Unit 1: Atomic Structure, Chemical Bonding & Solutions

Engineering Chemistry — DI01000071

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Unit 1 Roadmap (15-Frame Revision)

Syllabus Focus (GTU)

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

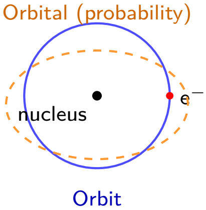
Exam Weightage

17% ($\approx$ 12 marks)

Study Strategy

Learn concepts + solve 3 numericals on concentration.

Orbit vs Orbital: Core Difference



Key Comparison

- **Orbit**: fixed path (Bohr idea), 2D picture.
- **Orbital**: probability region, 3D cloud.
- Orbit uses principal shell n; orbital uses s, p, d, f.
- Max electrons in shell $= 2n^2$; max in one orbital $= 2$.

Memory Hook

Orbit = *path*; Orbital = *probability cloud*.

Pauli, Hund, Aufbau: 3 Rules for Electron Filling

Rule 1: Pauli Exclusion Principle

One orbital holds max 2 electrons with opposite spins ($\uparrow\downarrow$).

Rule 2: Hund's Maximum Multiplicity

In same subshell, electrons occupy orbitals singly first, then pairing starts.

Rule 3: Aufbau Principle

Lower energy orbital fills first: $1s < 2s < 2p < 3s < 3p < 4s < 3d \ldots$

Exam Tip

Always justify **Cr** and **Cu** configurations using extra stability (half/full-filled *d*-subshell).

Electronic Configuration (Atomic Number 1–30)

Fast Method

- Write atomic number Z, then fill orbitals in Aufbau order.
- Respect Pauli + Hund during filling.
- Use noble gas core for compact form, e.g., $[Ar]\,4s^2\,3d^5$.

Important Configurations

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

Chemical Bond and Octet Rule

What is a Chemical Bond?

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

Octet Rule

Atoms tend to achieve 8 electrons in valence shell (noble gas-like stability).

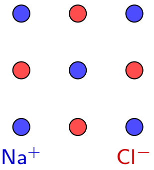
Why bond forms?

Because bonded state generally has **lower potential energy** than isolated atoms.

Exam Focus

Distinguish **bond formation mechanism** (electron transfer/sharing/delocalization) for each bond type.

Ionic (Electrovalent) Bond: NaCl Model



Formation

$$\mathrm{Na} \rightarrow \mathrm{Na}^{+} + \mathrm{e}^{-}, \qquad \mathrm{Cl} + \mathrm{e}^{-} \rightarrow \mathrm{Cl}^{-}$$

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

Characteristics

- High melting/boiling points
- Conductive in molten/aqueous state
- Usually soluble in polar solvents
- Brittle crystalline solids

Covalent Bond: Non-Polar vs Polar

Electron sharing bond

Covalent bond forms by **sharing** valence electrons.

Type	Meaning	Examples (GTU)
Non-polar	Equal sharing, no permanent dipole	H_2, O_2, N_2, CH_4
Polar	Unequal sharing due to EN difference	HCl, H_2O, NH_3

Quick Check

Greater electronegativity difference $\Rightarrow$ greater bond polarity.

Coordinate Bond, Metallic Bond, Hydrogen Bond, van der Waals

Coordinate (Dative) Bond

Shared pair is donated by one atom. Examples: NH_4^+, H_3O^+.

Metallic Bond

Positive metal ions in sea of delocalized electrons $\Rightarrow$ conductivity and malleability.

Hydrogen Bond

Inter- or intramolecular attraction involving H bonded to F/O/N.

van der Waals Forces

Weak intermolecular attractions; important in molecular solids and liquefaction behavior.

Types of Solids (1.5): One-Glance Table

Solid Type	**Constituent**	**Main Property**	**Example**
Ionic	Ions	Hard, high m.p., brittle	NaCl
Molecular	Molecules	Low m.p., soft-/volatile	I_2, Dry ice
Network	Covalent atoms	Very hard, very high m.p.	Diamond, SiO_2
Metallic	Metal cations + e^- sea	Conductive, malleable	Cu, Fe, Al

Why this table matters

Most 2-mark and 3-mark questions come from **property + example** comparisons.

Solutions: Basic Definitions (1.6)

Core Terms

- **Solute**: substance being dissolved.
- **Solvent**: medium that dissolves solute.
- **Solution**: homogeneous mixture of solute + solvent.
- **Concentration**: amount of solute in given amount of solution/solvent.

Daily Example

Salt water: salt = solute, water = solvent, mixture = solution.

Exam Pitfall

Always write concentration unit with numeric answer.

