BP106T · B.PHARM THEORY

Pharmaceutical Inorganic and Analytical Chemistry

Unit IV — GI Agents, Antimicrobials and Radiopharmaceuticals

Pills & Python Notes

From-zero teaching standard: every technical term is defined before use.

Syllabus coverage: Unit IV (10 hours).

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CHAPTER 13: GASTROINTESTINAL AGENTS

Unit IV · ~4 hours

13.1 Introduction

Your stomach makes **hydrochloric acid (HCl)** to digest food — normally a good thing. But sometimes there is **too much acid** (acidity, heartburn, ulcers) and sometimes **too little** (a condition called *achlorhydria*). Inorganic chemistry comes to the rescue in both cases: **acidifiers** add acid when it is missing, **antacids** neutralise acid when it is in excess, and **bowel-movement agents** (laxatives) keep the intestines moving. Almost every one of these is a simple salt you already met in general chemistry — $NaHCO_3$, $Mg(OH)_2$, $KMnO_4$'s cousins — now wearing a pharmacist's coat.

> **Learning objectives** — after studying this chapter, you should be able to:

- define acidifiers, antacids, and bowel-movement agents (scientific + simple);
- list the ideal properties of an antacid and explain why antacids are combined;
- for each official compound (sodium acid phosphate, dilute HCl, sodium bicarbonate, aluminium hydroxide gel, magnesium hydroxide, sodium orthophosphate, sodium potassium tartrate, magnesium trisilicate): give the formula, preparation principle, properties, assay principle, and uses;
- explain the acid-neutralising reaction of antacids with equations;
- explain how saline/osmotic laxatives work, starting from osmosis;
- counsel a patient on correct antacid use.

13.2 Definition

Gastrointestinal (GI) agent — scientific: an inorganic compound acting on the stomach or intestines to correct acidity or bowel function. **GI agent — simple:** a medicine-salt that fixes stomach/intestine problems — too much acid, too little acid, or a "stuck" bowel.

Acidifier — scientific: a substance that increases the acidity (lowers the pH) of gastric juice or urine. **Acidifier — simple:** a medicine that *adds* acid where the body is short of it.

Antacid — scientific: a weak base (or basic salt) that neutralises excess gastric HCl, raising stomach pH without making it alkaline. **Antacid — simple:** a medicine that *soaks up* extra stomach acid — the fire extinguisher for the acid fire.

Bowel-movement agent (laxative/purgative) — scientific: a substance that promotes defecation by increasing intestinal water content or stimulating peristalsis. **Simple:** a medicine that loosens the motion — it pulls water into the intestine so the stool softens and moves.

13.3 Key Terminology

Term	Meaning
Achlorhydria	Absence (or near-absence) of HCl in gastric juice — treated with acidifiers
Hyperacidity	Excess stomach acid — treated with antacids
Acid-neutralising capacity (ANC)	Amount of acid (in mEq) neutralised by one dose of antacid — the antacid's "strength"
Rebound acidity	Stomach making *extra* acid after an antacid wears off — a drawback of some antacids
Systemic alkalosis	Blood becoming too alkaline from absorbed antacid — a drawback of absorbable antacids
Osmosis	Movement of water across a membrane from dilute to concentrated side — the engine of saline laxatives
Peristalsis	Wave-like muscle contractions pushing food/stool along the intestine
Milk of magnesia	Aqueous suspension of magnesium hydroxide — antacid + laxative
Rochelle salt	Common name of sodium potassium tartrate

13.4 Detailed Explanation

13.4.1 Acidifiers — when the stomach needs more acid

Sodium acid phosphate — NaH_2PO_4

- **Preparation (principle):** neutralising phosphoric acid (H_3PO_4) with sodium hydroxide or sodium carbonate, stopping at the *first* neutralisation stage so the acid salt (not the normal salt) forms: $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$.
- **Properties:** white crystalline powder; freely soluble in water; its solution is **acidic** (it is an acid salt — it can still donate a proton).
- **Assay principle:** acid–base titration — the acidic salt is titrated with standard sodium hydroxide solution using a suitable indicator, as per pharmacopoeial procedure.
- **Uses: urinary acidifier** (makes urine acidic, which helps certain urinary antiseptics work and discourages some bacterial growth); also used in phosphate buffer systems.

Dilute hydrochloric acid — HCl (dilute)

- **Preparation (principle):** careful dilution of concentrated hydrochloric acid with purified water (always acid into water).
- **Properties:** colourless, strongly acidic liquid; the dilute form (about one-tenth the strength of the concentrated acid) is safe to handle with normal care.
- **Assay principle:** acid–base titration with standard sodium hydroxide using methyl orange indicator.
- **Uses:** in **achlorhydria** — given (usually with pepsin, as an "acid–pepsin mixture") to supply the missing stomach acid for digestion; also used to acidify preparations.

> **Exam Pearl:** Acidifiers are the *mirror image* of antacids — one adds H^+, the other removes it. Examiners love asking "give one acidifier and one antacid with formulas."

13.4.2 Antacids — ideal properties and combinations

An antacid neutralises gastric HCl, e.g.: $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$. The goal is to bring stomach pH up to about 3–4 (comfortable), **not** to make it alkaline.

Ideal properties of an antacid (the famous 6–7 point list — learn it verbatim):

1. **Fast onset** of action — relief should begin quickly.
2. **Sustained / prolonged duration** — relief should last, not vanish in minutes.
3. **High acid-neutralising capacity** — a small dose should neutralise a lot of acid.
4. **Should NOT cause systemic alkalosis** — the antacid (or its product) should not be absorbed into blood in large amounts.
5. **Should NOT cause rebound acidity** — the stomach should not over-produce acid afterwards.
6. **Should NOT evolve large volumes of CO_2** — no belching, flatulence, or discomfort.
7. Should be **palatable, non-toxic, inexpensive**, and should not disturb bowel function (neither constipating nor laxative) or interfere with other drugs.

Why antacids are combined: no single antacid is ideal, so two are mixed to **cancel each other's faults**:

- **Aluminium hydroxide (constipating)** + **magnesium hydroxide (laxative)** → bowel effects cancel out, stools stay normal.
- **Fast-acting** (sodium bicarbonate) + **slow, long-acting** (aluminium hydroxide) → quick relief that also lasts.
- Combinations also raise the total neutralising capacity per dose.

> **Exam Pearl:** "Al constipates, Mag loosens — together they balance." This one line answers most combination questions.

13.4.3 Monograph-style entries — the antacids

Sodium bicarbonate — $NaHCO_3$ (baking soda)

- **Preparation (principle):** the **ammonia–soda (Solvay) process** — brine (NaCl) is treated with ammonia and carbon dioxide: $NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3\downarrow + NH_4Cl$. The bicarbonate precipitates and is filtered off.
- **Properties:** white crystalline powder; soluble in water giving a mildly **alkaline** solution; on heating it decomposes: $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2\uparrow + H_2O$ (this is why it works in baking — and why old stock loses strength).
- **Assay principle:** acid–base titration with standard hydrochloric acid using **methyl orange** indicator: $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$.
- **Uses:** fast-acting **antacid**; **urinary alkaliniser**; ingredient of effervescent powders/granules; also used in baking and fire extinguishers (non-medical, but explains the CO_2).
- **Drawbacks (why it is not ideal):** releases **CO_2** (belching, flatulence); absorbed systemically → risk of **alkalosis** on prolonged use; can cause **rebound acidity**. So it is best for *occasional* use, often combined with other antacids.

