Metallic bonding

4.2.1.5 · Bonding, structure and the properties of matter · revision notes

How the atoms in a metal are held together: a giant structure of positive ions in a regular pattern, with delocalised electrons that are free to move through it. It is usually tested with 2 to 3 mark 'describe' questions or diagram labelling, and it is the key to explaining the properties of metals.

Key facts

- Metal = giant structure of atoms in a regular pattern (layers)
- Metallic bond = strong electrostatic attraction between positive ions and delocalised electrons
- Alloys have metallic bonding too
- Outer shell electrons are delocalised: free to move through the whole structure
- Charge on each ion = number of outer electrons given up (Na^+, Mg^{2+})
- Strong bonds → high melting points; delocalised electrons → conduction

Notes

The structure of a metal

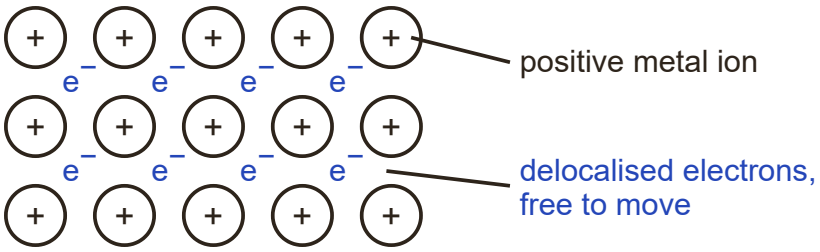
- Metals have **giant structures** of atoms arranged in a **regular pattern**, in layers.
- The electrons in the **outer shell** of each metal atom are **delocalised**: they do not belong to any one atom and are **free to move through the whole structure**.
- Once an atom has lost its outer electrons in this way, it is a **positive ion**. So a metal can be described as positive ions surrounded by delocalised electrons.

The metallic bond

- The delocalised electrons are shared by all the ions. This sharing gives **strong metallic bonds**.
- The bond is the **strong electrostatic attraction** between the **positive metal ions** and the **negative delocalised electrons**.
- The attraction acts throughout the giant structure, so there are a very large number of strong bonds.
- Alloys have metallic bonding too: they are mixtures of a metal with other elements, with delocalised electrons throughout.

Drawing metallic bonding

- Draw regular rows of circles, each marked + (or with the ion's charge, e.g. 2+ for magnesium).
- Draw electrons (e^- or small dots) scattered between the ions and label them 'delocalised electrons'.



Metallic bonding: attraction between positive ions and delocalised electrons.

- Like any model, this shows only a tiny part of the structure and is not to scale.

Why metallic bonding matters

- Metallic bonding explains the properties of metals: strong bonds give high melting points, layers of ions allow metals to be bent and shaped, and delocalised electrons that can move make metals conduct electricity and thermal energy.

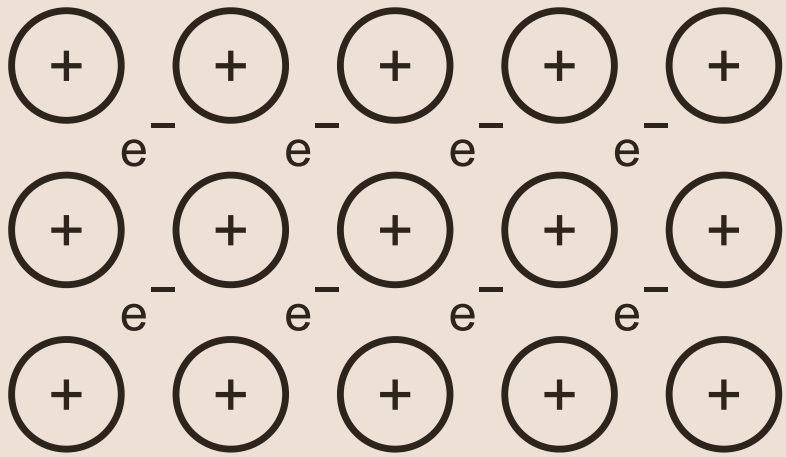
How to answer each type of question

Label a diagram of metallic bonding

2 marks **Grade 4**

1. The particles in regular rows marked + are positive (metal) ions.
2. The small particles spread between them are delocalised electrons.

Example. The diagram shows the structure of a metal.



(a) Name the particles marked +.

(b) Name the particles marked e^-.

Model answer.

(a) Positive (metal) ions (1)

(b) Delocalised electrons (1)

Describe the structure and bonding in a metal

3 marks **Grade 5**

1. Say it is a giant structure of atoms (positive ions) in a regular pattern, in layers.
2. Say the outer electrons are delocalised and free to move through the structure.
3. Say there is strong electrostatic attraction between the positive ions and the delocalised electrons.

Example. Describe the structure and bonding in copper.

Model answer. A giant structure of copper atoms (positive ions) arranged in a regular pattern / in layers (1). The outer shell electrons are delocalised, so they can move through the whole structure (1). There is strong electrostatic attraction between the positive ions and the delocalised electrons (1).

Explain why the particles in a metal are ions 2 marks **Grade 6**

1. Say how many outer electrons each atom has lost and that they have become delocalised.
2. Link this to the charge: more protons than electrons.

Example. In the structure of magnesium metal, each magnesium particle has a charge of 2+. Explain why.

Model answer. Each magnesium atom loses its two outer shell electrons, which become delocalised (1). So each particle has two more protons than electrons, giving a charge of 2+ (1).

Don't lose marks

- Saying the positive ions move. It is the delocalised electrons that move; the ions stay in their positions.
- Writing 'free electrons' or 'a sea of electrons' without the word 'delocalised'. Use 'delocalised' to be safe.
- Describing the bond as attraction between atoms, or between electrons. It is between positive ions and delocalised electrons.
- Calling metallic bonding ionic because the diagram shows ions. There are no negative ions in a metal.

More tips

Memory tricks

- Picture rows of positive ions held together by a cloud of moving electrons. The 'glue' is the attraction between + and −.
- Labelling check: the + particles are ions (not atoms or protons); the moving particles are electrons (not ions).
- One structure explains every metal property: strong bonds → high melting point; layers → can be bent; delocalised electrons → conducts.

Exam technique

- In 'describe the bonding' questions, three things score: a giant regular structure, delocalised electrons, and attraction between positive ions and delocalised electrons.
- If you draw a diagram, label both the positive ions and the delocalised electrons.
- Call metallic bonds 'strong': you need this word later to explain high melting points.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 **State that metals have giant structures**
The atoms in a metal are arranged in a regular pattern in a giant structure.

Grade 4 **Describe what delocalised electrons are**
The outer shell electrons of metal atoms are delocalised: free to move through the whole structure.

Grade 5 **Describe the metallic bond**
Strong electrostatic attraction between positive metal ions and the shared delocalised electrons.

Grade 6 **Explain why the metal particles are positive ions**
Each atom has lost its outer electrons to the delocalised electrons, so it has more protons than electrons.

Grade 7

Draw and label a diagram of metallic bonding

Regular rows of positive ions with electrons between them, labelled 'delocalised electrons'.

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