States of matter

A-Level Chemistry

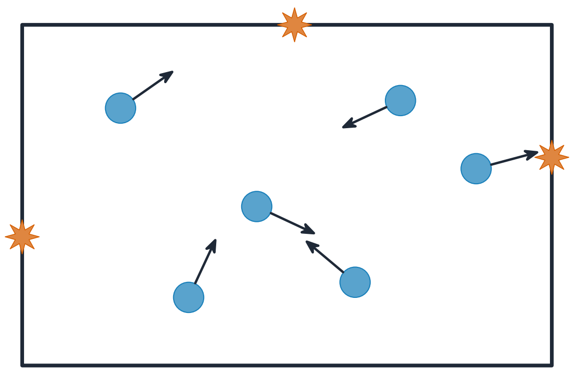
The gaseous state

Boiling turns liquid water into steam —a change between states of matter.

Image: W.carter, CC0 (commons.wikimedia.org)

Where gas pressure comes from

Gas molecules move fast in all directions. They keep hitting —**colliding** 碰撞 with — the walls of their container. Each hit gives the wall a tiny push. The **pressure** 压强 of the gas is the overall result of these many collisions on the walls.



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

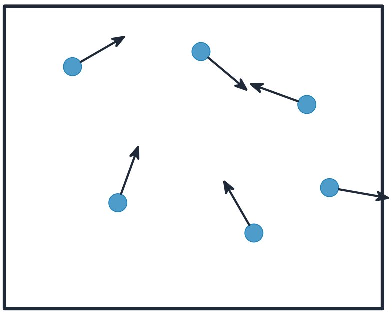
Gas pressure: fast molecules move in all directions and collide with the walls; the many tiny pushes add up to the pressure

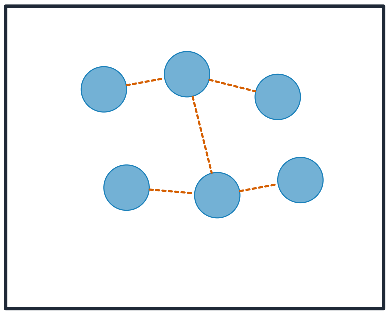
Ideal gases

An **ideal gas** 理想气体 is a simple model. We assume two things:

- the particles themselves take up zero volume.
- there are no **intermolecular forces** 分子间作用力 of attraction between the particles.

A **real gas** 实际气体 follows this model closely at low pressure and high temperature. It behaves least like an ideal gas at high pressure and low temperature, when the particles are squeezed close together and the forces between them start to matter.





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

The **ideal gas equation** 理想气体方程 links pressure, volume, amount and temperature:

$$pV = nRT$$

where p is the pressure in Pa, V is the volume in m^3, n is the amount in moles, T is the temperature in **kelvin** 开尔文 (K), and R is the **gas constant** 气体常量 (8.31 J K^{-1} mol^{-1}).

Always change the units first: °C to K (add 273), and cm^3 or dm^3 to m^3.

You can also use the equation to find a **molar mass** 摩尔质量. Since $n = m/M$:

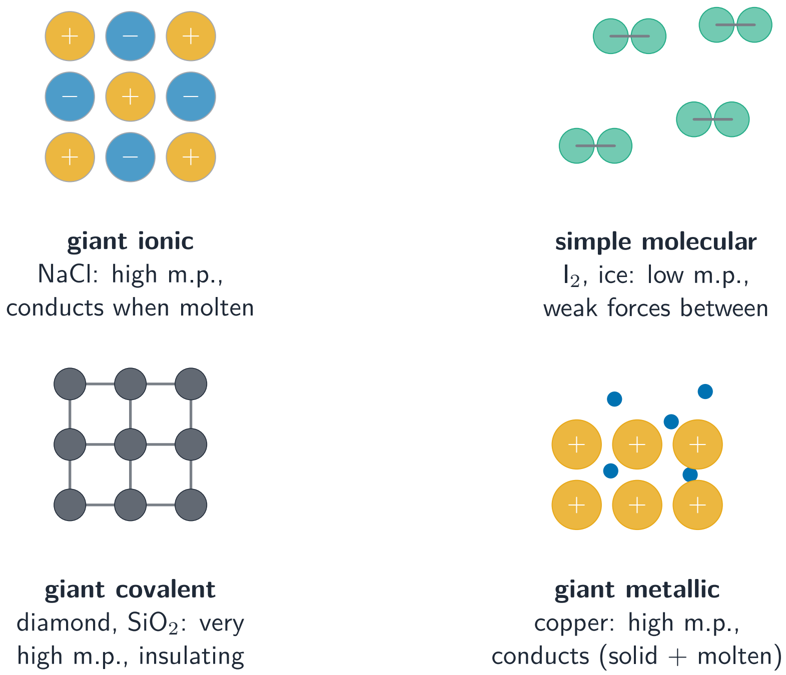
$$pV = \frac{m}{M}RT \qquad \Rightarrow \qquad M = \frac{mRT}{pV}$$

This lets you work out M_r from the mass (or the density) of a gas.

Bonding and structure

Quartz is a giant covalent structure of silicon and oxygen.

How a substance behaves depends on how its particles are joined. There are four main structures of a **crystalline solid** 晶体.



The four structures of a crystalline solid —the structure decides the melting point, conductivity and solubility

Giant ionic

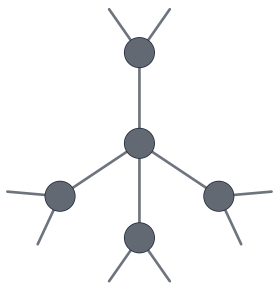
A **giant ionic** 离子晶体 structure is a huge regular **lattice** 晶格 of positive and negative **ions** 离子, held together by strong attraction in every direction. Examples are sodium chloride and magnesium oxide.

Simple molecular

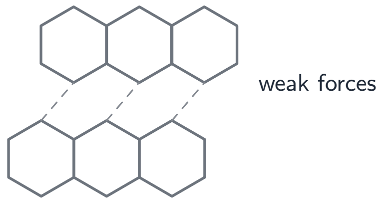
A **simple molecular** 分子晶体 structure is made of small **molecules** 分子. The bonds inside each molecule are strong, but the intermolecular forces between the molecules are weak. Examples are iodine (I_2), **fullerene** 富勒烯 (C_{60}) and ice.

Giant molecular

A **giant molecular** 原子晶体 structure (also called giant covalent) is a huge network of atoms joined by strong **covalent bonds** 共价键. Examples are **silicon(IV) oxide** 二氧化硅, **graphite** 石墨 and **diamond** 金刚石.



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



graphite
layers slide; spare
electrons let it conduct

Two giant covalent forms of carbon: diamond is a rigid 3D network (very hard); graphite has sliding layers and spare electrons that conduct

Giant metallic

A **giant metallic** 金属晶体 structure is a lattice of positive metal ions in a ”sea” of **delocalised electrons** 离域电子. An example is copper.

Physical properties

The structure decides the physical properties:

Structure	Melting/boiling point	Conducts electricity?	Solubility in water
giant ionic	high	only when molten or dissolved	usually soluble
simple molecular	low	no	usually low
giant molecular	very high	no (except graphite)	insoluble
giant metallic	high	yes (solid and molten)	insoluble

- **melting point** 熔点 and **boiling point** 沸点 are high when strong forces (ionic, covalent or metallic) must be broken, and low when only weak intermolecular forces break.

- **electrical conductivity** 导电性 needs charged particles that can move —ions that are free (when molten or dissolved) or delocalised electrons. Graphite conducts because some of its electrons are delocalised.
- **solubility** 溶解度 in water is usually high for ionic solids and low for molecular and giant covalent solids.

You can work backwards too: from the melting point, conductivity and solubility of an unknown substance, deduce the type of structure and bonding it has.