

Ions in a sea of electrons

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Metallic bonding is the attraction between positive metal ions in a regular lattice and a sea of delocalised electrons that move freely between them. It explains why metals conduct electricity and heat, can be hammered into shape, and have high melting points. Alloys are harder because different-sized atoms stop layers sliding.

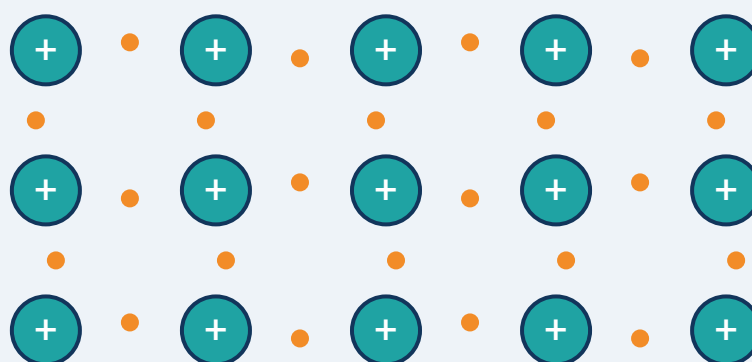
Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE C2

What is metallic bonding?

Metal atoms have few outer electrons, and they release them easily. In a piece of metal each atom gives up its outer electrons, which are no longer tied to any one atom. The atoms become positive ions arranged in regular layers, and the released electrons form a sea that moves freely between them.

Definition

A **metallic bond** is the electrostatic attraction between positive metal ions and the sea of **delocalised electrons** around them. Delocalised electrons belong to the whole structure, not to a single atom.



+ metal ion (fixed in layers) ● delocalised electron (free to move)

Metal ions sit in layers. The delocalised electrons move through the whole structure.

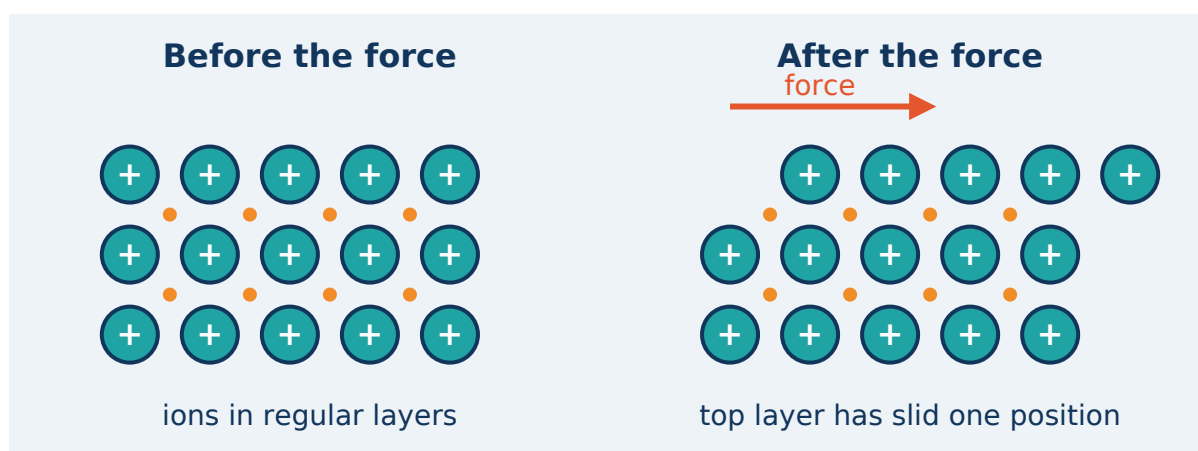
The metal as a whole is neutral, because the number of electrons equals the number of positive charges on the ions.

Why do metals conduct and bend without breaking?

The metallic bond explains the typical properties of metals.

Property	Explanation
Conducts electricity	Delocalised electrons move through the metal and carry charge.
Conducts heat	Free electrons pass energy quickly, and vibrating ions pass it on to their neighbours.
High melting point	The attraction between ions and electrons is strong and needs a lot of energy to overcome.
Malleable and ductile	Layers of ions slide over each other while the electrons keep holding them together.

Metals also look shiny because the free electrons reflect light, and most are dense because the ions pack closely together. Melting a metal does not remove the electron sea, so liquid metals still conduct electricity.



When a layer slides, every ion is still surrounded by electrons, so the bonding is not lost.

Common mistake

Metals do not conduct because ions flow. The positive ions stay in their layers, and only the electrons move. Also, the sea of electrons does not make the metal negative, because the ions carry an equal amount of positive charge.

Worked example

Explain why magnesium (melting point 650 °C) melts at a much higher temperature than sodium (98 °C).