Aluminium hydroxide gel — $Al(OH)_3$ (as the gel)

- **Preparation (principle): precipitation** — a soluble aluminium salt (e.g., aluminium chloride or alum) is treated with ammonia solution or sodium hydroxide; aluminium hydroxide precipitates as a white **gelatinous** mass, which is washed free of soluble impurities: $Al^{3+} + 3OH^- \rightarrow Al(OH)_3\downarrow$.
- **Properties:** white gelatinous precipitate (the *gel* form has a huge surface area, which is why it works well); **amphoteric** — dissolves both in acids (neutralising them) and in strong alkalis; practically insoluble in water.
- **Assay principle: complexometric (EDTA) back-titration** — the sample is boiled with a measured excess of EDTA (which complexes all the aluminium), and the unused EDTA is back-titrated with standard zinc solution, as per pharmacopoeial procedure.
- **Uses: slow, sustained antacid** (long duration, no CO_2, no systemic alkalosis since it is hardly absorbed); also used as an **adsorbent**.
- **Drawback: constipating** (astringent action) — hence combined with magnesium hydroxide.

13.4.4 Agents promoting bowel movement

How do these salts work? Through **osmosis**: they are **poorly absorbed** from the intestine, so they sit in the gut lumen and *pull water in* from the intestinal wall (water moves toward the saltier side). More water → softer, bulkier stool → the stretched intestine contracts (**peristalsis**) → motion. This family is called **saline / osmotic laxatives**.

Magnesium hydroxide — $Mg(OH)_2$ (milk of magnesia = its aqueous suspension)

- **Preparation (principle):** precipitation — a soluble magnesium salt + sodium hydroxide: $Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2\downarrow$; suspended in water as "milk of magnesia."
- **Properties:** white suspension; the hydroxide neutralises acids (antacid action) and the unabsorbed magnesium salt acts osmotically (laxative action).
- **Assay principle:** acid–base back-titration — excess standard acid is added and the remainder titrated with standard alkali.
- **Uses: antacid** (small dose) and **osmotic laxative** (larger dose) — the classic dual-purpose GI salt. **Caution:** magnesium can accumulate in kidney-failure patients.

Sodium orthophosphate — Na_3PO_4

- **Preparation (principle):** neutralising phosphoric acid fully with sodium hydroxide: $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$.
- **Properties:** white crystalline salt; soluble in water giving an alkaline solution; poorly absorbed from the gut.
- **Assay principle:** acid–base titration as per pharmacopoeial procedure.
- **Uses: saline laxative / purgative** (often before bowel examination or surgery, to empty the intestine); also used in buffer systems.

Sodium potassium tartrate — $KNaC_4H_4O_6{\cdot}4H_2O$ (Rochelle salt)

- **Preparation (principle):** neutralising cream of tartar (potassium hydrogen tartrate) with sodium carbonate.
- **Properties:** colourless crystals; soluble in water; mild saline taste.
- **Assay principle:** non-aqueous or aqueous acid–base titration as per pharmacopoeial procedure.
- **Uses: mild saline purgative**; also famous in analytical chemistry as a component of **Fehling's solution** (Unit III link — it keeps cupric ions in solution).

Magnesium trisilicate — $Mg_2Si_3O_8{\cdot}nH_2O$

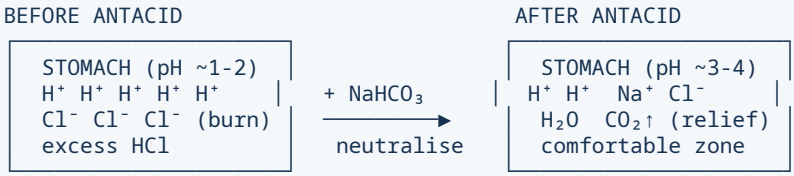
- **Preparation (principle):** precipitation from a soluble magnesium salt and sodium silicate.
- **Properties:** fine white powder; **adsorbent** — its large surface area adsorbs gases and toxins in addition to neutralising acid; practically insoluble in water.
- **Assay principle:** gravimetric/complexometric determination of magnesium and silica as per pharmacopoeial procedure.
- **Uses: antacid with adsorbent action** (relieves acidity *and* adsorbs intestinal gases — useful in flatulence); mild laxative tendency balances its use in combinations.

Exam Pearl: Two magnesium salts, two jobs — $Mg(OH)_2$ = antacid + laxative; magnesium trisilicate = antacid + adsorbent. If a question mentions "adsorbs gases," answer magnesium trisilicate.

13.5 Easy Analogy

- An **antacid** is a **fire extinguisher**: stomach acid is the small fire, the antacid is the foam that puts it out — but a good extinguisher shouldn't flood the whole house (no systemic alkalosis) or let the fire restart bigger (no rebound acidity).
- A **saline laxative** is like **sprinkling salt on a wet road in winter** — actually simpler: it is like putting a dry sponge (salt) in the intestine that *pulls water toward itself*; the water softens everything and gets things moving.
- An **acidifier** is topping up a nearly-empty ink pen — the stomach's acid "ink" ran out (achlorhydria), so you refill it.

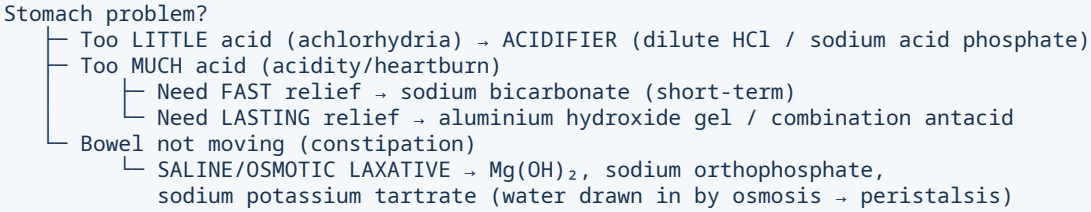
13.6 Diagram — Antacid Action in the Stomach



Reaction: $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2\uparrow$
$(Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$ — no gas evolved)

AI Image Prompt: "Educational textbook diagram, white background, cross-section of a human stomach shown twice side by side: left labelled 'Excess acid (pH 1–2)' with red H+ symbols and a discomfort expression icon, right labelled 'After antacid (pH 3–4)' with neutralised salts and a relief icon, the neutralisation reaction equation below, pharmacy textbook style, clear labels, minimal decoration."

13.7 Flowchart — Choosing a GI Agent



13.8 Examples

- **Eno / effervescent antacid powders** — sodium bicarbonate + citric acid: fizz neutralises acid fast (and tastes pleasant).
- **Gelusil-type tablets** — aluminium hydroxide + magnesium hydroxide: the textbook *combination* (bowel effects cancel).
- **Milk of magnesia** — the suspension on every Indian pharmacy shelf for "gas + constipation."
- **Acid–pepsin mixture** — dilute HCl + pepsin for achlorhydria.

13.9 Pharmacy Relevance

- **Counselling:** take antacids *after* meals / at bedtime (when acid peaks), not with other medicines — antacids **reduce absorption** of drugs like tetracyclines and iron (space them 2 hours apart).
- **QC:** the assay of $NaHCO_3$ (acid–base titration, methyl orange) and $Al(OH)_3$ gel (EDTA back-titration) are classic pharmacopoeial assays a QC chemist performs.
- **Formulation:** suspensions (milk of magnesia, aluminium hydroxide gel) must be **shaken well before use** — label counselling every pharmacist gives.

13.10 India Context

Antacid suspensions and tablets (aluminium–magnesium combinations) are among the highest-selling OTC products in Indian pharmacies; the **Indian Pharmacopoeia** includes monographs for sodium bicarbonate, aluminium hydroxide gel, magnesium hydroxide, and dilute hydrochloric acid, each with identification, assay, and limit tests.

