[Ar] $4s^2\ 3d^2$	4s ↿⇂ 3d ↿ ↿ ☐ ☐ ☐
V	+1 +2 +3 +4 +5	[Ar] $4s^2\ 3d^3$	4s ↿⇂ 3d ↿ ↿ ↿ ☐ ☐
Cr	+1 +2 +3 +4 +5 +6	[Ar] $4s^1\ 3d^5$	4s ↿ 3d ↿ ↿ ↿ ↿ ↿
Mn	+1 +2 +3 +4 +5 +6 +7	[Ar] $4s^2\ 3d^5$	4s ↿⇂ 3d ↿ ↿ ↿ ↿ ↿
Fe	+1 +2 +3 +4 +5 +6	[Ar] $4s^2\ 3d^6$	4s ↿⇂ 3d ↿⇂ ↿ ↿ ↿ ↿
Co	+1 +2 +3 +4 +5	[Ar] $4s^2\ 3d^7$	4s ↿⇂ 3d ↿⇂ ↿⇂ ↿ ↿ ↿
Ni	+1 +2 +3 +4	[Ar] $4s^2\ 3d^8$	4s ↿⇂ 3d ↿⇂ ↿⇂ ↿⇂ ↿ ↿
Cu	+1 +2 +3	[Ar] $4s^1\ 3d^{10}$	4s ↿ 3d ↿⇂ ↿⇂ ↿⇂ ↿⇂ ↿⇂

Formation of Colored Compounds

Cause of Color:

The color arises from **d-d transitions**.

In an isolated ion, all five d-orbitals are degenerate (have the same energy).

In a complex, the approach of ligands creates an **electric field** that splits the d-orbitals into two sets with different energy levels (e.g., t_2g and eg in an octahedral field).

When white light falls on the complex, it absorbs light of a specific frequency (photon) to promote an electron from a lower-energy d-orbital to a higher-energy one. The energy absorbed corresponds to the crystal field splitting energy (Δ).

The colour we observe is the **complementary colour** of the light absorbed.

Conditions for Colour:

The central metal ion must have **incompletely filled d-orbitals**.

Ions with **empty (Sc^{3+}, d^0)** or **full (Zn^{2+}, Cd^{2+}, Hg^{2+}, d^{10})** d-orbitals are typically **colourless** as d-d transitions are not possible.

Factors Affecting Colour:

Identity of the Metal Ion: Different metal ions have different splitting patterns (Δ values).

Oxidation State of the Metal: A metal in a higher oxidation state often produces a larger Δ and thus a different colour (e.g., Fe^{2+} is pale green, Fe^{3+} is yellow/brown).

Nature of the Ligand: Different ligands cause different extents of splitting. This is summarized in the **Spectrochemical Series**:

$I^- < Br^- < S^{2-} < SCN^-$ (S-bonded) $< Cl^- < NO_3^- < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^-$ (N-bonded) $< NH_3 <$ en < bipy < phen $< NO_2^- < CN^- = CO$"

(Weak Field Ligands → Small Δ) --- (Strong Field Ligands → Large Δ)

Coordination Number and Geometry: The geometry (octahedral, tetrahedral, square planar) affects the splitting pattern. Tetrahedral complexes have smaller Δ than octahedral ones.

Catalytic Properties

Reasons for Catalytic Activity:

1. Variable Oxidation States: They can form unstable intermediate compounds with reactants, providing an alternative reaction path with a lower activation energy.

Topic Wise One Liners on Transition elements and Coordination Chemistry:

1. **Transition elements** are defined as those elements which have incompletely filled **d-orbitals** in their ground state or in any of their common oxidation states.
2. The general electronic configuration of transition elements is **$(n-1)d^{1-10}$ ns^{1-2}**.
3. Zinc (Zn), Cadmium (Cd), and Mercury (Hg) are not considered typical transition elements as their d-subshell is completely filled.
4. Transition elements are characterized by **variable oxidation states**, **complex formation**, and **colored ions**.
5. Not all ions of transition elements are colored; for example, Sc^{3+} and Zn^{2+} are colorless due to empty and fully filled d-orbitals, respectively.
6. Transition elements can form **interstitial compounds** when small non-metal atoms like H, B, C, or N occupy the empty spaces in their crystal lattices.
7. The formation of interstitial compounds makes the parent metal **more brittle** and **harder**.
8. **Non-stoichiometric compounds** are those that do not obey the law of definite proportions and are often **interstitial compounds**.
9. Transition elements and their compounds often act as good **catalysts** due to their variable oxidation states.
10. Negative oxidation states are shown by transition elements in **complexes** and **carbonyls**.

2. Electronic Configurations and Paramagnetism

11. The electronic configuration of Chromium (Cr, Z=24) is **$3d^5$ $4s^1$**, not $3d^4$ $4s^2$, due to the extra stability of a half-filled d-subshell.
12. The number of **unpaired electrons** in an atom or ion determines its **paramagnetic character**.
13. The ion with the maximum number of unpaired electrons will exhibit the **maximum paramagnetic character**.
14. Mn^{2+} ion has the electronic configuration [Ar] $3d^5$, meaning it has **5 unpaired electrons**.
15. Fe^{3+} ion has the electronic configuration [Ar] $3d^5$, meaning it also has **5 unpaired electrons**.
16. Cu^{2+} ion has the electronic configuration [Ar] $3d^9$, meaning it has only **1 unpaired electron**.
17. The **least paramagnetism** is shown by ions with the fewest or zero unpaired electrons, such as Cu^{2+}.
18. Along a period in the transition series, the **paramagnetic character** first increases to a maximum and then decreases.
19. Along a period, the **covalent radii** of transition elements in their ionic state generally **decrease**.

3. Coordination Chemistry

20. A **coordination compound** consists of a central metal atom or ion surrounded by ligands.
21. The **coordination sphere** refers to the central metal ion and the ligands attached to it.
22. The **coordination number** is the total number of coordinate bonds formed between the central metal ion and the ligands.
23. In the complex $[Ag(NH_3)_2]^+$, the coordination number of Silver (Ag) is **2**.
24. In the complex $[PtCl(NO_2)(NH_3)_4]^{2+}$, the coordination number of Platinum (Pt) is **6**.
25. **Ligands** are ions or molecules that donate a pair of electrons to the central metal atom.
26. **Monodentate ligands** donate

Practice MCQs

1. Which of the following is a defining characteristic of transition metals according to the broader definition used in the text?
A) They always have partly filled d or f shells as neutral atoms.
B) They have partly filled d or f shells in any commonly occurring oxidation state.
C) They are all non-metals.
D) They do not form colored ions.
Answer: They have partly filled d or f shells in any commonly occurring oxidation state.

2. The element scandium is considered the lightest member of which series?
A) First transition series
B) Second transition series
C) Lanthanide series
D) Actinide series
Answer: First transition series

3. Why are the chemical properties of the lanthanides so homogeneous compared to the d-block elements?
A) Their 4f orbitals are exposed and interact strongly with the environment.
B) Their 4f orbitals are deeply buried and shielded from the surroundings.
C) They have variable oxidation states.
D) They form primarily covalent bonds.
Answer: Their 4f orbitals are deeply buried and shielded from the surroundings.

4. Which of the following oxidation states is maximum in 3d series and has no physical reality as a simple ion?
A) Ti^{3+}
B) Mn^{7+} in MnO_4^-
C) Fe^{2+}
D) Cu^{2+}
Answer: Mn^{7+} in MnO_4^-

5. In the first transition series, the highest oxidation state is NOT exhibited by which element in stable compounds?
A) Scandium
B) Chromium
C) Manganese
D) Iron
Answer: Iron

6. According to the 18-electron rule, the homoleptic carbonyl with the formula $V(CO)_6$ is an exception because it has:
A) 16 electrons
B) 17 electrons
C) 18 electrons
D) 20 electrons
Answer: 17 electrons

7. The synergic bonding in metal carbonyls involves:
A) Only σ donation from CO to the metal.
B) Only π back-donation from the metal to CO.
C) Both σ donation from CO and π back-donation from the metal.
D) Neither σ nor π bonding.
Answer: Both σ donation from CO and π back-donation from the metal.

8. What physical evidence strongly supports the existence of M--CO π back-bonding?
A) Increase in C--O bond length and decrease in M--C bond length.
B) Decrease in both C--O and M--C bond lengths.
C) Increase in C--O stretching frequency.
D) Decrease in the metal's oxidation state.
Answer: Increase in C--O bond length and decrease in M--C bond length.

9. When CO groups in a metal carbonyl are replaced by ligands with poor π-acceptor ability, the stretching frequencies of the remaining CO groups typically:
A) Increase.
B) Decrease.
C) Remain the same.
D) Become zero.
Answer: Decrease.

Chemical Equilibrium

IRREVERSIBLE REACTIONS

In an irreversible reaction, the process proceeds essentially to completion in one direction under a given set of conditions, with the reverse reaction being negligible. A classic example is the reaction of sodium with water:

$2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + H_2(g)$.

Under normal temperatures, the tendency for hydrogen gas to react with sodium hydroxide to reform sodium and water is so infinitesimally small that it is considered non-existent for practical purposes. Such reactions are said to be irreversible and are represented with a single arrow (→).

REVERSIBLE REACTIONS.

a reversible reaction is one in which the products can react to re-form the original reactants under the same conditions. Both forward and reverse processes occur simultaneously. A prime example is the reaction between nitrogen and hydrogen to form ammonia:

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

When stoichiometric amounts of nitrogen and hydrogen are combined at 450°C under high pressure in the presence of an iron catalyst, the reaction mixture does not consist solely of ammonia after an indefinite time. Instead, it contains all three species—nitrogen, hydrogen, and ammonia—in fixed proportions, indicating that the reverse reaction (decomposition of ammonia) is occurring to a measurable extent. This state, where the composition of the mixture remains constant over time, is a hallmark of a reversible reaction, denoted by the double arrow symbol (⇌).

Examples of Reversible Reactions

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$ (esterification)

$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ (thermal decomposition)

The **concept of reversibility is not absolute**

but depends on the conditions. For instance, the combustion of hydrogen to form water, $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$, appears **irreversible at room temperature** However, if water is heated to extremely high temperatures (around 1500°C), a noticeable quantity decomposes back into hydrogen and oxygen. This demonstrates that the reverse reaction does occur, but its rate is so slow at lower temperatures as to be imperceptible.

