# St. Luke's High School


# 1. Rates of Reaction

# Learning Outcomes

☐Nat 4 outcomes  O Nat 5 outcomes

**By the end of this unit you should know the following:**

- O *How to calculate the average rate of a reaction using:*

$$\text{average rate} = \frac{\text{change in concentration/ volume/mass}}{\text{Change in Time (s)}}$$

- O *How to follow a chemical reaction by measuring the change in mass or volume of gas produced.*
- O *How to plot a graph of mass of gas against time and use the graph to calculate the average rate of a reaction.*
- O *How changing the size of the reactant particles, concentration of solutions or the temperature affects the speed of a reaction.*
- ☐ How changing the particle size, concentration or temperature affects the shape of a graph following a reaction.
- ☐ Be able to explain how changing the particle size, concentration or temperature speeds up a chemical reaction.

# Chemical Reactions

In every chemical reaction a new substance is made. Chemical bonds within reactants are broken and new bonds form to make products.

In every chemical reaction the reacting particles need to collide and only successful collisions will result in products being formed.
Chemical equations are written to represent the process.

Reactant 1 + Reactant 2 $\Rightarrow$ Products

## Collision Theory

Successful collisions depend on the reactants colliding (bumping into each other with the following characteristics:-

- Collide with enough energy
- Collide in the correct orientation (geometry)

## Evidence of Chemical Reactions

Signs of a chemical reaction are:-

- Colour change (indicates a new substance)
- Gas produced (gas is the new substance)
- Energy change (products have different potential energy than reactants)
- Solid formed from solutions (precipitate is new substance)

**Fill in the table to and put the processes under the correct heading**

a puddle of water evaporating: frying an egg; salt dissolving in water;
the burning of petrol; the melting of a plastic;
nitrogen combining with hydrogen; wool growing on a sheep;
the breaking of glass; separating alcohol from water;
the rotting of compost; separating sand from water; heating a metal

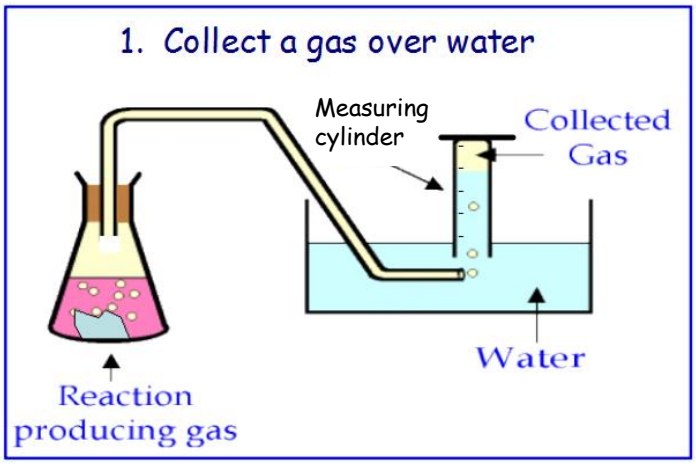
| Chemical Reaction | Physical Change |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |

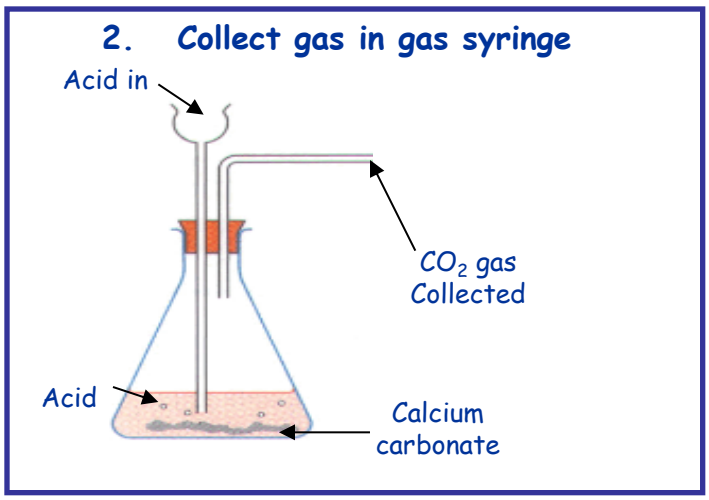
# Following the Course of a Reaction

## Measuring volume of Gas

A chemical reaction can be followed by measuring how quickly the reactants get used up or how quickly the products form.

