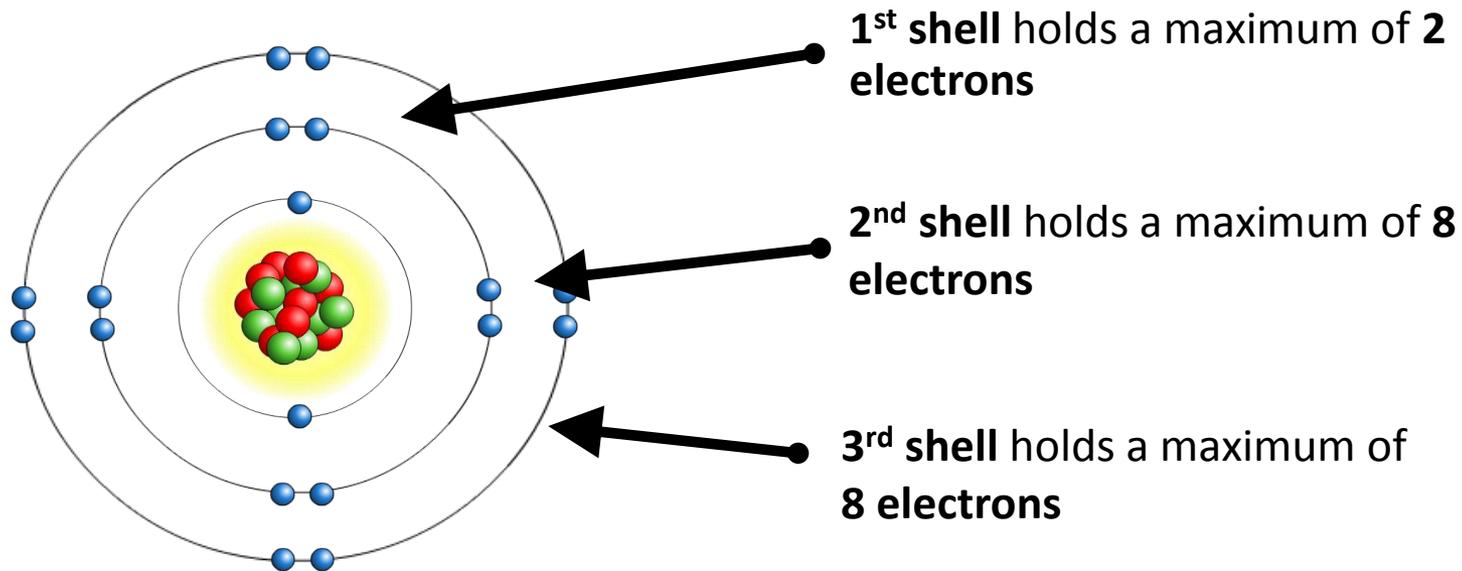


Ionic compounds and analysis

C2 Topic 2

Why do atoms form bonds?

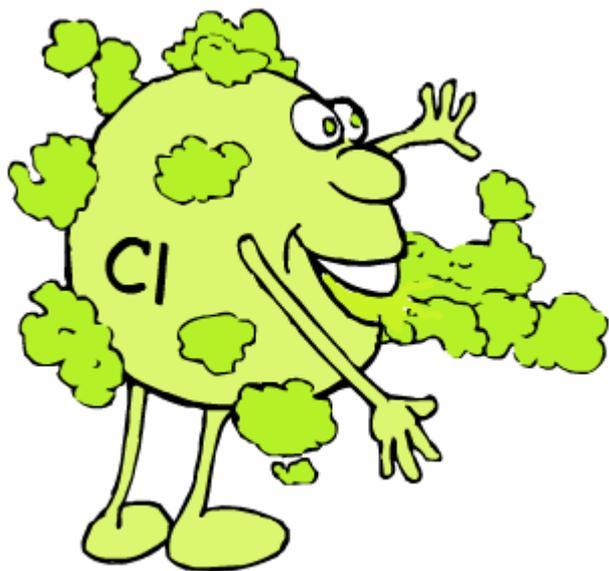
- Atoms of different elements can combine to form compounds by the formation of new chemical bonds
- Bonds involve the electrons in the outer shells of atoms



- Filled electron shells are very stable

Why do atoms form bonds?

- The atoms of noble gases have **completely full** outer shells and so are **stable**
- This makes the noble gases very **unreactive** and so they do not usually form bonds



- The atoms of other elements have **incomplete** outer electron shells and so are **unstable**
- By forming bonds, the atoms of these elements are able to have filled outer shells and become stable

Types of bonding

- Different types of bonds are formed depending on the atoms involved:
 - **Ionic bonding:** between **metal** and **non-metal** atoms
 - **Covalent bonding:** between **non-metal** atoms only
 - **Metallic bonding:** between **metal** atoms only
- All bonds involve electrons and all bonding involves changes to the number of electrons in the outer shell

Ionic bonding

- Ionic bonds are formed by the transfer of electrons to produce cations (+) and anions (-)
- Atoms in group 1 form ionic bonds with atoms in group 7
- Atoms in group 2 form ionic bonds with atoms in group 6

How do atoms form ions?

- 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 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

- An atom that **loses electrons** has more protons than electrons and so has a positive overall charge. This is called a **positive ion**
- An atom that **gains electrons** has more electrons than protons and so has a negative overall charge. This is called a **negative ion**

Positive ions (+)

- An atom that loses one or more electrons forms a positive ion
- **Metal atoms** form positive ions
- Positive ions have a small '+' symbol to indicate how many electrons have been lost
- This number is usually the same as the number of electrons in the atom's outer shell (group number)

lithium atom 2.1 → lithium ion [2] = Li⁺

magnesium atom 2.8.2 → magnesium ion [2.8] = Mg²⁺

How is a sodium ion formed?

Sodium atom:

11 protons = +11

11 electrons = -11

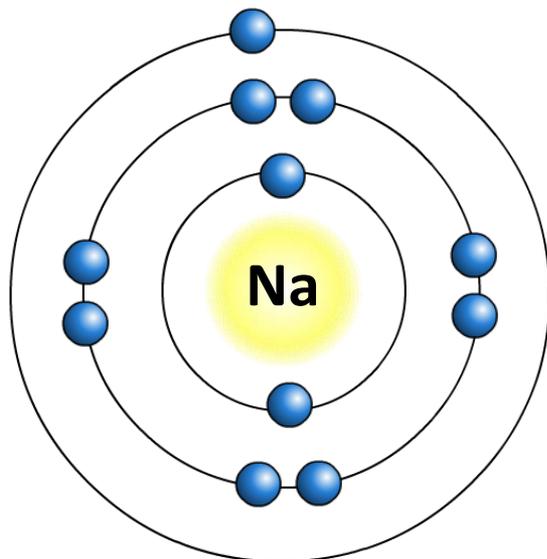
Total charge = 0

Sodium ion:

11 protons = +11

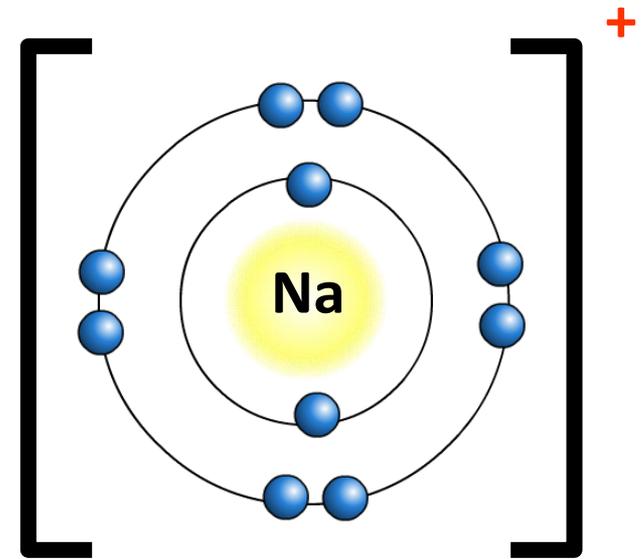
10 electrons = -10

Total charge = +1



2.8.1

loses
1 electron



[2.8]

How is a magnesium ion formed?

