# 5072 CHEMISTRY (NEW PAPERS WITH SPA)
# TOPIC 6: CHEMICAL REACCTIONS

# 5067 CHEMISTRY (NEW PAPERS WITH PRACTICAL EXAM)
# TOPIC 6: CHEMCIAL REACTIONS

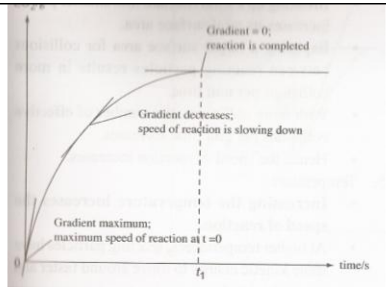
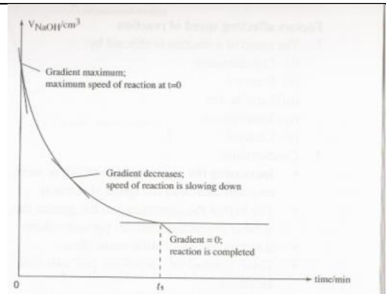
## SUB-TOPIC 6.1
## SPEED OF REACTION

| LEARNING OUTCOMES |
| --- |
| 1. Describe the effect of concentration, pressure, particle size and temperature on the speeds of reactions and explain these effects in terms of collisions between reacting particles<br>2. Define the term *catalyst* and describe the effect of catalysts (including enzymes) on the speeds of reactions<br>3. Explain how pathways with lower activation energies account for the increase in speeds of reactions<br>4. State that some compounds act as catalysts in a range of industrial processes and that enzymes are biological catalysts (*see* ***5****(b),* ***6.1****(c) and* ***10****(d)*)<br>5. Suggest a suitable method for investigating the effect of a given variable on the speed of a reaction<br>6. Interpret data obtained from experiments concerned with speed of reaction |

## A Introduction

- The speed of reaction measures how fast the reaction takes place.
- Different reactions occur at different speeds.
- Most precipitation reactions occur very quickly
  - E.g. A white precipitate of Silver Chloride appears the moment aqueous Silver Nitrate is added to dilute Hydrochloric Acid.
- Rusting of iron takes a very long time to complete.
- During a chemical reaction:
  - The quantity of the reactants decreases with time.
  - The quantity of the products increases with time.
- Hence, the speed of reaction can be determined by:
  - How fast the reactant is being used up
  - How fast the product is being produced.
- Often, a graph is drawn to follow-up on the experiments:
  - The gradient of the graph represents the speed of reaction.
  - The gradient of a tangent to the curve gives the speed of reaction at that instant.
  - The steeper the gradient, the faster the speed of reaction.
- Three experimental methods are used to determine the speed of a chemical reaction:

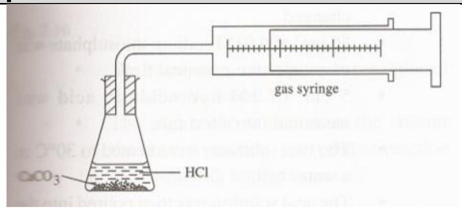
| Method | Procedure | Follow-Up |
|---|---|---|
| **Measuring the time for a reaction to be completed.** | - Obtain two pieces of Magnesium ribbon 2cm in length.<br>- Drop one piece into 5$cm^3$ of 1M Hydrochloric Acid.<br>- Drop the other piece into 5$cm^3$ of 1M Sulphuric Acid.<br>- Record the times taken for the Magnesium ribbon to completely dissolve.<br>➢ Hydrochloric Acid: 100s<br>➢ Sulphuric Acid: 50s | - Since the same amount of Magnesium is used in both cases, the speed of reaction is inversely proportional to the time taken for the reaction to be completed.<br>- The shorter the time taken for the reaction to be completed, the faster the speed of reaction<br>➢ Hydrochloric Acid: 0.01/s<br>➢ Sulphur Acid: 0.02/s<br>- Hence, the speed of reaction using Sulphuric Acid is twice the speed of reaction using Hydrochloric Acid. |