Concentration Units: Formula Sheet

Unit	Formula	Use Case
Molarity (M)	$M = \frac{\text{moles of solute}}{\text{litre of solution}}$	Lab solution prep
Normality (N)	$N = \frac{\text{gram equivalent}}{\text{litre of solution}}$	Acid-base/redox titration
Molality (m)	$m = \frac{\text{moles of solute}}{\text{kg of solvent}}$	Temp. independent measure
%w/w	$\frac{\text{mass of solute}}{\text{mass of solution}} \times 100$	Solid/liquid mixtures
%v/v	$\frac{\text{volume of solute}}{\text{volume of solution}} \times 100$	Liquid-liquid mixtures
%w/v	$\frac{\text{mass of solute(g)}}{\text{volume of solution(mL)}} \times 100$	Medical/lab labels

Worked Example: Molarity and %w/v

Q1

Find molarity of solution containing 5.85 g NaCl in 500 mL solution.

$$M = \frac{5.85/58.5}{0.5} = 0.2\ \mathrm{M}$$

Q2

10 g glucose in 200 mL solution. Find %w/v.

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

Scoring Rule

Write given data, formula, substitution, unit — this alone improves marks significantly.

How to Solve Any Unit-1 Problem (Flow)

Identify topic: atomic / bond / solid / solution

↓

Write principle/rule (Pauli, Hund, octet, formula)

↓

Apply with one proper example or calculation

↓

Conclude with property/units and final statement

PYQ Readiness

Practice: Cr/Cu e-config, NaCl bond characteristics, solids comparison, concentration numericals.

Unit 1 Final Rapid Revision

Must Remember

- Orbit vs orbital
- Pauli + Hund + Aufbau
- Bond types and examples
- 4 solid structures
- 6 concentration expressions

2-Hour Revision Plan

- 35 min: atomic structure
- 35 min: bonding + solids
- 35 min: concentration numericals
- 15 min: self-test from PYQ

Outcome Check

If you can explain each box in your own words, Unit 1 is exam-ready.

Unit 2: Electrochemistry

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Unit 2 Roadmap (15-Frame Revision)

Syllabus Flow

2.1–2.2	Ionization, oxidation, reduction, redox
2.3–2.5	Galvanic/electrolytic cells, EMF, Nernst equation
2.6–2.8	Conductance, conductivity, Kohlrausch law, applications
2.9–2.13	Electrolysis, Faraday laws, electroplating, refining, electrometallurgy

Exam Weightage

15% (about 11 marks)

Scoring Focus

Diagram + formula + one solved application.

Arrhenius Theory of Ionization

Main Statement

Electrolytes dissociate into ions in water; ions carry current.

Examples

$$NaCl \rightarrow Na^{+} + Cl^{-} \qquad HCl \rightarrow H^{+} + Cl^{-}$$

Strong vs Weak Electrolyte

Strong electrolytes ionize nearly completely; weak electrolytes ionize partially.

Remember

Conductivity depends on number and mobility of ions.

Oxidation, Reduction and Redox

Term	Electron View	Oxidation Number View
Oxidation	Loss of electrons	Increase in oxidation number
Reduction	Gain of electrons	Decrease in oxidation number
Redox reaction	Oxidation and reduction together	Electron transfer occurs

Example

$\mathrm{Zn} + \mathrm{Cu}^{2+} \rightarrow \mathrm{Zn}^{2+} + \mathrm{Cu}$
Zn is oxidized, Cu^{2+} is reduced.

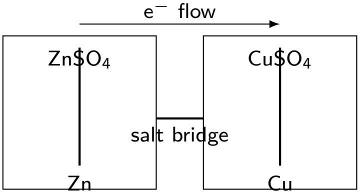
Galvanic Cell vs Electrolytic Cell

Point	**Galvanic Cell**	**Electrolytic Cell**
Energy conversion	Chemical to electrical	Electrical to chemical
Spontaneity	Spontaneous	Non-spontaneous
External source	Not required	Required (DC supply)
Anode sign	Negative	Positive
Cathode sign	Positive	Negative

Quick Rule

Oxidation always at anode, reduction always at cathode (in both cells).

Daniell Cell Diagram and EMF



Cell Notation

$\mathrm{Zn|Zn^{2+}||Cu^{2+}|Cu}$

EMF

$$E_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

Nernst Equation and Uses

At 298 K

$$E = E^\circ - \frac{0.0591}{n} \log Q$$

where n = electrons transferred, Q = reaction quotient.

Applications

- Calculate cell potential at non-standard concentration.
- Predict reaction direction.
- Find ionic concentration and pH in electrochemical systems.

Exam Tip

First write balanced redox equation, then identify n, then substitute.

Conductance and Conductivity

Quantity	**Symbol**	**Definition**
Resistance	R	Opposition to current flow
Conductance	$G = 1/R$	Ease of current flow
Specific conductivity	κ	Conductance of 1 cm cube of solution
Molar conductivity	Λ_m	Conductivity per mole of electrolyte

Trend

On dilution: κ decreases but Λ_m increases.

Kohlrausch Law of Independent Migration of Ions

Statement

At infinite dilution, each ion contributes independently to total molar conductivity.

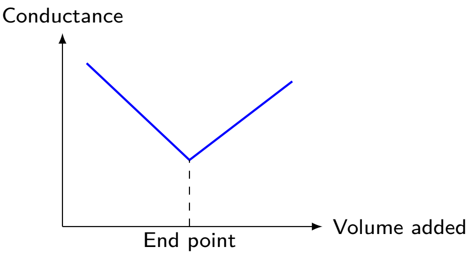
Expression

$$\Lambda_m^\circ = \nu_+ \lambda_+^\circ + \nu_- \lambda_-^\circ$$

Why important?