Magnesium atom:

12 protons = +12

12 electrons = -12

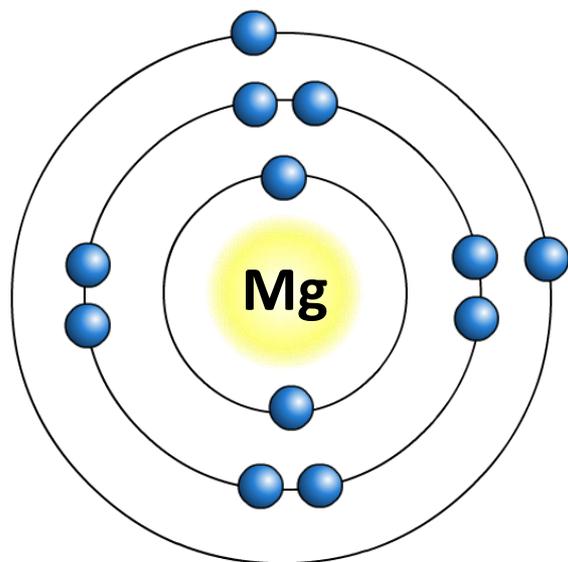
Total charge = 0

Magnesium ion:

12 protons = +12

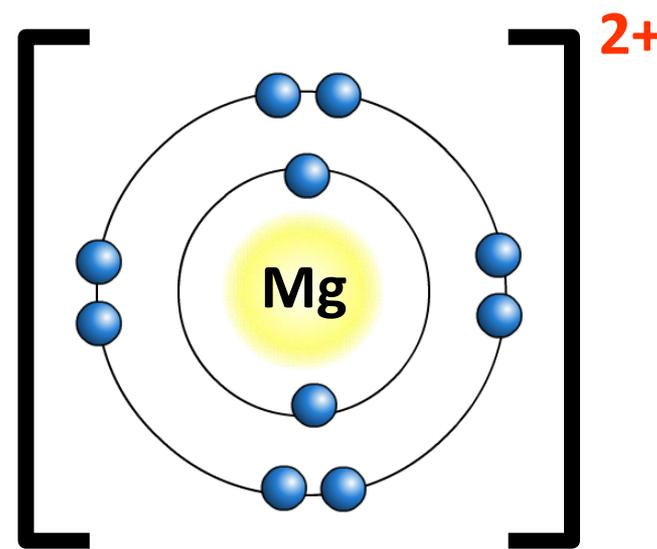
10 electrons = -10

Total charge = +2



2.8.2

loses
2 electrons



[2.8]²⁺

Negative ions (-)

- An atom that gains one or more electrons forms a negative ion
- **Non-metal atoms** form negative ions
- Negative ions have a small '-' symbol to indicate how many electrons have been gained
- This number is usually the same as the number of electrons in the atom's outer shell (group number)

chlorine atom 2.8.7 \longrightarrow chloride ion [2.8.8] = Cl⁻

oxygen atom 2.6 \longrightarrow oxide ion [2.8] = O²⁻

How is a fluoride ion formed?

Fluorine atom:

9 protons = +9

9 electrons = -9

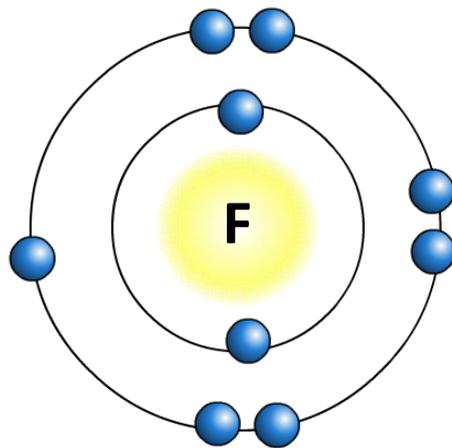
Total charge = 0

Fluoride ion:

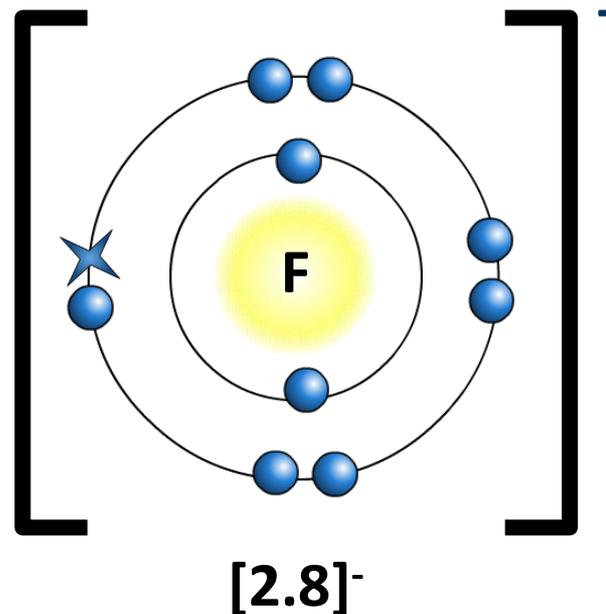
9 protons = +9

10 electrons = -10

Total charge = -1



gains 1
electron



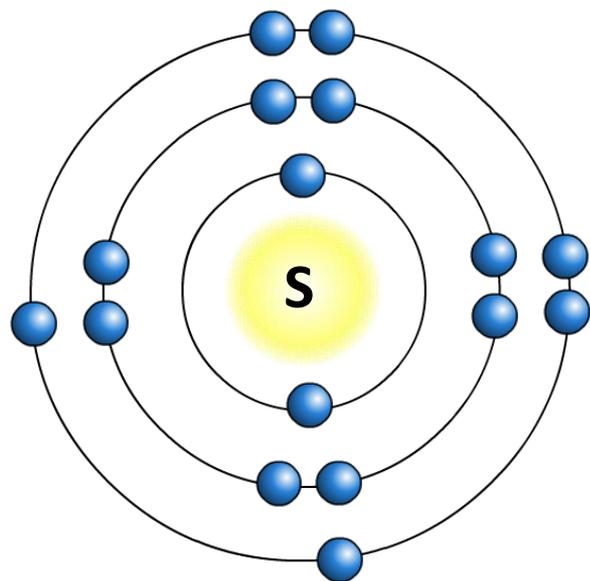
How is a sulphide ion formed?

