# Ionic bonding

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

How metal atoms and non-metal atoms form ions by transferring electrons, how to show this with a dot and cross diagram, and how to work out the charge on an ion from its group. Expect 'describe what happens, in terms of electrons' questions (3 to 4 marks), dot and cross diagrams to draw or complete, and formulae to work out.

## Key facts

- Metal atoms lose electrons → positive ions; non-metal atoms gain electrons → negative ions
- Ions from Groups 1, 2, 6 and 7 have a noble gas electronic structure (full outer shell)
- Mg 2,8,2 → $Mg^{2+}$ 2,8 O 2,6 → $O^{2-}$ 2,8
- Formula: total positive charge = total negative charge
- Group 1: 1+ Group 2: 2+ Group 6: 2− Group 7: 1−
- Na 2,8,1 → $Na^{+}$ 2,8 Cl 2,8,7 → $Cl^{-}$ 2,8,8
- Dot and cross: each ion in square brackets, charge at the top right

## Notes

### Forming ions

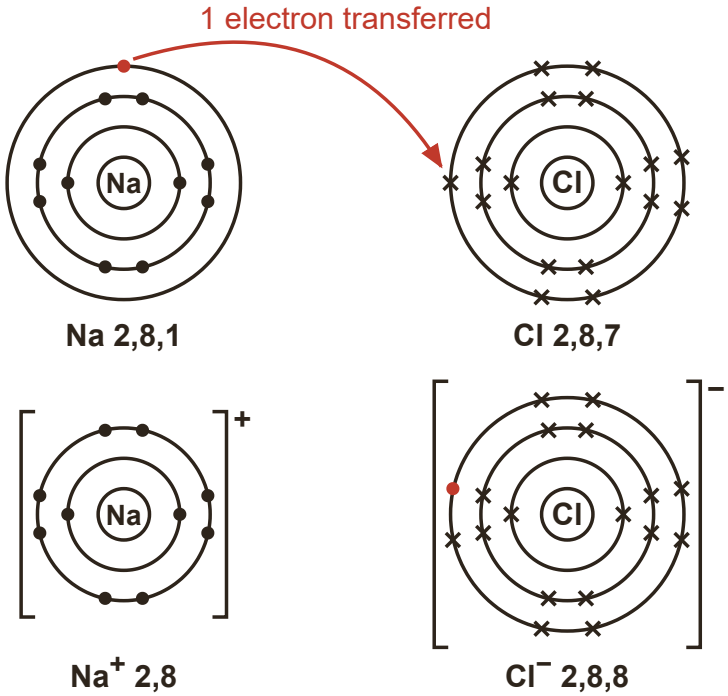
- When a metal reacts with a non-metal, electrons in the outer shell of the metal atom are **transferred** to the non-metal atom.
- The metal atom **loses** electrons and becomes a **positive ion**. The non-metal atom **gains** electrons and becomes a **negative ion**.
- An ion is charged because it now has unequal numbers of protons and electrons. The number of protons never changes.
- The ions formed by metals in Groups 1 and 2 and by non-metals in Groups 6 and 7 have the electronic structure of a **noble gas** (Group 0): a full outer shell.

### Charge from the group number

- Group 1 atoms lose 1 electron → **1+** ions, e.g. $Na^{+}$, $K^{+}$.
- Group 2 atoms lose 2 electrons → **2+** ions, e.g. $Mg^{2+}$, $Ca^{2+}$.
- Group 6 atoms gain 2 electrons → **2−** ions, e.g. $O^{2-}$, $S^{2-}$.
- Group 7 atoms gain 1 electron → **1−** ions, e.g. $F^{-}$, $Cl^{-}$.
- Negative ions made from one atom end in **-ide**: oxide, sulfide, fluoride, chloride.

