H

Z = 1 · 1.008

42 chapters
500+ MCQs
10 visual atlases

NIRBHAY 90+

Complete Chemistry

A visual, classroom-ready reference for BPSC Prelims

FACULTY
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SERIES
72nd BPSC Prelims

STAGE 1 · FOUNDATION AUDIT

Analysis of the Science Quick-Recall Pack

The attached *BPSC Module 5 — Science Quick-Recall Pack* is a 30-page rapid-revision module covering Biology, Physics and Chemistry. Its Chemistry material sits inside Section 04 ("Chemistry & Physics — Quick Recall"). Below is a faithful audit of what it already carries, what is thin, and what a complete BPSC Chemistry reference must add.

1 · ALREADY COVERED

- 13 elements with symbols & atomic numbers (H, C, N, O, Na, Mg, Al, Si, Fe, Cu, Au, Hg, U)
- Latin-derived symbols (Na, Fe, Cu, Au, Hg)
- Common acids & bases (H_2SO_4, HCl, HNO_3, CH_3COOH, NaOH, $Ca(OH)_2$)
- Key compounds & common names ($CaCO_3$, CaO, $NaHCO_3$, Na_2CO_3, CO_2, NH_3, O_3)
- pH scale with biological values (blood, gastric, saliva)
- Allotropes of carbon, aqua regia, dry ice, ozone shield
- PYQ markers on high-yield facts

2 · COVERED TOO BRIEFLY

- Elements shown as a list only — no periodic-table structure, groups, periods or trends
- pH given as a strip — no logarithmic meaning, indicators or applications
- Compounds listed without preparation, reaction or exam-trap layer
- No chemical equations, reaction types or bonding
- No metallurgy, organic chemistry, polymers or electrochemistry
- No diagrams, experiments, mnemonics or MCQ practice

3 · MISSING LUCENT CHAPTERS (TO BE BUILT)

- States of matter & changes of state
- Atomic structure, isotopes, periodic table
- Chemical bonding & reactions; redox, corrosion, rancidity
- Metallurgy, alloys, non-metals & important elements
- Organic chemistry, fuels, polymers, soaps & food chemistry
- Fertilisers, water, air, green chemistry, batteries
- Radioactivity, discoveries, Nobel prizes, apparatus

4 · STATEMENTS NEEDING CARE

- **Aqua regia** is HNO_3:HCl = 1:3 (the pack once writes "3:1" — corrected here)
- "Diamond = hardest natural substance" — true naturally, but say *naturally occurring* (synthetic materials can be harder)
- Copper is best conductor *after silver* — keep the qualifier
- "Universal solvent" (water) — exam convention only; note the precise position
- pH values shift with concentration & temperature — flag as approximate

PROPOSED BUILD — SCOPE AT A GLANCE

42	≈420	≈180	≈150	500+	60–70
CHAPTERS	PAGES	DIAGRAMS	AUTHENTIC PYQS	ORIGINAL MCQS	TEACHING HOURS

Design direction carried over from the Quick-Recall Pack: letter-spaced fact-grid labels, PYQ chips, compact comparison tables, a restrained navy / ivory / rust / teal / gold palette, classical serif headings and monospaced formulas.

STAGE 2 · ARCHITECTURE

Complete Table of Contents

Twelve parts, forty-two chapters, ten visual atlases and twenty-five reference sections. Estimates per chapter: pages (Pg), teaching hours (Hr), diagrams (Dg), authentic PYQs (PYQ) and original MCQs (MCQ). Chapters marked ● are developed in this volume.

END MATTER (≈70 PAGES)

10 visual atlases · 25 reference sections (master charts, Top-100 traps / applications / PYQ concepts, 500-MCQ bank, 5 sectional tests, night-before revision, index, bibliography) · class-delivery schedules (20-class, 30-class, 10-class crash, 3-day revision).

STAGE 3 · DESIGN LANGUAGE

The Nirbhay 90+ Page System

Every chapter uses the same visual grammar, carried over from the Quick-Recall Pack and extended for a full reference. The components below appear throughout Chapters 1–5.

PYQ BIHAR CONCEPT REACTION FORMULA TRAP APPLICATION EXPERIMENT NOBEL DISCOVERY MEMORY HOOK FACULTY NOTE RAPID RECALL ⚠ SAFETY

DEFINITION BOX

DEFINITION · MATTER

Anything that has **mass** and occupies **space** (volume) is matter.

EQUATION BOX

Quicklime + Water ⟶ Slaked lime + Heat

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) + heat$$

Combination · Exothermic · hissing sound, vessel becomes hot

EXAM CONVENTION VS PRECISE POSITION

EXAM CONVENTION	SCIENTIFICALLY PRECISE
Diamond is the hardest natural substance.	Hardest *naturally occurring* material; some synthetic materials rival or exceed it.

DO-NOT-CONFUSE BOX

✕ **DO NOT CONFUSE**

Strong acid (fully ionises) is not the same as **concentrated acid** (little water). Dilute HCl is still a strong acid.

PART I · FOUNDATIONS OF CHEMISTRY

1 Nature and Scope of Chemistry

Everything you touched today — toothpaste, tea, fertiliser, phone battery — is applied chemistry.

WHY BPSC ASKS THIS
Branches, everyday chemicals and Indian contributions appear as one-line factual MCQs.

QUESTION FREQUENCY
Low directly (~1 Q), but this chapter's vocabulary underpins every other Chemistry question.

PREREQUISITES
None. Start here even if you last saw Chemistry in Class X.

YOU WILL BE ABLE TO
Name the branches, place any exam topic in its branch, and recall India's chemical heritage facts.

1.1 Concept Story — A Morning in Patna

At 6 a.m. an aspirant in Patna brushes with toothpaste (a mild **base** neutralising mouth acid), lights an LPG stove (**combustion** of butane), boils milk (heat changes its **proteins**), and adds a pinch of salt (**NaCl**, an ionic compound) to breakfast. Outside, a farmer spreads urea (**nitrogen fertiliser** made by the Haber process) while the municipal tanker chlorinates drinking water (**disinfection**). Chemistry is not a laboratory subject — it is the science of *every material and every change of material* around you. BPSC tests exactly this everyday layer.

1.2 What Chemistry Is

DEFINITION · CHEMISTRY
The branch of science that studies the **composition** (what a substance is made of), **structure** (how its particles are arranged), **properties** (how it behaves) and **transformations** (how it changes into other substances) of matter.

The word is commonly traced to *alchemy* (Arabic *al-kīmiyā*), the medieval quest to turn base metals into gold. Alchemists failed at gold but invented distillation, crystallisation and many apparatus we still use. Antoine **Lavoisier** (France, 18th century) turned this craft into a measuring science — he is called the **Father of Modern Chemistry** and gave the **Law of Conservation of Mass** (1789): matter is neither created nor destroyed in a chemical change.

1.3 Branches of Chemistry

BRANCH	STUDIES...	EXAM EXAMPLE
Physical	Energy, rates, states, structure of change	pH, catalysts, states of matter
Inorganic	All elements & compounds other than most carbon compounds	metals, ores, acids, salts
Organic	Carbon compounds (hydrocarbons and their derivatives)	LPG, alcohol, polymers
Analytical	What and how much is present in a sample	water testing, forensics
Biochemistry	Chemistry of living organisms	enzymes, vitamins, DNA
Environmental	Pollutants, air, water and soil chemistry	acid rain, ozone, AQI
Industrial	Large-scale manufacture of chemicals	cement, fertilisers, H_2SO_4
Nuclear	Changes in the nucleus; radioactivity	C-14 dating, U-235 fuel

MEMORY HOOK

"PIO ABEIN" — **P**hysical, **I**norganic, **O**rganic (the three classical branches), then **A**nalytical, **B**iochemistry, **E**nvironmental, **I**ndustrial, **N**uclear. Hindi cue: *"पियो — अब पीन"* क्रम याद रखें; कार्बन वाला = Organic, धातु/अम्ल वाला = Inorganic.

1.4 Chemistry Around Us — From Kitchen to Space Mission

KITCHEN
Baking soda releases CO_2; cooking gas burns; vinegar preserves pickles; iodised salt prevents goitre.

FARM
Urea & DAP feed crops; lime corrects acidic soil; neem-coated urea slows nitrogen loss.

HEALTH
Antacids neutralise HCl; ORS restores salts; antiseptics stop microbes; paracetamol lowers fever.

ADMINISTRATION
Water chlorination after floods; food-adulteration checks; fertiliser quality inspection.

INDUSTRY
H_2SO_4 — "king of chemicals"; cement for roads; ethanol from Bihar's sugar mills blends into petrol.

ENERGY
Li-ion batteries in phones & EVs; green hydrogen; coal combustion in thermal plants.

ENVIRONMENT
Ozone shield; greenhouse gases; arsenic testing of Gangetic groundwater.

SPACE
Cryogenic H_2/O_2 fuel in ISRO rockets; heat-shield ceramics; solid propellants.

1.5 Indian Contributions to Chemistry and Metallurgy

CONTRIBUTION	PERIOD / PERSON	WHY IT MATTERS FOR THE EXAM
Atomic idea (*Paramāṇu*)	Maharshi Kanada (Vaisheshika school), ancient India	Indian atomic concept predates Dalton — classic MCQ
Rasashastra (alchemy & medicine)	Nagarjuna (~8th–10th c. CE), *Rasaratnakara*	Mercury & metal preparations; "Indian alchemist" questions
Delhi Iron Pillar (~1,600 yrs, rust-resistant)	Gupta period ironworkers	Phosphorus-rich protective layer — corrosion chapter link
Wootz steel, zinc distillation (Zawar mines)	Ancient/medieval India	India distilled zinc centuries before Europe
Indigo & natural dyes, ayurvedic pharmacy	Ancient trade era	"Indigo" = India-linked dye; Bihar's colonial indigo (Champaran) link
Modern chemistry school in India	Acharya **P. C. Ray** — mercurous nitrite (1896); founded Bengal Chemicals (1901); *History of Hindu Chemistry*	"Father of Indian Chemistry" — repeated PCS question
Industrial research	Shanti Swarup **Bhatnagar** — first CSIR Director-General	Bhatnagar Prize named after him

CHEMISTRY IN A DISTRICT MAGISTRATE'S DAY

Morning: sign off on **chlorination** of flood-relief drinking water (disinfection chemistry). Noon: festival raid on a sweets shop — **food-adulteration** field kit detects starch in khoya (iodine turns blue-black). Evening: review a fertiliser dealer's stock — checking **urea neem-coating** compliance. One officer, three branches of chemistry before dinner.

1.6 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ State PCS pattern (repeated) · Easy

Who is regarded as the "Father of Modern Chemistry"?

(a) John Dalton
(b) Antoine Lavoisier ✓
(c) Robert Boyle
(d) Joseph Priestley

Why: Lavoisier introduced quantitative measurement, named oxygen and hydrogen, and stated conservation of mass. **Eliminate:** Dalton = atomic theory (1808); Boyle = often "father of *chemistry*" for separating it from alchemy — if both appear, prefer Lavoisier for "*modern* chemistry"; Priestley = co-discoverer of oxygen.

PYQ BPSC / state exams (asked in variants) · Easy

Acharya Prafulla Chandra Ray is associated with the discovery/synthesis of —

(a) Mercurous nitrite ✓
(b) Mercuric chloride
(c) Zinc oxide
(d) Ammonium nitrate

Why: P. C. Ray prepared stable mercurous nitrite ($Hg_2(NO_2)_2$) in 1896 and founded Bengal Chemical & Pharmaceutical Works — India's first pharma company.

1.7 Common Traps

1. **Organic ≠ "natural".** Organic chemistry = carbon compounds; plastic is organic, common salt is not.
2. CO, CO_2 and carbonates are carbon compounds but are studied as **inorganic** by convention.
3. **Lavoisier vs Dalton:** conservation of mass (Lavoisier) vs atomic theory (Dalton).
4. **P. C. Ray vs C. V. Raman:** Ray = chemistry (mercurous nitrite); Raman = physics (Raman effect, Nobel 1930).
5. **Alchemy ≠ chemistry:** alchemy was pre-scientific; chemistry began with measurement (Boyle → Lavoisier).

1.8 Faculty Classroom Notes & Delivery Plan

FACULTY NOTE

OPENING & BOARD PLAN (90 MIN)

1. Opening question: *"आज सुबह से आपने कौन-कौन से chemicals use किये?"* — collect 10 answers on the board.
2. Sort those answers into branches → derive the branches table live.
3. Board: definition of chemistry → 8 branches → Lavoisier → Indian timeline (Kanada → Nagarjuna → Iron Pillar → P. C. Ray).
4. Demonstration: vinegar + baking soda in a glass — "chemistry = change of substance," gas extinguishes a matchstick (CO_2 preview).

DOUBTS · RECAP · HOMEWORK

- Likely doubt: "Is water organic? It's natural!" — use it to fix the organic = carbon rule.
- Ask the class: "Urea in a field — which branches touch it?" (organic, industrial, environmental, agricultural).
- 5-min recap: branches mnemonic + 3 Indian-contribution facts.
- Homework: list 10 household substances with their branch; solve the 8 practice MCQs.
- Bridge: "Everything we listed is *matter* — but what exactly is matter? Chapter 2."

RAPID RECALL · CHAPTER 1

① Chemistry = composition + structure + properties + change of matter.
② Father of Modern Chemistry — **Lavoisier**; conservation of mass, 1789.
③ Boyle separated chemistry from alchemy (*The Sceptical Chymist*, 1661).
④ Organic = carbon compounds; CO, CO_2, carbonates treated as inorganic.
⑤ Paramāṇu concept — Maharshi **Kanada**.
⑥ Indian alchemist Nagarjuna — *Rasaratnakara*, mercury preparations.
⑦ Delhi Iron Pillar — rust-resistant Gupta-era iron.
⑧ India distilled **zinc** at Zawar before Europe.
⑨ **P. C. Ray** — mercurous nitrite (1896), Bengal Chemicals (1901), "Father of Indian Chemistry".
⑩ S. S. Bhatnagar — first D-G of CSIR; Bhatnagar Prize.
⑪ H_2SO_4 = "king of chemicals".
⑫ Champaran (Bihar) — indigo cultivation history links dye chemistry to state GK.

1.9 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The study of reaction rates and energy changes belongs primarily to —
(a) Inorganic (b) Physical (c) Analytical (d) Nuclear chemistry

Q2. Which is treated as an *inorganic* compound by convention?
(a) Methane (b) Ethanol (c) Calcium carbonate (d) Acetic acid

Q3. The Law of Conservation of Mass was given by —
(a) Dalton (b) Proust (c) Lavoisier (d) Boyle

Q4. *Rasaratnakara*, an ancient Indian text on alchemy, is attributed to —
(a) Charaka (b) Nagarjuna (c) Sushruta (d) Aryabhata

Q5. Assertion (A): The Delhi Iron Pillar has resisted rust for ~1,600 years. Reason (R): It is made of stainless steel.
(a) Both true, R explains A (b) Both true, R does not explain A (c) A true, R false (d) A false, R true

Q6. Match: 1. P. C. Ray 2. Bhatnagar 3. Kanada 4. Lavoisier — P. CSIR Q. Paramāṇu R. Mercurous nitrite S. Oxygen named
(a) 1-R 2-P 3-Q 4-S (b) 1-P 2-R 3-S 4-Q (c) 1-R 2-Q 3-P 4-S (d) 1-S 2-P 3-Q 4-R

Q7. Testing arsenic concentration in a groundwater sample is chiefly —
(a) Organic chemistry (b) Analytical chemistry (c) Biochemistry (d) Nuclear chemistry

Q8. Which pair is INCORRECTLY matched?
(a) Enzymes — Biochemistry (b) Acid rain — Environmental (c) C-14 dating — Nuclear (d) Polymers — Inorganic

ANSWER KEY

1-b (rates/energy = physical). **2-c** (carbonates → inorganic by convention; the rest are organic). **3-c** (Dalton = atomic theory; Proust = constant proportions). **4-b**. **5-c** (pillar is wrought iron with high phosphorus, not stainless steel — R false). **6-a**. **7-b** (identifying & quantifying = analytical). **8-d** (polymers are carbon-based → organic).

PART I · FOUNDATIONS OF CHEMISTRY

2 Matter and Its Classification

Why does wet clothing dry faster on a windy day? Because particles of matter are always escaping.

WHY BPSC ASKS THIS
Sublimation, dry ice, evaporation-cooling and physical-vs-chemical change are recurring one-liners.

QUESTION FREQUENCY
Moderate — roughly one question every second year across BPSC & allied Bihar exams.

PREREQUISITES
Chapter 1 vocabulary only.

YOU WILL BE ABLE TO
Name all five states, every change of state, and separate physical from chemical change instantly.

2.1 Concept Story — The Disappearing Camphor

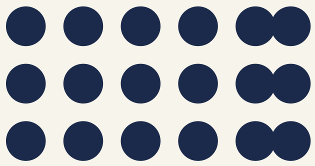
Place a camphor (कपूर) tablet in a puja room and return after a week — it has shrunk without ever melting into a puddle. Solid camphor turns *directly* into vapour. This single observation proves two exam-critical ideas: matter is made of **particles** that can escape from a surface, and some solids skip the liquid state entirely — **sublimation**.

2.2 Particle Nature of Matter

DEFINITION · MATTER
Anything that has **mass** and occupies **space**. All matter is made of tiny particles with **space between them** (intermolecular space), **attraction between them** (intermolecular force) and **continuous motion**.

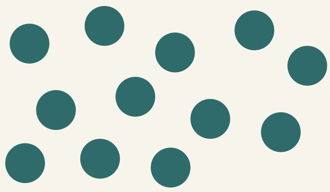
- **Diffusion** — intermixing of particles of two substances on their own (perfume spreading in a room, $KMnO_4$ colouring still water). Fastest in gases, slowest in solids; faster when hot.
- **Brownian motion** — zig-zag movement of suspended particles (pollen in water, dust in a sunbeam), first observed by Robert Brown (1827); explained by Einstein (1905) as evidence of particle collisions.
- **Compressibility** — gases compress easily because of large intermolecular spaces (this is why LPG and CNG can be filled into cylinders).

2.3 The Five States of Matter



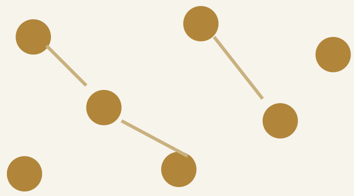
SOLID

Particles tightly packed in fixed positions · definite shape & volume · only vibrate · incompressible



LIQUID

Particles close but free to slide · definite volume, no fixed shape · flows · almost incompressible



GAS

Particles far apart, moving fast & randomly · no fixed shape or volume · highly compressible

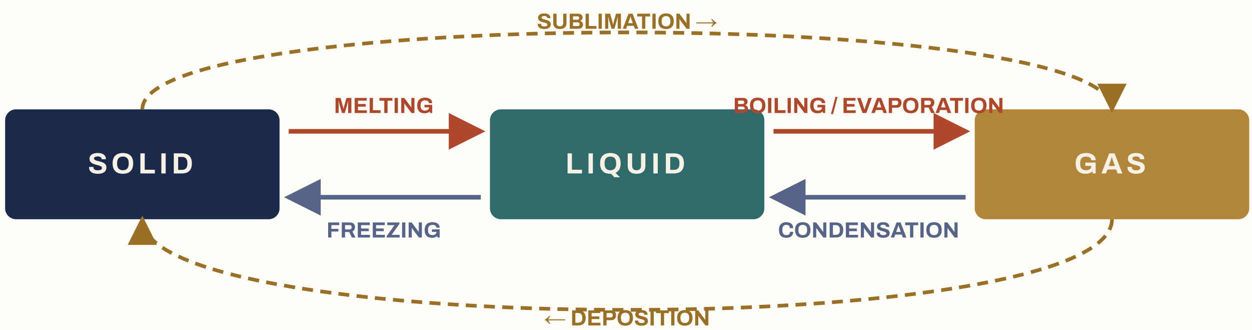
4TH STATE · PLASMA

Super-heated ionised gas — a mix of free electrons and ions. Found in the **Sun and stars, lightning, neon signs and fluorescent tubes**. Most abundant state of ordinary matter in the universe.

5TH STATE · BOSE–EINSTEIN CONDENSATE

Formed when a very dilute gas is cooled to near **absolute zero** (**–273.15 °C**); particles behave as one super-particle. Predicted by **S. N. Bose & Einstein**; made in the lab in 1995 (Cornell, Wieman, Ketterle — Nobel Physics 2001). Indian-name connection is a favourite MCQ.