Sulphur atom:

16 protons = +16

16 electrons = -16

Total charge = 0



2.8.6

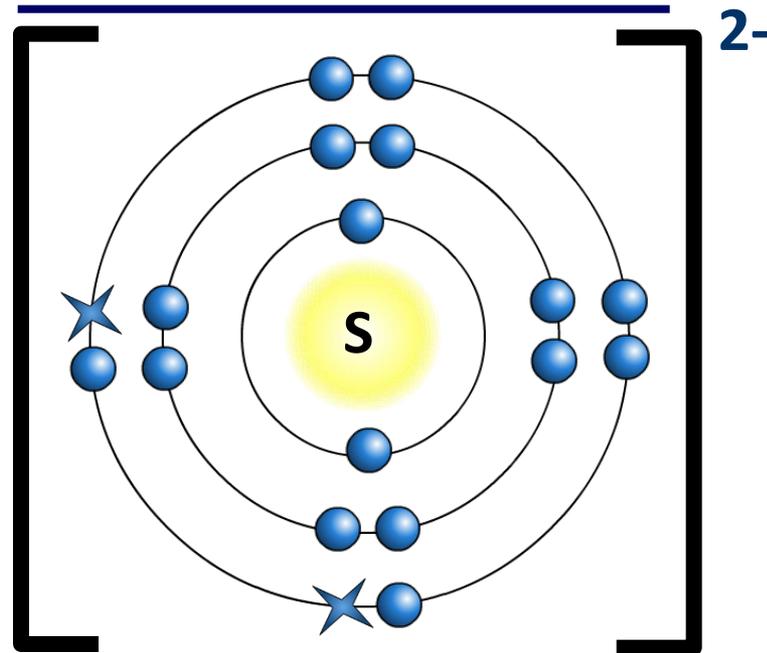
gains 2
electrons

Sulphide ion:

16 protons = +16

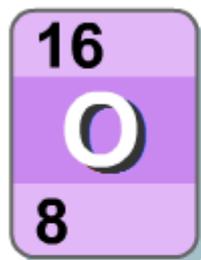
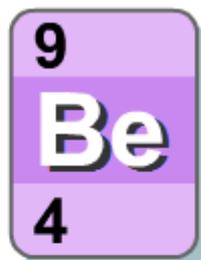
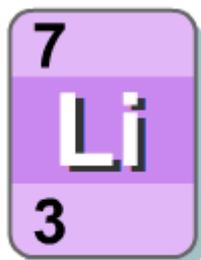
18 electrons = -18

Total charge = -2



[2.8.8]²⁻

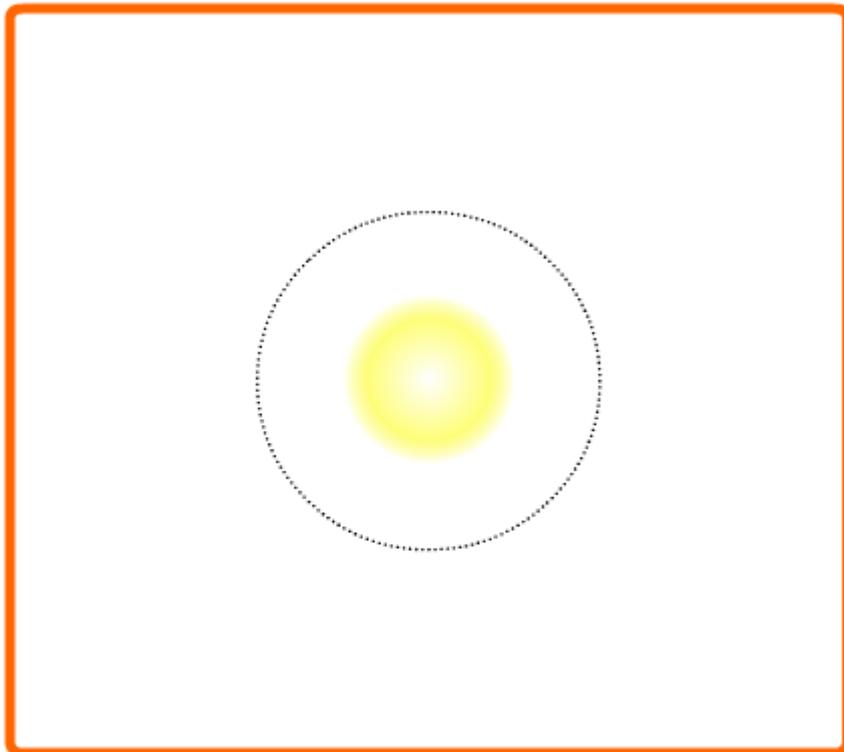
How are ions formed?



Select an element to investigate



Which particles have this stable electron configuration?



electron configuration

1 of 3

B^{3+}	Na^+	Cl^-
He	O^{2-}	Al^{3+}
Be^{2+}	Li^+	N^{3-}
Mg^{2+}	F^-	Ne
Br^-	H^+	S^{2-}

?

solve



Compound ions

- An ion made up of a group of atoms is called a **compound ion**

Ion	Formula	Charge	Atoms present
Hydroxide	OH^-	-1	O H
Sulphate	SO_4^{2-}	-2	S O O O O
Nitrate	NO_3^-	-1	N O O O
Carbonate	CO_3^{2-}	-2	C O O O
Ammonium	NH_4^+	+1	N H H H H

What are the facts about positive and negative ions?

Property	Positive ions	Negative ions
electron change	?	?
element type	?	?
element ion example	?	?
compound ion example	?	?



?

C

solve

↶



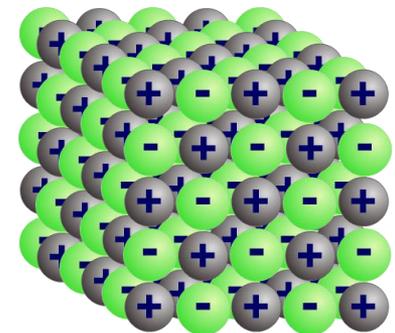
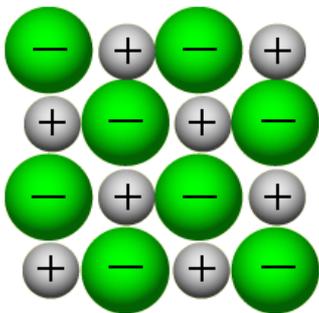
Naming ionic compounds

- The name of the metal is always written first
- Change the ending of the name of the non-metal to **-ide**, but only when there is a single non-metal present
- If there are two non-metals present and one of them is oxygen, then end the name in **-ate**

-ide compounds		-ate compounds	
potassium bromide	KBr	potassium bromate	KBrO ₃
iron (II) sulfide	FeS	iron sulfate	FeSO ₄
calcium carbide	CaC ₂	calcium carbonate	CaCO ₃

What is an ionic lattice?