If a gas is produced then we can measure the volume of gas collected at time intervals. The volume of gas can be collected by two methods.




In the reaction with excess hydrochloric acid 1 mol $l^{-1}$ and 2g marble chips (calcium carbonate), the gas carbon dioxide is a product. The volume of gas produced every 30 seconds can be recorded and a line graph of volume against time is plotted.

# Volume of gas collected over time

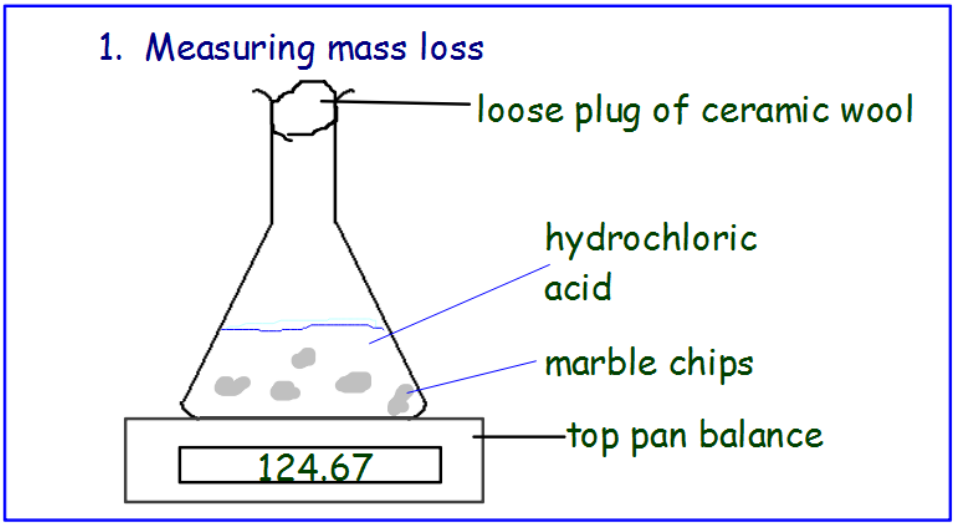
## Table of Results

| Time (s) | Volume of gas ($cm^3$) |
|---|---|
| 0 | 0.0 |
| 10 | 25.5 |
| 20 | 40.4 |
| 30 | 52.8 |
| 40 | 60.5 |
| 50 | 66.2 |
| 60 | 70.4 |
| 70 | 72.5 |
| 80 | 72.5 |

## Line Graph

Measuring Mass loss

If a gas is produced then the mass of the beaker will decrease since the gas leaves the flask. The reaction can be carried out on a balance and the mass recorded at time intervals of 30 seconds to follow the reaction.




In the reaction with hydrochloric acid and marble chips (calcium carbonate), carbon dioxide gas is produced which leaves the flask and the mass decreases.

Different factors such as temperature, particle size and concentration of acid can be used find factors which affect the rate of a reaction.

## ACTIVITY 1.1 Measuring the Mass of Gas Produced

1. Pour 50cm3 of 1moll-1 HCl into a conical flask, put a piece of cotton wool in its mouth and place on a balance.
2. Using a small beaker, weigh out 10g of marble chips and place it on the balance as well.
3. Record the initial mass in the following table.
4. Take out the cotton wool and pour in the marble chips, start the stop watch and replace the cotton wool.
5. Measure the mass every 30 seconds and put your results in the table.

