Intermolecular Forces & Phase Changes

Identifying IMFs, their trends, phase transitions and diagrams, heating curves, and crystalline solids.

01 Identify the main IMF — METHOD

Ionic solid → ionic attraction; ionic dissolved → ion-dipole. Polar molecule with H on F/O/N → hydrogen bonding; other polar → dipole-dipole; nonpolar → London dispersion (present in all). Geometry sets polarity: symmetric polar bonds cancel (nonpolar); a lone pair on the central atom breaks symmetry (polar).

02 IMF strength & properties — CORE RULE

Ionic > hydrogen bonding > dipole-dipole > dispersion (at similar size). But a big polarizable nonpolar molecule can beat a small polar one (I_2 > HCl). Stronger IMF → higher boiling point, viscosity, surface tension; lower vapor pressure.

03 Phase transitions — REFERENCE

Transition	Name	Heat
solid → liquid	melting	endo
liquid → solid	freezing	exo
liquid → gas	vaporization	endo
gas → liquid	condensation	exo
solid → gas	sublimation	endo
gas → solid	deposition	exo

04 Temperature is flat during a phase change — CORE RULE

During a phase change T stays constant: heat changes potential energy (breaking/forming IMFs), not kinetic. Phase change: Q = ΔH × moles (ΔH_fus or ΔH_vap). Within one phase: Q = m·s·ΔT.

05 Water heating curve (per mole/gram) — METHOD

Up to 5 steps: warm ice (s = 2.09 J/g·°C) → melt at 0 °C (6.02 kJ/mol) → warm water (4.18) → boil at 100 °C (40.7 kJ/mol) → warm steam (1.84). Sum only the segments the path crosses; convert mass → moles (÷ 18.015) for the ΔH steps.

06 Non-water substances — WATCH OUT

Use the water defaults (ΔH_fus 6.02, ΔH_vap 40.7 kJ/mol) ONLY for water. For any other substance, take its own ΔH_fus, ΔH_vap, and specific heats from the problem; all constants must match the named substance.

07 Phase diagram — CORE RULE

Regions: solid (low T, high P), liquid (middle), gas (high T, low P). Lines = two phases coexist. Triple point: all three coexist. Critical point: end of the liquid-gas line (supercritical beyond). Normal boiling point: liquid-gas line at 1 atm.

08 Crystalline solids — REFERENCE

Type	Bonding	Properties
Ionic	ion attractions	hard, brittle; conducts only molten/dissolved; high MP
Metallic	electron sea	shiny, malleable; conducts; variable MP
Covalent network	3D covalent	very hard; insulator; very high MP
Molecular	IMFs	soft; insulator; low MP

09 Unit-cell density — CORE RULE

ρ = n·M / (N_A·a³), n = atoms per cell (SC 1, BCC 2, FCC 4). Convert edge a from pm to cm first (1 pm = 10^{-10} cm) for ρ in g/cm³. Rearrange to solve for a, M, or n.

10 Atomic radius by cell type — REFERENCE

Cell	Atoms/cell	Radius
SC	1	r = a/2
BCC	2	r = a√3/4
FCC	4	r = a√2/4

11 Identify the element — CORE RULE

After computing M from density + cell data, match within ±0.5 g/mol of the tabulated mass AND confirm the crystal structure. Near-mass elements need the cell-type check: Co (58.93, hcp) and Ni (58.69, fcc) differ by only ~0.24 g/mol, so structure is what distinguishes them.