Unit 2: Structure and Bonding

Elements vs Compounds

- Elements are substances made of one kind of atom.
- There are around **100** elements, which are listed in the **Periodic Table**.
- Elements may chemically combine (bond) together in fixed proportions to make **compounds**
- Elements form bonds in order to be **more stable**.
- The type of bonding in a substance depends on whether the elements in it are **metals** or **non-metals**.

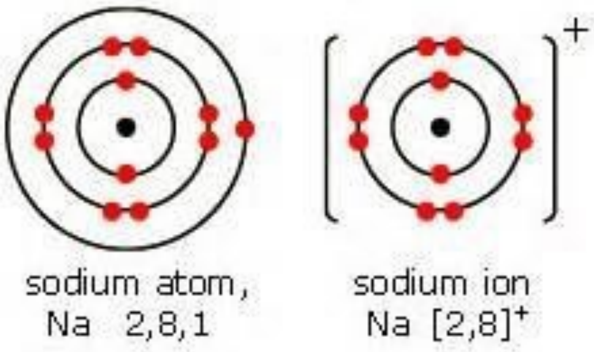
Key Term	Definitions
Alloy	A mixture containing mainly metal (may be mixed with other metals, or occasionally a non-metal such as carbon).
Atom	The smallest part of an element that can exist
Covalent Bond	A bond formed by two atoms sharing a pair (or pairs) of electrons
Electrostatic	The force between a positive and negative charge
Ion	A particle with a positive or negative charge, formed from an atom by loss or gain of electrons
Ionic Bond	A bond formed by the electrostatic force of attraction between oppositely charged ions
Metal	An element which loses electrons to form positive ions
Molecule	An uncharged particle made by two or more non-metal atoms covalently bonding together
Nanoparticle	A very small (1-100nm) particle made from a few hundred atoms
Non Metal	An element which gains electrons to form negative ions
Polymer	A very long chain made of repeating units, called monomers, covalently bonded together

Forming Ions

Atoms of elements form ions by gaining or losing electrons in order to gain a full outer shell. This is what will lead them to be most stable. The type of ion formed by an element depends on which Group in the Periodic Table it is in.

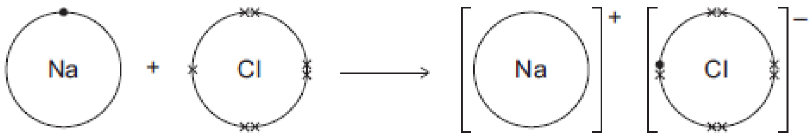
Group	What happens to the electrons	Charge on ions
1	Lose 1	+
2	Lose 2	2+
3	Lose 3	3+
4	Varies depending on circumstances. (Not covered at GCSE)	
5	Gain 3	3-
6	Gain 2	2-
7	Gain 1	-

Sodium is in Group 1, so it has 1 electron in its outer shell. It loses this 1 electron to make an ion with a + charge.

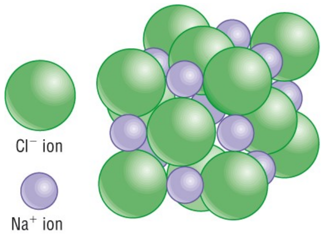


Ionic Bonding

- When a **metal** reacts with a **non-metal** they form an **ionic** compound.
- The **metal atom** loses one or more **electrons** to form **positive ions**.
- The **non-metal atom** gains one or more **electrons** to form **negative ions**.



- These ions are then held together by a **strong electrostatic force of attraction between oppositely charged ions** to form a **giant ionic lattice**.



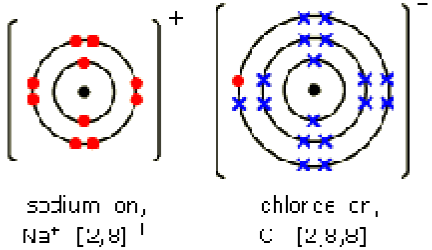
A small section of a NaCl lattice (from www.chemhume.co.uk)

Properties of Ionic Compounds

- Ionic compounds have **high melting** and **boiling points** because the forces holding them together are so strong (so they take a lot of **energy** to overcome).
- This means they are always **solids** at room temperature.
- They can only conduct electricity when they are **molten** or **dissolved** so the **ions** are free to move.

