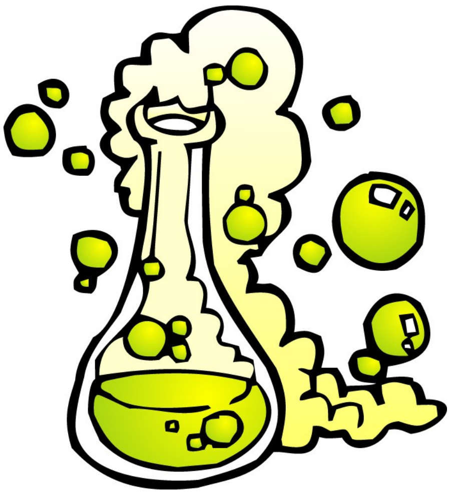
Chemistry Department



S3 Chemistry

Unit 1

Chemical Changes & Structure

Section 1.1

Rates of Reaction

Summary Notes

Name ____

Learning Outcomes

After completing this Section you should be able to :

1 state that all chemical reactions involve the formation of one or more new substances
2 identify a chemical reaction by a change in appearance of a substance
3 identify a chemical reaction by a detectable energy change
4 give examples of chemical reactions which occur in our day-to-day lives
5 describe how particle size, concentration and temperature affect the rate of a reaction
6 state that catalysts are substances which speed up chemical reactions but are not used up and can be recovered chemically unchanged
7 describe and demonstrate how to collect a gas produced by a chemical reaction
8 calculate the average rate of a chemical reaction from experimental data.

Signs of Chemical Reactions

A chemical reaction takes place when substances react together and are changed into **new substances**. Many chemical reactions are accompanied by noticeable signs. Often a colour change is observed, a gas produced or a solid (precipitate) formed. In all chemical reactions an energy change occurs and a new substance is produced.

There are many chemical reactions that produce gases. Common gases produced are carbon dioxide, oxygen and hydrogen each of which has an identification test.

Gas	Identification Test
Carbon Dioxide	Turns lime water milky (cloudy)
Oxygen	Relights a glowing splint
Hydrogen	Burns with a “pop”

Reactions which release heat energy cause the temperature of the surroundings to increase and are called **exothermic** reactions. Reactions which absorb heat and cause the temperature of the surroundings to decrease are called **endothermic** reactions.

Everyday Reactions

Chemical reactions do not just take place in a school laboratory or in industry. They make up a major part of our day to day lives. A reaction in plants, photosynthesis, produces the oxygen which animals need. Fruit ripening on plants, milk turning sour, logs burning in a fireplace and cars rusting, are other reactions which happen in our everyday lives. Many chemical reactions are happening inside our bodies, for example, food being digested in our stomachs and oxygen reacting with food in our body cells.

Rates of Chemical Reactions

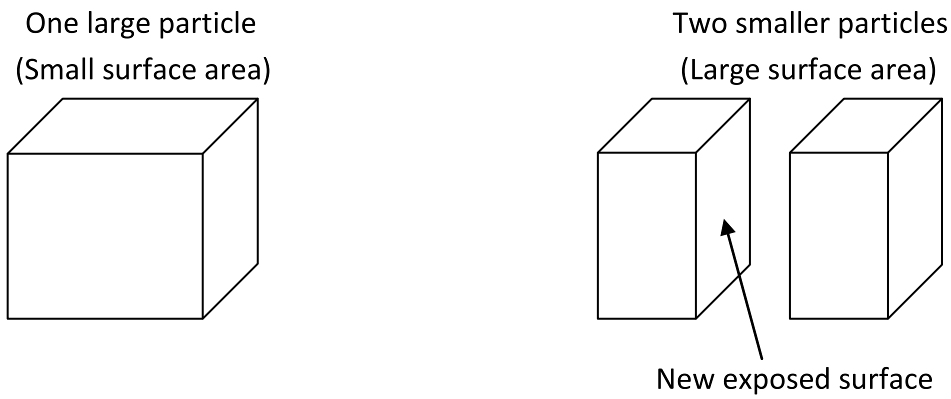
Chemical reactions do not all occur at the same rate (speed). In the laboratory the reaction between an acid and alkali is instantaneous but the reaction between magnesium and dilute hydrochloric acid to form bubbles of gas takes place over minutes. Other reactions are very much slower and can take years.