2.4 Changes of State — One Cycle to Remember



Red arrows = heat absorbed (endothermic) · Blue arrows = heat released (exothermic) · Gold dashed = skips liquid state

BOILING VS EVAPORATION — THE CLASSIC CONTRAST

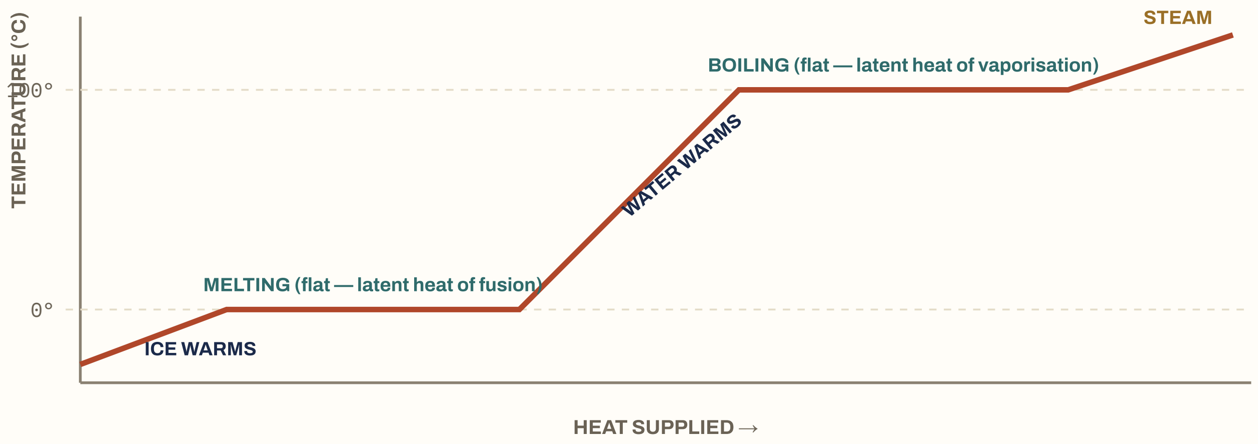
Boiling: at a fixed temperature (100 °C for water at 1 atm), throughout the liquid, fast, needs external heat. **Evaporation**: at any temperature, only at the surface, slow, causes **cooling** (earthen pot / matka water, sweating). Evaporation speeds up with heat, wind, larger surface, lower humidity.

FORMULA · LATENT HEAT

$Q = m \times L$

Heat absorbed during a state change *without temperature rise* (hidden = "latent"). For water: fusion ≈ 334 J/g at 0 °C; vaporisation ≈ 2,260 J/g at 100 °C. **Trap:** steam at 100 °C burns worse than water at 100 °C — it carries extra latent heat.

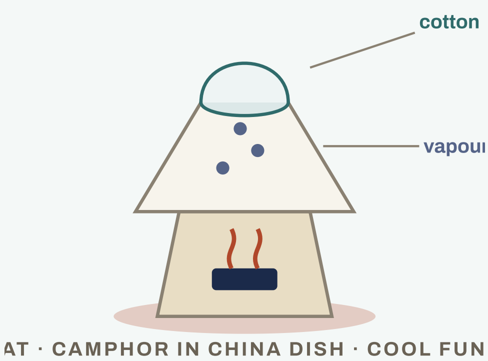
2.5 Heating Curve of Water (Ice → Steam)



Flat portions = temperature constant while state changes. Exam question: "Why does temperature not rise during melting?" — heat is consumed as latent heat.

2.6 Classroom Experiment — Sublimation of Camphor

EXPERIMENT



Objective: show a solid changing directly to gas and back.
Materials: camphor/ammonium chloride, china dish, inverted glass funnel, cotton plug, low flame.
Procedure: heat gently; vapour rises, meets the cool funnel wall and re-solidifies as fine crystals (deposition).
Observation: no liquid appears at any point.
Principle: sublimation — particles at the solid's surface gain enough energy to escape directly.
Exam link: substances that sublime — **camphor, naphthalene, iodine, ammonium chloride, dry ice** (mnemonic below).
⚠ **Safety:** low flame, ventilated room, no plastic funnel; do not inhale vapour directly.

2.7 Physical vs Chemical Change

PHYSICAL CHANGE	CHEMICAL CHANGE
No new substance; usually reversible; only state/shape/size changes. **Examples:** melting ice, dissolving sugar, magnetising iron, cutting paper, boiling water, glowing of an electric bulb filament.	New substance forms; usually irreversible; energy change common. **Examples:** rusting of iron, burning of paper/LPG, curdling of milk, digestion, ripening of fruit, electrolysis of water.

✕ **DO NOT CONFUSE**

Burning of a candle = chemical change, but **melting** of its wax = physical — both happen together. Dissolving salt = physical (recoverable by evaporation); dissolving a metal in acid = chemical (new substance, gas evolved).

2.8 Real-Life Applications & BPSC Connection

- **Matka cooling** — water seeps through pores and evaporates, absorbing latent heat (also why sweating cools you).
- **Dry ice** (solid CO_2, −78.5 °C) sublimes without wetting — ice-cream carts, stage fog, vaccine transport.
- **Naphthalene balls** vanish in the wardrobe over months — sublimation protects clothes from moths.
- **Steam pressing & steam burns** — vaporisation latent heat, ~2,260 J/g released on condensing.
- **Fog, dew, frost** — condensation and deposition on cold mornings in the Gangetic plain (BIHAR winter fog link).
- **LPG in cylinders** — gas liquefied under pressure (compressibility); it re-evaporates at the burner.

How BPSC frames it: "Which of the following sublimes?", "Dry ice is—", "Evaporation causes—", "Which is a chemical change?", statement pairs on boiling vs evaporation, and the Bose–BEC Indian-scientist angle.

2.9 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC Prelims (asked in multiple cycles) · Easy

"Dry ice" is —

(a) Solid ammonia (b) Solid sulphur dioxide

(c) **Solid carbon dioxide ✓** (d) Ice at −10 °C

Why: CO_2 solidifies at −78.5 °C and sublimes — "dry" because it never wets. **Concept:** sublimation. **Trap:** option (d) tempts aspirants who read "ice" literally.

PYQ State PCS pattern (repeated) · Easy–Moderate

Evaporation of a liquid causes —

(a) **Cooling ✓** (b) Heating

(c) No temperature change (d) First heating, then cooling

Why: the fastest (highest-energy) particles escape, lowering the average energy — hence temperature — of what remains. Basis of matka, sweating, spirit-on-skin coolness.

MEMORY HOOK

Subliming substances: **"CANDI"** — **C**amphor, **A**mmonium chloride, **N**aphthalene, **D**ry ice, **I**odine. Hindi cue: *"कपूर की तरह उड़ जाना"* — जो उड़ जाए बिना पिघले, वही sublime करता है.

COMMON TRAPS

1. Evaporation ≠ boiling (surface vs bulk; any temp vs fixed temp).
2. Temperature is constant *during* a state change.
3. Gas ≠ vapour: "vapour" = gaseous form of a substance liquid at room temperature.
4. Plasma is the most common state in the universe — not gas.
5. Dissolution of salt is physical, not chemical.

RAPID RECALL · CHAPTER 2

① Matter = mass + volume; particles have space, attraction, motion.
② Diffusion fastest in gases; faster when hot.
③ Brownian motion — Robert Brown (1827); explained by Einstein (1905).
④ 5 states: solid, liquid, gas, plasma, BEC.
⑤ Plasma — Sun, lightning, neon signs; most abundant in the universe.
⑥ BEC — near absolute zero; S. N. Bose + Einstein.
⑦ Solid→gas = sublimation; gas→solid = deposition.
⑧ Subliming: camphor, NH_4Cl, naphthalene, iodine, dry ice (CANDI).
⑨ Dry ice = solid CO_2, −78.5 °C.
⑩ Evaporation → cooling (matka, sweat).
⑪ Latent heat: fusion ≈ 334 J/g; vaporisation ≈ 2,260 J/g (water).
⑫ Steam burns worse than boiling water — extra latent heat.
⑬ Rusting/curdling/burning = chemical; melting/dissolving = physical.
⑭ Absolute zero = −273.15 °C = 0 K.

2.10 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. During melting of ice, the temperature —
(a) rises steadily (b) falls (c) remains constant (d) rises then falls

Q2. Which shows the greatest compressibility?
(a) Ice (b) Water (c) Steam (d) Equal in all

Q3. Fluorescent tube light and lightning are everyday examples of —
(a) BEC (b) Plasma (c) Vapour (d) Colloid

Q4. Statement I: Evaporation occurs only at boiling point. Statement II: Evaporation occurs only at the surface.
(a) Only I true (b) Only II true (c) Both true (d) Both false

Q5. Which is a chemical change?
(a) Sublimation of iodine (b) Magnetising a needle (c) Curdling of milk (d) Dissolving sugar

Q6. Assertion (A): A matka cools water in summer. Reason (R): Evaporation absorbs latent heat from the remaining water.
(a) Both true, R explains A (b) Both true, R does not explain A (c) A true, R false (d) A false, R true

Q7. Bose–Einstein condensate forms at temperatures close to —
(a) 0 °C (b) 100 K (c) −273 °C (d) −78.5 °C

Q8. Match: 1. Solid→Gas 2. Gas→Solid 3. Liquid→Gas at fixed T 4. Gas→Liquid — P. Deposition Q. Boiling R. Sublimation S. Condensation
(a) 1-R 2-P 3-Q 4-S (b) 1-P 2-R 3-S 4-Q (c) 1-R 2-S 3-Q 4-P (d) 1-Q 2-P 3-R 4-S

ANSWER KEY

1-c (latent heat of fusion consumed). **2-c** (gases have large intermolecular spaces). **3-b**. **4-b** (evaporation happens at any temperature — I false). **5-c** (new substance, irreversible; others reversible/physical). **6-a**. **7-c** (near absolute zero). **8-a**.

PART I · FOUNDATIONS OF CHEMISTRY

3 Elements, Compounds and Mixtures

Salt dissolved in water can be recovered unchanged; hydrogen burnt in oxygen can never be "un-burnt".

WHY BPSC ASKS THIS
"Which of these is an element/mixture?", separation-method matching, and colloid examples are staple questions.

QUESTION FREQUENCY
Moderate–high; separation techniques also reappear inside metallurgy and water-purification questions.

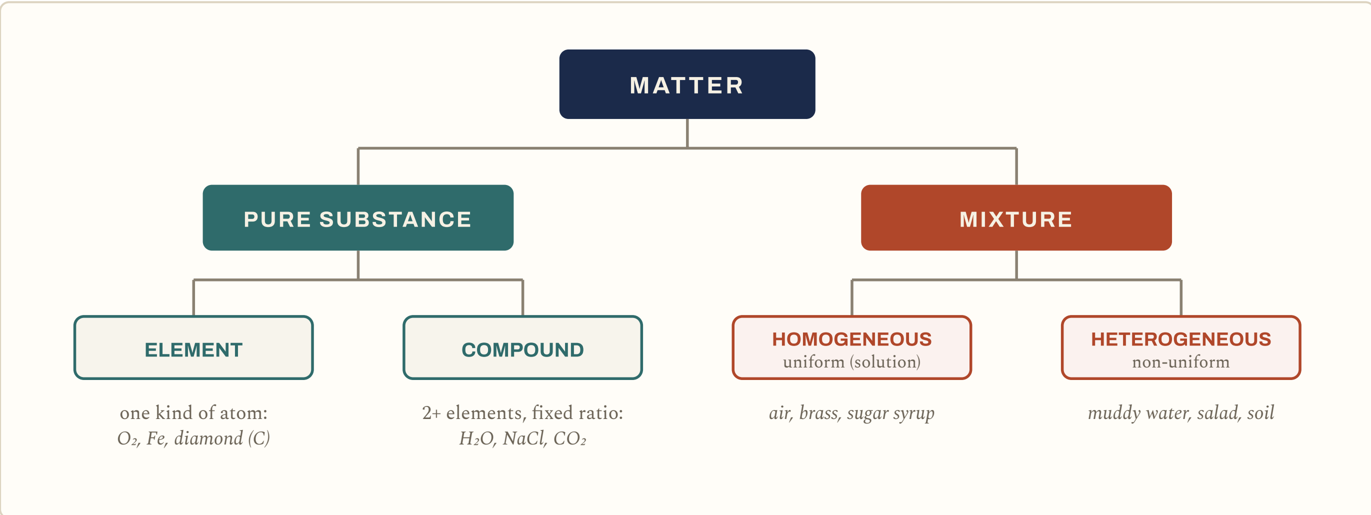
PREREQUISITES
Chapter 2 (particle picture of matter).

YOU WILL BE ABLE TO
Classify any substance and pick the correct separation method for any mixture.

3.1 Concept Story — The Village Rice Winnower

A farmer in Vaishali tosses threshed paddy into the breeze: heavy grain falls straight down, light husk drifts away. She has run a **separation technique** — winnowing — chosen because grain and husk differ in *weight*. Every separation method in this chapter follows the same logic: **find the property in which the components differ, then exploit it.** Size → sieving. Density → sedimentation. Boiling point → distillation. Magnetism → magnetic separation.

3.2 Classification of Matter



COMPOUND VS MIXTURE — THE EXAM'S FAVOURITE CONTRAST

A **compound** forms by chemical combination in a *fixed ratio*, has new properties, and needs a chemical method to break (H_2O: hydrogen burns, oxygen supports burning — water extinguishes!). A **mixture** keeps each component's properties, has any ratio, and separates by physical means. **Air is a mixture**, not a compound — composition varies place to place.

✕ DO NOT CONFUSE

- **Alloys are mixtures** (homogeneous, solid solutions) — brass, steel — not compounds.
- **Diamond and graphite are the element carbon**, not compounds.
- Distilled water = compound; sea water, milk, air, honey = mixtures.
- Atom = smallest particle of an element; **molecule** = smallest particle that exists freely (O_2, H_2O).

3.3 Solutions, Suspensions and Colloids — First Look

PROPERTY	TRUE SOLUTION	COLLOID	SUSPENSION
Particle size	< 1 nm	1–1000 nm	> 1000 nm (visible)
Appearance	Transparent	Translucent	Opaque, cloudy
Settles on standing?	Never	No	Yes
Scatters light (Tyndall)?	No	**Yes** — defining test	May scatter, but unstable
Examples	salt/sugar water, air	milk, fog, blood, jelly, smoke	muddy water, chalk in water

Tyndall effect — scattering of a light beam by colloidal particles: sunbeam in a dusty room, headlights in fog, light through forest canopy mist. Detailed colloid types (emulsion, aerosol, gel, foam) are developed in Chapter 13.

3.4 Which Separation Method Should Be Used?

COMPONENTS DIFFER IN...	METHOD	EVERYDAY / INDUSTRIAL EXAMPLE
Particle size (solid + solid)	**Sieving**	flour from bran; sand at construction sites
Weight, with wind (solid + solid)	**Winnowing**	grain from husk
Insoluble solid in liquid	**Sedimentation → decantation → filtration**	muddy water; tea leaves (strainer)
Density, fine particles	**Centrifugation**	cream from milk; blood tests; washing-machine dryer
Soluble solid in liquid — keep solid	**Evaporation / crystallisation**	sea salt pans; pure copper-sulphate crystals
Soluble solid in liquid — keep both	**Distillation**	distilled water for batteries & labs
Two liquids, boiling points < 25 °C apart	**Fractional distillation**	petroleum refining; O_2/N_2 from liquefied air; ethanol–water
Two immiscible liquids	**Separating funnel**	oil from water; slag from molten metal
One component sublimes	**Sublimation**	camphor/NH_4Cl from salt
Magnetic vs non-magnetic	**Magnetic separation**	iron scrap in ore dressing
Different adsorption/solubility of dissolved solutes	**Chromatography**	dyes in ink; drug tests; pigment analysis

MEMORY HOOK

Ask two questions in order: **घुला है या नहीं?** (dissolved or not?) → not dissolved = filter family; dissolved = heat family (evaporation/distillation). **दोनों चाहिए या एक?** (keep both or one?) → both = distillation, one = evaporation.

EXPERIMENT **Ink chromatography with a chalk stick**

Materials: black sketch-pen ink, chalk stick (or filter-paper strip), water in a saucer. **Procedure:** dot the ink 1 cm above the chalk base; stand the chalk in a few mm of water; wait 10 minutes. **Observation:** the dot climbs and splits into rings of different colours. **Principle:** different dyes rise at different speeds (differential adsorption) — "black" ink is itself a mixture. **Likely BPSC question:** chromatography is used to separate — *components of a dye/dissolved solutes.* ⚠ No hazards; water only.

3.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC / State PCS pattern (repeated) · Easy

Which of the following is a compound?

(a) Air
(b) Brass
(c) **Common salt ✓**
(d) Diamond

Eliminate: air & brass = mixtures; diamond = element (carbon). NaCl = two elements chemically combined in fixed ratio.

PYQ State PCS / SSC foundational pattern · Easy–Moderate

Cream is separated from milk by —

(a) Filtration
(b) Distillation
(c) **Centrifugation ✓**
(d) Sublimation

Why: rapid spinning pushes denser skim milk outward; lighter fat collects at the centre. Same principle: blood-sample separation, washing-machine spin dryer.

FACULTY NOTE

- Open with the winnowing story; ask the class to name 5 separations their family already does (tea strainer, dal picking, sieving flour, matka sediment, curd from whey).
- Board: classification tree → compound-vs-mixture table → method-selection logic (the two Hindi questions).
- Demo: chalk chromatography + torch-through-milk-water for Tyndall.
- Likely doubt: "Is milk a solution?" — no, a colloid (emulsion): use the torch beam as proof.
- Bridge: "Mixtures separate physically — but what holds a *compound* together? First we need the atom: Chapter 4."

COMMON TRAPS

1. **Air** = **mixture** (variable composition), never a compound.
2. **Alloys** = **homogeneous mixtures**; amalgam = alloy containing mercury.
3. Milk looks uniform but is a **colloid**, not a true solution.
4. Fractional distillation for close boiling points; simple distillation otherwise.
5. Decantation ≠ filtration — pouring off vs passing through a barrier.

RAPID RECALL · CHAPTER 3

① Element → one kind of atom; 118 known elements (94 natural).
② Compound → fixed ratio, new properties, chemical separation only.
③ Mixture → any ratio, physical separation, properties retained.
④ Air, brass, milk, honey = mixtures; water, salt = compounds; diamond = element.
⑤ Solution particles <1 nm; colloid 1–1000 nm; suspension >1000 nm.
⑥ Tyndall effect = light scattering by colloids (fog, milk).
⑦ Cream from milk / blood tests → centrifugation.
⑧ Petroleum & air gases → fractional distillation.
⑨ Oil + water → separating funnel (immiscible).
⑩ Ink dyes → chromatography (means "colour writing").
⑪ Sea salt → evaporation in salt pans.
⑫ Iron impurities → magnetic separation.

3.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. Which group contains ONLY mixtures?
(a) Air, brass, honey (b) Water, salt, sugar (c) Iron, oxygen, gold (d) CO_2, NaCl, NH_3

Q2. A beam of light is visible passing through liquid X but not liquid Y. X and Y could be —
(a) X: salt water, Y: milk (b) X: milk, Y: salt water (c) both true solutions (d) both suspensions

Q3. To obtain BOTH pure water and salt from brine, use —
(a) Evaporation (b) Filtration (c) Distillation (d) Decantation

Q4. Nitrogen and oxygen are separated from liquefied air by —
(a) Chromatography (b) Fractional distillation (c) Magnetic separation (d) Crystallisation

Q5. Assertion (A): Brass cannot be a compound. Reason (R): Its copper and zinc content can be varied at will.
(a) Both true, R explains A (b) Both true, R does not explain A (c) A true, R false (d) A false, R true

Q6. Match: 1. Husk from grain 2. NH_4Cl from NaCl 3. Butter from curd 4. Dyes in ink — P. Sublimation Q. Winnowing R. Chromatography S. Centrifugation
(a) 1-Q 2-P 3-S 4-R (b) 1-P 2-Q 3-R 4-S (c) 1-Q 2-S 3-P 4-R (d) 1-S 2-P 3-Q 4-R

Q7. Crystallisation is preferred over simple evaporation for copper sulphate because —
(a) it is faster (b) it gives purer, well-formed crystals without decomposing the salt (c) it needs no heat (d) $CuSO_4$ cannot be evaporated

Q8. Which statement about compounds is FALSE?
(a) Fixed composition (b) New properties emerge (c) Components separable by filtration (d) Formation involves energy change

ANSWER KEY

1-a (b = compounds; c = elements; d = compounds). **2-b** (Tyndall in colloidal milk, not in true solution). **3-c**. **4-b** (N_2 boils −196 °C, O_2 −183 °C). **5-a** (variable ratio is exactly why it is a mixture). **6-a**. **7-b**. **8-c** (compounds need chemical separation).

PART II · ATOMIC STRUCTURE AND PERIODIC CLASSIFICATION

4 Atomic Structure

A century of clever experiments turned the invisible atom into the best-mapped object in science.

WHY BPSC ASKS THIS
Discoverer-matching (electron/proton/neutron), isotope logic and configuration are perennial MCQs.

QUESTION FREQUENCY
High — atomic structure + isotopes yield ~1 question most years across BPSC-family exams.

PREREQUISITES
Chapter 3 (atom vs molecule).

YOU WILL BE ABLE TO
Write any configuration up to Z=20, compute p/n/e for any species, and never mix up isotopes/isobars/isotones.

4.1 Concept Story — Shooting Bullets at Tissue Paper

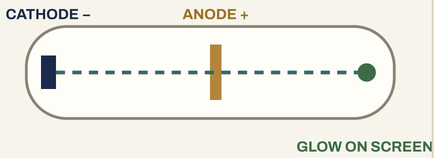
In 1909 Rutherford's students fired alpha particles at gold foil so thin it was almost transparent. Nearly all passed straight through — but about 1 in 8,000 bounced back. Rutherford said it was "as if you fired a 15-inch shell at tissue paper and it came back and hit you." Conclusion: the atom is mostly **empty space**, with all its positive charge and mass packed in a tiny centre — the **nucleus**. Every atomic model before and after is a step in this detective story.

