Ionic Bonding
Ionic Bonding

What are ions?

Ionic bonding

Summary activities
An ion is an atom or group of atoms that has an electrical charge, either positive or negative.

Atoms have an equal number of protons and electrons and so do not have an overall charge.

Atoms with incomplete outer electron shells are **unstable**. By either gaining or losing electrons, atoms can obtain full outer electron shells and become stable.

When this happens, atoms have an unequal number of protons and electrons and so have an overall charge. This is how atoms become **ions**.
Positive and negative ions
Electronic structure and charge

- Metals in group 1 have 1 electron in their outer shell. They lose this 1 electron to form ions with a +1 charge.

- Metals in group 2 have 2 electrons in their outer shell. They lose these 2 electrons to form ions with a +2 charge.

- Non-metals in group 6 have 6 electrons in their outer shell. They gain 2 electrons to form ions with a −2 charge.

- Non-metals in group 7 have 7 electrons in their outer shell. They gain 1 electron to form ions with a −1 charge.

The ions produced by elements in groups 1, 2, 6 and 7 all have full outer shells. This means they have the same electronic structure as a noble gas (group 0).
Calculating ion charges

What is the charge on the ion of each element?

<table>
<thead>
<tr>
<th>element</th>
<th>calcium</th>
<th>hydrogen</th>
<th>phosphorus</th>
<th>fluorine</th>
<th>beryllium</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron shells</td>
<td>2.8.8.2</td>
<td>1</td>
<td>2.8.5</td>
<td>2.7</td>
<td>2.2</td>
</tr>
<tr>
<td>metal / non-metal</td>
<td>metal</td>
<td>non-metal*</td>
<td>non-metal</td>
<td>non-metal</td>
<td>metal</td>
</tr>
<tr>
<td>group</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>charge on ion</td>
<td>+2</td>
<td>+1</td>
<td>−3</td>
<td>−1</td>
<td>+2</td>
</tr>
</tbody>
</table>

*hydrogen is not a metal, but it forms ions in the same way as group 1 metals
Protons and electrons in ions

In an atom, the number of protons and electrons is the same, and is given by the **atomic number** in the periodic table.

When an atom becomes an ion, it loses or gains electrons.

**How do we find the number of electrons in an ion?**

**Number of electrons = atomic number − charge on ion**

**e.g. For a sodium ion, Na⁺:**

Number of electrons = 11 − 1 = 10.

**e.g. For a oxide ion, O^{2−}:**

Number of electrons = 8 − (−2) = 10.
Building an ion

How are ions formed?

Select an element to investigate
Ions can be made up of a single atom or a group of atoms. An ion made up of a group of atoms is called a **compound ion**.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Formula</th>
<th>Charge</th>
<th>Atoms present</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydroxide</td>
<td>OH⁻</td>
<td>-1</td>
<td>O H</td>
</tr>
<tr>
<td>sulfate</td>
<td>SO₄²⁻</td>
<td>-2</td>
<td>S O O O O O O</td>
</tr>
<tr>
<td>nitrate</td>
<td>NO₃⁻</td>
<td>-1</td>
<td>N O O O O O</td>
</tr>
<tr>
<td>carbonate</td>
<td>CO₃²⁻</td>
<td>-2</td>
<td>C O O O O O</td>
</tr>
<tr>
<td>ammonium</td>
<td>NH₄⁺</td>
<td>+1</td>
<td>N H H H H H</td>
</tr>
</tbody>
</table>
Naming ions and compound ions

There are two common types of ions: –ide ions and –ate ions.

What is the difference?

Generally, –ide ions are negatively-charged ions of an element, e.g. sulfide (S^{2-}), fluoride (F^-), oxide (O^{2-}).

–ate ions are negatively-charged compound ions that include oxygen, e.g. sulfate (SO_4^{2-}), nitrate (NO_3^-), carbonate (CO_3^{2-}).

The exception to this rule is the hydroxide ion, which contains both hydrogen and oxygen (OH^-).
Dot and cross diagrams for positive ions

The dot and cross diagram for a sodium atom is shown below.