Chemical Collisions

Before a chemical reaction can take place between two substances they must be brought into contact. This is necessary, because for a new substance (**product**) to be formed the starting particles (**reactants**) must collide with each other. The speed of a reaction can be changed by making changes to particle size (surface area), concentration and temperature of the reactants.

Particle Size/Surface Area

Particle size refers to the size of solid reactant particles in a reaction. Solid reactants may exist as one large piece or much smaller pieces even a powder. Consider the following diagram.



As the size of the pieces decreases new surface is exposed. The surface area is increased by breaking up lumps into chips or even grinding it into a powder. Overall a decrease in particle size increases the surface area and so the number of collisions increases causes an increase in the rate of reaction.

Concentration

The concentration of a solution is a measure of the number of particles present in a given volume of solution. In chemistry we measure concentration in terms of moles of solute per litre of solution written as **mol l^{-1}** (Topic 7). Consider the following diagram.

An increase in concentration causes an increase in the number of collisions and therefore an increase in the rate of reaction.

Rates of Chemical Reactions

Temperature

The temperature of substance is a measure of the **average kinetic energy** of particles. A substance at a higher temperature will contain particles which have more kinetic energy and are therefore moving around more. Particles which move around more are more likely to collide and therefore react therefore an increase in temperature causes an increase in the rate of reaction. In general the rate of reaction doubles with each 10°C rise in temperature.

Catalysts

Catalysts are substances that can be used to increase the rate of a reaction. Different catalysts are required for different reactions. Catalysts are therefore said to be “reaction specific”.

Catalysts provide an “easy route” from reactants to products but they are not used up during the course of a reaction and can be recovered unchanged at the end of the reaction. The mass of catalyst at the end of a reaction will therefore be the same as that at the start of the reaction.

Enzymes

Enzymes are biological catalysts which are catalysts found in living things. In our body we have thousands of enzymes which catalyse reactions in the body allowing them to take place faster at lower temperatures. Enzymes in our mouth (saliva) and stomach help the breakdown of foods. Biological washing powders contain enzymes. Enzymes cause a peeled banana or apple to turn brown quickly.

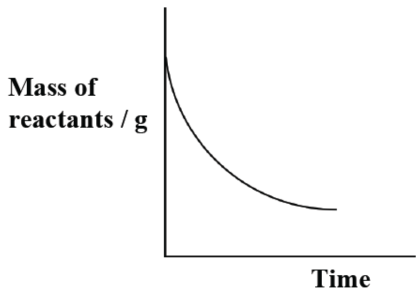
Measuring Rates of Reactions

As a reaction proceeds, reactants are being used up while products are being formed. The rate at which this happens can be followed by measuring the change in a “property” of a substance involved in the reaction over a period of time, e.g. the reaction of calcium carbonate with dilute acid.

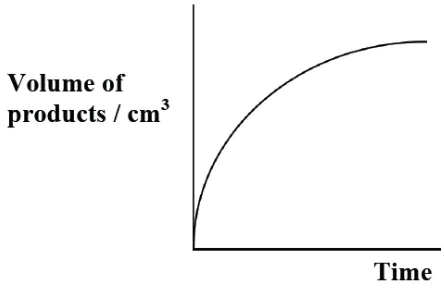
Calcium carbonate + Hydrochloric acid $\longrightarrow$ Calcium Chloride + Water + Carbon dioxide

The change in mass (due to a gas being given off), volume of gas produced, concentration of acid or the pH of the acid can all be measured as the reaction proceeds. The speed of change directly relates to the speed of the reaction.

As this reaction proceeds the mass of the apparatus will decrease and this can be plotted to produce a graph e.g.