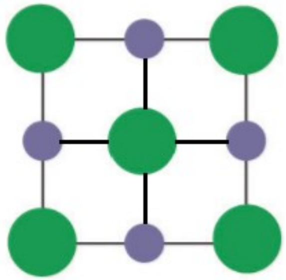
Models for ionic bonding

There are a number of ways we can represent ionic bonding. They all have **advantages** and **limitations.**



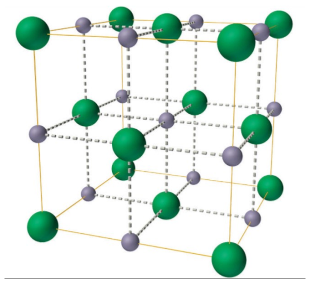
Dot and cross diagrams

These show clearly how the electrons are transferred. However, they do not show the 3D lattice structure of an ionic compound or that this is a giant compound.



2D ball and stick model of ionic bonding

This shows that electrostatic forces happen between **oppositely charged ions** in an ionic compound.
However it does not show the 3D structure. It also implies that the ions do not touch.



3D Ball and Stick model of ionic bonding

This clearly shows the 3D structure of the **ionic lattice** and how different ions interact with other ions **in all directions** to create an ionic lattice.
However, it still implies that the ions do not touch and the bonds are physical entities.

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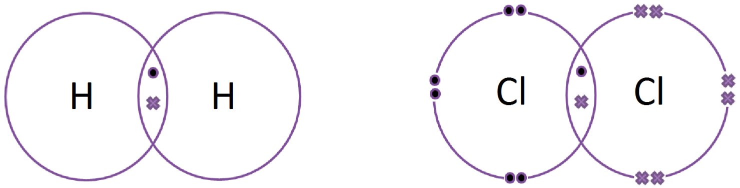
Covalent Substances

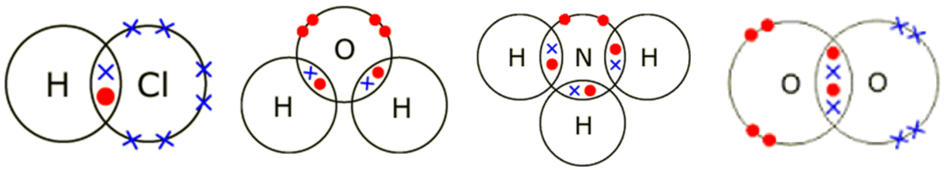
- Covalent bonds involving **sharing pairs of electrons**
- They form between two **non-metal** atoms.
- They occur in elements (e.g. hydrogen, chlorine and oxygen) and compounds (e.g. water, ammonia, methane and hydrogen chloride).

Small covalent substances

- A few **atoms** may make small covalent molecules



- Substances made of small covalent molecules have low melting and boiling points because the molecules are held together in the solid by **weak intermolecular forces** that are easily overcome by very little energy.
- The covalent molecules do **not** break when the substance is heated.
- Substances made of small covalent molecules do not **conduct electricity** because there are **no charged particles** to move and carry the charge, creating a current.
- There are seven named examples of small covalent molecules for you to draw: H_2, Cl_2, HCl, H_2O, NH_3, CH_4 and O_2.

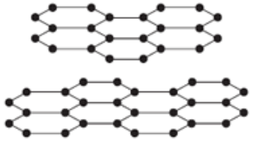


Giant Covalent Structures

- Thousands of atoms may also join together to make a **giant covalent structure**.
- These are held together by many strong covalent bonds. The substance can only melt if all of these bonds break, so giant covalent structures have high melting points.

Graphite and Graphene

- Graphite is a giant covalent structure made from **carbon** atoms.
- Every carbon atoms forms **three strong covalent bonds** to other carbon atoms.
- These form **flat sheets** of **hexagonal rings**.



- There are no strong covalent bonds *between* these layers, so the layer can slide easily over each other.
- This means graphite is **soft** and **slippery** (as the layers slide over each other), so it is used as a **lubricant**.
- Because the carbon atoms have only made 3 of 4 possible bonds, they have one "spare" **delocalised electron**. This allows graphite to **conduct electricity**.
- **Graphene** is a single layer of graphite.
- It is useful in **electronics** and **composites**.

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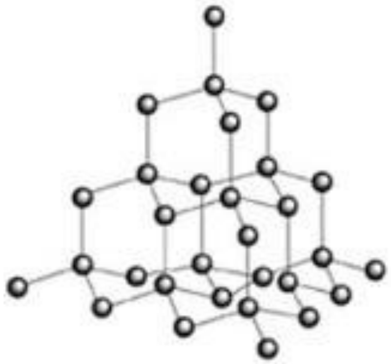
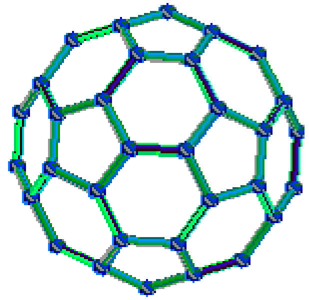
Diamond

- Diamond is another **giant covalent structure** made from **carbon**.