13.11 Important Points to Remember

1. **Remember:** Acidifier *adds* H^+ (achlorhydria); antacid *removes* H^+ (hyperacidity); saline laxative *pulls water* into the gut (osmosis).
2. **Exam Pearl:** Ideal antacid = fast + long-lasting + high ANC + no alkalosis + no rebound + no CO_2 + palatable.
3. **Exam Pearl:** $Al(OH)_3$ constipates, $Mg(OH)_2$ loosens — combined, they balance. Fast ($NaHCO_3$) + slow ($Al(OH)_3$) = quick relief that lasts.
4. **Exam Pearl:** $NaHCO_3$ assay = HCl titration, methyl orange; $Al(OH)_3$ gel assay = EDTA back-titration.
5. $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2\uparrow$ (gas = belching); $Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$ (no gas).
6. Saline laxatives work by **osmosis** — poorly absorbed salts draw water into the lumen → peristalsis.
7. Magnesium trisilicate is the **adsorbent** antacid (gases + toxins); Rochelle salt = sodium potassium tartrate = mild purgative (+ Fehling's solution component).

13.12 Common Confusions & Common Mistakes

Do not confuse: antacid ≠ acidifier (opposite jobs) · **laxative ≠ purgative** (laxative = gentle; purgative = stronger watery evacuation — same drugs, different dose/intensity) · **sodium bicarbonate ≠ sodium carbonate** (bicarbonate $NaHCO_3$ is the mild antacid; carbonate Na_2CO_3 is caustic) · **magnesium hydroxide ≠ magnesium trisilicate** (hydroxide = antacid+laxative; trisilicate = antacid+adsorbent). **Mistakes:** writing that $NaHCO_3$ is ideal (it fails: CO_2, alkalosis, rebound); forgetting that antacid combinations exist to *balance side effects*; calling milk of magnesia a solution (it is a **suspension** — shake well).

13.13 Memory Tricks

- "**Al** **C**onstipates, **Mag** **M**oves" — aluminium vs magnesium bowel effects.
- Ideal antacid: "**F**ast, **L**ong, **S**trong (high ANC), **N**o **A**lkalosis, **N**o **R**ebound, **N**o **G**as" — "**F**ather **L**oves **S**trong **N**o-**A**RG**N** tea."
- "Rochelle salt **R**uns the bowel (mild purgative) and **R**uns Fehling's test."

13.14 Exam-Oriented Summary

Acidifiers (dilute HCl, NaH_2PO_4) supply missing acid in achlorhydria. Antacids neutralise excess HCl; the ideal antacid is fast, long-acting, high-ANC, and causes no alkalosis, rebound, or CO_2. $NaHCO_3$ (Solvay process; HCl titration assay) is fast but gassy; $Al(OH)_3$ gel (precipitation; EDTA back-titration assay) is slow and constipating. Combinations balance bowel effects and onset. Saline laxatives — $Mg(OH)_2$, Na_3PO_4, Rochelle salt — work by osmosis: unabsorbed salts pull water into the gut → peristalsis. Magnesium trisilicate adds adsorbent action.

One-Minute Revision: Acidifier adds H^+; antacid removes H^+. Ideal antacid: fast, long, high ANC, no alkalosis/rebound/CO_2. Al constipates + Mag loosens = balanced combo. $NaHCO_3$: Solvay, HCl/methyl-orange assay, gassy. $Al(OH)_3$ gel: precipitation, EDTA back-titration, slow. Laxatives = osmosis ($Mg(OH)_2$, Na_3PO_4, Rochelle salt). Trisilicate = adsorbent antacid.

13.15 Questions

Very Short Answer: 1. Define antacid (scientific + simple). 2. Give the formula of Rochelle salt. 3. What is milk of magnesia? 4. Define acid-neutralising capacity. 5. Give one acidifier with formula.

Short Answer: 1. List the ideal properties of an antacid. 2. Why are antacids combined? Give one example. 3. Explain the osmotic mechanism of saline laxatives. 4. Write the preparation principle and assay principle of sodium bicarbonate. 5. Why is magnesium trisilicate preferred in flatulence with acidity?

Long Answer: 1. Classify GI agents. Describe the ideal properties of antacids and explain, with monograph-style entries (formula, preparation, properties, assay, uses), sodium bicarbonate and aluminium hydroxide gel. 2. Describe the agents promoting bowel movement with their mechanism, giving monograph-style entries for magnesium hydroxide and sodium potassium tartrate.

MCQs

1. Which pair shows the "balanced bowel effect" in antacid combinations? (a) $NaHCO_3$ + $Al(OH)_3$ (b) $Al(OH)_3$ + $Mg(OH)_2$ (c) $Mg(OH)_2$ + Na_3PO_4 (d) $Al(OH)_3$ + $NaHCO_3$ — **Ans: (b)**. Constipating + laxative cancel out.
2. Sodium bicarbonate is prepared industrially by the: (a) Contact process (b) Solvay process (c) Haber process (d) Ostwald process — **Ans: (b)**.
3. The assay of aluminium hydroxide gel is based on: (a) acid–base titration (b) EDTA back-titration (c) permanganometry (d) gravimetry only — **Ans: (b)**.
4. Rebound acidity is a drawback of: (a) aluminium hydroxide gel (b) magnesium trisilicate (c) sodium bicarbonate (d) magnesium hydroxide — **Ans: (c)**. Fast, absorbable, stimulates gastrin.
5. Saline laxatives act by: (a) stimulating gut nerves directly (b) osmosis — drawing water into the lumen (c) lubricating the stool (d) killing gut bacteria — **Ans: (b)**.

Viva: Why is sodium bicarbonate not an ideal antacid? What is Rochelle salt and where else is it used? Why must antacid suspensions be shaken before use? Which magnesium salt adsorbs gases? **Application-based:** A patient on tetracycline takes an aluminium–magnesium antacid at the same time daily and the antibiotic fails. Explain and advise. *(Ans: Antacids chelate/bind tetracycline and raise gastric pH, reducing absorption — space doses by 2+ hours.)* A constipated patient is prescribed milk of magnesia. Explain in simple words how it will work. *(Ans: The salt stays in the gut, pulls water in by osmosis, softens stool and triggers bowel movement.)*

13.16 References

- Schroff ML. *Pharmaceutical Chemistry (Inorganic)* — GI agents, antacid monographs.
- Bentley & Driver. *Textbook of Pharmaceutical Chemistry* — antacids, laxatives.
- Indian Pharmacopoeia — monographs: Sodium Bicarbonate, Aluminium Hydroxide Gel, Magnesium Hydroxide, Dilute Hydrochloric Acid.
- Vogel's *Quantitative Chemical Analysis* — acid–base and complexometric assay principles.

CHAPTER 14: INORGANIC ANTIMICROBIALS

Unit IV · ~3 hours

14.1 Introduction

Before antibiotics, humanity fought microbes with **inorganic chemistry** — purple potassium permanganate solutions, brown tincture of iodine, fizzing hydrogen peroxide. These agents still matter: iodine preps skin before every surgery, chlorinated lime disinfects water supplies, and hydrogen peroxide cleans wounds. Unlike antibiotics (which target specific bacterial machinery), inorganic antimicrobials are **chemical sledgehammers** — they oxidise, burn, or pickle microbes outright, which is why microbes rarely become resistant to them.

> **Learning objectives** — after studying this chapter, you should be able to:

- define antiseptic, disinfectant, and germicide (scientific + simple);
- explain the mechanism of antimicrobial action of inorganic agents from zero;
- classify inorganic antimicrobials by mechanism;
- for each compound (potassium permanganate, boric acid, hydrogen peroxide, chlorinated lime, iodine and its preparations): give formula, preparation principle, properties, and uses;
- explain why tincture of iodine contains potassium iodide, and what povidone-iodine is;
- counsel on safe use of iodine and peroxide antiseptics.

14.2 Definition

Antimicrobial — scientific: a substance that kills or inhibits the growth of microorganisms (bacteria, fungi, viruses). **Simple:** a microbe-killer or microbe-stopper.

Antiseptic — scientific: an antimicrobial applied to **living tissue** (skin, wounds, mucous membranes). **Simple:** the medicine you dab *on the body* to stop infection (e.g., tincture of iodine on a cut).

Disinfectant — scientific: an antimicrobial applied to **non-living** surfaces and objects. **Simple:** the chemical you use *on things* — floors, instruments, water (e.g., chlorinated lime in drains).