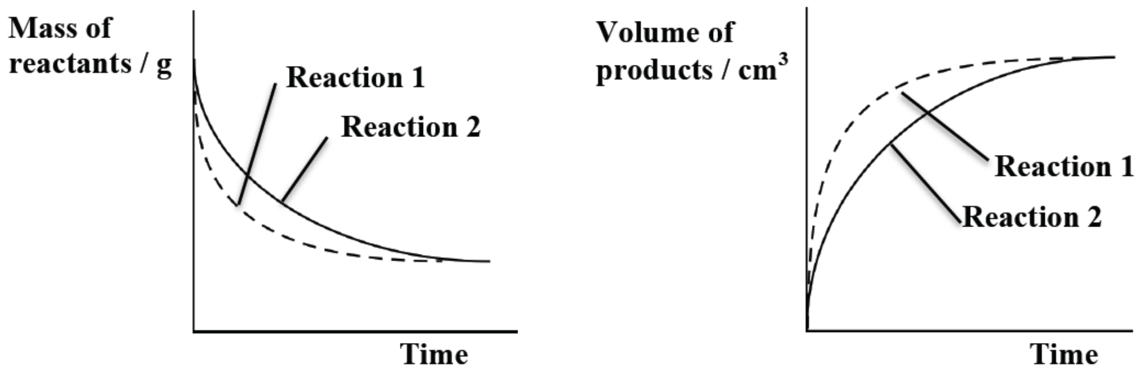


Alternatively as the volume of gas will increase as a reaction proceeds this could also be plotted e.g.



Special probes can be used to measure changes in concentration and also pH.

The rate of reaction is most rapid at the start and decreases as the reaction proceeds. The steeper the slope, the faster the rate of reaction, e.g. in the examples below, Reaction 1 is faster than Reaction 2.

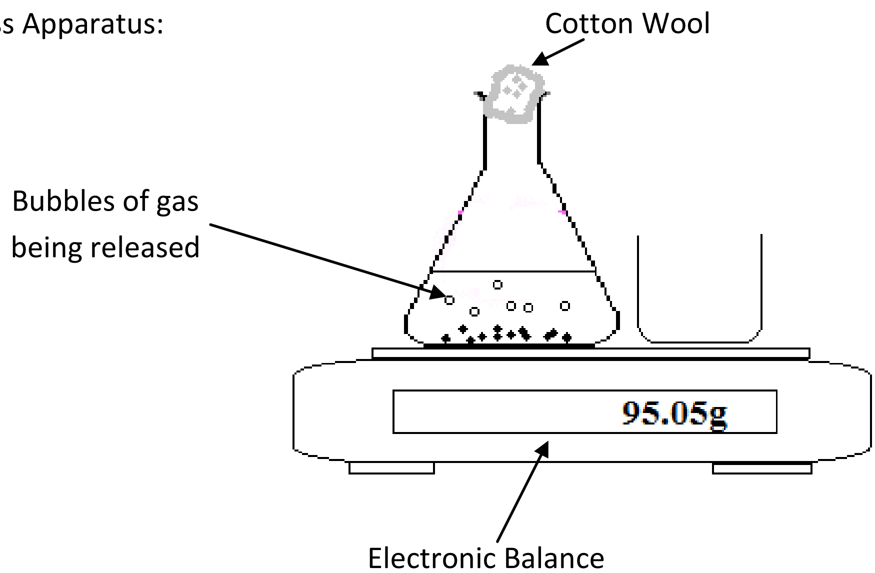


The shorter the time for a particular change to take place, the faster the rate of reaction.

Monitoring Mass Changes

In the reaction of marble chips and acid a gas is produced and therefore the mass of the apparatus will decrease as the reaction proceeds, this loss in mass can be measured.

Mass loss Apparatus:



Rates of Chemical Reactions

Average Rate of Reaction

The **average rate** of reaction can be defined as the measured change (mass for example) divided by the time take for this change to occur i.e.

$$\text{Average rate} = \frac{\text{measured change}}{\text{time taken}}$$

The units used for average rate depend on the measured change and the units of time used. For example if the change in mass was measured in grams and the time measured in minutes then the units of average rate would be grams per minute, written as g min^{-1}.