Used to determine Λ_m° of weak electrolytes and degree of dissociation.

Applications of Conductance Measurements



Major Applications

- Determine end point in conductometric titration.
- Check purity of water.
- Determine dissociation constant of weak acids.
- Determine solubility and ionic product.

Electrolysis and Faraday Laws

Electrolysis

Chemical decomposition due to passage of electric current.

Faraday First Law

Mass deposited m is directly proportional to charge Q:

$$m = ZIt$$

Faraday Second Law

For same charge, masses deposited are proportional to equivalent weights.

Unit Check

$Q = It$ in coulomb, current in ampere, time in second.

Electrolysis Applications

Application	Purpose
Electroplating	Protective + decorative metal coating
Electrorefining	Purification of metals (Cu, Ag, Au)
Electrometallurgy	Extraction of reactive metals (Al, Na, Mg)
Manufacture of chemicals	Cl_2, NaOH, H_2, O_2 production

Industrial Insight

Process control depends on current density, electrolyte concentration and temperature.

Electroplating Process Flow

Surface cleaning and degreasing

↓

Acid pickling and rinsing

↓

Electroplating in electrolyte bath

↓

Final washing, drying, polishing

Exam Question Type

Draw labeled setup and explain purpose of anode, cathode and electrolyte.

Electrometallurgy vs Electrorefining

Point	Electrometallurgy	Electrorefining
Objective	Extract metal from ore/molten salt	Purify impure metal
Feed material	Ore or fused electrolyte	Impure metal anode
Product location	Cathode deposition or molten metal	Pure metal at cathode
Example	Al from alumina	Cu refining

Memory Line

Extraction = electrometallurgy; purification = electrorefining.

Unit 2 Final Rapid Revision

Must Remember

- Arrhenius ionization concept
- Galvanic vs electrolytic differences
- EMF and Nernst equation
- Faraday laws
- Plating/refining/metallurgy uses

Practice Set

- 1 derivation: Nernst equation
- 1 numerical: Faraday law
- 1 labeled diagram: Daniell cell
- 1 short note: electroplating

Outcome Check

If you can explain each table and formula without notes, Unit 2 is exam-ready.

Unit 3: Corrosion of Metals and Its Prevention

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Unit 3 Roadmap (15-Frame Revision)

Syllabus Flow

3.1	Corrosion definition and examples
3.2	Dry (chemical) corrosion: oxidation and gas corrosion
3.3	Wet (electrochemical) corrosion: H_2 and O_2 mechanisms
3.4–3.6	Factors, prevention, cathodic protection methods

Exam Weightage

12% (about 8 marks)

High-Score Areas

Mechanisms + prevention tables + labeled sketches.

What is Corrosion?

Definition

Corrosion is gradual destruction of metal by chemical/electrochemical reaction with environment.

Daily Examples

Rusting of iron, tarnishing of silver, green layer on copper.

Why engineers care

Corrosion causes material failure, safety risk, production loss and high maintenance cost.

Key Idea

Corrosion is thermodynamically favorable; prevention is about slowing reaction kinetics.

Dry (Chemical) Corrosion

Type	Medium	Example/Feature
Oxidation corrosion	O_2, high temperature	Scale formation on metals
Corrosion by gases	SO_2, H_2S, halogens	Sulfide/chloride film formation

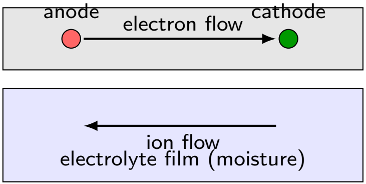
Protective Oxide Film

Compact, adherent film can protect (e.g., Al_2O_3); porous film cannot protect.

Typical Reaction

$2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$

Wet (Electrochemical) Corrosion: Basic Model



Anodic Reaction

$M \rightarrow M^{n+} + ne^-$

Cathodic Reaction

Reduction of H^+ or O_2 in electrolyte.

Hydrogen Evolution Corrosion

Acidic Medium Mechanism

$$\text{Anode: } Fe \rightarrow Fe^{2+} + 2e^-$$
$$\text{Cathode: } 2H^+ + 2e^- \rightarrow H_2 \uparrow$$

Overall

$Fe + 2H^+ \rightarrow Fe^{2+} + H_2 \uparrow$

Typical Case

Iron in acidic solution where dissolved oxygen is low.

Oxygen Absorption Corrosion (Rusting)

Neutral/Alkaline Medium

$$\text{Anode: } Fe \rightarrow Fe^{2+} + 2e^-$$

$$\text{Cathode: } O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

Rust Formation Path

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2 \rightarrow Fe_2O_3 \cdot xH_2O$

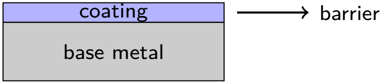
Memory Hook

Presence of moisture + oxygen accelerates rusting quickly.