# Mass over time

## Table of Results

| Time (s) | Mass of container (g) |
|---|---|
| 0 | 149.00 |
| 30 | 147.75 |
| 60 | 147.08 |
| 90 | 146.60 |
| 120 | 146.24 |
| 150 | 145.94 |
| 180 | 145.68 |
| 210 | 145.48 |
| 240 | 145.32 |
| 270 | 145.19 |
| 300 | 145.19 |

## Line Graph

## Calculating the Rate of Reaction 1

You can see from your graph that the steepness of the curve changes with time. This is because the speed of the reaction is always changing.

Use your graph to work out the speed of the reaction.

Use your graph to calculate the average rate of reaction over the following time intervals: Show your working clearly.

a. b.
c. d.

a.

b.

c.

d.

**Notes**

The slope of the graph is steeper at the start. This shows the rate of the

reaction is _____

The graph eventually levels off because _____

_____

When following the course of reaction for mass. The mass decreases because

_____

The rate is _____ at the start and then _____

As the reaction progresses. This is because _____

_____

## Calculating the Rate of Reaction 2

When the rate is fast the time taken to complete the reaction is _____.

When the rate is slow the time taken to complete the reaction is _____.

Rate and time are connected.

> Rate is the reciprocal of time rate s = 1/t (s)
>
> Time is the reciprocal of rate. time (s) = 1/r s

e.g. 1 A reaction that is complete in 50 s will have the following rate:

Rate = 1/time

Rate = 1/50 s

**Rate = 0.02 $s^{-1}$**

e.g. 2 A reaction that has a rate of 0.01 $s^{-1}$ will take the following time:

Time = 1/rate

Time = 1/0.01 $s^{-1}$

**Time = 100 s**

We use this method when we are only given the time of a reaction or the rate. so this method is used when we cannot measure volume of gas or a concentration difference.

This method is used when there is a sudden change which indicates the reaction has occurred . e.g. the iodine clock reaction, where the solutions turns suddenly from colourless to blue/black.

# Factors Affecting Rate

## Rate of Reaction is affected by

Changes in:

1._____

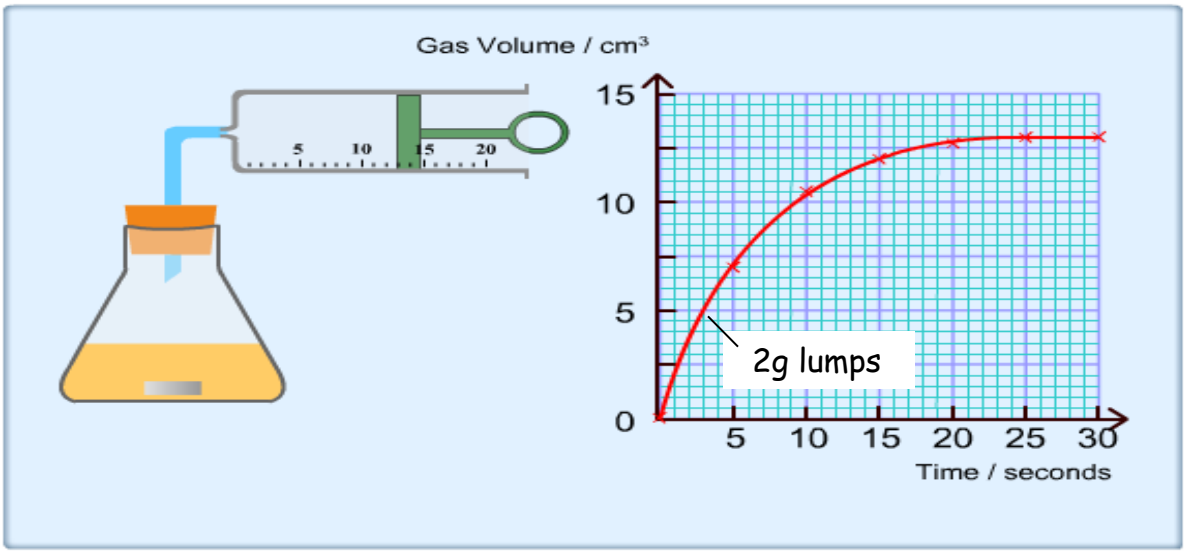
2._____

3._____

4._____

## Effect of Particle Size

The graph shows the volume of gas produced in the reaction with excess hydrochloric acid and **2g** of calcium carbonate **lumps**.
If the reaction is repeated with **2g** of **powdered** calcium carbonate a new line graph is drawn showing the effect of particle size on reaction rate.