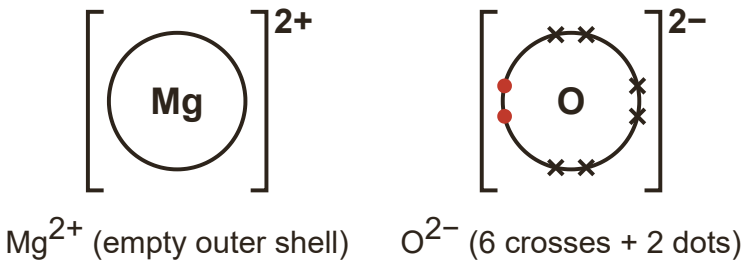
## Dot and cross diagrams

- Use dots for the electrons of one atom and crosses for the electrons of the other, so you can see where each electron came from.
- Sodium chloride: Na (2,8,1) transfers its outer electron to Cl (2,8,7). You get $[Na]^+$ (2,8) and $[Cl]^-$ (2,8,8). If sodium's electrons are dots, the outer shell of the chloride ion has 7 crosses and 1 dot.




Sodium's electrons are dots, chlorine's are crosses. The transferred electron is red.

- Draw each ion in **square brackets** with its charge at the top right. If you draw outer shells only, show the metal ion with an empty outer shell (or with the full shell below it) and the non-metal ion with 8 outer electrons.
- Magnesium oxide: Mg (2,8,2) transfers **two** electrons to O (2,6), forming $Mg^{2+}$ and $O^{2-}$.




MgO: two electrons (dots, red) have moved from magnesium to oxygen.

- When the ratio is not 1 : 1, draw every ion: calcium chloride has one $Ca^{2+}$ and two $Cl^-$ ions; sodium oxide has two $Na^+$ ions and one $O^{2-}$. Grade 6+ only

## Working out the formula

- A compound has no overall charge, so the total positive charge must equal the total negative charge.
- Two $K^+$ balance one $O^{2-}$, so potassium oxide is $K_2O$. One $Mg^{2+}$ balances two $F^-$, so magnesium fluoride is $MgF_2$.

## How to answer each type of question

### Work out the charge on an ion or the formula of a compound

1 to 2 marks | **Grade 5**

1. Find the group of each element: Groups 1 and 2 form positive ions, Groups 6 and 7 negative ions.
2. Write the charge on each ion.
3. Use enough of each ion to make the total charge zero, and write the numbers as subscripts.

**Example.** Barium is in Group 2. Bromine is in Group 7.
(a) Give the charge on a barium ion.
(b) Give the formula of barium bromide.

**Model answer.**

(a) 2+ (1)
(b) $BaBr_2$ (1)

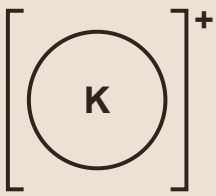
### Draw or complete a dot and cross diagram

2 to 3 marks | **Grade 5**

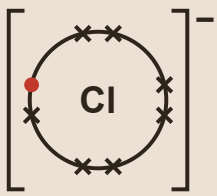
1. Work out the ions formed and how many of each you need.
2. Draw the outer shell of each ion: the non-metal ion has 8 electrons, with the transferred electrons shown as a different symbol.
3. Put square brackets round each ion and write its charge at the top right.

**Example.** Potassium has the electronic structure 2,8,8,1. Chlorine has the electronic structure 2,8,7. Draw a dot and cross diagram for potassium chloride. Show the outer shell electrons only.

**Model answer.**




$[K]^+$




$[Cl]^-$: 7 crosses, 1 dot

The diagram should show:

the potassium ion with no electrons in its outer shell (or a full shell of 8) (1)

the chloride ion with 8 outer electrons: 7 of one symbol and 1 of the other (1)

both ions in brackets with the correct charges, $[K]^+$ and $[Cl]^-$ (1)

**Explain why an ion has a particular charge** 2 marks **Grade 5**

1. Say how many outer electrons the atom has (from its group or electronic structure).
2. Say how many electrons it loses or gains to get a full outer shell, and so whether it has more protons or more electrons.