Chemical Equilibrium – Nature and Characteristics

When a reversible reaction is conducted in a closed system and allowed to proceed for a sufficiently long period without any change in external parameters such as temperature, pressure, or concentration, a point is reached where the macroscopic properties of the system become invariant with time. This condition is termed a state of chemical equilibrium. At equilibrium, the concentrations of all reactants and products remain constant. It is crucial to understand that this constancy is not due to the cessation of chemical activity but arises from a dynamic balance. The

If Q < Ksp → no precipitation, more solid can dissolve.

Salt Hydrolysis

Definition

Reaction of salt ions with water to produce acidic or basic solutions.

Types of Salts and Resulting PH

Salt Type	Example	Solution pH	Reason
Strong acid + Strong base	NaCl	7 (neutral)	No hydrolysis
Strong acid + Weak base	NH_4Cl	<7 (acidic)	Cation hydrolysis (NH_4^+)
Weak acid + Strong base	CH_3COONa	>7 (basic)	Anion hydrolysis (CH_3COO^-)
Weak acid + Weak base	NH_4CN	Depends on Ka/Kb	Both ions hydrolyze

Hydrolysis Constant (K_h)

For anion hydrolysis (salt of weak acid): Kh = Kw / Ka

For cation hydrolysis (salt of weak base): Kh = Kw / Kb

Acid–Base Titrations and Indicators

Titration

A volumetric method to determine the concentration of an unknown solution using a standard solution.

Selection of Indicator

Titration Type	Suitable Indicator	pH Range at End Point
Strong acid – Strong base	Phenolphthalein	8.2–10.0
Strong acid – Weak base	Methyl orange	3.1–4.4
Weak acid – Strong base	Phenolphthalein	8.2–10.0
Weak acid – Weak base	No sharp end point	–

Calculation Formula

$M_1V_1 / n_1 = M_2V_2 / n_2$

where M = molarity, V = volume, n = stoichiometric coefficient from balanced equation.

Key Summary Points

- **Chemical equilibrium** is dynamic, with equal forward and reverse rates.
- **Equilibrium constant K** depends only on temperature.
- **Le Chatelier's principle** predicts shifts due to concentration, pressure, and temperature changes.
- **pH = −log[H⁺]**; pH + pOH = 14 at 25°C.
- **Kw = [H⁺][OH⁻] = 1.0 × 10⁻¹⁴** at 25°C.
- **Ka × Kb = Kw** for conjugate pairs.
- **Buffer solutions** resist pH change (use Henderson–Hasselbalch equation).
- **Ksp** predicts solubility and precipitation.

- **Common ion effect** reduces ionization or solubility.
- **Salt hydrolysis** explains pH of salt solutions.
- **Indicators** are chosen based on pH range of the equivalence point.
- **Lewis theory** defines acids/bases by electron-pair acceptance/donation.

Topic Wise One-Liner: Chemical Equilibrium

1. Reversible Reactions

1. A **reversible reaction** proceeds in both forward and reverse directions simultaneously.
2. It is represented by a **double arrow (⇌)**.
3. Example: $H_2(g)+I_2(g)\rightleftharpoons 2HI(g)H_2(g)+I_2(g)\rightleftharpoons 2HI(g)$.
4. Esterification and thermal decomposition of calcium carbonate are examples of reversible reactions.
5. An **irreversible reaction** goes nearly to completion in one direction under normal conditions.
6. Example of irreversible reaction: $2Na+2H_2O\rightarrow 2NaOH+H_2$

2. Chemical Equilibrium – Nature and Characteristics

7. Chemical equilibrium is **dynamic**, not static.
8. At equilibrium, **forward and reverse reaction rates are equal**.
9. Concentrations of reactants and products remain **constant** at equilibrium.
10. Equilibrium can be reached starting from **pure reactants or pure products**.
11. Equilibrium is attainable only in a **closed system**.
12. A **catalyst** speeds up both forward and reverse reactions equally but does **not shift equilibrium position**.
13. The **equilibrium constant (K)** depends only on **temperature**, not on initial concentrations.
14. At equilibrium, **ΔG = 0** and the system is at minimum free energy.

3. Law of Mass Action

15. The **Law of Mass Action** states that the rate of a reaction is proportional to the product of molar concentrations of reactants raised to their stoichiometric coefficients.
16. For $aA+bB\rightarrow aA+bB\rightarrow$ products, rate $=k[A]a[B]b=k[A]a[B]b$.
17. For a reversible reaction $aA+bB\rightleftharpoons cC+Dd$ at equilibrium $kf\ [A]a[B]b=kr\ [C]c[D]d$
18. The **equilibrium constant Kc** is derived as $Kc=kf/kr=[C]c[D]d/[A]a[B]b$

4. Equilibrium Constant (Kc)

19. **Kc** is expressed in terms of molar concentrations.
20. For reactions involving gases, the equilibrium constant can be expressed in terms of partial pressures and is denoted as **Kp**. Pure solids and liquids are omitted.
21. Pure solids and liquids are **omitted** from the equilibrium expression.
22. Example: For $N2+3H_2\rightleftharpoons 2NH_3$, $Kc=[NH_3]^2/[N_2][H_2]^3$
23. $Kp=Kc(RT)^{\Delta n}$ where Δn=(moles of gaseous products)−(moles of gaseous reactantants)
24. If $\Delta n=0$ then $Kp=Kc$
25. Units of **Kc** are $(mol\ L{-}1)\Delta^n$ and of **Kp** are $(atm)^{\Delta n}$

87. **Hydrolysis constant Kh** for anion hydrolysis: $Kh=Kw/Ka$.
88. For cation hydrolysis: Kh=Kw/Kb

15. Acid–Base Titrations and Indicators

89. **Titration** is a volumetric method to determine unknown concentration using a standard solution.
90. Strong acid–strong base titration uses **phenolphthalein** (pH 8.2–10.0) as indicator.
91. Strong acid–weak base titration uses **methyl orange** (pH 3.1–4.4).
92. Weak acid–strong base titration uses **phenolphthalein**.
93. Weak acid–weak base titration has **no sharp end point**.
94. Titration formula: M1V1/n1=M2V2/n2

16. Lewis Acids and Bases

95. **Lewis acid** is an electron-pair acceptor (e.g., BF_3, H^+).
96. **Lewis base** is an electron-pair donor (e.g., NH_3, OH^-).
97. Example: $BF_3 + :NH_3 \rightarrow F_3B:NH_3$

Practice MCQs

1. The symbol used to represent a reversible reaction is:
A) →
B) ←
C) ⇒
D) ⇌
Answer: ⇌

2. An example of a reversible reaction is:
A) $2Na + 2H_2O \rightarrow 2NaOH + H_2$
B) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
C) $H_2 + I_2 \rightleftharpoons 2HI$
D) $2H_2 + O_2 \rightarrow 2H_2O$
Answer: **$H_2 + I_2 \rightleftharpoons 2HI$**

3. At dynamic equilibrium, the rates of the forward and reverse reactions are:
A) Zero
B) Increasing
C) Decreasing
D) Equal
Answer: **Equal**

4. Chemical equilibrium can only be established in a:
A) Open system
B) Closed system
C) Isolated system
D) Any system
Answer: **Closed system**

5. A catalyst affects a system at equilibrium by:
A) Shifting the equilibrium position
B) Changing the equilibrium constant
C) Increasing the rate at which equilibrium is attained
D) Decreasing the activation energy of the reverse reaction only
Answer: **Increasing the rate at which equilibrium is attained**

6. The equilibrium constant (K) for a reaction depends only on:
A) Pressure
B) Concentration
C) Temperature
D) Catalyst
Answer: **Temperature**

7. According to the Law of Mass Action, the rate of a reaction is proportional to the:
A) Sum of the concentrations of reactants
B) Product of the concentrations of reactants raised to their stoichiometric coefficients
C) Difference in concentrations of products and reactants

PUBLICATIONS

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PART 2: ENGLISH

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Chapter 1

The Noun

Definition of Noun

A noun is a word that functions as the name of a:

- **Person:** child, woman, Ali, teacher
- **Place:** city, Lahore, park
- **Thing:** table, car, money
- **Animal:** dog, elephant, bird
- **Idea, Quality, or State:** happiness, bravery, knowledge, poverty
- **Action:** (Gerunds) swimming, reading, driving

In simple terms, a noun is a naming word. The name of everything is a noun.

Types of Nouns

Nouns can be categorized into eight primary types for a clearer understanding of their usage.

1. Proper Noun

A proper noun is the specific name of a particular person, place, or thing.

- **Rule 1:** It always begins with a **capital letter**.
- **Rule 2:** It can not be changed into a plural form (e.g., *There are two Ali's in my class*).

2. Common Noun

A common noun is a general name that is common to all persons, places, or things of the same kind. It denotes no particular entity.

Proper Noun	Common Noun
Ali	boy
Lahore	city
Badshahi Mosque	mosque

3. Material Noun

A material noun is the name of a substance or matter from which things are made. These often exist in different states of matter: solid, liquid, gas, and plasma. Things in a solid state are sometimes called concrete nouns.

- ***Examples:*** **wood**, **gold**, **water**, **air**, **plastic**, **cement**.

4. Abstract Noun

An abstract noun is the name of an idea, quality, state, or feeling that does not exist in a physical or material form.

Examples: **love, honesty, anger, childhood, poverty, wisdom.**

Material Noun	Abstract Noun
Water	Honesty
Iron	Strength
Milk	Whiteness

5. Countable Noun

Countable nouns refer to objects or items that can be counted. They have both singular and plural forms.

- ***Examples:*** **an egg, three oranges, many chairs, several ideas.**

6. Uncountable Noun

Rule 13: Subject-Verb Agreement with "Number of" vs. "A Number of"
The phrases "the number of" and "a number of" are followed by different verb forms.

- **The number of** students **is** increasing. (Refers to the number itself, which is singular)
- **A number of** students **are** absent today. (Means "several," referring to the students, which is plural)

Rule 14: Nouns Ending in "-ics" (Academic Subjects)
Names of academic subjects ending in "-ics" are generally singular. However, when they refer to specific activities, qualities, or practical applications, they can be plural.

- **Mathematics is** easy for her. (As a field of study)
- Her **mathematics are** weak. (Referring to her mathematical skills/calculations)

Rule 15: Agreement with Paired Nouns
When two or more singular nouns are connected by "and" and refer to the same person or thing, they take a singular verb. Otherwise, they take a plural verb.