4.2 The Discovery Timeline

YEAR	SCIENTIST	CONTRIBUTION	EXPERIMENT / BASIS
1808	**John Dalton**	Atomic theory — atoms indivisible, identical within an element	laws of chemical combination
1897	**J. J. Thomson**	**Electron** (–); "plum-pudding" model	cathode rays (Nobel 1906)
1886/1919	**Goldstein → Rutherford**	**Proton** (+): Goldstein observed canal rays; Rutherford identified & named the proton	anode (canal) rays
1911	**Ernest Rutherford**	**Nucleus**; planetary model	gold-foil alpha scattering
1913	**Niels Bohr**	Electrons in fixed **orbits/shells** with fixed energies	hydrogen spectrum (Nobel 1922)
1932	**James Chadwick**	**Neutron** (no charge)	beryllium bombardment (Nobel 1935)

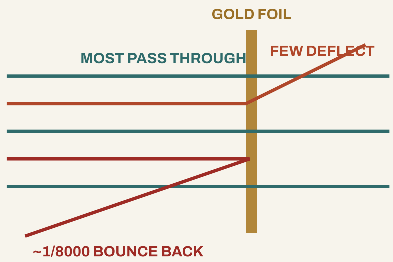
✕ DO NOT CONFUSE
Thomson **discovered** the electron but the name "electron" was coined earlier by **G. J. Stoney**. Goldstein saw canal rays; the **proton** as a particle is credited to Rutherford. Rutherford's Nobel (1908) was in **Chemistry**, not Physics.

4.3 Three Experiments, Three Pictures of the Atom

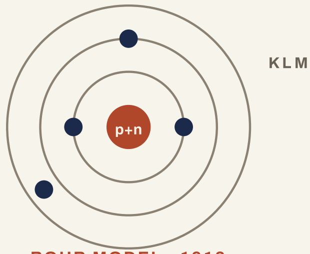


CATHODE-RAY TUBE · 1897

Rays travel cathode → anode, bend toward the + plate ⇒ negatively charged particles: **electrons**. Same for every gas ⇒ electrons are universal.



Gold-foil experiment (1909–11): atom mostly empty; tiny dense + nucleus holds nearly all mass. Nucleus ≈ 10^{-15} m vs atom ≈ 10^{-10} m.



BOHR MODEL · 1913

Electrons revolve only in **fixed shells** (K, L, M, N...) of fixed energy; jumping between shells absorbs/emits light — explains atomic spectra.

4.4 Atomic Number, Mass Number and Configuration

FORMULA BOX

```
Z = protons (= electrons in a neutral atom)
A = protons + neutrons
neutrons = A − Z
```

Solved: $^{23}Na_{11}$ → p = 11, e = 11, n = 23 − 11 = 12. For the ion Na^+: e = 10 (one lost), p and n unchanged. **Trap:** ions change electrons only, never protons.

SHELL FILLING (BOHR–BURY RULE)

Maximum electrons per shell = $2n^2$ → K 2, L 8, M 18, N 32; outermost never holds more than 8.

Na(11) = 2,8,1 · Cl(17) = 2,8,7 · Ca(20) = 2,8,8,2

Valence electrons = outermost-shell electrons → decide valency: Na (1) gives 1 e^- → Na^+; Cl (7) takes 1 e^- → Cl^-.

4.5 Isotopes, Isobars, Isotones

ISOTOPES — SAME Z, DIFFERENT A

^1H	^2H (D)	^3H (T)
PROTIUM	DEUTERIUM	TRITIUM
0 n	1 n	2 n · radioactive

Same chemical properties, different mass. Also: C-12/C-14, U-235/U-238, Cl-35/Cl-37.

ISOBARS — SAME A, DIFFERENT Z

$^{40}Ar_{18}$ · $^{40}K_{19}$ · $^{40}Ca_{20}$

Different elements, equal mass number. *Bar* = equal weight (बराबर).

ISOTONES — SAME NEUTRONS

$^{30}Si_{14}$ · $^{31}P_{15}$ · $^{32}S_{16}$ (16 n)

A − Z equal. *tone* → neutones → neutrons same.

RADIOISOTOPE	APPLICATION	EXAM NOTE
Carbon-14	Radiocarbon dating of fossils & artefacts	half-life ≈ 5,730 years; works on once-living material only
Cobalt-60	Cancer radiotherapy; food irradiation	gamma source
Iodine-131	Thyroid diagnosis & therapy	thyroid absorbs iodine
Uranium-235	Nuclear-reactor fuel (fissile)	U-238 is fertile, not fissile — classic trap
Phosphorus-32	Tracer in agriculture; leukaemia therapy	fertiliser-uptake studies

CHEMISTRY IN A DISTRICT MAGISTRATE'S DAY

A district hospital's radiotherapy unit requests transport clearance for a **Cobalt-60** source — the DM's office coordinates AERB-compliant escort. The same week, an archaeology team seeks permission to send excavated charcoal from a Gangetic mound for **C-14 dating**. Isotopes are administration, not just theory.

4.6 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Isotopes of an element differ in the number of —

(a) Protons
(b) Electrons
(c) Neutrons ✓
(d) Protons and electrons

Why: same Z (protons/electrons) keeps the chemistry identical; only neutron count — hence mass — differs.

PYQ State PCS pattern (repeated) · Easy

The neutron was discovered by —

(a) Rutherford
(b) James Chadwick ✓
(c) J. J. Thomson
(d) Niels Bohr

Eliminate by dates: Thomson 1897 electron → Rutherford 1911 nucleus → Bohr 1913 orbits → Chadwick 1932 neutron (last major particle).

MEMORY HOOK

Discoverers in one line: **"TGC — Thomson गया Chadwick तक"**: **T**homson e^- (1897) → **G**oldstein canal rays → Rutherford nucleus (1911) → Bohr shells (1913) → **C**hadwick n (1932). Isotope family: **P**rotium-**D**euterium-**T**ritium = 0-1-2 neutrons (*PDT = 012*).

COMMON TRAPS

1. Rutherford's Nobel = **Chemistry 1908**, before his nucleus experiment.
2. Mass of atom ≈ nucleus; **volume** ≈ electron cloud.
3. Cation forms by **losing electrons** — not by gaining protons.
4. Hydrogen (protium) has **no neutron** — the only such atom.
5. Electron mass ≈ 1/1836 of proton — not exactly "zero".

RAPID RECALL · CHAPTER 4

① Electron — Thomson, 1897, cathode rays; name coined by Stoney.
② Canal rays — Goldstein; proton named by Rutherford.
③ Nucleus — Rutherford, gold-foil, 1911; atom mostly empty.
④ Shells — Bohr, 1913; max e^- = $2n^2$.
⑤ Neutron — Chadwick, 1932 (Nobel 1935).
⑥ Z = p; A = p + n; ions change e^- only.
⑦ Configurations: Na 2,8,1 · Cl 2,8,7 · Ca 2,8,8,2.
⑧ Isotopes same Z; isobars same A; isotones same n.
⑨ H isotopes: protium 0n, deuterium 1n, tritium 2n (radioactive).
⑩ Heavy water = D_2O — reactor moderator.
⑪ C-14 dating (t½ ≈ 5,730 y); Co-60 cancer therapy; I-131 thyroid.
⑫ U-235 fissile; U-238 not.

4.7 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. In the gold-foil experiment, most alpha particles passed undeflected because —
(a) alpha particles are neutral (b) gold atoms are very light (c) most of the atom is empty space (d) the foil was charged

Q2. An atom has configuration 2,8,2. Its valency is —
(a) 2 (b) 8 (c) 12 (d) 6

Q3. Species with 17 protons, 18 electrons and 18 neutrons is —
(a) Cl atom (b) Cl^- ion (c) Ar atom (d) K^+ ion

Q4. $^{40}Ar_{18}$ and $^{40}Ca_{20}$ are —
(a) Isotopes (b) Isobars (c) Isotones (d) Allotropes

Q5. Assertion (A): C-14 dating cannot date an iron sword directly. Reason (R): Radiocarbon dating needs material that was once living.
(a) Both true, R explains A (b) Both true, R does not explain A (c) A true, R false (d) A false, R true

Q6. Match: 1. Thomson 2. Chadwick 3. Bohr 4. Goldstein — P. Canal rays Q. Neutron R. Cathode-ray electron S. Fixed orbits
(a) 1-R 2-Q 3-S 4-P (b) 1-P 2-R 3-Q 4-S (c) 1-R 2-S 3-Q 4-P (d) 1-Q 2-R 3-P 4-S

Q7. Which shell can hold a maximum of 18 electrons?
(a) K (b) L (c) M (d) N

Q8. Deuterium oxide (D_2O) is commonly called —
(a) Hard water (b) Heavy water (c) Mineral water (d) Aerated water

ANSWER KEY

1-c. **2-a** (2 valence electrons, easily lost — like Mg). **3-b** (17 p = chlorine; 18 e = one extra → anion). **4-b** (same A = 40, different Z). **5-a** (iron never respired carbon; a wooden handle could be dated). **6-a**. **7-c** ($2n^2$ with n = 3). **8-b** (heavy water ≠ hard water — hard water has Ca^{2+}/Mg^{2+} salts).

PART II · ATOMIC STRUCTURE AND PERIODIC CLASSIFICATION

5 Symbols, Formulae, Valencies & Chemical Language

Chemistry has its own grammar. Learn the alphabet (symbols) and the spelling rule (valency) and every formula writes itself.

WHY BPSC ASKS THIS
Latin symbols, formulae of common compounds and balanced-equation spotting appear directly and inside other chapters.

QUESTION FREQUENCY
Moderate directly; foundational for every reaction, salt and metallurgy question.

PREREQUISITES
Chapter 4 (valence electrons → valency).

YOU WILL BE ABLE TO
Write formulae by the criss-cross rule and balance a simple equation in under a minute.

5.1 Concept Story — Why is Sodium “Na”?

The letter on a periodic table is a shorthand agreed worldwide so a chemist in Patna and one in Paris mean the same thing. Most symbols come from the English name (H, O, C), but several old, long-known metals keep their **Latin** roots — sodium is *Natrium* → Na, iron is *Ferrum* → Fe. Berzelius fixed this system in 1813. These Latin symbols are the single most repeated “trap” in the whole subject, so we tackle them first.

5.2 Symbols from Latin Names

Symbol	Element	Latin name
Na	Sodium	*Natrium*
K	Potassium	*Kalium*
Fe	Iron	*Ferrum*
Cu	Copper	*Cuprum*
Ag	Silver	*Argentum*
Au	Gold	*Aurum*
Hg	Mercury	*Hydrargyrum*
Pb	Lead	*Plumbum*
Sn	Tin	*Stannum*
Sb	Antimony	*Stibium*

MEMORY HOOK
These 10 “Latin ten” are the classic set. Line: **“Na-K Fe-Cu, Ag-Au Hg, Pb-Sn Sb.”** — the coins-and-old-metals crew. Hindi cue: *“पुरानी धातुओं के नाम Latin में”* — जो धातु प्राचीन काल से ज्ञात है, उसका symbol अक्सर Latin से आता है.

5.3 Valency Chart

DEFINITION · VALENCY
The **combining capacity** of an element — the number of electrons it loses, gains or shares to complete its octet. Equal to valence electrons (if ≤4) or 8 – valence electrons (if ≥4).

VALENCY 1	VALENCY 2	VALENCY 3	VALENCY 4	VARIABLE
H, Na, K, Ag, Cl	O, Mg, Ca, Zn, Ba	Al, N, P (in most)	C, Si	Fe (2,3) Cu (1,2)
Li, F, Br, I	Cu(II), Fe(II), Pb, Sn	Fe(III), Cr	Pb, Sn (in IV)	Sn (2,4) N, S, Mn

✕ **DO NOT CONFUSE — VARIABLE VALENCY NAMING**

-ous = **lower**, **-ic** = **higher** valency. Ferr*ous* = Fe^{2+} ($FeCl_2$, green vitriol); Ferr*ic* = Fe^{3+} ($FeCl_3$). Cupr*ous* = Cu^{+}; Cupr*ic* = Cu^{2+} (blue vitriol $CuSO_4$).

5.4 Common Radicals (Polyatomic Ions)

POSITIVE (BASIC)	CHARGE	NEGATIVE (ACIDIC)	CHARGE
Ammonium NH_4^+	+1	Hydroxide OH^-, Nitrate NO_3^-, Bicarbonate HCO_3^-	−1
—		Chloride Cl^-, Permanganate MnO_4^-, Nitrite NO_2^-	−1
—		Carbonate CO_3^{2-}, Sulphate SO_4^{2-}, Sulphite SO_3^{2-}	−2
—		Phosphate PO_4^{3-}	−3

MEMORY HOOK

-ate has more oxygen, -ite has less: sulph*ate* SO_4^{2-} vs sulph*ite* SO_3^{2-}; nitr*ate* NO_3^- vs nitr*ite* NO_2^-. *"ATE ate more oxygen."*

5.5 The Formula-Writing Ladder (Criss-Cross Rule)

STEP 1 · write symbols with valencies

$\overset{3}{Al} \quad \overset{2}{O}$

STEP 2 · criss-cross the numbers

$Al_2 \quad O_3$

STEP 3 · final formula

Al_2O_3

Aluminium oxide · valencies become the other's subscript · reduce to simplest ratio

Polyatomic ions keep brackets: Ca + NO_3 → $Ca(NO_3)_2$ · Al + SO_4 → $Al_2(SO_4)_3$

5.6 The Chemical Equation & How to Balance It

Word: Hydrogen + Oxygen ⟶ Water · balance by the "H-O" count

Skeletal: $H_2 + O_2 \rightarrow H_2O$ (O unbalanced: 2 vs 1)

Balanced: $2H_2 + O_2 \rightarrow 2H_2O$ (H: 4=4, O: 2=2) ✓

Golden rule: change only COEFFICIENTS (the big numbers in front). NEVER change a subscript — that would change the substance.

STATE SYMBOLS & CONDITIONS

(s) solid · (l) liquid · (g) gas · (aq) dissolved in water. Conditions go over the arrow: Δ (heat), catalyst name, temperature/pressure. Example: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (Fe catalyst, ~450 °C, ~200 atm — Haber process).

BALANCING WORKED EXAMPLE

$Fe + H_2O \rightarrow Fe_3O_4 + H_2$

$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$

Balance metal first (Fe: 3), then O (4 waters give 4 O), then H (8 = 8). Rusting-related favourite.

5.7 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The chemical symbol Hg stands for —

(a) Hydrogen
(b) Mercury ✓
(c) Magnesium
(d) Manganese

Why: Hg = *Hydrargyrum* ("liquid silver"). **Trap:** H = hydrogen, Mg = magnesium, Mn = manganese — all near-look-alikes.

PYQ State PCS pattern (repeated) · Moderate

The correct formula of aluminium sulphate is —

(a) $AlSO_4$
(b) Al_2SO_4
(c) $Al_2(SO_4)_3$ ✓
(d) $Al_3(SO_4)_2$

Why: Al^{3+} criss-crossed with SO_4^{2-} → $Al_2(SO_4)_3$. Bracket needed because sulphate is polyatomic.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Opening question: "Sodium का symbol Na क्यों, S क्यों नहीं?" → derive the Latin story.
2. Board: Latin-10 cards → valency chart → radical table → criss-cross ladder (do Al_2O_3, $CaCO_3$, $Al_2(SO_4)_3$ live).
3. Demonstration on board: balance H_2+O_2 and Fe+H_2O step by step; emphasise "coefficients only".
4. Likely doubt: "Can I make O_2 into O_4 to balance?" — the golden-rule correction moment.
5. Recap: 10 Latin symbols + criss-cross + ate/ite rule. Homework: write formulae for 15 compounds & balance 5 equations. Bridge to Chapter 6 (Periodic Table): "Why does valency repeat down a column?"

COMMON TRAPS

1. Symbol case matters: **Co** = cobalt, **CO** = carbon monoxide.
2. Balancing changes coefficients, never subscripts.
3. Ferrous = Fe^{2+}, ferric = Fe^{3+} (-ous lower, -ic higher).
4. -ate = more O, -ite = less O.
5. Brackets for polyatomic ions taken more than once: $Ca(OH)_2$, not $CaOH_2$.

RAPID RECALL · CHAPTER 5

① Latin-10: Na, K, Fe, Cu, Ag, Au, Hg, Pb, Sn, Sb.
② Symbols standardised by Berzelius (1813).
③ Valency = combining capacity = e^- lost/gained/shared.
④ Variable: Fe (2,3), Cu (1,2), Sn (2,4).
⑤ -ous = lower valency, -ic = higher.
⑥ Radicals: NH_4^+, OH^-, NO_3^-, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}.
⑦ -ate more oxygen than -ite.
⑧ Criss-cross: valencies swap to subscripts, reduce to simplest ratio.
⑨ Brackets for repeated polyatomic ions: $Ca(OH)_2$, $Al_2(SO_4)_3$.
⑩ Balance coefficients only — never subscripts.
⑪ $2H_2 + O_2 \rightarrow 2H_2O$; $3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$.
⑫ States: (s)(l)(g)(aq); conditions over the arrow.

5.8 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The Latin name *Kalium* gives the symbol for —
(a) Calcium (b) Potassium (c) Krypton (d) Cobalt

Q2. The formula of calcium phosphate is —
(a) $CaPO_4$ (b) $Ca_2(PO_4)_3$ (c) $Ca_3(PO_4)_2$ (d) $Ca(PO_4)_2$

Q3. In balancing an equation you are allowed to change only the —
(a) subscripts (b) coefficients (c) symbols (d) charges

Q4. $FeCl_3$ is named —
(a) Ferrous chloride (b) Ferric chloride (c) Iron(II) chloride (d) Ferric chlorate

Q5. Which pair differs only in oxygen content?
(a) NO_3^- / NO_2^- (b) SO_4^{2-} / CO_3^{2-} (c) OH^- / Cl^- (d) NH_4^+ / NO_3^-

Q6. Assertion (A): The symbol CO is different from Co.
Reason (R): Chemical symbols are case-sensitive.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q7. The balanced form of $Al + O_2 \rightarrow Al_2O_3$ is —
(a) $2Al + 3O_2 \rightarrow Al_2O_3$ (b) $4Al + 3O_2 \rightarrow 2Al_2O_3$ (c) $Al + O_2 \rightarrow Al_2O_3$ (d) $2Al + O_2 \rightarrow Al_2O_3$

Q8. Match: 1. Na 2. Pb 3. Sn 4. Sb — P. Stibium Q. Natrium R. Stannum S. Plumbum
(a) 1-Q 2-S 3-R 4-P (b) 1-R 2-S 3-Q 4-P (c) 1-Q 2-R 3-S 4-P (d) 1-S 2-Q 3-R 4-P

ANSWER KEY

1-b. **2-c** ($Ca^{2+} \times PO_4^{3-} \rightarrow Ca_3(PO_4)_2$). **3-b**. **4-b** ($Fe^{3+}$ = ferric). **5-a** (nitrate vs nitrite). **6-a**. **7-b** (Al: 4=4, O: 6=6). **8-a**.

PART II · ATOMIC STRUCTURE AND PERIODIC CLASSIFICATION

6 The Periodic Table

118 elements arranged so that the entire chemistry of an element can be predicted from a single address: its group and its period.

WHY BPSC ASKS THIS
Mendeleev vs Moseley, position of hydrogen, trends and "which is most metallic/reactive" are recurring, high-confidence facts.

QUESTION FREQUENCY
High — at least one direct question most cycles, plus many indirect uses.

PREREQUISITES
Chapter 4 (electronic configuration) & Chapter 5 (valency).

YOU WILL BE ABLE TO
Read any element's group/period, predict its trend behaviour and answer the classic "most/least" questions.