Factors Affecting Corrosion

Factor	Effect on Corrosion
Purity of metal	Impurities create local galvanic cells, rate increases
Relative electrode potential	More active metal corrodes faster
Nature of oxide film	Porous film increases, compact film decreases corrosion
pH of medium	Acidic medium usually increases corrosion
Temperature and humidity	Higher values increase reaction rate
Differential aeration	Less oxygen area becomes anodic and corrodes

Prevention: Surface Coatings



Protective Coatings

- Painting and polymer coating
- Galvanizing (Zn coating on iron)
- Electroplating (Ni/Cr on steel)
- Anodizing (thick oxide film on Al)

Rule

Coating must be continuous; small pores can create severe localized attack.

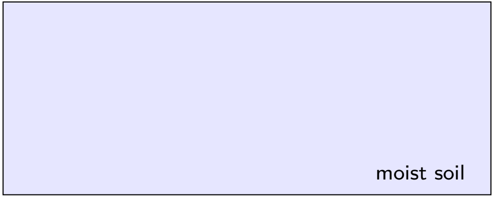
Cathodic Protection Methods

Method	Principle	Typical Use
Sacrificial anode	Attach more active metal (Zn/Mg)	Pipelines, ship hull
Impressed current	External DC keeps structure cathodic	Buried tanks, long pipelines

Core Objective

Force protected structure to behave as cathode so oxidation does not occur there.

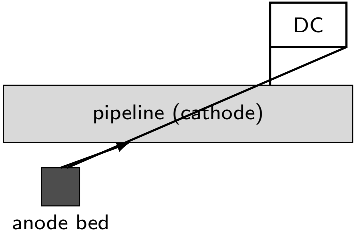
Sacrificial Anode: Labeled Sketch



Key Point

Sacrificial metal corrodes first; structure life increases significantly.

Impressed Current Cathodic Protection



Used When

- Structure is very large
- Current demand is high
- Long-term control needed

Prevention Strategy Selection Table

Condition	Best Method	Reason
Atmospheric steel parts	Paint + galvanizing	Low-cost barrier and Zn protection
Underground pipeline	Cathodic protection	Controls electro-chemical attack
Marine structures	Coating + sacrificial anode	High chloride environment
Aluminum body parts	Anodizing	Stable oxide layer

Exam Tip

Always justify method selection with environment and economics.

Typical 4-Mark Answer Structure

How to write full marks answer

- Start with clear definition.
- Draw neat labeled mechanism diagram.
- Write anodic and cathodic half-reactions.
- End with one practical prevention method.

Most Asked

Oxygen absorption corrosion and cathodic protection.

Unit 3 Final Rapid Revision

Must Remember

- Dry vs wet corrosion
- H_2 evolution mechanism
- O_2 absorption mechanism
- Corrosion factors
- Cathodic protection methods

Revision Task

- Draw 2 mechanism diagrams
- Learn 1 comparison table
- Memorize 1 prevention flow

Outcome Check

If you can explain "why corrosion occurs" and "how to stop it", Unit 3 is ready.

Unit 4: Fuels and Combustion

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Unit 4 Roadmap (15-Frame Revision)

Syllabus Flow

4.1–4.2	Fuel definition, classification, calorific value
4.3–4.6	Bomb calorimeter, good fuel, Dulong formula
4.7–4.9	Solid, liquid and gaseous fuels
4.10	LPG/CNG/Biogas calorific values and applications

Exam Weightage

14% (about 10 marks)

Scoring Focus

Fuel comparison tables + one calorific value numerical.

Fuel: Definition and Classification

Definition

Fuel is a substance that releases usable heat energy on combustion.

Basis	Type	Examples
Physical state	Solid	Coal, wood, coke
Physical state	Liquid	Petrol, diesel, kerosene
Physical state	Gaseous	LPG, CNG, biogas, producer gas
Source	Primary/secondary	Natural gas / coke, charcoal

Remember

Engineering preference: cleaner combustion, high calorific value, low residue.

Calorific Value and Units

Key Terms

- **HCV** (Gross CV): includes latent heat of steam formed.
- **LCV** (Net CV): excludes latent heat of steam.

Relationship

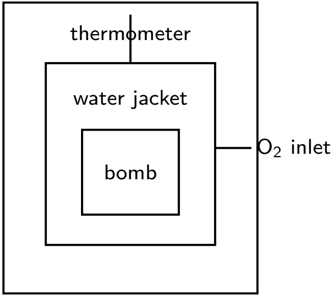
$$\mathrm{LCV} = \mathrm{HCV} - 0.09\mathrm{H} \times 587 \text{ kcal/kg}$$

where H is percentage hydrogen.

Units

- kcal/kg
- kJ/kg
- MJ/kg
- kcal/m^3 for gases

Bomb Calorimeter: Principle and Setup



Working Steps

- Burn known fuel mass in oxygen.
- Measure rise in water temperature.
- Compute heat released.

Exam Note

Diagram labeling is mandatory for full marks.

