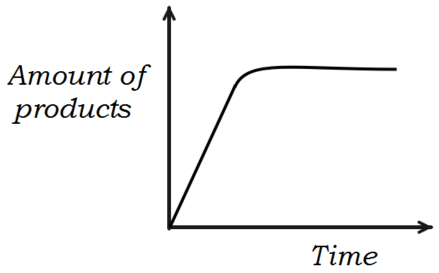
NTARE SCHOOL
S.4 CHEMISTRY
RATES OF REACTION (KINETICS)

Rate of chemical reaction is the amount of the products formed per unit time or is the amount or reactants consumed or used up per unit time

i.e rate $= \frac{\text{amount of products formed or amount of reactants used up}}{\text{time taken}}$

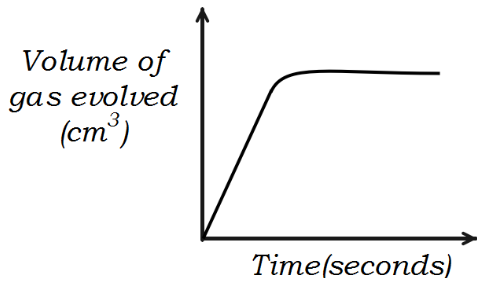
A graph of products formed against time is shown below



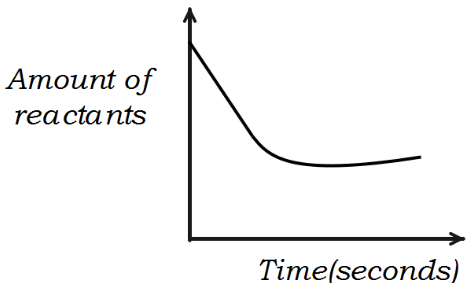
At the beginning, the amount of the product is low and increases as time goes on.
As the reactants get used up, the reaction slows down and when there are no more reactants the reaction stops and the curve becomes horizontal/constant.
At the point where the curve becomes horizontal, it means that the maximum amount of the product has been formed.

The rate of reaction can be determined by
1. measuring the volume of a gas evolved with time
2. measuring mass of reactants remaining with time

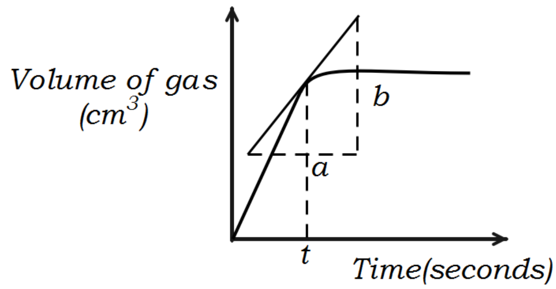
This can be illustrated by the graphs below
(i) when volume is to be measured



(ii) when mass is to be measured



From the above graphs, the rate of reaction at any time is determined by calculating the gradient of the tangent of the curve at that time



From the graph, the rate of reaction at time $t = \frac{\text{change in volume}}{\text{change in time}} = \frac{b}{a}$

The following reactions can be used to determine the rate of chemical reactions

(i) $Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$
Rate of chemical reaction is obtained by collecting and measuring the volume of the hydrogen gas produced.

(ii) $CaCO(s) + 2HCl(aq) \longrightarrow 2H_2O(l) + O_2(g)$
Rate of chemical reaction is obtained by collecting and measuring the volume of the carbon dioxide gas produced.

(iii) $2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$
Decomposition of hydrogen peroxide in the presence of manganese (IV) oxide as a catalyst. The rate of reaction is determined by collecting and measuring the volume of oxygen gas evolved.

N.B
In all the above reactions, rate of reaction can also be determined by measuring the change in mass of the reactant with time.

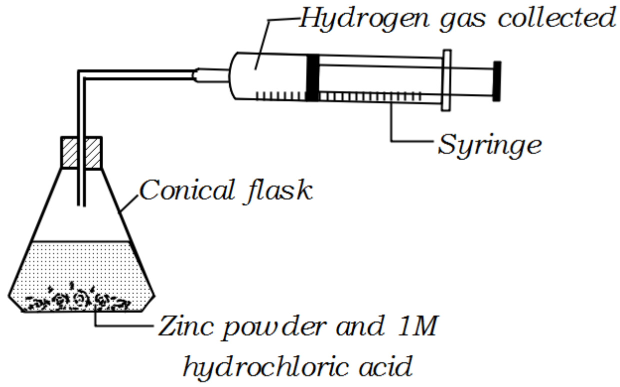
<u>FACTORS AFFECTING RATES OF REACTIONS</u>

- Concentration of the reactants
- Temperature
- Surface tension
- Pressure
- Catalyst
- Light

