EXPLORING SCIENCE

2nd edition

For the Junior Cycle

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Unit 3 Chemical World
Chapter 17 The chemist's compass - the periodic table

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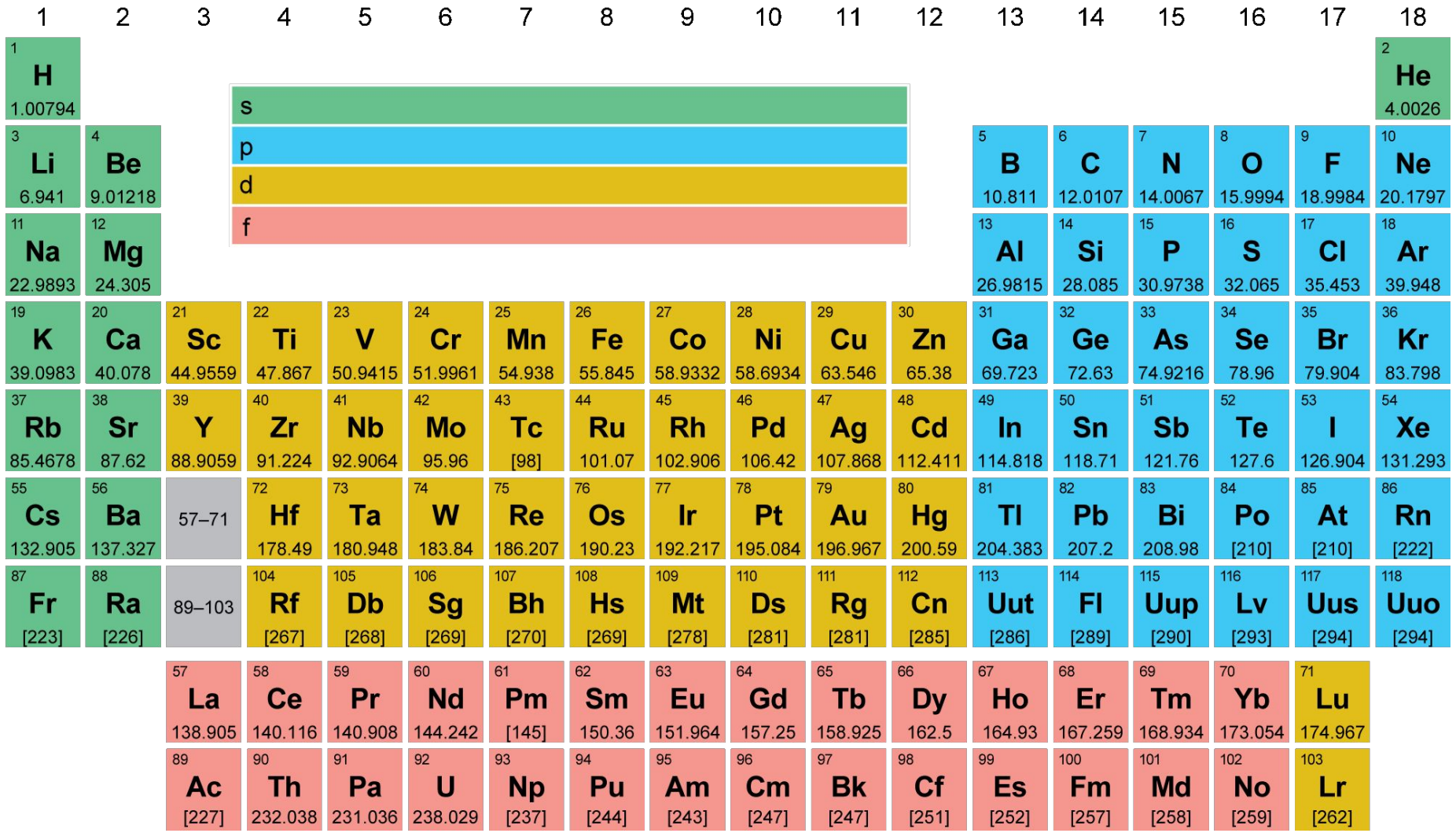
What is the periodic table?

The periodic table is considered to be one of the most important tools of the chemist. **It shows a list of all the elements**. In the 1880s, scientists discovered a number of elements. They realised that some of these elements behaved in similar ways to others. A Russian chemist called Dmitri Mendeleev arranged them in order of the mass of the atoms of each element. He also lined up elements that behaved similarly. Only about half of the elements had been discovered by this time. Mendeleev left gaps in his table for elements that had yet to be discovered.

