Unit 1: Atomic Structure, Chemical Bonding & Solutions

Engineering Chemistry — DI01000071

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Unit 1 Roadmap (30-Frame Master Revision)

Syllabus Coverage

1.1–1.3	Atomic structure: orbit/orbital, rules, e-configuration (Z=1–30)
1.4	Chemical bonds: ionic, covalent, coordinate, metallic, H-bond, van der Waals
1.5	Structures of solids: ionic, molecular, network and metallic
1.6	Solutions and concentration units: M, N, m, %w/w, %v/v, %w/v

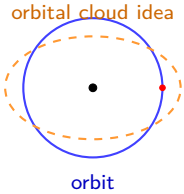
Exam Weightage

17% ($\approx$ 12 marks)

How to Use

Learn with tables + redraw diagrams from memory.

Orbit vs Orbital: The First Distinction



Key Difference

- **Orbit**: fixed circular/elliptical path (Bohr model).
- **Orbital**: 3D probability region for electron.
- Orbit is classical; orbital is quantum mechanical concept.

Memory Hook

Orbit = path, orbital = probability.

Orbit vs Orbital: Comparison Table

Point	Orbit	Orbital
Nature	Definite path	Probability region
Dimension	2D concept	3D concept
Basis	Bohr model	Quantum mechanics
Notation	$n = 1, 2, 3, \ldots$	s, p, d, f
Max electrons	$2n^2$ in shell	2 in one orbital

Exam Pattern

Very frequent 2-mark question: write any four differences.

Quantum Numbers: Full Set

Four Quantum Numbers

- Principal quantum number: n
- Azimuthal quantum number: l
- Magnetic quantum number: m_l
- Spin quantum number: m_s

Ranges

$$n = 1, 2, 3, \ldots, \quad l = 0 \text{ to } n-1, \quad m_l = -l \text{ to } +l, \quad m_s = \pm\frac{1}{2}$$

Quantum Numbers: Meaning Table

Symbol	Name	Represents	Important Note
n	Principal	Shell/energy level	Larger n, larger size/energy
l	Azimuthal	Subshell shape	0,1,2,3 correspond to s,p,d,f
m_l	Magnetic	Orbital orientation	Number of values $= 2l + 1$
m_s	Spin	Electron spin direction	$+\frac{1}{2}$ or $-\frac{1}{2}$

Pauli Exclusion Principle

Statement

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

Immediate Result

One orbital can contain maximum two electrons and their spins must be opposite.

Orbital Box Notation

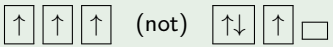
$\boxed{\uparrow\downarrow}$ allowed, $\boxed{\uparrow\uparrow}$ not allowed in same orbital.

Hund's Rule of Maximum Multiplicity

Rule

In degenerate orbitals, electrons occupy each orbital singly with parallel spins before pairing.

Example: $2p^3$



Reason

Half-filled arrangement has lower repulsion and higher stability.

Aufbau Principle and $(n + l)$ Rule

Aufbau Principle

Electrons fill lower energy orbitals first.

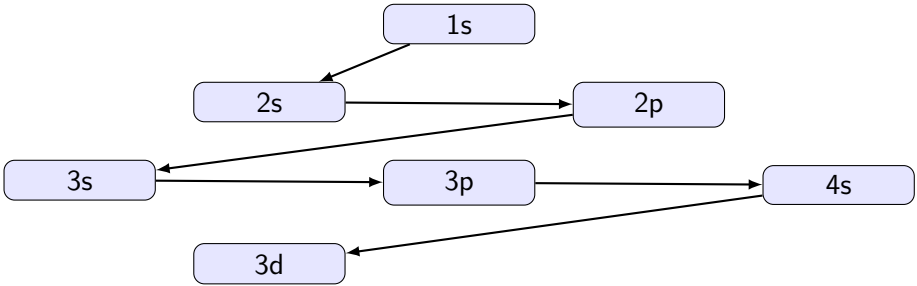
$(n + l)$ Rule

Orbital with lower $(n + l)$ fills first. If equal, lower n fills first.

Example

$4s$: $n + l = 4 + 0 = 4$, $3d$: $n + l = 3 + 2 = 5$. Therefore $4s$ fills before $3d$.

Energy Order Diagram for Filling



Common Mistake

Students often place $3d$ before $4s$; avoid this in exams.

Electronic Configuration: Z = 1 to 10

Element	Configuration
H(1), He(2)	$1s^1,\ 1s^2$
Li(3)–Ne(10)	$1s^2 2s^1,\ 1s^2 2s^2,\ 1s^2 2s^2 2p^1 \ldots 1s^2 2s^2 2p^6$

Shortcut

Ne = $1s^2 2s^2 2p^6$ is first complete octet reference.

Electronic Configuration: Z = 11 to 20

Range	Pattern
Na(11)–Ar(18)	$[Ne]\,3s^1$ to $[Ne]\,3s^2 3p^6$
K(19), Ca(20)	$[Ar]\,4s^1$, $[Ar]\,4s^2$

Valence Shell Trend

Third period fills $3s$ then $3p$; fourth period begins with $4s$.

Electronic Configuration: Z = 21 to 30

Element	Configuration		Remark
Sc to Mn	$[Ar]\,4s^2 3d^1$	to	gradual d-filling
	$[Ar]\,4s^2 3d^5$		
Fe to Zn	$[Ar]\,4s^2 3d^6$	to	transition range
	$[Ar]\,4s^2 3d^{10}$		

Special Attention

Cr and Cu are exceptions due to extra stability of half/full *d*-subshell.