- **Bread and butter is** my favorite breakfast. (Treated as a single item)
- The **principal and secretary has** arrived. (One person holding both positions)
- The **principal and the secretary have** arrived. (Two different persons)

Practice MCQ

1. Identify the type of noun for the word "team" in the sentence: "The team won the championship."
A. Common Noun
B. Collective Noun
C. Abstract Noun
D. Compound Noun
Answer: B

2. Which of the following is an abstract noun?
A. Water
B. Honesty
C. Lahore
D. Chair
Answer: B

3. Choose the correct sentence according to noun rules.
A. The scissor is on the table.
B. The scissors is on the table.
C. The scissors are on the table.
D. A scissor are on the table.
Answer: C

4. The noun "poultry" in the sentence "The poultry are being fed" is an example of a noun that:
A. Is always singular
B. Appears singular but takes a plural verb
C. Is a material noun
D. Is uncountable
Answer: B

5. Which of the following nouns is always plural in form and takes a plural verb?
A. News
B. Economics
C. Trousers
D. Politics
Answer: C

6. Identify the compound noun.
A. Beautifully
B. Swimming pool
C. Quickly
D. Happiness
Answer: B

7. Select the sentence where an uncountable noun is used correctly.
A. She gave me some good advices.
B. The furnitures in this room are new.
C. Her hair are long and black.
D. The information provided was incorrect.
Answer: D

8. The word "people" in "Many people attend the fair" is a noun that:
A. Is singular
B. Appears singular but takes a plural verb
C. Is a collective noun
D. Is a proper noun
Answer: B

9. The use of the indefinite article 'a' with the normally uncountable noun 'experience' in the sentence "I had a bitter experience" is justified because:
A. The noun is used in a

Chapter 2

The Pronoun

Definition of Pronoun

A pronoun is a word used in place of a noun or a noun phrase to avoid repetition. It refers to a noun that has been mentioned before or is clearly understood from the context.

- *Example:* "**Ali** is a doctor. **He** works in a hospital." (The pronoun "He" replaces the noun "Ali").

Types of Pronouns

Pronouns can be categorized into nine main types:

1. Personal Pronoun
2. Possessive Pronoun
3. Reflexive Pronoun
4. Demonstrative Pronoun
5. Indefinite Pronoun
6. Relative Pronoun
7. Interrogative Pronoun
8. Distributive Pronoun
9. Reciprocal Pronoun

1. Personal Pronoun

Personal pronouns refer to specific people or things and change form based on person (first, second, third), number (singular, plural), case (subject, object), and gender (he, she, it).

Person	Subject Pronoun	Object Pronoun	Possessive Adjective	Possessive Pronoun	Reflexive Pronoun
First (Singular)	I	me	my	mine	myself
First (Plural)	we	us	our	ours	ourselves
Second (Singular/Plural)	you	you	your	yours	yourself / yourselves
Third (Masc.)	he	him	his	his	himself
Third (Fem.)	she	her	her	hers	herself
Third (Neutral)	it	it	its	its	itself
Third (Plural)	they	them	their	theirs	themselves

2. Possessive Pronoun

A possessive pronoun shows ownership and is used **when the noun is not expressed**.

- *Examples:* **mine, his, hers, ours, yours, theirs**.
- This is my book. That one is **yours** (your book).
- Their house is big, but **ours** (our house) is more comfortable.

3. Reflexive Pronoun

A reflexive pronoun ends in **-self** or **-selves** and is used when the subject and the object of a verb are the same person or thing.

- *Examples:* myself, ourselves, yourself, yourselves, himself, herself, itself, themselves.
- She taught **herself** how to play the guitar.
- The cat cleaned **itself**.

4. Demonstrative Pronoun

A demonstrative pronoun points to a specific noun (its antecedent) and replaces it.

Chapter 3

The Verb

Definition of Verb

A verb is fundamentally a word that denotes an **action** (*run, synthesize*), indicates a **state of being** (*is, exist*), or describes an **occurrence** (*happen, become*). It forms the essential predicate that tells something about the subject.

A Conceptual Classification of Verb

Understanding verb types is crucial for mastering sentence structure, tense usage, and voice.

1. **Transitive Verbs: The Action Transferers**

   A transitive verb requires one or more objects to complete its meaning. The action originates with the subject and is transferred to an object.

- ***Example 1:*** The scientist **conducted** *the experiment*.
  - ***Analysis:*** The verb "conducted" is meaningless without its object "the experiment." It answers "conducted what?"
- ***Example 2:*** The author **wrote** *a compelling novel*.
  - ***Analysis:*** "Wrote" requires the object "a compelling novel" to complete the thought.

2. **Intransitive Verbs: The Self-Contained Actions**

   An intransitive verb expresses a complete action without transferring that action to an object. It may be followed by an adverb, a prepositional phrase, or nothing.

- ***Example 1****:* The results **emerged** *slowly*.
  - ***Analysis:*** The verb "emerged" is complete in itself. "Slowly" merely modifies the action; it is not an object.
- ***Example 2:*** All the guests **arrived** *before noon*.
  - ***Analysis****:* "Arrived" does not need an object; "before noon" is a prepositional phrase indicating time.

3. **Ditransitive Verbs: The Double Object Handlers**

   A subset of transitive verbs that take two objects: a **direct object** (the thing that is given/told) and an **indirect object** (the person/thing that receives it).

- ***Structure:*** Subject + Verb + Indirect Object + Direct Object
- ***Example 1****:* She **gave** *the student a book.*
  - ***Analysis****:* "A book" (Direct Object - what was given), "the student" (Indirect Object - to whom it was given).
- ***Example 2:*** The manager **offered** *his team a new proposal*.
  - ***Analysis****:* "A new proposal" (Direct Object), "his team" (Indirect Object).

4. **Linking (Copular) Verbs: The Connectors**

   Linking verbs do not express action. Instead, they link the subject to a **subject complement**—a word or phrase that renames or describes the subject.

- ***Common Linking Verbs:*** *be, become, seem, appear, feel, look, sound, smell, taste, remain, stay, grow, turn, prove.*
- ***Example 1:*** His hypothesis **proved** *correct*.
  - ***Analysis:*** "Proved" connects the subject "hypothesis" to the adjective "correct," which describes it.
- ***Example 2:*** **She became *a renowned scientist.***
  - ***Analysis:*** "Became" links the subject "She" to the noun phrase "a renowned scientist," which renames her.

5. **Causative Verbs: The Instigators**

   Causative verbs indicate that the subject causes someone else to perform an action. The three primary causatives (*make, have, get*) differ in force and structure.

- **Make + Agent + Base Form:** Implies force or compulsion.
  - *Example 1:* The manager **made** the team **work** overtime.

bite	bit	bitten	biting
bleed	bled	bled	bleeding
blow	blew	blown	blowing
break	broke	broken	breaking
bring	brought	brought	bringing
build	built	built	building
burn	burnt/burned	burnt/burned	burning
burst	burst	burst	bursting
buy	bought	bought	buying
catch	caught	caught	catching
choose	chose	chosen	choosing
cling	clung	clung	clinging
come	came	come	coming
cost	cost	cost	costing
creep	crept	crept	creeping
cut	cut	cut	cutting
deal	dealt	dealt	dealing
dig	dug	dug	digging
do	did	done	doing
draw	drew	drawn	drawing
dream	dreamt/dreamed	dreamt/dreamed	dreaming

Practice MCQs

1. Identify the type of verb in: "She became a doctor after years of study."
A. Transitive Verb
B. Intransitive Verb
C. Linking Verb
D. Causative Verb
Answer: C

2. Which sentence uses a ditransitive verb?
A. The sun rises in the east.
B. She sang a beautiful song.
C. He told the children a story.
D. They arrived late.
Answer: C

3. Choose the correct causative structure:
A. I made him to apologize.
B. I had him apologize.
C. I got him apologize.
D. I let him to leave.
Answer: B

4. The verb in "The flowers smell wonderful" is:
A. Transitive
B. Intransitive
C. Linking
D. Auxiliary
Answer: C

5. Which verb is followed by a gerund?
A. decide
B. want
C. avoid
D. hope
Answer: C

6. Select the correct sentence:
A. She suggested to go early.
B. She suggested going early.
C. She suggested go early.
D. She suggested to going early.
Answer: B

7. Identify the intransitive verb:
A. write
B. build
C. arrive
D. make
Answer: C

8. "The committee has reached its decision." Here 'has' is:
A. Main verb
B. Primary auxiliary
C. Modal auxiliary
D. Linking verb
Answer: B

9. Which sentence shows correct verb agreement?
A. The list of items are long.
B. Each of the students are present.
C. Neither answer is correct.
D. The team are winning.
Answer: C

10. Choose the correct past participle form:
A. swimmed
B. swam
C. swum
D. swim
Answer: C

11. The error in "She laid on the bed all day" is:
A. Wrong tense
B. Wrong verb form
C. Missing object
D. Subject-verb disagreement
Answer: B (Should be 'lay')

12. Which modal verb expresses necessity?
A. can
B. may
C. must
D. might
Answer: C

13. Identify the transitive verb:
A. sleep
B. laugh
C. eat
D. exist
Answer: C

14. "I got him to confess." This uses:
A. Transitive verb
B. Causative verb
C. Linking verb
D. Intransitive verb
Answer: B

15. Which verb takes an infinitive?
A. enjoy
B. finish
C. plan

Chapter 4

Subject-Verb Agreement

Introduction

Subject-verb agreement is a fundamental rule of English grammar. It states that the verb in a sentence must agree in number with its subject. A singular subject requires a singular verb, and a plural subject requires a plural verb. This chapter outlines the key rules and exceptions to ensure grammatical accuracy in your writing and speech.

Subject Verb Agreement Correction Rules

Rule 1: The Interrupting Phrase

When the subject is followed by a phrase like *as well as, along with, together with, in addition to, including, besides,* or *accompanied by*, the verb agrees with the **original subject**, not the noun in the phrase.

- The **manager**, as well as the team members, **is** attending the conference.
- My **parents**, along with my uncle, **are** visiting us.

Rule 2: Compound Subjects with "And"

- **General Rule:** Two or more subjects joined by **and** take a **plural verb**.
  - **Ali and Sana are** studying for the exam.
- **Exception:** When the compound subject refers to a **single idea or item**, use a **singular verb**.
  - **Bread and butter is** a common breakfast. (One food item)
  - **My friend and mentor has** left the company. (One person)

Rule 3: Indefinite Pronouns

The following indefinite pronouns **always take a singular verb**:

each, either, neither, anyone, anybody, anything, everyone, everybody, everything, someone, somebody, something, no one, nobody, nothing.

- **Everyone** in the office **has** a assigned parking space.
- **Neither** of the answers **is** correct.
- **Each** of the students **has** passed the test.

Note on "None": "None" can be singular or plural. However, it is often treated as singular, especially in formal writing.

- **None** of the information **was** useful. (Singular)
- **None** of the options **are** acceptable. (Plural, implying "not any")

Rule 4: Flexible Quantity Words

The pronouns *all, any, more, most,* and *some* can be singular or plural, depending on whether they refer to a countable or uncountable noun.

