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भाग - 2

SIERRA INNOVATIONS

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1 CHAPTER

रसायन विज्ञान (Chemistry)

Physical Chemistry (भौतिक रसायन)

Mole Concept | Atomic Structure | Chemical Bonding | States of Matter

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भाग 1: मोल अवधारणा (Mole Concept)

1.1 मोल की परिभाषा

1 Mole = किसी पदार्थ की वह मात्रा जिसमें उतने ही कण (atoms/molecules/ions) हों जितने 12g Carbon-12 में atoms होते हैं।

1 Mole = 6.022 × 10²³ particles [Avogadro's Number (N_a) — खोजकर्ता: Amedeo Avogadro]

Concept	Formula	Unit	Example
Mole (n)	n = W/M	mol	18g water = 1 mol | 36g = 2 mol
Molar Mass (M)	M = W/n	g/mol	H_2O = 18 g/mol | NaCl = 58.5 g/mol
Number of particles	N = n × N_a	—	1 mol H_2O = 6.022×10^{23} molecules
Molar volume (STP)	V = n × 22.4 L	L	1 mol any gas at STP = 22.4 L
Equivalent weight	E = M/n-factor	g/eq	n-factor = valency/charge change

1.2 Stoichiometry और Concentration

Concentration Unit	Formula	Definition	Example
Molarity (M)	M = moles/L solution	Moles of solute per litre of solution	1M NaCl = 58.5g NaCl in 1L
Molality (m)	m = moles/kg solvent	Moles of solute per kg of solvent	1m NaCl = 58.5g NaCl in 1kg water
Mole Fraction (χ)	$\chi = n_a/(n_a+n\_b)$	Ratio of moles of component to total	χ_water in 10% solution ≈ 0.93
Normality (N)	N = equivalents/L	Eq. of solute per litre solution	1N H_2SO_4 = 49g in 1L
% w/v	g solute/100mL solution	Grams per 100 mL	5% glucose = 5g/100mL (Clinical use)
ppm	mg/L or mg/kg	Parts per million	Drinking water standards

Molarity vs Molality: Molarity: Solution volume में change होता है with temperature | Molality: Solvent mass — temperature independent | Medical solutions mostly in Molarity (M) | IV fluids: 0.9% NaCl = 154 mEq/L = 0.154 M

1.3 Limiting Reagent और % Yield

- ✓ Limiting Reagent (अवरोधक अभिकारक): वह reactant जो पहले समाप्त हो — Product की मात्रा इसी से निर्धारित
- ✓ % Yield = (Actual yield / Theoretical yield) × 100
- ✓ Atom Economy = (Molar mass of desired product / Sum of molar masses of all reactants) × 100

भाग 2: परमाणु संरचना (Atomic Structure)

2.1 परमाणु के मूल कण

Particle	Symbol	Charge	Mass (amu)	Discoverer	Year
Proton	p	$+ 1.6\times10^{-19}$ C	1.0073	E. Rutherford	1919
Neutron	n	Neutral (0)	1.0087	James Chadwick	1932
Electron	e^-	$- 1.6\times10^{-19}$ C	0.000549 (1/1836)	J.J. Thomson	1897
Positron	e^+	$+ 1.6\times10^{-19}$ C	Same as e^-	Carl Anderson	1932

2.2 परमाणु मॉडल (Atomic Models)

Model	Scientist	Year	Key Features	Limitation
Plum Pudding	J.J. Thomson	1904	Electrons embedded in positive sphere	Cannot explain α-scattering
Nuclear	Rutherford	1911	Small dense +ve nucleus | Electrons orbit	Unstable (electron radiation)
Bohr's Model	Niels Bohr	1913	Fixed orbits (shells) | Quantized energy | No emission in orbit	Only for H-like atoms
Wave Mechanical	de Broglie + Schrödinger	1926	Orbitals (probability clouds) | ψ^2 = probability	Current accepted model

2.3 Quantum Numbers (क्वान्टम संख्याएँ)

Quantum Number	Symbol	Values	Determines
Principal (मुख्य)	n	1, 2, 3, 4... (K,L,M,N)	Energy of shell | Size | Max electrons = $2n^2$
Azimuthal/Angular (दिगंशीय)	l	0 to (n-1) (s,p,d,f)	Shape of orbital | Subshell
Magnetic (चुम्बकीय)	m_l	-l to +l	Orientation in space | Number of orbitals
Spin (चक्रण)	m_s	+1/2 or -1/2	Electron spin direction

Subshell	l	m_l values	Orbitals	Max electrons
s	0	0	1	2
p	1	-1, 0, +1	3	6
d	2	-2,-1,0,+1,+2	5	10
f	3	-3,-2,-1,0,+1,+2,+3	7	14