- Ionic bonds form between a positive metal ion (cation) and a negative non-metal ion (anion)
- Ionic bonds are the electrostatic forces of attraction between oppositely charged ions
- The oppositely charged ions are arranged in a regular way to form giant ionic lattices
- Ionic compounds often form crystals as a result

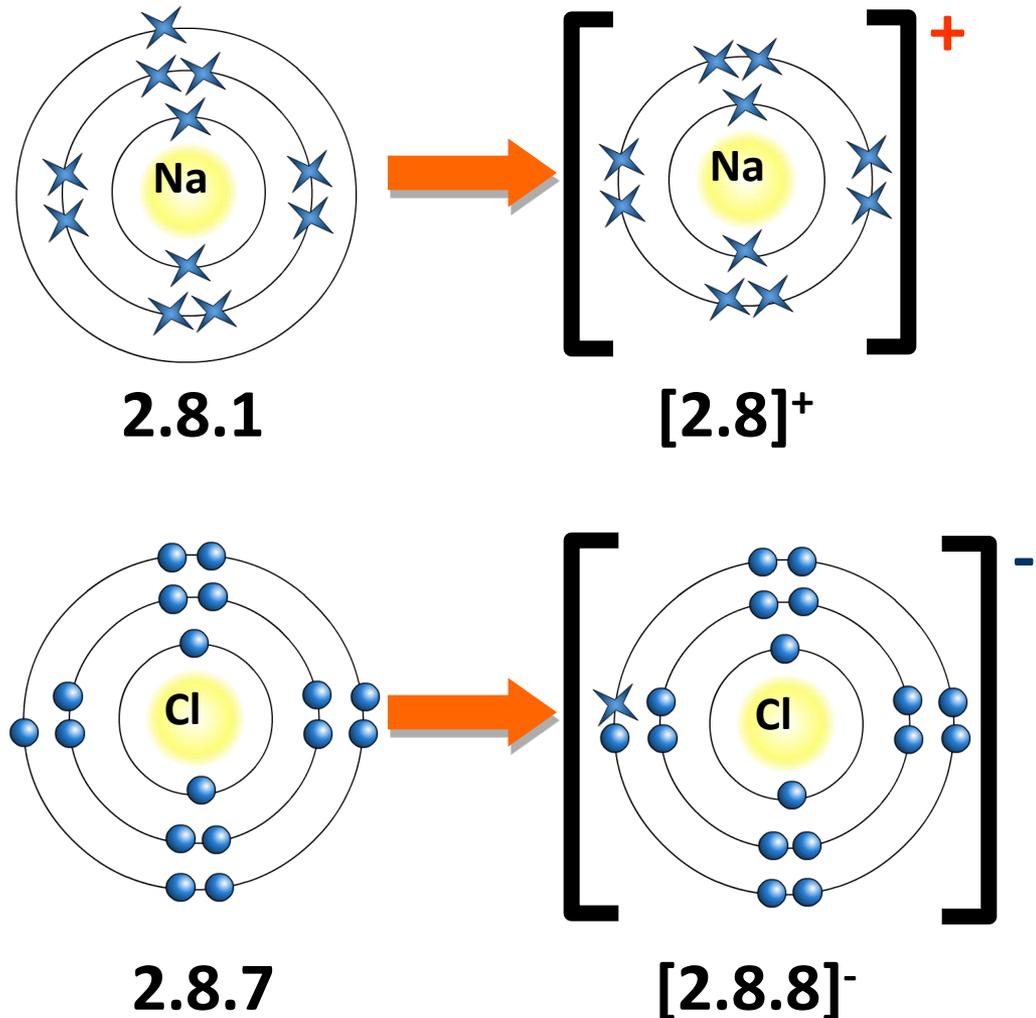


Ionic bonds – Sodium chloride

Sodium chloride is an ionic compound formed by the reaction between the metal sodium and the non-metal chlorine

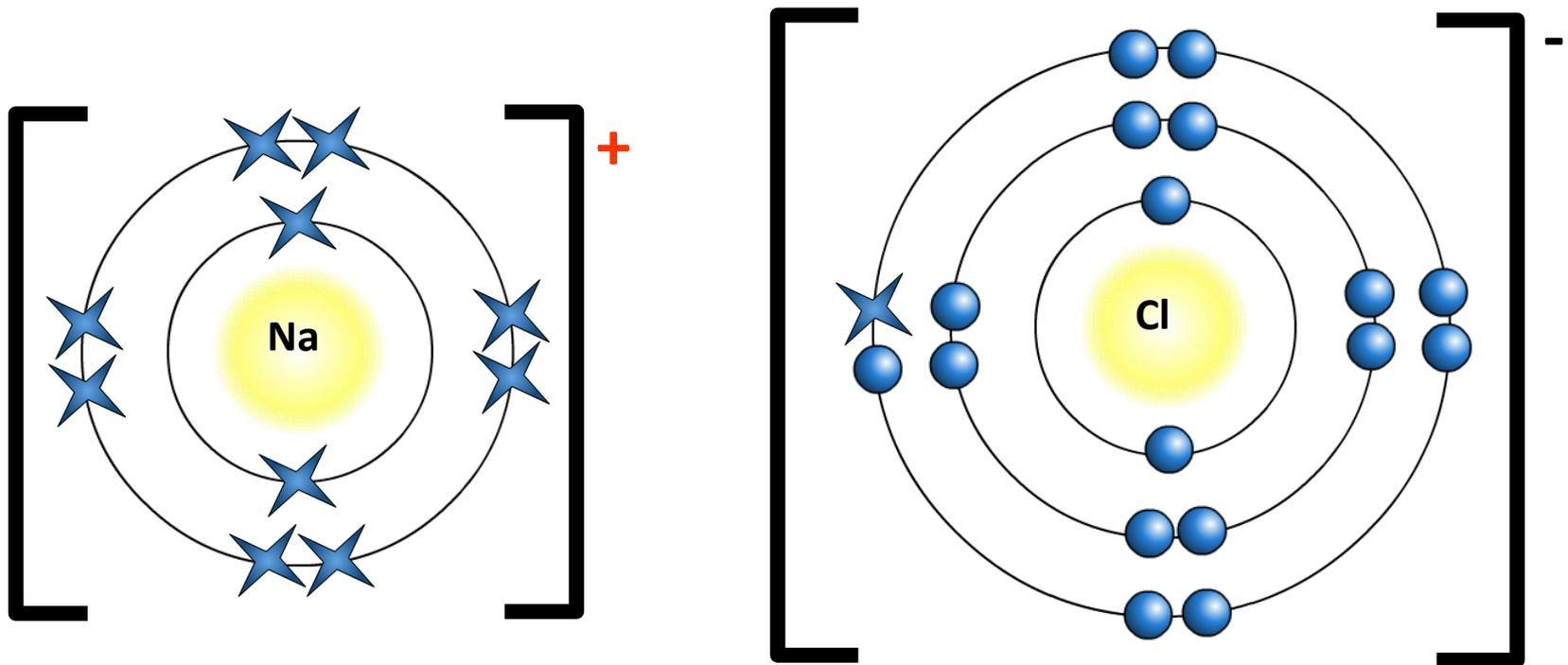
Sodium has 1 electron in its outer shell. By losing this electron, it has a filled outer shell and forms a positive ion

Chlorine has 7 electrons in its outer shell. By gaining an electron from sodium, it has a filled outer shell and forms a negative ion



Ionic bonds – Sodium chloride

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



How does an ionic bond form?