Special Cases: Chromium and Copper

Element	Expected	Actual
Cr(24)	$[Ar]\,4s^2 3d^4$	$[Ar]\,4s^1 3d^5$
Cu(29)	$[Ar]\,4s^2 3d^9$	$[Ar]\,4s^1 3d^{10}$

Reason

Half-filled (d^5) and fully-filled (d^{10}) configurations are comparatively more stable.

Quick Atomic Structure Practice

Try in 3 minutes

- Write configuration of Mg (12), Cl (17), Fe (26), Cu (29).
- Identify valence electrons and block ($s/p/d$).
- State one rule used in each step.

Exam Habit

For 3–4 mark answers: write order, then final configuration, then one-line reason.

Chemical Bond and Octet Rule

Chemical Bond

Attractive force that holds atoms/ions together to form stable species.

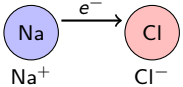
Octet Rule

Atoms tend to attain 8 electrons in outer shell (noble gas-like stability).

Why bond forms

Bonded state has lower potential energy than isolated atoms.

Ionic Bond Formation: NaCl



Formation Steps

$$\mathrm{Na} \rightarrow \mathrm{Na}^+ + \mathrm{e}^-$$

$$\mathrm{Cl} + \mathrm{e}^- \rightarrow \mathrm{Cl}^-$$

$$\mathrm{Na}^+ + \mathrm{Cl}^- \rightarrow \mathrm{NaCl}$$

Ionic Bond: Characteristics

Property	Reason
High melting/boiling point	Strong electrostatic attraction
Conductive in molten/aqueous state	Free ions available
Brittle solid	Shifted layers create strong repulsion
Soluble in polar solvents	Ion-dipole interactions

Covalent Bond: Basic Idea

Definition

Covalent bond forms by sharing of one or more electron pairs between atoms.

Bond Types

Single ($-$), double ($=$), triple ($\equiv$)

Examples

H_2 single, O_2 double, N_2 triple covalent bonds.

Non-polar vs Polar Covalent Bonds

Type	Electron Sharing	Examples
Non-polar covalent	Equal sharing	H_2, O_2, N_2, CH_4
Polar covalent	Unequal sharing	HCl, H_2O, NH_3

Key Rule

Greater electronegativity difference implies higher polarity.

Coordinate (Dative) Bond

Definition

Shared pair is donated by one atom and accepted by another atom/ion.

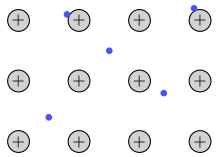
Important GTU Examples

NH_4^+ and H_3O^+

Notation

Arrow notation indicates donor to acceptor, e.g., : $NH_3 \rightarrow H^+$.

Metallic Bond and Properties



Model

Positive metal ions are surrounded by a "sea" of delocalized electrons.

Resulting Properties

Electrical conductivity, thermal conductivity, malleability and ductility.

Hydrogen Bond: Types and Significance

Type	Meaning	Importance
Intermolecular H-bond	Between molecules	Raises boiling point of water
Intramolecular H-bond	Within same molecule	Affects molecular shape/reactivity

Significance

Stability of DNA helix, protein structure, unusual properties of water.

van der Waals Forces (Intermolecular Attraction)

Definition

Weak attractions between neutral molecules/atoms due to temporary or induced dipoles.

Why Important

- Control liquefaction and boiling behavior.
- Important in molecular crystals and adsorption.
- Influence polymer and biological interactions.

Exam Tip

Mention “weaker than ionic/covalent” and give one practical effect.

Bond Types: One-Glance Comparison

Bond	How formed	Main property	Example
Ionic	Electron transfer	High m.p., brittle	NaCl
Covalent	Electron sharing	Directional bond	H_2, H_2O
Coordinate	Pair donated by one atom	Donor-acceptor interaction	NH_4^+
Metallic	Delocalized electrons	Conductive, malleable	Cu, Fe
H-bond	H with F/O/N interaction	Raises b.p./stability	H_2O
van der Waals	Temporary dipole forces	Weak attraction	Noble gases (liquid state)

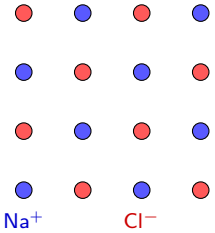
Structures of Solids: Four Classes

Type	Constituent	General Behavior
Ionic solid	Ions	Hard, brittle, high m.p.
Molecular solid	Molecules	Soft, low m.p.
Network solid	Covalent atoms	Very hard, very high m.p.
Metallic solid	Metal cations + e^-	Conductive, malleable

Exam Pattern

Often asked as "differentiate any two solid types with examples".

NaCl Lattice Snapshot (Ionic Solid)



Key Points

- Alternating Na^+ and Cl^- in crystal.
- Strong Coulombic attraction.
- Coordination number 6 in NaCl structure.

Solutions and Concentration Units

Basic Terms

Solute + solvent = solution; concentration tells quantity of solute.

Unit	Expression	Common Use
Molarity (M)	$\frac{\text{moles solute}}{\text{litre solution}}$	Lab prep
Normality (N)	$\frac{\text{gram equivalent}}{\text{litre solution}}$	Titration
Molality (m)	$\frac{\text{moles solute}}{\text{kg solvent}}$	Temp-independent
%w/w	$\frac{\text{mass solute}}{\text{mass solution}} \times 100$	Solid-liquid
%v/v	$\frac{\text{volume solute}}{\text{volume solution}} \times 100$	Liquid-liquid
%w/v	$\frac{\text{mass(g)}}{\text{volume(mL)}} \times 100$	Pharmacy/lab labels

Worked Numericals: Molarity and %w/v

Q1: Molarity

5.85 g NaCl is dissolved to make 500 mL solution.
Moles of NaCl $= 5.85/58.5 = 0.1$.

$$M = \frac{0.1}{0.5} = 0.2 \text{ M}$$

Q2: %w/v

10 g glucose in 200 mL solution:

$$\%w/v = \frac{10}{200} \times 100 = 5\%$$

Scoring Rule

Write given data, formula, substitution and unit in sequence.

