Ionic compounds

Knowledge:

An ion is an atom or group of atoms with a positive or negative charge.

Ions form when atoms lose or gain electrons to obtain a full outer shell:

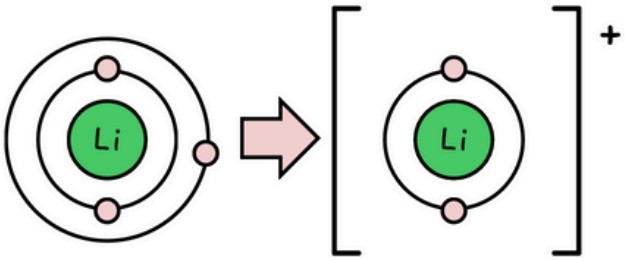
- metal atoms lose electrons to form positively charged ions
- non-metal atoms gain electrons to form negatively charged ions

Forming positive ions

Metal atoms lose electrons from their outer shell when they form ions:

- the ions are positive because they have more protons than electrons
- the ions formed have full outer shells
- the ions have the electronic structure of a noble gas (group 0 element), with a full outer shell

Forelements in groups 1, 2 and 3, the number of electrons lost is the same as the group number.



A Lithium atom loses one electron to form a Lithium ion

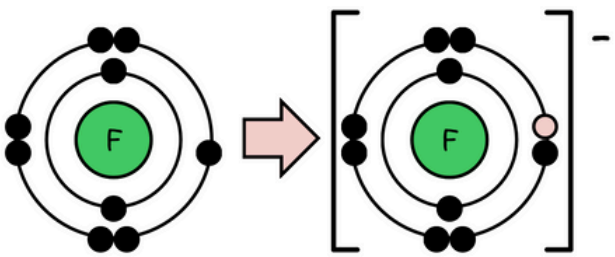
Forming negative ions

The outer shells of non-metal atoms gain electrons when they form ions:

- the ions formed are negative because they have more electrons than protons
- the ions have the electronic structure of a noble gas (group 0 element), with a full outer shell

For elements in groups 6 and 7, the charge on the ion is equal to (8 minus group number).

An Fluorine atom gains 1 electron to form a Fluorine Ion



Example of ion charges and groups:

Group	Element	Ion charge	Ion symbol
1	Na	+	Na+
2	Mg	2+	Mg2+
6	O	2-	O2-
7	Cl	-	Cl-

Worked example

Sulphur is in group 6 of the periodic table. What is the charge on its ions, and is the charge positive or negative?

Answer:

The charge is negative since sulphur isanon-metal. The charge on the ion is (8- 6)=2.

Question

Iodine is in group 7. What is the charge on its ions, and is the charge positive or negative?

_____

_____

_____

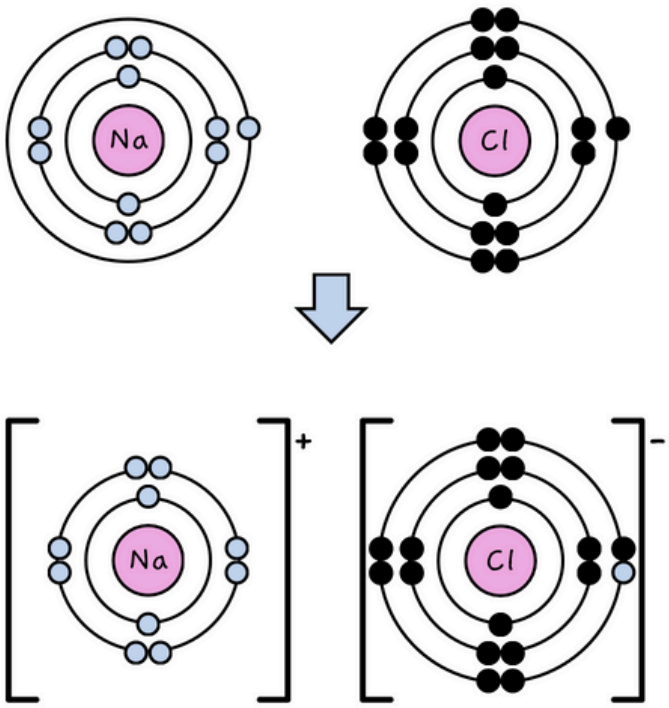
Forming ionic bonds

Positive and negative ions form when a metal reacts with a non-metal, by transferring electrons. The oppositely charged ions are strongly attracted to each other, forming ionic bonds.

Dot and cross diagrams

A dot and cross diagrams model the transfer of electrons from metal atoms to non-metal atoms. The electrons from one atom are shown as dots, and the electrons from the other atom are shown as crosses.

