JEE MAIN · PAPER 1 · CHEMISTRY

21 Polymers, Metallurgy & Chemistry in Everyday Life

Formula & concept sheet

The remaining NCERT chapters: how metals are extracted and refined (ores, concentration, roasting, the blast furnace, the Ellingham diagram, aluminium, copper, zinc), polymers and their monomers, the chemistry of drugs, soaps and food additives, and the environment (smog, ozone, greenhouse gases, water quality). Each idea is explained first, then the reactions and tables.

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READ ALONGSIDE NCERT XII · General Principles and Processes of Isolation of Elements · NCERT XII · Polymers · NCERT XII · Chemistry in Everyday Life · NCERT XI · Environmental Chemistry

HOW TO USE THIS SHEET

1. **Skim** — Read the Key ideas, then the formula cards.
2. **Memorise** — Learn the formulas and check every Trap box.
3. **Test** — Do the worked examples, then this chapter's PYQs.
4. **Revise** — Use the last-minute checklist before the exam.

Formula memorise · **Key idea** why it works · **Trap** marks lost here · **PYQ** how it is asked

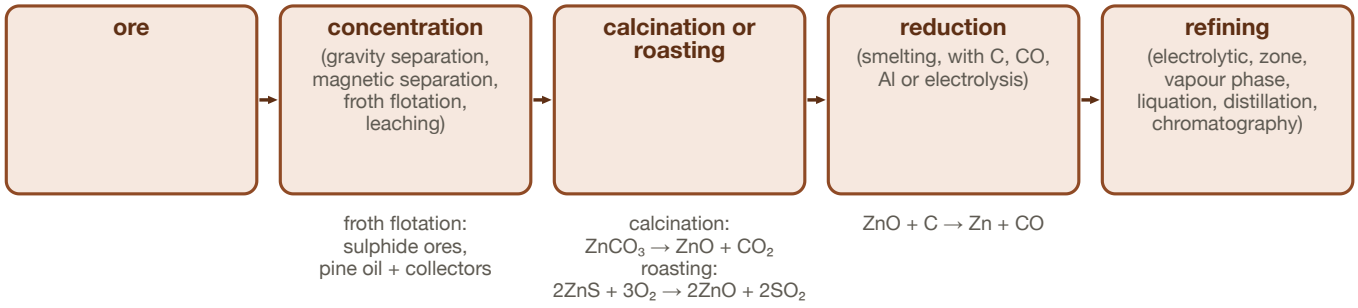
CHAPTER 21

Polymers, Metallurgy & Chemistry in Everyday Life

NCERT XII · General Principles and Processes of Isolation of Elements | NCERT XII · Polymers | NCERT XII · Chemistry in Everyday Life | NCERT XI · Environmental Chemistry

Covers: ores and their treatment, calcination, roasting, reduction, Ellingham diagram, extraction of Fe, Cu, Zn, Al, refining methods, alloys · classification of polymers, addition and condensation polymers, rubber, molecular mass of polymers, biodegradable polymers · drugs, antacids, analgesics, antibiotics, sweeteners, preservatives, soaps and detergents · atmospheric pollution, ozone, greenhouse effect, water pollution.

1 Metallurgy: from ore to metal



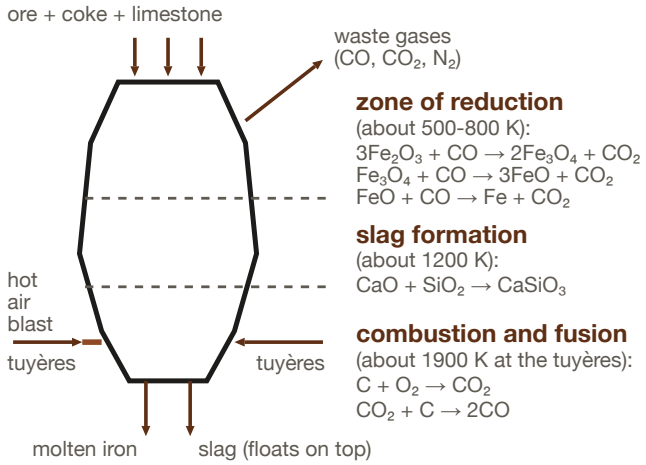
the steps from ore to pure metal: each step removes a different kind of impurity