Germicide — scientific: an agent that *kills* microbes (as opposed to merely stopping their growth). **Simple:** the killer (not just the jailer) of germs.

> **Exam Pearl:** Antiseptic = on the **body**; disinfectant = on **things**. One word — "living or not?" — decides the term.

14.3 Key Terminology

Term	Meaning
Bactericidal / bacteriostatic	Kills bacteria / merely stops their growth
Oxidation	Loss of electrons (here: the antimicrobial *steals* electrons from microbe molecules, destroying them)
Nascent oxygen / nascent chlorine	Freshly released, highly reactive [O] or Cl atoms — far more destructive than ordinary O_2/Cl_2
Halogen	Group 17 elements (F, Cl, Br, I) — iodine and chlorine compounds dominate this chapter
Astringent	A substance that tightens/precipitates surface proteins — mild antiseptic action (boric acid)
Tincture	An alcoholic solution of a drug (tincture of iodine = iodine in alcohol)
Lugol's iodine	Aqueous solution of iodine + potassium iodide (no alcohol)

14.4 Detailed Explanation

14.4.1 Mechanism of antimicrobial action — from zero

A microbe is a tiny bag of **proteins and enzymes**. Inorganic antimicrobials destroy the bag by three chemical attacks:

1. **Oxidation (the burn):** agents like $KMnO_4$, H_2O_2, and chlorinated lime release **nascent oxygen [O]** or chlorine, which *rips electrons* from microbial proteins and cell walls. Oxidised proteins unfold and die — like paper catching fire. Reaction idea: $2KMnO_4 + H_2O \rightarrow 2KOH + 2MnO_2 + 3[O]$ (in neutral/alkaline conditions, simplified).
2. **Halogenation (the tagging):** iodine penetrates the microbe and **attaches to proteins** (halogenation) and oxidises them — enzymes are permanently switched off.
3. **Protein precipitation / astringent action (the pickling):** weak agents like boric acid **denature surface proteins** mildly — creating conditions where microbes cannot thrive (bacteriostatic rather than bactericidal).

Why resistance is rare: antibiotics pick one lock (one enzyme); inorganic agents **smash the whole door** — oxidising everything at once. A microbe cannot easily mutate around total chemical burning.

14.4.2 Classification of inorganic antimicrobials

Class	Mechanism	Examples
Oxidising agents	Release nascent oxygen	Potassium permanganate, hydrogen peroxide
Chlorine releasers	Release chlorine / hypochlorite	Chlorinated lime
Halogens	Halogenation + oxidation of proteins	Iodine and its preparations
Weak antiseptics / astringents	Mild protein precipitation	Boric acid

14.4.3 Monograph-style entries

Potassium permanganate — $KMnO_4$

- **Preparation (principle):** from **pyrolusite ore (MnO_2)** — fused with potassium hydroxide in air to give potassium manganate (K_2MnO_4, green), which is then oxidised (electrolytically or with CO_2) to the permanganate (purple): $2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$; then $3K_2MnO_4 + 2H_2O \rightarrow 2KMnO_4 + MnO_2 + 4KOH$.
- **Properties:** dark purple, almost black crystals; soluble in water giving an intense **purple** solution; a **powerful oxidising agent**; **stains skin and clothes brown** (MnO_2 deposit) — the classic identification giveaway; decomposes in light/heat, so stored in dark bottles.
- **Uses: antiseptic** (very dilute solution for gargles, mouthwash, wound/ulcer washing); **disinfectant and deodoriser** (drains, wells); in the analytical lab for **permanganometry** (Unit III redox titrations — the same oxidising power titrates iron, oxalates, and H_2O_2).
- **Caution:** concentrated solutions burn tissue — only *dilute* solutions touch the body.

Boric acid — H_3BO_3

- **Preparation (principle):** from **borax** (sodium tetraborate, $Na_2B_4O_7$) by acidification with a mineral acid (e.g., HCl): $Na_2B_4O_7 + 2HCl + 5H_2O \rightarrow 2NaCl + 4H_3BO_3$; boric acid crystallises out on cooling.
- **Properties:** white crystalline powder or scales; **weak acid**; soluble in water and glycerin; **mild, non-irritating** antiseptic.
- **Uses: weak antiseptic** — eye lotions, mouthwashes, dusting powders; also used as a **buffer** component. **Caution:** poisonous if swallowed in quantity (especially dangerous to infants/children) — never use concentrated or on large broken skin areas casually.
- **Exam Pearl:** Boric acid is the *gentlest* antimicrobial in this chapter — weak, soothing, but toxic if ingested. "Mild outside, poison inside."

Hydrogen peroxide — H_2O_2

- **Preparation (principle):** laboratory: barium peroxide + sulphuric acid: $BaO_2 + H_2SO_4 \rightarrow BaSO_4\downarrow + H_2O_2$. Industrially by modern auto-oxidation processes (principle-level only).
- **Properties:** colourless liquid; **decomposes** into water and oxygen: $2H_2O_2 \rightarrow 2H_2O + O_2\uparrow$ — faster in **light, heat, or contact with rough surfaces**; hence stored in **dark, cool bottles**, often with stabilisers, and never filled to the brim.
- **Assay principle: redox (permanganate) titration** — H_2O_2 reduces purple $KMnO_4$ to colourless Mn^{2+} in acid medium; the disappearance of purple colour is the end point: $2KMnO_4 + 5H_2O_2 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$.
- **Uses: antiseptic for wounds** — the fizzing oxygen *mechanically* lifts dirt and dead tissue out of the wound; **disinfectant**; dilute solutions as **mouthwash/gargle** and ear-wax softener; bleaching agent.
- **Exam Pearl:** The fizz is the therapy — effervescence = mechanical cleansing. That's why peroxide "feels" like it's working.

Chlorinated lime — Ca(OCl)Cl (bleaching powder)

- **Preparation (principle):** passing **chlorine gas over dry slaked lime**: $Ca(OH)_2 + Cl_2 \rightarrow Ca(OCl)Cl + H_2O$.
- **Properties:** white amorphous powder with a characteristic **chlorine odour**; **releases chlorine** on exposure to air, moisture, or acids; loses strength on storage (must be stored airtight, cool, dry).
- **Uses: disinfectant** — water supplies, drains, latrines, hospital sanitation; **bleaching** agent. (The chlorine smell of a cleaned public toilet in India? That's this family of chemistry.)
- **Assay idea:** available chlorine is estimated **iodometrically** (liberated chlorine oxidises KI to iodine, titrated with thiosulphate) — principle-level.

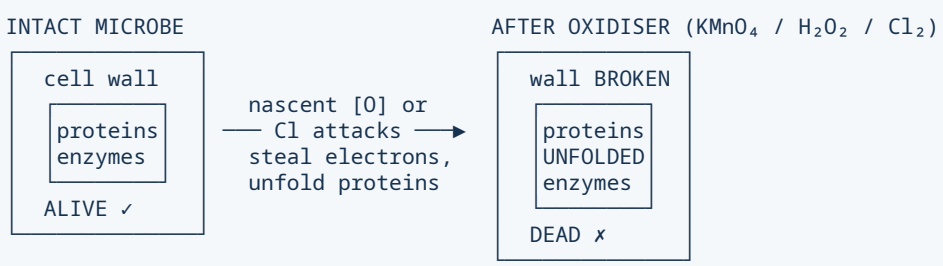
Iodine — I_2, and its preparations

- **Preparation (principle):** from seaweed ash or caliche (crude sodium nitrate) liquors — iodide oxidised to iodine (e.g., with chlorine or MnO_2/H_2SO_4) and sublimed: $2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$.
- **Properties:** greyish-black plates with metallic lustre; characteristic odour; **sublimes** (solid → violet vapour); **poorly soluble in water**, freely soluble in alcohol and in **potassium iodide solution** (forming KI_3 — this is *why* KI is added to preparations).
- **Mechanism recap:** halogenation + oxidation of microbial proteins — broad-spectrum, fast.
- **Preparations:**
- **Tincture of iodine:** iodine + **potassium iodide in alcohol** — the classic brown bottle for cuts. Alcohol itself disinfects and helps iodine penetrate; KI keeps iodine dissolved.
- **Aqueous iodine solution (Lugol's):** iodine + KI **in water** (no alcohol) — for mucous membranes where alcohol would sting.
- **Povidone-iodine (basic concept):** iodine **complexed with povidone** (polyvinylpyrrolidone) — a "slow-release" iodine: less staining, less irritation, longer action. The brown scrub surgeons paint on skin before operations.
- **Uses: antiseptic** for skin, wounds, pre-surgical skin preparation; water disinfection (emergency).
- **Caution:** stains skin temporarily; some people are iodine-sensitive; not for deep puncture wounds without medical advice.