2.4 Electronic Configuration — Rules

- ✓ Aufbau Principle: Electrons fill lowest energy orbital first — 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p...
- ✓ Pauli Exclusion Principle: एक orbital में अधिकतम 2 electrons — opposite spins
- ✓ Hund's Rule: एक subshell में पहले सभी orbitals में 1-1 electron (same spin), फिर pairing

Energy Order: 1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p | याद करें: (n+l) rule — Lower (n+l) fills first | Same (n+l) → Lower n first

Element	Z	Configuration	Notes
Hydrogen (H)	1	$1s^1$	1 electron
Carbon (C)	6	$1s^2\ 2s^2\ 2p^2$	6 electrons — 2 unpaired (2 bonds possible)
Nitrogen (N)	7	$1s^2\ 2s^2\ 2p^3$	3 unpaired (Hund's) — 3 bonds
Oxygen (O)	8	$1s^2\ 2s^2\ 2p^4$	2 unpaired — 2 bonds + 2 lone pairs
Sodium (Na)	11	$[Ne]\ 3s^1$	1 valence electron — alkali metal
Chlorine (Cl)	17	$[Ne]\ 3s^2\ 3p^5$	7 valence electrons — 1 electron short
Iron (Fe)	26	$[Ar]\ 3d^6\ 4s^2$	Exception — 3d partially filled
Copper (Cu)	29	$[Ar]\ 3d^{10}\ 4s^1$	Exception — Extra stability of full 3d
Chromium (Cr)	24	$[Ar]\ 3d^5\ 4s^1$	Exception — Extra stability of half-filled 3d

भाग 3: रासायनिक बन्धन (Chemical Bonding)

3.1 Types of Chemical Bonds

Bond Type	Between	Example	Properties
Ionic Bond	Metal + Non-metal | e^- transfer	NaCl, MgO, $CaCl_2$	High MP/BP, Conducts electricity when molten/dissolved, Brittle, Crystalline
Covalent Bond	Non-metal + Non-metal | e^- sharing	H_2O, CO_2, CH_4, HCl	Variable MP/BP, Poor electrical conductors (mostly), Directional
Coordinate/Dative	Both electrons from one atom	NH_4^+, H_3O^+, $[Fe(CN)_6]^{4-}$	Like covalent after formation
Metallic Bond	Metal atoms | Delocalized e^- sea	Cu, Fe, Na metals	Conducts electricity, Malleable, Ductile, Lustre

Hydrogen Bond	H bonded to N, O, F + lone pair	H_2O, HF, DNA, Proteins	Weak but important | Responsible for water properties
Van der Waals	Non-polar molecules	Noble gases, CH_4, hydrocarbons	Weakest | London dispersion forces

3.2 VSEPR Theory (Valence Shell Electron Pair Repulsion)

- ✓ VSEPR Theory: Electron pairs (bond pairs + lone pairs) repel each other और जितनी हो सके दूर रहती हैं — Molecular shape निर्धारित होती है।

Molecule	Bond Pairs	Lone Pairs	Shape	Bond Angle	Example
2 BP, 0 LP	2	0	Linear	180°	$BeCl_2$, CO_2, HCN
3 BP, 0 LP	3	0	Trigonal Planar	120°	BF_3, SO_3, $AlCl_3$
2 BP, 1 LP	2	1	Bent/Angular	< 120° (≈119°)	SO_2, $SnCl_2$
4 BP, 0 LP	4	0	Tetrahedral	109.5°	CH_4, CCl_4, NH_4^+
3 BP, 1 LP	3	1	Trigonal Pyramidal	107°	NH_3, PCl_3
2 BP, 2 LP	2	2	Bent/V-shape	104.5°	H_2O, H_2S
5 BP, 0 LP	5	0	Trigonal Bipyramidal	90° + 120°	PCl_5
6 BP, 0 LP	6	0	Octahedral	90°	SF_6, $[Fe(CN)_6]^{3-}$

Lone Pair Effect: Lone pairs more repulsive than bond pairs | NH_3: 109.5° → 107° (1 lone pair) | H_2O: 109.5° → 104.5° (2 lone pairs) | Lone pairs occupy equatorial position in Trigonal bipyramidal

