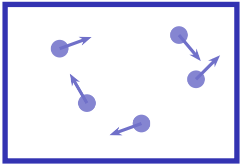
States of Matter

A-Level Chemistry ▪ Topic 4

A-Level Chemistry



What we will cover

1. Gas pressure
2. Ideal gases
3. The ideal gas equation
4. The four structures
5. Diamond & graphite
6. Physical properties

boiling changes state

1 The gaseous state

Gas pressure

Pressure is the force from molecules hitting the walls.

more molecules

more hits per second $\Rightarrow$ higher p

higher T

faster molecules $\Rightarrow$ harder hits

smaller V

hits more often $\Rightarrow$ higher p

Ideal gases

An **ideal gas** 理想气体 is a model: point particles, no attractions, elastic collisions. Real gases approach it at low pressure and high temperature (far apart, moving fast).

> The model fails when molecules take up a real volume (high p) or attract each other (low T).

The ideal gas equation

$$pV = nRT$$

Worked example

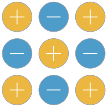
0.50 mol at 27 °C, 100 kPa: $V = \dfrac{nRT}{p} = \dfrac{0.50 \times 8.31 \times 300}{1.00 \times 10^5} = 0.0125\,\mathrm{m}^3$

Convert first: °C → K (+273), volume → m^3. From $n = m/M$: $M = \dfrac{mRT}{pV}$ gives the **molar mass** 摩尔质量.

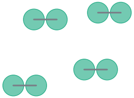
Quartz

2 Structure

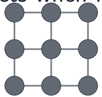
The four structures



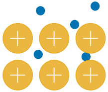
giant ionic
NaCl: high m.p., conducts when molten



simple molecular
I_2, ice: low m.p., weak forces between



giant covalent
diamond, SiO_2: very high m.p., insulating



giant metallic
copper: high m.p., conducts (solid + molten)

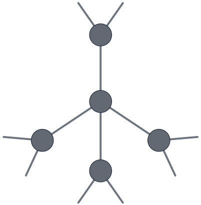
Four structures of a crystalline solid:

- **giant ionic** 离子晶体 – lattice of ions
- **simple molecular** 分子晶体 – small molecules
- **giant molecular** 原子晶体 – covalent network
- **giant metallic** 金属晶体 – ions in an electron sea

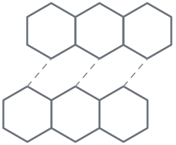
Diamond and graphite

Two giant covalent forms of carbon:

- **diamond** 金刚石 – a rigid 3-D network (very hard)
- **graphite** 石墨 – sliding layers & spare electrons that conduct



diamond
every C bonded to 4:
rigid 3D network, very hard



graphite
layers slide; spare
electrons let it conduct

Physical properties

giant ionic 离子晶体 – high m.p.; conducts when molten/dissolved; soluble

simple molecular – low m.p.; does not conduct; low solubility

giant molecular – very high m.p.; no conduction (except graphite); insoluble

giant metallic – high m.p.; conducts (solid & molten); insoluble

Strong forces → high **melting point** 熔点; **conductivity** 导电性 needs mobile ions or delocalised electrons.

Giant metallic

A piece of pure copper metal. The shine, and the way metals conduct and bend, all come from that giant lattice of copper ions sitting in a shared sea of delocalised electrons

Giant molecular

A real diamond in the rock it grew in. That whole crystal is one giant molecule – a single unbroken network of carbon atoms, each bonded to four others. Breaking it means breaking countless strong covalent bonds, which is why diamond is the hardest natural material

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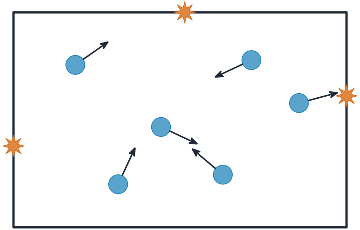
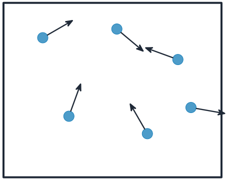
Where gas pressure comes from



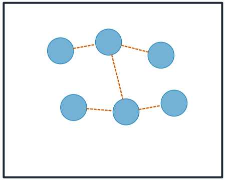
fast particles collide with the walls; the many pushes make the **pressure**

> Gas pressure: fast molecules move in all directions and collide with the walls; the many tiny pushes add up to the pressure

Ideal gases, continued



ideal gas (model)
point particles, *no* forces



real gas: high p, low T
real size + attractions (dashed)

> An ideal gas is a model: point particles with no forces between them. A real gas behaves least like this at high pressure and low temperature, when the particles are crowded and their real size and attractions start to matter

The ideal gas equation: what to remember

the equation	$pV = nRT$, with R the **gas constant** 气体常数 and T in **kelvin** 开尔文
its use	work out M_r from the mass or the density of a gas: $M_r = \dfrac{mRT}{pV}$

> Every quantity goes in SI units: p in Pa, V in m^3, T in K. Converting cm^3 and °C is where most marks are lost

Reading a structure from its properties

giant ionic 离子晶体	a huge regular **lattice** 晶格 of positive and negative **ions** 离子 – high melting point, brittle, conducts only when molten or aqueous
giant molecular	diamond, graphite, **silicon(IV) oxide** 二氧化硅, **fullerene** 富勒烯 – very high melting point; only graphite conducts
giant metallic	high melting point, malleable, and conducts as a solid
simple molecular	low melting and **boiling point** 沸点, and no **electrical conductivity** 导电性 at all

> You can work backwards: from an unknown's melting point, conductivity and solubility, deduce which of the four structures it has. That is the standard question.

Exam tips

- Use **SI units** in $pV = nRT$: pressure in Pa, volume in m^3 ($cm^3 \times 10^{-6}$), temperature in K ($°C + 273$).
- State the **ideal-gas assumptions** (negligible molecular volume, no intermolecular forces) and when real gases deviate (high pressure, low temperature).
- Link each property to structure: giant ionic (high m.p., conducts molten), giant covalent (very high m.p.), simple molecular (low m.p.), giant metallic (conducts, malleable).
- Graphite conducts because each carbon has a **delocalised** electron; diamond does not – a favourite comparison.

3 Recap

Topic 4 – key takeaways

1 Gas pressure

collisions with the walls add up

2 Ideal gas

$pV = nRT$; zero volume, no forces

3 Structures

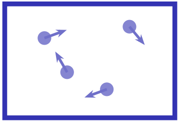
ionic, molecular, covalent, metallic

4 Properties

structure sets m.p., conductivity, solubility

Check yourself

1. Write the ideal gas equation.
2. When does a real gas behave least ideally?
3. Which giant covalent form of carbon conducts?
4. When does a giant ionic solid conduct electricity?



Answers **1.** $pV = nRT$ **2.** high pressure, low temperature **3.** graphite **4.** when molten or dissolved