Click on the compounds below to find out more.



sodium chloride

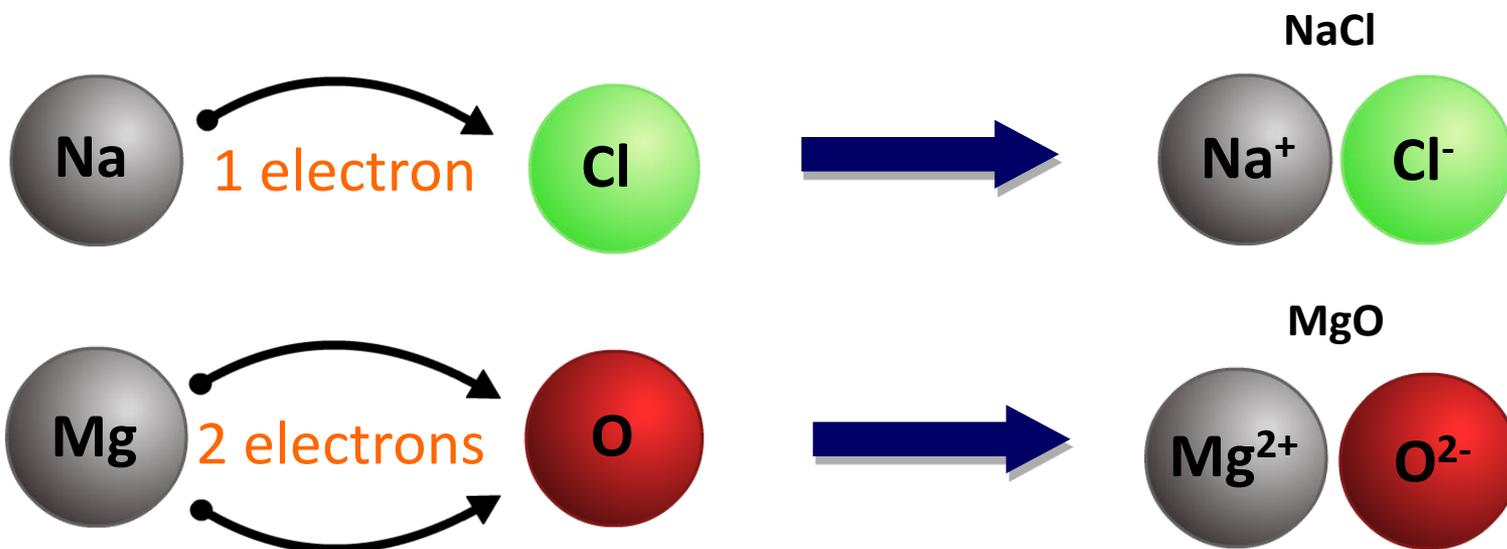


magnesium oxide



What is the ratio of ions?

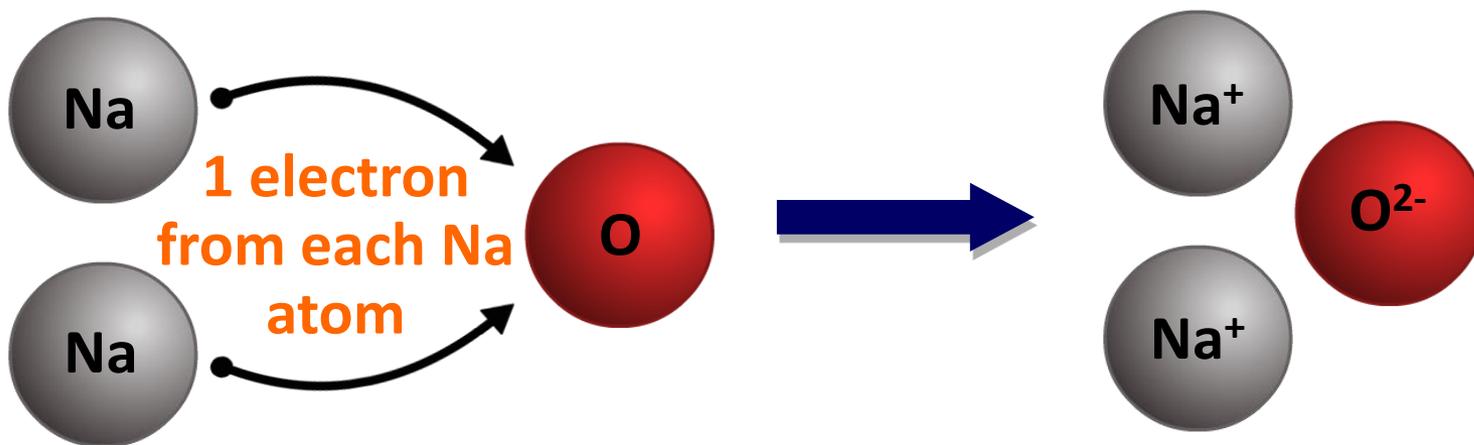
- In each compound, the metal needs to lose the same number of electrons that the non-metal needs to gain



- Both compounds have a 1:1 ratio of metal ions to non-metal ion, which is shown by the formula of each compound

What is the ratio of ions?

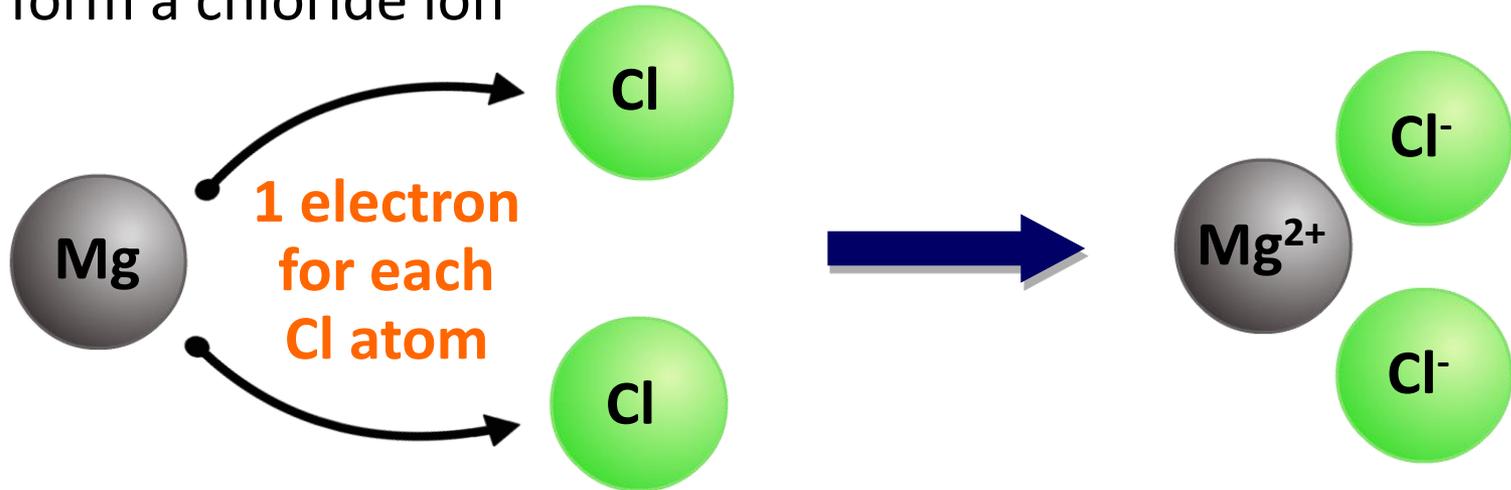
- Sodium (2,8,1) needs to lose 1 electron to form a sodium ion but oxygen (2,6) must gain 2 electrons to form an ion



- Two sodium atoms are required for each oxygen atom and so the ratio of sodium ions to oxide ions is 2:1
- From this ratio, the formula of sodium oxide is **Na₂O**

What is the ratio of ions?