3.3 Hybridization (संकरण)

Hybridization	Geometry	Bond Angle	Example	Notes
sp	Linear	180°	$BeCl_2$, CO_2, HC≡CH, HCN	2 hybrid orbitals | Triple bond
sp^2	Trigonal Planar	120°	BF_3, C_2H_4 (Ethylene), SO_3	3 hybrid | Double bond | π bond
sp^3	Tetrahedral	109.5°	CH_4, NH_3, H_2O, C_2H_6 (Ethane)	4 hybrid | Single bonds only
sp^3d	Trigonal Bipyramidal	90°+120°	PCl_5, SF_4	5 hybrid
sp^3d^2	Octahedral	90°	SF_6, $[Co(NH_3)_6]^{3+}$	6 hybrid
dsp^2	Square Planar	90°	$[Ni(CN)_4]^{2-}$, $[PtCl_4]^{2-}$	Inner d-orbital | Strong field ligands

3.4 Molecular Orbital Theory (MOT)

- ✓ MOT में Atomic orbitals combine करके Molecular orbitals बनाते हैं
- ✓ Bonding MO (BMO): Energy lower than AO — Electrons यहाँ = Stable bond
- ✓ Anti-bonding MO (ABMO): Energy higher than AO — Electrons यहाँ = Weakens bond (marked *)

Bond Order = ½ × (Bonding electrons − Antibonding electrons) [Higher Bond Order = Stronger + Shorter bond]

Molecule	**Bond Order**	**Magnetic Property**	**Stability**
H_2	1	Diamagnetic	Stable
He_2	0	—	Does not exist
O_2	2	Paramagnetic (2 unpaired)	Stable | MOT explains paramagnetism
N_2	3	Diamagnetic	Very stable (Triple bond)
O_2^+	2.5	Paramagnetic	More stable than O_2
O_2^- (Superoxide)	1.5	Paramagnetic	Less stable

भाग 4: पदार्थ की अवस्थाएँ (States of Matter)

4.1 Gas Laws

Law	**Relation**	**Condition**	**Formula**
Boyle's Law	$P \propto 1/V$	Constant T, n	$P_1V_1 = P_2V_2$
Charles' Law	$V \propto T$	Constant P, n	$V_1/T_1 = V_2/T_2$
Gay-Lussac's	$P \propto T$	Constant V, n	$P_1/T_1 = P_2/T_2$
Avogadro's	$V \propto n$	Constant P,T	Equal volumes = Equal moles
Dalton's Partial P	$P\_total = \Sigma P_i$	Gas mixture	$P_1 = \chi_1 \times P\_total$

Ideal Gas: PV = nRT [R = 8.314 J/mol·K = 0.0821 L·atm/mol·K]

Van der Waals (Real Gas): $(P + an^2/V^2)(V - nb) = nRT$ [a = intermolecular attraction | b = volume of molecules]

4.2 Liquid State — Surface Tension, Viscosity

Property	**Definition**	**Temperature effect**	**Example / Application**
Surface Tension (γ)	Force per unit length at surface — due to cohesive forces	Decreases with T↑	Water droplets, Soap bubbles, Lung surfactant

Viscosity (η)	Resistance to flow — Internal friction	Decreases with T↑ (Liquids) | Increases with T (Gases)	Blood viscosity (3-4 mPas) important in CVD
Vapour Pressure	Pressure of vapour above liquid at equilibrium	Increases with T↑	Boiling when VP = Atmospheric pressure

Blood Viscosity: Blood viscosity = 3-4 mPa·s (water = 1 mPa·s) | High viscosity = Poor circulation risk | Haematocrit ↑ → Viscosity ↑ | Anaemia → Viscosity ↓ | Temperature ↑ → Viscosity ↓ (improved flow)

4.3 Solid State

Crystal Type	Particles	Forces	Properties	Examples
Ionic Crystal	Cations + Anions	Electrostatic	High MP, Brittle, Conducts when dissolved	NaCl, $CaCO_3$, KNO_3
Covalent Crystal	Atoms	Covalent bonds	Very high MP, Hard, Non-conductor	Diamond, SiO_2, SiC
Metallic Crystal	Metal ions + e^- sea	Metallic bonds	Conducts electricity, Malleable, Ductile, Lustrous	Fe, Cu, Na, Au
Molecular Crystal	Molecules	H-bond / VdW	Low MP, Soft, Non-conductor	Ice, Dry ice (CO_2), Naphthalene

Bragg's Law: $n\lambda = 2d \cdot \sin\theta$ [X-ray diffraction — Crystal structure determination | n=integer, λ=wavelength, d=interplanar spacing, θ=angle]