Characteristics of a Good Fuel

Property	Reason
High calorific value	More heat per unit mass/volume
Moderate ignition temperature	Easy to ignite, safe to handle
Low moisture and ash	Better combustion efficiency
Low smoke and toxic gases	Cleaner environment
Easy storage and transport	Practical industrial use
Economical and available	Sustainable operation

Quick Line

Best fuel gives high heat with low pollution and low handling cost.

Solid vs Liquid vs Gaseous Fuel

Point	Solid	Liquid	Gaseous
Handling	Difficult	Moderate	Easy
Combustion control	Poor	Better	Best
Ash/smoke	High	Medium	Very low
Calorific value	Lower	Higher	High and clean
Storage	Easy but bulky	Tank required	Cylinder/pipeline

Conclusion

For clean combustion and process control, gaseous fuels are preferred.

Dulong Formula for Theoretical HCV

Formula

$$\mathrm{HCV} = \frac{1}{100}\left[8080\mathrm{C} + 34500\left(\mathrm{H} - \frac{\mathrm{O}}{8}\right) + 2240\mathrm{S}\right]\ \mathrm{kcal/kg}$$

where C, H, O, S are mass percentages of carbon, hydrogen, oxygen and sulfur.

Use

Estimate calorific value from ultimate analysis data.

Common Mistake

Do not forget $\left(H - \frac{O}{8}\right)$ correction term.

Coal: Classification and Analysis

Coal Rank

Peat $<$ Lignite $<$ Bituminous $<$ Anthracite

Ultimate Analysis

Elemental composition: C, H, N, S, O

Proximate Analysis

Moisture, volatile matter, ash, fixed carbon

Why needed?

Predict fuel quality, furnace design and pollution behavior.

Petroleum and Fuel Rating

Petroleum Processing

Origin of petroleum $\rightarrow$ fractional distillation $\rightarrow$ products (LPG, petrol, kerosene, diesel, lubricating oil).

Fuel Rating	**Meaning**
Octane number	Anti-knock quality of petrol (spark ignition engine)
Cetane number	Ignition quality of diesel (compression ignition engine)

Memory Hook

Petrol: higher octane is better. Diesel: higher cetane is better.

Gaseous Fuels: Types and Features

Fuel	**Main Component**	**Typical Use**
Natural gas	CH_4-rich	Industrial heating, power
LPG	Propane + butane	Domestic cooking, vehicles
CNG	Methane compressed	Transport fuel
Producer gas	$CO + N_2$	Industrial furnace
Water gas	$CO + H_2$	Synthesis fuel
Biogas	$CH_4 + CO_2$	Rural cooking, small plants

LPG, CNG, Biogas: Calorific Value and Applications

Fuel	Approx. CV	Applications
LPG	11000–12000 kcal/kg	Domestic cooking, hotel kitchens
CNG	9000–11000 kcal/m^3	Buses, cars, city transport
Biogas	4500–6000 kcal/m^3	Rural cooking, community energy

Green Choice

CNG and biogas reduce particulate emission compared with coal and diesel.

Combustion Efficiency Flow

Select suitable fuel (high CV, low pollutants)

Ensure proper air-fuel ratio

Complete combustion and heat transfer

Lower fuel cost and lower emissions

Exam-Oriented Numerical Template

Dulong-based Problem

Steps:

- Write C, H, O, S percentages.
- Substitute in HCV formula.
- Compute LCV from HCV using hydrogen correction.
- Report final unit clearly (kcal/kg or kJ/kg).

Most Common Error

Missing unit conversion and wrong decimal placement.

Unit 4 Final Rapid Revision

Must Remember

- Fuel classification
- HCV vs LCV
- Bomb calorimeter sketch
- Dulong formula
- Octane and cetane numbers

Practice

- 1 bomb calorimeter question
- 1 Dulong numerical
- 1 fuel comparison table

Outcome Check

If you can justify fuel choice for a given application, Unit 4 is exam-ready.

Unit 5: Lubricants

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Unit 5 Roadmap (15-Frame Revision)

Syllabus Flow

5.1–5.2	Lubricants, lubrication functions and mechanisms
5.3	Classification: solid, semi-solid, liquid, synthetic
5.4–5.5	Physical and chemical properties
5.6–5.7	Selection for machinery and biodegradable lubricants

Exam Weightage

10% (about 7 marks)

Scoring Focus

Property definitions + selection table + test methods.

Lubricants and Lubrication: Basics

Definition

Lubricant is a substance introduced between moving surfaces to reduce friction, wear and heat.

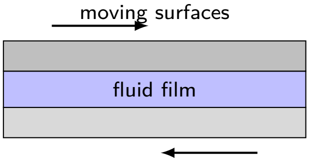
Functions

- Reduce friction and wear
- Remove heat from contact zone
- Protect against corrosion
- Seal clearances and reduce noise

Key Idea

Good lubrication increases machine life and decreases energy loss.

Mechanism: Fluid and Boundary Lubrication



Fluid Lubrication

Full fluid film separates surfaces.

Boundary Lubrication

Thin adsorbed layer works when load is high and speed is low.