**Notes:**

The graph with powdered calcium carbonate has a _____ curve which shows the rate of reaction is _____with powdered calcium carbonate than lumps.
Both graphs have the same final volume of gas because _____

_____

A third curve shows the reaction when **1g** calcium carbonate lumps is used with excess acid.

The final volume of gas collected is _____ the original value.

## Effect of Temperature

The graph shows the volume of gas produced in the reaction with excess hydrochloric acid and 2g of calcium carbonate lumps at **20°C**.
If the reaction is repeated at **30°C** a new curve is added to the graph showing the effect of temperature on reaction rate.

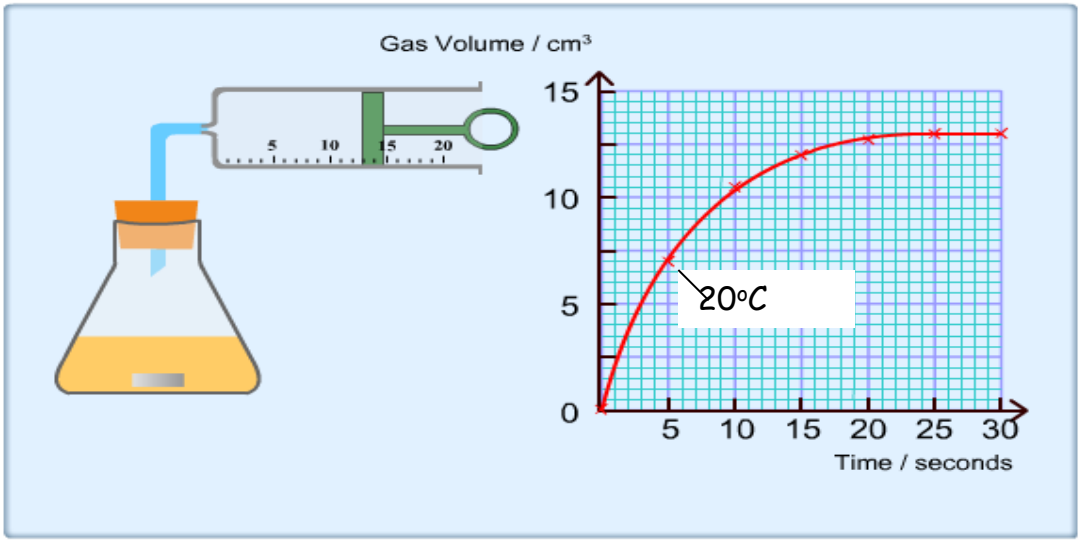



Diagram showing effect of temperature

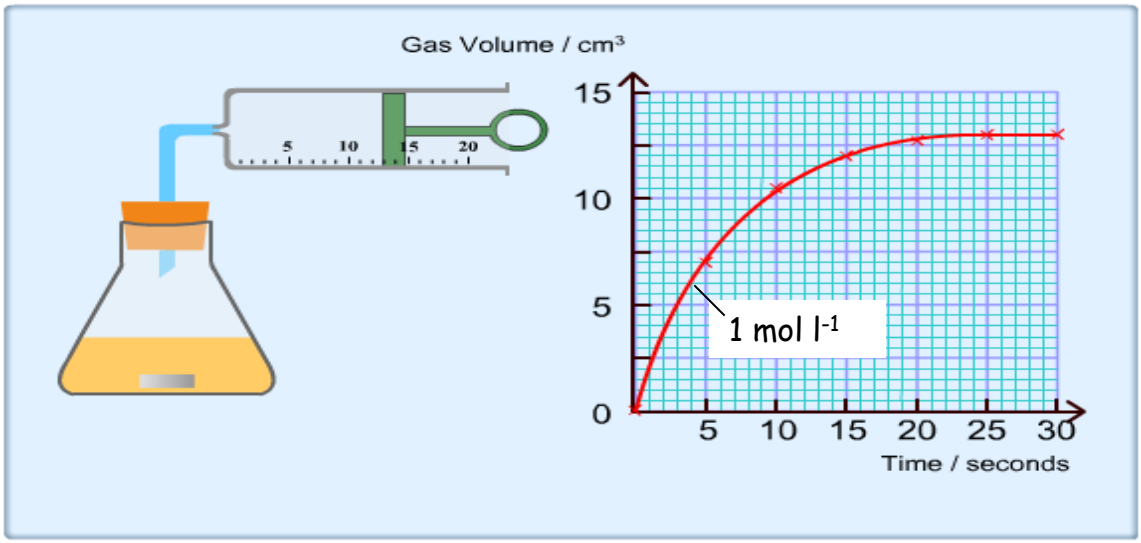
**Notes:**

At **30°C** the graph has a _____ curve which shows the higher the temperature, the _____ the rate of reaction.

_____

## Effect of Concentration

The graph shows the volume of gas produced in the reaction with excess hydrochloric acid and 2g lumps of calcium carbonate at 20°C.
If the reaction is repeated at with an excess of acid at a higher concentration a new curve is added to the graph.




