St Ninian's High School

Chemistry Department

National 5 Chemistry

Unit 1: Chemical Changes & Structure

Section 3: Bonding & Properties of Substances

Summary Notes

Name _____

Learning Outcomes

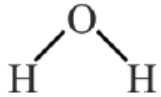
After completing this section you should be able to :

1 state that atoms can be held together by bonds
2 describe a covalent bond as a shared pair of electrons
3 explain the covalent bond as a situation in which two positive nuclei are held together by their common attraction for the shared pair of electrons
4 draw a diagram to show how the outer electrons form a covalent bond
5 draw a diagram to show the shape of a molecule for simple two-element compounds
6 state that covalent compounds (solid, liquid, solution) do not conduct electricity
7 state that metal elements and carbon (graphite) are conductors of electricity and that most non-metal elements are insulators of electricity
8 state that ionic bonds are the electrostatic attraction between positive and negative ions
9 state that ionic solids exist as networks/lattices of oppositely charged ions
10 explain why ionic compounds do not conduct electricity in solid state and why these compounds do conduct electricity when dissolved in water or when molten
11 state that solid compounds can be ionic or covalent and that compounds which exist as liquids or gases at room temperature are covalent
12 explain why ionic and covalent network substances are solid (high melting points), and why covalent molecular substances can be solid, liquid or gas (low melting points)
13 identify the elements which are formed when an ionic solution is electrolysed, explaining the products at each electrode, in terms of positive metal ions being attracted to the negative electrode and negative non-metal ions being attracted to the positive electrode.

Covalent Bonding

Molecules

The join between atoms in an element or different atoms in a compound is called a **bond. Covalent** bonds are usually formed between non-metal elements. A covalent bond is a pair of electrons shared by two atoms. The shared pair of electrons holds the atoms together. A group of atoms held together by covalent bonds is called a **molecule**. A molecule made of only two atoms bonded together is called a **diatomic** molecule.

E.g. A water molecule 

Since water contains 2 hydrogen atoms and 1 oxygen atom it has the chemical formula H_2O.

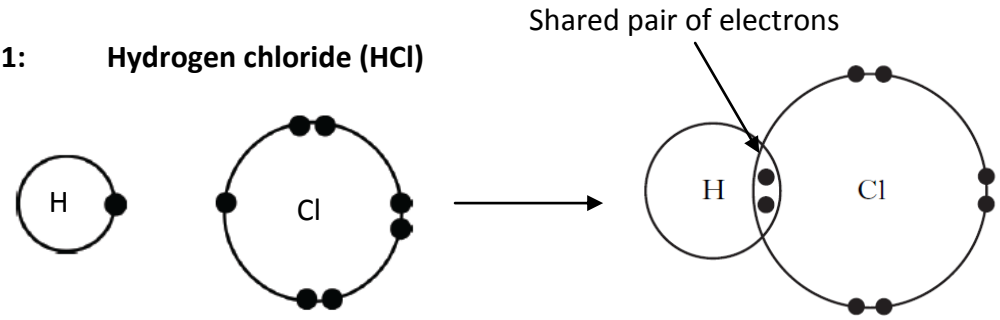
The chemical formula of a substance tells us which elements it is made from and also the number of atoms of each element in one molecule of the substance.

Covalent Bonding

Covalent Bonding using Electron Shells

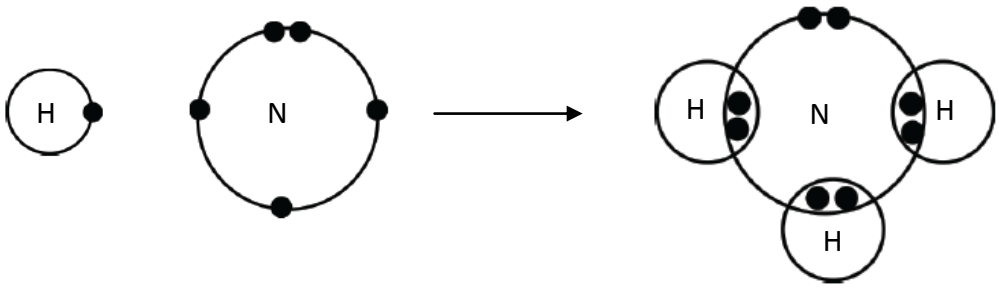
The noble gases have full outer energy levels and are therefore unreactive. When atoms form covalent bonds they share electrons in order to gain a full outer energy level. An electron sharing diagram can be used to show the sharing of electron pairs which make up covalent bonds.