What is the periodic table?



The modern periodic table

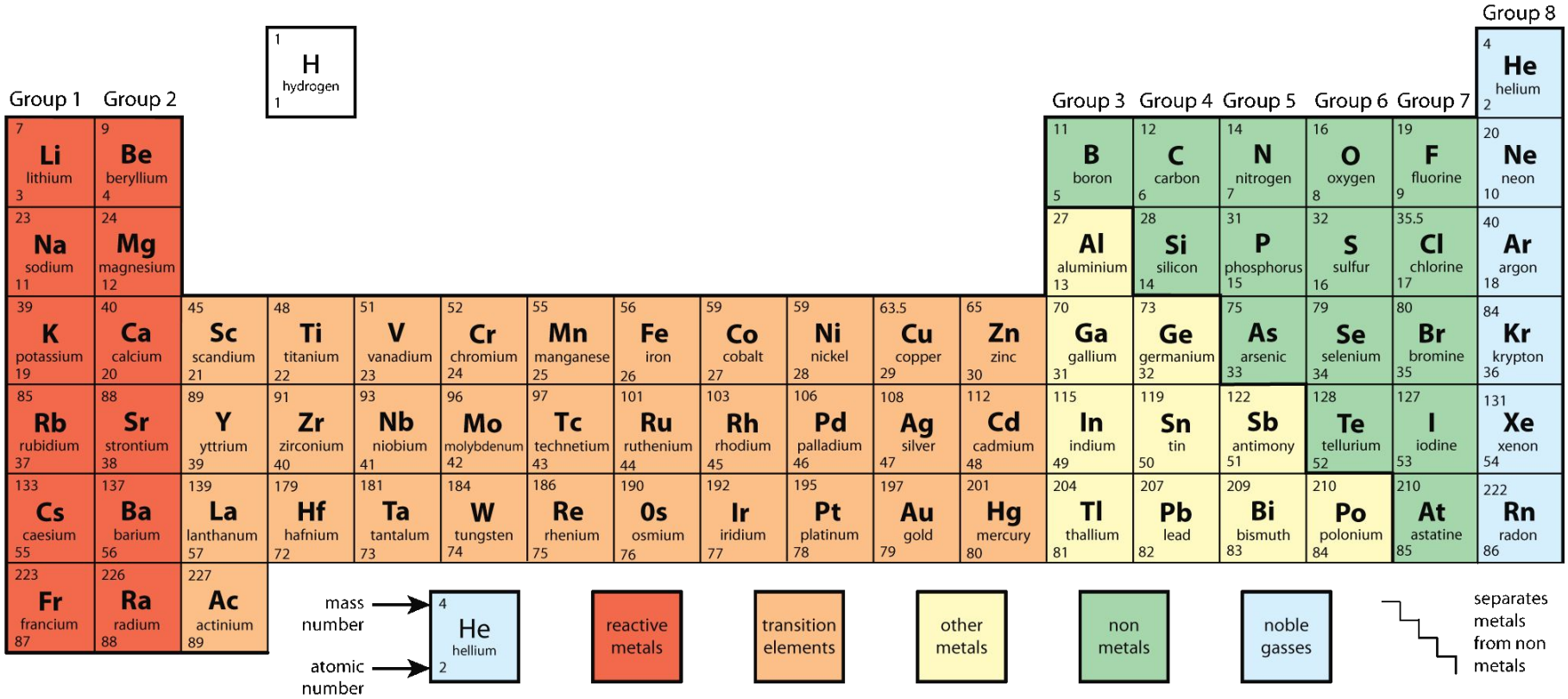
The modern periodic table has no gaps in it. The elements are not arranged according to atomic mass but by atomic number. The table is arranged into:

- **Vertical columns, called groups, in which the elements with similar physical and chemical properties (behaviours) are grouped together**
- **Horizontal rows, called periods, which are in order of increasing proton number**.

Group names

The periodic table has four named groups. They are:

- Group 1 – the **alkali** metals
- Group 2 – the **alkaline** earth metals
- Group 7 – the **halogens**
- Group 8 – the **noble gases**.



Group 1 – the alkali metals

All the alkali metals have one electron in their outer shell. The atoms 'want' to get rid of this loose electron. As a result, the alkali metals are very reactive and behave similarly. Elements in this group include:

- Lithium (Li)
- Sodium (Na)
- Potassium (K).

