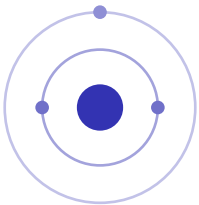
Atoms, Elements & Compounds

IGCSE Chemistry ▪ Topic 2

IGCSE Chemistry



What we will cover

1. Elements, compounds & mixtures
2. Inside the atom
3. Electron shells & isotopes
4. Ionic bonding
5. Covalent & giant structures
6. Metallic bonding

1 Classifying matter

Elements, compounds and mixtures

An **element** 元素 is one type of atom. A **compound** 化合物 is two or more elements chemically bonded, in a fixed ratio. A **mixture** 混合物 is not bonded – it can be separated physically.

Element, compound, mixture

the building blocks	all substances are made from about 100 elements
an element 元素	only one type of **atom** 原子 – and it cannot be broken into anything simpler by a chemical reaction
a compound 化合物	two or more elements chemically joined, in a fixed ratio, with new properties
a mixture 混合物	substances just mixed, not joined – the parts keep their own properties and can be separated physically
the atomic number 原子序数	the number of protons – it is what makes an atom that element
telling them apart	a compound has a fixed formula and a sharp melting point; a mixture has neither

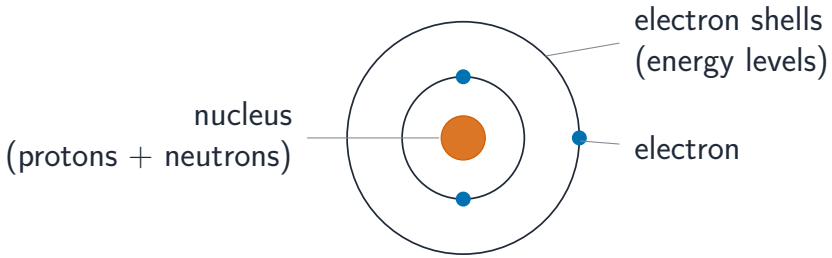
Air is a mixture, water is a compound, and both are colourless liquids or gases. The distinction is about bonding, not appearance.

2 The atom

Inside the atom

A tiny **nucleus** 原子核 of **protons** 质子 & **neutrons** 中子; **electrons** 电子 in **shells** 电子层 around it.

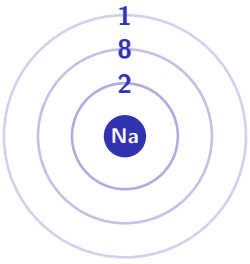
proton	**neutron**	**electron**
mass 1	mass 1	mass ≈ 0
charge $+1$	charge 0	charge -1



Two numbers, and electron shells

- **proton number** 质子数 = protons = which element
- **mass number** 质量数 = protons + neutrons
- neutrons = mass number − proton number

Shells fill from the inside: 2, then 8, then 8...



outer = 1 → Group I

3 shells → Period 3

The particles, and the two numbers

Relative mass and charge	Proton: **relative charge** 相对电荷 $+1$, relative mass 1. Neutron: 0 and 1. Electron: -1 and almost nothing.
Proton number	The number of protons – it fixes which element the atom is.
Nucleon number	The mass number, also called the **nucleon number** 核子数: protons plus neutrons.
The noble gases	The **noble gases** 稀有气体 in Group VIII have a full outer shell, which is why they are so unreactive – and why every other atom bonds to reach one.

Electrons decide the chemistry; the nucleus decides the identity and the mass.

Isotopes and relative atomic mass

Isotopes 同位素: same protons, different neutrons – same element, same chemistry.

$^{35}_{17}\mathrm{Cl}$
18 neutrons

$^{37}_{17}\mathrm{Cl}$
20 neutrons

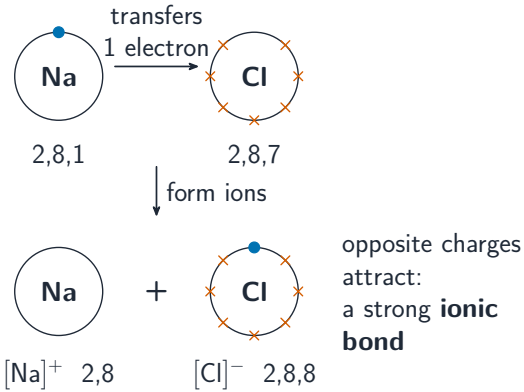
A_r is the weighted average mass.

$$A_r = \frac{(35 \times 75) + (37 \times 25)}{100} = 35.5$$

3

Bonding

Ionic bonding



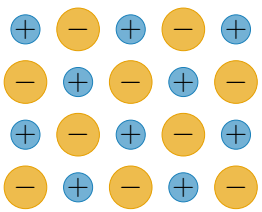
opposite charges attract:
a strong **ionic bond**

A metal gives electrons to a non-metal; both reach full shells.