Unit 1 Final Rapid Revision Map

Top 5 Must-Remember Items

- Orbit vs orbital differences
- Pauli, Hund and Aufbau rules
- Ionic/covalent/coordinate/metallic bonds
- Four structures of solids
- Six concentration expressions

2-Hour Revision Plan

- 40 min: atomic structure
- 40 min: chemical bonding
- 25 min: solids + concentration
- 15 min: 2 numericals + 1 short note

Outcome Check

If you can explain each table and redraw each diagram, Unit 1 is exam-ready.

Unit 1: Atomic Structure, Chemical Bonding & Solutions

Engineering Chemistry — DI01000071

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unit-2 — Overview

Syllabus Topics

2.1 Oxidation & Reduction (Redox)
2.2 Electrochemical Cells
2.3 Standard Electrode Potential & EMF
2.4 Nernst Equation
2.5 Conductance & Kohlrausch's Law
2.6 Faraday's Laws of Electrolysis
2.7 Applications of Electrolysis

Weightage: $\approx 14\%$

Teaching Hrs: ≈ 7 hrs

Topic 1: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 3–4 (reference for further study)

Topic 2: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 5–6 (reference for further study)

Topic 3: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 7–8 (reference for further study)

Topic 4: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 9–10 (reference for further study)

Topic 5: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 11–12 (reference for further study)

Topic 6: Key Concepts

Key Topics

- Platinum electrode coated with platinum black
- Immersed in 1 M HCl ($H^+ = 1\,M$)
- H_2 gas bubbled at 1 atm, 298 K

Key Definition

Platinum electrode coated with platinum black

Source Coverage

Frames 13–14 (reference for further study)

Topic 7: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 15–17 (reference for further study)

Topic 8: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 18–19 (reference for further study)

Topic 9: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 20–21 (reference for further study)

Topic 10: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 22–23 (reference for further study)

Topic 11: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 24–25 (reference for further study)

Topic 12: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 26–27 (reference for further study)

Topic 13: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 28–29 (reference for further study)

Topic 14: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 30–32 (reference for further study)

Topic 15: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 33–34 (reference for further study)

Topic 16: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 35–36 (reference for further study)

Topic 17: Key Concepts

Key Topics

- Hard, corrosion-resistant surface
- Porous $\rightarrow$ can be dyed (coloured finishes)
- Better paint adhesion

Key Definition

Hard, corrosion-resistant surface

Source Coverage

Frames 37–38 (reference for further study)

Topic 18: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 39–40 (reference for further study)

Topic 19: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 41–42 (reference for further study)

Topic 20: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 43–44 (reference for further study)

Topic 21: Key Concepts

Key Topics

- At cathode: ion with higher reduction potential discharges first
- At anode: ion requiring least energy to oxidize discharges first

Key Definition

At cathode: ion with higher reduction potential discharges first

Source Coverage

Frames 45–47 (reference for further study)

Topic 22: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 48–49 (reference for further study)

Topic 23: Key Concepts

Key Topics

- No pollution (product: H_2O)
- High efficiency
- No moving parts

Key Definition

No pollution (product: H_2O)

Source Coverage

Frames 50–51 (reference for further study)

Topic 24: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 52–53 (reference for further study)

Topic 25: Key Concepts

Key Topics

- Write full half-reactions for both electrodes
- State Faraday's laws in words before formula
- Show units at every step in numericals

Key Definition

Write full half-reactions for both electrodes

Source Coverage

Frames 54–55 (reference for further study)

Topic 26: Key Concepts

Key Topics

- Use metals close in series
- Use insulating spacers
- Apply protective coatings

Key Definition

Use metals close in series

Source Coverage

Frames 56–57 (reference for further study)

Topic 27: Key Concepts

Key Topics

- SHE potential = 0.00 V (by convention)
- 1 Faraday = 96500 C = charge of 1 mol e^-
- Daniel cell: Zn anode, Cu cathode, $E^\circ = 1.10$ V

Key Definition

SHE potential = 0.00 V (by convention)

Source Coverage

Frames 58–60 (reference for further study)

Unit Summary & Revision

Next Steps

- Review all condensed frames above
- Compare with original full unit for deep understanding
- Practice worked examples and PYQ problems

Unit 1: Atomic Structure, Chemical Bonding & Solutions

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unit-3 — Overview

Unit 3 Syllabus Overview

Topics Covered

#	Topic
1	Definition & Significance of Corrosion
2	Types: Dry (Chemical) Corrosion
3	Types: Wet (Electrochemical) Corrosion
4	Mechanism of Rusting of Iron
5	Factors Affecting Corrosion
6	Prevention: Coatings (metallic, non-metallic)
7	Prevention: Galvanizing & Tinning
8	Prevention: Cathodic Protection
9	Prevention: Corrosion Inhibitors

Weightage: ≈12% of paper **PYQ:** 7-mark asked every exam

Topic 1: Key Concepts

Key Topics

- Rusting of iron ($Fe_2O_3 \cdot xH_2O$)
- Tarnishing of silver (Ag_2S)
- Green patina on copper ($CuCO_3 \cdot Cu(OH)_2$)

Key Definition

Rusting of iron ($Fe_2O_3 \cdot xH_2O$)

