9701 CHEMISTRY · TOPIC 4 · AS LEVEL

States of Matter

SHEET 1 OF 1
QUICK REVISION

01 · THE THREE STATES

State	Arrangement	Motion
solid	regular, touching	vibrate in place
liquid	close, disordered	slide past
gas	far apart, random	rapid, random

Changes of state break or make **intermolecular** forces, not covalent bonds. Temperature stays constant during a change of state.

02 · IDEAL GAS EQUATION

$pV = nRT$ · $R = 8.31\ J\ K^{-1}\ mol^{-1}$

Units: p in Pa, V in **m³**, T in K. $1\ dm^3 = 1 \times 10^{-3}\ m^3$, $1\ cm^3 = 1 \times 10^{-6}\ m^3$, T(K) = °C + 273.

Rearranged with n = m ÷ M it gives **M = mRT ÷ pV** — the standard route to an M_r from gas data.

03 · IDEAL VS REAL GASES

Assumptions of an ideal gas: molecular volume negligible compared with the container, no intermolecular forces, collisions perfectly elastic, motion rapid and random, average kinetic energy proportional to T.

Deviation is greatest at high pressure and low temperature — molecules are close, so their own volume is significant and attractions pull them together, making the real volume smaller than predicted.

Gases with strong intermolecular forces or high M_r (NH_3, H_2O) deviate most; He and H_2 behave most ideally.

04 · WORKED EXAMPLE

0.500 g of a volatile liquid gives 152 cm³ of vapour at 373 K and 101 kPa. Find M_r.

n = pV ÷ RT
$n = (1.01 \times 10^5 \times 1.52 \times 10^{-4}) \div (8.31 \times 373)$
$n = 15.4 \div 3100 = 4.95 \times 10^{-3}$ mol
$M = 0.500 \div 4.95 \times 10^{-3}$ = **101 g mol⁻¹**

05 · GIANT IONIC LATTICES

NaCl — 6:6 coordination, each ion surrounded by six of the opposite charge. Strong electrostatic attraction throughout, so high melting point.

Brittle: a struck layer slips, like charges align and repel. Conducts only when molten or aqueous, when the ions are free to move.

06 · GIANT COVALENT

Diamond — each C bonded to four others tetrahedrally, 109.5°. Very hard, very high melting point, does not conduct: no free electrons.

Graphite — hexagonal layers, each C bonded to three others at 120°, the fourth electron delocalised. Conducts along the layers; layers held by weak London forces so they slide — a lubricant.

SiO_2 — like diamond, each Si bonded to four O. High melting point, hard, insulating.

07 · GIANT METALLIC

Cations in a sea of delocalised electrons. Bond strength rises with **greater cationic charge** and **smaller radius**: Na < Mg < Al.

Malleable and ductile — layers slide without breaking the bonding. Good conductor of heat and electricity in the solid.

08 · SIMPLE MOLECULAR

Discrete molecules held by weak intermolecular forces — low melting and boiling points, non-conductors, soluble in solvents of matching polarity.

Iodine forms a molecular lattice: strong I–I covalent bonds inside each molecule, weak London forces between them, so it sublimes readily.

09 · COMPARING THE FOUR STRUCTURES

Type	m.p.	Conducts
giant ionic	high	molten / aqueous only
giant covalent	very high	no (graphite yes)
giant metallic	high	solid and molten
simple molecular	low	no

Identify a structure from three clues together: melting point, conductivity in each state, and solubility.

10 · INTERMOLECULAR FORCES RECAP

Weakest to strongest: **London (dispersion)** in everything and stronger with more electrons; **permanent dipole–dipole** in polar molecules; **hydrogen bonding** where H is bonded to N, O or F.

These forces set the melting and boiling points of molecular substances. Hydrogen bonding explains water's anomalous boiling point and why ice is less dense than water — the open lattice holds the molecules further apart.

11 · WORKED EXAMPLE — GAS MIXTURE

A flask holds 0.20 mol N_2 and 0.30 mol O_2 at a total pressure of 150 kPa.

total n = 0.50 mol
$x(N_2) = 0.20 \div 0.50 = 0.40$
$p(N_2) = 0.40 \times 150$ = **60 kPa**
$p(O_2) = 150 - 60$ = **90 kPa**

Partial pressures always sum to the total.

12 · CHANGES OF STATE

Melting and boiling need energy to overcome the forces holding particles together, so both are endothermic; freezing and condensing release it.

On a heating curve the **plateaus** are the changes of state: energy goes into separating particles, not into raising the temperature, so the kinetic energy is unchanged while the potential energy rises.

Boiling needs more energy than melting because the particles must be separated completely. **Sublimation** goes straight from solid to gas — iodine, solid CO_2.

13 · WORKED EXAMPLE — GAS DENSITY

Find the density of CO_2 at 100 kPa and 298 K.

Rearranging sc-camel-p-v = nRT with n = m ÷ M:
ρ = m ÷ V = pM ÷ RT
$\rho = (1.00 \times 10^5 \times 0.0440) \div (8.31 \times 298)$
ρ = 4400 ÷ 2476 = **1.78 kg m⁻³**

Denser than air (1.2 kg m⁻³), which is why CO_2 sinks and smothers a flame.

MARKS LOST HERE

— Using dm³ or cm³ in sc-camel-p-v = nRT instead of m³, or °C instead of K.

— Saying covalent bonds break when a simple molecular solid melts.

— Saying real gases deviate at high temperature; it is **low** temperature and high pressure.

— Describing graphite's layers as held by covalent bonds rather than London forces.