COMMON ORES

METAL	ORE	FORMULA (TYPE)
iron	haematite; magnetite; siderite; iron pyrites	Fe_2O_3; Fe_3O_4 (oxides); $FeCO_3$ (carbonate); FeS_2 (sulphide)
aluminium	bauxite; cryolite	$AlO_x(OH)_{3-2x}$ $(0 < x < 1)$; Na_3AlF_6 (fluoride)
copper	copper pyrites; malachite; cuprite	$CuFeS_2$; $CuCO_3 \cdot Cu(OH)_2$; Cu_2O
zinc	zinc blende; calamine	ZnS; $ZnCO_3$
lead; calcium	galena; fluorspar	PbS; CaF_2

STEPS AND REACTIONS

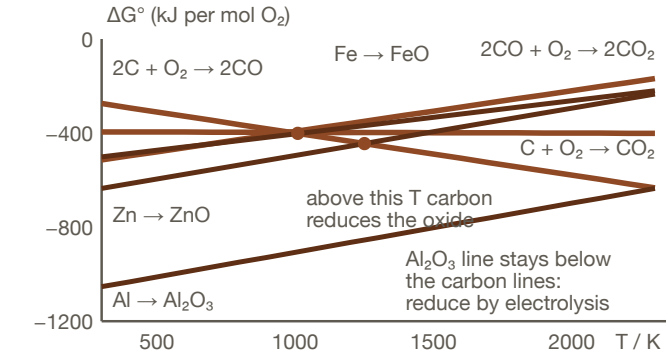
STEP	METHOD, WITH EQUATIONS
concentration	hydraulic washing (gravity), magnetic separation, **froth flotation** for sulphide ores (pine oil frother, xanthate collector; NaCN depresses ZnS when separating PbS from ZnS), **leaching**: Bayer process for bauxite $Al_2O_3 + 2\,NaOH + 3\,H_2O \longrightarrow 2\,Na[Al(OH)_4]$, then $2\,Na[Al(OH)_4] + 2\,CO_2 \longrightarrow 2\,Al(OH)_3 + 2\,NaHCO_3$, ignition to Al_2O_3 (about 1470 K); cyanide leaching of Au and Ag
calcination	heating without air (carbonates, hydrates): $ZnCO_3 \longrightarrow ZnO + CO_2$; $CaCO_3 \longrightarrow CaO + CO_2$
roasting	heating in excess air (sulphides): $2\,ZnS + 3\,O_2 \longrightarrow 2\,ZnO + 2\,SO_2$; $2\,PbS + 3\,O_2 \longrightarrow 2\,PbO + 2\,SO_2$; $2\,Cu_2S + 3\,O_2 \longrightarrow 2\,Cu_2O + 2\,SO_2$
reduction by carbon	$ZnO + C \longrightarrow Zn + CO$ (coke; NCERT writes 673 K, the Ellingham crossing for ZnO is near 1250 K); $Fe_2O_3 + 3\,CO \longrightarrow 2\,Fe + 3\,CO_2$
thermite	$Fe_2O_3 + 2\,Al \longrightarrow Al_2O_3 + 2\,Fe$ (aluminium as reducing agent, for welding)
self-reduction (Cu)	$2\,Cu_2O + Cu_2S \longrightarrow 6\,Cu + SO_2$ gives blister copper; iron removed as slag $FeO + SiO_2 \longrightarrow FeSiO_3$
electrolysis (Al)	Hall-Héroult: Al_2O_3 in molten cryolite with CaF_2 (lowers the melting point and raises conductivity); carbon anodes burn: overall $2\,Al_2O_3 + 3\,C \longrightarrow 4\,Al + 3\,CO_2$