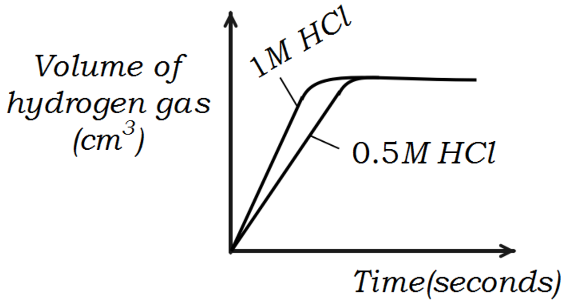
1. <u>Concentration</u>
   <u>Effect of concentration</u>
   During a chemical reaction, the reactants approach one another, collide and the reaction takes place. Concentration of the reactants refers to how close together the solute particles are in a given solution. The higher the concentration the higher the rate of reaction. This is because increase in concentration of reactants increases the number of reacting particles per unit volume. This in turn increases the chances of collision of the particles therefore the higher the concentration, the higher the rate of reaction.

   <u>An experiment to show the effect of concentration on the rate of reaction</u>
   Consider a reaction between zinc and dilute hydrochloric acid
   Procedure
   - A known mass of zinc particles is added to 1M hydrochloric acid in a conical flask fitted with a graduated syringe set at point zero.
   - The stop clock is immediately started and the volume of hydrogen gas evolved is measured at regular intervals until a constant volume is registered by the syringe.
   - The recorded results in regular time intervals are then plotted in a graph of volume of hydrogen collected against time.

Diagram of the setup



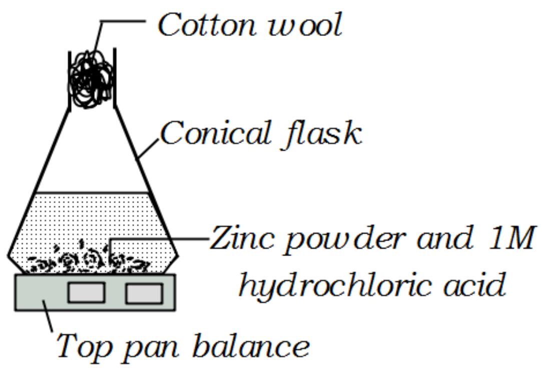
The gradient of the graph at any particular part is a measure of rate of reaction at the time represented by that time.
The experiment is repeated using the same mass of zinc powder but with 0.5M HCl.
Results are plotted



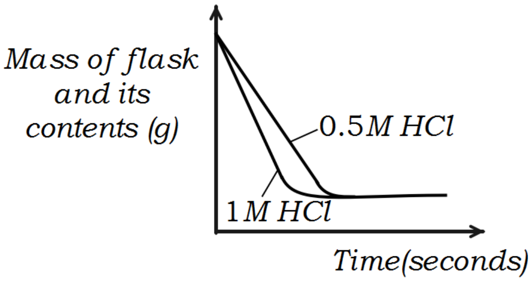
It is found out that the curve for 1M HCl is steeper than that of 0.5M HCl.
Also the horizontal part for the curve of 1M HCl begins earlier showing that the maximum value of hydrogen is evolved faster at a higher concentration. Therefore the rate of reaction is higher at a higher concentration.
Instead of measuring the volume of hydrogen produced we may measure the mass of reactants.

Procedure

- About 10g of zinc powder is carefully added to 1M HCl in a conical flask and weighed
- A stop clock is immediately started as the zinc powder is added to HCl in the flask. The change in weight of reactant is directly taken from the top pan balance in a given time interval. The mass of the flask and the reactants is measured at regular time intervals.
- The mass of the flask and its contents is plotted against time.



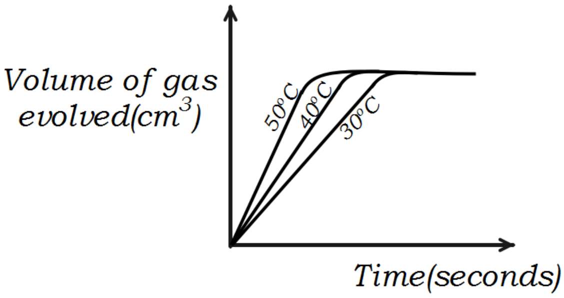
The experiment can be repeated using the same mass of zinc and the same volume of HCl with different concentration. A graph of mass of flask and its contents against time is shown below



2. <u>Temperature</u>

The rate of reaction increases with increase in temperature. This is because when temperature increases, the reactant particles gain kinetic energy and move faster. This in turn increases the frequency of collision of the reacting particles per second.