How do we draw the dot and cross diagram for a sodium ion?

sodium atom, 2.8.1

sodium ion, [2.8]^+

Sodium, other metals and hydrogen become ions by losing the electrons in their outer shell. Draw the dot and cross diagram for the ion without the outer shell electron.

Draw square brackets around the diagram, and draw a “+” sign to show the positive charge.
The dot and cross diagram for a chlorine **atom** is shown below.

How do we draw the dot and cross diagram for a chlorine **ion**?

Chlorine atom, 2.8.7

Chlorine and other non-metals become ions by gaining electrons to fill their outer shell. The electrons from the atom are dots, so draw the extra electron as a cross.

Draw square brackets around the diagram, and draw a “-” sign to show the negative charge.

Chlorine ion, [2.8.7]⁻
Ionic Bonding

What are ions?

Ionic bonding

Summary activities
Elements are made up of just one type of atom, sometimes joined to other atoms of the same element by chemical bonds. This forms molecules such as chlorine (Cl\(_2\)).

Compounds are formed when different elements chemically react and form bonds with each other, e.g. water (H\(_2\)O).

Different types of bonds are formed depending on the types of atoms involved:

- **Ionic bonding** occurs between metal and non-metal atoms.
- **Covalent bonding** occurs between non-metals atoms only.

All bonding involves changes to the number of electrons in the outer shells of atoms.
Why do some ions attract while others repel?
Compounds that contain ions are called **ionic compounds**. These compounds are usually formed by a reaction between a metal and a non-metal.

**Why do these substances react together and form bonds?**

The metal and non-metal atoms have incomplete outer electron shells and so are **unstable**.

Electrons are transferred from each metal atom to each non-metal atom. The metal and the non-metal atoms form ions with completely full outer shells and become stable.

There are strong **electrostatic forces** of attraction in all directions between oppositely charged ions. This electrostatic attraction is called **ionic bonding**.
Group 1 and group 7 elements

The **alkali metals**, found in group 1 of the periodic table, react with non-metals to form ionic compounds.

The alkali metals all have one electron in their outer shell. They lose this electron to form an ion with a **single positive charge**.

The **halogens**, found in group 7 of the periodic table, react with metals to form ionic compounds.

The halogens all have seven electrons in their outer shell. They gain an extra electron to form an ion with a **single negative charge**.
Sodium chloride is an ionic compound formed by the reaction between sodium (group 1) and chlorine (group 7).

Sodium has 1 electron in its outer shell.

By losing this electron, it has a full outer shell and forms a positive ion.

Chlorine has 7 electrons in its outer shell.

By gaining an electron from sodium, it has a full outer shell and forms a negative ion.

How are ionic bonds formed?
How are ionic bonds formed?

The **positive** sodium ions and the **negative** chloride ions are strongly attracted to each other.

It is this electrostatic attraction that forms **ionic bonds** in sodium chloride and other ionic compounds.
What is ionic bonding?
To draw dot and cross diagrams for an ionic compound, you need to draw a dot and cross diagram for each ion in the formula of the compound.

If crosses are used for the electrons in the positive ion, then in the negative ion the electrons from the atom should be dots and the gained electrons should be crosses.

**Sodium chloride, NaCl**

```
Na+          Cl-
```

**Lithium oxide, Li₂O**

```
Li+        O²-
```

```
Other diagrams for ionic compounds

Other ways to draw ionic compounds are ball-and-stick models and space filling models.

In a ball-and-stick model, the balls show the ions, and the sticks show the electrostatic attraction between them.

In a space filling model, the ions are shown packed together, and their charges are labelled.

Key

- $\text{Na}^+$
- $\text{Cl}^-$
### Comparing ways to draw ionic compounds

<table>
<thead>
<tr>
<th></th>
<th>Empirical formula</th>
<th>Dot and cross</th>
<th>Ball-and-stick</th>
<th>Space filling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>NaCl</td>
<td><img src="image" alt="Na⁺ Cl⁻" /></td>
<td><img src="image" alt="Ball-and-stick" /></td>
<td><img src="image" alt="Space filling" /></td>
</tr>
<tr>
<td>Simple to draw</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Easy to see the ratio of ions</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shows the charges on each ion</td>
<td>X</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Shows the 3D arrangement</td>
<td>X</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Ions and ionic bonding – summary
Multiple-choice quiz