Source Coverage

Frames 3–4 (reference for further study)

Topic 2: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 5–6 (reference for further study)

Topic 3: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 7–8 (reference for further study)

Topic 4: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 9–10 (reference for further study)

Topic 5: Key Concepts

Key Topics

- Ship hulls
- Water storage tanks
- Marine structures

Key Definition

Ship hulls

Source Coverage

Frames 11–12 (reference for further study)

Topic 6: Key Concepts

Key Topics

- Thin (nanometres thick)
- Adherent — does not peel
- Impervious to gases/liquids

Key Definition

Thin (nanometres thick)

Source Coverage

Frames 13–14 (reference for further study)

Topic 7: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 15–17 (reference for further study)

Topic 8: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 18–19 (reference for further study)

Topic 9: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 20–21 (reference for further study)

Topic 10: Key Concepts

Key Topics

- Underground pipelines (oil, gas, water)
- Ship hulls
- Marine structures (jetties, offshore platforms)

Key Definition

Underground pipelines (oil, gas, water)

Source Coverage

Frames 22–23 (reference for further study)

Topic 11: Key Concepts

Key Topics

- External current can be adjusted
- Inert anode lasts longer
- Economical for large structures (pipelines >100 km)

Key Definition

External current can be adjusted

Source Coverage

Frames 24–25 (reference for further study)

Topic 12: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 26–27 (reference for further study)

Topic 13: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 28–29 (reference for further study)

Topic 14: Key Concepts

Key Topics

- Stress relief annealing
- Reduce Cl^- concentration
- Use SCC-resistant alloys

Key Definition

Stress relief annealing

Source Coverage

Frames 30–32 (reference for further study)

Topic 15: Key Concepts

Key Topics

- Seal crevices with weld/sealant
- Use non-absorbent gaskets
- Design to allow drainage

Key Definition

Seal crevices with weld/sealant

Source Coverage

Frames 33–34 (reference for further study)

Topic 16: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 35–36 (reference for further study)

Topic 17: Key Concepts

Key Topics

- Biocides in water systems
- Protective coatings
- Cathodic protection

Key Definition

Biocides in water systems

Source Coverage

Frames 37–38 (reference for further study)

Topic 18: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 39–40 (reference for further study)

Topic 19: Key Concepts

Key Topics

- Write all 4 steps of rusting mechanism with chemical equations
- Clearly label anode/cathode in cathodic protection diagram
- State P-B ratio with all three cases

Key Definition

Write all 4 steps of rusting mechanism with chemical equations

Source Coverage

Frames 41–42 (reference for further study)

Topic 20: Key Concepts

Key Topics

- Rusting: Fe $\rightarrow$ rust (4 reactions)
- P-B ratio: <1 = porous; ≈ 1 = protective
- Galvanizing temp: $\approx 450\,^{\circ}\mathrm{C}$ (hot-dip Zn)

Key Definition

Rusting: Fe $\rightarrow$ rust (4 reactions)

Source Coverage

Frames 43–44 (reference for further study)

Topic 21: Key Concepts

Key Topics

- Use high Cr/Ni alloys (Inconel, stainless)
- Protective coatings (aluminizing, chromizing)
- Ceramic coatings for furnace parts

Key Definition

Use high Cr/Ni alloys (Inconel, stainless)

Source Coverage

Frames 45–47 (reference for further study)

Topic 22: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 48–49 (reference for further study)

Topic 23: Key Concepts

Key Topics

- Avoid galvanic couples: Use metals close in series, or insulate joints
- Eliminate crevices: Seal joints; use butt welds instead of lap welds
- Allow drainage: No pockets where water collects; incline surfaces

Key Definition

Avoid galvanic couples: Use metals close in series, or insulate joints

Source Coverage

Frames 50–51 (reference for further study)

Topic 24: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 52–53 (reference for further study)

Topic 25: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 54–55 (reference for further study)

Topic 26: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 56–57 (reference for further study)

Topic 27: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 58–60 (reference for further study)

Unit Summary & Revision

Next Steps

- Review all condensed frames above
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Unit 4 covers the chemistry of fuels — their classification, calorific value, analysis, and types of solid/liquid/gaseous fuels. Topics include Dulong's formula, coal analysis, petroleum fractions, and combustion calculations.

unit-4 — Overview

Unit 4 — Topics and Weightage

Topics at a Glance

#	Topic	Key Concepts
1	Classification of Fuels	Natural, artificial, solid/liquid/gas
2	Calorific Value	GCV, NCV, formula
3	Dulong's Formula	Calculation of GCV from composition
4	Solid Fuels: Coal	Types, proximate, ultimate analysis
5	Coal Products	Coke, coal gas, coal tar
6	Petroleum	Origin, fractions, cracking
7	Gaseous Fuels	Natural gas, LPG, water gas, producer gas
8	Combustion	Air/fuel ratio, flue gas analysis
9	Numericals	GCV, NCV, Dulong, combustion air

Weightage: ∼14% | GTU pattern: 2 × 7 mark + short answers

Topic 1: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 3–4 (reference for further study)

Topic 2: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 5–6 (reference for further study)

Topic 3: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 7–8 (reference for further study)

Topic 4: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 9–10 (reference for further study)

Topic 5: Key Concepts

Key Topics

- Soft coke (smokeless domestic fuel)
- More tar (more light oil)
- Less gas

Key Definition

Soft coke (smokeless domestic fuel)

Source Coverage

Frames 11–12 (reference for further study)

Topic 6: Key Concepts

Key Topics

- Grey, porous, hard
- High carbon content ($\sim$92
- Low moisture, low ash

Key Definition

Grey, porous, hard

Source Coverage

Frames 13–14 (reference for further study)