14.5 Easy Analogy

- Inorganic antimicrobials are **fire**, antibiotics are **keys**: an antibiotic is a key cut for one specific lock (one bacterial enzyme) — change the lock (resistance) and the key fails. Fire (oxidation) burns the whole house down — no lock change can stop it. That's why microbes don't become "fire-resistant."
- **Povidone-iodine** is a **slow-release capsule** version of iodine — like a time-release fertilizer versus raw fertilizer: same chemical, gentler and longer.
- **Hydrogen peroxide fizz** is like **soda fizz lifting dirt** — the bubbles do the scrubbing.

14.6 Diagram — How Oxidising Antimicrobials Kill



AI Image Prompt: "Educational textbook diagram, white background, two bacterial cell illustrations side by side: left intact bacterium labelled 'Living microbe — proteins folded, enzymes working', right damaged bacterium labelled 'After oxidising agent — proteins unfolded, cell wall broken', red [O] symbols attacking, pharmacy textbook style, clear labels, minimal decoration."

14.7 Flowchart — Choosing an Inorganic Antimicrobial

```
Need to kill microbes — on WHAT?
   ├─ LIVING tissue (antiseptic)
   │     ├─ Skin/cut → tincture of iodine / povidone-iodine
   │     ├─ Wound with dirt → hydrogen peroxide (fizz cleans)
   │     └─ Mouth/throat → very dilute KMnO4 gargle / boric-acid mouthwash
   └─ NON-LIVING thing (disinfectant)
         ├─ Water supply → chlorinated lime
         └─ Drains/floors → chlorinated lime / KMnO4 solution
```

14.8 Examples

- The **brown bottle** in every Indian home first-aid box = tincture of iodine.
- **Betadine®-type** brown surgical scrub = povidone-iodine.
- Municipal workers adding powder to drains during monsoon = **chlorinated lime** disinfection.
- Purple crystals dissolved for a foot-soak for fungal feet = **$KMnO_4$**.

14.9 Pharmacy Relevance

- **Dispensing:** tincture of iodine and H_2O_2 are OTC staples — counsel: iodine stings briefly and stains; peroxide fizzes (normal) but don't use daily on healing wounds (it can slow healing).
- **Compounding awareness:** never mix iodine preparations with ammonia (explosive nitrogen triiodide can form) — a classic pharmacy safety pearl.
- **Analytical link:** $KMnO_4$ (permanganometry) and H_2O_2 assays are Unit III redox titration territory — the same chemistry serves analysis and therapy.

14.10 India Context

Chlorinated lime is the backbone of **rural water disinfection** in India (wells, overhead tanks during outbreaks); tincture of iodine and povidone-iodine are on the **National List of Essential Medicines**-type hospital formularies as antiseptics; the **Indian Pharmacopoeia** includes monographs for potassium permanganate, boric acid, hydrogen peroxide solution, and iodine preparations.

14.11 Important Points to Remember

1. **Remember:** Antiseptic = living tissue; disinfectant = non-living things.
2. **Exam Pearl:** Three kill mechanisms — **oxidation** ($KMnO_4$, H_2O_2, chlorinated lime), **halogenation** (iodine), **protein precipitation** (boric acid).
3. **Exam Pearl:** Microbes rarely resist inorganic agents — they smash everything at once, not one enzyme.
4. **Exam Pearl:** KI is added to iodine preparations because **iodine is poorly soluble in water** (forms soluble KI_3).
5. $KMnO_4$: pyrolusite → KOH fusion → oxidation; purple solution; **brown skin stains**; dilute only on body.
6. H_2O_2: $2H_2O_2 \rightarrow 2H_2O + O_2\uparrow$; store dark/cool; assay by **permanganate redox titration**; fizz = mechanical cleansing.
7. Chlorinated lime: Cl_2 + slaked lime; chlorine odour; water/drain disinfectant; loses strength in air.
8. Boric acid: from borax + acid; **mildest** antiseptic; **toxic if swallowed** (children at risk).
9. Povidone-iodine = slow-release iodine complex — less stain, less irritation, longer action.

14.12 Common Confusions & Common Mistakes

Do not confuse: antiseptic ≠ disinfectant (body vs things) · **tincture of iodine ≠ Lugol's iodine** (alcohol vs water base) · **bactericidal ≠ bacteriostatic** (kills vs stops growth — boric acid is mainly the latter) · **hydrogen peroxide ≠ water** (looks the same, behaves very differently — label carefully!). **Mistakes:** saying $KMnO_4$ solution is safe concentrated (it burns); forgetting *why* KI is in tincture (solubility!); calling chlorinated lime an antiseptic for wounds (it's a *disinfectant* — too harsh for tissue); writing H_2O_2 as stable (it decomposes — storage conditions matter).

14.13 Memory Tricks

- "**A**ntiseptic on **A**natomy (body); **D**isinfectant on **D**ead things."
- Kill mechanisms: "**O**xidise ($KMnO_4$, H_2O_2, lime), **H**alogenate (iodine), **P**ickle (boric acid)" — "**O**ur **H**ero **P**revails."
- "Iodine needs **KI** to **K**eep dissolved."
- "Peroxide **P**ops (fizzes) to **P**urify."

14.14 Exam-Oriented Summary

Inorganic antimicrobials kill by oxidation ($KMnO_4$, H_2O_2, chlorinated lime → nascent [O]/Cl), halogenation (iodine → protein damage), or mild protein precipitation (boric acid). Antiseptics go on living tissue; disinfectants on non-living things. $KMnO_4$ (from pyrolusite; purple; stains brown) is used dilute as antiseptic/gargle. H_2O_2 ($2H_2O_2 \rightarrow 2H_2O + O_2$; permanganate assay; dark storage) cleans wounds by effervescence. Chlorinated lime (Cl_2 + slaked lime; chlorine odour) disinfects water and drains. Boric acid (from borax; mildest; toxic if swallowed) suits eyes/mouth. Iodine preparations — tincture (alcohol + KI), Lugol's (water + KI), povidone-iodine (slow-release complex) — are the surgical-skin antiseptics; KI is added because iodine is water-insoluble.

One-Minute Revision: Antiseptic = body, disinfectant = things. Kill by oxidation / halogenation / pickling. $KMnO_4$: pyrolusite, purple, brown stains, dilute use. H_2O_2: fizzes to $2H_2O + O_2$, dark bottle, permanganate assay. Lime: Cl_2 + $Ca(OH)_2$, water disinfectant. Boric acid: mildest, toxic swallowed. Iodine + KI (solubility) → tincture, Lugol's, povidone-iodine (slow release).

14.15 Questions

Very Short Answer: 1. Define antiseptic and disinfectant. 2. Why is KI added to tincture of iodine? 3. Give the formula of chlorinated lime. 4. What is povidone-iodine, in one line? 5. Name two oxidising antimicrobials.

Short Answer: 1. Explain the three mechanisms of antimicrobial action of inorganic agents. 2. Why do microbes rarely develop resistance to inorganic antimicrobials? 3. Describe the preparation and properties of potassium permanganate. 4. Why must hydrogen peroxide be stored in dark, cool bottles? 5. Compare tincture of iodine, Lugol's iodine, and povidone-iodine.