Example 1: **Hydrogen chloride (HCl)**



Hydrogen atom Chlorine atom Hydrogen chloride molecule

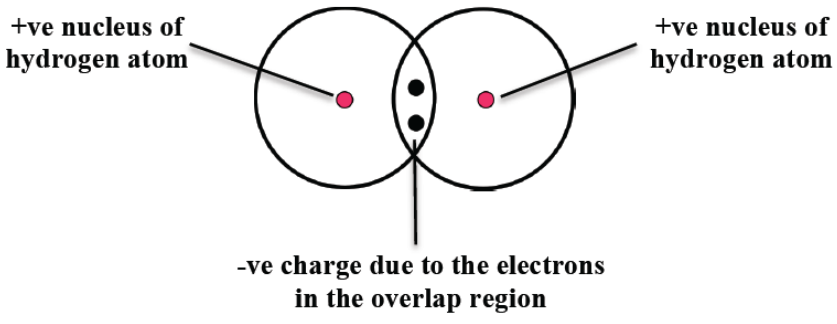
Example 2: **Nitrogen hydride (NH_3)**



Hydrogen atom Nitrogen atom Nitrogen hydride molecule

What holds a Covalent Bond together?

The negatively charged electrons are attracted to the positively charged nuclei. A lot of energy is needed to break this force of attraction i.e. to break a covalent bond.



+ve ↔ -ve ↔ +ve

Covalent Bonding

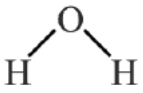
Shapes of Molecules

The chemical formula for covalent substance indicates the number of atoms of each element present but it gives no indication of the shape of a molecule. In some molecules the atoms are arranged in a straight line (called linear), e.g. hydrogen chloride.

Hydrogen chloride, a **linear** molecule: H—Cl

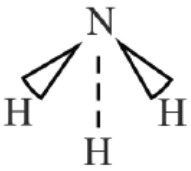
Water is an example of a flat molecule which is bent in shape.

Water, a flat **bent** molecule:



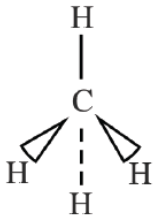
Nitrogen hydride (ammonia) is an example of a 3 dimensional molecule which is pyramidal in shape.

Ammonia, a **pyramidal** molecule:



Carbon hydride (methane) is also 3 dimensional and is tetrahedral in shape.

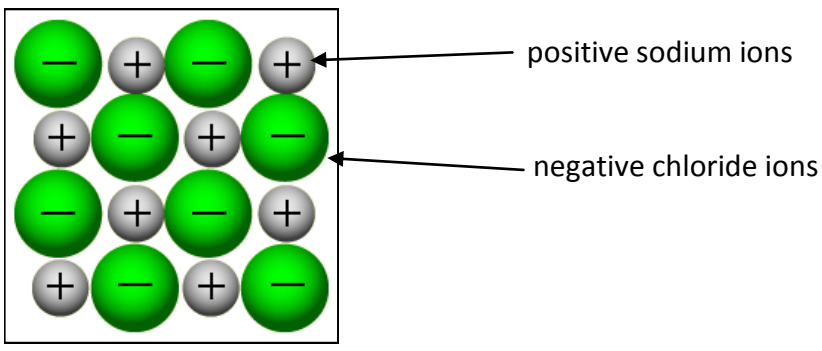
Methane, a **tetrahedral** molecule:



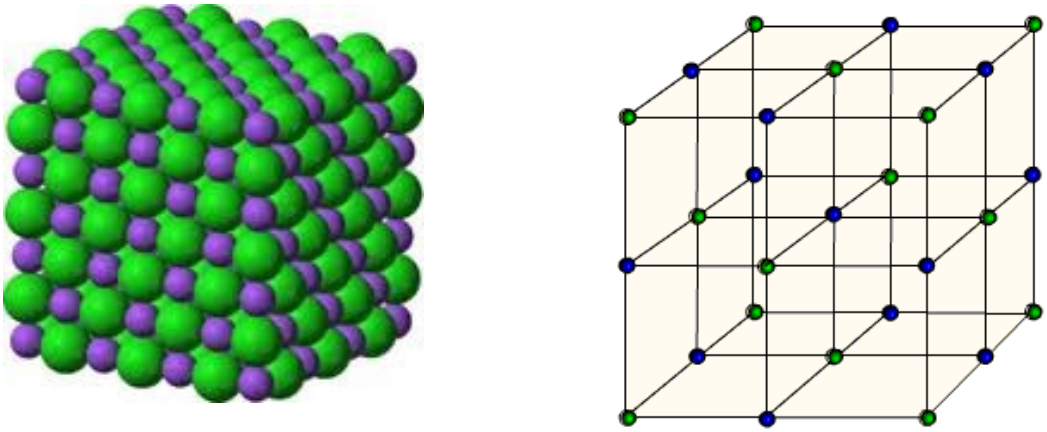
Ionic Bonding

Ionic compounds contain both positively charged ions and negatively charged ions. Positive ions attract negative ions and the electrostatic force of attraction between oppositely charged ions is known as an **ionic bond**. The ions in an ionic compound are arranged in a pattern forming an **ionic lattice**. This arrangement will repeat in all directions.

Example: Sodium Chloride



Ionic Bonding

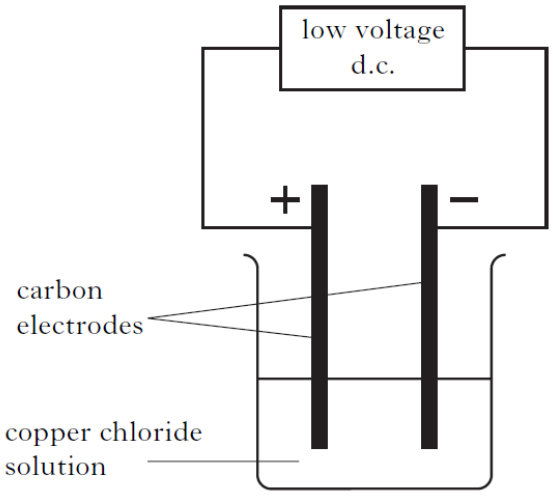


3 dimensional diagrams of the sodium chloride lattice.

Metal ions are positively charged and non-metal ions are negatively charged. Group 1 elements form ions with a charge or +1. e.g sodium ions Na^+ with an ion electron arrangement of 2, 8. Group 7 elements such as chlorine form ions with a charge of –1, e.g. chloride ions Cl^- with an ion electron arrangement of 2, 8.

Electrolysis

Electrolysis is the breakdown of a substance using an electric current (electricity). An electric current is a flow of charged particles either electrons or ions. In carrying out an electrolysis experiment a d.c. (direct current) power supply must be used to ensure that one product is formed at each electrode.



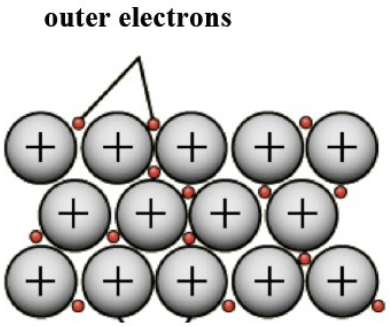
In this example copper ions (Cu^{2+}) will be attracted to the negative electrode forming copper and the chloride ions (Cl^-) will be attracted to the positive electrode forming chlorine gas.

Carbon in the form of graphite is used as electrodes since it is the only non-metal element which conducts electricity. Graphite is also cheap and will not react.