temperatures are approximate and rise down the furnace

IRON: THE BLAST FURNACE

- Charge: ore (Fe_2O_3), coke and limestone (flux). Reduction by CO rising from below: $3\,Fe_2O_3 + CO \longrightarrow 2\,Fe_3O_4 + CO_2$, $Fe_3O_4 + CO \longrightarrow 3\,FeO + CO_2$, $FeO + CO \longrightarrow Fe + CO_2$ (overall $Fe_2O_3 + 3\,CO \longrightarrow 2\,Fe + 3\,CO_2$).
- $CaCO_3 \longrightarrow CaO + CO_2$; the flux removes silica as slag: $CaO + SiO_2 \longrightarrow CaSiO_3$ (floats on the iron). At the bottom $C + O_2 \longrightarrow CO_2$ and $CO_2 + C \longrightarrow 2\,CO$ generate the reducing gas.
- Pig iron about 4% C, cast iron about 3%, wrought iron (purest, about 0.2% C); steel is iron with controlled carbon and other metals.



a metal oxide is reduced by carbon above the temperature where the C → CO line falls below the oxide line

ELLINGHAM DIAGRAM A plot of ΔG° of formation of oxides (per mole of O_2) against T ($\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$). Most metal-oxide lines slope up (the gas O_2 is consumed, $\Delta S < 0$). A reducing agent can reduce an oxide when its own line lies **below** that of the oxide at that temperature: carbon forms CO with a line sloping **down** ($\Delta S > 0$), so above a certain temperature carbon reduces many oxides (ZnO above about 1250 K, FeO above about 1000 K). Al_2O_3 and MgO lines stay below, so they are reduced by electrolysis. CO is a better reductant at low T, carbon at high T.

REFINING AND ALLOYS

METHOD	USED FOR
distillation	low-boiling metals: Zn, Hg
liquation	low-melting metals: Sn, Pb
electrolytic refining	Cu, Zn, Al (impure metal anode, pure cathode)
zone refining	ultra-pure semiconductors: Si, Ge, Ga, In
vapour-phase	Mond: $Ni + 4\,CO \longrightarrow Ni(CO)_4$ (330 to 350 K) then $Ni(CO)_4 \longrightarrow Ni + 4\,CO$ (450 to 470 K); van Arkel: $Zr + 2\,I_2 \longrightarrow ZrI_4$, decomposed on a hot W filament $ZrI_4 \longrightarrow Zr + 2\,I_2$ (Zr, Ti)
chromatography	trace elements, small quantities
alloys	duralumin (Al, Cu, Mg, Mn; aircraft), brass (Cu-Zn), bronze (Cu-Sn), stainless steel (Fe-Cr-Ni), misch metal (lanthanoids about 95% + Fe; lighter flints)

TRAP

Calcination is heating without (or limited) air; roasting is heating in excess air. Haematite is an **oxide** ore, not a carbonate. Cryolite and fluorspar are fluoride ores. Sulphide ores are concentrated by froth flotation, then roasted; carbonates are calcined.