BOOSTER POINTS — Paramedical Entrance Exam
1. 1 Mole = 6.022×10^{23} particles (Avogadro's number) | Molar mass = molecular mass in grams
2. STP: 0°C, 1 atm | 1 mol gas at STP = 22.4 L | SATP: 25°C, 1 bar = 24.8 L
3. Molarity (M) = mol/L solution — Temperature dependent | Molality (m) = mol/kg solvent — Temperature independent
4. 0.9% NaCl (Normal Saline) = 9g NaCl/L = 154 mEq/L Na^+ = 154 mEq/L Cl^- (Clinical)
5. J.J. Thomson = Electron (1897) | Rutherford = Proton + Nuclear model (1911) | Chadwick = Neutron (1932)
6. Bohr's model: $E_n = -13.6/n^2$ eV | $r_n = 0.529n^2$ Å | Only valid for H-like (1 electron) atoms

7. Aufbau: 1s,2s,2p,3s,3p,4s,3d,4p | Pauli: $2e^-$ per orbital (opposite spin) | Hund's: Max unpaired
8. Cu=[Ar]$3d^{10}4s^1$ (NOT $3d^9 4s^2$) | Cr=[Ar]$3d^5 4s^1$ (NOT $3d^4 4s^2$) — Extra stability
9. Ionic bond: Metal+Non-metal | Covalent: Non-metal+Non-metal | Metallic: Metal+Metal
10. H-bond: H bonded to N,O,F | Responsible for water's high BP, Surface tension, DNA structure
11. sp=Linear(180°) | sp^2=Trigonal Planar(120°) | sp^3=Tetrahedral(109.5°)
12. H_2O: sp^3, 2 lone pairs → bent (104.5°) | NH_3: sp^3, 1 lone pair → pyramidal (107°)
13. VSEPR: Lone pair > Bond pair repulsion | Order: LP-LP > LP-BP > BP-BP
14. Bond Order = ½(BMO-ABMO) | O_2: Bond Order=2, Paramagnetic | N_2: Bond Order=3, Diamagnetic
15. Van der Waals equation: 'a' = intermolecular attraction | 'b' = volume excluded
16. Surface tension ↓ with T↑ | Blood viscosity 3-4 mPas | High Haematocrit → High viscosity
17. Crystal types: Ionic (high MP) | Covalent (hardest) | Metallic (conducts) | Molecular (low MP)
18. Diamond = Covalent crystal (Hardest natural substance) | Graphite = Layered covalent (conducts)

ऊष्मागतिकी, साम्य, विलयन एवं विद्युत रसायन
Thermodynamics | Equilibrium | Solutions | Electrochemistry

भाग 1: रासायनिक ऊष्मागतिकी (Chemical Thermodynamics)

1.1 System, Surroundings और State Functions

Term	Definition	Examples
System (तंत्र)	जिसका अध्ययन किया जाए	Reaction vessel, Body cell
Open System	Mass + Energy दोनों exchange	Beaker (open), Human body
Closed System	Only energy exchange, No mass	Sealed container with gas
Isolated System	No exchange (mass or energy)	Thermos flask (ideal), Universe
State Functions	Path-independent — depend only on initial + final state	H, S, G, U, P, V, T
Process Functions	Path-dependent	Q (heat), W (work)

1.2 Thermodynamic Laws

Law	Statement	Equation	Significance
Zeroth Law	A = Equilib. B, B = Equilib. C → A = Equilib. C	—	Defines Temperature | Basis of thermometers
First Law	$\Delta U = Q - W$	$\Delta U = Q - P\Delta V$	Conservation of energy | Hess's law basis
Second Law	Entropy increases for spontaneous processes	$\Delta S_{universe} > 0$	Explains direction of change
Third Law	S → 0 as T → 0 K	S(perfect crystal at 0K) = 0	Absolute entropy calculation

1.3 Enthalpy (ΔH) — Heat of Reaction

ΔH = H_products − H_reactants [ΔH < 0: Exothermic | ΔH > 0: Endothermic]

Type of Enthalpy	Symbol	Definition	Example
Enthalpy of combustion	ΔH_c	Complete combustion of 1 mole in O_2	$\Delta H_c(C)$ = -393.5 kJ/mol
Enthalpy of formation	$\Delta H_f°$	Formation of 1 mole from elements	$\Delta H_f°(H_2O,l)$ = -286 kJ/mol
Enthalpy of neutralisation	ΔH_n	Neutralisation of 1 mole H^+ by OH^-	Strong acid+base: -57.1 kJ/eq
Enthalpy of fusion	ΔH_{fus}	Solid → Liquid for 1 mole	Ice→Water: +6.0 kJ/mol
Enthalpy of vaporisation	ΔH_{vap}	Liquid → Gas for 1 mole	Water→Steam: +44 kJ/mol at 25°C
Bond Enthalpy	—	Energy to break 1 mole of bonds	C-C: 347, C=C: 620, C≡C: 812 kJ/mol