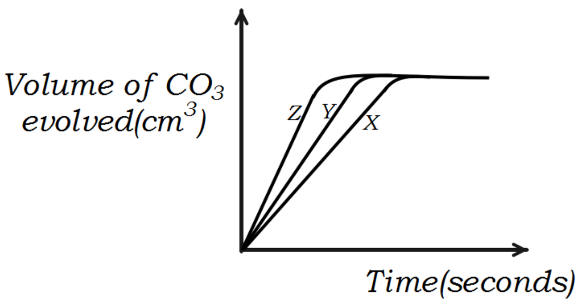
Therefore, the higher the temperature the higher the rate of reaction. This can be explained by the graph below



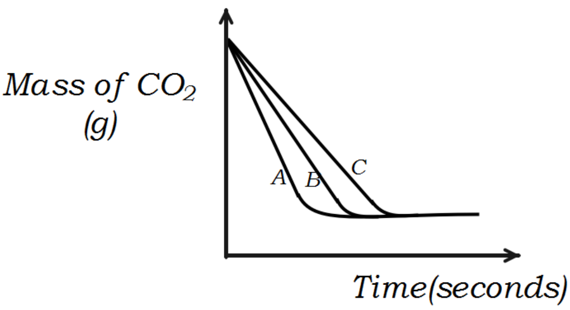
3. <u>Surface area</u>

The rate of reaction increases with increase in surface area. This is because the smaller the size of the reacting particles, the greater the total surface area exposed to the reaction. This in turn increases the number of effective collision per second causing the rate of chemical reaction to increase.

E.g A given mass of large marble chips ($CaCO_3$) is reacted with hydrochloric acid. It is found that the reaction will be faster when the marble chips are crushed into powder. Illustration graphs as shown below



X- large marble chips
Y-small marble chips
Z-powdered marble chips

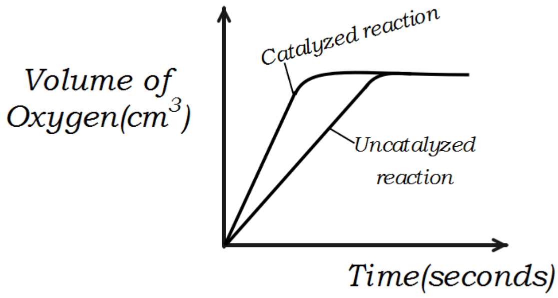


A- powdered marble chips
B-small marble chips
C- large marble chips

Instead of plotting volume of gas evolved against time, the mass of the solid can be plotted against time as shown above.
Similarly, the reaction between magnesium ribbon and dilute Sulphuric acid is slower compared to the reaction between magnesium powder and dilute Sulphuric acid.
This is so because magnesium ribbon has small surface area exposed to the reaction with dilute Sulphuric acid because magnesium ribbon has big particles.
Magnesium powder has a large surface area exposed to the reaction with Sulphuric acid because magnesium powder has the smaller particles hence the rate of reaction is faster when magnesium powder is used.

4. Pressure
Pressure affects only gaseous reactions. This is because gases are compressible. Increasing pressure gas particles are compressed into smaller volumes and come closer together and this makes them collide frequently. Therefore the higher the pressure, the higher the rate of reaction.
E.g the reaction between nitrogen and hydrogen to liberate ammonia requires high pressure.

5. Catalyst
A catalyst is a substance which alters the rate of a chemical reaction but remains unchanged at the end of the reaction. The rate of reaction increases when a catalyst is used because the catalyst lowers the activation energy of the reaction.
The effect of the catalyst on the rate of reaction can be illustrated by decomposition of hydrogen peroxide.
The rate can be determined by measuring the volume of oxygen liberated at different regular time intervals.
The experiment is then repeated using the same volume of hydrogen peroxide but with no catalyst.
The graph of volume of oxygen against time is then plotted



6. Light
In some reactions, the rate of reaction is influenced by light. Reactions which are affected by light are called photochemical reactions.
Some important reactions that take place in presence of light include
(a) Photosynthesis in green plants takes place during the day in presence of light by which carbon dioxide and water are combined into sugar or starch and oxygen.
$6CO_2(g) + 6H_2O(l) \longrightarrow C_6H_{12}O_6(s) + 6O_2(g)$

(b) Chlorine water contains hypochlorous acid which decomposes in direct sunlight to hydrochloric acid and oxygen
$2HOCl(aq) \longrightarrow 2HCl(aq) + O_2(g)$

(c) Decomposition of silver chloride. When silver nitrate and sodium chloride solutions are mixed, a white precipitate of insoluble silver chloride is formed.
$Ag^{+}(aq) + Cl^{-}(aq) \longrightarrow AgCl(s)$
When this precipitate is exposed to light, it darkens due to the decomposition of silver chloride to silver and chlorine.

$$AgCl(s) \xrightarrow{light} Ag(s) + \frac{1}{2}Cl_2(g)$$

In the absence of light, the precipitate remains white. This decomposition reaction of silver is important because it is used in photography.

<u>Question</u>
State and explain the effect of each of the following conditions on the rate of a chemical reaction.
(a) Particle size
(b) Concentration
(c) temperature

END