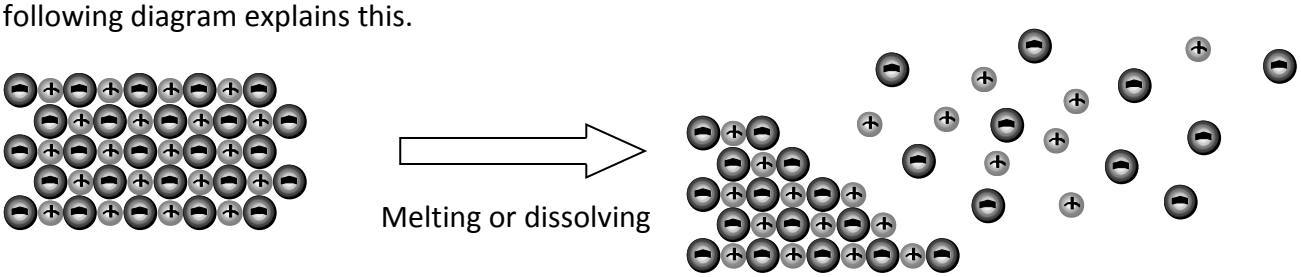
Ionic Bonding

Explaining Conduction

Electricity is a flow of charged particles. The charged particles which flow are either ions or electrons. In metals (and graphite) it is the outer electrons of atoms (delocalised electrons) which are able to move as shown in the diagram below.



Ionic substances will not conduct electricity as solids. This is due to the fact that ions are not free to move in a solid as they are arranged in an ionic lattice. When an ionic substance is dissolved in solution or molten the ionic lattice is broken down allowing the ions to move freely and so conduction occurs. The following diagram explains this.



ions in crystal lattice

- ions can't move
- ionic solid can't conduct

ions in solution or melt (molten/liquid)

- ions break away from lattice
- ions free to move around
- ionic solution or melt can conduct

A molten substance or a solution which conducts is called an **electrolyte**. Molten ionic compounds or ionic solutions are examples of electrolytes. In electrolysis experiments the positive ions are attracted to the negative electrodes and vice versa.

Knowing the electrical conductivity of a substance allows you to be able to predict the type of bonding in a substance. The following conduction rules can be used:

Rule 1: All metals conduct as solid or as a liquid.

Rule 2: All non-metals (except graphite) and covalent substances are electrical insulators.

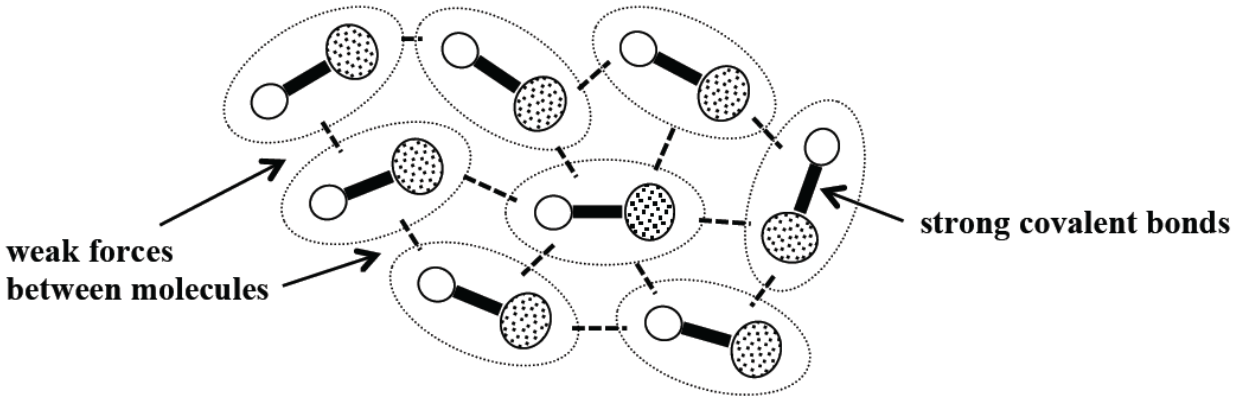
Rule 3: Ionic substances do not conduct as solids but do conduct when molten or in solution.