Hess's Law: $\Delta H_{reaction} = \Delta H_{products} - \Delta H_{reactants}$ | Hess's Law: ΔH is independent of path | Standard state: 25°C (298K), 1 bar | Born-Haber cycle uses Hess's Law for ionic compounds

1.4 Entropy (S) और Gibbs Free Energy (G)

ΔS = Q_rev/T [Entropy change | Unit: J/mol·K]

ΔG = ΔH − TΔS [Gibbs Free Energy | ΔG < 0: Spontaneous | ΔG = 0: Equilibrium | ΔG > 0: Non-spontaneous]

$\Delta G° = -RT \ln K = -nFE°$ [Relationship between ΔG, K (equilibrium), and E (cell potential)]

ΔH	ΔS	ΔG = ΔH-TΔS	Spontaneity
Negative (−)	Positive (+)	Always Negative (−)	Always spontaneous
Positive (+)	Negative (−)	Always Positive (+)	Never spontaneous
Negative (−)	Negative (−)	Negative at low T	Spontaneous at low T
Positive (+)	Positive (+)	Negative at high T	Spontaneous at high T

भाग 2: रासायनिक साम्य (Chemical Equilibrium)

2.1 Equilibrium Constants

- ✓ Reversible reaction में आगे और पीछे की reaction की rates बराबर हो जाती हैं — Dynamic Equilibrium।

$aA + bB \rightleftharpoons cC + dD$ [Kc = [C]c[D]d / [A]a[B]b | Kp = Pc^c × Pd^d / Pa^a × Pb^b]

⚗ ***$Kp = Kc(RT)^{\Delta n}$*** [Δn = moles of gaseous products − moles of gaseous reactants]

K Value	Meaning
K >> 1 (very large)	Products favoured — Reaction nearly complete
K << 1 (very small)	Reactants favoured — Reaction barely proceeds
K = 1	Equal concentration of reactants and products at equilibrium

2.2 Le Chatelier's Principle

- ✓ Le Chatelier's Principle: जब equilibrium system पर stress (disturbance) डाला जाता है तो system उस stress को कम करने की दिशा में shift होती है।

Stress Applied	Equilibrium Shifts	Explanation
Concentration of reactant ↑	Forward →	More reactant = More product formed
Concentration of product ↑	Backward ←	Excess product consumed
Pressure ↑ (gas)	Toward fewer moles of gas	Fewer molecules = Lower pressure
Temperature ↑	Toward endothermic direction	System absorbs excess heat
Catalyst added	No shift (Rate increases both ways)	Equilibrium reached faster | K unchanged
Volume ↑ (gas)	Toward more moles of gas	Lower pressure compensated

Industrial Application: Haber Process (N_2+3H_2 ⇌ 2NH_3): High P (200 atm), Low T (favours NH_3) but Moderate T (450°C) for rate, Fe catalyst | Contact Process (SO_2+O_2 → SO_3): V_2O_5 catalyst | Le Chatelier explains optimal conditions

2.3 Acids, Bases और pH

Theory	**Acid**	**Base**	**Limitation**
Arrhenius	H^+ in water	OH^- in water	Only aqueous solutions
Bronsted-Lowry	H^+ donor (Proton donor)	H^+ acceptor (Proton acceptor)	Cannot explain Lewis acids without H^+
Lewis	Electron pair acceptor	Electron pair donor	Most general | Includes BF_3, $AlCl_3$

pH = −log[H⁺] [pOH = −log[OH⁻] | pH + pOH = 14 (at 25°C) | Neutral: pH=7]

Kw = [H⁺][OH⁻] = 10⁻¹⁴ at 25°C [Ionic product of water]

pH	**Nature**	**[H⁺]**	**Example**
0	Very strongly acidic	1 mol/L	1M HCl
2	Strongly acidic	0.01 mol/L	Stomach acid (pH 1-2)
7	Neutral	10^{-7} mol/L	Pure water at 25°C
7.35-7.45	Slightly alkaline	~4×10^{-8} mol/L	Normal blood pH
9	Weakly alkaline	10^{-9} mol/L	Baking soda
14	Very strongly alkaline	10^{-14} mol/L	1M NaOH

Body pH: Blood: 7.35-7.45 | Stomach: 1.5-3.5 | Urine: 4.5-8.0 | Saliva: 6.5-7.5 | Acidosis: pH<7.35 | Alkalosis: pH>7.45 | pH change ±0.4 = life-threatening

भाग 3: विलयन (Solutions)

3.1 Colligative Properties

- ✓ Colligative Properties = Properties that depend on NUMBER of solute particles (not their nature). Four main colligative properties:

Colligative Property	**Formula**	**Symbol**	**Application**
Relative Lowering of Vapour Pressure	(P°-P)/P° = χ_solute	RLVP	Raoult's Law
Elevation of Boiling Point	ΔTb = Kb × m	Kb (Ebullioscopic const)	Water: Kb=0.52 K·kg/mol
Depression of Freezing Point	ΔTf = Kf × m	Kf (Cryoscopic const)	Water: Kf=1.86 K·kg/mol | Antifreeze in cars
Osmotic Pressure	π = MRT = CRT	π (Pi)	Medical: IV fluids, Dialysis, RO water purification

Van't Hoff factor: i = Observed/Expected [i>1: Dissociation (electrolytes) | i<1: Association (e.g., acetic acid in benzene)]

π = iMRT [Osmotic pressure with Van't Hoff factor]

3.2 Osmosis — Clinical Importance

Solution Type	Osmolarity vs Blood	RBC Response	Clinical Use
Isotonic	Same (285-295 mOsm/L)	Normal (No change)	0.9% NaCl (NS), 5% Dextrose (D5W in practice)
Hypotonic	Less than blood	Cell swells → Lysis (Haemolysis)	0.45% NaCl — For hypertonic dehydration
Hypertonic	More than blood	Cell shrinks → Crenation	3% NaCl — Cerebral oedema, Hyponatraemia

Dialysis Principle: Dialysis works on principle of Osmosis + Diffusion | Semi-permeable membrane allows small molecules (urea, creatinine) to pass | Large molecules (proteins, blood cells) are retained | Used in Renal failure — Haemodialysis, Peritoneal dialysis

भाग 4: विद्युत रसायन (Electrochemistry)

4.1 Electrochemical Cells

Cell Type	Energy Conversion	Reaction	Example
Galvanic/Voltaic Cell	Chemical → Electrical	Spontaneous redox	Daniel cell, Battery, Fuel cell
Electrolytic Cell	Electrical → Chemical	Non-spontaneous redox	Electroplating, Electrolysis, Na/Al extraction

4.2 Standard Electrode Potential और EMF

E°_cell = E°_cathode − E°_anode [Reduction potential at cathode − Reduction potential at anode]

ΔG° = −nFE°_cell [n=electrons transferred | F=96500 C/mol (Faraday's constant)]

Nernst Equation: E = E° − (0.0592/n) log Q [At 25°C | Q=reaction quotient | E=EMF at non-standard]

Half-Reaction	E° (V)	Notes
$F_2 + 2e^- \rightarrow 2F^-$	+2.87	Strongest oxidising agent

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	+1.51	$KMnO_4$ — purple oxidising agent
$Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.36	Water purification, Bleaching
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.23	Reduction of O_2
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.77	Iron redox — biological importance
$Cu^{2+} + 2e^- \rightarrow Cu$	+0.34	Copper electroplating
$2H^+ + 2e^- \rightarrow H_2$	0.00	Reference electrode (SHE)
$Zn^{2+} + 2e^- \rightarrow Zn$	−0.76	Zinc anode in Daniel cell
$Na^+ + e^- \rightarrow Na$	−2.71	Strongest reducing agent (metal)
$Li^+ + e^- \rightarrow Li$	−3.05	Most negative — Strongest reducing agent

4.3 Conductance (चालकता)

Conductance G = 1/R | Conductivity κ = G × l/A [Unit: S (Siemens) | l=length, A=area]

⚗ ***Molar conductance Λm = κ/C × 1000*** [C=molarity | Unit: $S \cdot cm^2/mol$]

Type of Electrolyte	Λm behaviour with dilution	Examples	Kohlrausch's Law
Strong electrolyte	$\Lambda m = \Lambda m° - bC^{1/2}$ | Linear relationship	NaCl, HCl, NaOH	$\Lambda m° = \Sigma(\lambda+ + \lambda-)$
Weak electrolyte	Λm increases rapidly near zero concentration	CH_3COOH, NH_4OH	Cannot extrapolate to Λm°

4.4 Faraday's Laws of Electrolysis

1st Law: m = ZQ = ZIt [m=mass deposited | Z=electrochemical equivalent | I=current | t=time]

2nd Law: m ∝ E (Equivalent Weight) [Same charge → Mass ∝ Equivalent weight | $m_1/m_2 = E_1/E_2$]

Application	Process	Example
Electroplating	Metal deposition from solution	Ag, Ni, Cr, Au plating | Jewellery, Corrosion protection
Metal extraction	Electrolysis of molten ore	Al from Bauxite (Hall-Heroult), Na from NaCl (Down's cell)
Electrolysis of water	$2H_2O \rightarrow 2H_2 + O_2$	Hydrogen fuel production | H_2 at cathode, O_2 at anode
Medical applications	Iontophoresis	Drug delivery through skin using electrical current