- Magnesium (2,8,2) needs to lose 2 electrons to form a magnesium ion but chlorine (2,8,7) needs to gain 1 electron to form a chloride ion



- Two chlorine atoms are required for each magnesium atom and so the ratio of magnesium ions to chloride ions is 1:2
- From this ratio, the formula of magnesium chloride is **MgCl₂**

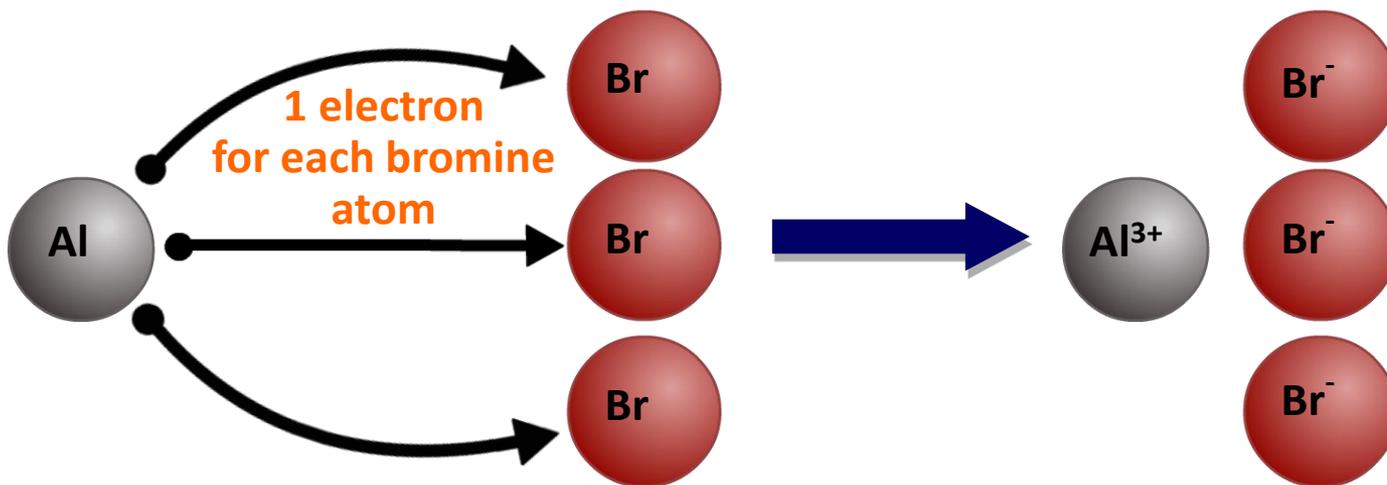
Writing the formulae of ionic compounds

- To work out the formula of an ionic compound:

1. Write down the symbol for each element – the metal is always written first.
2. Calculate the charge for each type of ion.
3. Balance the number of ions so that the positive and negative charges are balanced and equal zero. This gives the ratio of ions.
4. Use the ratio to write down the formula of the ionic compound.

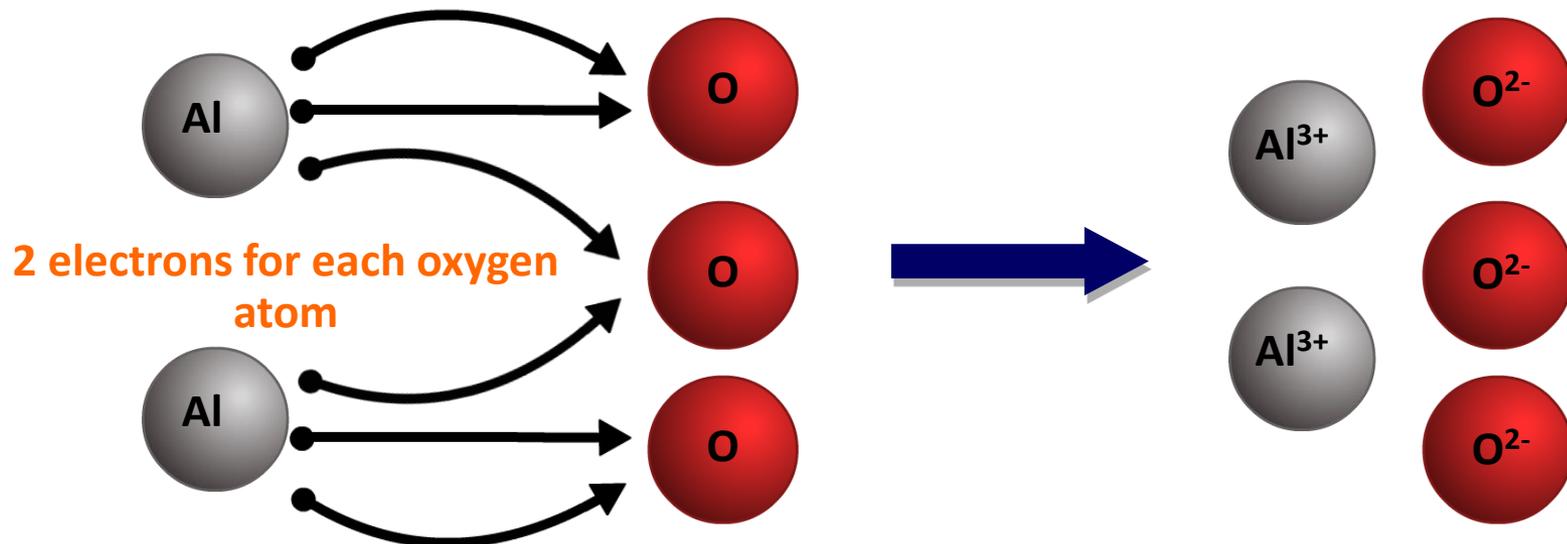
Formula of aluminium bromide

Symbol	Al	Br
Ion charge	+3	-1
Balance the number of ions	3 bromide ions are needed for each aluminium ion	
Ratio of ions	1 : 3	
Formula	AlBr₃	