Topic 7: Key Concepts

Key Topics

- Paraffins (alkanes)
- Naphthenes (cycloalkanes)
- Aromatics

Key Definition

Paraffins (alkanes)

Source Coverage

Frames 15–17 (reference for further study)

Topic 8: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 18–19 (reference for further study)

Topic 9: Key Concepts

Key Topics

- Found with petroleum deposits
- Main: CH_4 (85–90
- Also: C_2H_6, C_3H_8, CO_2, N_2

Key Definition

Found with petroleum deposits

Source Coverage

Frames 20–21 (reference for further study)

Topic 10: Key Concepts

Key Topics

- Renewable; reduces waste
- Low pollution
- Slurry = excellent manure

Key Definition

Renewable; reduces waste

Source Coverage

Frames 22–23 (reference for further study)

Topic 11: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 24–25 (reference for further study)

Topic 12: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 26–27 (reference for further study)

Topic 13: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 28–29 (reference for further study)

Topic 14: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 30–32 (reference for further study)

Topic 15: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 33–34 (reference for further study)

Topic 16: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 35–36 (reference for further study)

Topic 17: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 37–38 (reference for further study)

Topic 18: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 39–40 (reference for further study)

Topic 19: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 41–42 (reference for further study)

Topic 20: Key Concepts

Key Topics

- Show full substitution in Dulong's formula
- Write combustion reactions for each element separately
- For proximate: state temperature and time at each step

Key Definition

Show full substitution in Dulong's formula

Source Coverage

Frames 43–44 (reference for further study)

Topic 21: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 45–47 (reference for further study)

Topic 22: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 48–49 (reference for further study)

Topic 23: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 50–51 (reference for further study)

Topic 24: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 52–53 (reference for further study)

Topic 25: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 54–55 (reference for further study)

Topic 26: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 56–57 (reference for further study)

Topic 27: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 58–60 (reference for further study)

Unit Summary & Revision

Next Steps

- Review all condensed frames above
- Compare with original full unit for deep understanding
- Practice worked examples and PYQ problems

Unit 1: Atomic Structure, Chemical Bonding & Solutions

Engineering Chemistry — DI01000071

Milav Dabgar

Lecturer, Dept of ECE
GP Palanpur

May 1, 2026

Unit 5 covers classification of lubricants, mechanisms of lubrication, essential properties (viscosity, flash/fire point, cloud/pour point, acid value, saponification number, aniline point), and industrial applications.

unit-5 — Overview

Unit 5 — Topics and Weightage

Topics at a Glance

#	Topic	Key Concepts
1	Definition and functions	Reduce friction, wear, heat
2	Classification	Liquid, semi-solid, solid
3	Liquid lubricants	Mineral, vegetable, animal, blended
4	Greases	Semi-solid; extreme pressure
5	Solid lubricants	Graphite, MoS_2; high-temp use
6	Mechanisms	Hydrodynamic, boundary, extreme pressure
7	Viscosity and index	Resistance to flow; VI improvers
8	Flash/fire point	Safety; volatile impurities
9	Cloud/pour point	Low-temp performance
10	Acid value, saponification	Quality, degradation
11	Aniline point	Aromatic content indicator

Topic 1: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 3–4 (reference for further study)

Topic 2: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 5–6 (reference for further study)

Topic 3: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 7–8 (reference for further study)

Topic 4: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 9–10 (reference for further study)

Topic 5: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 11–12 (reference for further study)

Topic 6: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 13–14 (reference for further study)

Topic 7: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 15–17 (reference for further study)

Topic 8: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 18–19 (reference for further study)

Topic 9: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 20–21 (reference for further study)

Topic 10: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 22–23 (reference for further study)

Topic 11: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 24–25 (reference for further study)

Topic 12: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 26–27 (reference for further study)

Topic 13: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 28–29 (reference for further study)

Topic 14: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 30–32 (reference for further study)

Topic 15: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 33–34 (reference for further study)

Topic 16: Key Concepts

Key Topics

- Rapidly biodegradable
- Non-toxic to aquatic life
- Renewable resource

Key Definition

Rapidly biodegradable

Source Coverage

Frames 35–36 (reference for further study)

Topic 17: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 37–38 (reference for further study)

Topic 18: Key Concepts

Key Topics

- State units for every property (cSt, mg KOH/g, °C)
- For acid value: mention significance (oil degradation)
- For saponification no.: mention what it measures (ester content)

Key Definition

State units for every property (cSt, mg KOH/g, °C)

Source Coverage

Frames 39–40 (reference for further study)

Topic 19: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 41–42 (reference for further study)

Topic 20: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 43–44 (reference for further study)

Topic 21: Key Concepts

Key Topics

- VI $= 75 \rightarrow$ Medium quality
- VI $> 100 \rightarrow$ Multigrade/synthetic
- VI $< 40 \rightarrow$ Naphthenic (poor)

Key Definition

VI $= 75 \rightarrow$ Medium quality

Source Coverage

Frames 45–47 (reference for further study)

Topic 22: Key Concepts

Key Topics

- Wheel bearings
- Electric motor bearings
- General purpose

Key Definition

Wheel bearings

Source Coverage

Frames 48–49 (reference for further study)

Topic 23: Key Concepts

Key Topics

- FeCl (from Cl-compounds)
- FeS / Fe S (from S-compounds)
- FePO (from P-compounds)

Key Definition

FeCl (from Cl-compounds)

Source Coverage

Frames 50–51 (reference for further study)