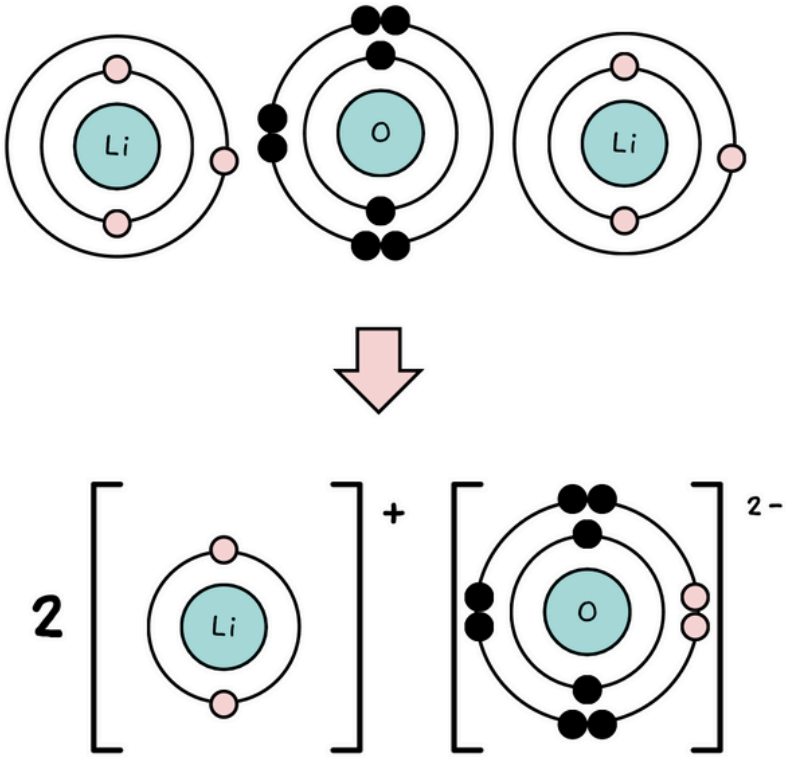
For example, when sodium reacts with chlorine, electrons transfer from sodium atoms to chlorine atoms.



Sodium chloride

Chlorine gains an electron from sodium to become a negative ion (-1). Sodium loses an electron to become a positive ion (+1). Both ions now have a full outer shell of electrons and the ionic compound sodium chloride is formed.

More examples:



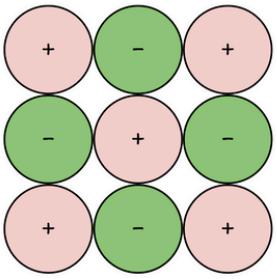
Lithium Oxide

Each lithium atom loses an electron to become a positively charged ion (1+). The oxygen atom gains two electrons to become a negatively charged ion (2-).

Question:

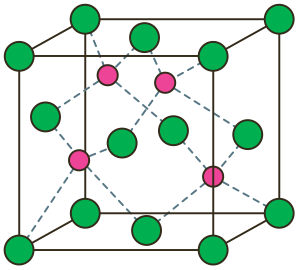
Draw a diagram, with outer electrons only, to show how the electrons are transferred when magnesium chloride is formed from its elements.

The ionic lattice



An ionic compound is a giant structure of ions. The ions have a regular, repeating arrangement called an ionic lattice.

The lattice is formed because the ions attract each other and form a regular pattern with oppositely charged ions next to each other.



The lattice arrangement continues in three dimensions. This is why solid ionic compounds form crystals with regular shapes.

Ionic bonding:

An ionic lattice is held together by strong **electrostatic forces** of attraction between the oppositely charged ions. The forces act in all directions in the lattice. This is called ionic bonding.

Different types of models are used to represent giant ionic structures. Each has its advantages and limitations. For example:

- the two-dimensional space-filling model clearly shows the arrangement of ions in one layer, but it does not show how the next layer of ions is arranged
- the three-dimensional ball and stick model shows the arrangement of ions in a larger section of the crystal, but using sticks for bonds is misleading because the forces of attraction between ions actually act in all directions
- the three-dimensional model is also misleading because it shows lots of free space between the ions, which there isn't

Properties of ionic compounds

Ionic compounds have regular structures, called giant ionic lattices. In a giant ionic lattice, there are strong electrostatic forces of attraction acting in all directions between the oppositely charged ions. The structure and bonding of ionic compounds explain their properties.

Ionic compounds have high melting and boiling points, so they are in the solid state at room temperature.

Energy must be transferred to a substance to make it melt or boil.

This energy **overcomes** the strong electrostatic forces of attraction which act in all directions between the oppositely charged ions:

- some forces are overcome during melting
- all remaining forces are overcome during boiling

The more energy needed, the higher the melting point or boiling point. Since the electrostatic forces of attraction between oppositely charged ions are strong, their melting and boiling points are high.

Ionic compounds are held together by electrostatic forces between the oppositely charged ions. These forces are usually referred to as ionic bonding. As the ionic lattice contains such so ions, a lot of energy is needed to overcome this ionic bonding so ionic compounds have high melting and boiling points.