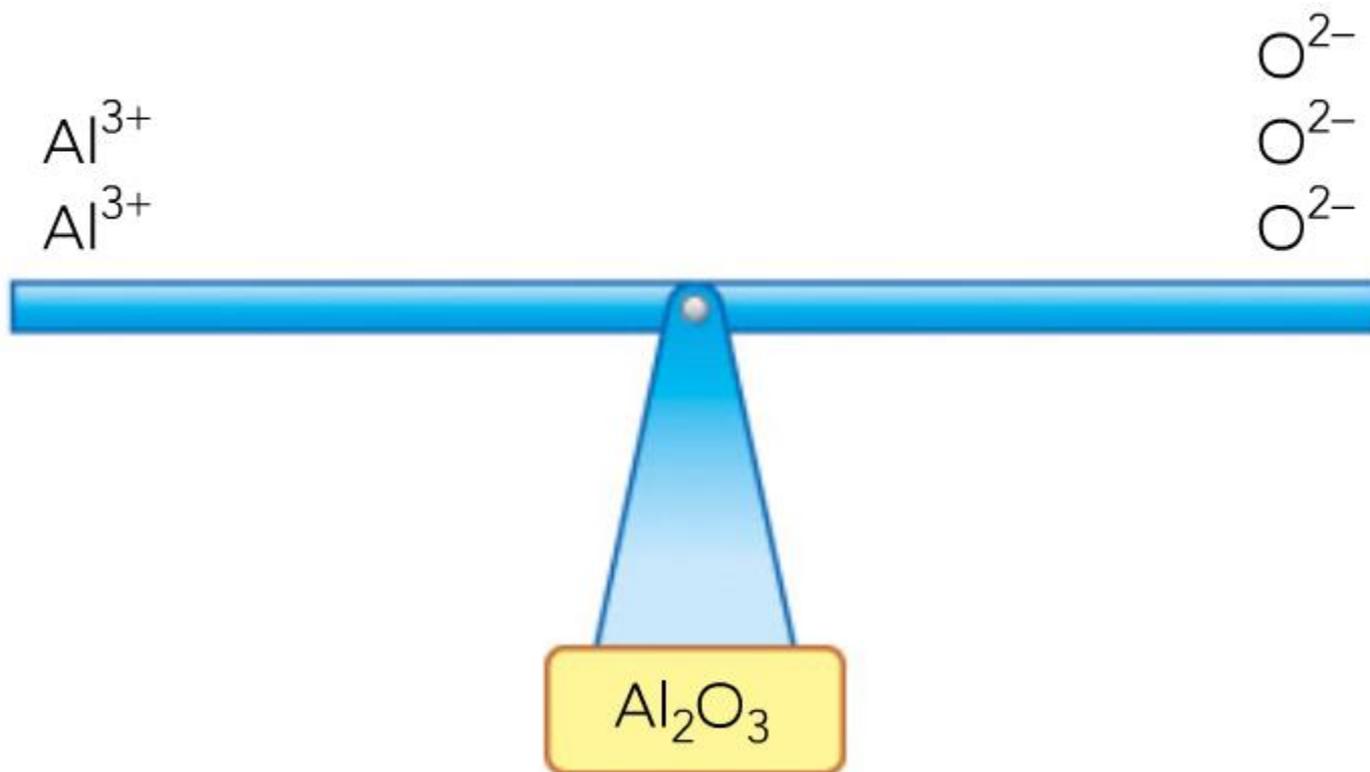


Formula of aluminium oxide

Symbol	Al	O
Ion charge	+3	-2
Balance the number of ions	2 aluminium ions are needed for 3 oxide ions	
Ratio of ions	2 : 3	
Formula	Al_2O_3	



Formulae of aluminium oxide



Formulae of ionic compounds

metals non- metals	Li	Ca	Na	Mg	Al	K
F	LiF	CaF ₂	NaF	MgF ₂	AlF ₃	KF
O	Li ₂ O	CaO	Na ₂ O	MgO	Al ₂ O ₃	K ₂ O
N	Li ₃ N	Ca ₃ N ₂	Na ₃ N	Mg ₃ N ₂	AlN	K ₃ N
Br	LiBr	CaBr ₂	NaBr	MgBr ₂	AlBr ₃	KBr
S	Li ₂ S	CaS	Na ₂ S	MgS	Al ₂ S ₃	K ₂ S
Cl	LiCl	CaCl ₂	NaCl	MgCl ₂	AlCl ₃	KCl

What is the formula for each ionic compound?

Symbol	Li	NO ₃
Ion charge	1+	1-
Balance the number of ions	1 lithium ion is needed for each nitrate ion	
Ratio of ions	1 : 1	
Formula	?	



Formula 1 of 4



solve

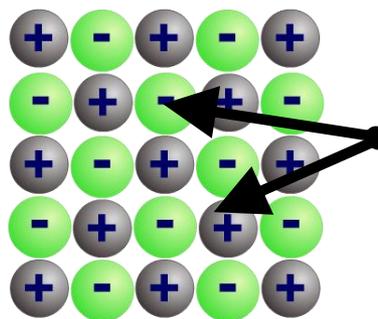


Properties of ionic compounds

- **High melting and boiling points**- Ionic bonds are very strong (strong electrostatic attraction between positively and negatively charged ions)- a lot of energy is required to break them. So ionic compounds have high melting and boiling points
- **Conductive when liquid**- Ions are charged particles, but ionic compounds can only conduct electricity if their ions are free to move and act as a current. Ionic compounds do not conduct electricity when they are solid- only when dissolved in water or melted

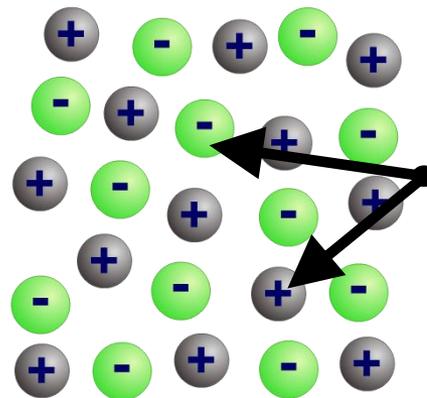
How can ionic compounds conduct electricity?

- As solids, ionic compounds cannot conduct electricity because their ions are bonded together in the lattice



ions in solid state cannot move

- When liquid (molten), the ions can break free of the lattice and are able to move. The ions are charged particles and so can carry an electric current



ions in molten state can move and conduct electricity

Properties of ionic compounds

Ionic compound	Properties
Sodium chloride, NaCl	<p>High melting point: 800°C</p> <p>Non-conductive in its solid state, but when dissolves in water or molten NaCl will conduct electricity</p>
Magnesium oxide, MgO	<p>Higher melting point than sodium chloride: around 2800°C. This is because its Mg²⁺ and O²⁻ ions have a greater number of charges, so they form stronger ionic bonds than the Na⁺ and Cl⁻ ions in sodium chloride</p> <p>Because magnesium oxide stays solid at such high temperatures, it remains non-conductive. It is used for high-temperature electrical insulation</p>

Solubility

acid + alkali \rightarrow salt + water

- **Soluble** salts dissolve in water
- **Insoluble** salts do not dissolve in water

Solubility of salts

- All common sodium, potassium and ammonium salts are soluble
- All nitrates are soluble
- Common chlorides are soluble except those of silver and lead
- Common sulphates are soluble except those of lead, barium and calcium
- Common carbonates are insoluble except those of sodium, potassium and ammonium

Soluble and insoluble salts

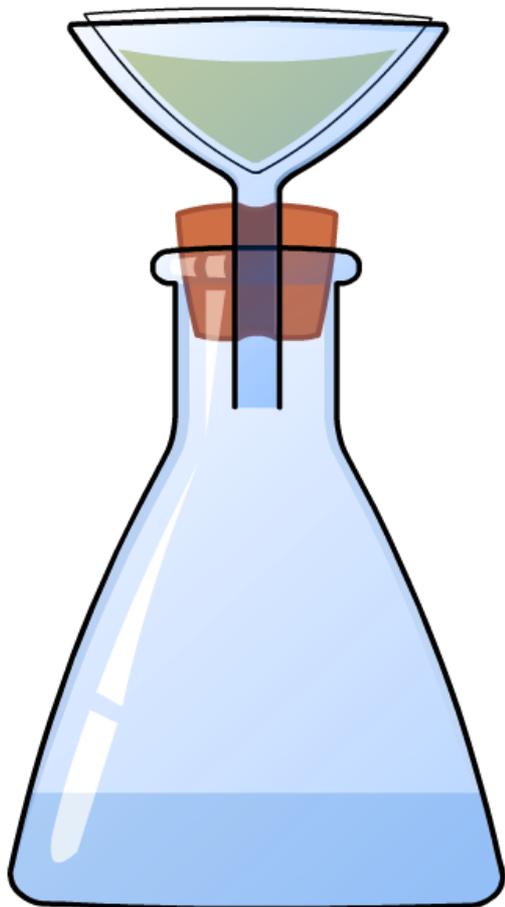
Soluble	Insoluble
All nitrates	None
Most sulphates	Lead sulphate, barium sulphate, calcium sulphate
Most chlorides, bromides and iodides	Silver chloride, silver bromide, silver iodide, lead chloride, lead bromide, lead iodide
Sodium carbonate, potassium carbonate, ammonium carbonate	Most other carbonates
Sodium hydroxide, potassium hydroxide, ammonium hydroxide	Most other hydroxides