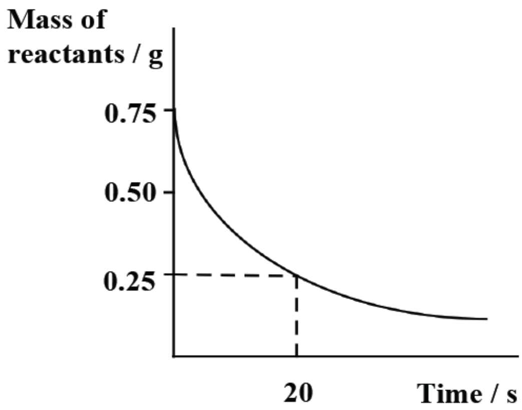
Example

The average rate of reaction over the first 20s is:

$$\frac{\text{change in mass}}{\text{time}} = \frac{0.75 - 0.25}{20}$$

$$= \frac{0.5}{20}$$

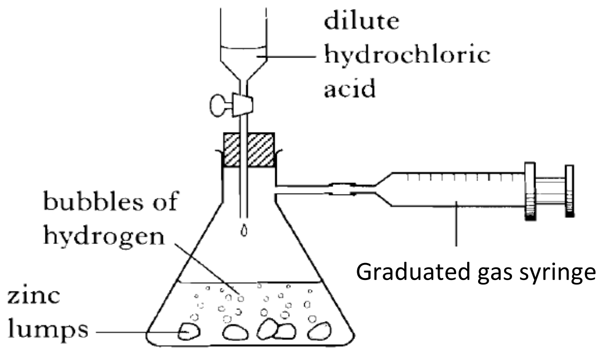
$$= \mathbf{0.025\ g\ s^{-1}}$$



Monitoring Volume Changes

The volume of gas can be monitored when a reaction releases a gas.

Sample apparatus to measure volume of a gas produced using a syringe:



Alternatively the gas can be collect using a water trough and measuring cylinder.
The average rate of a reaction can be calculated using change in volume (page 7) as the measured change. The units used this time could be cm^3 for volume and seconds for time and therefore the units of average rate would be cm^3 per second written as cm^3 s^{-1}.

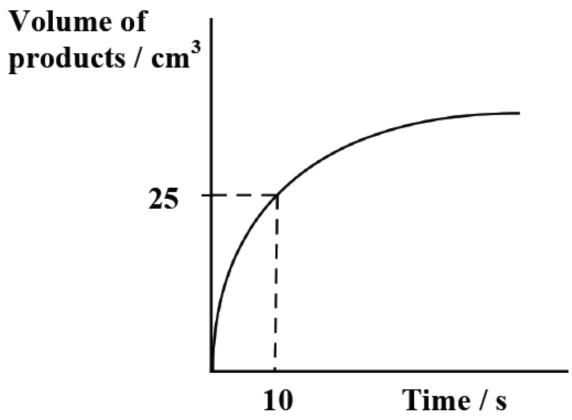
Rates of Chemical Reactions

Example

The average rate of reaction over the first 10s is

$$\frac{\text{change in volume}}{\text{time}} = \frac{25 - 0}{10}$$

$$= \mathbf{2.5\ cm^3\ s^{-1}}$$



Experiments can be repeated using the same quantity of reactants but under conditions where the rate is different. If the same quantity of reactants is used in different reactions then it can be expected that the same volume of gas will be produced or the same mass of gas will be released.

Section 1.1 Summary Statements

- ☐ All chemical reactions involve the formation of one or more new substances.
- ☐ Chemical reactions are often detectable by a colour change, a solid produced or a gas being released.
- ☐ Chemical reactions always occur by a detectable energy change. Exothermic reactions release heat to the surroundings, endothermic reactions absorb energy.
- ☐ The rate of a chemical reaction can be increased by decreasing particle size (increasing surface area), increasing concentration and increasing temperature.
- ☐ For a reaction to occur reactant particles must first collide, if the number of collisions increases the rate of reaction will also increase.
- ☐ A catalyst is a substance which can speed up a chemical reaction but will not used up and can be recovered chemically unchanged.
- ☐ Enzymes are biological catalysts which help speed up reactions in living things.
- ☐ The average rate of reaction is found using the following relationship:

$$\text{Average rate} = \frac{\text{measured change}}{\text{time taken}}$$