Long Answer: 1. Define antiseptic, disinfectant, and germicide. Classify inorganic antimicrobials by mechanism with examples, and give monograph-style entries (formula, preparation, properties, uses) for potassium permanganate and hydrogen peroxide. 2. Write monograph-style entries for chlorinated lime, boric acid, and iodine, including the preparations of iodine.

MCQs

1. An antiseptic differs from a disinfectant in that it is applied to: (a) non-living surfaces (b) living tissue (c) water supplies (d) air — **Ans: (b)**.
2. Potassium iodide is added to tincture of iodine to: (a) add colour (b) dissolve iodine in water/alcohol (c) reduce irritation only (d) act as preservative — **Ans: (b)**. I_2 is poorly water-soluble; KI forms soluble KI_3.
3. Hydrogen peroxide is assayed by titration with: (a) EDTA (b) sodium thiosulphate (c) potassium permanganate (d) silver nitrate — **Ans: (c)**. Redox titration, purple → colourless end point.
4. The antimicrobial action of chlorinated lime is due to: (a) nascent oxygen (b) released chlorine (c) acidity (d) heat — **Ans: (b)**.
5. Which is the mildest antiseptic of this chapter, but toxic if swallowed? (a) $KMnO_4$ (b) H_2O_2 (c) Boric acid (d) Chlorinated lime — **Ans: (c)**.

Viva: Why does $KMnO_4$ stain skin brown? What gas makes H_2O_2 fizz on a wound? Why is povidone-iodine preferred over tincture for surgical scrub? Which compound links this chapter to Unit III redox titrations? **Application-based:** A rural health worker asks what to add to a village well after flooding. What do you recommend and why? *(Ans: Chlorinated lime — disinfects water; cheap, effective chlorine releaser; dose as per public-health guidelines.)* A mother applies concentrated $KMnO_4$ crystals directly to her child's wound. What is wrong? *(Ans: Concentrated $KMnO_4$ burns tissue — only very dilute solutions are antiseptic; wash off, use dilute solution or povidone-iodine.)*

14.16 References

- Schroff ML. *Pharmaceutical Chemistry (Inorganic)* — antimicrobials, iodine preparations.
- Bentley & Driver. *Textbook of Pharmaceutical Chemistry* — oxidising agents, halogens.
- Indian Pharmacopoeia — monographs: Potassium Permanganate, Boric Acid, Hydrogen Peroxide Solution, Iodine preparations.
- Vogel's *Quantitative Chemical Analysis* — permanganate and iodometric assay principles.

CHAPTER 15: RADIOPHARMACEUTICALS

Unit IV · ~3 hours

15.1 Introduction

Some atoms are **unstable** — their nuclei literally fall apart, throwing out invisible energy called **radiation**. This sounds frightening, and uncontrolled radiation is dangerous. But medicine tamed it: a tiny, precisely measured dose of a radioactive atom can **photograph the thyroid from inside**, or **burn away a cancer** without a single cut. These medicines are **radiopharmaceuticals** — and the pharmacist's job is not to fear them, but to **handle, store, and dispose of them by strict safety rules**. This chapter builds radioactivity from absolute zero: atoms first, fear never.

> **Learning objectives** — after studying this chapter, you should be able to:

- define atom, isotope, radioisotope, and radioactivity (scientific + simple);
- name and compare the three types of radiation (alpha, beta, gamma) including shielding;
- explain what a radiopharmaceutical is and why I-131, Tc-99m, Co-60, and P-32 are used;
- state the applications of each of these four radioisotopes;
- explain the safety principles of time, distance, and shielding;
- describe safe storage and disposal of radiopharmaceuticals;
- outline the regulatory safety framework (AERB, India) at a general level.

15.2 Definition

Atom — scientific: the smallest unit of matter — a central **nucleus** (protons + neutrons) with **electrons** orbiting around it. **Simple:** the tiny solar system everything is made of — heavy centre (nucleus), light planets (electrons).

Isotope — scientific: atoms of the *same* element (same number of protons) with *different* numbers of neutrons — e.g., carbon-12 and carbon-14. **Simple:** siblings of the same element — same identity (protons), different weight (neutrons).

Radioisotope — scientific: an *unstable* isotope whose nucleus spontaneously decays, emitting radiation. **Simple:** a wobbly atom that can't hold itself together — it breaks apart and throws out energy rays.

Radioactivity — scientific: the spontaneous disintegration of unstable nuclei with emission of alpha, beta, or gamma radiation. **Simple:** atoms falling apart on their own and shooting out invisible energy.

Radiopharmaceutical — scientific: a pharmaceutical preparation containing a radioisotope, used for **diagnosis** (tracing/imaging) or **therapy** (destroying diseased tissue). **Simple:** a medicine with a tiny radioactive atom inside — it either *lights up* the disease so doctors can see it, or *burns* the disease away.

Half-life — scientific: the time for half the radioactive atoms in a sample to decay. **Simple:** the "cooling-down timer" — after one half-life, the radioactivity is half; after two, a quarter, and so on.

15.3 Key Terminology

Term	Meaning
Alpha (α) radiation	Helium nuclei (2 protons + 2 neutrons) — heavy, slow, stopped by **paper/skin**
Beta (β) radiation	Fast electrons — stopped by **aluminium/plastic**
Gamma (γ) radiation	High-energy light waves (like super-X-rays) — needs **lead/concrete** to stop
Becquerel (Bq)	SI unit of radioactivity — one disintegration per second
Tracer	A tiny radioactive dose that *maps* the body (diagnosis) without harming it
Teletherapy	Treatment with radiation from a source **outside** the body (e.g., Co-60 unit)
AERB	**Atomic Energy Regulatory Board** — India's regulator for radiation safety
ALARA	"**A**s **L**ow **A**s **R**easonably **A**chievable" — the golden rule: keep every dose minimal

15.4 Detailed Explanation

15.4.1 Why some atoms are radioactive — from zero

Think of the nucleus as a **crowded bus**: protons (all positively charged) repel each other, while neutrons act as peacemakers holding everyone together. If the bus is **too crowded with neutrons** (or the balance is wrong), it becomes unstable — passengers start jumping off. Each "jump" is a **disintegration**, and the energy thrown off is **radiation**. The three things thrown off:

Radiation	What it is	Penetrating power	Stopped by
Alpha (α)	Helium nucleus — big and heavy	Very low (can't cross skin)	**Paper**, skin
Beta (β)	Fast electron — small and quick	Medium (few mm of tissue)	**Aluminium sheet**, thick plastic
Gamma (γ)	Pure energy wave (like X-rays, stronger)	Very high (through the body)	**Lead**, thick concrete

> **Exam Pearl:** Penetrating power order: **α < β < γ**. Shielding order: **paper < aluminium < lead**. Examiners ask this as a direct one-marker — learn the pairs.

15.4.2 Why gamma is the diagnostic favourite

For **imaging**, doctors want radiation that *escapes the body* to reach the camera — that's **gamma**. Alpha and beta mostly get absorbed inside the patient (useless for imaging, and they deposit their energy in tissue — which is exactly why they're useful for **therapy**, where you *want* to destroy cells locally).

15.4.3 The four syllabus radioisotopes

Sodium iodide I-131 (Iodine-131)

- **What it is:** radioactive iodine as sodium iodide — taken by mouth as capsule/solution.
- **Why the thyroid:** the thyroid gland **hungrily concentrates iodine** (it needs it to make thyroid hormone) — so radioactive iodine goes *straight* to the thyroid and almost nowhere else. A perfect postal address.
- **Radiation:** emits **beta** (destroys thyroid cells — therapy) **+ gamma** (escapes for imaging — diagnosis).
- **Applications: diagnosis** of thyroid function (thyroid uptake scans) and **treatment** of hyperthyroidism and thyroid cancer — the beta rays burn away overactive/cancerous thyroid tissue from inside.