Classification of Lubricants

Type	Nature	Examples
Solid	Layered or soft solids	Graphite, MoS_2
Semi-solid	Grease form	Calcium/sodium greases
Liquid	Mineral/vegetable oils	Engine oil, turbine oil
Synthetic	Chemically designed oils	Silicone, ester oils

Selection Thumb Rule

High load and high temperature systems often need additives or synthetic oils.

Physical Property: Viscosity and Viscosity Index

Viscosity

Resistance offered by fluid to flow; crucial for load-carrying oil film.

Viscosity Index (VI)

Indicates change of viscosity with temperature.

- High VI: small change with temperature (preferred).
- Low VI: large change with temperature.

Machine View

Low viscosity causes wear; very high viscosity causes power loss.

Physical Properties: Flash/Fire/Cloud/Pour/Oiliness

Property	**Meaning**
Flash point	Lowest temperature at which vapors ignite momentarily
Fire point	Temperature at which vapors burn continuously
Cloud point	Temperature where wax first appears (cloudy look)
Pour point	Lowest temperature at which oil still flows
Oiliness	Ability to adhere and maintain film under load

Chemical Properties of Lubricants

Property	Indicates	Importance
Saponification number	Ester/fatty content	Useful for vegetable oils
Neutralization number	Acidic or basic impurities	Corrosion tendency
Emulsification number	Tendency to form emulsion with water	Suitability in wet systems

Interpretation

Lower acid value and controlled emulsification are generally preferred for machine health.

Selection of Lubricants for Machinery

Machine	Requirement	Typical Lubricant
Gears	EP performance, load capacity	Gear oil with additives
Cutting tools	Cooling + lubrication	Cutting fluid/emulsion
Steam turbine	Oxidation stability, low sludge	Turbine oil
Transformer	Electrical insulation + cooling	Transformer mineral oil

Exam Pattern

Often asked: "select suitable lubricant and justify".

Biodegradable Lubricants

Definition

Lubricants that break down naturally by microbial action with lower environmental impact.

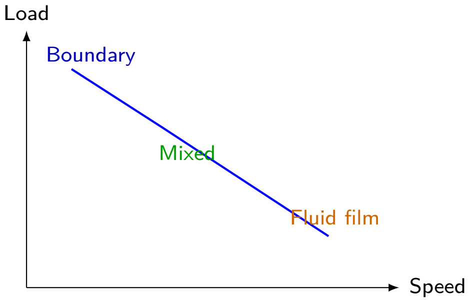
Advantages

- Reduced soil and water contamination
- Better sustainability compliance
- Suitable for agriculture and eco-sensitive zones

Limitation

Oxidation stability and cost can be concerns in some applications.

Lubrication Regime Map (Speed vs Load)



Interpretation

Low speed/high load tends to boundary regime; high speed favors fluid film lubrication.

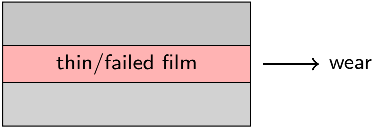
Property Tests Often Linked to Practicals

Test	Outcome
Redwood viscometer test	Viscosity behavior of oil
Flash and fire point test	Safe operating temperature range
Acid value test	Acidity and deterioration level
Saponification value test	Ester content indication

Lab to Theory Link

Practical observations directly explain machine lubrication choices.

Failure If Wrong Lubricant Is Selected



Possible Problems

- Excessive friction and temperature
- Surface scoring and wear
- Corrosion and sludge formation
- Power loss and vibration

Exam-Ready Short Notes

2-mark and 3-mark preparation

- Define viscosity index with significance.
- Differentiate flash point and fire point.
- Write any four functions of lubricants.
- Explain fluid and boundary lubrication with sketch.
- Write notes on biodegradable lubricants.

Unit 5 Final Rapid Revision

Must Remember

- Functions of lubricants
- Fluid vs boundary mechanism
- Classification with examples
- Key physical and chemical properties
- Machine-wise lubricant selection

Quick Practice

- Draw one lubrication sketch
- Learn one property table
- Solve one selection case

Outcome Check

If you can select lubricant by property and operating condition, Unit 5 is ready.

Unit 6: Polymers, Elastomers, Insulating Materials and Semiconductors

Engineering Chemistry — DI01000071

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May 1, 2026

Unit 6 Roadmap (15-Frame Revision)

Syllabus Flow

6.1–6.7	Polymers: definitions, classification, polymerization, examples
6.8–6.10	Elastomers: natural rubber, vulcanization, synthetic rubbers
6.11–6.12	Insulating materials: types, properties, applications
6.13–6.15	Semiconductors: types, devices, intrinsic/extrinsic

Exam Weightage

20% (about 14 marks)

Scoring Focus

Classification tables + polymer examples + semiconductor sketch.