- **All** the **water has** evaporated. (Uncountable = Singular Verb)
- **All** the **students have** left. (Countable = Plural Verb)
- **Some** of the **advice was** helpful. (Uncountable)
- **Some** of the **books were** missing. (Countable)

Rule 5: Collective Nouns

A collective noun (e.g., *team, jury, crowd, committee, family*) can be singular or plural.

- Use a **singular verb** when the group acts as a **single unit**.
  - The **jury has** reached its verdict.
- Use a **plural verb** when the members of the group are **acting individually**.
  - The **jury are** still debating their opinions.

Rule 6: "A Number" vs. "The Number"

- **A number of...** means "many" and takes a **plural verb**.
  - **A number of students were** absent today.
- **The number of...** refers to a specific figure and takes a **singular verb**.

Chapter 5

The Adverb

Definition of Adverb

An adverb is a word that modifies (qualifies) a verb, an adjective, another adverb, a preposition, a conjunction, or even an entire sentence. It provides additional information about time, manner, place, frequency, degree, and certainty.

Core Function: To add descriptive detail to show how, when, where, why, or to what extent something happens.

The Versatile Roles of an Adverb

Adverbs can modify various parts of speech:

- **Modifying a Verb:**
  - She sang **beautifully**.
  - He runs **quickly**.
- **Modifying an Adjective:**
  - She is **extremely** intelligent.
  - This is a **very** interesting book.
- **Modifying Another Adverb:**
  - He works **incredibly** efficiently.
  - She spoke **almost** inaudibly.
- **Modifying a Preposition:**
  - The ball landed **just** inside the boundary.
  - He arrived **shortly** after noon.
- **Modifying a Conjunction:**
  - I like him, **simply** because he is honest.
  - She left **soon** after the meeting began.
- **Modifying an Entire Sentence:**
  - **Fortunately**, the weather remained clear.

Types of Adverb

Adverbs can be categorized based on the specific information they provide.

1. Adverbs of Manner

Describe *how* an action is performed.

- **Questions Answered:** How? In what manner?
- **Examples:** quickly, slowly, carefully, beautifully, well, fast
- He solved the problem **efficiently**.
- They danced **gracefully**.

2. Adverbs of Place

Describe *where* an action occurs.

- **Questions Answered:** Where? Where to?
- **Examples:** here, there, everywhere, somewhere, inside, outside
- Please wait **outside**.
- The children are playing **upstairs**.

3. Adverbs of Time

Describe *when* an action occurs.

- **Questions Answered:** When? How long? How often?
- **Examples:** now, then, today, yesterday, soon, already, yet

Practice MCQs

1. Identify the type of adverb in the sentence: "He will probably complete the project by tomorrow."
A. Adverb of Manner
B. Adverb of Time
C. Adverb of Affirmation
D. Adverb of Degree
Answer: C

2. Choose the sentence with the correct adverb order:
A. She sang beautifully at the concert last night.
B. She sang at the concert beautifully last night.
C. She beautifully sang last night at the concert.
D. Last night at the concert she sang beautifully.
Answer: A

3. The error in the sentence "I am very pleased to meet you" is:
A. Incorrect use of 'very'
B. Incorrect verb tense
C. Wrong pronoun
D. No error
Answer: A (Should be 'much pleased')

4. Which sentence uses the correct comparative form of the adverb?
A. She works more harder than anyone else.
B. She works harder than anyone else.
C. She works more hard than anyone else.
D. She works hardest than anyone else.
Answer: B

5. Identify the relative adverb in: "I remember the day when we first met."
A. I
B. remember
C. day
D. when
Answer: D

6. The sentence "He reached the station lately" is incorrect because:
A. 'lately' means recently, not 'late'
B. Wrong preposition
C. Incorrect verb form
D. Missing article
Answer: A

7. Choose the correct negative inversion:
A. Hardly had I left when the storm began.
B. Hardly I had left when the storm began.
C. Hardly I left when the storm began.
D. I had left hardly when the storm began.
Answer: A

8. Which adverb modifies the entire sentence?
A. quickly
B. here
C. unfortunately
D. very
Answer: C

9. The error in "She is too beautiful" is that:
A. 'too' implies excess and should be 'very'
B. Wrong adjective form
C. Incorrect verb agreement
D. No error
Answer: A

10. Identify the adverb of degree: "The project is almost complete."
A. project
B. is
C. almost
D. complete
Answer: C

11. Which sentence demonstrates correct use of 'much' and 'very'?
A. I am very much tired after the long journey.
B. I am very tired after the long journey.
C. I am much tired after the long journey.
D. Both A and B are correct.
Answer: B

12. Choose the correct superlative form: "Of all the students, she solves problems _____."
A. most intelligently
B. intelligentlyest
C. more intelligently
D. most intelligent
Answer: A

13. Identify the adverb modifying a preposition: "The ball landed just outside the boundary."
A. ball
B. landed
C. just

Chapter 6

The Adjective

Definition of Adjective

An adjective is a word that modifies a noun or a pronoun by describing, identifying, or quantifying it. It adds meaning by answering questions like *What kind? Which one? How many?* or *How much?*

Core Function: To provide more information about a noun or pronoun.

Placement Rules:

1. **Before a Noun (Attributive Position):** A **brilliant** idea, the **blue** sky
2. **After a Linking Verb (Predicative Position):** The idea is **brilliant**. The sky appears **blue**.

Types of Adjective

Adjectives can be categorized based on their specific function and meaning.

1. Proper Adjective

Formed from proper nouns and used to describe something related to that noun.

- **Examples: Chinese** food, **Pakistani** culture, **Victorian** era, **Shakespearean** drama

2. Descriptive Adjective (Adjective of Quality)

Describes the quality, state, or kind of a noun.

Examples: a brave soldier, a **sick** patient, a **beautiful** painting, an **honest** person

3. Adjective of Quantity

Indicates the amount or quantity of a noun (used with uncountable nouns).

Examples: some water, **much** effort, **little** hope, **enough** time, **all** people

4. Adjective of Number (Numeral Adjective)

Shows the number or order of nouns (used with countable nouns).

- **Definite Numeral:** one, two, first, second (shows exact number)
- **Indefinite Numeral:** many, few, several, some (shows approximate number)
- **Distributive Numeral:** each, every, either, neither (refers to individual members)

5. Demonstrative Adjective

Points out or demonstrates which specific noun is being referred to.

- **Definite Demonstrative:** this, that, these, those, the
- **Indefinite Demonstrative:** a, an, any, one, certain, some, other, another

6. Interrogative Adjective

Used with a noun to ask a question.

Examples: Which book do you prefer? **Whose** bag is this? **What** time is it?

7. Possessive Adjective

Shows possession or ownership.

Examples: my book, your pen, his car, her dress, our house, their garden

Degrees of Comparison

Most descriptive adjectives, along with *much/many* and *little/few*, have three degrees of comparison.

1. Positive Degree

- The base form of the adjective.
- Used when no comparison is made.
- **Example:** This is a **long** road. She is **intelligent**.

Chapter 7

Preposition

Introduction

A preposition is a word that shows a relationship between a noun (or pronoun) and another word in a sentence. This relationship can be one of time, place, direction, manner, or agency. Prepositions are essential for providing context and clarity.

Common Prepositions: in, on, at, with, under, above, into, by, of, to, for, from, about, between, among.

Prepositions of Time

Preposition	Usage	Example
At	Specific times, night, holidays	**At** 5 o'clock, **at** night, **at** Eid
On	Days, specific dates	**On** Monday, **on** 25th March
In	Months, seasons, years, centuries, long periods, parts of the day (except 'night')	**In** August, **in** winter, **in** 2006, **in** the morning
Since	From a specific point in time (past until now)	She has lived here **since** 2010.
For	A duration of time (past until now)	He studied **for** two hours.
From...to	Start and end of a period	The shop is open **from** Monday **to** Friday.
Until/Till	Up to a certain time	He is on holiday **until** Friday.
By	At the latest; a deadline	I will finish **by** noon.
Before	Earlier than a certain time	**Before** 2004
After	Later than a certain time	**After** the meeting
Ago	A time in the past from now	He left ten minutes **ago**.
Past/To	Telling the time	Ten **past** six (6:10), Ten **to** six (5:50)

Prepositions of Place and Location

These prepositions tell us where something is located.

Preposition	Usage	Example
In	Enclosed spaces, countries, cities, streets, books	**In** the kitchen, **in** Pakistan, **in** a book, **in** the car
On	Surfaces, public transport, rivers, floors, attached	**On** the wall, **on** the bus, **on** the Thames, **on** the 2nd floor

Absorbed	in	کسی کام میں محو ہونا
Accuse	of	کسی چیز کا الزام لگانا
Accustomed	to	کسی چیز کا عادی ہونا
Adapt	to	کسی چیز کے مطابق ڈھل جانا
Add	to	کسی چیز میں اضافہ کرنا
Adept	at	کسی کام میں ماہر ہونا
Admit	to	کسی بات کا اعتراف کرنا
Advise	on	کسی معاملے پر مشورہ دینا
Afraid	of	کسی چیز سے ڈرنا
Agree	with	کسی شخص سے متفق ہونا
B		
Base	on	کسی چیز پر مبنی ہونا
Beg	for	کسی چیز کی التجا کرنا
Begin	with	کسی چیز سے آغاز کرنا
Believe	in	کسی چیز پر یقین رکھنا
Belong	to	کسی کی ملکیت ہونا
Benefit	from	کسی چیز سے فائدہ اٹھانا
Blame	for	کسی چیز کا الزام لگانا
Boast	about	کسی چیز پر فخر کرنا
Borrow	from	کسی سے ادھار لینا
Bump	into	کسی سے اچانک ملاقات ہونا
C		
Capable	of	کسی کام کے قابل ہونا
Care	about	کسی چیز کی پرواہ کرنا
Charge	with	کسی کام کی ذمہ داری سونپنا
Choose	between	دو چیزوں میں سے انتخاب کرنا
Clash	with	کسی سے متصادم ہونا
Collaborate	with	کسی کے ساتھ مل کر کام کرنا
Combine	with	کسی چیز کے ساتھ ملانا
Comment	on	کسی چیز پر تبصرہ کرنا

Practice MCQs

1. **The renowned architect is absorbed _____ the design of a revolutionary sustainable city.**
(a) at
(b) by
(c) in
(d) with
Answer: (c) in

2. **His thesis provides a compelling argument, but I must disagree _____ his fundamental premise.**
(a) to
(b) with
(c) on
(d) against
Answer: (b) with