Technetium-99m (Tc-99m)

- **What it is:** the **workhorse of nuclear medicine** — a *pure gamma* emitter with a **short half-life (about 6 hours)**.
- **Why ideal for diagnosis:** pure gamma = clear pictures; short half-life = the patient stops being radioactive within a day or so (low radiation burden).
- **Source:** obtained from a **molybdenum-99/technetium-99m generator** (the "moly cow") — Mo-99 decays to Tc-99m, which is "milked" (eluted) daily with saline in the hospital radiopharmacy.
- **Applications:** bone scans, heart scans, kidney scans, brain scans — attached to different carrier molecules, it images different organs (SPECT imaging).

Cobalt-60 (Co-60)

- **What it is:** a **strong gamma emitter** (high energy, long half-life — several years).
- **Applications: external beam radiotherapy (teletherapy)** — the gamma beam is aimed at deep tumours from outside the body to destroy cancer cells; also used for **sterilising** medical equipment and food (gamma irradiation).
- **Why not injected:** its penetrating gamma and long half-life make it a *machine* source, not a medicine you swallow.

Phosphorus-32 (P-32)

- **What it is:** a **pure beta emitter**.
- **Applications: therapy** — e.g., polycythaemia vera (a blood disorder with too many red cells; P-32 suppresses the overactive bone marrow) and some skin conditions; also widely used as a **tracer in research**.
- **Logic:** beta particles travel only a few millimetres — they destroy diseased cells *locally* without reaching far.

> **Exam Pearl:** "I-131 → **thyroid** (beta+gamma, diagnose + treat); Tc-99m → **pictures** (pure gamma, short half-life); Co-60 → **beam** (teletherapy, from outside); P-32 → **local burn** (pure beta, blood/skin disorders)."

15.4.4 Safe handling — the three golden principles

1. **TIME — minimise it:** radiation dose = rate × time. Plan the work, handle quickly and confidently, never linger near the source. (Less time near fire = less burn.)
2. **DISTANCE — maximise it:** dose falls with the **square of the distance** (double the distance → one-quarter the dose). Use tongs, trolleys, and remote handling — never carry sources in hands or pockets.
3. **SHIELDING — interpose it:** put the right barrier between you and the source — **lead** for gamma, **aluminium/perspex** for beta. (Note: lead is *wrong* for high-energy beta — it generates secondary X-rays; another examiner favourite.)

Handling rules: trained personnel only; wear **dosimeters** (film badges/TLD badges that record personal dose); no eating, drinking, or smoking in the work area; monitor hands, clothes, and benches with survey meters; work over trays to catch spills; label everything with the radiation trefoil symbol.

15.4.5 Storage and disposal

- **Storage:** in **lead-lined, locked containers/cabinets**; in a dedicated, signposted, access-controlled room; sources **labelled** (isotope, activity, date); inventory records; leak-proof secondary containment for liquids.
- **Disposal — "delay and decay":** short-lived waste is **stored securely until its radioactivity decays** to safe levels, then disposed as ordinary waste; longer-lived waste is collected by **authorised agencies** for proper disposal. **Never** pour radioactive liquids down drains or throw sources in ordinary bins.

15.4.6 Regulatory guidelines for safety — general level (AERB/India)

- India's **Atomic Energy Regulatory Board (AERB)** regulates the use of radiation sources in medicine, industry, and research.
- **General principles** (no regulation numbers needed for exams): any facility using radiopharmaceuticals needs **authorisation/licensing**; only **trained, designated personnel** handle sources; **personal dose monitoring** (badges) and **area monitoring** are mandatory; **records** of receipt, use, storage, and disposal are maintained; **emergency procedures** for spills/loss of sources are in place; and the guiding philosophy is **ALARA** — keep every dose **A**s **L**ow **A**s **R**easonably **A**chievable.
- **Exam-safe line:** "In India, AERB lays down the safety requirements; the operator's duty is licensing, training, monitoring, shielding, and ALARA."

15.5 Easy Analogy

- An **unstable nucleus** is a **wobbly tower of blocks** — sooner or later blocks tumble off (radiation). **Half-life** is the time for half the towers in the room to collapse.
- **Alpha/beta/gamma** are like **a thrown stone, a bullet, and a flashlight beam**: the stone (alpha) is stopped by a curtain (paper); the bullet (beta) needs a wooden door (aluminium); the light beam (gamma) goes through curtains and doors — you need a **brick wall** (lead).
- **Time–distance–shielding** is **sunbathing safety**: spend less time in the sun (time), sit under a tree farther from the glare (distance), wear sunscreen (shielding).
- **Tc-99m generator ("moly cow")** is a **cow you milk daily** — the mother (Mo-99) keeps producing milk (Tc-99m), which you draw off with saline each morning.

15.6 Diagram — Radiation Types and Shielding

```
SOURCE  →   α (stone)       | paper      → STOPPED ✓
(unstable   →   β (bullet)      | aluminium  → STOPPED ✓
 nucleus)   →   γ (light beam) | lead       → STOPPED ✓
                                    (nothing lighter stops γ)

Penetration:  α < β < γ          Shielding: paper < aluminium < lead
```

AI Image Prompt: "Educational textbook diagram, white background, a radioactive source on the left emitting three labelled rays: alpha stopped by a sheet of paper, beta stopped by an aluminium plate, gamma stopped only by a thick lead block, penetration depth shown with arrows, pharmacy textbook style, clear labels, minimal decoration."

15.7 Flowchart — Is This Use Safe? (Handling Checklist)

```
Before handling a radiopharmaceutical:
    ├─ Am I TRAINED and AUTHORISED? → No → STOP, call the RSO*
    ├─ Is my DOSIMETER badge on? → No → put it on
    ├─ Planned to minimise TIME near source? → plan first
    ├─ Maximised DISTANCE (tongs/trolley)? → arrange
    ├─ Correct SHIELDING in place (Pb for γ)? → verify
    └─ Spill kit + survey meter ready? → then proceed
*RSO = Radiological Safety Officer
```

15.8 Examples

- A **thyroid scan**: patient swallows tiny I-131 capsule → gamma camera photographs the glowing thyroid.
- **Bone scan** for suspected cancer spread: Tc-99m injection → whole-body gamma image shows "hot spots."
- **Co-60 teletherapy unit**: patient lies still while the rotating gamma beam targets the tumour — no surgery, no pain during treatment.
- Hospital **nuclear medicine department** sign with the trefoil (☢-like) symbol = restricted area.

15.9 Pharmacy Relevance

- **Radiopharmacist** is a real career: preparing Tc-99m kits, dispensing I-131 capsules, and running the "moly cow" generator under aseptic + radiation-safe conditions.
- **Counselling:** reassure patients — diagnostic doses are tiny and short-lived ("the radioactivity mostly leaves your body within a day"); advise on simple precautions after I-131 therapy (as instructed by the nuclear medicine team).
- **Safety culture:** the time–distance–shielding habit protects *you* for your whole career — ALARA is a professional ethic, not just a rule.

15.10 India Context

India's nuclear medicine network (government hospitals, cancer centres, and private diagnostic chains) routinely uses **Tc-99m generators and I-131**; the **Board of Radiation and Isotope Technology (BRIT)** supplies radioisotopes within the country; and **AERB** authorises and inspects facilities using them. (General, well-established facts — no regulation numbers cited.)