Bonding Comparisons

Covalent Molecular Substances

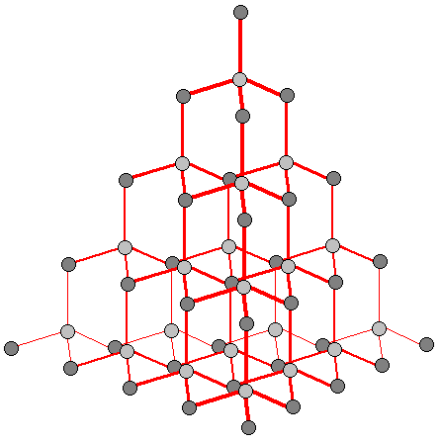
Covalent bonds are formed when atoms **share electrons** creating strong bonds. In a molecular substance groups of atoms are held together in molecules. Covalent molecular substances have low melting and boiling points and usually exist as liquids or gases at room temperature.

When a covalent molecular substance is melted or boiled the strong bonds between atoms are not broken but instead the much weaker forces between the molecules which are broken.

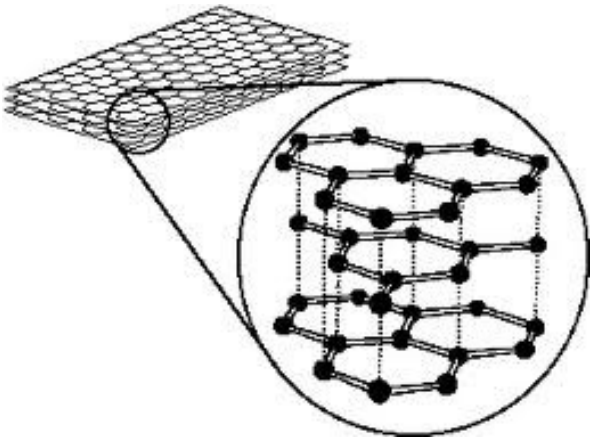


Covalent Networks

Some covalent substances do not exist as molecules but instead exist as giant **covalent network** structures such as carbon, silicon, boron and silicon dioxide.



Structure of Diamond



Structure of Graphite

To melt a covalent network requires a lot of energy since every strong covalent bond must be broken down. This is unlike covalent molecular substances where only weak forces must be broken at the melting or boiling point.

Bonding Comparisons

- **Covalent molecular substances have low melting and boiling points. (< 100°C)**
- **Ionic substances have high melting and boiling points. (≈ 800°C)**
- **Covalent network substances have very high melting and boiling points. (> 1500°C)**
- **Metals usually have high melting points although it is lower for some e.g. mercury.**
- **The melting and boiling points along with electrical conductivity data allows the type of bonding and structure to be determined.**

Section 1.3 Summary Statements

- ☐ Atoms can be held together by bonds.
- ☐ A covalent bond is a shared pair of electrons.
- ☐ A covalent bond is held together since the two positive nuclei are attracted to the shared pair of electrons.
- ☐ Diagrams can be drawn to show the shape of molecules.
- ☐ Covalent compounds (solid, liquid, solution) do not conduct electricity.
- ☐ Metal elements and carbon (graphite) are conductors of electricity but non-metal elements are insulators of electricity.
- ☐ Ionic bonds are the electrostatic attraction between positive and negative ions.
- ☐ Ionic solids exist as networks/lattices of oppositely charged ions.
- ☐ Ionic compounds do not conduct electricity in solid state as the ions are not free to move.
- ☐ Ionic compounds conduct as liquids or when in solution as the ions are free to move.
- ☐ Covalent molecular compounds exist as liquids or gases at room temperature since they have low melting and boiling points.
- ☐ On melting a molecular substance it is only the weak forces between molecules which are broken.
- ☐ Ionic substances have high melting points and are solid at room temperature.
- ☐ Covalent network substances (diamond) have very high melting points since every covalent bond must be broken to melt the substance.
- ☐ In an electrolysis experiment an electric current is used to break up a substance.
- ☐ A d.c. supply must be used during electrolysis to ensure one product is formed at each electrode.
- ☐ An electrolyte is a liquid or solution which can conduct electricity.
- ☐ During electrolysis of an ionic substance the positive ions will be attracted to the negative electrode and the negative ions will be attracted to the positive electrode.
- ☐ Graphite electrodes are often used during electrolysis since graphite conducts electricity, is cheap and will not react.