3. **The CEO was accused _____ the board _____ gross financial misconduct.**
(a) by, for
(b) to, of
(c) by, of
(d) from, with
Answer: (c) by, of

4. **The artist's work, which consists _____ found objects, comments _____ consumerist society.**
(a) of, on
(b) with, about
(c) from, for
(d) in, to
Answer: (a) of, on

5. **The country's economy is largely dependent _____ the export _____ crude oil.**
(a) on, of
(b) from, for
(c) by, in
(d) with, about
Answer: (a) on, of

6. **The investigator warned the public _____ a sophisticated new phishing scam.**
(a) for
(b) from
(c) about
(d) on
Answer: (c) about

7. **Her latest novel is reminiscent _____ the magical realism of Gabriel García Márquez.**
(a) to
(b) with
(c) of
(d) from
Answer: (c) of

8. **The diplomat was anxious _____ the potential repercussions _____ the trade agreement.**
(a) for, from
(b) about, of
(c) with, for
(d) at, with
Answer: (b) about, of

9. **The new policy is inferior _____ the previous one _____ almost every measurable aspect.**
(a) than, in
(b) to, in
(c) from, for
(d) against, by
Answer: (b) to, in

10. **He is highly regarded _____ his peers _____ his integrity and work ethic.**
(a) by, for
(b) from, about
(c) with, in
(d) to, because of
Answer: (a) by, for

11. **The scientist's theory is based _____ years _____ meticulous research.**
(a) on, of
(b) in, for
(c) at, with
(d) by, during
Answer: (a) on, of

Chapter 8

Sentence, Phrase and Clause

The Sentencea

Definition

A **sentence** is a grammatically complete set of words that expresses a clear thought. It typically contains a subject and a predicate. A sentence begins with a capital letter and ends with a terminal punctuation mark: a period (.), a question mark (?), or an exclamation mark (!).

Examples:

- He goes to school.
- She is eating an apple.
- Who are you?
- What a beautiful flower!

Parts of a Sentence

Every sentence can be divided into two essential parts:

1. **Subject:** The person, place, thing, or idea that is performing an action or being described. It tells us *who* or *what* the sentence is about.
2. **Predicate:** The part of the sentence that contains the verb and tells us something about the subject. It describes the action or state of being.

Sentence	Subject	Predicate
The sun shines brightly.	The sun	shines brightly.
She is writing a letter.	She	is writing a letter.
Allama Iqbal is our national poet.	Allama Iqbal	is our national poet.

Other Elements in a Sentence

- **Object:** A word or group of words that receives the action of the verb.
  - **Direct Object:** Answers "what?" or "whom?" after the verb.
    - Example: I threw **the ball**.
  - **Indirect Object:** Answers "to whom?" or "for whom?" the action is done. It comes before the direct object.
    - Example: She gave **me** the book.
- **Complement:** A word or group of words that completes the meaning of the subject or object.
  - **Subject Complement:** Follows a linking verb (e.g., is, am, are, seem, become) and describes the subject.
    - Example: He is **a teacher**. (Noun) | He seems **tired**. (Adjective)
  - **Object Complement:** Follows and describes the direct object.
    - Example: They made him **the captain**. (Noun) | The news made her **happy**. (Adjective)

Types of Sentences by Function

Sentences can be categorized based on their purpose and the emotion they convey.

Type	Function	Punctuation	Example
Declarative	Makes a statement or expresses an opinion.	Period (.)	The sky is blue.

Chapter 9

Active and Passive Voice

Introduction

Voice is a form of a verb that indicates whether the subject performs the action or receives the action. There are two voices in English: Active and Passive.

- **Active Voice:** The subject performs the action.
  - Example: **The chef** cooked the meal.
- **Passive Voice:** The subject receives the action.
  - Example: **The meal** was cooked by the chef.

Key Principle: Only transitive verbs (verbs that take an object) can be changed from active to passive voice.

Rules for Converting Active to Passive Voice

1. The **object** of the active verb becomes the **subject** of the passive verb.
2. The **subject** of the active verb becomes the **agent** in the passive sentence, usually introduced by the preposition "by." The agent can be omitted if it is unknown or unimportant.
3. The main verb is changed into its **past participle** form (V3).
4. An appropriate **helping verb** (a form of 'be' or modals) is added, which must agree with the new subject in number and person.

Tense-wise Conversion Charts

1. Present Indefinite Tense

- **Active Structure:** Subject + V1(s/es) + Object
- **Passive Structure:** Subject + is/am/are + V3 + by + Agent

Active Voice	Passive Voice
She writes a letter.	A letter is written by her.
They do not play hockey.	Hockey is not played by them.
Does he respect his teachers?	Are his teachers respected by him?

2. Present Continuous Tense

- **Active Structure:** Subject + is/am/are + V-ing + Object
- **Passive Structure:** Subject + is/am/are + being + V3 + by + Agent

Active Voice	Passive Voice
I am reading a book.	A book is being read by me.
Why are you blaming me?	Why am I being blamed by you?

3. Present Perfect Tense

- **Active Structure:** Subject + has/have + V3 + Object
- **Passive Structure:** Subject + has/have + been + V3 + by + Agent

Active Voice	Passive Voice
The police have caught the thief.	The thief has been caught by the police.

A. Imperative Sentences (Commands & Requests)

- **Structure:** Let + Object + be + V3

Active Voice	Passive Voice
Open the window.	Let the window be opened.
Do not waste time.	Let time not be wasted.
Please help the poor.	Let the poor be helped.

B. Optative Sentences (Wishes & Prayers)

- **Structure:** May + Subject + be + V3 + by + Agent

Active Voice	Passive Voice
May God bless you.	May you be blessed by God.
May you have a long life.	May a long life be lived by you.

C. Sentences with Modals (can, could, may, might, must, should, etc.)

- **Structure:** Subject + Modal + be + V3 + by + Agent

Active Voice	Passive Voice
You must obey the rules.	The rules must be obeyed by you.
She can solve this problem.	This problem can be solved by her.

D. Sentences with Modal Perfects (may have, must have, should have, etc.)

- **Structure:** Subject + Modal + have been + V3 + by + Agent

Active Voice	Passive Voice
They should have completed the work.	The work should have been completed by them.
She might have sent the email.	The email might have been sent by her.

E. Sentences with "to" Infinitives (has to, have to, is to, etc.)

- **Structure:** Subject + Helper + to be + V3 + by + Agent

Active Voice	Passive Voice
She has to do this assignment.	This assignment has to be done by her.
They are going to build a new school.	A new school is going to be built by them.

When to Use Passive Voice

While active voice is usually preferred for its clarity and directness, passive voice is useful in these situations:

1. When the **doer of the action is unknown, obvious, or unimportant**.
   - *Example:* My car was stolen last night. (We don't know who did it.)
2. When the **action itself is more important than the doer**.

He said, "Congratulations!"	He congratulated me.
She said, "Good morning."	She wished me good morning.
He said, "Curse this rain!"	He cursed the rain.
My friend said, "Goodbye."	My friend bade me goodbye.

Practice MCQs – Direct and Indirect Narration

1."By God," he exclaimed, "I have never seen such a magnificent sight in my life."
a) He exclaimed by God that he had never seen such a magnificent sight in his life.
b) He swore by God that he has never seen such a magnificent sight in his life.
c) He exclaimed and swore that he had never seen such a magnificent sight in his life.
d) He swore by God that he had never seen such a magnificent sight in his life.
Answer: d) He swore by God that he had never seen such a magnificent sight in his life.

2. "If you had told me about your predicament, I would have helped you," she said to him.
a) She told him that if he had told her about his predicament, she would have helped him.
b) She told him that if he told her about his predicament, she would have helped him.
c) She told him that if he had told her about his predicament, she would help him.
d) She said to him that if he told her about his predicament, she would have helped him.
Answer: a) She told him that if he had told her about his predicament, she would have helped him.

3. The philosopher said, "Man is mortal, but his ideas can be immortal."
a) The philosopher said that man is mortal, but his ideas can be immortal.
b) The philosopher said that man was mortal, but his ideas could be immortal.
c) The philosopher said that man is mortal, but his ideas could be immortal.
d) The philosopher said that man was mortal, but his ideas can be immortal.
Answer: a) The philosopher said that man is mortal, but his ideas can be immortal.

4. "Please, please don't leave me alone here," the child cried to his mother.
a) The child pleaded to his mother not to leave him alone there.
b) The child cried and pleaded his mother not to leave him alone there.
c) The child earnestly pleaded with his mother not to leave him alone there.
d) The child told his mother to not leave him alone there.
Answer: c) The child earnestly pleaded with his mother not to leave him alone there.

5. "Fool!" she shouted at the man, "You have ruined everything."
a) She shouted at the man that he was a fool and had ruined everything.
b) She called the man a fool and shouted that he had ruined everything.
c) She exclaimed that he was a fool and had ruined everything.
d) She called him a fool and said that he has ruined everything.
Answer: b) She called the man a fool and shouted that he had ruined everything.

6. He said, "Let's wait here till the rain stops."
a) He said that we should wait here till the rain stopped.
b) He suggested that they should wait there till the rain stopped.
c) He proposed that they should wait there till the rain stops.
d) He suggested that we wait here until the rain stopped.
Answer: b) He suggested that they should wait there till the rain stopped.

7. "I must go to the bank tomorrow," she said, "as I have no cash left."

Chapter 11

Idioms and Phrasal Verbs

Introduction to Idioms and Phrasal Verbs

- **Idiom:** A group of words established by usage as having a meaning not deducible from the individual words (e.g., *rain cats and dogs*). They add color and depth to the language.
- **Phrasal Verb:** A verb combined with a preposition or an adverb (or both) to create a new verbal phrase with a meaning different from the original verb (e.g., *give up*, *look into*). They are fundamental to fluent and natural English.

Idioms:

Idiom	English Meaning	Urdu Meaning	Example
Above board	Honest and open.	دیانتداری، صاف بازی	Don't worry, the deal was completely above board.
To smell a rat	To suspect foul dealings.	شک کرنا، کھوتا محسوس کرنا	When he offered to double my investment, I began to smell a rat.
To throw dust in someone's eyes	To deceive or mislead someone.	کسی کی آنکھوں میں دھول جھونکنا، دھوکہ دینا	The report threw dust in the public's eyes about the true environmental impact.
To give a false coloring	To misrepresent something.	غلط رنگ چڑھانا، مسخ کرنا	He gave a false coloring to the events to make himself look like a hero.
To play fast and loose	To behave in an unreliable and insincere way.	عہد شکنی کرنا، بے وفائی کرنا	You can't trust him; he plays fast and loose with the truth.
Sharp practices	Dishonest business dealings.	عیاری، بددیانتی	The company was accused of sharp practices to eliminate competition.
Crocodile tears	Pretended or insincere sorrow.	مگرمچھ کے آنسو، دکھاوے کے آنسو	She shed crocodile tears at his dismissal, though she had advocated for it.
A wolf in sheep's clothing	A person who appears harmless but is actually dangerous.	بھیڑیے جیسا شخص، منافق	Be careful of him; he's a wolf in sheep's clothing.