Reactions of alkali metals with water

When an alkali metal such as lithium is added to water it floats on the surface of the water and forms a ball shape. Hydrogen gas is released and lithium hydroxide is formed, which dissolves in the water.

lithium + water → lithium hydroxide + hydrogen

Sodium is more reactive than lithium. It may even catch fire (orange flame) as it fizzes about on the surface.

sodium + water → sodium hydroxide + hydrogen

Potassium is even more reactive than sodium. Can you predict the products of the reaction between potassium and water?

Reactions of alkali metals with water

Potassium is even more reactive than sodium. Can you predict the products of the reaction between potassium and water?

Reactions of alkali metals with water

All metals are shiny. Alkali metals look dull, but when they are cut a shiny surface is revealed. This shiny surface quickly goes dull again as the metal reacts with oxygen in the air, forming the metal oxide. For lithium the reaction with oxygen is:

lithium + oxygen → lithium oxide

For sodium the reaction with oxygen is:

sodium + oxygen → sodium oxide

Group 2 – the alkaline earth metals

Elements in this group include:

- Beryllium (Be)
- Magnesium (Mg)
- Calcium (Ca).

All elements in this group have two electrons in their outer shell. Group 2 elements are not as reactive as group 1 elements.

Group 7 – the halogens

The elements in group 7 have seven electrons in their atom's outer shell.

(The word 'halogen' also contains seven letters!) Elements in this group include:

- Fluorine (F), in the form of compounds such as sodium fluoride, which is sometimes added to water to strengthen enamel in our teeth.
- Chlorine (Cl), which is sometimes added to water to kill bacteria.

Elements in this group are 'trying' to gain an electron because they want a full outer shell.

Group 8 (group 0) – the noble gases

The elements in group 8 are all gases and have full outer shells of electrons in their atoms. As a result, the noble gases are unreactive and thus very stable. Members of the noble gases include:

- Helium (He)
- Neon (Ne)
- Argon (Ar), which is used in filament lamps (light bulbs).

What are ions?

All atoms would 'like' full outer shells and will either lose or gain electrons in order to achieve this. **When atoms lose or gain electrons they become charged particles and are called ions**. The elements that readily form ions make up groups 1, 2, 6 and 7.

- Group 1 – alkali metals. These have only one electron in the outer shell, which they lose to form a positive ion (+1), e.g. Na^{+1}.
- Group 2 – alkaline earth metals. These have two electrons in their outer shell so will lose two electrons to form a positive ion (+2), e.g. Mg^{+2}.
- Group 6 – non-metals. These have six electrons in their outer shell and so will gain two electrons for a full outer shell to form a negative ion (−2), e.g. O^{-2}.
- Group 7 – halogens. These have seven electrons in their outer shell and so will gain one electron to form a negative ion (−1), e.g. Cl^{-1}.

How are chemical bonds formed?

A compound forms when two different elements chemically combine. The question is why these elements react and combine with each other. They react to have a full outer shell of electrons. In a compound the atoms are joined by chemical bonds.

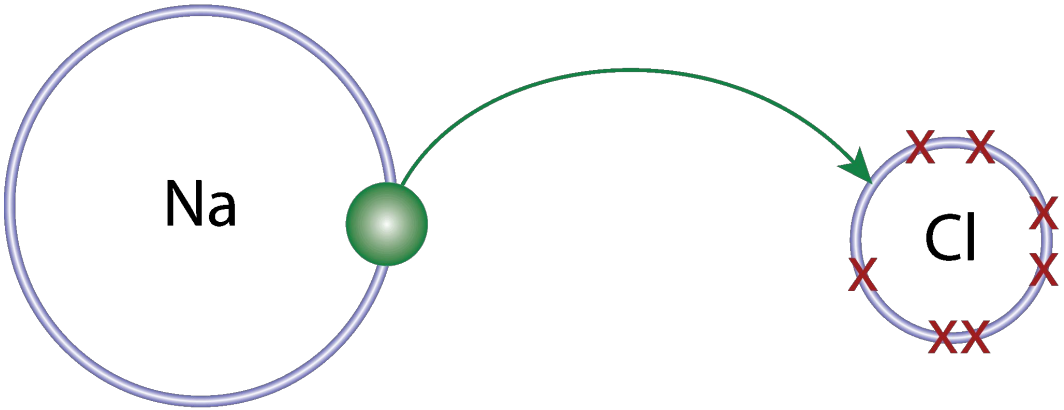
Making bonds involves atoms giving away, taking or sharing electrons. There are two ways for atoms to achieve this: ionic bonding and covalent bonding.