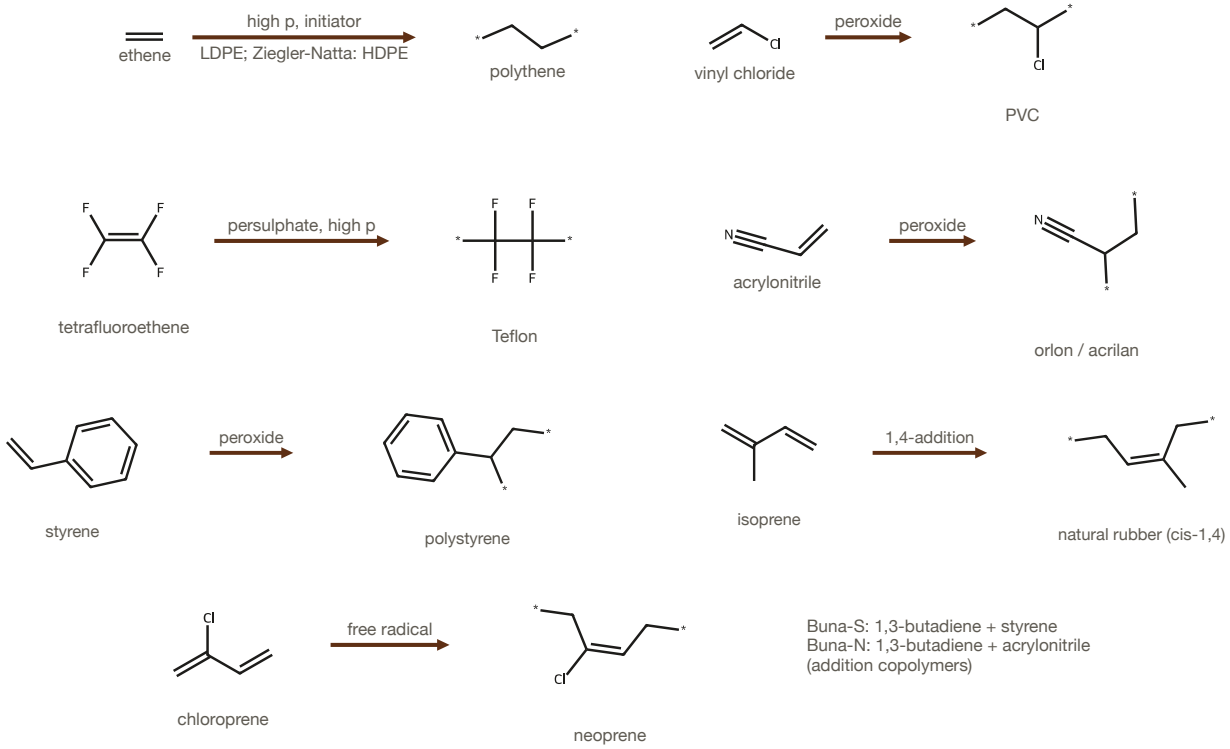
QUICK CHECK

Mass of Al from 1 hour of electrolysis at 1000 A ($M = 27$, $n = 3$, $F = 96500$)?

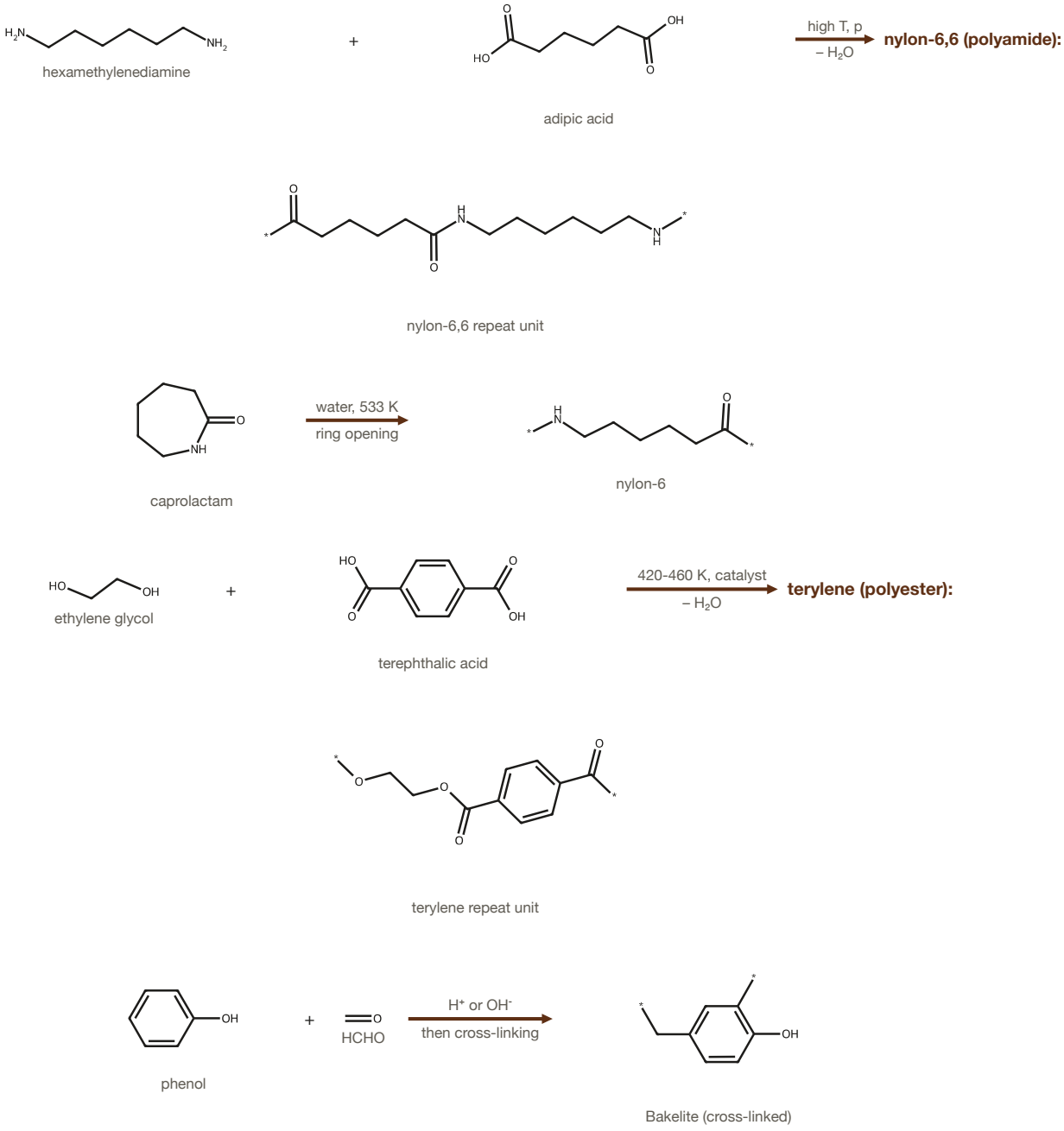
Answer: $m = \dfrac{ItM}{nF} = \dfrac{1000 \times 3600 \times 27}{3 \times 96500} = 336$ g.