- Unlike graphite, each carbon atom in diamond forms **four strong covalent bonds**.
- These bonds prevent the atoms from sliding or moving past each other.
- This makes diamond very **hard**. It is used to make drill bits for this reason.
- There are no charged particles in diamond so it **cannot conduct electricity**.
- The many strong covalent bonds also mean diamond has a **very high melting point.**

Fullerenes



- Fullerenes are another form of carbon.
- They are molecules of carbon with hollow shapes, including balls and tubes.
- They are an example of a **nanoparticle**.
- Most of their structures are based around hexagonal and pentagonal rings.
- The most famous example is **Buckminsterfullerene (C_{60})**, which contains 60 carbon atoms, formed into a ball.
- Fullerenes have uses in drug delivery and as catalysts, due to their huge **surface area to volume ratio**.
- Carbon nanotubes are cylinder shaped fullerenes. These are strong and are excellent conductors of heat and electricity.

Silica / Silicon dioxide

- Silica is the common name for the compound silicon dioxide (SiO_2) .

- In the structure, every silicon atom is bonded to four oxygen atoms, while every oxygen atom is bonded to two silicon atoms.
- Like diamond, silica is very hard and has a very high melting point, because it contains so many strong covalent bonds.
- This makes it perfect for lining **furnaces**.
- It cannot conduct electricity, because it contains no charged particles.

Nanoparticles

- Nanoparticles are incredibly small particles containing just a few hundred atoms. They are 1-100nm in diameter.
- This is smaller than **fine particles** (100-2500nm or $PM_{2.5}$) or **coarse particles** (2500—10 000nm or PM_{10}). Coarse particles are referred to as **dust**.
- They are so small that they have completely different **properties** to larger particles of the same material.
- Due to their small size they have an incredibly high **surface area to volume ratio**.
- They are used in **medicine**, in **electronics**, in **cosmetics** and **suncreams** and in **deoderants**.
- They are useful as catalysts, as it is much more likely that the reactants will collide with them than with a larger particle.
- Some people are concerned about the safety of them as they have not yet been fully tested.

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Metals

- The metals are found in the **left**-hand side of the **Periodic Table**
- Most elements are metals
- Atoms of metals will lose electrons to form **positive ions**.

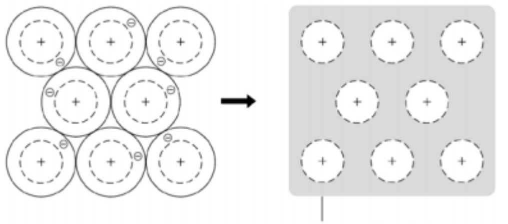
Properties of metals

Typically metals:

- Are hard and strong
- Have high melting and boiling points
- Are good conductors of heat and electricity
- Are malleable and ductile

Structure of metals

Metals are made up of **regular rows of positive ions**, surrounded by a sea of **delocalised electrons**

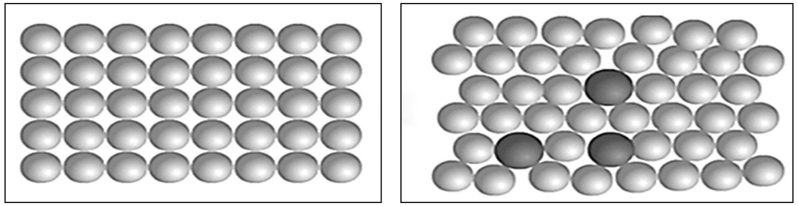


The **strong electrostatic force of attraction** between the positive ions and negative electrons forms a **metallic bond**. The strength of this bond is what gives metals a high **melting point**.
The **delocalised electrons** are able to carry charge, and therefore allow metals to conduct electricity.

Alloys

Many **pure** metals are too **soft** to be useful, so they are made into **alloys**.

An alloy is a **mixture** containing mainly metal.
In an alloy, the regular rows of ions are **distorted**, due to the difference in size of the particles.



This means the rows are no longer able to slide over each other. This makes alloys **harder**.

Polymer

- Polymers are **very** long chains of repeating units called **monomers**.
- The monomers are joined by **strong covalent bonds**.
- Because the polymer chains are so long (often containing thousands of atoms) the **intermolecular forces** between those chains are quite strong. This means that polymers are solid at room temperature.
- Some polymers also contain **strong covalent bonds** between layers. These are sometimes called **cross-links**.
- Polymers are named according to the monomer they are made out of e.g. the polymer made from ethene is called poly(ethene).
- Polymers can be given different properties (e.g. melting point and tensile strength) based on the **reaction conditions** when they are made (e.g. **temperature**, **pressure** and the use of a **catalyst**).