Ionic bonding

Ionic bonding produces a compound that is formed from a metal and a non-metal and is made up of ions. This occurs when one atom loses electrons and another atom gains electrons.

The metal atom will lose electrons to form a positive ion and the non-metal atom will gain electrons to form a negative ion. These positive and negative ions are strongly attracted to each other.

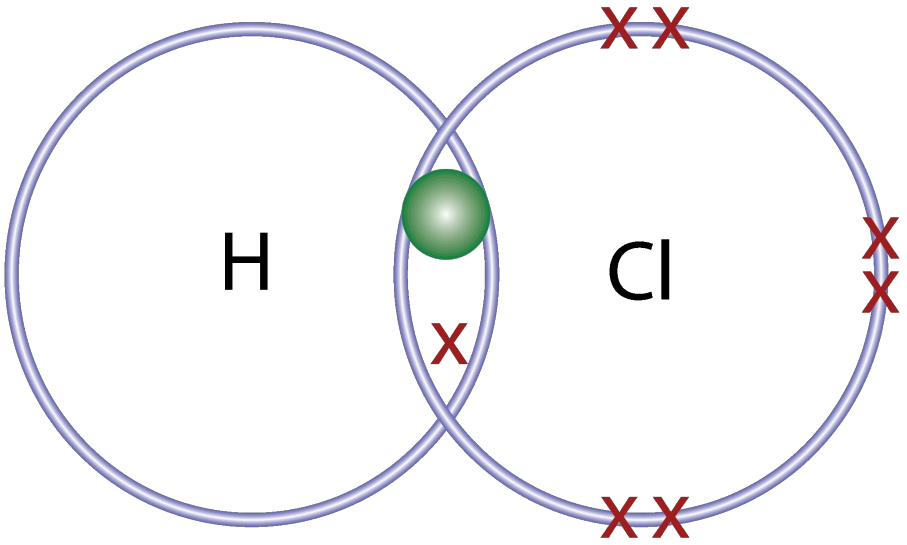
For example, sodium chloride (NaCl) is a compound formed from a metal (sodium) and a non-metal (chlorine). The sodium atom loses an electron and the chlorine atom gains an electron (below).



Covalent bonding

Covalent bonding produces a compound formed from non-metals in which each atom shares electrons with another atom. Neither atom wants to donate electrons as they both need electrons to achieve a full outer shell. The solution is that they share electrons.

For example, hydrochloric acid (HCl) is a compound formed from two non-metals (hydrogen and chlorine). A hydrogen atom bonds with a chlorine atom by sharing an electron with it. The outer shells of the two atoms overlap and they share one electron.

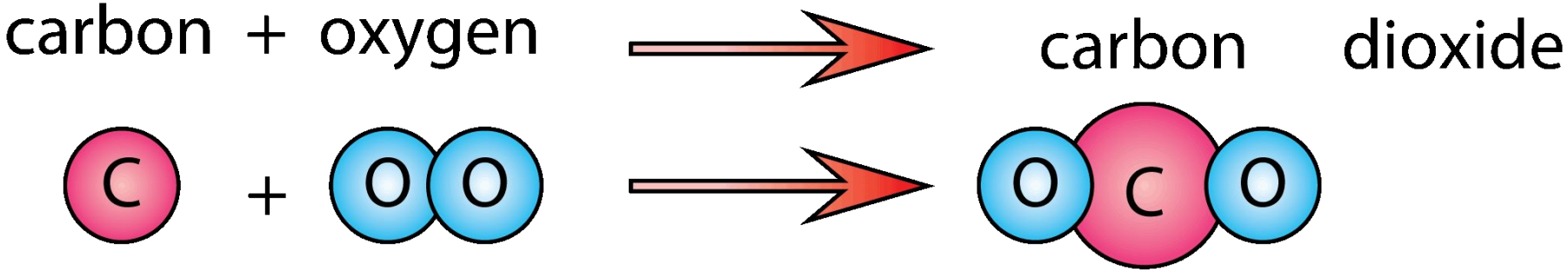


Chemical formulas

Every compound has a formula – it tells you the type and number of atoms present in a compound. The **chemical formula** is made up of letters and numbers, e.g. CH_4, H_2O.

- The letters in the formula tell you the type of atoms it is made of.
- The numbers tell you how many of that atom there are.

The chemical formula for carbon dioxide is CO_2 as it contains 1 carbon atom and 2 oxygen atoms.