6.1 Concept Story — From Chaos to a Map

By 1860 chemists knew about 60 elements but no order. **Döbereiner** spotted triads (Li–Na–K: the middle atomic mass ≈ average of the other two). **Newlands' Law of Octaves** noticed every 8th element repeated properties — but it failed after calcium. **Mendeleev** (**1869**) arranged elements by *increasing atomic mass*, left **gaps** for undiscovered elements (eka-aluminium = Gallium, eka-silicon = Germanium) and even corrected wrong atomic masses — the boldness that made his table famous. Its one flaw: a few pairs sat "wrong" (Ar before K, Co before Ni). **Moseley** (**1913**) fixed this by re-basing the table on **atomic number** (**Z**), giving the *Modern Periodic Law*: *properties are a periodic function of atomic number.*

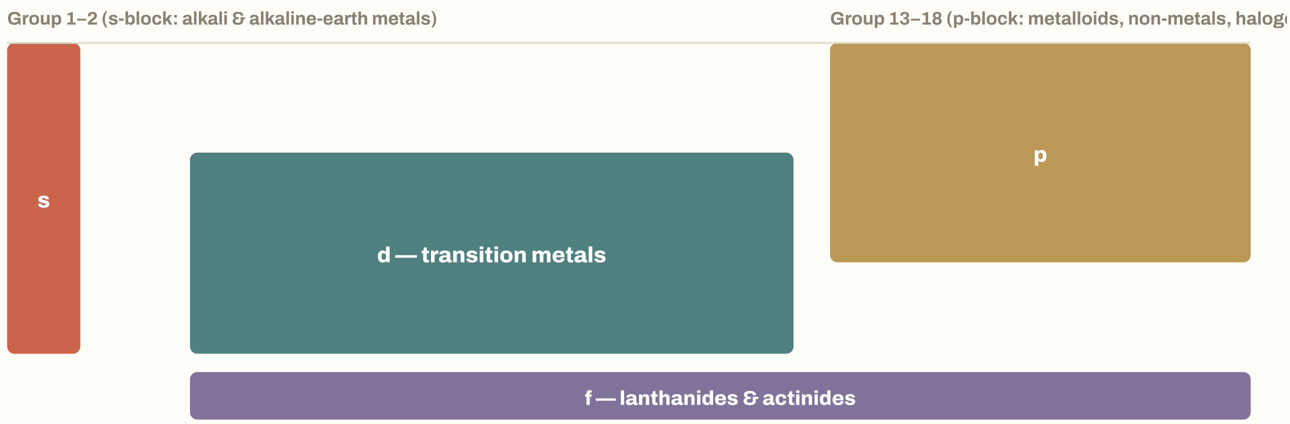
6.2 Milestones — Who Did What

SCIENTIST	YEAR	CONTRIBUTION	LIMITATION
Döbereiner	1817	Law of Triads (Li, Na, K)	Very few triads existed
Newlands	1866	Law of Octaves (every 8th repeats)	Broke down after Ca
Mendeleev	1869	Table by atomic mass; gaps + predictions	Anomalous pairs; H, isotopes
Moseley	1913	Basis = atomic number (Z)	Position of H still special

MEMORY HOOK

"Three Newly Made Metals" = **T**riads (Döbereiner) → **N**ewlands → **M**endeleev → **M**oseley. Mass gave way to number in **1913**. Hindi cue: *"गिनती से क्रम — atomic number से आधुनिक table."*

6.3 Structure — 18 Groups, 7 Periods, Four Blocks



Groups (**columns 1–18**) = same number of valence electrons = similar chemistry. **Periods** (**rows 1–7**) = same number of shells. **Group 1** alkali metals, **Group 2** alkaline-earth, **Group 17** halogens, **Group 18** noble gases. Metals on the left, non-metals top-right, metalloids (B, Si, Ge, As, Sb, Te) along the staircase.

6.4 Periodic Trends — The Two Arrows

ACROSS A PERIOD (LEFT → RIGHT)

- Atomic size **decreases** (more nuclear pull, same shell)
- Metallic character **decreases**, non-metallic increases
- Ionisation energy & electronegativity **increase**
- Valency: 1→4→0 (rises then falls)

DOWN A GROUP (TOP → BOTTOM)

- Atomic size **increases** (extra shells added)
- Metallic character **increases**
- Ionisation energy & electronegativity **decrease**
- Valency stays **constant** (same valence electrons)

× DO NOT CONFUSE — THE "MOST" RECORDS

Most reactive metal = **Cs** (Fr is rarer/radioactive); most reactive non-metal = **F**; most electronegative = **F**; largest atom = **Cs**/**Fr**; smallest = **He**. Bottom-left = most metallic, top-right (excluding noble gases) = most non-metallic.

6.5 Special Positions & Named Families

ANOMALOUS HYDROGEN

Hydrogen (1 valence e^-) resembles **Group 1** (forms H^+) yet also **Group 17** (forms H^-, is a diatomic gas). It sits alone at the top — the classic "no fixed position" PYQ.

GROUP 1
Alkali metals
Soft, stored in kerosene, 1 e^-

GROUP 17
Halogens
F, Cl, Br, I — salt-formers

GROUP 18
Noble gases
Inert, full octet (He = 2)

6.6 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The modern periodic table is based on —

(a) Atomic mass
(b) Atomic number ✓
(c) Number of neutrons
(d) Density

Why: Moseley's law (1913). **Trap:** Mendeleev used atomic *mass* — a very common confusion.

PYQ State PCS pattern (repeated) · Moderate

Which element has the highest electronegativity?

(a) Oxygen
(b) Chlorine
(c) Fluorine ✓
(d) Nitrogen

Why: F is top-right (excluding noble gases), smallest halogen. **Trap:** O is second — some keys wrongly pick it.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: hand out 60 "element cards" unsorted → ask class to invent an order → reveal Mendeleev's logic.
2. Board: milestone table → group/period map → two-arrow trends drawn as literal arrows.
3. Drill the "most/least" records (Cs, F, He) as a chant.
4. Doubt to pre-empt: "Why is Ar before K if it is heavier?" → atomic-number ordering.
5. Recap + homework: place 10 elements by group/period; solve 8 MCQs. Bridge to Chapter 7: "Neighbouring atoms want full octets — how do they bond?"

COMMON TRAPS

1. Mendeleev = mass, Moseley = number.
2. Down a group size *increases*; across a period it *decreases*.
3. Noble gases have zero valency, not one.
4. Most electronegative = F, not O or Cl.
5. Metallic character is highest at bottom-left.

RAPID RECALL · CHAPTER 6

① Modern law: properties are periodic function of atomic number.
② Mendeleev (mass, 1869) → Moseley (number, 1913).
③ 18 groups, 7 periods, blocks s-p-d-f.
④ Group = valence electrons; Period = shells.
⑤ Across period: size ↓, non-metallic ↑, IE ↑.
⑥ Down group: size ↑, metallic ↑, IE ↓.
⑦ Most reactive metal Cs; non-metal F.
⑧ Most electronegative = F; largest = Cs/Fr; smallest = He.
⑨ Group 1 alkali, 2 alkaline-earth, 17 halogens, 18 noble gases.
⑩ H has no fixed position (resembles Gp 1 & 17).
⑪ Metalloids: B, Si, Ge, As, Sb, Te (staircase).
⑫ Mendeleev's gaps predicted Ga (eka-Al) & Ge (eka-Si).

6.7 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The Law of Octaves was proposed by —
(a) Mendeleev (b) Newlands (c) Moseley (d) Döbereiner

Q2. Number of periods in the modern periodic table —
(a) 7 (b) 8 (c) 18 (d) 9

Q3. As we move down Group 1, reactivity —
(a) decreases (b) increases (c) unchanged (d) first ↑ then ↓

Q4. Elements of the same group have the same —
(a) number of shells (b) atomic mass (c) valence electrons (d) neutrons

Q5. Which is a metalloid?
(a) Na (b) Si (c) Cl (d) Ca

Q6. Eka-silicon predicted by Mendeleev is now —
(a) Gallium (b) Scandium (c) Germanium (d) Technetium

Q7. Assertion (A): Noble gases are inert. Reason (R): They have a complete octet (He, duplet).
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. Across a period, atomic size —
(a) increases (b) decreases (c) constant (d) doubles

ANSWER KEY

1-b. **2-a**. **3-b** (larger atoms lose e^- easily). **4-c**. **5-b**. **6-c**. **7-a**. **8-b**.

PART III · CHEMICAL BONDING AND REACTIONS

7 Chemical Bonding

Every atom wants a full outer shell. The three ways it gets one — give, share or pool electrons — explain almost every property of matter.

WHY BPSC ASKS THIS
Ionic vs covalent property contrasts, conduction, and the special roles of hydrogen bonding appear as reasoning questions.

QUESTION FREQUENCY
Moderate directly; foundational for reactions, water, metals and organic chapters.

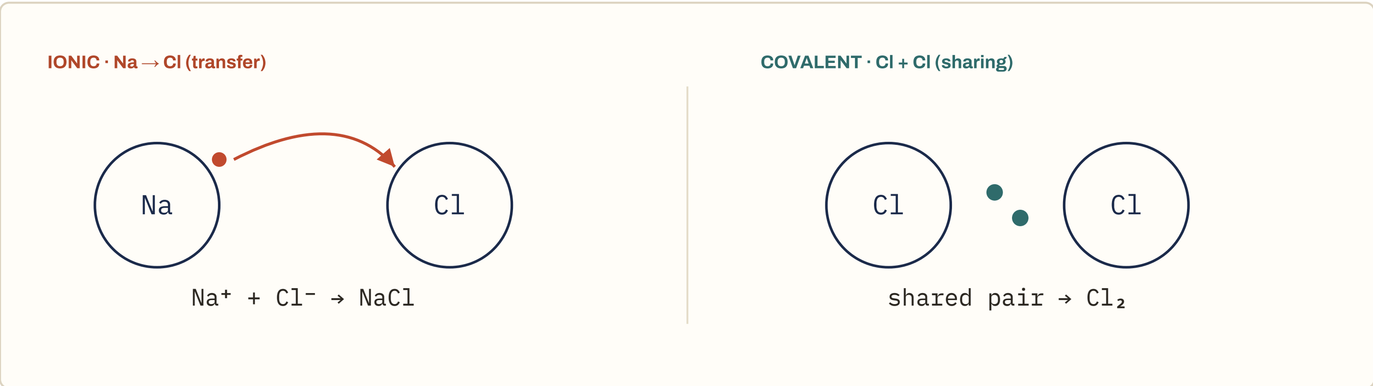
PREREQUISITES
Chapters 4–6 (valence electrons, octet, groups).

YOU WILL BE ABLE TO
Classify any compound's bond type and predict its melting point, conductivity and solubility.

7.1 Concept Story — The Octet Rule

Noble gases barely react because their outer shell is already full (8 electrons; He has 2). Every other atom bonds to reach that same stability — the **octet rule** (Kössel & Lewis, 1916). A metal like sodium (1 outer e^-) finds it easy to *give* that electron; chlorine (7 outer e^-) is desperate to *gain* one. When they meet, sodium hands its electron to chlorine — that is an **ionic bond**. When two non-metals both need electrons, neither will give, so they *share* — a **covalent bond**. In a lump of metal, atoms pool their electrons into a shared "sea" — the **metallic bond**.

7.2 Ionic vs Covalent — The Formation Diagram



PROPERTY	IONIC (E.G. NACL)	COVALENT (E.G. SUGAR, CH_4)
Formed between	metal + non-metal	non-metal + non-metal
Melting/boiling point	high	low
State (room temp)	solid crystals	gas/liquid/soft solid
Conducts electricity	molten or aqueous (yes)	generally no
Solubility in water	high	usually low (soluble in organic solvents)

MEMORY HOOK

"I-onic gives, Co-valent shares." Ionic = high melting point + conducts when molten/aqueous; covalent = low melting + poor conductor. Hindi cue: *"धातु देती है, अधातु बाँटती है।"*

7.3 Metallic Bonding & the Electron Sea

ELECTRON-SEA MODEL

Metal atoms release their valence electrons into a mobile "sea" shared by all positive ion cores. This explains **electrical & thermal conductivity** (free electrons carry charge/heat), **malleability & ductility** (layers slide without breaking bonds) and **metallic lustre**.

7.4 Hydrogen Bonding — Small Force, Big Effects

WHAT IT IS

A weak attraction when H is bonded to a small, highly electronegative atom (N, O, F) and is drawn to a lone pair on a neighbour. Much weaker than a covalent bond, but decisive in bulk.

WHAT IT EXPLAINS

- Water's unusually high boiling point
- Ice floats (open, less dense lattice)
- DNA double helix & protein shape

7.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The bond in common salt (NaCl) is —

(a) **Ionic ✓** (b) Covalent

(c) Metallic (d) Hydrogen

Why: metal (Na) + non-metal (Cl) → electron transfer. **Trap:** molten/aqueous NaCl conducts — solid NaCl does not.

PYQ State PCS pattern (repeated) · Moderate

Ice floats on water because —

(a) it is colder (b) **hydrogen bonds form an open lattice, lowering density ✓**

(c) it has more air (d) covalent bonds break

Why: H-bonding spaces molecules apart in ice → less dense than liquid water.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: "Why does salt melt at 800 °C but wax at 60 °C?" → bond strength story.
2. Board: octet rule → draw Na→Cl transfer and Cl–Cl sharing → property table.
3. Demo idea: conductivity of salt solution vs sugar solution with a bulb circuit.
4. Doubt: "Is graphite covalent yet conducting?" → note the free-electron exception.
5. Recap + homework: classify 12 compounds; solve 8 MCQs. Bridge to Chapter 8: "Now bonds break and re-form — that is a reaction."

COMMON TRAPS

1. Solid ionic solids do *not* conduct; molten/aqueous do.
2. Graphite (covalent) conducts — exception via delocalised e^-.
3. H-bond is an *inter*molecular force, not a real covalent bond.
4. Diamond & SiO_2 are covalent yet high-melting (giant networks).
5. Metallic bonding, not ionic, gives malleability.

RAPID RECALL · CHAPTER 7

① Octet rule: atoms bond to reach a full outer shell.
② Ionic = transfer (metal + non-metal).
③ Covalent = sharing (non-metal + non-metal).
④ Metallic = electron sea (free e^-).
⑤ Ionic: high m.p., water-soluble, conducts molten/aqueous.
⑥ Covalent: low m.p., poor conductor.
⑦ H-bond needs H with N, O or F.
⑧ Ice floats — open H-bonded lattice.
⑨ Metals: conduct, malleable, lustrous (electron sea).
⑩ Graphite conducts (covalent exception).
⑪ Diamond & SiO_2 = giant covalent, very high m.p.
⑫ Octet rule proposed by Kössel & Lewis (1916).

7.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. A covalent bond is formed by —
(a) transfer of e^- (b) sharing of e^- (c) pooling of e^- (d) losing e^-

Q2. Which conducts electricity in molten state?
(a) Sugar (b) NaCl (c) Wax (d) Diamond

Q3. Malleability of metals is due to —
(a) ionic bonds (b) covalent bonds (c) mobile electron sea (d) H-bonds

Q4. Hydrogen bonding is NOT present in —
(a) H_2O (b) HF (c) NH_3 (d) CH_4

Q5. Number of electrons shared in an N≡N triple bond —
(a) 2 (b) 4 (c) 6 (d) 8

Q6. The octet rule was proposed by —
(a) Bohr (b) Kössel & Lewis (c) Dalton (d) Moseley

Q7. Assertion (A): Graphite conducts electricity. Reason (R): It has one free (delocalised) electron per carbon.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. High melting point + water solubility suggests bonding is —
(a) covalent (b) ionic (c) metallic (d) van der Waals

ANSWER KEY

1-b. **2-b**. **3-c**. **4-d** (CH_4 has no N/O/F–H). **5-c** (three shared pairs). **6-b**. **7-a**. **8-b**.

PART III · CHEMICAL BONDING AND REACTIONS

8 Chemical Reactions

A handful of reaction types covers almost everything that happens in a test-tube, a kitchen or a factory. Learn to spot the pattern.

WHY BPSC ASKS THIS
Reaction-type identification, exo/endothermic examples and catalyst facts are frequent one-mark questions.

QUESTION FREQUENCY
High — reaction classification appears almost every cycle.

PREREQUISITES
Chapter 5 (balancing) & Chapter 7 (bonds break/form).

YOU WILL BE ABLE TO
Name a reaction from its equation and give an everyday example of each type.

8.1 Concept Story — Signs a Reaction Happened

A chemical reaction rearranges atoms into new substances — old bonds break, new bonds form, and mass is conserved (Lavoisier). You can usually *see* that one occurred: a **colour change** (iron rusting), **gas evolution** (baking soda + vinegar fizzing), a **precipitate** forming, a **temperature change**, or light/sound. In the classroom we sort every reaction into five families plus the energy label of exothermic or endothermic.

8.2 The Five Reaction Types

TYPE	PATTERN	EXAMPLE
Combination	A + B → AB	$CaO + H_2O \rightarrow Ca(OH)_2$ (slaking of lime)
Decomposition	AB → A + B	$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$ (lime kiln)
Displacement	A + BC → AC + B	$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$
Double displacement	AB + CD → AD + CB	$AgNO_3 + NaCl \rightarrow AgCl\downarrow + NaNO_3$
Combustion	fuel + O_2 → oxides + heat	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

MEMORY HOOK

"Come, Dance, Don't Double-Dance, Combust" = **C**ombination, **D**ecomposition, **D**isplacement, **D**ouble-displacement, **C**ombustion. Displacement follows the *reactivity series* — a more reactive metal kicks out a less reactive one.

8.3 Identification Flowchart

How many products?

ONE product → Combination

MANY → look further

Ions swap? → Double displacement

One reactant splitting → Decomposition · a metal replacing another → Displacement · burns in O_2 + heat → Combustion

8.4 Energy, Rate & Catalysts

EXO VS ENDO

Exothermic releases heat (combustion, respiration, quicklime + water). **Endothermic** absorbs heat (photosynthesis, thermal decomposition, cooking).

CATALYST

A substance that **speeds up** a reaction by lowering activation energy and is **recovered unchanged**. Rate also rises with temperature, concentration and surface area. Biological catalysts = **enzymes**.

✕ DO NOT CONFUSE — CATALYST FACTS

A catalyst changes *rate*, never the *amount* of product or the position of equilibrium. It is not "used up". A substance that slows a reaction is an **inhibitor** (negative catalyst).

8.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Respiration is an example of a — reaction.

(a) **Exothermic ✓** (b) Endothermic

(c) Decomposition only (d) Displacement

Why: glucose + O_2 releases energy (heat). **Trap:** photosynthesis is endothermic — the mirror process.

PYQ State PCS pattern (repeated) · Moderate

$CaCO_3 \xrightarrow{heat} CaO + CO_2$ is a reaction of type —

(a) Combination (b) **Decomposition ✓**

(c) Displacement (d) Combustion

Why: one compound splits into two on heating (thermal decomposition).

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Demos: baking soda + vinegar (gas), Fe nail in $CuSO_4$ (displacement + colour), $AgNO_3$ + NaCl (white precipitate).
2. Board: five-type table → flowchart → exo/endo examples.
3. Drill: give 10 equations, class names each type in 30 seconds.
4. Doubt: "Is rusting a reaction?" → yes, slow oxidation (leads into Chapter 9).
5. Recap + homework: classify 12 reactions; solve 8 MCQs. Bridge to Chapter 9: "The most exam-heavy reaction family — redox."

COMMON TRAPS

1. Photosynthesis = endothermic; respiration = exothermic.
2. Catalyst changes rate, not yield; recovered unchanged.
3. Precipitate = double-displacement signal.
4. Displacement obeys the reactivity series.
5. Combustion always needs oxygen and releases heat.

RAPID RECALL · CHAPTER 8

① Reaction = atoms rearranged; mass conserved (Lavoisier).
② Signs: colour, gas, precipitate, temperature, light.
③ Combination A+B→AB (CaO + H_2O).
④ Decomposition AB→A+B ($CaCO_3$ heat).
⑤ Displacement A+BC→AC+B (Fe + $CuSO_4$).
⑥ Double displacement swaps ions (AgCl↓).
⑦ Combustion: fuel + O_2 → oxides + heat.
⑧ Exothermic releases heat; endothermic absorbs.
⑨ Respiration exo; photosynthesis endo.
⑩ Catalyst speeds rate, recovered unchanged.
⑪ Rate ↑ with temp, conc, surface area.
⑫ Enzymes = biological catalysts.

8.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. Fe + $CuSO_4$ → $FeSO_4$ + Cu is a — reaction.
(a) combination (b) displacement (c) decomposition (d) combustion

Q2. Formation of a precipitate indicates —
(a) combustion (b) double displacement (c) combination (d) decomposition

Q3. A catalyst —
(a) increases yield (b) is consumed (c) lowers activation energy (d) shifts equilibrium

Q4. Which is endothermic?
(a) burning of coal (b) photosynthesis (c) respiration (d) quicklime + water

Q5. $2H_2O$ →(electricity) $2H_2$ + O_2 is —
(a) combination (b) decomposition (c) displacement (d) combustion

Q6. Biological catalysts are called —
(a) hormones (b) enzymes (c) vitamins (d) inhibitors

Q7. Assertion (A): Reaction rate rises on powdering a solid. Reason (R): Powder increases surface area.
(a) Both true, R explains A (b) Both true, R doesn't explain A (c) A true, R false (d) A false, R true

Q8. Slaking of lime (CaO + H_2O → $Ca(OH)_2$) is —
(a) endothermic (b) exothermic combination (c) displacement (d) decomposition

ANSWER KEY

1-b. **2-b**. **3-c**. **4-b**. **5-b**. **6-b**. **7-a**. **8-b** (releases heat while combining).

PART III · CHEMICAL BONDING AND REACTIONS

9 Oxidation, Reduction, Corrosion & Rancidity

One transfer of electrons — redox — quietly rusts a bridge, spoils cooking oil, powers a battery and keeps you breathing.

WHY BPSC ASKS THIS
Rusting conditions, galvanisation, and "what stops rancidity" are classic applied-science one-markers.

QUESTION FREQUENCY
Moderate–high; corrosion & antioxidants are very predictable.

PREREQUISITES
Chapter 8 (reaction types) & the reactivity idea.

YOU WILL BE ABLE TO
Identify what is oxidised/reduced and explain everyday prevention methods.

9.1 Concept Story — Oxidation Beyond Oxygen

The old idea was simple: *oxidation = adding oxygen, reduction = removing it*. The modern, more powerful definition is in terms of electrons: **oxidation is loss of electrons; reduction is gain of electrons**. The two always happen together — one substance can only lose electrons if another gains them — so we call the combined process a **redox** reaction. The species that grabs electrons (and is itself reduced) is the **oxidising agent**; the one that donates them is the **reducing agent**.

MEMORY HOOK

OIL RIG — **O**xidation **I**s **L**oss, **R**eduction **I**s **G**ain (of electrons). The oxidising agent gets reduced; the reducing agent gets oxidised.

