C1: Stoichiometric Relationships

1.1: The Particulate Nature of Matter

1.2: The Mole Concept

1.3: Reacting Masses and Volume

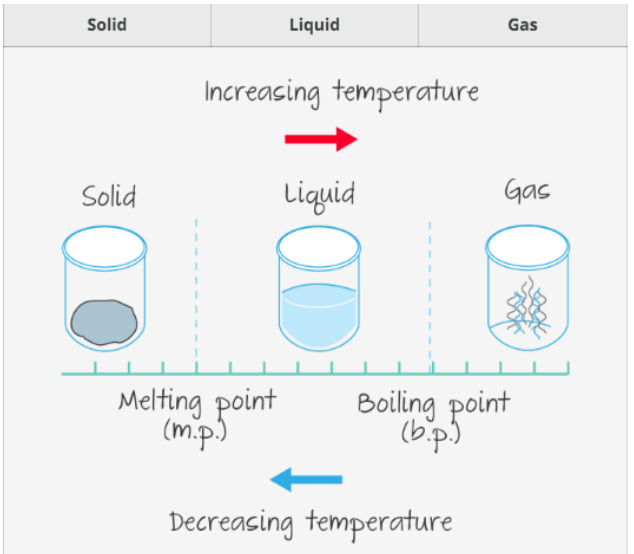
1.1: The Particulate Nature of Matter

Stoichiometry

Stoichiometry is the relationship between the amounts of reactants and the amounts of products in a chemical reaction. The application of the ideas of stoichiometry allows chemists to determine what amounts of substances should react together and to predict how much product will be formed.

States of Matter

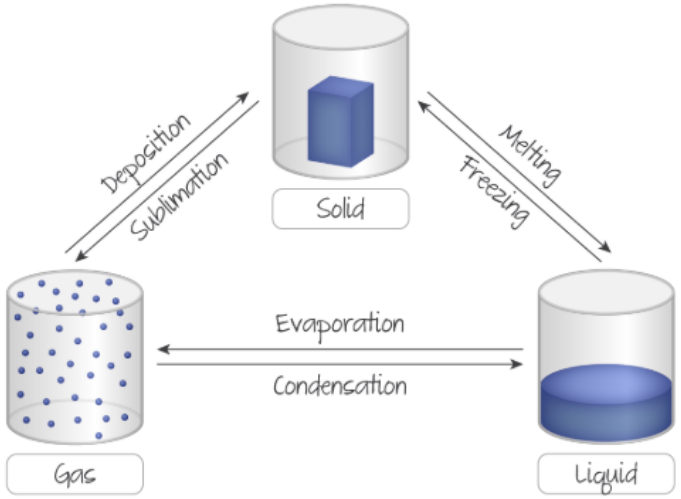
Matter can exist in different states depending on the temperature and pressure. The different physical states are characterised by the different arrangement and movement of the particles. This is dependent on the amount of kinetic energy that the particles possess.



Solid	Liquid	Gas
Particles closely packed	Particles slightly more spread out	Particles very spread out
Strong forces between particles, they vibrate about fixed positions	Weaker forces between particles, they can move past each other	Negligible forces between particles, they move randomly
Fixed shape	Take the shape of the container	No fixed shape
Fixed volume	Fixed volume	No fixed volume

Changes of State

Changes of state at constant pressure are directly related to changes in temperature. An increase in temperature causes an increase in the average kinetic energy of the particles in a substance. When heated, the particles gain kinetic energy and are able to overcome the intermolecular forces that exist between them, which results in a change of state.



Change of state	Description	Energy absorbed or released?
Sublimation	Solid to gas (with no liquid state)	Absorbed
Deposition	Gas to solid (with no liquid state)	Released
Evaporation	Liquid to gas	Absorbed
Boiling	Liquid to gas	Absorbed
Condensation	Gas to liquid	Released
Freezing	Liquid to solid	Released
Melting	Solid to liquid	Absorbed