Carbon dioxide is formed from a chemical reaction between carbon and oxygen

Combining metals and non-metals

When a metal and a non-metal are combined, the resultant compound is called after the name of the metal followed by the name of the non-metal, with its ending changed to '-ide'. For example:

sodium	+	chlorine	→	sodium chloride
Metal		*Non-metal*		*Compound*

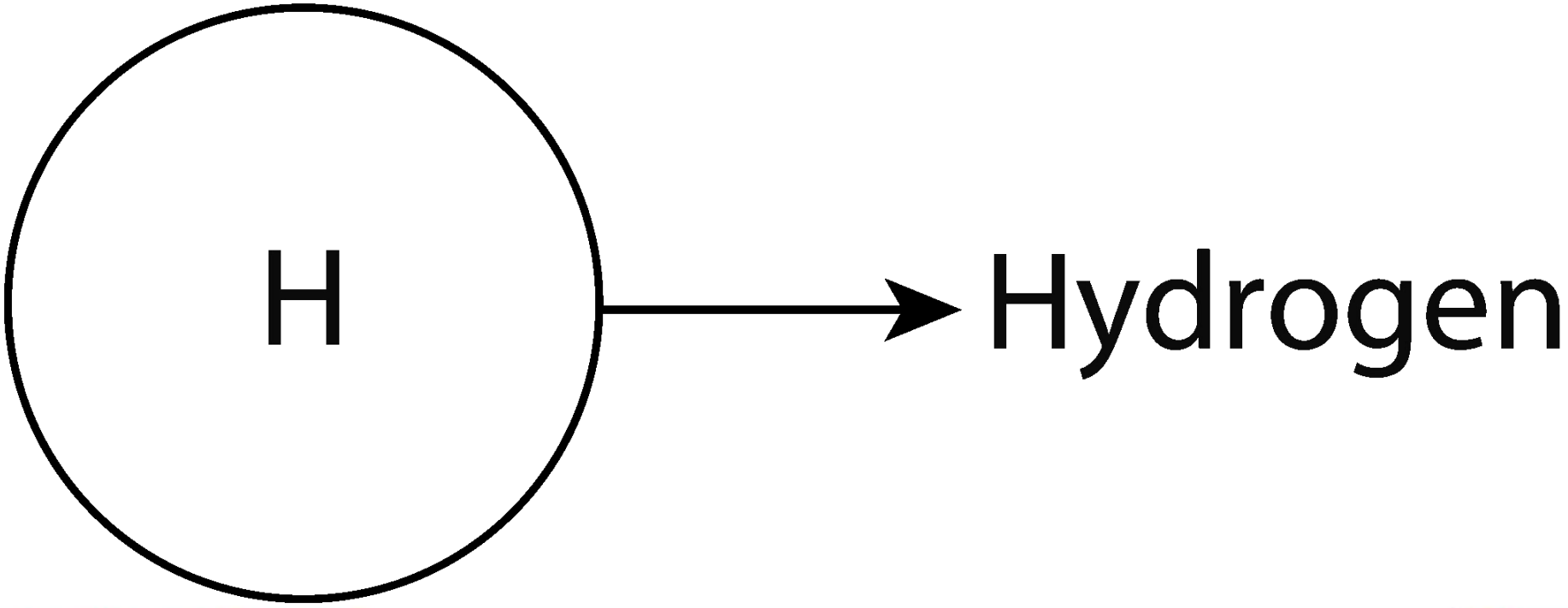
Sodium is in group 1 of the periodic table so it needs to lose one electron. Chlorine is in group 7 of the periodic table so it needs to gain one electron. So the ratio of atoms in the compound sodium chloride is 1:1: one sodium atom bonds with one chlorine atom.