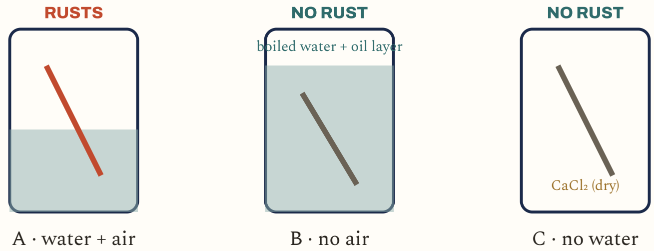
9.2 A Worked Redox Example

$$ZnO + C \rightarrow Zn + CO$$

Zinc oxide **loses** oxygen → Zn is **reduced**. Carbon **gains** oxygen → C is **oxidised**. Here carbon is the reducing agent and ZnO the oxidising agent — the exact chemistry used to extract metals from their ores (Chapter 15 preview).

9.3 Corrosion & the Rusting Experiment

THREE-TUBE RUSTING TEST · iron nails



Rust needs BOTH
water + oxygen

Rust is hydrated iron(III) oxide, $Fe_2O_3 \cdot xH_2O$ (reddish-brown). Salt speeds it up (coastal iron corrodes faster). Copper forms a green *basic carbonate* layer (verdigris); silver blackens (Ag_2S); aluminium forms a protective, adherent oxide that *stops* further attack.

9.4 Preventing Corrosion & Rancidity

STOP THE RUST

- **Galvanisation** — zinc coat (sacrificial: Zn corrodes first)
- Painting, greasing, oiling, tinning
- **Electroplating** (chromium, nickel)
- **Alloying** — stainless steel (Fe + Cr + Ni)
- Cathodic protection with a sacrificial Mg/Zn anode

STOP THE RANCIDITY

Rancidity = oxidation of fats/oils in food → bad smell & taste.

- Add **antioxidants** (BHA, BHT)
- Flush packets with **nitrogen gas** (chips)
- Refrigerate; store in airtight, dark containers
- Vacuum packing removes oxygen

× DO NOT CONFUSE — SACRIFICIAL PROTECTION

In galvanisation, zinc protects iron *even if the coating is scratched*, because Zn is more reactive and corrodes in preference to Fe. Tin (in tin cans) protects only while intact — a scratch makes iron rust *faster*.

9.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Coating iron with zinc to prevent rusting is called —

(a) **Galvanisation ✓** (b) Tinning
(c) Vulcanisation (d) Annealing

Why: zinc coat. **Trap:** vulcanisation is for rubber, annealing is heat-treatment of metal.

PYQ State PCS pattern (repeated) · Moderate

Chips packets are flushed with which gas to prevent rancidity?

(a) Oxygen (b) Carbon dioxide
(c) **Nitrogen ✓** (d) Chlorine

Why: inert N_2 displaces O_2, stopping oxidation of fats.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: pass around a rusted nail and a galvanised bucket — "why doesn't the bucket rust?"
2. Board: OIL RIG → ZnO + C worked example → three-tube rust experiment.
3. Demo (set up a week early): the three-tube experiment, revealed in class.
4. Everyday links: chips packets (N_2), vacuum-packed ghee, painted railings, stainless-steel utensils.
5. Recap + homework: label oxidised/reduced species in 6 equations; solve 6 MCQs. Bridge to Chapter 10: acids & bases.

COMMON TRAPS

1. Oxidation = loss of e^- (OIL), not just gain of oxygen.
2. Rust needs both water AND oxygen.
3. Rust = $Fe_2O_3 \cdot xH_2O$, reddish-brown, flaky.
4. Zinc protects even if scratched; tin does not.
5. Rancidity = oxidation of fats, prevented by antioxidants / N_2.

RAPID RECALL · CHAPTER 9

① OIL RIG: oxidation loses e^-, reduction gains.
② Redox = oxidation + reduction together.
③ Oxidising agent is itself reduced.
④ Rust = $Fe_2O_3 \cdot xH_2O$ (reddish-brown).
⑤ Rusting needs water + oxygen; salt speeds it.
⑥ Galvanisation = zinc coat (sacrificial).
⑦ Stainless steel = Fe + Cr + Ni.
⑧ Copper → green verdigris; silver → black Ag_2S.
⑨ Aluminium oxide layer is protective.
⑩ Rancidity = oxidation of fats/oils.
⑪ Antioxidants (BHA/BHT) & N_2 flushing prevent it.
⑫ Vacuum/airtight/cold storage slows oxidation.

9.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. Oxidation is defined as —
(a) gain of e^- (b) loss of e^- (c) gain of H (d) loss of O

Q2. Rust is chemically —
(a) FeO (b) Fe_3O_4 (c) $Fe_2O_3 \cdot xH_2O$ (d) FeS

Q3. Rusting requires —
(a) only water (b) only air (c) water and oxygen (d) heat alone

Q4. The greenish coating on old copper is —
(a) rust (b) basic copper carbonate (c) Ag_2S (d) Al_2O_3

Q5. Substances that prevent oxidation of food are —
(a) preservatives (b) antioxidants (c) emulsifiers (d) enzymes

Q6. In ZnO + C → Zn + CO, carbon acts as —
(a) oxidising agent (b) reducing agent (c) catalyst (d) solvent

Q7. Assertion (A): A scratched galvanised sheet still resists rust. Reason (R): Zinc is more reactive and corrodes before iron.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. Stainless steel contains iron with —
(a) Cu + Zn (b) Cr + Ni (c) Sn + Pb (d) C only

ANSWER KEY

1-b. **2-c**. **3-c**. **4-b**. **5-b**. **6-b** (C removes O from ZnO). **7-a**. **8-b**.

PART IV · ACIDS, BASES, SALTS AND SOLUTIONS

10 Acids and Bases

Sour lemon, slippery soap, stinging ants, an antacid tablet — all of it is the same tug-of-war over a single hydrogen ion.

WHY BPSC ASKS THIS
Indicators, strong-vs-concentrated distinction, common acids in food and acid rain are highly repeated.

QUESTION FREQUENCY
Very high — one of the most examined chemistry areas in prelims.

PREREQUISITES
Chapters 5 & 8 (formulae, reaction types).

YOU WILL BE ABLE TO
Predict indicator colours, name the acid in a food, and write a neutralisation.

10.1 Concept Story — It's All About H^+

On the classic (Arrhenius) picture, an **acid** releases hydrogen ions H^+ (really H_3O^+) in water; a **base** releases hydroxide ions OH^-. A base that dissolves in water is called an **alkali** (NaOH, KOH). Acids taste sour, turn blue litmus red and react with metals to give hydrogen gas; bases taste bitter, feel soapy and turn red litmus blue. When an acid meets a base, the H^+ and OH^- join to make water — a **neutralisation** — leaving a salt behind.

Acid + Base → Salt + Water · $HCl + NaOH \rightarrow NaCl + H_2O$
Acid + Metal → Salt + $H_2\uparrow$ · $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
Acid + Carbonate → Salt + Water + $CO_2\uparrow$ (the fizz test)

10.2 Indicators — Nature's Colour Code

INDICATOR	IN ACID	IN BASE
Litmus	red	blue
Phenolphthalein	colourless	pink
Methyl orange	red	yellow
Turmeric (haldi)	yellow (no change)	red
Olfactory (onion, clove)	smell fades in base — used to detect acid/base by odour	

MEMORY HOOK
"Phenolphthalein is shy in acid (colourless), blushes pink in base." Litmus: acid → red (A & R together). Turmeric stain on cloth turns red with soap (base) — the classic home demo.

10.3 Strong vs Weak, Concentrated vs Dilute

STRONG VS WEAK (ABOUT IONISATION)

Strong acids/bases ionise almost completely (HCl, H_2SO_4, HNO_3; NaOH, KOH). **Weak** ones ionise only partly (acetic acid CH_3COOH, carbonic acid; ammonium hydroxide NH_4OH).

CONCENTRATED VS DILUTE (ABOUT AMOUNT OF WATER)

Describes how much acid is dissolved per unit water — *not* its strength. A dilute solution of a strong acid, and a concentrated solution of a weak acid, both exist.

✕ DO NOT CONFUSE — ALWAYS ADD ACID TO WATER

Diluting concentrated acid is highly exothermic. **Always pour acid slowly into water** (never water into acid), or the heat can splash concentrated acid out. "Strong" ≠ "concentrated".

10.4 Everyday Acids & Acid Rain

SOURCE	ACID	SOURCE	ACID
Lemon / orange	`Citric acid`	Vinegar	`Acetic acid`
Curd / milk	`Lactic acid`	Ant / nettle sting	`Formic acid`
Tamarind / grapes	`Tartaric acid`	Tomato	`Oxalic acid`
Gastric juice (stomach)	`Hydrochloric acid`	Apple	`Malic acid`

ACID RAIN

Oxides of sulphur and nitrogen (SO_2, NO_2) from burning fossil fuels dissolve in rain to form **sulphuric & nitric acid** (pH < 5.6). It corrodes buildings (Taj Mahal "marble cancer"), acidifies lakes and damages crops.

10.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The acid present in the sting of an ant is —

(a) **Formic acid ✓**
(b) Acetic acid
(c) Citric acid
(d) Lactic acid

Why: ant/nettle → formic acid (HCOOH). **Trap:** vinegar = acetic; curd = lactic.

PYQ State PCS pattern (repeated) · Moderate

Phenolphthalein in a basic solution turns —

(a) red
(b) **pink ✓**
(c) yellow
(d) colourless

Why: colourless in acid, pink in base. **Trap:** methyl orange gives red/yellow.

FACULTY NOTE · DELIVERY PLAN (120 MIN)

1. Demo: litmus / turmeric / phenolphthalein on lemon juice, soap and baking soda.
2. Board: H^+/OH^- definitions → three reaction equations → indicator table.
3. Fizz test: baking soda + lemon → CO_2 turns lime water milky.
4. Drill everyday-acid table as a rapid oral quiz.
5. Safety point: always acid-to-water. Recap + homework: 10 acid sources + 3 equations; 8 MCQs. Bridge to Chapter 11 (pH).

COMMON TRAPS

1. Strong ≠ concentrated (ionisation vs amount of water).
2. All alkalis are bases, but not all bases are alkalis.
3. Acid + metal → H_2 gas (pop test), not O_2.
4. Phenolphthalein: colourless in acid, pink in base.
5. Ant sting = formic, curd = lactic, tomato = oxalic.

RAPID RECALL · CHAPTER 10

① Acid → H^+; base → OH^- (Arrhenius).
② Alkali = water-soluble base (NaOH, KOH).
③ Acid + base → salt + water (neutralisation).
④ Acid + metal → salt + H_2↑ (pop test).
⑤ Acid + carbonate → CO_2↑ (lime water milky).
⑥ Litmus: acid red, base blue.
⑦ Phenolphthalein: colourless / pink.
⑧ Methyl orange: red / yellow.
⑨ Strong = fully ionised; concentrated = little water.
⑩ Always add acid to water (exothermic).
⑪ Ant formic, vinegar acetic, curd lactic, tomato oxalic.
⑫ Acid rain from SO_2 & NO_2 (H_2SO_4, HNO_3).

10.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. A water-soluble base is called —
(a) an acid (b) a salt (c) an alkali (d) an oxide

Q2. Acid + metal usually gives —
(a) O_2 (b) H_2 (c) CO_2 (d) N_2

Q3. The acid in curd is —
(a) citric (b) acetic (c) lactic (d) tartaric

Q4. Which is a weak acid?
(a) HCl (b) H_2SO_4 (c) HNO_3 (d) CH_3COOH

Q5. Methyl orange in acid is —
(a) yellow (b) red (c) pink (d) colourless

Q6. Acid rain is mainly caused by —
(a) CO_2 & CH_4 (b) SO_2 & NO_2 (c) O_3 & O_2 (d) H_2 & He

Q7. Assertion (A): We dilute acid by adding acid to water.
Reason (R): The dilution is strongly exothermic.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. Gas that turns lime water milky (from acid + carbonate) —
(a) H_2 (b) O_2 (c) CO_2 (d) SO_2

ANSWER KEY

1-c. 2-b. 3-c. 4-d. 5-b. 6-b. 7-a. 8-c.

PART IV · ACIDS, BASES, SALTS AND SOLUTIONS

11 pH and Its Applications

A single number from 0 to 14 decides whether soil grows a crop, a tooth survives a toffee, or a fish lives in a lake.

WHY BPSC ASKS THIS
pH values of blood, everyday substances and the "tooth decay/soil pH" applications are perennial one-markers.

QUESTION FREQUENCY
Very high — pH applications are among the most-repeated GS-science facts.

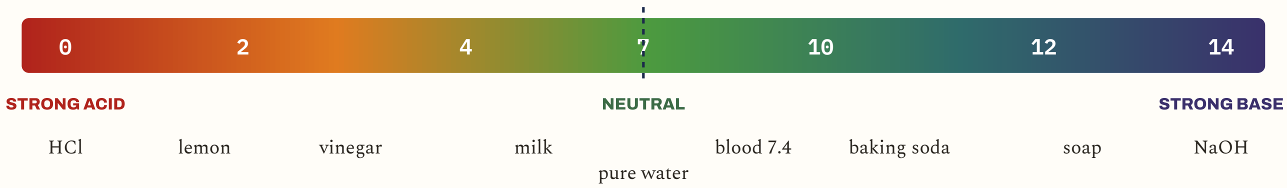
PREREQUISITES
Chapter 10 (H^+/OH^-, indicators).

YOU WILL BE ABLE TO
Place any substance on the pH scale and explain a real-world pH application.

11.1 Concept Story — Measuring Sourness

Litmus tells us *whether* something is acidic, but not *how* acidic. In 1909 **Sørensen** gave us the **pH scale** — "power of Hydrogen" — a number from **0 to 14** that measures the concentration of H^+ ions. **pH 7 is neutral** (pure water). **Below 7 is acidic** — the lower the number, the stronger the acid. **Above 7 is basic/alkaline** — the higher the number, the stronger the base. Crucially the scale is **logarithmic**: each step is a ten-fold change, so pH 3 is *ten times* more acidic than pH 4 and a hundred times more than pH 5.

11.2 The pH Scale — A Visual Ruler



Human blood is tightly held at pH 7.35–7.45 — slightly basic.

MEMORY HOOK

"7 is heaven — neutral. Low is sour, high is soapy." Lower sc-camel-p-h = more H^+ = more acidic. Each unit = ×10. Hindi cue: *"कम मतलब खट्टा, ज़्यादा मतलब साबुन जैसा।"*

11.3 pH in Everyday Life — The Applications

TOOTH DECAY
Enamel corrodes when mouth pH falls below **5.5** (bacteria + sugar make acid). Toothpaste is **basic** to neutralise it.

ACIDITY & ANTACIDS
Excess stomach HCl → antacid (milk of magnesia, $Mg(OH)_2$ / $NaHCO_3$) neutralises it.

SOIL & CROPS
Too acidic → add **lime** (CaO); too basic → add gypsum/organic matter. Most crops like pH ≈ 6–7.5.

STINGS & NATURE
Bee/ant sting (acidic, formic) → rub **baking soda**; wasp sting (basic) → rub **vinegar**.

11.4 Key pH Values to Memorise

SUBSTANCE	APPROX. PH	SUBSTANCE	APPROX. PH
Gastric juice	1–2	Pure water	7
Lemon juice	2–3	Human blood	7.4
Vinegar	3	Baking soda soln.	9
Milk	6.5	NaOH solution	13–14

✕ DO NOT CONFUSE — PH VS STRENGTH
A *lower* pH means *more* acidic (more H^+). Acid rain has pH below 5.6. pH is logarithmic — pH 2 is **10**×, not 2×, more acidic than pH 3. Distilled water can drift slightly acidic from dissolved CO_2.

11.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The pH of pure water at 25 °C is —

(a) 0
(b) 7 ✓
(c) 14
(d) 1

Why: equal H^+ and OH^- → neutral. **Trap:** 0 and 14 are the extremes, not neutral.

PYQ State PCS pattern (repeated) · Moderate

Tooth enamel starts to decay when mouth pH falls below —

(a) 7
(b) 5.5 ✓
(c) 3
(d) 9

Why: below 5.5 acid dissolves calcium phosphate enamel — brushing with basic paste neutralises it.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Demo: universal indicator / pH paper on lemon, water, soap, baking soda → build the colour ruler live.
2. Board: 0–14 scale → logarithmic idea (×10 per step) → applications grid.
3. Story links: toffee & toothache, acidity & antacid, bee vs wasp sting.
4. Drill the pH-value table as a rapid oral quiz.
5. Recap + homework: place 10 substances on the scale; 8 MCQs. Bridge to Chapter 12 (salts).

COMMON TRAPS

1. Lower sc-camel-p-h = more acidic (not less).
2. Scale is logarithmic — one unit = 10×.
3. Blood is slightly basic (7.4), not neutral.
4. Bee sting acidic → soda; wasp sting basic → vinegar.
5. Antacids are bases that neutralise stomach acid.

RAPID RECALL · CHAPTER 11

① pH scale 0–14 (Sørensen, 1909).
② pH 7 neutral; <7 acidic; >7 basic.
③ Logarithmic — 1 unit = ×10 in H^+.
④ Lower sc-camel-p-h = more H^+ = more acidic.
⑤ Blood pH 7.35–7.45 (slightly basic).
⑥ Gastric juice pH ≈ 1–2.
⑦ Tooth decay below pH 5.5.
⑧ Antacids ($Mg(OH)_2$, $NaHCO_3$) neutralise acidity.
⑨ Acidic soil corrected with lime.
⑩ Bee sting acidic → baking soda.
⑪ Wasp sting basic → vinegar.
⑫ Acid rain pH < 5.6.

11.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. A solution of pH 4 compared to pH 5 is —
(a) equally acidic (b) 10× more acidic (c) 2× more acidic (d) basic

Q2. The pH scale was introduced by —
(a) Arrhenius (b) Sørensen (c) Lewis (d) Moseley

Q3. Which has the highest pH?
(a) lemon juice (b) pure water (c) NaOH solution (d) vinegar

Q4. Milk of magnesia acts as an —
(a) acid (b) antacid (c) indicator (d) catalyst

Q5. Human blood pH is close to —
(a) 5 (b) 6 (c) 7.4 (d) 9

Q6. To treat a bee sting (acidic) one applies —
(a) vinegar (b) lemon (c) baking soda (d) HCl

Q7. Assertion (A): Farmers add lime to acidic soil. Reason (R): Lime is basic and raises soil pH.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. A substance with pH 2 is —
(a) strongly basic (b) neutral (c) strongly acidic (d) weakly basic

ANSWER KEY

1-b. 2-b. 3-c. 4-b. 5-c. 6-c. 7-a. 8-c.

PART IV · ACIDS, BASES, SALTS AND SOLUTIONS

12 Salts and Important Compounds

Five white powders — table salt, baking soda, washing soda, bleaching powder and plaster of Paris — sit behind half the applied-chemistry questions ever asked.

WHY BPSC ASKS THIS
Formula + common-name + use of the "big five" salts are near-certain one-mark facts.

QUESTION FREQUENCY
Very high — "common name / chemical name" pairs are asked every cycle.

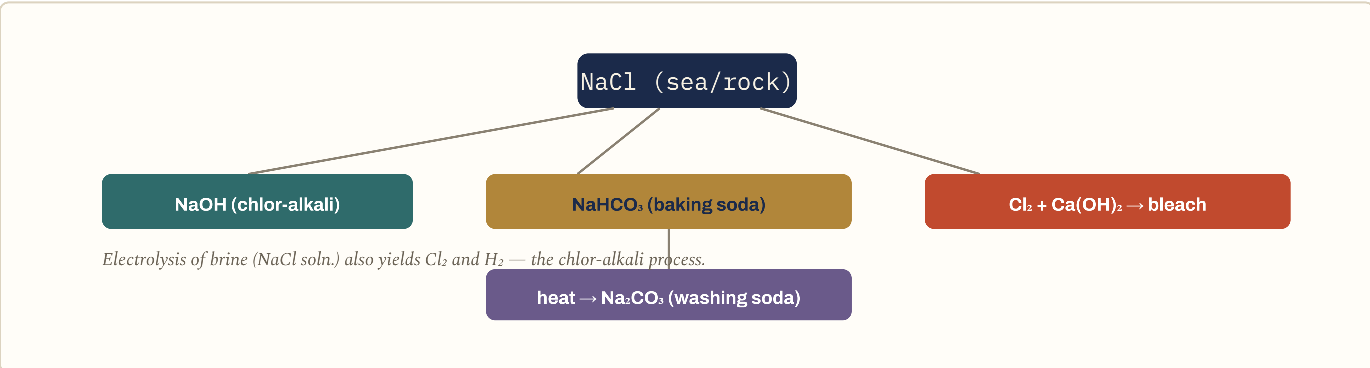
PREREQUISITES
Chapters 10–11 (neutralisation, pH).

YOU WILL BE ABLE TO
Match every common salt to its formula, method of making, and everyday use.