Polymer Basics: Core Definitions

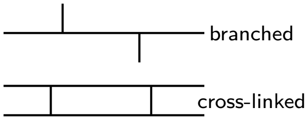
Term	Meaning
Monomer	Small molecule capable of joining repeatedly
Polymer	High molecular mass chain of repeating units
Polymerization	Process of converting monomers to polymer
Degree of polymerization (n)	Number of repeating units in chain
Repeating unit	Structural unit repeated along polymer chain

Simple Notation

$\mathrm{n(CH_2{=}CH_2) \rightarrow (-CH_2 - CH_2-)_n}$ (polyethylene)

Classification by Molecular Structure

Type	Feature
Linear	Long straight chains
Branched	Side branches present
Cross-linked	Network with bridges



Other Polymer Classifications

Basis	Type	Example
Monomer type	Homopolymer	Polyethylene (PE)
Monomer type	Copolymer	Buna-S rubber
Thermal behavior	Thermoplastic	PE, PP, PVC, PTFE
Thermal behavior	Thermosetting	Bakelite, Epoxy resin

Memory Hook

Thermoplastics soften repeatedly on heating; thermosets do not.

Addition vs Condensation Polymerization

Addition Polymerization

- Unsaturated monomers
- No by-product
- Example: PE, PP, PVC

Condensation Polymerization

- Bi/tri-functional monomers
- Small molecule by-product (H_2O, HCl)
- Example: Bakelite, Nylon

Exam Tip

Always mention monomer type and by-product difference.

Thermoplastic Polymers: Key Uses

Polymer	Property	Typical Use
PE	Flexible, chemical resistant	Packaging, containers
PP	Tough, light weight	Auto parts, fibers
PVC	Rigid or flexible, durable	Pipes, cable insulation
PTFE	Very low friction, inert	Non-stick coating, seals

More Polymer Examples: PS, PAN, Bakelite, Epoxy

Material	Nature	Use
Polystyrene (PS)	Thermoplastic	Disposable cups, insulation
PAN	Fiber-forming polymer	Acrylic fibers, textiles
Bakelite	Thermosetting	Switches, handles, electrical parts
Epoxy resin	Thermosetting adhesive	Coatings, composites, PCB use

Exam Pattern

Often asked: “properties and uses” for any two polymers.

Biodegradable Polymers

Definition

Polymers that degrade by microbial/enzymatic action to safer products.

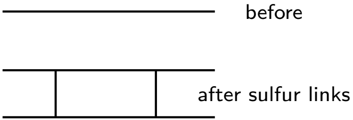
Syllabus Examples

PHBV and Nylon-2-nylon-6.

Why important?

Reduce long-term plastic waste and improve sustainability in packaging and biomedical fields.

Elastomers: Natural Rubber and Vulcanization



Natural Rubber

Polyisoprene with high elasticity but poor thermal and oil resistance.

Vulcanization

Heating rubber with sulfur forms cross-links, improving strength, elasticity and wear resistance.

Synthetic Rubbers: Buna-S, Buna-N, Neoprene

Rubber	Special Property	Use
Buna-S (GR-S)	Good abrasion resistance	Tyres, footwear
Buna-N (GR-A)	Oil and fuel resistance	Gaskets, hoses, seals
Neoprene (GR-M)	Heat and weather resistance	Belts, cable jackets

Insulating Materials: Types and Properties

Definition

Materials that resist flow of heat or electricity, depending on intended insulation.

Type	**Property Needed**	**Example**
Electrical insulator	High resistivity, dielectric strength	Porcelain, mica, PVC
Thermal insulator	Low thermal conductivity	Glass wool, asbestos substitute

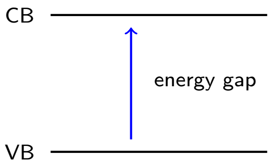
Applications of Insulating Materials

Domain	**Applications**
Electrical systems	Cable insulation, switchgear, transformer insulation
Thermal systems	Furnace lining, boilers, refrigeration insulation
Electronics	PCB substrate, semiconductor packaging supports
Buildings	Roof/wall thermal control for energy saving

Design Goal

Select material based on both operating temperature and electrical stress.

Semiconductors: Classification and Devices



Types

- Intrinsic semiconductor (pure Si/Ge)
- Extrinsic semiconductor
- n-type (donor doped)
- p-type (acceptor doped)

Enlist Devices

Diode, transistor, LED, solar cell, integrated circuits.

Unit 6 Final Rapid Revision

Must Remember

- Polymer definitions and classifications
- Addition vs condensation polymerization
- Key polymers with uses
- Vulcanization and synthetic rubbers
- Insulator and semiconductor basics

Practice Set

- 2 classification tables
- 1 polymerization comparison
- 1 semiconductor labeled sketch

Outcome Check

If you can map materials to applications correctly, Unit 6 is exam-ready.

Unit 7: Electrochemical Energy Sources

Engineering Chemistry — DI01000071

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Unit 7 Roadmap (15-Frame Revision)

Syllabus Flow

7.1	Batteries: primary, secondary and fuel cells
7.2–7.4	Dry cell, lead-acid cell, nickel-cadmium cell
7.5	Hydrogen-oxygen fuel cell, pros and cons
7.6	Solar cell construction, working and applications

Exam Weightage

12% (about 8 marks)

Scoring Focus

Construction + working diagrams and comparison tables.