$$Na + Cl \rightarrow Na^{+}1$$
$$Cl^{-1}$$

Combining non-metals and non-metals

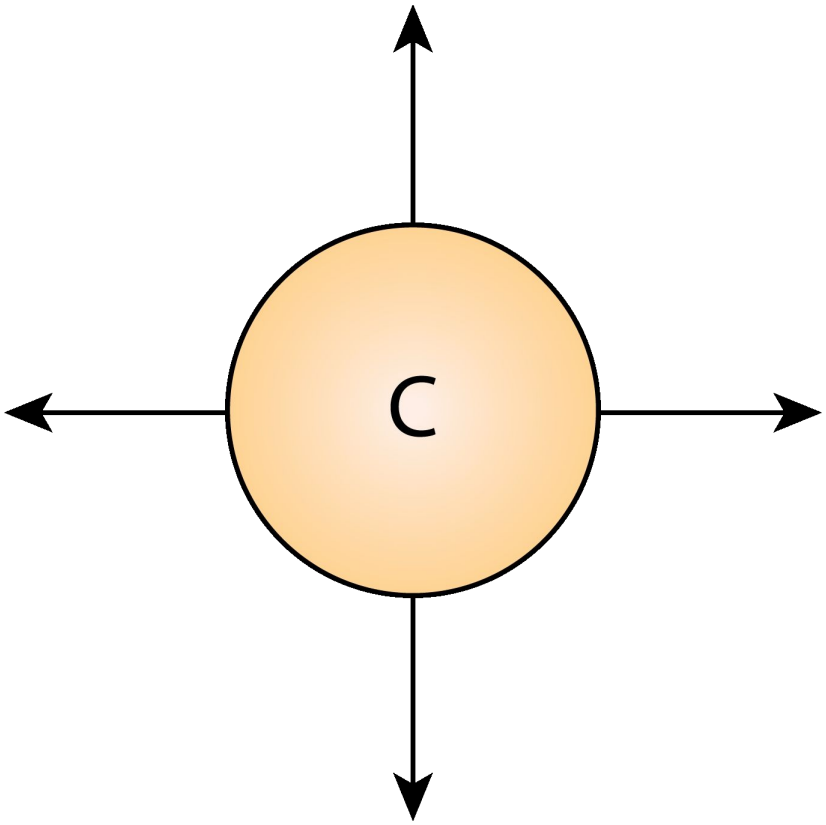
Use the periodic table to predict the ratio of atoms in compounds. You need to work out the combining power of each atom. This is the number of bonds each atom can form. For example:

- Hydrogen is in group 1 of the periodic table, which shows it has only one electron and needs one more electron in order to be stable so that it can form one bond; so its combining power = 1.



Combining non-metals and non-metals

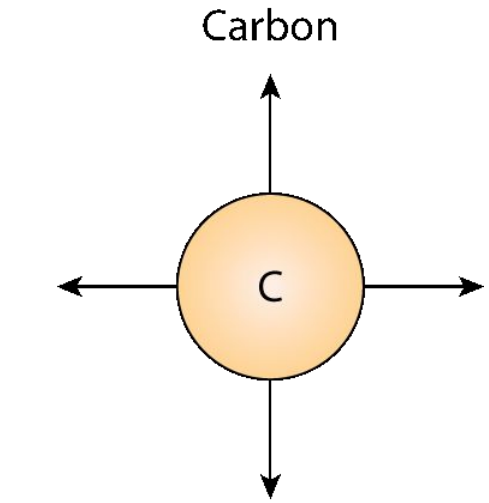
- Carbon is found in group 4 of the periodic table, which shows it has four electrons in its outer shell and it requires four more electrons in order to be stable so it can form four bonds; so its combining power = 4.

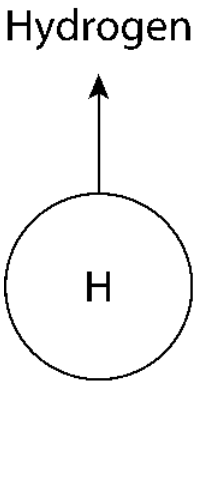


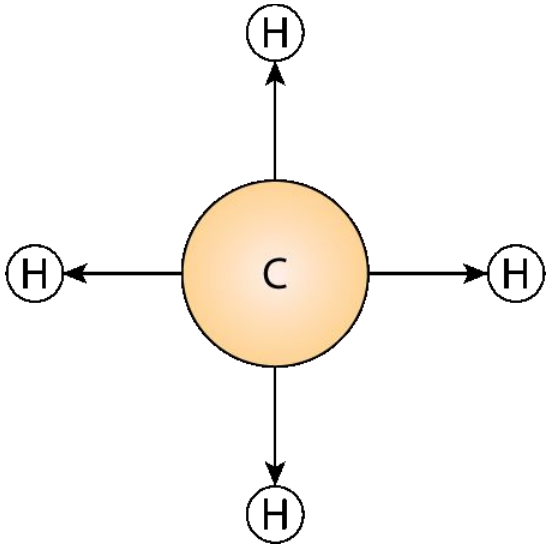
Carbon

Combining non-metals and non-metals

For carbon and hydrogen to bond and stabilise, one carbon atom (combining power = 4) requires 4 hydrogen atoms (combining power = 1) to bond with it. This combination makes the carbon atom stable because of the four hydrogen electrons, and each of the four hydrogen atoms stable because of one carbon electron. The resultant chemical formula is CH_4, which is methane (the main constituent of natural gas).