- metal → positive **cation** 阳离子
- non-metal → negative **anion** 阴离子

An **ionic bond** 离子键 is the pull between + and − ions.

Ionic lattices and their properties



Cl^- ion

Na^+ ion

a regular, repeating 3-D pattern of alternating + and − ions

Ions pack into a giant **lattice** 晶格 of alternating + and −.

- high melting & boiling points
- solid: does not conduct (ions fixed)
- molten / aqueous: does conduct (ions free)

Dot-and-cross diagrams, and what the bonding explains

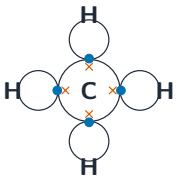
a dot-and-cross diagram	draw each atom's outer-shell electrons – dots for one element, crosses for the other – and show where they end up
ionic	electrons are transferred; show the ion charges and use square brackets
covalent	electrons are shared; show the overlapping outer shells
electrostatic attraction 静电引力	the strong force between oppositely charged ions – so ionic compounds have high melting points
electrical conductivity 导电性	an **ionic compound** 离子化合物 conducts only when molten or dissolved, because the ions must be free to move
metals	delocalised electrons give conductivity, **ductility** 延展性, and malleability

Draw only the outer shell unless asked otherwise, and label which atom the dots came from. Both are marked.

Covalent bonding

hydrogen, H_2
one shared pair

water, H_2O
two shared pairs



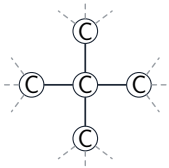
methane, CH_4
four shared pairs

Non-metals **share** 共用 pairs of electrons in a **covalent bond** 共价键.

Simple molecules (H_2O, CH_4): low melting points (weak **intermolecular forces** 分子间作用力) & poor conductors.

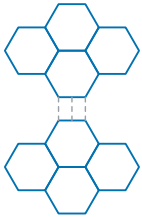
Giant covalent structures

diamond



each carbon bonded to **4** others: a hard 3-D network

graphite



flat layers of hexagonal rings (each C bonded to **3**); weak forces let the layers slide

Millions of atoms bonded into one network:

- **diamond** 金刚石 – 4 bonds each; very hard
- **graphite** 石墨 – 3 bonds, sliding **layers** 层; soft, conducts

Graphite's free electrons let it conduct.

Three giant covalent structures

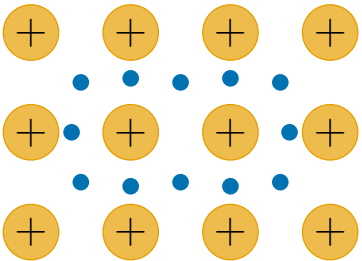
Diamond	Every carbon bonded to four others in a rigid 3D network: extremely hard, so it is used in **cutting tools** 切削工具, and it does not conduct.
Graphite	Flat layers, three bonds each. The fourth outer electron is delocalised, so graphite conducts and is used as an **electrode** 电极; weak forces let the layers slide, which makes it a **lubricant** 润滑剂.
Silicon(IV) oxide	**Silicon(IV) oxide** 二氧化硅 (SiO_2) has a giant covalent structure like diamond – very hard, very high melting point.

Same element, opposite properties: diamond and graphite differ only in how the bonds are arranged.

Metallic bonding

Positive ions in a **sea of delocalised electrons** 离域电子海.

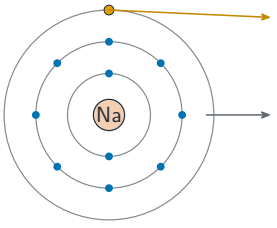
- conducts – free electrons carry charge
- **malleable** 有展性 & **ductile** 有延性 – layers slide



‘sea’ of **delocalised electrons**, free to move and carry charge

positive metal ions in a fixed lattice

Electronic configuration



1 electron in the outer shell
→ **Group I**

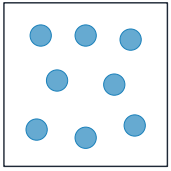
3 shells in use
→ **Period 3**

shells fill from the inside:
1st holds 2, then 8, then 8

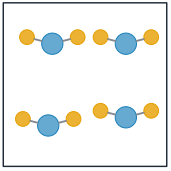
sodium: **2, 8, 1**

Sodium's configuration 2,8,1 links to the Periodic Table: one outer electron means Group I, three shells means Period 3

