

Atoms, elements and compounds

IGCSE Chemistry 0620 · Topic 2 revision notes

Everything from the 6 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Elements, compounds and mixtures

2. Atomic structure and the Periodic Table

3. Isotopes

4. Ions and ionic bonding

5. Simple molecules and covalent bonds

6. Giant covalent structures and metallic bonding

1 Elements, compounds and mixtures

Syllabus 2.1

An **element** is a substance made of only one type of atom. A **compound** is a substance made of two or more elements chemically combined in a **fixed ratio**, and it has new properties of its own. A **mixture** contains two or more substances that are **not** chemically combined: its composition can vary and its parts can be separated by physical methods such as a magnet, filtering or distillation.

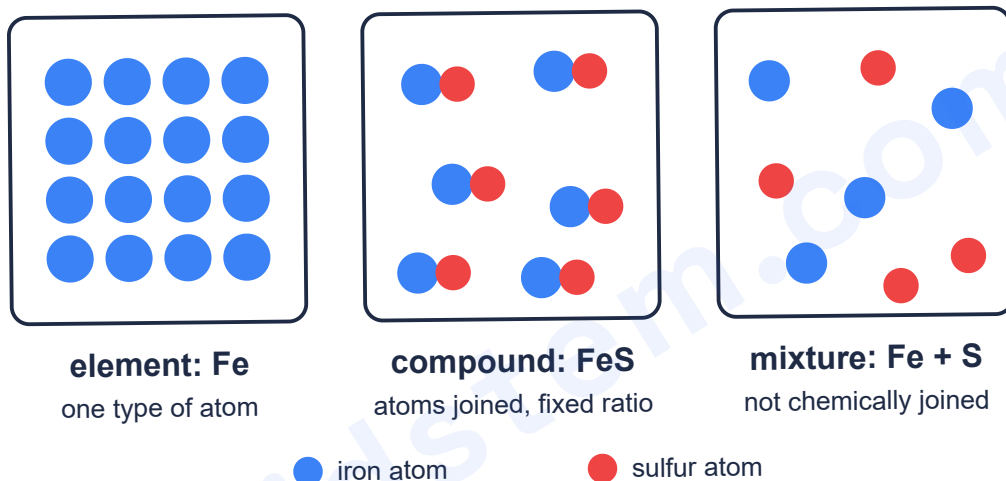


Fig. 1: particle diagrams for an element, a compound and a mixture made from iron and sulfur

Count the atom types, then check for bonds.

- ✓ **Element:** one type of atom only, even if the atoms are joined in molecules.
- ✓ **Compound:** different elements chemically combined in a fixed ratio.
- ✓ **Mixture:** not chemically joined; composition can vary.
- ✓ **Separation:** mixtures by physical methods, compounds only by reactions.

Watch out!

A **molecule** is not the same thing as a **compound**. Oxygen, O_2 , and nitrogen, N_2 , are made of molecules but contain only one type of atom, so they are elements. A compound needs at least two different elements, as in carbon dioxide, CO_2 .

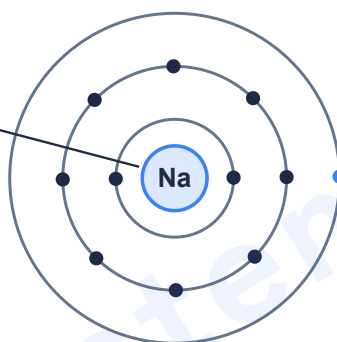
2 Atomic structure and the Periodic Table

Syllabus 2.2

An atom has a small central **nucleus** of protons and neutrons, surrounded by electrons in **shells**. The **proton number** (atomic number) is the number of protons; in a neutral atom it also equals the number of electrons. The **mass number** (nucleon number) is protons plus neutrons. Electrons fill shells in order: 2 in the first, then 8, then 8 for the first 20 elements. The number of outer-shell electrons gives the group (I to VII), and the number of occupied shells gives the period.

nucleus

11 protons
12 neutrons



shell 1: 2 electrons
shell 2: 8 electrons
shell 3: 1 electron

sodium: proton number 11, so 11 electrons arranged 2,8,1
1 outer electron: Group I. 3 occupied shells: Period 3.

Fig. 1: a sodium atom, electronic configuration 2,8,1

Two numbers tell you everything.

- ✓ **Protons** = proton number; **electrons** = protons in a neutral atom.
- ✓ **Neutrons** = mass number – proton number.
- ✓ **Shells fill** 2, 8, 8 for the first 20 elements.
- ✓ **Outer electrons** = group (I to VII); **shells** = period.

Watch out!

The mass number is **not** the number of neutrons. It counts protons and neutrons together, so always subtract: neutrons = mass number – proton number. Also check which number is which: the mass number is always the larger one.

3 Isotopes

Syllabus 2.3

Isotopes are different atoms of the same element that have the same number of protons but different numbers of neutrons, so they have different mass numbers. **(Extended)** Isotopes of an element have the same chemical properties because they have the same number of electrons and therefore the same electronic configuration. The relative atomic mass, A_r , is the average mass of the isotopes weighted by their percentage abundances.