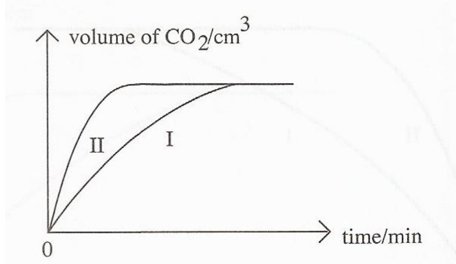
| | | | |
|---|---|---|---|
| **Measuring the quantity of a product formed in a fixed interval of time.** | - Pour 50cm$^3$ of Hydrochloric Acid into a conical flask.<br>- Place the flask on an electronic balance.<br>- Add about 20g of Marble chips into the Acid<br>- Record the mass of Carbon Dioxide produced every 30 seconds.<br>- Plot a graph of mass of Carbon Dioxide produced against time. | From the graph,<br>- The gradient of the tangent at t=0 indicates the initial speed of reaction.<br>➢ The initial speed of reaction is the greatest.<br>- The gradient decreases with time<br>➢ The speed of reaction decreases with time.<br>- The gradient of the tangent at t = $t_1$<br>➢ Speed of reaction is 0.<br>➢ The reaction stops at t = $t_1$ |  |
| **Measuring the quantity of a reactant remaining after a fixed interval of time.** | - Mix Ethanol and Ethanoic Acid together.<br>- At 5 minute intervals, pipette 2cm$^3$ of the reaction mixture.<br>- Titrate the reaction mixture with standard Sodium Hydroxide solution.<br>- Record the volume of Sodium Hydroxide used.<br>- Plot a graph of Volume of Sodium Hydroxide added against time. | From the graph,<br>- The gradient of the tangent at t=0 indicates the initial speed of reaction.<br>➢ The initial speed of reaction is the greatest.<br>- The gradient decreases with time<br>➢ The speed of reaction decreases with time.<br>- The gradient of the tangent at t = $t_1$<br>➢ Speed of reaction is 0.<br>➢ The reaction stops at t = $t_1$ | <br>Fig. 7.3 |

## B The Collision Theory

- The collision theory is used to explain how a chemical reaction occurs.
- According to the collision theory:
  - ➢ A chemical reaction occurs when reactant particles collide with each other.
  - ➢ Not all collisions are effective, (effective collisions result in the formation in the products.)
  - ➢ An effective collision occurs when the reactant particles:
    - ♦ Have sufficient energy to overcome the activation energy of the reaction.
    - ♦ Collide at the proper orientation.
- The activation energy of a reaction is the energy barrier which the reactant particles must overcome to start the reaction.
- Hence the speed of reaction depends on the number of effective collisions between reacting particles.
- The greater the number of effective collisions per unit time, the higher the speed of reaction.

## C Investigating Factors affecting Speed of Reaction

<table>
<tr><th>Factor</th><th>To increase Speed of Reaction...</th><th>Experimentation</th><th>Interpretation of Data</th></tr>
<tr>
<td>Concentration</td>
<td><u>Increase concentration of reactants</u><br>- The higher the concentration, the greater the number of reacting particles per unit volume<br>- Reactant particles collide more often<br>- Total number of collisions per unit time increases<br>- This increases the number of effective collisions</td>
<td>

<br>- <u>Reaction</u><br>$CaCO_3$ (s) + 2HCl (aq) → $CaCl_2$ (aq) + $H_2O$ (l) + $CO_2$ (g)<br>- Concentration of Hydrochloric Acid is changed, all others are kept constant:
<table>
<tr><th>Experiment I</th><th>Experiment II</th></tr>
<tr><td>50$cm^3$ of 1M HCl</td><td>50$cm^3$ of 2M HCl</td></tr>
<tr><td>0.2g $CaCO_3$</td><td>0.2g $CaCO_3$</td></tr>
<tr><td>Room Temp</td><td>Room Temp</td></tr>
</table>
- 0.2g of Marble chips was weighed and added to 50$cm^3$ of Hydrochloric Acid of each experiment.<br>- The volume of Carbon Dioxide given off is measured every 30s</td>
<td>