12.1 Concept Story — What Is a Salt?

A **salt** is the ionic compound left when the H^+ of an acid is replaced by a metal (or ammonium) ion — the product of **neutralisation**. Its "surname" comes from the acid, its "first name" from the base: HCl gives **chlorides**, H_2SO_4 gives **sulphates**, HNO_3 gives **nitrates**, H_2CO_3 gives **carbonates**. The nature of a salt's solution depends on its parents — **strong acid** + **strong base** → **neutral salt** (NaCl); **strong base** + **weak acid** → **basic salt** (Na_2CO_3); **strong acid** + **weak base** → **acidic salt** (NH_4Cl).

12.2 The Big Five — from Common Salt



COMMON NAME	FORMULA	KEY USE / FACT
Common salt	NaCl	food, raw material for all others
Baking soda	$NaHCO_3$	antacid, baking (CO_2), fire extinguishers
Washing soda	$Na_2CO_3 \cdot 10H_2O$	removes hardness of water, glass & soap
Bleaching powder	$CaOCl_2$	disinfect water, bleach cloth/paper
Plaster of Paris	$CaSO_4 \cdot \frac{1}{2}H_2O$	plaster casts, moulds; from heating gypsum

MEMORY HOOK

Baking soda = **BIcarbonate** ($NaHCO_3$, one Na); **Washing soda** = **carbonate** + **water** ($Na_2CO_3 \cdot 10H_2O$, two Na). PoP: *"Paris uses a half glass of water"* → *$CaSO_4 \cdot \frac{1}{2}H_2O$*.

12.3 Water of Crystallisation & Hydrates

DEFINITION

The fixed number of water molecules built into one formula unit of a salt crystal. Heating drives it off (turns colour); adding water restores it.

MUST-KNOW HYDRATES

- Blue vitriol $CuSO_4 \cdot 5H_2O$ (blue → white on heating)
- Green vitriol $FeSO_4 \cdot 7H_2O$
- Gypsum $CaSO_4 \cdot 2H_2O$ → PoP $CaSO_4 \cdot \frac{1}{2}H_2O$
- Washing soda $Na_2CO_3 \cdot 10H_2O$

✕ DO NOT CONFUSE — SODA COUSINS

Baking soda = $NaHCO_3$ (sodium bicarbonate); washing soda = $Na_2CO_3 \cdot 10H_2O$; caustic soda = NaOH; soda ash = anhydrous Na_2CO_3. Bleaching powder is $CaOCl_2$ — *not* chlorine gas itself.

12.4 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The chemical name of baking soda is —

(a) **Sodium bicarbonate ✓**
(b) Sodium carbonate
(c) Sodium hydroxide
(d) Calcium carbonate

Why: $NaHCO_3$. **Trap:** sodium carbonate (Na_2CO_3) is washing soda.

PYQ State PCS pattern (repeated) · Moderate

Plaster of Paris is obtained by heating —

(a) **Gypsum ✓**
(b) Limestone
(c) Common salt
(d) Chalk

Why: gypsum ($CaSO_4 \cdot 2H_2O$) heated to ~100 °C → $CaSO_4 \cdot \frac{1}{2}H_2O$. **Trap:** over-heating gives dead-burnt (useless) plaster.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: pass around five white powders — “all look the same, all do different jobs.”
2. Board: the NaCl family tree → common-name/formula/use table.
3. Demo: baking soda + vinegar (CO_2 puts out a candle); heat blue vitriol → turns white.
4. Drill common-name ↔ formula pairs as flash-cards.
5. Recap + homework: 12 common-name/formula matches; 8 MCQs. Bridge to Chapter 13 (solutions).

COMMON TRAPS

1. Baking soda $NaHCO_3 \neq$ washing soda Na_2CO_3.
2. Caustic soda = NaOH; soda ash = anhydrous Na_2CO_3.
3. Bleaching powder = $CaOCl_2$, not Cl_2.
4. PoP = $CaSO_4 \cdot \frac{1}{2}H_2O$ (half, not full, water).
5. Blue vitriol $CuSO_4 \cdot 5H_2O$ turns white on heating.

RAPID RECALL · CHAPTER 12

① Salt = product of neutralisation (acid + base).
② Strong+strong → neutral; strong base+weak acid → basic.
③ Common salt $NaCl$ → raw material for the rest.
④ Baking soda $NaHCO_3$ — antacid, baking.
⑤ Washing soda $Na_2CO_3{\cdot}10H_2O$ — softens water.
⑥ Bleaching powder $CaOCl_2$ — disinfects water.
⑦ Plaster of Paris $CaSO_4{\cdot}\frac{1}{2}H_2O$ — from gypsum.
⑧ Caustic soda = $NaOH$ (chlor-alkali).
⑨ Chlor-alkali: brine electrolysis → $NaOH + Cl_2 + H_2$.
⑩ Blue vitriol $CuSO_4{\cdot}5H_2O$ (blue → white).
⑪ Green vitriol $FeSO_4{\cdot}7H_2O$.
⑫ Water of crystallisation = fixed H_2O in crystal.

12.5 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. Washing soda is —
(a) $NaHCO_3$ (b) $Na_2CO_3{\cdot}10H_2O$ (c) $NaOH$ (d) $NaCl$

Q2. The gas released when baking soda meets an acid is —
(a) O_2 (b) H_2 (c) CO_2 (d) Cl_2

Q3. Bleaching powder is chemically —
(a) $CaCO_3$ (b) $CaOCl_2$ (c) $Ca(OH)_2$ (d) $CaSO_4$

Q4. Which salt gives a neutral solution?
(a) Na_2CO_3 (b) NH_4Cl (c) $NaCl$ (d) CH_3COONa

Q5. Blue vitriol is —
(a) $FeSO_4{\cdot}7H_2O$ (b) $CuSO_4{\cdot}5H_2O$ (c) $CaSO_4{\cdot}2H_2O$ (d) $Na_2CO_3{\cdot}10H_2O$

Q6. Caustic soda is —
(a) $NaHCO_3$ (b) Na_2CO_3 (c) $NaOH$ (d) $CaOCl_2$

Q7. Assertion (A): Plaster of Paris hardens on adding water. Reason (R): It reconverts to gypsum, setting into a solid.
(a) Both true, R explains A (b) Both true, R doesn't explain A (c) A true, R false (d) A false, R true

Q8. The chlor-alkali process electrolyses —
(a) molten $NaCl$ (b) brine solution (c) sea sand (d) limestone

ANSWER KEY

1-b. 2-c. 3-b. 4-c. 5-b. 6-c. 7-a. 8-b (aqueous $NaCl$).

PART IV · ACIDS, BASES, SALTS AND SOLUTIONS

13 Solutions and Concentration

Sugar in tea, salt in the sea, oxygen in your blood — a solution is simply one substance hiding evenly inside another.

WHY BPSC ASKS THIS
Solute/solvent identification, colloids & the Tyndall effect and solubility-vs-temperature are steady favourites.

QUESTION FREQUENCY
Moderate; the Tyndall effect & types of mixture recur reliably.

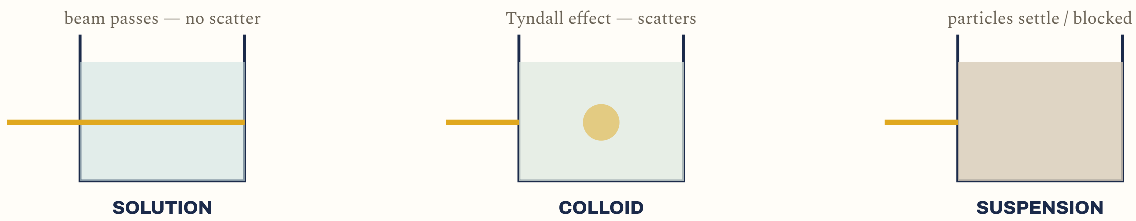
PREREQUISITES
Chapter 3 (mixtures) & basic arithmetic.

YOU WILL BE ABLE TO
Distinguish solution / colloid / suspension and compute a simple concentration.

13.1 Concept Story — Solute, Solvent, Solution

A **solution** is a *homogeneous* mixture of two or more substances. The one present in the larger amount is the **solvent** (usually water — the "universal solvent"); the one dissolved in it is the **solute**. In salt water, salt is the solute, water the solvent. Solutions are not just liquid: air is a solution of gases, and alloys like brass are solid solutions. A solution that can dissolve no more solute at a given temperature is **saturated**; heating usually lets a solvent hold more solid solute (but *less* gas).

13.2 Solution vs Colloid vs Suspension



A **true solution** (sugar in water) is clear, particles <1 nm, passes through filter paper, no scattering. A **colloid** (milk, fog, blood) has 1–1000 nm particles that **scatter light** — **the Tyndall effect**. A **suspension** (muddy water, chalk in water) has large particles that settle and can be filtered out.

MEMORY HOOK
"Sunbeam in a forest / **headlight in fog** = **Tyndall** = **colloid."** Solution is see-through and stable; suspension settles; colloid scatters but does not settle. Milk, blood, fog, cloud, ink, jelly = colloids.

13.3 Concentration — How Much Is Dissolved

MASS PERCENTAGE

% = (mass of solute ÷ mass of solution) × 100

e.g. 20 g salt in 80 g water → 20/100 × 100 = **20%**.

OTHER MEASURES

- **Volume %** — for liquid-in-liquid
- **Molarity** — moles of solute per litre of solution
- Dilute vs concentrated = little vs much solute

✕ DO NOT CONFUSE — GAS SOLUBILITY

Heating increases the solubility of most *solids* but *decreases* the solubility of *gases* — which is why a warm fizzy drink goes flat and warm rivers hold less dissolved oxygen for fish.

13.4 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The scattering of light by colloidal particles is called the —

(a) **Tyndall effect ✓** (b) Doppler effect
(c) Raman effect (d) Brownian motion

Why: colloid particles scatter a light beam. **Trap:** Brownian motion is the zig-zag movement, not the scattering.

PYQ State PCS pattern (repeated) · Moderate

Milk is an example of a —

(a) true solution (b) **colloid ✓**
(c) suspension (d) pure substance

Why: fat droplets (1–1000 nm) dispersed in water — shows Tyndall effect.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Demo: shine a torch through salt water, milk and muddy water → reveal the Tyndall beam.
2. Board: solute/solvent → three-way mixture table → concentration formula.
3. Worked sum: mass % of a salt solution done live, then one for the class.
4. Everyday link: flat warm cola, fish gasping in warm water (gas solubility ↓).
5. Recap + homework: classify 10 mixtures; 2 concentration sums; 8 MCQs. Bridge to Part V (metals).

COMMON TRAPS

1. Colloid scatters light; true solution does not.
2. Milk & blood are colloids, not solutions.
3. Heating raises solid solubility but lowers gas solubility.
4. Solvent = larger amount; solute = dissolved part.
5. Suspension particles settle; colloid particles don't.

RAPID RECALL · CHAPTER 13

① Solution = homogeneous mixture.
② Solvent = larger part; solute = dissolved part.
③ Water = universal solvent.
④ Saturated = holds no more solute at that temp.
⑤ True solution: <1 nm, no scattering, clear.
⑥ Colloid: 1–1000 nm, shows Tyndall effect.
⑦ Suspension: large particles, settle, filterable.
⑧ Milk, blood, fog, ink, jelly = colloids.
⑨ Tyndall effect = scattering of light by colloid.
⑩ Mass % = (solute ÷ solution) × 100.
⑪ Heating ↑ solid solubility, ↓ gas solubility.
⑫ Air = solution of gases; alloys = solid solutions.

13.5 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. In salt water, the solvent is —
(a) salt (b) water (c) both (d) neither

Q2. Which shows the Tyndall effect?
(a) sugar solution (b) salt solution (c) milk (d) copper sulphate solution

Q3. Particle size in a true solution is —
(a) >1000 nm (b) 1–1000 nm (c) <1 nm (d) exactly 1 mm

Q4. Muddy water is an example of a —
(a) solution (b) colloid (c) suspension (d) compound

Q5. 25 g of sugar in 100 g solution has a mass % of —
(a) 25% (b) 20% (c) 75% (d) 2.5%

Q6. On heating, the solubility of a gas in water —
(a) increases (b) decreases (c) stays same (d) doubles

Q7. Assertion (A): A warm soft drink goes flat quickly.
Reason (R): Gas solubility falls as temperature rises.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. Brass is an example of a —
(a) gaseous solution (b) liquid solution (c) solid solution (d) suspension

ANSWER KEY

1-b. 2-c. 3-c. 4-c. 5-a. 6-b. 7-a. 8-c.

PART V · METALS, NON-METALS AND METALLURGY

14 Metals and Non-Metals

Roughly three-quarters of all elements are metals — shiny, bendable, electron-givers — and the handful of non-metals that make life possible sit against them like opposites.

WHY BPSC ASKS THIS
Physical-property contrasts, the reactivity series and famous exceptions (mercury, graphite, diamond) are perennial one-markers.

QUESTION FREQUENCY
Very high — properties and the reactivity series appear almost every cycle.

PREREQUISITES
Chapters 6–7 (periodic table, bonding) & Chapter 9 (redox).

YOU WILL BE ABLE TO
Contrast metals and non-metals, order metals by reactivity and predict displacement reactions.

14.1 Concept Story — Givers and Takers

The great divide in the periodic table is between elements that *lose* electrons easily and those that *gain* them. **Metals** (left and centre) are electron-givers: they form positive ions, basic oxides, and are lustrous, malleable, ductile and good conductors. **Non-metals** (top-right) are electron-takers: they form negative ions, acidic oxides, and are mostly dull, brittle and poor conductors. A thin diagonal staircase of **metalloids** (B, Si, Ge, As, Sb, Te) shows properties of both. It is the *chemistry* — how an oxide behaves in water — that settles borderline cases, not just the shine.

14.2 Property Face-Off

PROPERTY	METALS	NON-METALS
Lustre	shiny	dull (except iodine, diamond)
State	solid (except mercury, liquid)	solid/liquid/gas (Br liquid)
Malleable / ductile	yes	no — brittle
Conductivity	good	poor (except graphite)
Sonorous	yes (ring when struck)	no
Nature of oxide	basic	acidic
Ion formed	positive (cation)	negative (anion)

MEMORY HOOK — THE FAMOUS EXCEPTIONS

Mercury = only liquid metal; **Bromine** = only liquid non-metal; **Graphite** = non-metal that conducts; **Diamond** = hardest natural substance, a non-metal; **Sodium**/**Potassium** = metals soft enough to cut with a knife.

14.3 The Reactivity Series

MOST REACTIVE — **LEAST REACTIVE (noble)**

K → Na → Ca → Mg → Al → Zn → Fe → Pb → H → Cu → Ag → Au

↑ *hydrogen reference line*

- Above H: displace H_2 from acids (K, Na react even with cold water)
- Below H (Cu, Ag, Au): do NOT displace H_2; found "native" in nature
- A metal higher up displaces a lower one from its salt ($Fe + CuSO_4 \rightarrow FeSO_4 + Cu$)

MEMORY HOOK

"Please Stop Calling Me A Zebra, Instead Try Learning How Copper Saves Gold." = K, Na, Ca, Mg, Al, Zn, Fe, Pb, H, Cu, Ag, Au (Hg between Ag & Au). The higher a metal, the more eagerly it corrodes and the harder it is to extract.

14.4 Key Reactions of Metals

WITH OXYGEN

Metal + O_2 → basic oxide. $4Na + O_2 \rightarrow 2Na_2O$; amphoteric oxides ($Al_2O_3$, ZnO) react with both acids and bases.

WITH WATER

K, Na react violently with cold water; Mg with hot water; Fe with steam. Cu/Ag/Au do not react.

WITH ACIDS

Metal above H + dilute acid → salt + $H_2\uparrow$ (pop test). $Zn + 2HCl \rightarrow ZnCl_2 + H_2$.

SPECIAL — AQUA REGIA

3 HCl : 1 HNO_3 dissolves even gold & platinum. Na/K stored in kerosene to stop reaction with air/moisture.

✕ DO NOT CONFUSE — AMPHOTERIC & EXCEPTIONS

Amphoteric oxides (Al_2O_3, ZnO, PbO) react with *both* acids and bases. Metals below hydrogen (Cu, Ag, Au) do *not* release H_2 from acids. Gold & platinum dissolve only in aqua regia.

14.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The only metal that is liquid at room temperature is —

(a) Bromine
(b) Mercury ✓
(c) Sodium
(d) Gallium

Why: mercury is liquid. **Trap:** bromine is the liquid *non-metal*; gallium melts just above room temp (in the hand).

PYQ State PCS pattern (repeated) · Moderate

Which metal does NOT react with dilute hydrochloric acid to give hydrogen?

(a) Zinc
(b) Iron
(c) Magnesium
(d) Copper ✓

Why: copper is below hydrogen in the reactivity series, so it cannot displace H_2.

FACULTY NOTE · DELIVERY PLAN (120 MIN)

1. Hook: hammer a nail flat vs snap a piece of chalk → malleable metal vs brittle non-metal.
2. Board: property face-off table → reactivity series with the mnemonic.
3. Demo: Fe nail in blue $CuSO_4$ turns brown; Zn + dilute HCl gives the pop test.
4. Drill the reactivity-series order and the famous exceptions as chants.
5. Recap + homework: 10 property/exception facts, 4 displacement equations; 8 MCQs. Bridge to Chapter 15 (metallurgy — why reactive metals are hard to extract).

COMMON TRAPS

1. Mercury = liquid metal; bromine = liquid non-metal.
2. Graphite (non-metal) conducts; diamond is hardest.
3. Metal oxides basic; non-metal oxides acidic.
4. Cu, Ag, Au don't give H_2 with acids.
5. Amphoteric oxides (Al_2O_3, ZnO) react with acids and bases.

RAPID RECALL · CHAPTER 14

① Metals: lustrous, malleable, ductile, conduct, sonorous.
② Non-metals: dull, brittle, poor conductors.
③ Metal oxides basic; non-metal oxides acidic.
④ Metals form cations; non-metals form anions.
⑤ Mercury = only liquid metal.
⑥ Bromine = only liquid non-metal.
⑦ Graphite conducts; diamond hardest.
⑧ Reactivity: K Na Ca Mg Al Zn Fe Pb H Cu Ag Au.
⑨ Metals above H displace H_2 from acids.
⑩ Higher metal displaces lower from its salt.
⑪ Amphoteric oxides: Al_2O_3, ZnO, PbO.
⑫ Aqua regia (3HCl:1HNO_3) dissolves gold.

14.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The most reactive metal among these is —
(a) Fe (b) Cu (c) K (d) Zn

Q2. Non-metal that conducts electricity —
(a) sulphur (b) graphite (c) phosphorus (d) iodine

Q3. Metal oxides are generally —
(a) acidic (b) basic (c) neutral (d) amphoteric

Q4. Which is stored in kerosene?
(a) copper (b) gold (c) sodium (d) iron

Q5. Aqua regia is a mixture of —
(a) HCl + H_2SO_4 (b) HNO_3 + H_2SO_4 (c) 3HCl + 1HNO_3 (d) HCl + water

Q6. An amphoteric oxide is —
(a) Na_2O (b) Al_2O_3 (c) CO_2 (d) MgO

Q7. Assertion (A): Copper vessels don't liberate H_2 with dilute acid. Reason (R): Copper lies below hydrogen in the reactivity series.
(a) Both true, R explains A (b) Both true, R doesn't explain A (c) A true, R false (d) A false, R true

Q8. Which pair correctly matches the odd states?
(a) Hg-metal-liquid, Br-nonmetal-liquid (b) Hg-nonmetal-liquid, Br-metal-liquid (c) both solids (d) both gases

ANSWER KEY

1-c. 2-b. 3-b. 4-c. 5-c. 6-b. 7-a. 8-a.

PART V · METALS, NON-METALS AND METALLURGY

15 Ores, Minerals and Metallurgy

Getting a shining metal out of a dull rock is one long fight against the reactivity series — the more reactive the metal, the more energy its extraction demands.

WHY BPSC ASKS THIS
Ore-of-a-metal matches, the extraction method by reactivity, and India's mineral belts are steady favourites.

QUESTION FREQUENCY
High — "ore of aluminium/iron/copper" & extraction terms recur every cycle.

PREREQUISITES
Chapter 9 (redox) & Chapter 14 (reactivity series).

YOU WILL BE ABLE TO
Match ores to metals and pick the right extraction route from a metal's position.

15.1 Concept Story — Mineral, Ore, Gangue

A **mineral** is any naturally occurring substance in which a metal is found. When a mineral contains *enough* metal to be extracted *profitably*, it is called an **ore** — so every ore is a mineral, but not every mineral is an ore. The unwanted earthy/rocky impurity mixed with the ore is the **gangue**. Because reactive metals (K, Na, Ca, Mg, Al) hold their compounds tightly, they are never found free; unreactive metals (Au, Ag, Pt) occur **native** — as the pure metal. The whole science of getting a metal from its ore is **metallurgy**.

15.2 Extraction by Reactivity — The Three Zones

HIGH — K Na Ca Mg Al	MIDDLE — Zn Fe Pb Cu	LOW — Ag Au Pt
Electrolysis of molten ore	Roast/calcine → oxide, then reduce with C	Found native or by mild heating alone
Al from bauxite (Hall–Héroult)	*Fe in blast furnace; $ZnO + C \rightarrow Zn$*	*$HgS \rightarrow Hg$ just by heating in air*

The rule of thumb: the **more reactive the metal, the more powerful** (**and expensive**) **the reducing method** — carbon can't pull the most reactive metals out, so electricity does the job.