^{35}Cl (chlorine-35)

17 protons

18 neutrons

17 electrons: 2,8,7

abundance 75%

^{37}Cl (chlorine-37)

17 protons

20 neutrons

17 electrons: 2,8,7

abundance 25%

same protons and electrons, different numbers of neutrons
same outer electrons, so the same chemical reactions

$$A_r = (35 \times 75 + 37 \times 25) \div 100 = 35.5$$

Fig. 1: the two isotopes of chlorine and the weighted average they give

Same protons, different neutrons.

- ✓ **Isotopes:** same proton number, different mass number.
- ✓ **Same chemistry:** same number of electrons and the same configuration.
- ✓ **A_r :** sum of (mass number $\times$ % abundance) $\div$ 100.
- ✓ **Sense check:** A_r lies nearer the most abundant isotope.

Watch out!

Do not just average the mass numbers. For chlorine, $(35 + 37) \div 2 = 36$ is wrong because there are three times as many ^{35}Cl atoms as ^{37}Cl atoms. Each mass must be weighted by its abundance, and the total divided by 100, not by 2.

4 Ions and ionic bonding

Syllabus 2.4

An **ion** is a charged particle formed when an atom loses or gains electrons. Metal atoms lose their outer electrons to form **positive** ions; non-metal atoms gain electrons to form **negative** ions, and both usually end with a noble-gas configuration. An **ionic bond** is the strong electrostatic attraction between oppositely charged ions. **(Extended)** Ionic compounds form a giant lattice of alternating positive and negative ions.

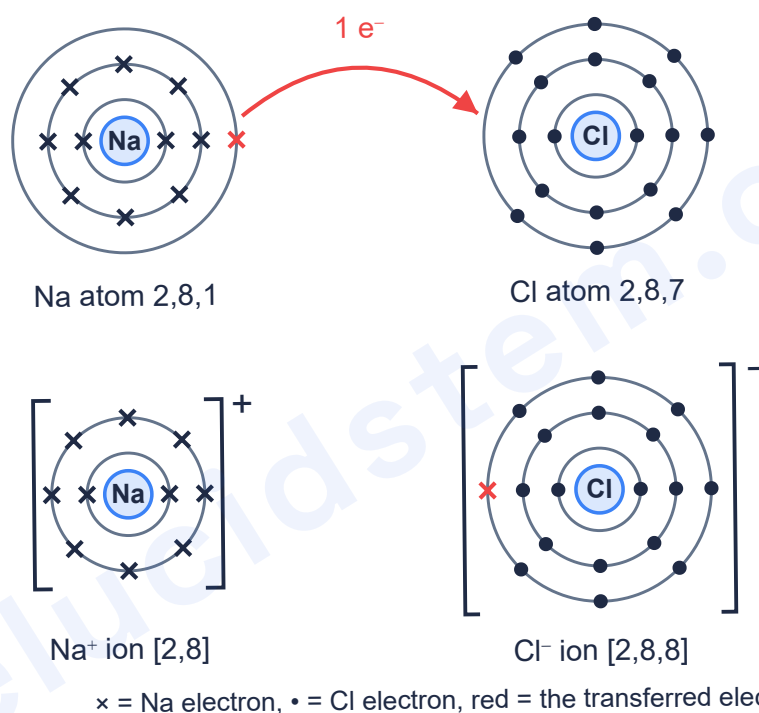


Fig. 1: a sodium atom transfers its outer electron to a chlorine atom, forming Na⁺ and Cl⁻

Metals lose, non-metals gain.

- ✓ **Metal atoms** lose outer electrons to form positive ions.
- ✓ **Non-metal atoms** gain electrons to form negative ions.
- ✓ **Balance the charges** to find the formula.
- ✓ **Molten or aqueous:** ions move and carry the current.

Watch out!

In calcium fluoride there are two separate F^- ions, each with a single negative charge. Do not draw an F_2 unit or write F_2^{2-} : the small 2 in CaF_2 counts ions, it does not mean the fluorine atoms are bonded together.

Molten or dissolved ionic compounds conduct because **ions** move and carry the charge. Writing that 'electrons move' through molten sodium chloride scores no marks: free electrons are the explanation for metals and graphite, not for ionic compounds.

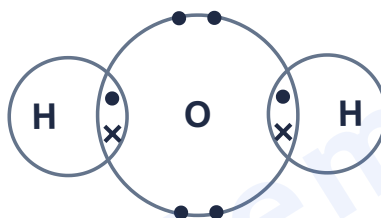
5 Simple molecules and covalent bonds

Syllabus 2.5

A **covalent bond** is formed when a pair of electrons is shared between two atoms, usually non-metals. By sharing, each atom reaches a noble-gas configuration. Simple molecular substances have **low melting and boiling points** and are **poor conductors** of electricity.