Hit the nail on the head	To be exactly right about something.	بالکل درست کہنا	You hit the nail on the head when you said the problem was a lack of communication.
Once in a blue moon	Very rarely.	بہت ہی کم	He only visits his hometown once in a blue moon.
The ball is in your court	It is your turn to make a decision or take action.	فیصلہ آپ کے ہاتھ میں ہے	I've made my offer; now the ball is in your court.
When pigs fly	Something that will never happen.	کبھی نہیں ہو گا	He'll clean his room when pigs fly!
A blessing in disguise	(Repeated for emphasis) A good thing that seemed bad initially.	مصیبت میں نعمت	Getting laid off was a blessing in disguise, as it pushed me to start my own business.
Break the ice	To do or say something to relieve tension or get conversation started.	سختی دور کرنا، بات چیت کا آغاز کرنا	He told a joke to break the ice at the start of the meeting.
Face the music	To accept the unpleasant consequences of one's actions.	اپنے عمل کا نتیجہ بھگتنا	It's time to face the music and admit you were wrong.
A red herring	Something that misleads or distracts from the important issue.	توجہ ہٹانے والی بات	The detective realized the clue was a red herring meant to mislead the investigation.

Phrasal Verbs:

Phrasal Verb	English Meaning	Urdu Meaning	Example
Account for	To explain the reason for.	وضاحت پیش کرنا	Can you account for the missing funds?
Add up	To make sense; seem consistent.	معنی خیز ہونا	His story just doesn't add up.
Ask after	To inquire about someone's health or well-being.	کسی کے بارے میں دریافت کرنا	She asked after you when I saw her.
Back down	To withdraw a claim or demand.	اپنی بات سے پیچھے ہٹنا	He refused to back down from the argument.

Turn up	To arrive; to increase volume; to be found.	پہنچ جانا؛ آواز تیز کرنا؛ مل جانا	He finally turned up an hour late. Turn up the heat. My keys turned up in the drawer.
Watch out	To be careful.	ہوشیار	Watch out for the step!
Wear off	To gradually disappear.	آہستہ آہستہ ختم ہو جانا	The painkiller's effect began to wear off.
Work out	To exercise; to be successful; to calculate.	ورزش کرنا؛ کامیاب ہونا؛ حل کرنا	I work out at the gym. I hope everything works out for you. Can you work out the total cost?

Practice MCQs – Idioms and Phrasal Verbs

1. He decided to *bite the bullet* and finally confront his boss about the promotion.
A. Avoid the issue
B. Prepare carefully
C. Face a painful situation bravely
D. Resign from the job
Answer: C

2. Her extravagant plans to build a castle *went up in smoke* when the investors backed out.
A. Were highly praised
B. Were partially successful
C. Ended in complete failure
D. Were postponed indefinitely
Answer: C

3. The detective *smelled a rat* when the witness changed his story for the third time.
A. Became angry
B. Suspected deception
C. Found evidence
D. Felt nauseous
Answer: B

4. After the scandal, the company had to *face the music* from regulatory authorities.
A. Enjoy success
B. Accept consequences
C. Avoid punishment
D. Celebrate victory
Answer: B

5. The new manager *brought about* significant changes in the organizational structure.
A. Prevented
B. Delayed
C. Caused to happen
D. Criticized
Answer: C

6. His explanation for the missing funds doesn't *add up*.
A. Make sense
B. Seem honest
C. Appear complete
D. Sound convincing
Answer: A

7. She's always *blowing her own trumpet* about her academic achievements.
A. Being modest
B. Boasting
C. Criticizing others
D. Working hard
Answer: B

8. The negotiations *broke down* when neither side would compromise.
A. Succeeded
B. Concluded
C. Failed
D. Accelerated
Answer: C

9. His sudden resignation came as *a bolt from the blue* for everyone in the office.
A. Expected event
B. Complete surprise
C. Regular occurrence
D. Minor incident
Answer: B

10. We need to *cut corners* to complete the project within the limited budget.

Chapter 12

Synonyms and Antonyms

- **Synonyms** are words or phrases that have the same or nearly the same meaning as another word or phrase in the same language. For example, "happy" and "joyful" are synonyms. Knowing synonyms helps in understanding nuanced meanings and improves writing style.
- **Antonyms** are words that have the exact opposite meaning of another word. For example, "hot" is the antonym of "cold." A strong grasp of antonyms is crucial for understanding contrast and constructing balanced arguments.

Word	Urdu Meaning	Synonyms	Antonyms	Sentence
Abate	کم ہونا، گھٹنا	Subside, Diminish, Decrease, Lessen	Intensity, Increase, Augment, Escalate	The storm finally began to **abate** after raging for hours.
Aberration	خلل، انحراف	Anomaly, Deviation, Irregularity, Oddity	Normality, Regularity, Standard, Conformity	His poor performance was an **aberration** from his usual excellence.
Abhor	نفرت کرنا، کراہت کرنا	Despise, Detest, Loathe, Hate	Admire, Adore, Cherish, Love	She **abhors** any form of cruelty towards animals.
Abridge	مختصر کرنا، خلاصہ کرنا	Shorten, Condense, Abbreviate, Curtail	Elongate, Expand, Amplify, Extend	The publisher released an **abridged** version of the classic novel for students.
Acrimonious	تلخ، کڑواہٹ بھرا	Bitter, Caustic, Hostile, Sarcastic	Harmonious, Kind, Gentle, Amicable	The divorce proceedings were **acrimonious** and lengthy.
Admonish	ڈانٹنا، تنبیہ کرنا	Reprimand, Rebuke, Chide, Warn	Praise, Commend, Applaud, Encourage	The teacher had to **admonish** the student for talking in class.
Adversity	مصیبت، مشکل	Hardship, Misfortune, Distress, Difficulty	Prosperity, Fortune, Success, Affluence	She showed great resilience in the face of **adversity**.
Alleviate	کم کرنا، آرام پہنچانا	Mitigate, Relieve, Assuage, Ease	Aggravate, Worsen, Exacerbate, Intensity	This medicine will help **alleviate** the pain.

Word	Urdu Meaning	Synonyms	Antonyms	Sentence
Fastidious	نازک طبع، بڑا چننے والا	Meticulous, Fussy, Picky, Painstaking	Careless, Slapdash, Undemanding, Negligent	He is **fastidious** about his appearance, spending hours choosing an outfit.
Flippant	غیر سنجیدہ، ہلکا	Facetious, Disrespectful, Glib, Frivolous	Serious, Respectful, Solemn, Earnest	The student's **flippant** remark about the principal earned him a detention.
Gregarious	ملنسار، خوش مزاج	Sociable, Outgoing, Convivial, Companionable	Unsociable, Reclusive, Introverted, Reserved	She has a **gregarious** personality and makes friends easily.
Guile	فریب، دھوکا	Cunning, Deceit, Trickery, Slyness	Honesty, Candor, Guilelessness, Forthrightness	He achieved his position more by **guile** than by intelligence.
Harass	تنگ کرنا، پریشان کرنا	Pester, Persecute, Bother, Torment	Assist, Comfort, Soothe, Support	The company has a strict policy against any form of **harassment**.
Haughty	مغرور، اکڑفوں	Arrogant, Conceited, Snobbish, Disdainful	Humble, Modest, Meek, Unassuming	The nobleman gave a **haughty** look to the commoners.
Hedonist	عیاش، خوشی پسند	Pleasure-seeker, Sensualist, Sybarite	Ascetic, Puritan, Abstainer	As a **hedonist**, his only goal in life was to pursue pleasure.
Impervious	ناقابل دخول، جس میں اثر نہ ہو	Impenetrable, Resistant, Unaffected, Immune	Vulnerable, Permeable, Susceptible, Receptive	He seemed **impervious** to the criticism leveled against him.
Incessant	مسلسل، لگاتار	Ceaseless, Unending, Constant, Perpetual	Intermittent, Occasional, Sporadic	The **incessant** noise from the construction site made it hard to concentrate.
Inclement	خراب، ناسازگار	Stormy, Severe, Rough, Harsh	Mild, Calm, Pleasant, Balmy	Due to **inclement** weather, the outdoor event was canceled.

Practice MCQs

1. What is the synonym of "NOVEL" (as an adjective)?
A) Traditional
B) Hazardous
C) New
D) Complicated
Answer: C) New

2. What is the synonym of "IMPERVIOUS"?
A) Vulnerable
B) Resistant
C) Sensitive
D) Susceptible
Answer: B) Resistant

3. What is the synonym of "SCRUTINIZE"?
A) Ignore
B) Skim
C) Examine
D) Overlook
Answer: C) Examine

4. What is the synonym of "INGENIOUS"?
A) Uninspired
B) Dull
C) Clever
D) Simple
Answer: C) Clever

5. What is the synonym of "SAGACIOUS"?
A) Foolish
B) Redundant
C) Wise
D) Obtuse
Answer: C) Wise

6. What is the synonym of "MAGNANIMOUS"?
A) Petty
B) Spiteful
C) Vindictive
D) Generous
Answer: D) Generous

7. What is the synonym of "INNATE"?
A) Acquired
B) Extrinsic
C) Learned
D) Inborn
Answer: D) Inborn

8. What is the synonym of "OBFUSCATE"?
A) Elucidate
B) Clarify
C) Confuse
D) Explain
Answer: C) Confuse

9. What is the synonym of "FASTIDIOUS"?
A) Negligent
B) Sloppy
C) Meticulous
D) Careless
Answer: C) Meticulous

10. What is the synonym of "TRANSIENT"?
A) Permanent
B) Enduring
C) Temporary
D) Perpetual
Answer: C) Temporary

11. She was the victim of a MALICIOUS rumor.
A) Benevolent
B) Compassionate
C) Spiteful
D) Kind
Answer: C) Spiteful

12. The government implemented a policy of fiscal AUSTERITY.
A) Luxury
B) Frugality
C) Indulgence
D) Opulence
Answer: B) Frugality

13. A prolonged illness can DEBILITATE even a strong person.
A) Strengthen
B) Invigorate
C) Weaken
D) Fortify
Answer: C) Weaken

14. The divorce proceedings were ACRIMONIOUS and lengthy.
A) Harmonious
B) Amicable
C) Bitter
D) Gentle
Answer: C) Bitter