2 Polymers

- A **polymer** is a very large molecule made by joining many small **monomers**. By source: natural (starch, cellulose, proteins, natural rubber), semi-synthetic (cellulose acetate), synthetic. By structure: linear, branched, cross-linked. By mode of formation: **addition** (monomers with a C=C add without loss of atoms: chain-growth, free radical or ionic, e.g. polythene) or **condensation** (step-growth, with loss of a small molecule such as H_2O, e.g. nylon). By forces: **elastomers** (weak forces, rubber), **fibres** (strong H bonds or dipole forces, nylon, terylene), **thermoplastics** (soften on heating: PE, PVC, PS), **thermosetting** (cross-linked, cannot be remoulded: Bakelite, melamine-formaldehyde).



addition polymers (repeat unit in the chain; * marks the continuation): polythene, PVC, Teflon, polyacrylonitrile, polystyrene



condensation and ring-opening polymers: nylon-6,6 (amide link, loss of water), nylon-6 (caprolactam), terylene (ester link), Bakelite from phenol and formaldehyde

SUMMARY OF MONOMERS

POLYMER	MONOMER(S)	TYPE
polythene (LDPE / HDPE)	ethene	addition; LDPE: free radical, high p, branched; HDPE: Ziegler-Natta, linear
PVC; Teflon; orlon	$CH_2{=}CHCl$; $CF_2{=}CF_2$; $CH_2{=}CHCN$	addition
polystyrene	styrene	addition
natural rubber	isoprene (2-methylbuta-1,3-diene), cis-1,4-polyisoprene (gutta-percha is trans)	addition, elastomer
neoprene; Buna-S; Buna-N	chloroprene; butadiene + styrene; butadiene + acrylonitrile	addition (copolymers for Buna)
nylon-6,6; nylon-6	hexamethylenediamine + adipic acid; caprolactam	condensation / ring-opening polyamides
terylene (dacron); glyptal	ethylene glycol + terephthalic acid; ethylene glycol + phthalic acid	condensation polyesters
Bakelite; melamine-formaldehyde	phenol + HCHO; melamine + HCHO	condensation, thermosetting
PHBV; nylon-2-nylon-6	3-hydroxybutanoic + 3-hydroxypentanoic acid; glycine + amino-caproic acid	biodegradable condensation polymers

RUBBER

- **Natural rubber**: cis-1,4-polyisoprene, soft and sticky, weak forces.
- **Vulcanisation**: heating with sulphur (373 to 415 K) creates S cross-links: harder, stronger, less sticky, elastic over a wider temperature range.
- **Synthetic**: neoprene (oil-resistant), Buna-S, Buna-N.

