

## C6: The Rate and Extent

of chemical change

ASM Tuition Academy

# Measuring Rates of Reaction

## Calculating Rates of Reaction

- ▶ Rates are used to express the **speed** or **frequency** with which a given process happens. When measuring the speeds of a process, rates are calculated by **dividing** the **change** of a given variable by the **time** in which the change has taken place.

For the mean rate of a **chemical reaction**, we measure the changes the amount of either the **reactants** or the **products** of the reaction:

$$\text{Mean Rate of Reaction} = \frac{\text{Amount of Reactant Used}}{\text{Time Taken}}$$

or

$$\text{Mean Rate of Reaction} = \frac{\text{Amount of Product Formed}}{\text{Time Taken}}$$

- ▶ The **amounts of reactant used or product** formed are typically measured in either **grams (g)** if it is a **solid** or in **cubic centimeters (cm<sup>3</sup>)** if it is a **Gas**.
- ▶ The **time** over which these changes take place is almost always measured in **seconds (s)**.
- ▶ The mean rate of a reaction is telling us about the **change in an amount over a given time** so its units are the **unit change in amount per the unit change in time**

(g/s or cm<sup>3</sup>/s)

- ▶ Mean rates of reaction may also be measured in terms of **moles**, giving units of mol/s
- ▶ The mean rate of a chemical reaction will tell us how **quickly or slowly** that reaction takes place. If a reaction has a **low rate**, then it will happen **slowly**. Reactions with a **higher rate** will happen much more **quickly**. There are a number of factors that influence the rate, from temperature to **concentration**.

## Ways of measuring Rate of Reactions

- ▶ Three methods to measure the rate of reaction are

1. Measuring mass loss
2. Measuring gas volume
3. Monitoring color changes or Precipitation.

## C6: The Rate and Extent

### of chemical change **ASM Tuition Academy**

- These methods allow you to track how quickly reactants are used up or products are formed over time.

#### 1. **Measuring Mass Loss:**

- This method is suitable when a reaction produces a gas that escapes.
- The reaction is carried out in an open container, and the mass of the container and its contents is measured periodically using a balance.
- As gas escapes, the mass will decrease, and this change in mass over time indicates the reaction rate.

#### 2. **Measuring Gas Volume:**

- This method is used when a reaction produces a gas.
- The gas produced is collected in a gas syringe, and the volume of gas is measured at regular intervals.
- The change in gas volume over time is then used to calculate the reaction rate.

#### 3. **Monitoring Color Changes:**

- This method is used when the reaction involves a change in color.
- The reaction mixture is monitored, and the time it takes for a specific color change to occur is recorded.
- The shorter the time for the color change, the faster the reaction rate



## Rate of reaction - magnesium & hydrochloric acid

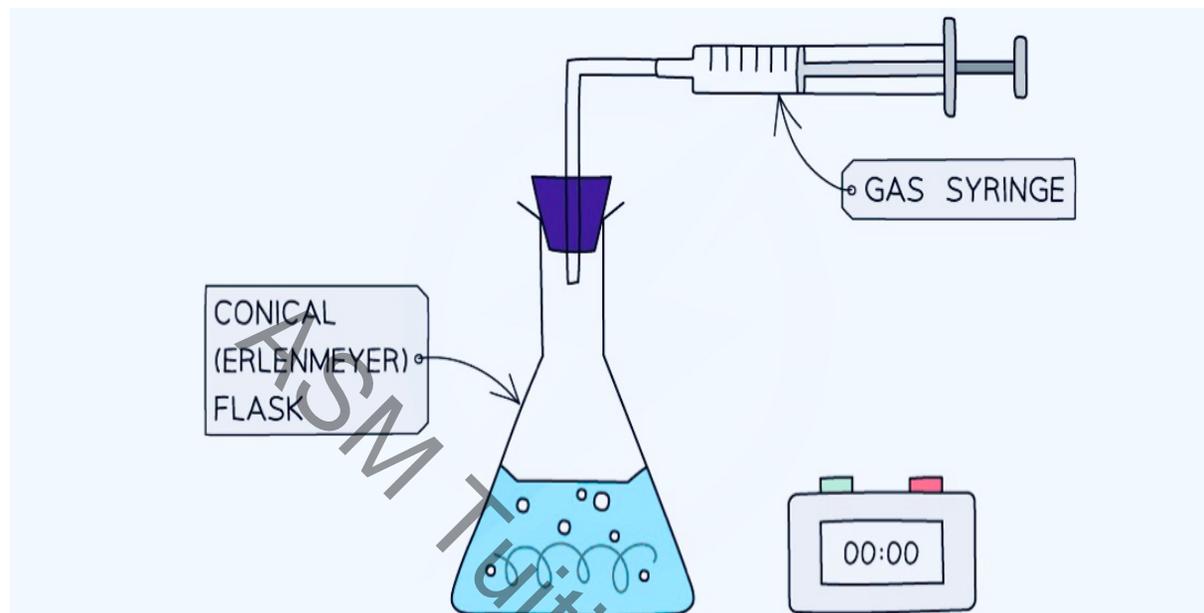
- This reaction can be used to investigate the effect of varying the concentration of the acid while keeping the temperature constant.
- When a gas is released in a reaction you can either try to measure the volume of gas given off or the mass change in the reaction flask.
- Volume can be measured either by displacement of water into an inverted measuring cylinder or by using a gas syringe.