**Example.** Explain why a sulfide ion has a charge of 2−.

**Model answer.** A sulfur atom has 6 electrons in its outer shell (1). It gains 2 electrons to get a full outer shell, so it has 2 more electrons than protons (1).

**Describe how the ions form, in terms of electrons** 3 to 4 marks **Grade 5**

1. Say which atom loses electrons, how many, and that they are transferred to the non-metal.
2. Say which atom gains electrons and how many each atom gains.
3. Name the ions formed, with their charges.
4. Say that the ions have full outer shells (the electronic structure of a noble gas).

**Example.** Lithium reacts with oxygen to form lithium oxide, $Li_2O$.
Describe what happens when lithium atoms react with oxygen atoms.
Answer in terms of electrons.

**Model answer.** Each lithium atom loses one electron, which is transferred to oxygen (1). Each oxygen atom gains two electrons, so two lithium atoms are needed for each oxygen atom (1). $Li^+$ ions and $O^{2-}$ ions are formed (1). Both ions have a full outer shell / the electronic structure of a noble gas (1).

## Don’t lose marks

- Saying a metal atom becomes positive by gaining protons. Ions form by losing or gaining electrons; the number of protons does not change.
- Saying atoms share electrons in ionic bonding. Electrons are transferred.
- Getting the sign wrong: losing electrons gives a positive ion; gaining electrons gives a negative ion.
- Leaving out the brackets or charges on a dot and cross diagram, or drawing a shared pair between the ions.
- Drawing only one ion of each type when two are needed, e.g. one $Cl^-$ for calcium chloride.
- Writing 'chlorine ion' instead of 'chloride ion'. Use the -ide name for the negative ion.

## More tips

### Memory tricks

- Metals lose (positive ions); non-metals gain (negative ions).
- Charge rule: Groups 1 and 2, charge = group number, positive. Groups 6 and 7, charge = 8 − group number, negative.
- Swap and drop for formulae: write the charges, swap the numbers over as subscripts, then cancel. $Ca^{2+}$ $Cl^{-}$ → $CaCl_2$; $Mg^{2+}$ $O^{2-}$ → $Mg_2O_2$ → MgO.
- Check: $Na^{+}$, $Mg^{2+}$, $O^{2-}$ and $F^{-}$ are all 2,8, the same as neon.

### Exam technique

- In 'answer in terms of electrons' questions, give numbers: 'each magnesium atom loses two electrons' scores; 'magnesium loses electrons' may not.
- Always give the direction of transfer: from the metal atom to the non-metal atom.
- Use the electronic structures given in the question and check that each ion ends with a full outer shell.
- In a dot and cross diagram, the number of transferred electrons shown in the negative ions must equal the number the metal atoms lost.
- Write about atoms losing and gaining: 'each sodium atom loses one electron', 'each chlorine atom gains one electron'. Mark schemes reject 'the sodium ion loses' or 'the chloride gains'.

## 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 lose and non-metals gain electrons**
Metal atoms lose outer electrons to form positive ions; non-metal atoms gain electrons to form negative ions.

**Grade 4** — **Work out the charge from the group number**
Group 1 → 1+, Group 2 → 2+, Group 6 → 2−, Group 7 → 1−.

**Grade 5** — **Write the electronic structure of an ion**
For example, Na (2,8,1) becomes $Na^{+}$ (2,8) and O (2,6) becomes $O^{2-}$ (2,8).

**Grade 5** — **Draw dot and cross diagrams for ionic compounds**
Show each ion in square brackets with its charge, using dots and crosses for electrons from different atoms.

**Grade 6** — **Work out the formula of an ionic compound**
Balance the charges so the total is zero, e.g. $Ca^{2+}$ and $Cl^{-}$ give $CaCl_2$.

**Grade 7** — **Describe electron transfer when the ratio is 2 : 1**
For example, in lithium oxide two lithium atoms each transfer one electron to one oxygen atom.

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