MOLECULAR MASS

- $\bar{M}_n = \dfrac{\sum N_i M_i}{\sum N_i}$, $\bar{M}_w = \dfrac{\sum N_i M_i^2}{\sum N_i M_i}$.
- $PDI = \bar{M}_w/\bar{M}_n \geq 1$ ($= 1$ for monodisperse natural polymers such as proteins); $DP = \bar{M}_n/M_{\text{repeat}}$.
- Example: 100 chains of 10^4 and 200 of 3×10^4: $\bar{M}_n = 23\,333$, $\bar{M}_w = 27\,143$, $PDI = 1.16$.

3 Chemistry in everyday life

DRUGS AND THEIR CLASSES

CLASS	EXAMPLES AND USE
antacids	$NaHCO_3$, $Mg(OH)_2$, $Al(OH)_3$; H_2-receptor blockers cimetidine, ranitidine (reduce acid secretion)
antihistamines	brompheniramine, terfenadine (act on the histamine receptors of allergy, do not affect acid secretion)
tranquilisers	equanil (meprobamate), chlordiazepoxide, barbiturates (veronal, luminal, seconal); antidepressants iproniazid, phenelzine
analgesics	non-narcotic: aspirin, paracetamol; narcotic: morphine, codeine, heroin
antibiotics	bactericidal: penicillin, aminoglycosides, ofloxacin; bacteriostatic: erythromycin, tetracycline, chloramphenicol; narrow spectrum: penicillin G; broad: chloramphenicol, ampicillin, amoxycillin
antiseptics and disinfectants	antiseptics (on living tissue): Dettol (chloroxylenol + terpineol), bithionol, iodoform, 0.2% phenol; disinfectants (on objects): 1% phenol, chlorine 0.2 to 0.4 ppm in water, low-concentration SO_2
antifertility	norethindrone, ethynylestradiol (novestrol)

FOOD, SOAPS AND DETERGENTS

ITEM	FACTS
artificial sweeteners (sucrose = 1)	saccharin 550, aspartame 100 (unstable at cooking temperature, not for cooked food), sucralose 600, alitame 2000
preservatives and antioxidants	sodium benzoate, salts of sorbic and propanoic acids; antioxidants BHT and BHA
soaps	sodium or potassium salts of long-chain fatty acids (saponification of fats with NaOH); not effective in hard water (Ca and Mg salts precipitate)
detergents	anionic (sodium dodecylbenzenesulphonate, sodium lauryl sulphate), cationic (cetyltrimethylammonium bromide: germicidal, hair conditioners), non-ionic (polyethylene glycol stearate); **branched-chain** detergents are non-biodegradable (pollution), linear ones biodegradable

4 Environmental chemistry

ATMOSPHERE AND POLLUTION

TOPIC	FACTS
atmosphere	troposphere 0 to 10 km (weather, clouds); stratosphere 10 to 50 km (ozone layer)
classical smog	SO_2 + smoke + fog; cool, humid; **reducing**
photochemical smog	NO_2, O_3, PAN, hydrocarbons, aldehydes; warm, sunny; **oxidising**
ozone depletion	CFCs release $Cl\cdot$ in the stratosphere: $Cl\cdot + O_3 \longrightarrow ClO\cdot + O_2$, $ClO\cdot + O \longrightarrow Cl\cdot + O_2$ (a chain); the ozone hole over Antarctica
greenhouse gases	CO_2, CH_4, N_2O, CFCs, O_3, H_2O vapour; global warming
acid rain	pH below 5.6 (normal rain is about 5.6 from dissolved CO_2); SO_2 and NO_x; damages marble ($CaCO_3$, Taj Mahal)
water: BOD	clean water < 5 ppm, highly polluted > 17 ppm; eutrophication from phosphates and nitrates
drinking water limits (NCERT)	F^- about 1 ppm (above 2 ppm mottling of teeth), Pb 50 ppb, SO_4^{2-} 500 ppm, NO_3^- 50 ppm, Cu 3 ppm, Fe 0.2 ppm, Zn 5 ppm, Cd 0.005 ppm, Mn 0.05 ppm, Al 0.2 ppm

PARTS PER MILLION

$$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$$

1 ppm $=$ 1 mg per litre of a dilute aqueous solution

KEY IDEA

The same reasoning links the three topics: metallurgy rests on $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ and electrolysis ($m = ItM/nF$), polymers on the functional groups of the monomers (C=C for addition; $-COOH$ with $-NH_2$ or $-OH$ for condensation), and drug and environmental facts on the properties already met in the other sheets.

