Ionic compounds

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

What an ionic compound is like: a giant lattice of oppositely charged ions held by strong electrostatic forces acting in all directions. You need to recognise ionic structures in diagrams, work out empirical formulae from diagrams, and give the limitations of each type of diagram.

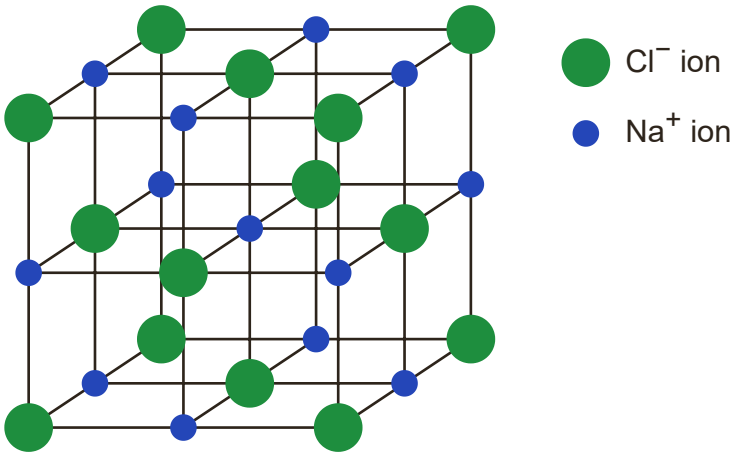
Key facts

- Ionic compound = giant lattice of oppositely charged ions
- No molecules: the formula gives the ratio of the ions
- Ball and stick: shows the 3D pattern, but the gaps and sticks are not real
- Every diagram shows only a tiny part of the lattice
- Held by strong electrostatic forces of attraction, acting in all directions
- Empirical formula = simplest whole-number ratio of ions
- 2D diagram: only one layer. Space-filling: can't see the ions inside

Notes

Giant ionic lattices

- An ionic compound is a **giant structure of ions**, called a **giant ionic lattice**. The ions are arranged in a regular, repeating pattern.
- The ions are held together by **strong electrostatic forces of attraction** between **oppositely charged ions**. This is ionic bonding.
- The forces act in **all directions** in the lattice: each ion is attracted to all the oppositely charged ions around it, not just to one partner.
- In sodium chloride, each Na^+ ion is surrounded by six Cl^- ions, and each Cl^- ion by six Na^+ ions.



Ball and stick model of sodium chloride. The centre ion has six neighbours of the opposite charge.

- There are no molecules in an ionic compound. A formula such as NaCl gives the ratio of the ions.

Diagrams of ionic structures and their limitations

- **Dot and cross diagram**: shows how the ions formed (electron transfer) and their charges. It does not show how the ions are arranged in the lattice or their relative sizes.
- **Ball and stick model**: shows the regular 3D arrangement of the ions. But the sticks are not real, there are no large gaps between ions in reality, and the forces act in all directions, not just along the sticks.
- **2D diagram**: easy to draw and shows the alternating pattern of ions, but only one layer, not the 3D arrangement.
- **3D space-filling diagram**: shows the ions touching and their relative sizes (a Cl^- ion is bigger than an Na^+ ion). But you can only see the outside ions, and the forces are not shown.
- Every diagram shows only a tiny part of the lattice, which really continues in all directions.

Empirical formula from a diagram

- The **empirical formula** is the simplest whole-number ratio of the ions (or atoms) in a compound.
- Count the ions of each type in the diagram, write the ratio, and cancel it down: 12 of X and 6 of Y gives X : Y = 2 : 1, so X_2Y.
- If charges are shown, check that they balance: two 1+ ions and one 2− ion give zero overall.

How to answer each type of question

Describe the structure and bonding in an ionic compound

3 marks | Grade 5

1. Say it is a giant lattice (giant ionic structure).
2. Name the particles: oppositely charged ions, with their formulae if you can.
3. Say they are held by strong electrostatic forces of attraction acting in all directions.

Example. Describe the structure and bonding in magnesium oxide.

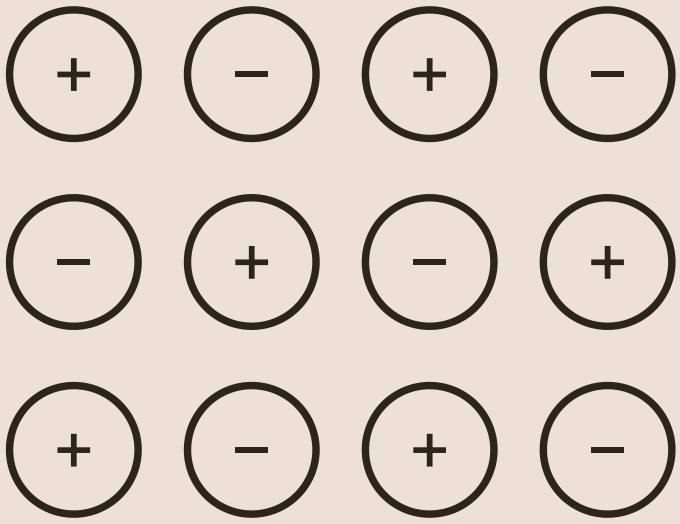
Model answer. Magnesium oxide is a giant (ionic) lattice (1) of Mg^{2+} ions and O^{2-} ions (1), held together by strong electrostatic forces of attraction between the oppositely charged ions, acting in all directions (1).