15.3 Steps of Metallurgy

1 · CONCENTRATION (DRESSING)
Remove gangue — by hand-picking, froth flotation (sulphide ores), magnetic separation or hydraulic washing.

2 · CONVERSION TO OXIDE
Roasting (sulphide + air → oxide + SO_2); **Calcination** (carbonate → oxide + CO_2, heated without air).

3 · REDUCTION TO METAL
Oxide → metal by carbon, or by electrolysis for reactive metals. Thermite (Al reduces Fe_2O_3) welds rails.

4 · REFINING
Purify the crude metal — usually by **electrolytic refining** (impure anode → pure cathode).

15.4 Ore Directory — Match the Metal

METAL	CHIEF ORE	FORMULA	INDIA NOTE
Aluminium	Bauxite	$Al_2O_3 \cdot 2H_2O$	Odisha, Jharkhand
Iron	Haematite	Fe_2O_3	Odisha, Chhattisgarh, Jharkhand
Copper	Copper pyrites	$CuFeS_2$	Rajasthan, Jharkhand
Zinc	Zinc blende	ZnS	Rajasthan (Zawar)
Mercury	Cinnabar	HgS	imported mostly
Lead	Galena	PbS	Rajasthan

MEMORY HOOK

Sulphide ores end in -blende/-ena/pyrites (ZnS zinc blende, PbS galena, $CuFeS_2$ pyrites, HgS cinnabar); the oxide of iron is haematite Fe_2O_3; aluminium's ore is bauxite. Pair them by drilling: Bauxite→Al, Haematite→Fe, Cinnabar→Hg, Galena→Pb.

✕ DO NOT CONFUSE — ROASTING VS CALCINATION

Roasting = heating a *sulphide* ore in presence of air (gives SO_2). **Calcination** = heating a *carbonate* ore in *limited/no* air (gives CO_2). Every ore is a mineral, but not every mineral is an ore.

15.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Bauxite is the chief ore of —

(a) Iron
(b) Aluminium ✓
(c) Copper
(d) Zinc

Why: $Al_2O_3 \cdot 2H_2O$. **Trap:** haematite is the ore of iron.

PYQ State PCS pattern (repeated) · Moderate

Highly reactive metals such as sodium and aluminium are extracted by —

(a) reduction with carbon
(b) electrolysis of molten ore ✓
(c) heating in air
(d) hand-picking

Why: carbon cannot reduce very reactive metals — electricity does the job (Hall–Héroult for Al).

FACULTY NOTE · DELIVERY PLAN (120 MIN)

1. Hook: "Why is aluminium foil cheap now but was once costlier than gold?" → extraction energy story.
2. Board: mineral/ore/gangue → three reactivity zones → four metallurgy steps.
3. Drill the ore-directory table as flash-cards (metal ↔ ore ↔ formula).
4. Link to India: iron & bauxite belts of Odisha/Jharkhand (GS-geography overlap).
5. Recap + homework: 10 ore-matches, roasting vs calcination; 8 MCQs. Bridge to Chapter 16 (alloys — improving the extracted metal).

COMMON TRAPS

1. Roasting = sulphide + air; calcination = carbonate, no air.
2. Reactive metals need electrolysis, not carbon.
3. Bauxite → Al; haematite → Fe (don't swap).
4. Native metals: Au, Ag, Pt.
5. Ore is a profitable mineral; gangue is the impurity.

RAPID RECALL · CHAPTER 15

① Mineral = natural source; ore = profitable mineral.
② Gangue = earthy impurity in ore.
③ Native metals: Au, Ag, Pt.
④ Reactive metals (Na, Al) → electrolysis.
⑤ Middle metals (Fe, Zn) → reduce oxide with C.
⑥ Roasting = sulphide + air → oxide + SO_2.
⑦ Calcination = carbonate → oxide + CO_2 (no air).
⑧ Bauxite $Al_2O_3{\cdot}2H_2O$ → aluminium.
⑨ Haematite Fe_2O_3 → iron (blast furnace).
⑩ Copper pyrites $CuFeS_2$; zinc blende ZnS.
⑪ Cinnabar HgS; galena PbS.
⑫ Thermite: Al reduces Fe_2O_3 (welds rails).

15.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. Haematite is an ore of —
(a) aluminium (b) iron (c) copper (d) zinc

Q2. The earthy impurity in an ore is called —
(a) flux (b) slag (c) gangue (d) matte

Q3. Heating a carbonate ore in limited air is —
(a) roasting (b) calcination (c) smelting (d) refining

Q4. Which metal occurs native?
(a) sodium (b) aluminium (c) gold (d) zinc

Q5. The ore ZnS is called —
(a) galena (b) zinc blende (c) cinnabar (d) bauxite

Q6. Froth flotation is used to concentrate —
(a) oxide ores (b) sulphide ores (c) native metals (d) carbonate ores

Q7. Assertion (A): Aluminium is extracted by electrolysis. Reason (R): It is too reactive to be reduced by carbon.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. The thermite reaction uses aluminium to reduce —
(a) CuO (b) ZnO (c) Fe_2O_3 (d) PbO

ANSWER KEY

1-b. 2-c. 3-b. 4-c. 5-b. 6-b. 7-a. 8-c.

PART V · METALS, NON-METALS AND METALLURGY

16 Alloys

Pure metals are often too soft, too rust-prone or too dull. Mixing them turns weakness into strength — the reason bridges, coins, jewellery and aircraft exist.

WHY BPSC ASKS THIS
Composition of brass/bronze/steel and "which alloy for what" are near-certain one-mark facts.

QUESTION FREQUENCY
Very high — alloy composition is one of the safest scoring topics.

PREREQUISITES
Chapter 14 (metal properties) & Chapter 13 (solid solutions).

YOU WILL BE ABLE TO
Recall each alloy's composition and use, and explain why alloying improves a metal.

16.1 Concept Story — Why Mix Metals?

An **alloy** is a *homogeneous mixture* of a metal with one or more other metals or non-metals — essentially a solid solution. We alloy metals to **increase hardness & strength** (pure gold and iron are too soft), **resist corrosion** (stainless steel), **lower the melting point** (solder), **change colour/lustre** (jewellery) and **reduce electrical conductivity** where needed. Adding even a little carbon to iron turns bendable wrought iron into hard, structural steel — the single most important alloy on Earth.

16.2 The Alloy Directory

ALLOY	MAIN COMPOSITION	CHIEF USE
Brass	Copper + Zinc	utensils, fittings, decorative items
Bronze	Copper + Tin	statues, medals, bells
Stainless steel	Iron + Chromium + Nickel	cutlery, utensils, surgical tools
Solder	Lead + Tin	joining wires (low melting point)
Duralumin	Al + Cu + Mg + Mn	aircraft bodies (light & strong)
Amalgam	any metal + Mercury	dental fillings, extracting gold
German silver	Copper + Zinc + Nickel	ornaments, resistance wire (no silver!)

MEMORY HOOK

Brass = **Cu** + **Zinc** ("bra-Z-Z"); **Bronze** = **Cu** + **Tin** ("bron-Tin"). Solder is **so-l-Low-melt** = Pb + Sn. Duralumin flies (aircraft). German silver has **no silver** — a classic trap.

16.3 Steel & Gold — Two Special Cases

IRON & STEEL

Wrought iron (<0.25% C, soft), **steel** (0.25–2% C, strong, structural), **cast iron** (2–4% C, brittle). Just a pinch of carbon transforms the metal — the essence of alloying.

CARAT GOLD

24-carat = **pure gold** (too soft for jewellery). **22-carat** (≈91.6%) and **18-carat** (75%) gold are alloyed with copper/silver for strength. Purity % = carat ÷ 24 × 100.

✕ DO NOT CONFUSE — THE CLASSIC TRAPS

Brass = Cu + **Zn**; bronze = Cu + **Sn** (don't swap). German silver contains **no silver**. Amalgam always contains **mercury**. Steel is an alloy of iron with **carbon** (a non-metal), not another metal.

16.4 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Brass is an alloy of —

(a) **Copper and Zinc ✓**
(b) Copper and Tin
(c) Copper and Nickel
(d) Iron and Carbon

Why: Cu + Zn. **Trap:** copper + tin is bronze.

PYQ State PCS pattern (repeated) · Moderate

An amalgam is an alloy in which one component is always —

(a) carbon
(b) nickel
(c) **mercury ✓**
(d) tin

Why: amalgam = metal + mercury (e.g. dental fillings).

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: pass a brass utensil, a bronze medal and a steel spoon — "all metal, all different, why?"
2. Board: why we alloy (5 reasons) → alloy-directory table.
3. Special cases: carbon % in iron/steel/cast iron; carat gold arithmetic.
4. Drill composition flash-cards; spotlight the German-silver & brass/bronze traps.
5. Recap + homework: 12 alloy compositions/uses; 8 MCQs. Bridge to Part VI (Carbon & its compounds).

COMMON TRAPS

1. Brass = Cu+Zn; bronze = Cu+Sn (never swap).
2. German silver has no silver (Cu+Zn+Ni).
3. Amalgam always contains mercury.
4. Steel = iron + carbon (non-metal).
5. 24-carat = pure gold; jewellery is 22/18-carat.

RAPID RECALL · CHAPTER 16

① Alloy = homogeneous mix (solid solution) of metals.
② Alloying ↑ hardness, corrosion-resistance, ↓ m.p.
③ Brass = Cu + Zn.
④ Bronze = Cu + Sn.
⑤ Stainless steel = Fe + Cr + Ni.
⑥ Solder = Pb + Sn (low m.p.).
⑦ Duralumin = Al+Cu+Mg+Mn (aircraft).
⑧ Amalgam = metal + mercury.
⑨ German silver = Cu+Zn+Ni (no silver).
⑩ Steel = iron + carbon.
⑪ Cast iron 2–4% C; wrought iron <0.25% C.
⑫ 24-carat = pure gold; 22/18-carat alloyed.

16.5 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. Bronze is an alloy of copper and —
(a) zinc (b) tin (c) nickel (d) iron

Q2. Which alloy is used for aircraft bodies?
(a) solder (b) brass (c) duralumin (d) bronze

Q3. Stainless steel contains iron, chromium and —
(a) tin (b) nickel (c) zinc (d) lead

Q4. German silver contains —
(a) silver (b) no silver (c) gold (d) tin

Q5. Pure gold is —
(a) 18-carat (b) 22-carat (c) 24-carat (d) 20-carat

Q6. Solder (Pb + Sn) is chosen because it has a —
(a) high m.p. (b) low m.p. (c) high density (d) magnetic nature

Q7. Assertion (A): 24-carat gold is not used in jewellery.
Reason (R): Pure gold is too soft, so it is alloyed with copper.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

Q8. Cast iron contains carbon in the range —
(a) <0.25% (b) 0.25–2% (c) 2–4% (d) 6–8%

ANSWER KEY

1-b. 2-c. 3-b. 4-b. 5-c. 6-b. 7-a. 8-c.

STAGE 7 · REVIEW CHECKPOINT

Chapters 1–16 are now delivered — **Part V** (**Metals, Non-Metals and Metallurgy**) **fully closed** — all in the same 16-section format with concept stories, diagrams, PYQ zones, memory hooks, faculty plans, rapid-recall grids and MCQ banks. Next is **Part VI — Non-Metals and Important Elements** (**Chapters 17–21: Hydrogen, Oxygen & Ozone, Nitrogen, Carbon, and the Sulphur–Phosphorus–Halogen–Noble-gas group**).

PART VI · NON-METALS AND IMPORTANT ELEMENTS

17 Hydrogen

The lightest and most abundant element in the universe — and the fuel most likely to power India's clean-energy future.

WHY BPSC ASKS THIS
Isotopes, lightest-gas facts and the National Green Hydrogen Mission are recurring current-affairs-linked questions.

QUESTION FREQUENCY
High — spikes further with the green-hydrogen policy push.

PREREQUISITES
Chapter 4 (atomic structure) & Chapter 6 (periodic position).

YOU WILL BE ABLE TO
Name hydrogen's three isotopes, its industrial uses, and distinguish green/blue/grey hydrogen.

17.1 Concept Story — The Element That Won't Sit Still

Hydrogen (**H, Z** = **1**) has a single proton and a single electron — the simplest atom there is. It makes up about **75% of the universe's mass**, yet is rare as free gas on Earth (it is too light to be held by gravity and escapes to space). The periodic table can't decide where to put it: with one valence electron it resembles **Group 1 alkali metals**, but needing one electron to fill its shell it also resembles **Group 17 halogens** — so it is usually placed at the top of Group 1 with a footnote. Discovered by **Henry Cavendish** (**1766**) as "inflammable air"; the name (Greek *hydro-genes*, "water-former") was given by **Lavoisier**.

17.2 The Three Isotopes

ISOTOPE	SYMBOL	NEUTRONS	NOTE
Protium	^{1}H	0	Ordinary hydrogen (99.98%); no neutron at all.
Deuterium	^{2}H (D)	1	Forms "heavy water" D_2O — moderator in nuclear reactors.
Tritium	^{3}H (T)	2	Radioactive; used in fusion research and luminous dials.

MEMORY HOOK
Pro-Deu-Tri = **0-1-2 neutrons.** Only tritium is radioactive. "Heavy water = **D**euterium water", the reactor moderator.

17.3 Preparation, Properties & Everyday Uses

MAKING IT
Lab: Zn + dil. $H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$. **Industry:** mostly from steam + natural gas (steam reforming) or by **electrolysis of water** (splits into H_2 at cathode, O_2 at anode, 2:1 by volume).

KEY USES
Hydrogenation of vegetable oils → vanaspati ghee (Ni catalyst); synthesis of **ammonia** (Haber); **oxy-hydrogen flame** for welding/cutting metals; rocket fuel (liquid H_2); fuel cells.

17.4 Hydrogen as Fuel — The Colour Code

GREEN
Electrolysis of water using **renewable** electricity. Zero carbon — India's target under the National Green Hydrogen Mission.

BLUE
From fossil fuels, but the CO_2 is **captured & stored** (CCS). Lower emissions than grey.

GREY
From natural gas **without** capture — cheapest but most polluting; the bulk of today's supply.

FUEL CELL & MISSION
A **hydrogen fuel cell** combines $H_2 + O_2 \rightarrow$ water + electricity, with **water as the only exhaust**. India launched the **National Green Hydrogen Mission in 2023** to become a global production hub. Highest calorific value of any fuel by mass, but hard to store (very low density; flammable).

17.5 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Heavy water is —

(a) H_2O at 4°C
(b) D_2O ✓
(c) H_2O_2
(d) tritium oxide

Why: heavy water = deuterium oxide, D_2O; used as a moderator in nuclear reactors.

PYQ State PCS pattern (repeated) · Moderate

"Green hydrogen" is produced by —

(a) burning coal
(b) electrolysis of water using renewable energy ✓
(c) steam reforming of natural gas
(d) refining petroleum

Why: renewable-powered electrolysis makes it carbon-free — the basis of the National Green Hydrogen Mission.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: "The Sun runs on it, and so might your next car."
2. Board: position dilemma (Group 1 vs 17) → three isotopes with a neutron sketch.
3. Uses chain: vanaspati → ammonia → welding flame → rocket/fuel cell.
4. Current affairs: green/blue/grey colour code + 2023 Mission.
5. Recap + homework: isotope table + 10 MCQs. Bridge to Chapter 18 (Oxygen & Ozone).

COMMON TRAPS

1. Protium has **zero** neutrons — not one.
2. Only **tritium** is radioactive.
3. Heavy water = D_2O, *not* H_2O_2 (that's hydrogen peroxide).
4. Hydrogen is most abundant in the **universe**, not Earth's crust (that's oxygen).
5. Green ≠ blue: blue still uses fossil fuel + capture.

RAPID RECALL · CHAPTER 17

① H, Z = 1 — lightest, most abundant in universe.
② Discovered by Cavendish; named by Lavoisier.
③ Isotopes: protium (0n), deuterium (1n), tritium (2n).
④ Only tritium is radioactive.
⑤ Heavy water = D_2O — reactor moderator.
⑥ Hydrogenation of oils → vanaspati (Ni catalyst).
⑦ Used to make ammonia (Haber process).
⑧ Fuel cell: $H_2 + O_2 \rightarrow$ water + electricity.
⑨ Green = renewable electrolysis (zero C).
⑩ Blue = fossil + carbon capture; grey = fossil, no capture.
⑪ National Green Hydrogen Mission — 2023.
⑫ Highest calorific value per unit mass.

17.6 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. Which isotope of hydrogen has no neutron?
(a) deuterium (b) tritium (c) protium (d) all have one

Q2. Vanaspati ghee is made by hydrogenation using the catalyst —
(a) Pt (b) Ni (c) Fe (d) V_2O_5

Q3. The only product of a hydrogen fuel cell (besides electricity) is —
(a) CO_2 (b) water (c) O_3 (d) methane

Q4. Hydrogen is generally placed in the periodic table with Group —
(a) 1 (b) 17 (c) 18 (d) 2

Q5. On electrolysis of water, the ratio of H_2 to O_2 by volume is —
(a) 1:1 (b) 1:2 (c) 2:1 (d) 3:1

Q6. Which is radioactive?
(a) protium (b) deuterium (c) tritium (d) none

Q7. India's National Green Hydrogen Mission was launched in —
(a) 2019 (b) 2021 (c) 2023 (d) 2015

Q8. Assertion (A): Hydrogen is rare as free gas on Earth. Reason (R): It is too light to be retained by Earth's gravity.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

ANSWER KEY

1-c. 2-b. 3-b. 4-a. 5-c. 6-c. 7-c. 8-a.

PART VI · NON-METALS AND IMPORTANT ELEMENTS

18 Oxygen and Ozone

The gas we breathe, and its high-altitude cousin that shields all life from the Sun's ultraviolet rays.

WHY BPSC ASKS THIS
Ozone layer, Montreal Protocol and oxide classification are perennial environment-linked favourites.

QUESTION FREQUENCY
Very high — the ozone hole is a guaranteed environment topic.

PREREQUISITES
Chapter 3 (allotropes) & Chapter 8 (oxidation).

YOU WILL BE ABLE TO
Classify oxides, explain the ozone shield, and state what the Montreal Protocol banned.

18.1 Concept Story — The Breath of Life

Oxygen (**O, Z** = **8**) is the **most abundant element in Earth's crust** (~46%) and the third most abundant in the universe. Free oxygen exists as diatomic **O_2** — 21% of air by volume. It was discovered independently by **Scheele and Priestley**, but named by **Lavoisier** (Greek "acid-former"). Oxygen supports **respiration** and **combustion**: it is not itself flammable but is a strong **supporter of burning**. In the lab it is made by heating potassium chlorate with a MnO_2 catalyst ($2KClO_3 \rightarrow 2KCl + 3O_2$); industrially by **fractional distillation of liquefied air**.

18.2 Classifying Oxides

TYPE	NATURE	EXAMPLES
Acidic	non-metal oxides; form acids with water	CO_2, SO_2, SO_3, NO_2
Basic	metal oxides; form bases with water	Na_2O, CaO, MgO
Amphoteric	react with *both* acids and bases	Al_2O_3, ZnO, PbO
Neutral	neither acidic nor basic	CO, N_2O, H_2O, NO

MEMORY HOOK
Metal → basic, non-metal → acidic. Amphoteric = "both" — remember **Al, Zn, Pb** ("All Zebras Play both sides"). Neutral oxides: **CO, NO, N_2O, H_2O**.

18.3 Ozone — The Same Element, a Different Job

Ozone (**O_3**) is an **allotrope of oxygen** — three atoms instead of two — a pale-blue, pungent gas. It forms in the **stratosphere** when UV splits O_2 and the atoms recombine with O_2. This **ozone layer absorbs harmful UV-B radiation**, protecting life from skin cancer and cataracts. Ozone is a case of "good up high, bad nearby": at ground level it is a toxic pollutant and a component of photochemical smog.

THE OZONE HOLE

CFCs (chlorofluorocarbons, once used in refrigerants and aerosols) release **chlorine atoms** that destroy ozone. The worst thinning appears over **Antarctica**. Ozone is measured in **Dobson Units**.

MONTREAL PROTOCOL (1987)

The global treaty that **phased out CFCs and other ozone-depleting substances**. Widely called the most successful environmental agreement — the layer is slowly recovering. **World Ozone Day: 16 September.**

× DO NOT CONFUSE — THE CLASSIC TRAPS

Oxygen is most abundant in Earth's **crust**, not in air (that's nitrogen at 78%). Ozone protects us **in the stratosphere** but is a **pollutant at ground level**. The Montreal Protocol targets **ozone-depleting substances**, while the Kyoto/Paris agreements target **greenhouse gases** — don't mix them.

18.4 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The ozone layer protects us by absorbing —

(a) infrared rays

(b) ultraviolet rays ✓

(c) X-rays

(d) visible light

Why: stratospheric O_3 absorbs harmful UV-B radiation.

PYQ State PCS pattern (repeated) · Moderate

Which oxide is amphoteric?

(a) CO_2

(b) Na_2O

(c) Al_2O_3 ✓

(d) SO_2

Why: Al_2O_3 reacts with both acids and bases. Trap: CO_2/SO_2 are acidic; Na_2O is basic.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: strike a splint, blow it out, relight in oxygen — "supports burning but doesn't burn."
2. Board: preparation ($KClO_3$) → oxide classification table.
3. Ozone: draw O_2 vs O_3; "good up high, bad nearby."
4. Current affairs: CFCs → ozone hole → Montreal Protocol (16 Sep).
5. Recap + homework: oxide table + 10 MCQs. Bridge to Chapter 19 (Nitrogen).