## Diagram showing effect of Concentration

**Notes:**
With a **higher concentration** of acid the curve is _____ which shows the higher the concentration the _____ the rate of reaction.

# Catalysts

Catalysts speed up reaction by providing an alternative pathway for the reaction with a lower Activation energy.
Catalysts do not get used up in reactions.

## Advantages

Economical - catalysts speed up a reaction without the need to increase the temperature therefore saves money.
Environment - No need to waste energy or materials since the catalyst is used at low temperatures and can also be used again.

## Types of Catalysts

**Heterogeneous** – Catalyst is in _____ the reactants.

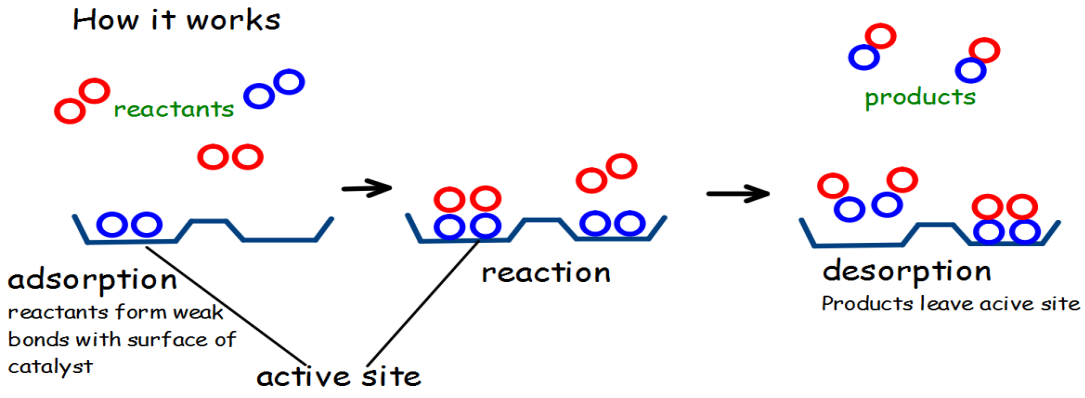
**Homogeneous** – Catalyst is in _____ the reactants.

## Examples of Catalysts

- Catalytic converters in car exhaust systems (platinum)
- Gas powered hair stlylers - the catalyst is platinum
- Enzymes - biological catalysts (from living organisms)

* _____
* _____
* _____

## Heterogeneous Catalysts




* The catalyst has a large surface area to adsorb reacting particles.
* If lead or other unwanted particles get **adsorbed onto the catalyst surface** then they **block the active sites** and the catalyst becomes POISONED.
* Lead in leaded petrol poisons the platinum catalyst in catalytic converters.