The strength of the ionic bonds depends on the charge on the ions. Ions with higher charge will have stronger forces between them, so will need more energy in order to overcome these.

Conducting electricity

A substance can conduct electricity if:

- it contains charged particles, such as ions, and
- these particles are free to move from place to place

An ionic compound can conduct electricity when:

- it has melted to form a liquid, or
- it has dissolved in water to form an aqueous solution

Both these processes allow ions to move from place to place. Ionic compounds cannot conduct electricity in the solid state because their ions are held in fixed positions and cannot move.

Application:

Q5. This question is about salts.

(a) Salt (sodium chloride) is added to many types of food.

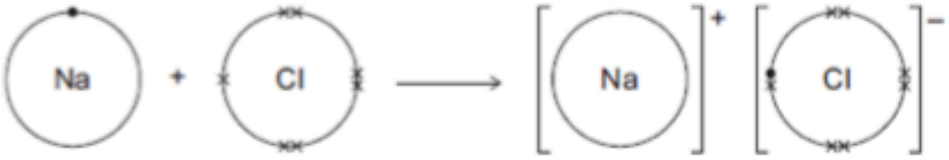
Sodium chloride is produced by reacting sodium with chlorine.

sodium + chlorine ⟶ sodium chloride

The diagram shows what happens to atoms of sodium and chlorine in this reaction.

The dots (•) and crosses (×) represent electrons.

Only the outer electrons are shown.



Describe, in terms of electrons, what happens when a sodium atom reacts with a chlorine atom to produce sodium chloride.

.....

.....

.....

.....

.....

.....

(3)

(b) Lack of iodine can affect the learning ability of children.

One idea is that salt (sodium chloride) should have iodine added.

(i) Iodine consists of simple molecules.

What is a property of substances that have simple molecules?

Tick (✓) **one** box.

Have no overall electric charge ☐

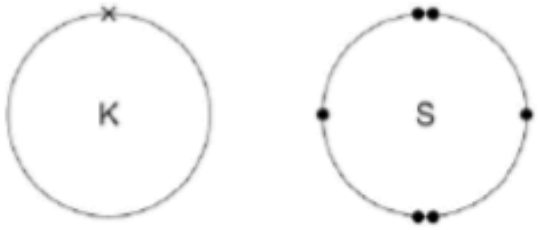
Have high boiling points ☐

Have giant covalent structures ☐

(1)

Q1.Figure 1 shows the outer electrons in an atom of the Group 1 element potassium and in an atom of the Group 6 element sulfur.

Figure 1



(a) Potassium forms an ionic compound with sulfur.

Describe what happens when **two** atoms of potassium react with **one** atom of sulfur.

Give your answer in terms of electron transfer.

Give the formulae of the ions formed.

.....

.....

.....

.....

.....

.....

.....

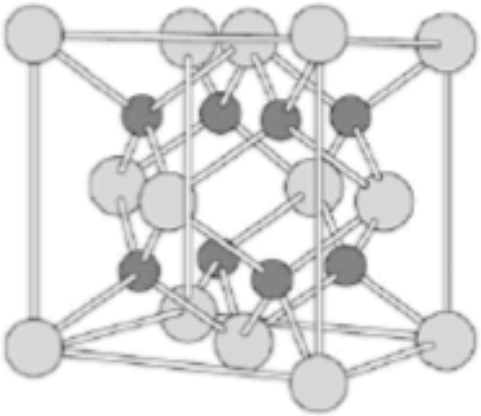
.....

.....

.....

(5)

(b) The structure of potassium sulfide can be represented using the ball and stick model in **Figure 2**.



The ball and stick model is **not** a true representation of the structure of potassium sulfide.

Give **one** reason why.

……

……

(1)

(f) Ionic compounds such as potassium sulfide have high boiling points and conduct electricity when dissolved in water.

Draw **one** line from each property to the explanation of the property.

Property	Explanation of property
High boiling point	There are no charged particles free to move
Conduct electricity when molten	Ions are free to move
	Weak intermolecular forces of attraction
	Bonds are weak
	Bonds are strong
	Electrons are free to move

(2)

Q5. This question is about sodium chloride and iodine.

(a) Describe the structure and bonding in sodium chloride.

.....

.....

.....

.....

.....

.....

.....

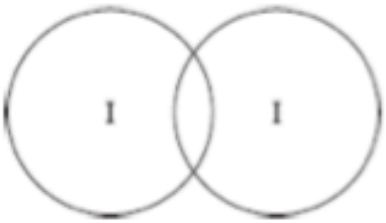
.....

(4)

(d) The bonding in iodine is similar to the bonding in chlorine.

(i) Complete the diagram below to show the bonding in iodine.

Show the outer electrons only.



(2)

(ii) Explain why iodine has a low melting point.

.....

.....

.....

.....

.....

.....

(3)