5 Worked examples

IDENTIFY THE MONOMER

Monomers of nylon-6,6, nylon-6, terylene and Bakelite.

hexamethylenediamine + adipic acid; caprolactam; ethylene glycol + terephthalic acid; phenol + formaldehyde

WHICH STEP

Which treatment for galena (PbS), calamine ($ZnCO_3$) and bauxite?

galena: froth flotation, then roasting; calamine: calcination to ZnO, then reduction with carbon; bauxite: leaching (Bayer), then electrolysis

AVERAGE MASSES

$N_1 = 100$ chains of $M_1 = 10^4$ and $N_2 = 200$ of $M_2 = 3 \times 10^4$. $\bar{M}_n$, $\bar{M}_w$, PDI?

$\bar{M}_n = \dfrac{10^6 + 6 \times 10^6}{300} = 2.33 \times 10^4$; $\bar{M}_w = \dfrac{10^{10} + 1.8 \times 10^{11}}{7 \times 10^6} = 2.71 \times 10^4$; **PDI** $= 1.16$

DEGREE OF POLYMERISATION

A polyethene sample has $\bar{M}_n = 14\,000$. DP?

repeat unit $-CH_2CH_2- = 28$: $DP = 14000/28 = 500$

ELLINGHAM REASONING

Why is carbon unable to reduce Al_2O_3 but able to reduce ZnO?

the Al_2O_3 line lies far below the $C \to CO$ line at any usable temperature, the ZnO line crosses it near 1250 K, above which carbon reduces it

SOAPS AND DETERGENTS

Why is a detergent with a branched chain a pollutant?

bacteria cannot degrade the branched chain, so foam persists in rivers; linear detergents are biodegradable

6 Last-minute checklist

BEFORE YOU ANSWER

Ore type decides the steps: sulphide (flotation, roast), carbonate (calcine), oxide (reduce); leaching for Al and Au. For polymers: addition (C=C) or condensation (loss of small molecule)?

- Calcination (no air; carbonates) vs roasting (air; sulphides); flotation for sulphides; Bayer for bauxite; Hall-Héroult (cryolite + $\mathrm{CaF_2}$, C anode); blast furnace (CO reduction, CaO flux, slag); self-reduction of Cu; thermite.
- Refining: distillation (Zn, Hg), liquation (Sn), electrolytic (Cu, Zn, Al), zone (Si, Ge), Mond (Ni), van Arkel (Zr, Ti); Ellingham: oxide reduced where the reductant's line is below it; $m = ItM/nF$.
- Polymers: addition (PE, PVC, Teflon, orlon, PS, rubber, neoprene, Buna), condensation (nylon-6,6 from diamine + diacid; nylon-6 from caprolactam; terylene; Bakelite thermosetting; glyptal; PHBV, nylon-2-nylon-6 biodegradable); vulcanisation with sulphur.
- Drugs: antacids (ranitidine blocks $\mathrm{H_2}$), antihistamines, tranquilisers, analgesics (aspirin non-narcotic), antibiotics (bactericidal vs bacteriostatic), antiseptic vs disinfectant, sweeteners (aspartame not for cooking), detergents (branched are non-biodegradable).
- Environment: classical smog reducing ($\mathrm{SO_2}$), photochemical oxidising ($\mathrm{NO_2}$, $\mathrm{O_3}$, PAN); CFCs and ozone; greenhouse gases; acid rain pH below 5.6; BOD < 5 clean, > 17 polluted.

Now test it. Practise this chapter with past-paper and bank questions on Prep Vault. **Practice this chapter →**