Topic 24: Key Concepts

Key Topics

- Detergents (clean deposits)
- Dispersants (suspend soot)
- ZDDP (anti-wear)

Key Definition

Detergents (clean deposits)

Source Coverage

Frames 52–53 (reference for further study)

Topic 25: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 54–55 (reference for further study)

Topic 26: Key Concepts

Key Topics

- Confusing flash point (vapour ignites momentarily) with fire point (sustained burning)
- Saying high VI = high viscosity (Wrong! VI = stability of viscosity with temperature)
- Cloud point > pour point (always cloud pt is higher)

Key Definition

Confusing flash point (vapour ignites momentarily) with fire point (sustained burning)

Source Coverage

Frames 56–57 (reference for further study)

Topic 27: Key Concepts

Key Topics

- Polymer definition
  classification
- Addition vs Condensation polymerization
- Thermoplastics vs Thermosets

Key Definition

Polymer definition
classification

Source Coverage

Frames 58–60 (reference for further study)

Unit Summary & Revision

Next Steps

- Review all condensed frames above
- Compare with original full unit for deep understanding
- Practice worked examples and PYQ problems

Unit 1: Atomic Structure, Chemical Bonding & Solutions

Engineering Chemistry — DI01000071

Milav Dabgar

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May 1, 2026

Polymer Definition · Polymerization · Thermoplastics & Thermosets
Elastomers · Conducting Polymers · Biodegradable Polymers

unit-6 — Overview

Unit 6 Overview: Polymers

Topics Covered

- Polymer definition & terminology
- Classification of polymers
- Addition polymerization
- Condensation polymerization
- Thermoplastics vs Thermosets
- Important thermoplastics
- Important thermosets (Bakelite, epoxy)
- Elastomers (natural & synthetic rubber)
- Conducting polymers
- Biodegradable polymers
- Fiber-reinforced composites

Exam Weightage

≈20% of paper
(Highest weightage unit)

Frequent PYQ topics:

- Nylon-66 synthesis
- Bakelite preparation (mechanism)
- Natural rubber vulcanization
- Buna-S / Neoprene structure
- Conducting polymers (PANI)
- Biodegradable polymers (PLA)

Topic 1: Key Concepts

Key Topics

- Polyethylene: $n(-CH_2 - CH_2-)$ from ethene
- PVC: $n(-CH_2 - CHCl-)$ from vinyl chloride
- Nylon-66: from hexamethylene diamine + adipic acid

Key Definition

Polyethylene: $n(-CH_2 - CH_2-)$ from ethene

Source Coverage

Frames 3–4 (reference for further study)

Topic 2: Key Concepts

Key Topics

- Nylon-6 (caprolactam ring opening)
- Polyester (diol + diacid)
- Bakelite (phenol + formaldehyde)

Key Definition

Nylon-6 (caprolactam ring opening)

Source Coverage

Frames 5–6 (reference for further study)

Topic 3: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 7–8 (reference for further study)

Topic 4: Key Concepts

Key Topics

- Hard, brittle thermoset
- Excellent electrical insulator
- Heat resistant

Key Definition

Hard, brittle thermoset

Source Coverage

Frames 9–10 (reference for further study)

Topic 5: Key Concepts

Key Topics

- High tensile strength
- Abrasion resistant
- Good elasticity

Key Definition

High tensile strength

Source Coverage

Frames 11–12 (reference for further study)

Topic 6: Key Concepts

Key Topics

- Highly elastic
- Soft, tacky
- Poor tensile strength

Key Definition

Highly elastic

Source Coverage

Frames 13–14 (reference for further study)

Topic 7: Key Concepts

Key Topics

- Better abrasion resistance than NR
- Good aging resistance
- Less elastic than NR

Key Definition

Better abrasion resistance than NR

Source Coverage

Frames 15–17 (reference for further study)

Topic 8: Key Concepts

Key Topics

- Conjugated double bonds (alternating C=C)
- Doping (oxidation/reduction introduces charge carriers)
- Polyacetylene (PA) — first, highest conductivity

Key Definition

Conjugated double bonds (alternating C=C)

Source Coverage

Frames 18–19 (reference for further study)

Topic 9: Key Concepts

Key Topics

- Hydrolysis (ester, amide bonds)
- Microbial attack
- Photo-/thermo-oxidative degradation

Key Definition

Hydrolysis (ester, amide bonds)

Source Coverage

Frames 20–21 (reference for further study)

Topic 10: Key Concepts

Key Topics

- Glass fibers (GFRP) — most common
- Carbon fibers (CFRP) — high strength-to-weight
- Kevlar (aramid) — bullet-resistant

Key Definition

Glass fibers (GFRP) — most common

Source Coverage

Frames 22–23 (reference for further study)

Topic 11: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 24–25 (reference for further study)

Topic 12: Key Concepts

Key Topics

- GPPS: clear, brittle (CD cases)
- HIPS: impact-modified with rubber
- EPS (expanded): Thermocol — packaging foam

Key Definition

GPPS: clear, brittle (CD cases)

Source Coverage

Frames 26–27 (reference for further study)

Topic 13: Key Concepts

Key Topics

- Harder than Bakelite
- Light-colored (can be made in any color)
- Good electrical insulation

Key Definition

Harder than Bakelite

Source Coverage

Frames 28–29 (reference for further study)

Topic 14: Key Concepts

Key Topics

- Wide temperature range: $-60°C$ to $+250°C$
- Water repellent (hydrophobic)
- Biocompatible and non-toxic

Key Definition

Wide temperature range: $-60°C$ to $+250°C$

Source Coverage

Frames 30–32 (reference for further study)