COMMON TRAPS

1. Oxygen = most abundant in **crust**; nitrogen dominates air.
2. Ozone = **allotrope** of oxygen (O_3), not a compound.
3. Ground-level ozone is a **pollutant**.
4. CFCs destroy ozone via **chlorine** atoms.
5. Montreal = ozone; Kyoto/Paris = greenhouse gases.

RAPID RECALL · CHAPTER 18

① O, Z = 8 — most abundant in Earth's crust (~46%).
② Air is 21% O_2 by volume.
③ Supports combustion but is not flammable itself.
④ Acidic oxides = non-metal (CO_2, SO_2).
⑤ Basic oxides = metal (Na_2O, CaO).
⑥ Amphoteric = Al_2O_3, ZnO, PbO.
⑦ Neutral = CO, NO, N_2O, H_2O.
⑧ Ozone = O_3, allotrope of oxygen.
⑨ Stratospheric ozone absorbs UV-B.
⑩ CFCs (chlorine) cause the ozone hole (Antarctica).
⑪ Montreal Protocol (1987) phased out CFCs.
⑫ Ozone measured in Dobson Units; Ozone Day 16 Sep.

18.5 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The most abundant element in Earth's crust is —
(a) silicon (b) oxygen (c) aluminium (d) iron

Q2. Ozone is an allotrope of —
(a) nitrogen (b) carbon (c) oxygen (d) sulphur

Q3. Which gas destroys the ozone layer?
(a) CO_2 (b) CFCs (c) O_2 (d) N_2

Q4. Which is a neutral oxide?
(a) CO_2 (b) CO (c) SO_2 (d) CaO

Q5. The Montreal Protocol (1987) deals with —
(a) greenhouse gases (b) ozone-depleting substances (c) plastics (d) nuclear waste

Q6. The thickness of the ozone layer is measured in —
(a) ppm (b) Dobson Units (c) pascals (d) lux

Q7. Oxygen supports combustion but —
(a) is itself flammable (b) is itself not flammable (c) is inert (d) forms only basic oxides

Q8. Assertion (A): Ground-level ozone is harmful. Reason (R): Stratospheric ozone shields us from UV.
(a) Both true, R doesn't explain A (b) Both true, R explains A (c) A false, R true (d) A true, R false

ANSWER KEY

1-b. **2-c**. **3-b**. **4-b**. **5-b**. **6-b**. **7-b**. **8-a** (both true, but R is a separate fact — it does not explain why ground-level ozone is harmful).

PART VI · NON-METALS AND IMPORTANT ELEMENTS

19 Nitrogen and Its Compounds

Four-fifths of every breath, yet locked away — until nature and the Haber process learned to unlock it and feed the world.

WHY BPSC ASKS THIS
Nitrogen cycle, Haber process and fertiliser links tie chemistry to agriculture and ecology.

QUESTION FREQUENCY
High — process + cycle facts recur across prelims.

PREREQUISITES
Chapter 8 (reactions, catalysts) & Chapter 5 (formulae).

YOU WILL BE ABLE TO
Trace the nitrogen cycle, name the Haber & Ostwald processes, and link them to fertilisers.

19.1 Concept Story — The Unreactive Giant

Nitrogen (N, Z = 7) makes up **78% of air by volume** — the most abundant gas in the atmosphere. It exists as **N_2**, held by a very strong **triple bond** that makes it almost inert at room temperature. This inertness is useful: nitrogen is packed into **food packets and light bulbs** to prevent oxidation, and liquid nitrogen (−196 °C) is a cryogenic coolant. But that same stability means plants cannot use atmospheric N_2 directly — it must first be "fixed" into usable compounds.

19.2 The Nitrogen Cycle

1 · FIXATION
N_2 → ammonia/nitrates by **Rhizobium** bacteria (in legume roots), lightning, or industry.

2 · NITRIFICATION
Soil bacteria convert ammonia → nitrites → **nitrates** (**NO_3^-**), the form plants absorb.

3 · ASSIMILATION
Plants build **proteins**; animals eat plants — nitrogen enters the food chain.

4 · DENITRIFICATION
Denitrifying bacteria return **N_2 to the air**, closing the loop.

MEMORY HOOK
Fix → Nitrify → Assimilate → Denitrify. Rhizobium lives in legume (pulse) roots — that's why farmers rotate with pulses to enrich soil. Plants take nitrogen as **nitrates**, not as N_2 gas.

19.3 Two Compounds That Feed Nations

AMMONIA — HABER PROCESS
$N_2 + 3H_2 \rightleftharpoons 2NH_3$ at high pressure (~200 atm), ~450 °C, with an **iron catalyst**. NH_3 is the feedstock for **urea and nitrogenous fertilisers**. Pungent, alkaline gas; turns red litmus blue.

NITRIC ACID — OSTWALD PROCESS
Ammonia is oxidised (Pt catalyst) to make **HNO_3** — used in fertilisers, explosives (TNT) and aqua regia. **Oxides of nitrogen** (**NO, NO_2**) cause acid rain and smog; **N_2O** is "laughing gas", an anaesthetic.

✕ DO NOT CONFUSE — THE CLASSIC TRAPS
Haber = ammonia (NH_3); **Ostwald** = nitric acid (HNO_3) — don't swap. Nitrogen fixation is done by **Rhizobium** (symbiotic) and free-living *Azotobacter*, not by all soil microbes. **Laughing gas** = **N_2O**, not NO or NO_2.

19.4 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

The Haber process is used to manufacture —

(a) nitric acid
(b) ammonia ✓
(c) sulphuric acid
(d) urea directly

Why: $N_2 + 3H_2 \rightarrow 2NH_3$ (Fe catalyst). Trap: nitric acid is the Ostwald process.

PYQ State PCS pattern (repeated) · Moderate

Biological nitrogen fixation in legumes is carried out by —

(a) E. coli
(b) Rhizobium ✓
(c) Lactobacillus
(d) yeast

Why: Rhizobium in root nodules of legumes fixes atmospheric N_2.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: "78% of air is a fertiliser we can't use — until we crack the triple bond."
2. Board: nitrogen cycle as a 4-arrow loop; mark Rhizobium at fixation.
3. Two processes: Haber (NH_3) vs Ostwald (HNO_3) side by side.
4. Link to agriculture: urea, DAP, pulse rotation, eutrophication preview.
5. Recap + homework: cycle diagram + 12 MCQs. Bridge to Chapter 20 (Carbon).

COMMON TRAPS

1. Haber = NH_3; Ostwald = HNO_3.
2. Plants absorb **nitrates**, not N_2.
3. Rhizobium fixes nitrogen in **legume** roots.
4. Laughing gas = $\mathbf{N_2O}$.
5. N_2 is inert due to a **triple bond**, not because it is heavy.

RAPID RECALL · CHAPTER 19

① N, Z = 7 — 78% of air, most abundant gas.
② N_2 is inert (strong triple bond).
③ Used in food packing & bulbs; liquid N_2 = coolant.
④ Cycle: fixation → nitrification → assimilation → denitrification.
⑤ Rhizobium fixes N in legume roots.
⑥ Plants absorb nitrogen as nitrates (NO_3^-).
⑦ Haber: $N_2+3H_2 \rightarrow 2NH_3$ (Fe catalyst).
⑧ Ostwald: $NH_3 \rightarrow HNO_3$ (Pt catalyst).
⑨ NH_3 is alkaline; reddens no litmus — turns red→blue.
⑩ NO, NO_2 → acid rain & smog.
⑪ N_2O = laughing gas (anaesthetic).
⑫ Ammonia feeds urea & nitrogenous fertilisers.

19.5 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The most abundant gas in the atmosphere is —
(a) oxygen (b) nitrogen (c) argon (d) carbon dioxide

Q2. The catalyst in the Haber process is —
(a) platinum (b) iron (c) nickel (d) vanadium

Q3. Laughing gas is —
(a) NO (b) NO_2 (c) N_2O (d) NH_3

Q4. Plants absorb nitrogen mainly as —
(a) N_2 gas (b) nitrates (c) ammonia gas (d) proteins

Q5. The Ostwald process manufactures —
(a) ammonia (b) nitric acid (c) sulphuric acid (d) urea

Q6. Nitrogen is unreactive at room temperature because of its —
(a) low mass (b) single bond (c) triple bond (d) high density

Q7. Which bacterium returns N_2 to the atmosphere?
(a) nitrifying (b) denitrifying (c) Rhizobium (d) decomposers

Q8. Assertion (A): Legumes enrich soil nitrogen. Reason (R): Rhizobium in their roots fixes atmospheric nitrogen.
(a) Both true, R explains A (b) Both true, R doesn't explain A (c) A true, R false (d) A false, R true

ANSWER KEY

1-b. 2-b. 3-c. 4-b. 5-b. 6-c. 7-b. 8-a.

PART VI · NON-METALS AND IMPORTANT ELEMENTS

20 Carbon and Its Allotropes

One element, many faces — the hardest gem, the softest lubricant, the wonder-sheet of the future, and the clock that dates the past.

WHY BPSC ASKS THIS
Diamond-vs-graphite properties, graphene and carbon dating are high-yield one-mark facts.

QUESTION FREQUENCY
Very high — allotrope contrasts appear almost every cycle.

PREREQUISITES
Chapter 3 (allotropes) & Chapter 7 (covalent bonding).

YOU WILL BE ABLE TO
Contrast the allotropes, explain catenation, and describe carbon dating.

20.1 Concept Story — The Element of Life

Carbon (**C, Z** = **6**) has four valence electrons, so it is **tetravalent** — it forms four covalent bonds. Two special powers make it the backbone of life: **catenation** (carbon atoms link into long chains and rings) and the ability to form **multiple bonds**. This gives millions of organic compounds. Carbon appears in two families of forms: **crystalline allotropes** (diamond, graphite, fullerenes, graphene) and **amorphous** forms (coal, coke, charcoal, lampblack).

20.2 Diamond vs Graphite — Same Atom, Opposite Personalities

PROPERTY	DIAMOND	GRAPHITE
Structure	each C bonded to 4 others (3-D tetrahedral)	each C bonded to 3 others in layers/sheets
Hardness	hardest natural substance	soft, slippery (layers slide)
Electricity	non-conductor (no free electrons)	good conductor (free electrons)
Uses	jewellery, cutting/drilling tools	pencil lead, lubricant, electrodes

THE NEWER FORMS
Fullerene (C_{60}) — football-shaped "buckyball". **Graphene** — a single sheet of carbon, the thinnest and one of the strongest materials known, an excellent conductor. **Carbon nanotubes** — rolled graphene, ultra-strong.

AMORPHOUS FORMS
Coal, coke, charcoal, lampblack. Activated charcoal adsorbs gases & impurities (used in water filters and gas masks). Coke is used in metallurgy (blast furnace).

MEMORY HOOK
Diamond = **4 bonds, hard, insulator; Graphite** = **3 bonds, soft, conductor.** Graphite conducts because the 4th electron is free. "**Graph**ite is in your pencil and **graph**ene is one layer of it."

20.3 Oxides & Carbon Dating

TWO OXIDES

CO — colourless, odourless, **poisonous** (binds haemoglobin, blocks oxygen); a neutral oxide. **CO_2** — a **greenhouse gas**; used in fire extinguishers, fizzy drinks; solid CO_2 = dry ice.

CARBON DATING

Radioactive **C-14** (half-life ≈ **5,730 years**) decays at a known rate. Measuring how much remains dates **once-living material** (fossils, wood, bone) up to ~50,000 years. Developed by Willard Libby.

× DO NOT CONFUSE — THE CLASSIC TRAPS

Diamond is a **non-conductor**; graphite is a **conductor** (opposite of what many expect). Diamond is hardest **naturally occurring** substance. **CO** is the poisonous one; **CO_2** is the greenhouse gas. Carbon dating uses **C-14**, not C-12.

20.4 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Which allotrope of carbon conducts electricity?

(a) diamond
(b) graphite ✓
(c) both
(d) neither

Why: in graphite each C bonds to 3 others; the free 4th electron carries current. Diamond has no free electrons.

PYQ State PCS pattern (repeated) · Moderate

Carbon dating is based on the isotope —

(a) C-12
(b) C-13
(c) C-14 ✓
(d) C-11

Why: radioactive C-14 (half-life ≈ 5,730 yr) dates once-living material.

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: hold up a pencil and a (photo of a) diamond — "same atom, opposite properties."
2. Board: tetravalency + catenation; diamond vs graphite comparison table.
3. New forms: buckyball, graphene, nanotubes; amorphous coke/charcoal.
4. Oxides: CO (poison) vs CO_2 (greenhouse); then carbon dating with C-14.
5. Recap + homework: comparison table + 14 MCQs. Bridge to Chapter 21.

COMMON TRAPS

1. Graphite conducts; diamond does **not**.
2. Diamond = hardest **natural** substance.
3. CO is poisonous; CO_2 is the greenhouse gas.
4. Carbon dating uses **C-14** (half-life ≈ 5,730 yr).
5. Graphene = single layer; fullerene = C_{60} buckyball.

RAPID RECALL · CHAPTER 20

① C, Z = 6 — tetravalent; catenation → millions of compounds.
② Crystalline: diamond, graphite, fullerene, graphene.
③ Amorphous: coal, coke, charcoal, lampblack.
④ Diamond: 4 bonds, hardest natural, insulator.
⑤ Graphite: 3 bonds, soft, conductor (free electron).
⑥ Graphite → pencil lead, lubricant, electrodes.
⑦ Fullerene = C_{60} buckyball; graphene = single sheet.
⑧ Activated charcoal adsorbs gases/impurities.
⑨ CO = poisonous, neutral oxide.
⑩ CO_2 = greenhouse gas; dry ice = solid CO_2.
⑪ Carbon dating uses C-14, half-life ≈ 5,730 yr.
⑫ Coke used in the blast furnace (metallurgy).

20.5 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The hardest naturally occurring substance is —
(a) graphite (b) diamond (c) quartz (d) iron

Q2. Which is used as a lubricant and as pencil lead?
(a) diamond (b) graphite (c) coke (d) fullerene

Q3. The football-shaped allotrope C_{60} is called —
(a) graphene (b) fullerene (c) coke (d) charcoal

Q4. The poisonous oxide of carbon is —
(a) CO_2 (b) CO (c) both (d) neither

Q5. Dry ice is —
(a) frozen water (b) solid CO_2 (c) solid CO (d) solid N_2

Q6. The property of carbon to form long chains is called —
(a) allotropy (b) catenation (c) isomerism (d) polymerisation

Q7. The half-life of C-14 is about —
(a) 570 yr (b) 5,730 yr (c) 57,300 yr (d) 573 yr

Q8. Assertion (A): Graphite conducts electricity. Reason (R): Each carbon in graphite has one free (delocalised) electron.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

ANSWER KEY

1-b. 2-b. 3-b. 4-b. 5-b. 6-b. 7-b. 8-a.

PART VI · NON-METALS AND IMPORTANT ELEMENTS

21 Sulphur, Phosphorus, Halogens & Noble Gases

The "king of chemicals", the element that glows, the salts that iodise our diet, and the gases too proud to react.

WHY BPSC ASKS THIS
Contact process, iodised salt, bleaching powder and noble-gas uses are dependable fact questions.

QUESTION FREQUENCY
High — this cluster yields several safe one-markers.

PREREQUISITES
Chapter 6 (groups/periods) & Chapter 10 (acids).

YOU WILL BE ABLE TO
Recall each element's key compound, process and use, and the noble-gas applications.

21.1 Sulphur — The King of Chemicals

Sulphur (S) is a yellow non-metal with allotropes (rhombic & monoclinic). Its great product is **sulphuric acid (H_2SO_4)**, made by the **Contact process** ($SO_2 \rightarrow SO_3$ over a V_2O_5 catalyst → oleum → H_2SO_4). Called the **"King of Chemicals"** because a nation's industrial output was once judged by its consumption. **SO_2** bleaches and preserves but causes acid rain; sulphur is also in gunpowder, vulcanised rubber and Plaster of Paris chemistry's cousin, gypsum.

21.2 Phosphorus, Halogens & Noble Gases

PHOSPHORUS (P)

White phosphorus — very reactive, glows in the dark, stored under water, poisonous. **Red phosphorus** — stable, used in **safety matches**. Phosphorus is a key plant nutrient (the "P" in NPK fertiliser).

HALOGENS (GROUP 17)

F, Cl, Br, I. Chlorine disinfects water & makes **bleaching powder**; **fluoride** strengthens teeth (excess → fluorosis); **iodine** as iodised salt prevents **goitre**; bromine is used in photographic film.

NOBLE GAS	CHIEF USE
Helium (He)	filling balloons/airships (non-flammable), diver's breathing mix, coolant for MRI magnets
Neon (Ne)	glowing advertisement/discharge signs (red-orange glow)
Argon (Ar)	inert filling in electric bulbs; shielding gas in welding
Krypton / Xenon	high-power lamps, flash bulbs, lighthouse lights
Radon (Rn)	radioactive; once used in cancer radiotherapy

MEMORY HOOK

Sulphuric acid = **Contact** + **V_2O_5**, "King of Chemicals". **Red** phosphorus → safety matches; **white** → glows & poison. Iodine stops **goitre**; fluoride excess → **fluorosis**. Noble gases are **inert** — full outer shell.

21.3 PYQ Zone

MEMORY-BASED · VERIFY WITH OFFICIAL KEYS

PYQ BPSC-family exams (recurring) · Easy

Sulphuric acid is manufactured by the —

(a) Haber process
(b) Contact process ✓
(c) Ostwald process
(d) Bosch process

Why: Contact process uses a V_2O_5 catalyst. Trap: Haber = ammonia, Ostwald = nitric acid.

PYQ State PCS pattern (repeated) · Moderate

Iodine is added to common salt to prevent —

(a) anaemia
(b) goitre ✓
(c) rickets
(d) scurvy

Why: iodine deficiency causes goitre (thyroid enlargement).

FACULTY NOTE · DELIVERY PLAN (90 MIN)

1. Hook: "One acid built the industrial age — H_2SO_4."
2. Board: Contact process flow ($S \rightarrow SO_2 \rightarrow SO_3 \rightarrow$oleum$\rightarrow$acid).
3. Phosphorus: red vs white; halogen uses (water, teeth, salt).
4. Noble-gas use table; stress inertness = full outer shell.
5. Recap + homework: process + use table, 14 MCQs; close Part VI.

COMMON TRAPS

1. Contact = H_2SO_4 (V_2O_5); not Haber/Ostwald.
2. **Red** phosphorus in safety matches, not white.
3. Iodine → goitre; fluoride excess → fluorosis.
4. Helium fills balloons (H_2 is flammable).
5. Noble gases inert due to full outer shell.

RAPID RECALL · CHAPTER 21

① H_2SO_4 = Contact process (V_2O_5); "King of Chemicals".
② SO_2 bleaches/preserves; causes acid rain.
③ White P: reactive, glows, poison, under water.
④ Red P: stable → safety matches.
⑤ Halogens = F, Cl, Br, I (Group 17).
⑥ Chlorine → water disinfection, bleaching powder.
⑦ Iodised salt prevents goitre.
⑧ Fluoride helps teeth; excess → fluorosis.
⑨ He → balloons, MRI coolant; Ne → signs.
⑩ Argon → bulbs & welding shield.
⑪ Noble gases inert = full outer shell.
⑫ Radon is radioactive.

21.4 Practice MCQs

ORIGINAL · ANSWERS BELOW

Q1. The catalyst used in the Contact process is —
(a) Fe (b) Pt (c) V_2O_5 (d) Ni

Q2. Which form of phosphorus is used in safety matches?
(a) white (b) red (c) black (d) violet

Q3. Which gas is used to fill electric bulbs?
(a) oxygen (b) argon (c) hydrogen (d) chlorine

Q4. Deficiency of iodine causes —
(a) anaemia (b) goitre (c) scurvy (d) rickets

Q5. Sulphuric acid is popularly called the —
(a) oil of vitriol / King of Chemicals (b) universal solvent (c) aqua regia (d) spirit of salt

Q6. Balloons are filled with helium instead of hydrogen because helium is —
(a) lighter (b) non-flammable (c) cheaper (d) coloured

Q7. Which noble gas is used in advertisement (glow) signs?
(a) argon (b) neon (c) helium (d) radon

Q8. Assertion (A): Noble gases are chemically inert. Reason (R): They have a completely filled outermost shell.
(a) Both true, R explains A (b) Both true, R doesn't explain A
(c) A true, R false (d) A false, R true

ANSWER KEY

1-c. 2-b. 3-b. 4-b. 5-a. 6-b. 7-b. 8-a.

REVIEW CHECKPOINT · PART VI CLOSED

Chapters 1–21 are now delivered — **Part VI** (**Non-Metals and Important Elements**) **fully closed**: Hydrogen, Oxygen & Ozone, Nitrogen, Carbon, and the Sulphur–Phosphorus–Halogen–Noble-gas group — all in the same section format with concept stories, comparison tables, PYQ zones, memory hooks, faculty plans, rapid-recall grids and MCQ banks. Next is **Part VII** — **Organic Chemistry** (**Chapters 22–25**). **Tell me what to adjust — density, diagram style, Hindi-cue ratio, MCQ difficulty — or say "continue with Chapter 22".**