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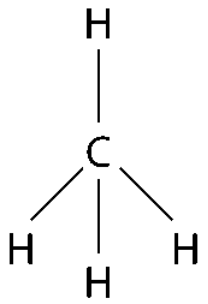
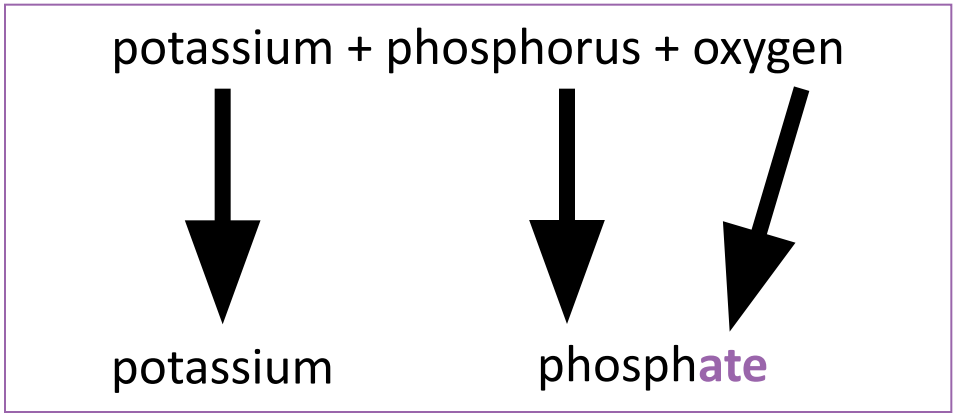


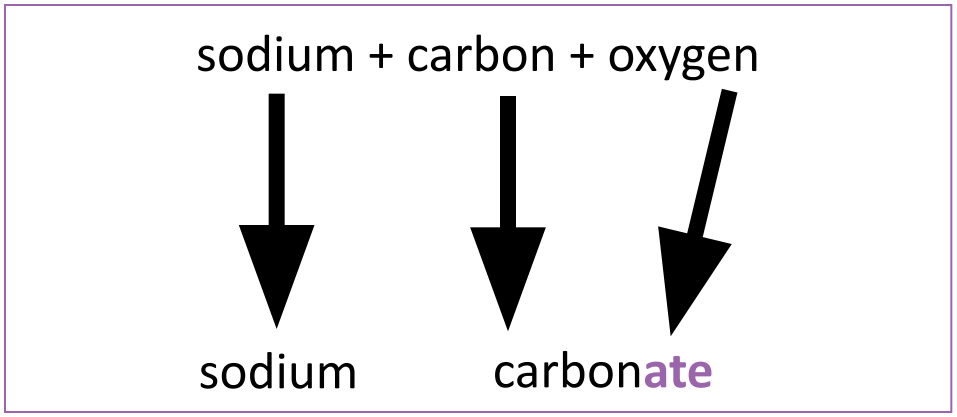
Combining non-metals and non-metals

Note: Atoms do not always obey the octet rule (eight electrons in the outer shell). For example, hydrogen, beryllium and boron have too few electrons in the outer shell to form an octet.

Combining metal atoms, non-metal atoms and oxygen

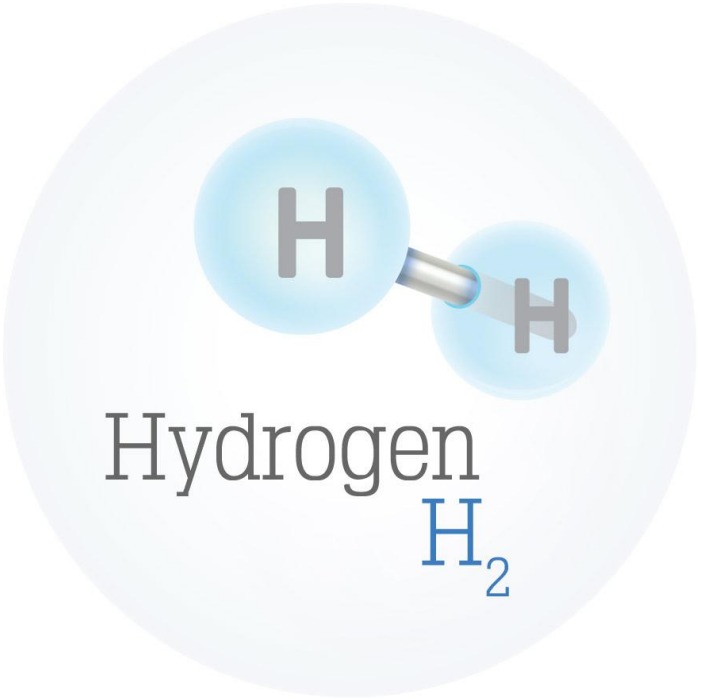
When naming compounds formed by combining a metal atom, a non-metal atom and oxygen, the name of the metal comes first, the name of the non-metal comes next and the ending is '-ate'. This occurs only when an oxygen atom is present. For example:





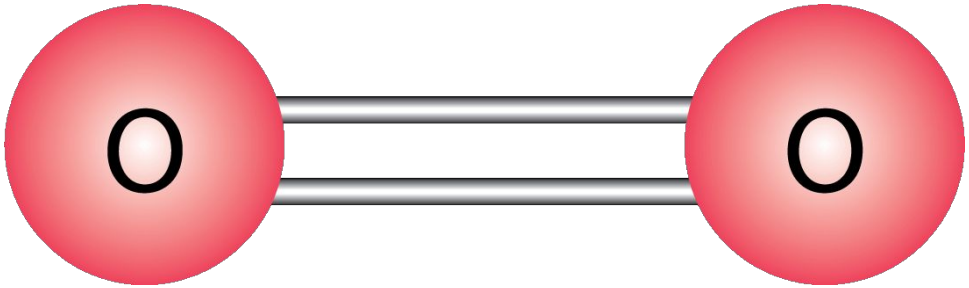
Hydrogen molecule (H_2)

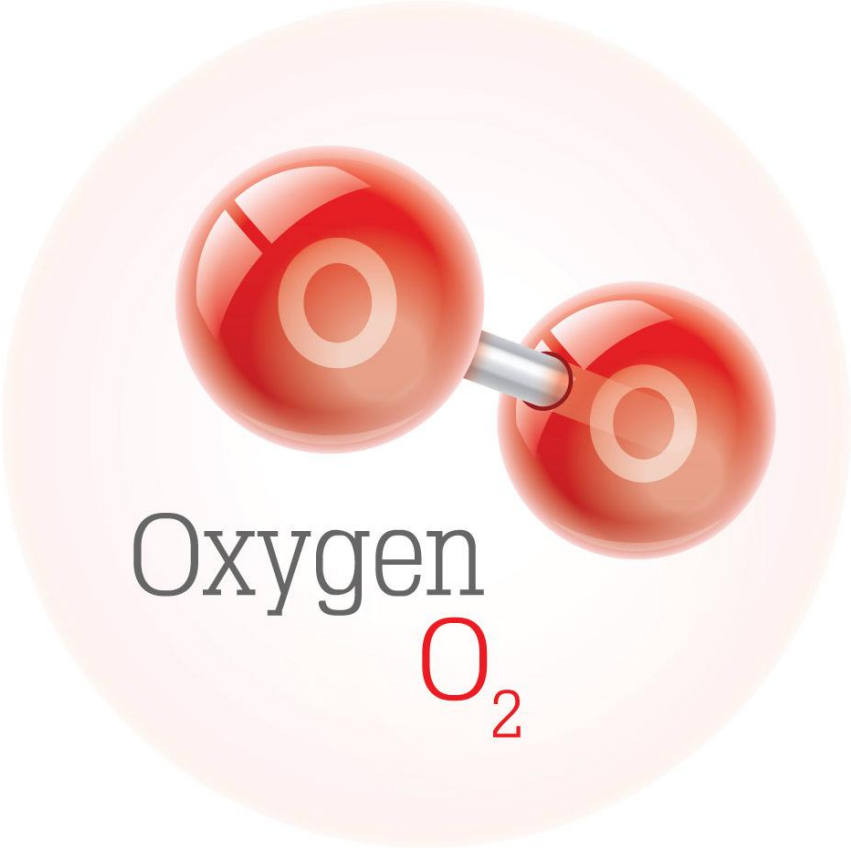
Each hydrogen atom has one electron in its shell and so has a combining power of 1. This means that two hydrogen atoms will overlap their shells and bond, forming a hydrogen molecule (H_2).



Oxygen molecule (O_2)

Each oxygen atom has six electrons in the outer shell and needs to gain two electrons to fill it and so has a combining power of 2. In an oxygen molecule, two oxygen atoms are bonded together and there is a double bond.





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