## C6: The Rate and Extent

### of chemical change

### ASM Tuition Academy

- The choice of the size of the gas syringe needs to be considered and the quantities of reagents judged accordingly so that a reasonable volume of gas can be evolved and also recorded.



### Method

1. Check that the apparatus is gas-tight before starting.
2. Assemble the setup without magnesium or acid and gently push the plunger.
3. Pour the acid into the conical flask first.
4. This allows the magnesium ribbon to be dropped in quickly to start the reaction.
5. Prepare a range of acid concentrations by serial dilution of the stock acid:
6. Measure a set volume of acid (e.g. 40 cm<sup>3</sup>) in one measuring cylinder

**Note:** Measure distilled water in another cylinder and mix to make serial dilutions (e.g. 40 cm<sup>3</sup> acid + 0 cm<sup>3</sup> water, 35 cm<sup>3</sup> acid + 5 cm<sup>3</sup> water, etc.)

7. Use a suitable volume of acid for your flask size (e.g. 40 cm<sup>3</sup>).
8. Start with a concentration no higher than 2.0 mol dm<sup>-3</sup> to ensure the reaction proceeds at a measurable rate

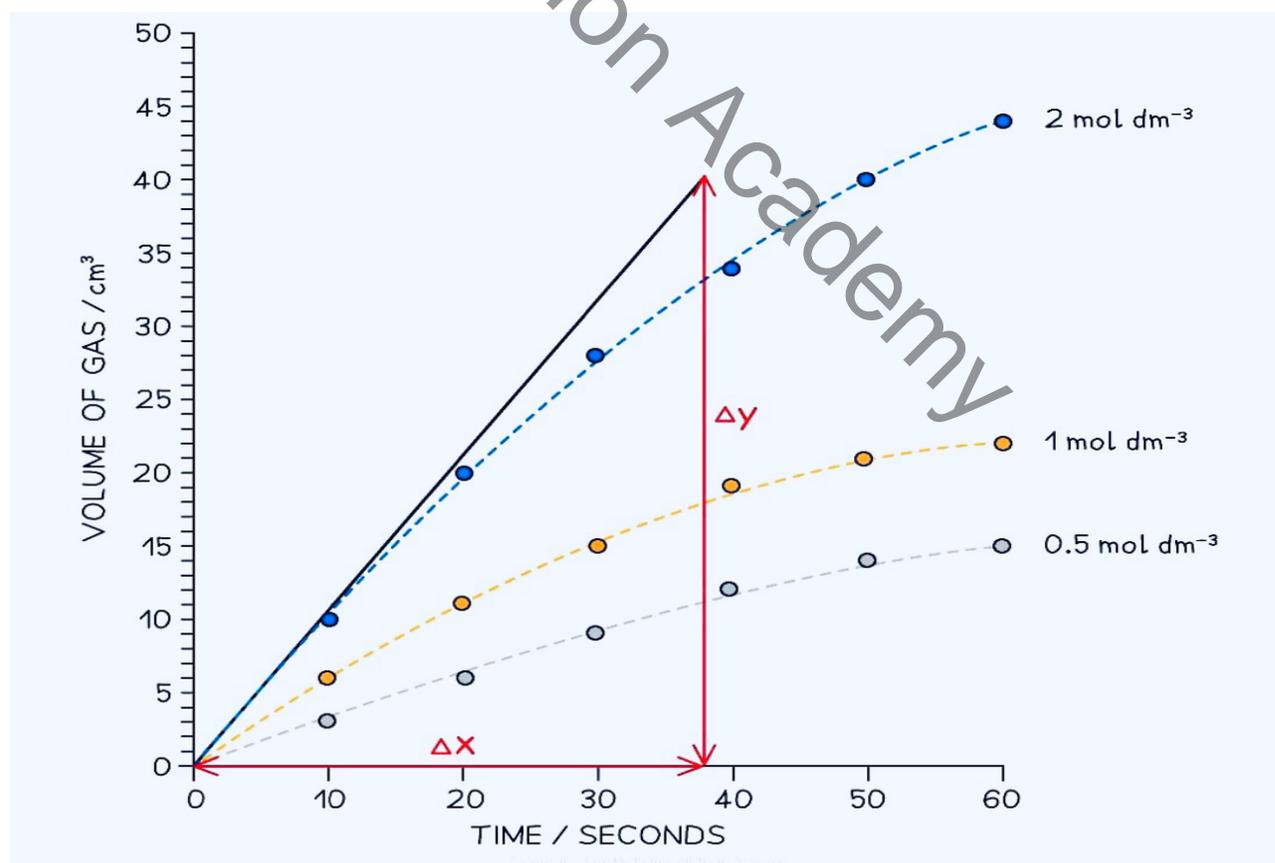
## C6: The Rate and Extent

of chemical change

ASM Tuition Academy

## Results

Time / s	Volume of gas / cm <sup>3</sup>		
	2.0 mol dm <sup>-3</sup>	1.0 mol dm <sup>-3</sup>	0.5 mol dm <sup>-3</sup>
0	0	0	0
10	10	6	3
20	20	11	6
30	28	15	9
40	34	19	12
50	40	21	14