15.11 Important Points to Remember

1. **Remember:** Isotope = same protons, different neutrons; radioisotope = unstable, decays with radiation.
2. **Exam Pearl:** α < β < γ in penetration; shielding = **paper < aluminium < lead**.
3. **Exam Pearl:** Gamma = diagnosis (escapes body to camera); beta = local therapy (absorbed in tissue).
4. **Exam Pearl:** I-131 → thyroid (β+γ, diagnose + treat); Tc-99m → imaging (pure γ, ~6 h half-life, "moly cow" generator); Co-60 → teletherapy beam + sterilisation; P-32 → pure β, local therapy (polycythaemia vera).
5. **Exam Pearl:** Safety = **Time, Distance, Shielding**; philosophy = **ALARA**.
6. Dose ∝ $1/(\text{distance})^2$ — doubling distance quarters the dose.
7. Storage: lead-lined, locked, labelled, access-controlled. Disposal: **delay and decay**; never down drains.
8. India: **AERB** regulates; BRIT supplies isotopes; badges (TLD) monitor personnel dose.

15.12 Common Confusions & Common Mistakes

Do not confuse: isotope ≠ radioisotope (all radioisotopes are isotopes, not vice versa) · **irradiation ≠ contamination** (irradiation = exposed to rays, like an X-ray — you don't *become* radioactive; contamination = radioactive material *on* you — you carry it) · **Tc-99m ≠ Co-60** (diagnostic tracer vs therapy machine source) · **half-life ≠ expiry** (half-life is a physics constant; the drug doesn't "expire" like a tablet). **Mistakes:** saying lead shields beta best (use aluminium/perspex — lead makes secondary X-rays); saying gamma is used for local therapy (beta is — gamma escapes); claiming exact dose limits or regulation numbers (never invent these); thinking patients "glow" dangerously after a scan (diagnostic doses are tiny and decay fast).

15.13 Memory Tricks

- "**A**lpha stopped by p**A**per; **B**eta by **B**arrier (aluminium); **G**amma by **G**iant lead." (A-B-G, paper-alu-lead)
- Safety: "**T**ime down, **D**istance up, **S**hield on" — "**T**he **D**octor **S**tays safe."
- ALARA: "**A**lways **L**ower **A**ll **R**adiation **A**mounts."
- I-131: "**I**odine loves the **T**hyroid." Tc-99m: "**T**echnetium **T**akes **P**ictures." Co-60: "**Co**balt **C**uts **C**ancer (beam)." P-32: "**P**ure **B**eta **B**urns **L**ocally."

15.14 Exam-Oriented Summary

Radioactivity = unstable nuclei (radioisotopes) decaying with α/β/γ emission. Penetration α<β<γ; shielding paper<aluminium<lead. Radiopharmaceuticals diagnose (gamma tracers) or treat (beta/beam). I-131 (β+γ) targets the thyroid for diagnosis and therapy of hyperthyroidism/thyroid cancer. Tc-99m (pure γ, ~6 h half-life, from the Mo-99 "moly cow" generator) is the universal imaging agent. Co-60 (strong γ) gives external teletherapy and sterilisation. P-32 (pure β) treats locally (e.g., polycythaemia vera). Safety = time, distance, shielding + ALARA; storage in lead-lined locked rooms; disposal by delay-and-decay; AERB regulates in India with licensing, training, monitoring, and records.

One-Minute Revision: α<β<γ; paper<Al<lead. γ = pictures, β = local burn. I-131 → thyroid (β+γ). Tc-99m → imaging (γ, 6 h, moly cow). Co-60 → beam therapy. P-32 → β therapy. Safety: time, distance, shielding, ALARA. Store lead-locked; dispose by decay. AERB regulates.

15.15 Questions

Very Short Answer: 1. Define radioisotope (scientific + simple). 2. Arrange α, β, γ in order of penetrating power. 3. What does ALARA stand for? 4. Which radioisotope is used for thyroid therapy? 5. Expand AERB.

Short Answer: 1. Compare alpha, beta, and gamma radiation with their shielding. 2. Why is Tc-99m ideal for diagnostic imaging? 3. Explain the time–distance–shielding principles with the inverse-square idea. 4. Why does the thyroid selectively take up I-131? 5. Describe the storage and disposal of radiopharmaceuticals.

Long Answer: 1. Define radioactivity, isotope, and radiopharmaceutical. Describe the applications of I-131, Tc-99m, Co-60, and P-32. 2. Discuss the safe handling, storage, and disposal of radiopharmaceuticals, including the regulatory safety framework in India.

MCQs

1. Which radiation is stopped by a sheet of paper? (a) Alpha (b) Beta (c) Gamma (d) X-ray — **Ans: (a)**.
2. Tc-99m is preferred for diagnostic scanning because it is a: (a) pure alpha emitter (b) pure beta emitter (c) pure gamma emitter with short half-life (d) neutron emitter — **Ans: (c)**.
3. I-131 concentrates in the thyroid because: (a) thyroid attracts all metals (b) thyroid needs iodine for hormone synthesis (c) iodine is magnetic (d) of blood flow only — **Ans: (b)**.
4. Doubling the distance from a radiation source reduces the dose to: (a) half (b) one-quarter (c) one-eighth (d) zero — **Ans: (b)**. Inverse-square law.
5. The "delay and decay" method refers to: (a) postponing treatment (b) storing radioactive waste till activity decays (c) delaying generator milking (d) shielding with lead — **Ans: (b)**.

Viva: Why is lead NOT the best shield for high-energy beta? What is the "moly cow"? Irradiation vs contamination — which one makes the patient radioactive? (Ans: Neither for irradiation; contamination can.) Why is Co-60 not given as an injection? **Application-based:** A nurse must carry an I-131 capsule from the radiopharmacy to the ward. List three safety steps using time–distance–shielding. *(Ans: Plan route to minimise time; use a lead-lined carrier at arm's length/trolley for distance; keep the lead container closed = shielding; wear dosimeter.)* A student says "the patient will remain dangerously radioactive for weeks after a Tc-99m scan." Correct them. *(Ans: ~6 h half-life — activity falls to a small fraction within a day; diagnostic doses are tiny by design.)*

15.16 References

- Schroff ML. *Pharmaceutical Chemistry (Inorganic)* — radiopharmaceuticals.
- Bentley & Driver. *Textbook of Pharmaceutical Chemistry* — radioactivity basics.
- Indian Pharmacopoeia — radiopharmaceutical monographs (general).
- Vogel's *Quantitative Chemical Analysis* — detection/measurement principles.

UNIT IV INFOGRAPHIC CONCEPTS

Infographic 1 — "Radioactivity Safety 101"

Layout: a triangular warning-style poster with the trefoil symbol at top.

- **Top:** "☢ RADIOACTIVITY SAFETY 101"
- **Three pillars (icons):** ⏱ TIME (minimise) → 📏 DISTANCE (maximise, $1/d^2$) → 🛡 SHIELDING (paper < Al < lead)
- **Middle band:** "α < β < γ — match the shield to the ray"
- **Bottom strip:** "Store: lead-lined, locked, labelled · Dispose: delay and decay · Rule: ALARA"
- **Side note:** "I-131 → thyroid · Tc-99m → pictures · Co-60 → beam · P-32 → local burn"

Infographic 2 — "The Ideal Antacid — 6 Properties"

Layout: a hexagonal badge, one property per side, antacid tablet at centre.

1. Fast onset
2. Long duration
3. High acid-neutralising capacity
4. No systemic alkalosis
5. No rebound acidity
6. No CO_2 evolution

- **Centre caption:** "No single antacid is perfect — that's why we COMBINE: Al (constipating) + Mg (laxative) = balanced."

UNIT IV REFERENCES (COMBINED)

- Schroff ML. *Pharmaceutical Chemistry (Inorganic).*
- Bentley & Driver. *Textbook of Pharmaceutical Chemistry.*
- Indian Pharmacopoeia — monographs: Sodium Bicarbonate, Aluminium Hydroxide Gel, Magnesium Hydroxide, Dilute Hydrochloric Acid, Potassium Permanganate, Boric Acid, Hydrogen Peroxide Solution, Iodine preparations, radiopharmaceuticals (general).
- Vogel's *Quantitative Chemical Analysis* — assay principles (acid–base, complexometric, redox, iodometric).