Identify an ionic structure from a diagram

1 to 2 marks | Grade 5

1. Look for two types of particle, labelled + and − or with charges.
2. Check they are in a regular arrangement that continues in all directions, with no separate molecules.
3. Give the structure and the evidence you used.

Example. The diagram shows part of the structure of substance Z. The pattern continues in all directions.



What type of structure does Z have? Give a reason.

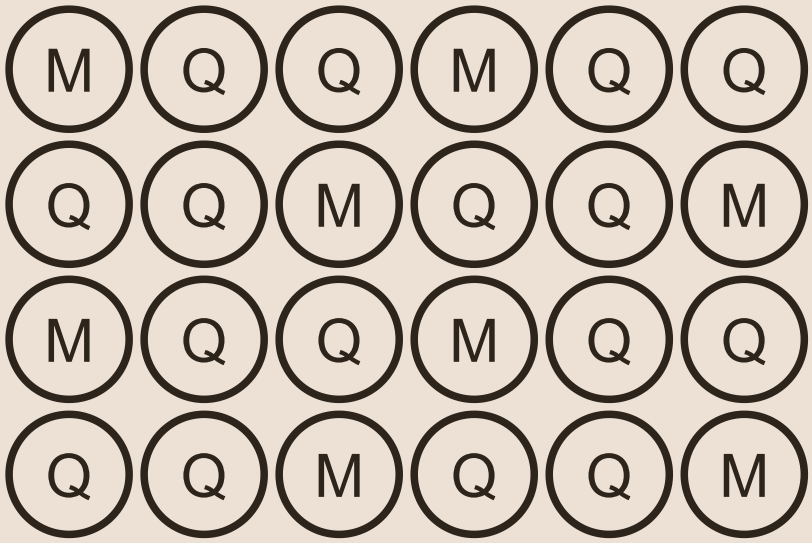
Model answer. Giant ionic lattice (1). It is made of oppositely charged ions in a regular pattern (1).

Work out the empirical formula from a diagram

1 to 2 marks | **Grade 5**

1. Count the ions of each type shown.
2. Write the ratio and cancel to the simplest whole numbers.
3. If you are told one ion's charge, use the ratio to work out the other.

Example. The diagram shows part of a layer of an ionic lattice made of ions of metal M and non-metal Q.



(a) Give the empirical formula of the compound.
(b) The ion of M has a charge of 2+. Give the charge on the ion of Q.

Model answer.

(a) MQ_2 (1)

(8 : 16 = 1 : 2)

(b) 1− (1)

(one 2+ ion is balanced by two ions of Q)

Give an advantage and a limitation of a diagram

2 marks | **Grade 5**

1. Advantage: say what the diagram shows clearly (3D arrangement, pattern, charges, relative sizes).
2. Limitation: say exactly what is wrong or missing for that type of diagram (sticks, gaps, not to scale, only one layer, only a tiny part).

Example. A student uses a ball and stick model to represent sodium chloride.
Give one advantage and one disadvantage of using this model.

Model answer.

Advantage: it shows the 3D arrangement of the ions / the regular repeating pattern (1).

Disadvantage, any one from: the ions are not joined by sticks; there are no gaps between the ions in reality; the ions are not drawn to scale; it shows only a small part of the lattice (1).

Don’t lose marks

- Calling an ionic compound 'molecules' or mentioning intermolecular forces. It is a giant lattice of ions.
- Saying the forces act only between pairs of ions or in one direction. They act in all directions.
- Writing the numbers counted (e.g. M_8Q_{16}) instead of the simplest ratio.
- Giving a vague limitation such as 'it is not accurate'. Say exactly what is wrong, e.g. 'the ions are not really joined by sticks'.
- Writing 'strong forces' without saying they are electrostatic and between oppositely charged ions.

More tips

Memory tricks

- Picture a 3D chessboard of + and − ions that keeps going in every direction.
- Limitations checklist: sticks, gaps, scale, 3D, tiny part. Pick the ones that apply to the diagram in the question.
- Cancel a ratio of ions like a fraction: 6 : 12 → 1 : 2.

Exam technique

- Learn the key phrase word for word: 'strong electrostatic forces of attraction between oppositely charged ions'.
- For advantage and disadvantage questions, make each point specific to the type of diagram named.
- If the diagram labels the ions with charges, use the charges to check your empirical formula.

What each grade needs

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

Grade 3 — **Describe an ionic compound as a giant structure**
It is a giant structure (lattice) of ions arranged in a regular pattern.

Grade 4 — **Name the force holding the ions together**
Strong electrostatic forces of attraction between oppositely charged ions.

Grade 5 — **State that the forces act in all directions**
Each ion is attracted to all the oppositely charged ions around it, throughout the lattice.

Grade 5 — **Recognise an ionic structure from a diagram**
Look for a regular lattice of two types of ion, often labelled with charges, and no separate molecules.

Grade 5 — **Work out an empirical formula from a diagram**
Count the ions of each type and simplify the ratio, e.g. 8 : 16 gives XY_2.

Grade 5 — **Give limitations of each type of diagram**
For example, ball and stick models show gaps and sticks that are not really there; 2D diagrams do not show the 3D arrangement.

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