Topic 15: Key Concepts

Key Topics

- Mechanical: Melt and re-process (thermoplastics only)
- Chemical: Depolymerize back to monomers (PET $\rightarrow$ ethylene glycol + TPA)
- Energy recovery: Incineration with heat recovery

Key Definition

Mechanical: Melt and re-process (thermoplastics only)

Source Coverage

Frames 33–34 (reference for further study)

Topic 16: Key Concepts

Key Topics

- Random: –A-B-A-A-B-B-A– (SBR)
- Alternating: –A-B-A-B-A-B–
- Block: –AAAA-BBBB– (SBS thermoplastic elastomer)

Key Definition

Random: –A-B-A-A-B-B-A– (SBR)

Source Coverage

Frames 35–36 (reference for further study)

Topic 17: Key Concepts

Key Topics

- Nylon-66: monomers, reaction, structure, properties, uses
- Bakelite: preparation mechanism (novolac $\rightarrow$ resole $\rightarrow$ Bakelite), properties, uses
- Natural rubber: structure, limitations, vulcanization (process + effect), uses

Key Definition

Nylon-66: monomers, reaction, structure, properties, uses

Source Coverage

Frames 37–38 (reference for further study)

Topic 18: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 39–40 (reference for further study)

Topic 19: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 41–42 (reference for further study)

Topic 20: Key Concepts

Key Topics

- Calling Nylon-66 an addition polymer (it is condensation — amide bond with H O loss)
- Drawing cis-isoprene as trans (must be cis for elastic properties)
- Saying all rubbers are natural (SBR/NBR/Neoprene are synthetic)

Key Definition

Calling Nylon-66 an addition polymer (it is condensation — amide bond with H O loss)

Source Coverage

Frames 43–44 (reference for further study)

Topic 21: Key Concepts

Key Topics

- Optically transparent
- Impact strength $\sim 250\times$ glass
- $T_g = 147°C$ (high heat resistance)

Key Definition

Optically transparent

Source Coverage

Frames 45–47 (reference for further study)

Topic 22: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 48–49 (reference for further study)

Topic 23: Key Concepts

Key Topics

- UV stabilizers (HALS) — absorb/quench UV energy
- Antioxidants — interrupt radical chain oxidation
- Heat stabilizers (Ca/Zn) — prevent HCl elimination in PVC

Key Definition

UV stabilizers (HALS) — absorb/quench UV energy

Source Coverage

Frames 50–51 (reference for further study)

Topic 24: Key Concepts

Key Topics

- Nanoclay: montmorillonite (MMT) $\rightarrow$ barrier, flame retardancy
- Carbon nanotubes (CNT): conductivity, strength
- Graphene: barrier, conductivity, mechanical

Key Definition

Nanoclay: montmorillonite (MMT) $\rightarrow$ barrier, flame retardancy

Source Coverage

Frames 52–53 (reference for further study)

Topic 25: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 54–55 (reference for further study)

Topic 26: Key Concepts

Key Topics

- Flexible foam (furniture, mattresses)
- Rigid foam (insulation panels)
- Elastomeric (spandex/Lycra fibers)

Key Definition

Flexible foam (furniture, mattresses)

Source Coverage

Frames 56–57 (reference for further study)

Topic 27: Key Concepts

Key Topics

- Bio-PE (from sugarcane ethanol $\rightarrow$ ethylene)
- Bio-PET (30
- Bio-based drop-in replacements — same properties, renewable source

Key Definition

Bio-PE (from sugarcane ethanol $\rightarrow$ ethylene)

Source Coverage

Frames 58–60 (reference for further study)

Unit Summary & Revision

Next Steps

- Review all condensed frames above
- Compare with original full unit for deep understanding
- Practice worked examples and PYQ problems

Unit 1: Atomic Structure, Chemical Bonding & Solutions

Engineering Chemistry — DI01000071

Milav Dabgar

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GP Palanpur

May 1, 2026

Water Quality · Hardness · Softening Methods
Boiler Feed Water · Desalination · Wastewater Treatment

unit-7 — Overview

Unit 7 Overview: Water

Topics Covered

- Water quality parameters
- DO, BOD, COD
- Hardness: types, units, causes
- Lime-soda process
- Zeolite/Permutit process
- Ion exchange process
- Reverse osmosis
- Boiler feed water treatment
- Desalination methods
- Municipal water treatment
- Sewage treatment

Exam Weightage

≈15% of paper

Frequently asked:

- Hardness numericals (ppm, mg/L, °F, °Cl)
- Lime-soda process reactions
- Zeolite process (regeneration)
- BOD vs COD distinction
- Reverse osmosis principle
- Boiler troubles (scale, priming)
- Drinking water treatment flowchart

Topic 1: Key Concepts

Key Topics

- Turbidity: Suspended particles scattering light (NTU); drinking water <1 NTU
- Color: True (dissolved) vs apparent (suspended); Hazen units
- Odour
  taste: H S (rotten egg), algal metabolites

Key Definition

Turbidity: Suspended particles scattering light (NTU); drinking water <1 NTU

Source Coverage

Frames 3–4 (reference for further study)

Topic 2: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 5–6 (reference for further study)

Topic 3: Key Concepts

Key Topics

- Free CO : $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + H_2O$
- Temp. Ca^2 : $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$
- Temp. Mg^2 : $Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + Mg(OH)_2 \downarrow + 2H_2O$

Key Definition

Free CO : $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + H_2O$

Source Coverage

Frames 7–8 (reference for further study)

Topic 4: Key Concepts

Key Topics

- Simple operation, no sludge
- Complete softening possible
- Regeneration is easy (NaCl)