Elements, compounds and mixtures, continued



element
only one
type of atom

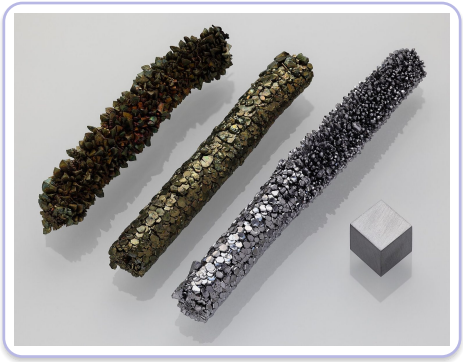


compound
different
atoms bonded
in a fixed ratio

mixture
not bonded,
easy to separate

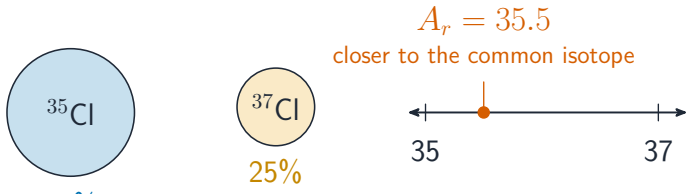
An element has one type of atom; a compound has different atoms bonded in a fixed ratio; a mixture is not bonded

Elements, compounds and mixtures, continued (2)



A pure element (vanadium): elements are the simplest substances.

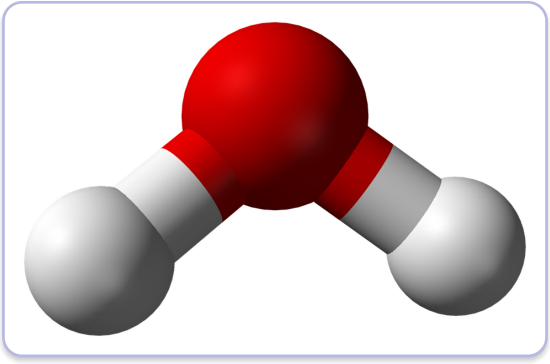
Calculating relative atomic mass



$$A_r = \frac{(35 \times 75) + (37 \times 25)}{100} = 35.5$$ - a **weighted average** by abundance

Relative atomic mass is a weighted average: chlorine is 75 percent Cl-35 and 25 percent Cl-37, so A_r is 35.5

Simple molecules and covalent bonds



A model of a water molecule: atoms share electrons in covalent bonds.

Exam tips

- Number of neutrons = mass number − proton number. The **proton number** is what decides which element an atom is.
- **Isotopes** have the same chemical properties because reactions involve only electrons, and isotopes share the same electron configuration; only the mass differs.
- Match structure to properties: **ionic** = giant lattice (high melting point; conducts only when molten or aqueous); **simple molecular** = weak forces *between* molecules (low melting point; no conduction); **giant covalent** = very hard, very high melting point.
- **Graphite** conducts and is slippery (one free electron per carbon; layers slide); **diamond** does neither (all four electrons bonded, so hard and non-conducting). Metals conduct and bend thanks to the sea of **delocalised electrons**.
- For relative atomic mass, take the weighted average:
  $A_r = \dfrac{\sum(\text{isotope mass} \times \text{abundance})}{100}$.

4 Recap

Worked example – relative atomic mass

Chlorine is 75% ^{35}Cl and 25% ^{37}Cl. Find its relative atomic mass.

- Isotopes are atoms of the same element with different numbers of neutrons.
- A_r is the weighted average of the isotopes:
- $A_r = \dfrac{(75 \times 35) + (25 \times 37)}{100} = \dfrac{2625 + 925}{100}$
- $= 35.5$ – which is why the value is not a whole number.

Isotopes have identical chemistry (same electrons), only different mass. Weight by abundance – never take a plain average of 35 and 37.

Topic 2 – key takeaways

1 Atom

nucleus of protons & neutrons; electrons in shells

2 Isotopes

same protons, different neutrons; A_r averages

3 Ionic

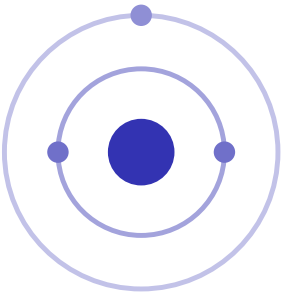
metal gives electrons; giant lattice

4 Covalent & metallic

shared pairs; ions in an electron sea

Check yourself

1. How many neutrons are in $^{35}_{17}\mathrm{Cl}$?
2. What is the electronic configuration of sodium?
3. Why does molten NaCl conduct but solid NaCl not?
4. Why can metals be hammered into sheets?



Answers **1.** 18 $(35 - 17)$ **2.** $2, 8, 1$ **3.** molten ions are free to move **4.** layers of ions slide over each other