Battery Types: Dry cell (Leclanché): Zn-MnO_2, 1.5V, Non - rechargeable | Lead-Acid: Pb-PbO_2, 2V/cell, Rechargeable (Car battery) | Li-ion: 3.7V, Rechargeable (Mobile, Laptop) | Fuel cell: $H_2+O_2 \rightarrow H_2O$, Continuous operation

BOOSTER POINTS — Paramedical Entrance Exam
1. $\Delta G = \Delta H - T\Delta S$ | $\Delta G<0$: Spontaneous | $\Delta G=0$: Equilibrium | $\Delta G>0$: Non-spontaneous
2. Hess's Law: ΔH independent of path | $\Delta H\_rxn = \Sigma\Delta Hf(products) - \Sigma\Delta Hf(reactants)$
3. Neutralisation enthalpy: Strong acid + Strong base = -57.1 kJ/eq | Weak acid/base = less exothermic
4. Le Chatelier: Pressure ↑ → shift to fewer moles | Temp ↑ → shift endothermic direction | Catalyst: No shift
5. Haber Process: $N_2+3H_2 \rightleftharpoons 2NH_3$ | Fe catalyst, 450°C, 200 atm | Le Chatelier compromise conditions
6. pH = $-\log[H^+]$ | Blood pH = 7.35-7.45 | Stomach pH = 1.5-3.5 | Acidosis < 7.35 | Alkalosis > 7.45
7. $K_w = [H^+][OH^-] = 10^{-14}$ at 25°C | pH + pOH = 14
8. Colligative properties depend on NUMBER not NATURE of particles: RLVP, ΔTb, ΔTf, Osmotic pressure
9. $\Delta Tf = Kf \times m$ | Water Kf = 1.86 K·kg/mol | $\Delta Tb = Kb \times m$ | Water Kb = 0.52 K·kg/mol
10. Van't Hoff factor i: NaCl → i≈2, $MgCl_2$ → i≈3, Glucose → i=1
11. Isotonic: 0.9% NaCl, ~285 mOsm | Hypotonic → Cell swells | Hypertonic → Cell shrinks
12. $\pi = iMRT$ | Osmosis: Dialysis, Kidney filtration, Reverse osmosis water purification
13. $E°\_cell = E°\_cathode - E°\_anode$ | Positive = Spontaneous | $\Delta G° = -nFE°$
14. Faraday's constant F = 96500 C/mol | 1st Law: m=ZIt | 2nd Law: $m_1/m_2 = E_1/E_2$
15. Strongest oxidising agent = F_2 (+2.87V) | Strongest reducing agent metal = Li (-3.05V)
16. At cathode: Reduction (gain e^-) | At anode: Oxidation (lose e^-) — BOTH electrochemical cells
17. Lead-acid battery: 2V/cell, 6 cells=12V (car) | Rechargeable | Pb(anode)+PbO_2(cathode)+H_2SO_4

Inorganic Chemistry

अकार्बनिक रसायन

आवर्त सारणी | रासायनिक अभिक्रियाएँ | उपसहसंयोजक यौगिक | p-ब्लॉक | d-ब्लॉक

Periodic Table | Chemical Reactions | Coordination Compounds | p-block | d-block

भाग 1: आवर्त सारणी (Periodic Table)

1.1 आवर्त सारणी का इतिहास

Scientist	Year	Contribution
Döbereiner	1829	Law of Triads — groups of 3 elements with similar properties
Newlands	1866	Law of Octaves — 8th element similar to 1st
Mendeleev	1869	Periodic Law: Properties are periodic functions of ATOMIC MASS | Predicted missing elements (Eka-silicon=Ge, Eka-boron=Ga)
Moseley	1913	Modern periodic law: Properties are periodic function of ATOMIC NUMBER

Modern Periodic Table: 118 elements | 7 Periods | 18 Groups | Based on ATOMIC NUMBER

1.2 आवर्त सारणी की संरचना

Block	Elements	Filling Orbital	Groups
s-block	H, He, Alkali metals, Alkaline earths	s-orbital (1-2 e^-)	1-2 | Reactive, electropositive metals
p-block	Boron to Noble gases (B-Ne etc.)	p-orbital (1-6 e^-)	13-18 | Non-metals, Metalloids, Noble gases
d-block (Transition metals)	Sc to Zn, etc.	d-orbital	3-12 | Coloured compounds, Variable valency
f-block (Inner transition)	Lanthanides (57-71) + Actinides (89-103)	f-orbital	Separate rows | Lanthanides: natural | Actinides: radioactive