## C6: The Rate and Extent

### of chemical change

ASM Tuition Academy

### Analysis

- For each concentration of hydrochloric acid, plot a graph to show:
  - volume of gas ( $\text{cm}^3$ ) on the vertical axis
  - time (s) on the horizontal axis
  - draw a curve of best fit
- A tangent is then drawn starting from (0,0) since this method is to find the **initial rate** of reaction
- For each concentration of acid, calculate the mean rate of reaction:

$$\text{mean rate of reaction (g/cm}^3\text{)} = \frac{\text{total mass of gas produced (cm}^3\text{)}}{\text{reaction time (s)}}$$

- The gradient of the tangent is determined which gives the rate of reaction.
- In the example above, the rate of reaction for  $2.0 \text{ mol dm}^{-3}$  acid is:

$$\text{Gradient} = \Delta y / \Delta x$$

$$= 40 / 38 = 1.05 \text{ mol dm}^{-3} \text{ s}^{-1}$$



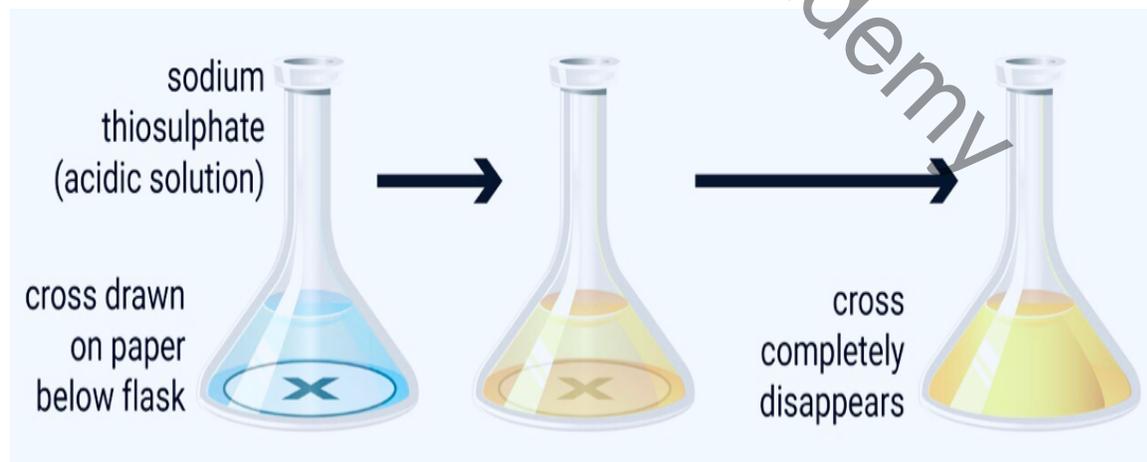
## Investigating the Effect of Concentration on the Rate of Reaction ( Sodium sulphate and HCl produces cloudy precipitates)

- To investigate how the rate of reaction changes as the concentration of sodium thiosulphate is changed.
- In this practical, you will React different concentrations of sodium thiosulfate with dilute hydrochloric acid. The equation for this reaction is:

**Sodium thiosulfate + Hydrochloric acid → Sodium chloride + Water + Sulfur dioxide + Sulfur**



- Use a stopwatch to measure the time taken for a mixture to become **cloudy or yellow precipitate of sulphur** at each concentration of sodium thiosulphate.
- Use your results to calculate how the rate of reaction changes as you change the concentration of sodium thiosulfate.



## C6: The Rate and Extent

### of chemical change

ASM Tuition Academy

### Method:

1. Take a conical flask and add a set volume of diluted sodium Thiosulfate.
2. Place the flask on a paper with the black cross drawn on it
3. Add some dilute HCl to the flask and start the stop watch
4. Now watch the black cross disappear through the cloudy sulphur and record how long time it takes to go.
5. The reaction can be repeated 1 - 4 times with the solution of either reactant at different concentrations

Note: only change in concentration of One reactant at a time though

### Results

Time/s taken for mark disappear	Concentration of HCl g/dm <sup>3</sup>
193	20
<b>184</b>	<b>35</b>
178	<b>50</b>
171	<b>65</b>
164	<b>80</b>

- The **higher the concentration** the quicker the reaction and there for **less time** it takes for the mark to disappear