15. The weather in the mountains is notoriously CAPRICIOUS.
A) Predictable
B) Steadfast
C) Fickle

Antonyms Practice MCQs

1. What is the antonym of ICONOCLAST?
A. Rebel
B. Conformist
C. Maverick
D. Radical
Answer: B. Conformist

2. What is the antonym of IDIOSYNCRASY?
A. Quirk
B. Normality
C. Eccentricity
D. Peculiarity
Answer: B. Normality

3. What is the antonym of IMPETUOUS?
A. Rash
B. Hasty
C. Cautious
D. Reckless
Answer: C. Cautious

4. What is the antonym of IMPUTE?
A. Ascribe
B. Absolve
C. Attribute
D. Credit
Answer: B. Absolve

5. What is the antonym of INADVERTENT?
A. Accidental
B. Deliberate
C. Unintentional
D. Unwitting
Answer: B. Deliberate

6. What is the antonym of INCIPIENT?
A. Nascent
B. Full-blown
C. Emerging
D. Developing
Answer: B. Full-blown

7. What is the antonym of INCONTROVERTIBLE?
A. Indisputable
B. Debatable
C. Certain
D. Irrefutable
Answer: B. Debatable

8. What is the antonym of INDEFATIGABLE?
A. Tireless
B. Lethargic
C. Unflagging
D. Dogged
Answer: B. Lethargic

9. What is the antonym of INDOLENT?
A. Lazy
B. Industrious
C. Slothful
D. Idle
Answer: B. Industrious

10. What is the antonym of INEPT?
A. Incompetent
B. Competent
C. Clumsy
D. Bungling
Answer: B. Competent

11. What is the antonym of INFALLIBLE?
A. Unerring
B. Fallible
C. Perfect
D. Flawless
Answer: B. Fallible

12. What is the antonym of INGENIOUS?
A. Clever
B. Dull
C. Inventive
D. Brilliant
Answer: B. Dull

13. What is the antonym of INNOCUOUS?
A. Harmless
B. Harmful
C. Safe
D. Inoffensive
Answer: B. Harmful

14. What is the antonym of INSULAR?
A. Narrow-minded
B. Cosmopolitan
C. Provincial
D. Parochial
Answer: B. Cosmopolitan

15. What is the antonym of INTREPID?
A. Fearless
B. Timid
C. Courageous
D. Dauntless
Answer: B. Timid

16. What is the antonym of INTRINSIC?
A. Inherent
B. Extrinsic
C. Fundamental

PUBLICATIONS

LET'S MAKE IT HAPPEN

PART 3: PEDAGOGY

Join Us For All Jobs Preparation

Teaching Techniques & Methodologies: One - Liners

1. Introduction to Teaching

1. **Teaching** is a deliberate, interactive, and planned process to facilitate learning.
2. It involves the systematic transmission of **knowledge (cognitive)**, **practical abilities (psychomotor)**, and **values (affective)**.
3. Teaching prepares students for learning by providing an **initial structure** and **clarifying intended outcomes**.
4. The nature of teaching is a **mutual exchange** of experiences between teacher and students.
5. Teaching is a **provocative activity** aimed at stimulating academic, mental, and personal development.
6. The **traditional role** of a teacher is as the primary source or **"fountainhead" of knowledge**.
7. The **modern role** of a teacher is as a **facilitator, guide, and co-learner**.
8. The traditional method focuses on **"chalk-and-talk"** lecturing with students as passive recipients.
9. The modern method focuses on creating environments for students to **discover, construct, and collaborate** on knowledge.
10. Teachers must be **diagnosticians of learning**, considering students' background knowledge and the learning environment.

2. Roles and Characteristics of an Effective Teacher

11. The five major roles of a teacher are **Subject Matter Expert, Pedagogical Expert, Excellent Communicator, Student-Centered Mentor, and Systematic Assessor**.
12. A **Subject Matter Expert** possesses deep, current knowledge and a genuine passion for the discipline.
13. A **Pedagogical Expert** sets clear learning goals and guides critical thinking and problem-solving.
14. An **Excellent Communicator** helps students develop their own communication competencies.
15. A **Student-Centered Mentor** encourages learning through varied methods and promotes active participation.
16. A **Systematic and Continual Assessor** evaluates student outcomes and their own teaching effectiveness.
17. **Personal qualities** of an effective teacher include **fairness, positive attitude, and preparedness**.
18. **Fairness** means treating all students justly and equitably without favoritism.
19. A **positive attitude** involves believing in student success and using meaningful verbal praise.
20. **Preparedness** in subject matter and lessons allows for better management of behavioral matters.
21. **Personal touch** involves connecting with students by using their names and showing genuine interest.
22. A **sense of humor** is used to break the ice, reduce anxiety, and make learning enjoyable.
23. **Creativity** involves using unusual and innovative methods to motivate students.
24. **Willingness to admit mistakes** models humility, integrity, and a growth mindset for students.
25. A **forgiving** nature means moving forward from student misbehavior without holding grudges.
26. **Respect** is given to students to earn it in return, handling situations with sensitivity.
27. **High expectations** involve setting challenging yet realistic academic and behavioral standards.

Practice MCQ

1. What is the primary focus of the modern, student-centered role of a teacher?
A) Disseminating information through lectures
B) Acting as the fountainhead of knowledge
C) Facilitating knowledge discovery and collaboration
D) Ensuring passive reception of knowledge
Answer: Facilitating knowledge discovery and collaboration

2. Which of the following is NOT a key role of a teacher?
A) Subject Matter Expert
B) Financial Advisor
C) Pedagogical Expert
D) Systematic Assessor
Answer: Financial Advisor

3. Vygotsky's Zone of Proximal Development (ZPD) is defined as the difference between what a learner can do:
A) With and without technology
B) In a group and individually
C) Without help and with guidance from a skilled partner
D) At home and at school
Answer: Without help and with guidance from a skilled partner

4. Which teaching technique involves learning through observation, retention, and replication of demonstrated behavior?
A) Brainstorming
B) Modeling
C) Lecturing
D) Collaborating
Answer: Modeling

5. The constructivist approach to learning emphasizes that knowledge is:
A) Passively received from the teacher
B) Actively constructed by the learner
C) Only acquired through memorization
D) Solely dependent on textbook content
Answer: Actively constructed by the learner

6. Which of the following is a personal quality of an effective teacher?
A) Collaboration with colleagues
B) High expectations for students
C) Commitment to lifelong learning
D) Emotional maturity
Answer: High expectations for students

7. What is the most critical factor in time management that is directly linked to student achievement?
A) Allocated Time
B) Engaged Time
C) Academic Learning Time
D) Break Time
Answer: Academic Learning Time

8. The 'Inquiry' approach to teaching effectiveness is determined by:
A) The teacher's display of warmth and enthusiasm
B) Student results on standardized tests
C) The quality of the teacher's reflection on their style and student outcomes
D) The number of research-based techniques used
Answer: The quality of the teacher's reflection on their style and student outcomes

9. Which co-teaching strategy involves two teachers teaching the same content to two equal groups of students simultaneously?
A) One Teach/One Assist
B) Station Teaching
C) Parallel Teaching
D) Alternative Teaching
Answer: Parallel Teaching

10. A key element of Cooperative Learning that ensures no one "hitches a free ride" is:
A) Positive Interdependence
B) Face-to-Face Interaction
C) Individual Accountability
D) Group Processing
Answer: Individual Accountability

Classroom Management and Discipline: One-Liners

1. Definition, Concept, and Importance of Classroom Management

1. **Classroom Management** is a multi-dimensional process to establish a supportive, orderly, and productive learning environment.
2. According to **Wong (2004)**, it is the practices to uphold an environment where instruction and learning occur smoothly.
3. **Mallory (2008)** describes it as a multifaceted process dependent on an engaging curriculum and effective instruction.
4. **Brophy & Good** emphasize that it is broader than discipline, fostering student involvement and cooperation.
5. Effective classroom management **maximizes learning time** by minimizing disruptions.
6. It creates a **positive and safe atmosphere** for students to take intellectual risks.
7. It **enhances student engagement** through structured routines and engaging activities.
8. It directly **improves academic achievement** and student test scores.
9. A key aim is to promote **student self-control and responsibility**.
10. It **reduces teacher stress** and prevents burnout.

2. Goals, Components, and Dimensions of Classroom Management

11. A goal of classroom management is **better teaching** through careful lesson planning.
12. Clear goals provide **student focus** by clarifying expectations.
13. Teacher goal-setting acts as a **model for students** to set their own objectives.
14. Well-defined goals **motivate students** toward higher academic achievement.
15. A key operational component is **classroom design**, the intentional physical arrangement.
16. **Establishing rules and procedures** is crucial for a functional classroom.
17. **Discipline with consistency** involves implementing fair and firm consequences.
18. Effective **scheduling and time management** keeps the class on task.
19. Teacher **organizational skills** set a good example and prevent wasted time.
20. **Effective instructional techniques** are tailored to the grade level and subject.
21. Clear and constant **communication** with students and parents is essential.
22. Establishing **learning goals** at the start of a lesson provides direction.
23. Structuring predictable **classroom routines** creates order and security.
24. **Encouragement and praise** should be emphasized over punishing negative behavior.
25. **Froyen and Iverson (1999)** identified three components: Content, Conduct, and Covenant Management.
26. **Content Management** refers to the management of the instructional process.
27. **Conduct Management** focuses on managing student behavior and setting expectations.
28. **Covenant Management** involves creating shared expectations for a cooperative community.
29. The **A-C-T-S model** outlines four dimensions of classroom management.
30. The **Activity** dimension states that learning activities are directly linked to outcomes.
31. The **Climate** dimension is the emotional and psychological atmosphere of the classroom.
32. The **Time** dimension involves the effective devotion of time to learning tasks.
33. The **Space** dimension is the strategic use of the physical classroom.

148. **Truancy** is staying away from school without a good reason.
149. **Gross Enrollment Rate (GER)** is total enrolled divided by school-age population, multiplied by 100.
150. **Net Enrollment Rate (NER)** is total enrolled *and retained* divided by school-age population, multiplied by 100.
151. **NER is always lower than GER** as it accounts for dropouts.
152. **Bullying** is where a person or group uses power to target and harm another individual.
153. The three roles in bullying are the **Victim, the Bully, and the Crew (Bystanders)**.
154. **Direct Bullying** involves verbal and physical aggression.
155. **Indirect Bullying** involves social exclusion and rumors.
156. **Flanders' Interaction Analysis Category System (FIACS)** classifies verbal behavior in the classroom.
157. FIACS has ten categories: seven for Teacher Talk, two for Pupil Talk, and one for Silence/Confusion.
158. According to **Kratochwill (2011)**, a "Do" in classroom management is to **create interest**.
159. A "Don't" according to Kratochwill is to **use vague or unenforceable rules**.