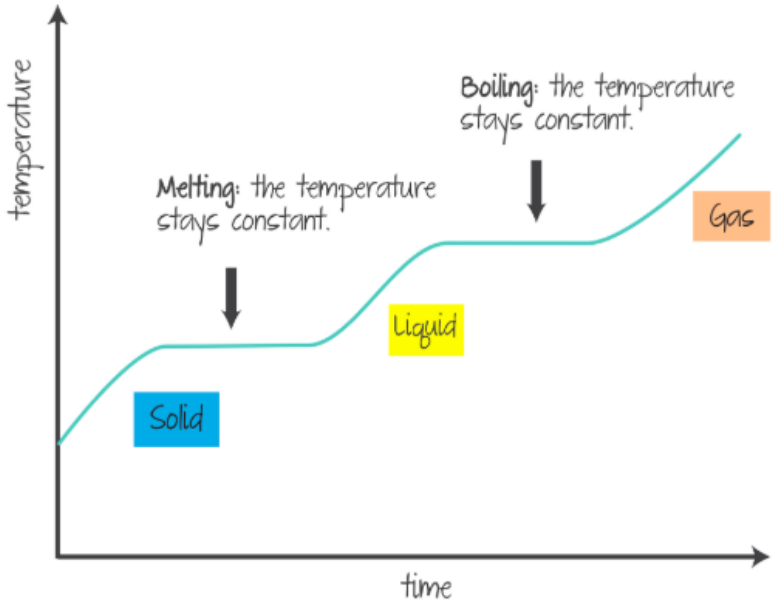
Substances that undergo sublimation at atmospheric pressure:

- Iodine
- Carbon dioxide
- Aluminum chloride

Evaporation differs from boiling in that it takes place only at the surface of a liquid and can occur at temperatures below the boiling point of the liquid. Boiling occurs at a specific temperature and takes place throughout the liquid. Bubbles of gas are formed within the liquid, not only at the surface.

Heating and Cooling Curves

Heating and cooling curves can be produced by either heating a solid, or by freezing a liquid and observing the temperature change.



In the upward sloping regions of the graph, the temperature increases as the substance is heated. The kinetic energy of the particles increases and they vibrate and move faster. However, during the changes of state the temperature remains constant as the energy is being used to overcome the intermolecular forces.

During melting, the energy input is being used to overcome the intermolecular forces that hold the particles in the solid fixed positions. This explains why, during a change of state, the temperature remains constant.

Density

Density: Mass per unit volume. The units of density are usually given as g cm^{-3} or kg m^{-3}.

To calculate the density, *d* or *ρ* (the Greek letter rho), of a substance, its mass, *m*, is divided by its volume, *V*.

$$d = \frac{m}{V}$$
$$m = dV$$

Elements

Elements can be thought of as the building blocks of the universe. Elements are made up of the same kind of atom and cannot be broken down into simpler substances by chemical means.

We now know of over one hundred elements, of which ninety-two occur naturally. Elements can be divided into metals and non-metals. There are also a small number

of elements that have properties of both metals and nonmetals, which are known as semi-metals or metalloids.

Compounds

Elements combine in chemical reactions to make compounds. A compound is a substance composed of two or more different elements that are chemically combined. When atoms of different elements react, they lose their characteristic properties. The properties of the elements are replaced by those of the new compound formed in the chemical reaction.

This point is illustrated in the reaction between sodium and chlorine to produce the compound sodium chloride (NaCl). Sodium is a member of the alkali metals, a group of very reactive metals that react vigorously with water. Chlorine is a toxic gas that was used as a chemical weapon during World War One, as well as being used to kill bacteria in water treatment.

The reaction between sodium and chlorine produces sodium chloride, a white solid, according to the following equation:

$$2Na_{(s)} + Cl_{2\,(g)} \rightarrow 2NaCl_{(s)}$$

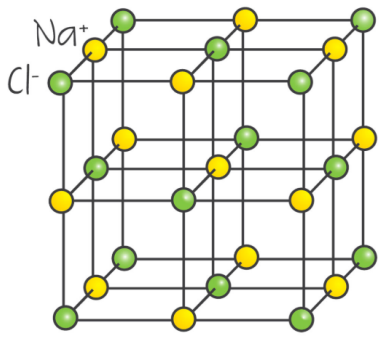
Sodium chloride is a relatively safe substance that has been used for centuries to flavour our food. The important point here is that the properties of sodium chloride are very different from the elements that it is made from.

Chemical Formulae

The chemical formula of NaCl and H_2O indicate the ratio of the atoms that make up the compound. H_2O exists as discrete molecules that consist of one oxygen atom and two hydrogen atoms. Other compounds such as ethanol (C_2H_5OH) and carbon dioxide (CO_2) also exist as discrete molecules.

Molecules are electrically neutral (they do not have a positive or negative charge) although some molecules have a dipole (a slight positive or negative charge).

Note that molecules such as H_2, O_2 and N_2 are not compounds because they are composed of the same kind of atom bonded together.



It is incorrect to use the term 'molecule' when discussing ionic compounds such as sodium chloride. NaCl is a formula unit which