Insoluble salts

- Insoluble salts can be formed as **precipitates** by the reaction of suitable reagents in solution



Separating and purifying insoluble salts



To prepare a pure, dry sample of an insoluble salt:

- Separate using filtration (the insoluble salt cannot pass through the filter paper)
- Purify the insoluble solid using deionised water
- Dried by leaving the excess solution to evaporate or using a warm oven

Uses of insoluble salts

- Barium sulphate is given to patients as a 'barium meal' to x-ray patients because:
 - it is opaque to x-rays
 - It is safe to use as, although barium salts are toxic, its insolubility prevents it entering the blood



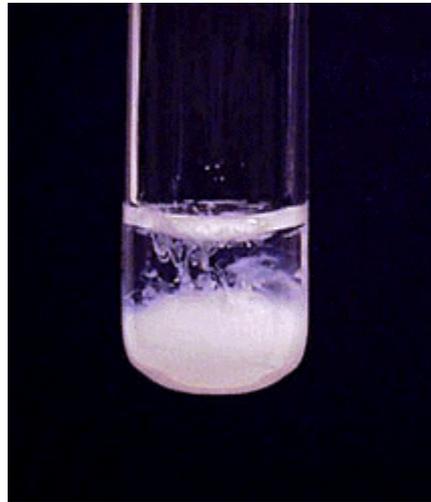
Identifying carbonate (CO_3^{2-}) ions

- Carbonates react with dilute acids to produce carbon dioxide (CO_2)
- The CO_2 can be identified by testing it with limewater
- Limewater turns cloudy/milky if CO_2 is present



Identifying sulphate (SO_4^{2-}) ions

- When hydrochloric acid and barium chloride solution are added to SO_4^{2-} ions, a white precipitate forms



Identifying chloride (Cl^-) ions

- When dilute nitric acid and silver nitrate solution are added to Cl^- ions, a white precipitate forms

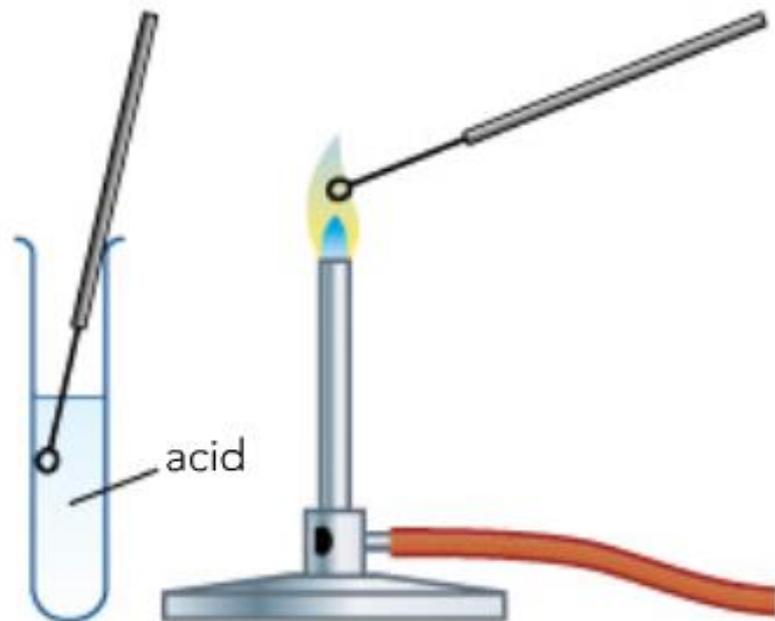


Flame tests

Metal	Flame test colour
Sodium (Na^+)	Orange-yellow
Potassium (K^+)	Lilac
Calcium (Ca^{2+})	Brick red
Copper (Cu^{2+})	Blue-Green

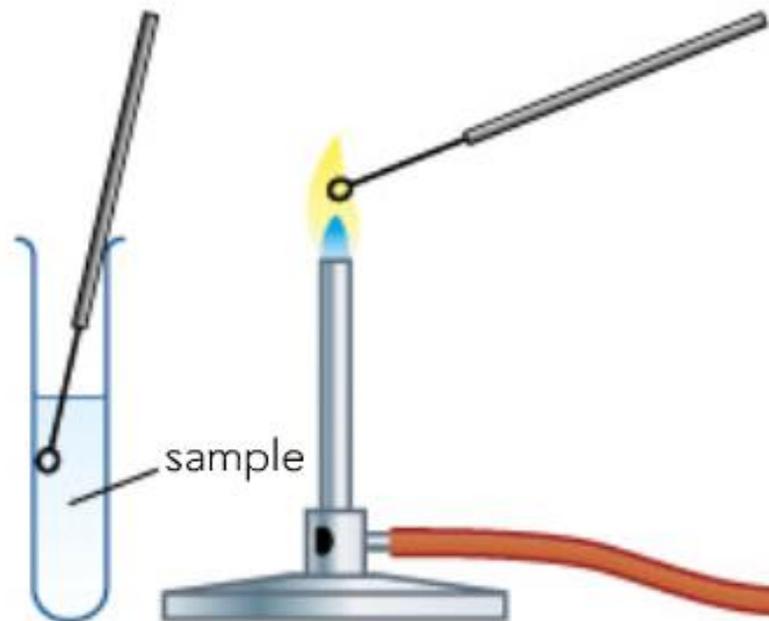


Flame tests



Step 1: Dip the flame test loop in acid, then hold the loop at the edge of the Bunsen burner flame.

Step 2: If the flame changes colour, repeat Step 1 until the loop is clean.

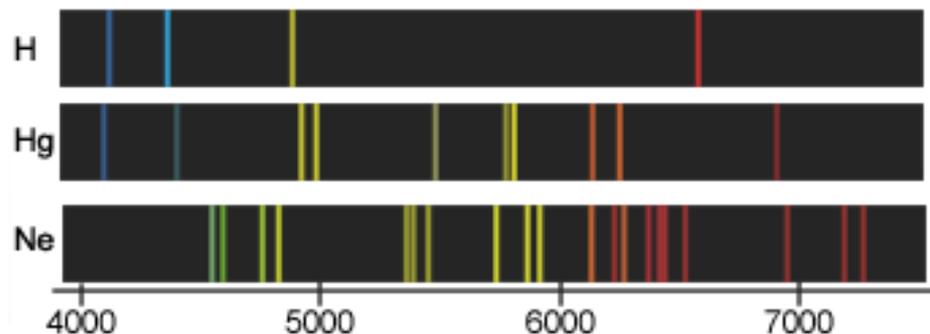


Step 3: Dip the clean flame test loop in the sample, then hold the loop at the edge of the Bunsen burner flame. Observe and record the flame colour.

Step 4: Repeat Steps 1–3 with each sample.

Spectroscopy

- Chemists use spectroscopy to detect the presence of very small amounts of elements
- This has led to the discovery of new elements, including rubidium and caesium



- Each metal has a distinct 'fingerprint'