Batteries as Electrochemical Energy Sources

Definition

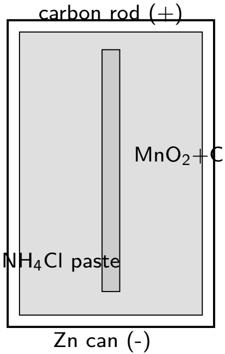
Battery converts chemical energy into electrical energy through redox reactions.

Type	**Rechargeable?**	**Examples**
Primary cell	No	Dry cell, alkaline cell
Secondary cell	Yes	Lead-acid, Ni-Cd, Li-ion
Fuel cell	Continuous fuel feed	H_2-O_2 fuel cell

Memory Hook

Primary = single use; Secondary = recharge; Fuel cell = reactants supplied continuously.

Dry Cell: Construction



Main Parts

- Zinc container (anode)
- Carbon rod (cathode collector)
- Electrolyte paste
- MnO_2 depolarizer

Dry Cell: Working and Characteristics

Working

Chemical reactions produce about 1.5 V cell potential.

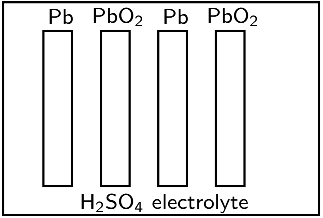
Characteristics

- Low cost and portable
- Cannot be recharged
- Suitable for low current devices

Typical Uses

Flashlights, clocks, remote controls and small electronic gadgets.

Lead-Acid Storage Cell: Construction



Basics

- Negative plate: Pb
- Positive plate: PbO_2
- Electrolyte: sulfuric acid

Lead-Acid Cell: Working

Discharge Reaction

$$Pb + PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$$

Important Features

- Rechargeable secondary cell
- Nominal voltage about 2 V per cell
- High surge current capability

Applications

Automotive batteries, UPS, backup power systems.

Nickel-Cadmium (Ni-Cd) Cell

Part	Description
Positive electrode	$NiO(OH)/Ni(OH)_2$
Negative electrode	$Cd/Cd(OH)_2$
Electrolyte	KOH solution
Nominal voltage	About 1.2 V per cell

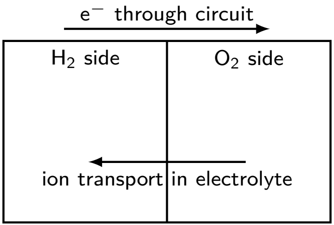
Pros and Cons

- Strong cycle life and reliability
- Good low-temperature behavior
- Cadmium toxicity is a major limitation

Battery Type Comparison

Type	Recharge?	Voltage	Typical Use
Dry cell	No	1.5 V	Portable low-load devices
Lead-acid	Yes	2.0 V/cell	Vehicle and UPS
Ni-Cd	Yes	1.2 V/cell	Emergency tools and backup
Fuel cell	Continuous	Depends on stack	High-efficiency power systems

Hydrogen-Oxygen Fuel Cell: Principle



Overall Reaction

$$2H_2 + O_2 \rightarrow 2H_2O$$

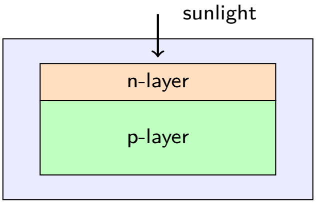
Merit

High efficiency and low pollution.

Fuel Cell: Advantages and Disadvantages

Advantages	**Disadvantages**
High efficiency conversion	High initial cost
Low emissions (water product)	Hydrogen storage and handling challenge
Quiet operation	Catalyst and system complexity
Continuous operation with fuel feed	Infrastructure dependency

Solar Cell: Construction and Working



Working

Light creates electron-hole pairs at p-n junction and generates DC output.

Applications

Rooftop systems, street lights, calculators, satellites.

Energy Source Selection Table

Need	Best Source	Reason
Portable low-cost use	Dry cell	Cheap and simple
Vehicle starting	Lead-acid	High surge current
Repeated cycle tool use	Ni-Cd	Rechargeable and robust
Clean continuous power	Fuel cell	High efficiency, low emission
Renewable daylight power	Solar cell	Direct sunlight conversion

Safety and Sustainability Notes

Battery Handling

- Avoid short circuit and overheating.
- Use proper charging profile for secondary cells.
- Handle acidic and alkaline electrolytes carefully.

Disposal and Recycling

Recycle lead-acid and Ni-Cd batteries through authorized channels to reduce heavy metal pollution.

Future Trend

Shift towards cleaner energy systems: fuel cells and solar technologies.

Unit 7 Final Rapid Revision

Must Remember

- Primary vs secondary vs fuel cell
- Dry cell and lead-acid construction
- Ni-Cd cell basics
- Fuel cell reaction and pros/cons
- Solar cell working

Practice Set

- Draw 2 labeled diagrams
- Learn 2 comparison tables
- Write 1 application-based answer

Outcome Check

If you can choose the right energy source for a use-case, Unit 7 is exam-ready.