1.3 Periodic Trends (आवर्ती प्रवृत्तियाँ)

Property	Along Period (→)	Down Group (↓)	Reason
Atomic radius	Decreases →	Increases ↓	More protons pull electrons | More shells added
Ionic radius	Cations < Atom < Anions	Increases ↓	Same trend as atomic radius
Ionisation energy	Increases →	Decreases ↓	Smaller atoms hold electrons tighter
Electron affinity	Increases → (generally)	Decreases ↓	Smaller atoms gain electrons more readily
Electronegativity	Increases → (F highest)	Decreases ↓	F = most electronegative (3.98) | Cs = least (0.79)
Metallic character	Decreases →	Increases ↓	Na>Mg>Al>Si>P>S>Cl (Period 3)

Important Values: Smallest atom: He | Largest atom: Cs | Highest IE: He | Lowest IE: Cs | Highest EN: F (3.98) | Lowest EN: Cs/Fr

1.4 Important Families of Elements

Group	Name	Elements	Key Properties
Group 1	Alkali Metals	H, Li, Na, K, Rb, Cs, Fr	1 valence e^- | Highly reactive | React with water → H_2 + MOH
Group 2	Alkaline Earth Metals	Be, Mg, Ca, Sr, Ba, Ra	2 valence e^- | Less reactive than Group 1 | Ca = Bone formation
Group 17	Halogens	F, Cl, Br, I, At	7 valence e^- | Highly electronegative | Strong oxidising agents
Group 18	Noble Gases	He, Ne, Ar, Kr, Xe, Rn	Full valence shell | Inert | He for balloons, Ne for signs
Groups 3-12	Transition Metals	Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn...	Variable valency, Coloured ions, Catalysts, Paramagnetic

भाग 2: रासायनिक अभिक्रियाएँ (Chemical Reactions)

2.1 Types of Chemical Reactions

Reaction Type	Definition	General Form	Example
Combination (Synthesis)	Two or more → One product	A + B → AB	$2H_2 + O_2 \rightarrow 2H_2O$ | $CaO + CO_2 \rightarrow CaCO_3$
Decomposition	One compound → Two or more	AB → A + B	$2KClO_3 \rightarrow 2KCl + 3O_2$ | $CaCO_3 \rightarrow CaO + CO_2$

Single Displacement	More reactive displaces less reactive	A + BC → AC + B	$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ | $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$
Double Displacement	Exchange of ions between two compounds	AB + CD → AD + CB	$NaCl + AgNO_3 \rightarrow AgCl\downarrow + NaNO_3$
Redox (Oxidation-Reduction)	Transfer of electrons	—	$Fe + 2HCl \rightarrow FeCl_2 + H_2$ | Combustion reactions
Precipitation	Insoluble product forms	—	$Pb(NO_3)_2 + 2KI \rightarrow PbI_2\downarrow + 2KNO_3$ (yellow ppt)
Acid-Base (Neutralisation)	$H^+ + OH^- \rightarrow H_2O$	—	$HCl + NaOH \rightarrow NaCl + H_2O$

2.2 Oxidation-Reduction (Redox) Reactions

Term	**Old Definition**	**Modern Definition**	**Example**
Oxidation	Addition of O / Loss of H	Loss of electrons (LEO)	$Fe \rightarrow Fe^{3+} + 3e^-$ | $Zn \rightarrow Zn^{2+}$
Reduction	Removal of O / Gain of H	Gain of electrons (GER)	$Cu^{2+} + 2e^- \rightarrow Cu$ | $H_2O \rightarrow H_2$

OIL RIG: OIL = Oxidation Is Loss (of electrons) | RIG = Reduction Is Gain (of electrons) | Oxidising agent: Gets reduced (gains e^-) | Reducing agent: Gets oxidised (loses e^-)

2.3 Oxidation States

Element/Rule	**Oxidation State**	**Example**
Free element	0	Fe=0, O_2=0, Cl_2=0
Monoatomic ion	Equals charge	+2 for Ca^{2+}, -1 for Cl^-
O (Oxygen) in compounds	Usually -2 (except peroxide=-1, OF_2=+2)	H_2O: O=-2, H_2O_2: O=-1
H (Hydrogen) in compounds	Usually +1 (except with metals=-1)	HCl: H=+1, NaH: H=-1
Sum of OS in compound	= 0	-
Sum of OS in ion	= charge of ion	NO_3^-: N+3(-2)=-1 → N=+5
Mn in $KMnO_4$	Mn=+7	K=+1, 4O=-8, Mn must=+7
Cr in $K_2Cr_2O_7$	Cr=+6	Potassium dichromate