## Heterogeneous Catalysts

E.g. Hydrogen peroxide breaks down into water and oxygen gas

Hydrogen peroxide $\rightarrow$ water + oxygen

$H_2O_{2(aq)} \rightarrow H_2O_{(l)} + O_{2(g)}$

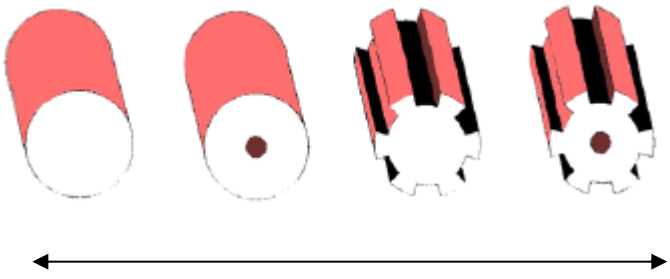
The catalyst is Manganese Dioxide.

Diagram of experiment

If 1 g of manganese dioxide was used in the experiment _____ of manganese dioxide would be present at the end of the experiment.

## Surface area

The _____ the surface area of the catalyst the better it works.



## Effect of Temperature on Enzyme Activity

•The optimum temperature of living things is _____

•Enzymes have _____ _____ that work like a lock and key.

•The _____ temperature of enzymes is _____.

Enzymes activity increases as temperature increases up to about _____

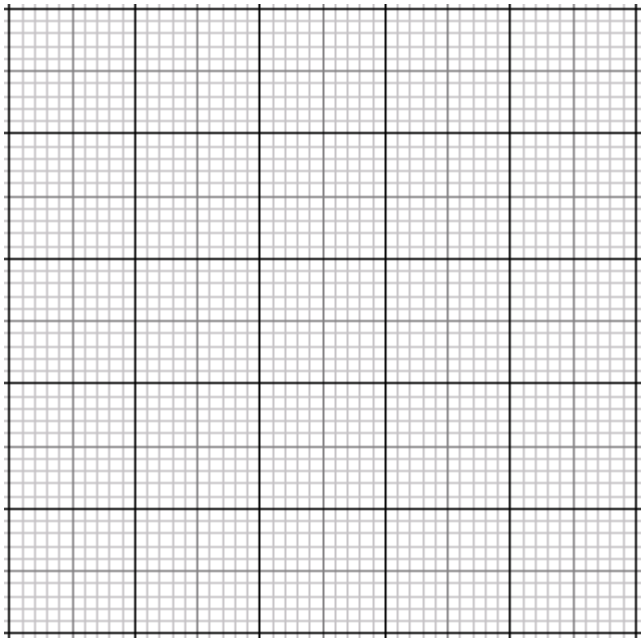
Above 40°C this the enzyme gets _____ and changes shape so the activity decreases.
At high temperatures the activity stops as the active site has

_____ _____.

## Enzyme Activity Graph

An investigation was carried out on how temperature affects enzyme activity and the following data obtained. The graph shows how enzyme activity is affected by temperature.

| Temperature °C | Enzyme Activity units |
|---|---|
| 0 | 0.0 |
| 10 | 3.0 |
| 19 | 5.0 |
| 26 | 6.0 |
| 30 | 6.7 |
| 37 | 7.0 |
| 40 | 6.2 |
| 45 | 4.2 |
| 50 | 0.0 |



The graph shows _____

_____

_____

This is because _____

_____

# Collision Theory

## Collision Theory

In a chemical reaction the particles will only react if the reactants collide (bump into) the other reactants am meet the following criteria:-

- _____
- _____

## Increasing Temperature

By increasing the temperature the particles are given _____ _____

_____ therefore move about faster. There is a _____ chance of

more _____ _____.

## Increasing concentration

If there are more particles in a solution there is a _____

_____ of more successful collisions.

## Smaller Particle size (powder)

If the particles are small then there is a greater _____ _____

therefore a greater chance of more successful collisions.

## Using a Catalyst

The catalyst forms bonds with the molecules of one or both reactants.

This weakens the bonds within the molecules.