Key Definition

Simple operation, no sludge

Source Coverage

Frames 9–10 (reference for further study)

Topic 5: Key Concepts

Key Topics

- Dissolved salts (TDS reduction >95
- Bacteria, viruses
- Heavy metals (Pb, As, Hg)

Key Definition

Dissolved salts (TDS reduction >95

Source Coverage

Frames 11–12 (reference for further study)

Topic 6: Key Concepts

Key Topics

- Coagulation: Alum Al (SO) $\rightarrow$ Al(OH) gel adsorbs colloidal particles
- Disinfection (chlorination): Cl + H O $\rightarrow$ HOCl + HCl; HOCl kills pathogens; residual Cl maintained 0.2–0.5 mg/L
- Breakpoint chlorination: Add Cl until all NH oxidized + free Cl residual appears

Key Definition

Coagulation: Alum Al (SO) $\rightarrow$ Al(OH) gel adsorbs colloidal particles

Source Coverage

Frames 13–14 (reference for further study)

Topic 7: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 15–17 (reference for further study)

Topic 8: Key Concepts

Key Topics

- Thermal insulation: scale ($k \approx 0.1$–2 W/mK) vs steel (≈ 50 W/mK) $\rightarrow$ poor heat transfer
- Overheating of boiler walls $\rightarrow$ metal weakening
- Risk of explosion

Key Definition

Thermal insulation: scale ($k \approx 0.1$–2 W/mK) vs steel (≈ 50 W/mK) $\rightarrow$ poor heat transfer

Source Coverage

Frames 18–19 (reference for further study)

Topic 9: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 20–21 (reference for further study)

Topic 10: Key Concepts

Key Topics

- Land application: Biosolids as agricultural fertilizer (if heavy metal limits met)
- Landfill: Dewatered cake disposal
- Incineration: High energy; reduces volume 90

Key Definition

Land application: Biosolids as agricultural fertilizer (if heavy metal limits met)

Source Coverage

Frames 22–23 (reference for further study)

Topic 11: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 24–25 (reference for further study)

Topic 12: Key Concepts

Key Topics

- Mandatory for textile, pharma, tannery in India (CPCB norms)
- Uses evaporators, crystallizers, RO in sequence

Key Definition

Mandatory for textile, pharma, tannery in India (CPCB norms)

Source Coverage

Frames 26–27 (reference for further study)

Topic 13: Key Concepts

Key Topics

- PYQ short
  7-mark questions
- More hardness + lime-soda numericals
- Boiler scale numericals

Key Definition

PYQ short
7-mark questions

Source Coverage

Frames 28–29 (reference for further study)

Topic 14: Key Concepts

Key Topics

- Nalgonda technique: Alum + lime $\rightarrow$ floc adsorbs F ; low cost, widely used in India
- Activated alumina (AA): F adsorbed on Al O ; regenerated with NaOH + H SO
- RO: Removes >95

Key Definition

Nalgonda technique: Alum + lime $\rightarrow$ floc adsorbs F ; low cost, widely used in India

Source Coverage

Frames 30–32 (reference for further study)

Topic 15: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 33–34 (reference for further study)

Topic 16: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 35–36 (reference for further study)

Topic 17: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 37–38 (reference for further study)

Topic 18: Key Concepts

Key Topics

- Forgetting $CaCO_3$ equivalent in ppm formula
- Confusing bicarbonates = temporary with chlorides/sulphates = permanent
- Zeolite regenerated by NaCl, not Na_2CO_3

Key Definition

Forgetting $CaCO_3$ equivalent in ppm formula

Source Coverage

Frames 39–40 (reference for further study)

Topic 19: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 41–42 (reference for further study)

Topic 20: Key Concepts

Key Topics

- Hardness ppm = (mg/L $\times$ 100) / MW of salt as $CaCO_3$
- 1 ppm = 0.1°F = 0.07°Cl = 0.056°d
- Temporary hardness = bicarbonate salts; removed by boiling

Key Definition

Hardness ppm = (mg/L $\times$ 100) / MW of salt as $CaCO_3$

Source Coverage

Frames 43–44 (reference for further study)

Topic 21: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 45–47 (reference for further study)

Topic 22: Key Concepts

Key Topics

- Seawater desalination (SWRO)
- Brackish water treatment
- Boiler feed water production

Key Definition

Seawater desalination (SWRO)

Source Coverage

Frames 48–49 (reference for further study)

Topic 23: Key Concepts

Key Topics

- Groundwater over-extraction (Punjab, Rajasthan, UP)
- River pollution (Ganga, Yamuna)
- Industrial effluents in water bodies

Key Definition

Groundwater over-extraction (Punjab, Rajasthan, UP)

Source Coverage

Frames 50–51 (reference for further study)

Topic 24: Key Concepts

Key Topics

- pH meter, conductivity meter, turbidimeter
- DO probe (polarographic or optical)
- TDS meter (conductivity-based)

Key Definition

pH meter, conductivity meter, turbidimeter

Source Coverage

Frames 52–53 (reference for further study)

Topic 25: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 54–55 (reference for further study)

Topic 26: Key Concepts

Key Definition

See materials for detailed content.

Source Coverage

Frames 56–57 (reference for further study)

Topic 27: Key Concepts

Key Topics

- Lime-soda process (all reactions + advantages)
- Zeolite process (reactions + regeneration)
- Boiler troubles and prevention (full table)

Key Definition

Lime-soda process (all reactions + advantages)

Source Coverage

Frames 58–60 (reference for further study)

Unit Summary & Revision

Next Steps

- Review all condensed frames above
- Compare with original full unit for deep understanding
- Practice worked examples and PYQ problems