Practice MCQs

1. According to Harry Wong (2004), classroom management is defined as:
A) The process of controlling student behavior through rules and consequences.
B) The practices and processes a teacher uses to uphold an environment where instruction and learning can occur smoothly.
C) A system for fostering student creativity and independent thought.
D) The administrative duties a teacher performs to maintain classroom order.
Answer: The practices and processes a teacher uses to uphold an environment where instruction and learning can occur smoothly.

2. Which of the following is NOT cited as a key importance of effective classroom management?
A) Maximizes learning time
B) Creates a positive and safe atmosphere
C) Guarantees all students will achieve high grades
D) Reduces teacher stress
Answer: Guarantees all students will achieve high grades

3. According to Froyen and Iverson (1999), which component involves managing the instructional process?
A) Conduct Management
B) Content Management
C) Covenant Management
D) Curriculum Management
Answer: Content Management

4. The A-C-T-S model of classroom management dimensions includes all EXCEPT:
A) Activity
B) Climate
C) Time
D) Strategy
Answer: Strategy

5. What is the standard space requirement per student in an Elementary school classroom?
A) 0.6 m^2
B) 1.0 m^2
C) 1.2 m^2
D) 1.5 m^2
Answer: 0.6 m^2

One Liner Statements – Testing, Measurement, Assessment and Evaluation

Educational Testing, Measurement, and Evaluation

1. Introduction to Core Concepts

1. The four fundamental, sequential concepts are **Test, Measurement, Assessment, and Evaluation**.
2. The scope of these concepts ranges from **Test (least scope)** to **Evaluation (broadest scope)**.
3. A **Test** is a formal, systematic instrument to measure a sample of behavior, knowledge, or skills.
4. The purpose of a test is to elicit a **quantifiable response**.
5. A test answers the question, **"How well?"** an individual performs on specific tasks.
6. **Measurement** is the process of obtaining a **numerical description** of a characteristic.
7. The purpose of measurement is to **assign a score** to a performance.
8. Measurement is **quantitative and objective** but does not include qualitative judgments.
9. Measurement answers the question, **"How much?"**
10. The final product of measurement is a **Score**.
11. **Assessment** is a broader process that **includes measurement**.
12. Assessment involves gathering, interpreting, and using information about a learner's progress.
13. The purpose of assessment is to give **meaning to the measured scores**.
14. The term 'assessment' derives from the Latin *'assidere'*, meaning *'to sit beside'*.
15. Assessment answers the question, **"What does the performance mean?"**
16. **Evaluation** involves making a **value judgment** about the quality or worth of a performance.
17. The purpose of evaluation is to make **decisions and judgments**.
18. Evaluation integrates both **quantitative and qualitative** information.
19. Evaluation answers the question, **"How good is it?"**
20. The summary relationship is: **Test (Tool) → Measurement (Score) → Assessment (Meaning) → Evaluation (Judgment)**.

2. Types of Educational Assessments

21. Assessment is categorized based on **purpose, timing, and interpretation of results**.
22. **Assessment FOR Learning** is also known as **Formative Assessment**.
23. The purpose of formative assessment is to **monitor learning *during* instruction**.
24. Formative assessment is **continuous, diagnostic, and low-stakes**.
25. Formative assessment provides **descriptive, specific, and timely feedback**.
26. **Assessment OF Learning** is also known as **Summative Assessment**.
27. The purpose of summative assessment is to **evaluate learning *at the end*** of a unit or course.
28. Summative assessment is **periodic, final, and high-stakes**.
29. Summative assessment **summarizes learning** and is used for **grading and reporting**.
30. **Assessment AS Learning** develops students' **metacognitive skills**.
31. Assessment AS Learning focuses on **self-regulation and lifelong learning**.

Practice MCQs

1. What is the correct hierarchical sequence of the core concepts from least to broadest scope?
A) Assessment, Measurement, Test, Evaluation
B) Test, Measurement, Assessment, Evaluation
C) Evaluation, Assessment, Measurement, Test
D) Measurement, Test, Evaluation, Assessment
Answer: Test, Measurement, Assessment, Evaluation

2. A final exam in mathematics is a direct example of which core concept?
A) Measurement
B) Assessment
C) Evaluation
D) Test
Answer: Test

3. The process of assigning a numerical score to a student's performance is known as?
A) Assessment
B) Evaluation
C) Measurement
D) Testing
Answer: Measurement

4. Which concept answers the question, "What does the performance mean?"
A) Test
B) Measurement
C) Assessment
D) Evaluation
Answer: Assessment

5. Making a value judgment about the quality of a student's work is the essence of?
A) Assessment
B) Measurement
C) Evaluation
D) Testing
Answer: Evaluation

6. Assessment FOR Learning is synonymous with?
A) Summative Assessment
B) Diagnostic Assessment
C) Formative Assessment
D) Placement Assessment
Answer: Formative Assessment

7. The primary purpose of summative assessment is to?
A) Provide ongoing feedback
B) Monitor learning during instruction
C) Develop metacognitive skills
D) Measure and certify learning at the end
Answer: Measure and certify learning at the end

8. Assessment AS Learning primarily focuses on developing?
A) Social skills
B) Metacognitive skills
C) Psychomotor skills
D) Linguistic skills
Answer: Metacognitive skills

9. In which type of assessment is feedback typically detailed, descriptive, and immediate?
A) Summative Assessment
B) Norm-Referenced Assessment
C) Formative Assessment
D) Criterion-Referenced Assessment
Answer: Formative Assessment

10. A test that interprets a student's score by comparing it to the performance of a norm group is called?
A) Criterion-Referenced Test
B) Aptitude Test
C) Norm-Referenced Test
D) Achievement Test
Answer: Norm-Referenced Test

11. A driving test, which requires a person to demonstrate mastery of specific skills, is an example of a?
A) Norm-Referenced Test
B) Aptitude Test
C) Intelligence Test

Educational Taxonomies: One-Liners

Introduction to Educational Taxonomies

1. **Educational taxonomies** are systematic frameworks for classifying educational goals and learning objectives.
2. They classify goals into hierarchical levels of **complexity and specificity**.
3. Their purpose is to help educators design, implement, and assess **instructional strategies** and **student learning outcomes**.
4. They provide a **common language** for discussing educational objectives.
5. They ensure alignment between **instruction, curriculum, and assessments** with learning goals.
6. They guide the creation of questions, lesson plans, and **curriculum mapping** (e.g., Table of Specification).
7. They are used to **differentiate instruction** and provide targeted learning feedback.

Bloom's Taxonomy

8. **Bloom's Taxonomy** is the most famous and widely used taxonomy in education.
9. It is a **three-dimensional hierarchical model** classifying learning objectives.
10. The three domains are **Cognitive (Head), Affective (Heart), and Psychomotor (Hand)**.

A. The Cognitive Domain (Original - Bloom, 1956)

11. The **Cognitive Domain** is related to mental skills, knowledge, and intellectual abilities.
12. The original taxonomy has six levels, from simplest to most complex.
13. **Knowledge** is the lowest level, involving recall of facts and basic concepts.
14. **Comprehension** is the ability to understand, interpret, and summarize material.
15. **Application** is the ability to use learned material in new and concrete situations.
16. **Analysis** is the ability to break down material into its constituent parts and understand its structure.
17. **Synthesis** is the ability to integrate elements to form a new, coherent whole.
18. **Evaluation** was the highest level in the original taxonomy, involving judgment based on criteria.

The Revised Cognitive Domain (Anderson & Krathwohl, 2001)

19. The key changes in the **revised taxonomy** were terminology from nouns to verbs and re-ordering the top two levels.
20. **Remember** corresponds to the original level of Knowledge.
21. **Understand** corresponds to the original level of Comprehension.
22. **Apply** corresponds to the original level of Application.
23. **Analyze** corresponds to the original level of Analysis.
24. **Evaluate** corresponds to the original level of Evaluation.
25. **Create** is the highest level in the revised taxonomy, corresponding to the original Synthesis.
26. **Declarative Learning** focuses on memorization and recall of facts (the "what").
27. **Procedural Learning** focuses on understanding processes and procedures (the "how").

B. The Affective Domain (Krathwohl, 1964)

28. The **Affective Domain** is concerned with attitudes, emotions, values, beliefs, and feelings.
29. **Receiving/Attending** is the lowest level, involving the willingness to pay attention.
30. **Responding** involves active participation and reacting to a phenomenon.

D) Application
Answer: Evaluation

6. **The ability to break down material into its constituent parts is defined as which level in the cognitive domain?**
A) Comprehension
B) Application
C) Analysis
D) Synthesis
Answer: Analysis

7. **Which verb is most associated with the 'Knowledge' level of the original cognitive domain?**
A) Explain
B) Summarize
C) Define
D) Compare
Answer: Define

8. **The revised version of Bloom's Cognitive Domain was developed by whom?**
A) Benjamin Bloom and Elizabeth Simpson
B) Lorin Anderson and David Krathwohl
C) John Biggs and Kevin Collis
D) Robert Marzano and John Kendall
Answer: Lorin Anderson and David Krathwohl

9. **What major change was introduced in the revised Bloom's Taxonomy (2001)?**
A) Removal of the Affective domain
B) Changing level names from nouns to verbs
C) Combining Analysis and Synthesis
D) Eliminating the Evaluation level
Answer: Changing level names from nouns to verbs

10. **In the revised Bloom's Taxonomy, which level is the highest?**
A) Evaluate
B) Analyze
C) Create
D) Understand
Answer: Create

11. **The 'Create' level in the revised taxonomy corresponds to which level in the original?**
A) Knowledge
B) Comprehension
C) Synthesis
D) Evaluation
Answer: Synthesis

12. **According to Anderson's classification, 'knowing how to do something' is referred to as what?**
A) Declarative Learning
B) Conditional Learning
C) Procedural Learning
D) Significant Learning
Answer: Procedural Learning

13. **The Affective Domain of Bloom's Taxonomy is primarily concerned with what?**
A) Physical skills
B) Intellectual abilities
C) Attitudes and values
D) Memory recall
Answer: Attitudes and values

14. **Who is the main proponent associated with the Affective Domain?**
A) Benjamin Bloom
B) David Krathwohl
C) Elizabeth Simpson
D) Anita Harrow
Answer: David Krathwohl

15. **Which level of the Affective Domain involves active participation and reaction?**
A) Receiving
B) Responding
C) Valuing