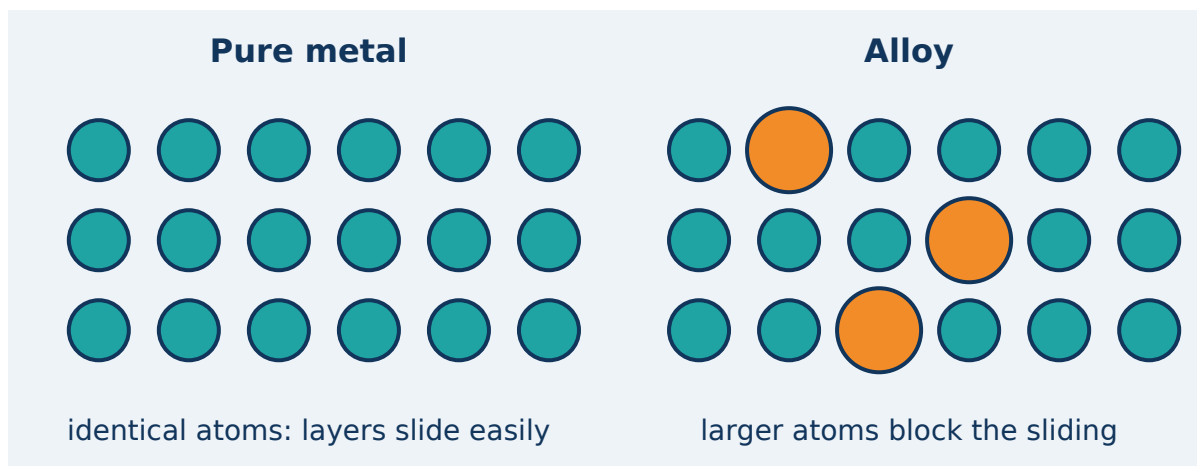
A sodium atom has 1 outer electron, so it forms Na^+ and gives 1 electron to the sea. A magnesium atom has 2 outer electrons, so it forms Mg^{2+} and gives 2 electrons. Mg^{2+} ions have a bigger charge and there are more electrons in the sea, so the attraction is stronger.

Answer: a stronger metallic bond needs more energy to overcome, so magnesium has the higher melting point.

What is an alloy and why is it harder than a pure metal?

An **alloy** is a mixture of a metal with at least one other element, often another metal. Pure metals are soft because their identical atoms form neat layers that slide easily. In an alloy, atoms of a different size disturb the layers, so the layers cannot slide so easily and the

material is harder and stronger.



The larger atoms in the alloy make sliding much harder.

Alloy	Made from	Typical use
Brass	copper and zinc	taps, door handles, musical instruments
Bronze	copper and tin	bells, statues, ship propellers
Steel	iron and carbon	bridges, rails, bicycle frames
Duralumin	aluminium and a little copper	aircraft parts

Worked example

A ring is made of 18-carat gold and has a mass of 9.0 g. Carats show the number of parts of gold in 24 parts. Calculate the mass of gold.

Fraction of gold = $18 \div 24 = 0.75$. Mass of gold = $0.75 \times 9.0 \text{ g} = 6.75 \text{ g}$.

Answer: 6.75 g of gold (about 6.8 g).

Lina's tip

To explain why a metal bends, draw layers of ions with the electron sea around them.

Then draw one layer moved along by a position: the picture looks the same, which shows that the bonding survives.

Key points to remember

- Metallic bond = attraction between positive ions and delocalised electrons.
- Free electrons carry charge and energy, so metals conduct electricity and heat.
- Layers of ions slide without breaking the bonding, so metals are malleable and ductile.
- More delocalised electrons and a higher ion charge give a stronger bond and a higher melting point.
- An alloy contains atoms of different sizes, so its layers slide less easily than those of a pure metal.

Ions in a sea of electrons: frequently asked questions

What are delocalised electrons?

Delocalised electrons are outer electrons that are not attached to a single atom. They move freely through the whole metal structure and carry electric charge and thermal energy.

Why can metals be hammered into sheets?

The layers of positive ions can slide over each other. The sea of electrons keeps attracting the ions in their new positions, so the metal changes shape without breaking.

Why do metals have high melting points?

Every ion is strongly attracted to the electron sea in all directions. Melting needs enough energy to loosen this strong attraction, so the temperature must be high.

What is the difference between a pure metal and an alloy?

A pure metal contains one kind of atom. An alloy is a mixture of a metal with other elements, and its different-sized atoms make it harder than the pure metal.

Why does steel last longer than pure iron?

Steel contains a small amount of carbon. The carbon atoms disturb the iron layers, so they resist sliding, which makes steel stronger and harder than pure iron.