(Extended) Their melting points are low because only the weak intermolecular forces between molecules are overcome; the strong covalent bonds inside the molecules do not break.

water, H_2O (outer shells only)



2 bonding pairs (two O-H bonds) and 2 lone pairs on O
O has 8 outer electrons (like Ne); each H has 2 (like He)

× = hydrogen electron, • = oxygen electron

Fig. 1: dot-and-cross diagram of a water molecule

Every atom ends full.

- ✓ **One bond** = one shared pair = two electrons.
- ✓ **Hydrogen** ends with 2 outer electrons; other atoms with 8.
- ✓ **Lone pairs** are outer electrons not used in bonds.
- ✓ **Melting or boiling** overcomes weak intermolecular forces, not covalent bonds.

Watch out!

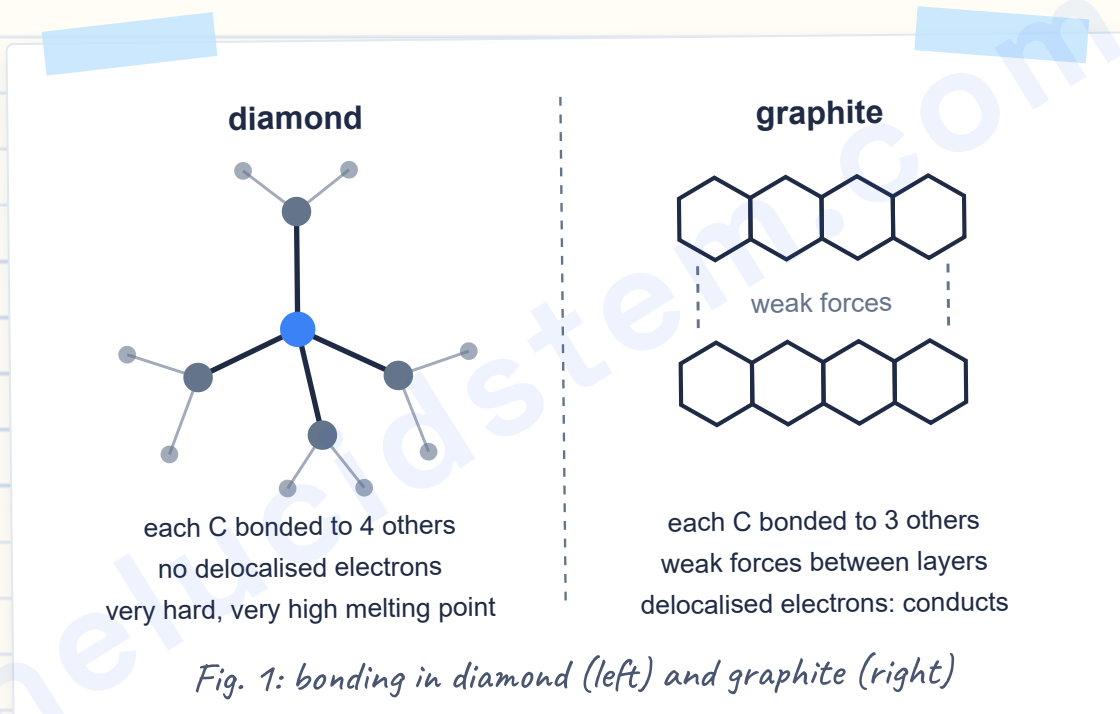
Each bond line stands for one shared **pair**, two electrons. A double bond is two pairs, four electrons; a triple bond three pairs, six electrons. Drawing CO_2 with single bonds leaves each oxygen with only seven outer electrons, so always check that every atom other than hydrogen ends with eight.

When water boils, the O-H covalent bonds do **not** break; the molecules simply move apart and the steam is still H_2O . An answer saying 'covalent bonds are weak' or 'covalent bonds break on boiling' loses the mark: it is the intermolecular forces that are weak.

6 Giant covalent structures and metallic bonding

Syllabus 2.6

In a **giant covalent structure** a huge number of atoms are joined by strong covalent bonds in a continuous network. In **diamond** each carbon atom is bonded to four others, so it is very hard, has a very high melting point and does not conduct. In **graphite** each carbon atom is bonded to three others in flat layers of hexagons; there are weak forces between the layers and one delocalised electron per atom, so graphite is soft, slippery and conducts. **(Extended)** Metallic bonding is the electrostatic attraction between a lattice of positive ions and a sea of delocalised electrons.



Link every property to a bond.

- ✓ **Diamond:** 4 bonds per C, no free electrons: hard, non-conductor.
- ✓ **Graphite:** 3 bonds per C, weak forces between layers, delocalised electrons.
- ✓ **SiO₂ (Extended):** 4 O per Si, 2 Si per O, like diamond.
- ✓ **Metals (Extended):** positive ions in a sea of delocalised electrons.

Watch out!

Graphite is soft because the forces **between** its layers are weak, not because its covalent bonds are weak. The bonds within each layer are very strong, which is why graphite still has a very high melting point. 'Graphite has weak covalent bonds' is a classic lost mark.

Metals conduct because **delocalised electrons** move, not ions. In a solid metal the positive ions stay in the lattice. Mixing this up with ionic compounds, which conduct only when their ions are free to move, is a common error.