<br>- Same mass of Calcium Carbonate (Limiting Reagent) was used in both experiments.<br>- Hence, the same volume of Carbon Dioxide is collected in both experiments.<br>- The speed of reaction in Experiment II is higher because:<br>➢ The reaction took a shorter time to complete.<br>➢ The gradient to the curve at time = 0 is steeper</td>
</tr>
<tr>
<td>Pressure of Gaseous Reactants</td>
<td><u>Increasing the pressure</u><br>- At higher pressures, the concentration of gases increases<br>- The reacting particles are crowded into a smaller volume enabling the particles to collide more frequently.<br>- The frequency of effective collisions will thus increase.</td>
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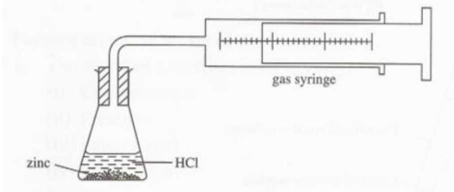
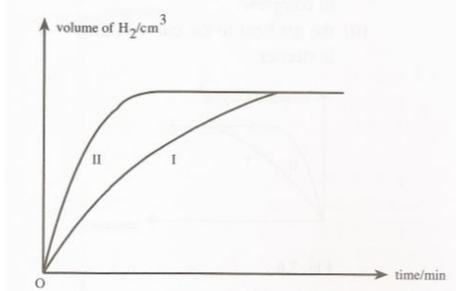
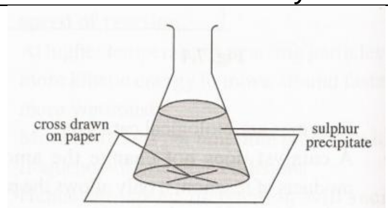
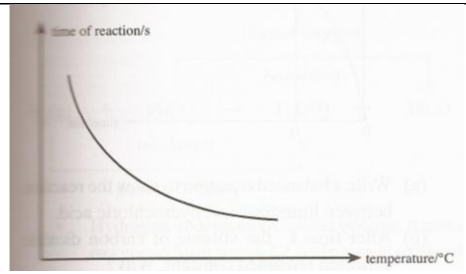
</table>

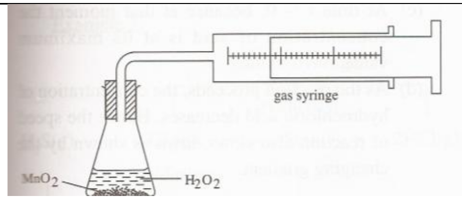
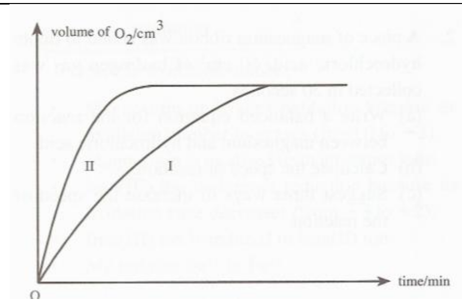
<table>
<tr>
<td>Particle Size of Solid reactants</td>
<td><u>Decreasing the particle size</u><br>- Breaking up a solid reactant into smaller pieces increases its surface area.<br>- Exposing a larger surface area for collisions between reacting particles results in more collisions per unit time.<br>- With more collisions, the number of effective collisions per unit time increases</td>
<td>

- <u>Reaction</u><br>$Zn$ (s) + 2$HCl$ (aq) → $ZnCl_2$ (aq) + $H_2$ (g)<br>- Article size of zinc is changed.<br>- All other factors stay constant.
<table>
<tr><th>Experiment I</th><th>Experiment II</th></tr>
<tr><td>50cm$^3$ 1M HCl</td><td>50cm$^3$ 1M HCl</td></tr>
<tr><td>0.1g granulated Zinc</td><td>0.1g powdered Zinc</td></tr>
<tr><td>Room Temp</td><td>Room Temp</td></tr>
</table>
- 0.1G OF Zinc was weighed and added to 50cm$^3$ of 1M Hydrochloric Acid.<br>- The volume of Hydrogen given off is measured every 30s.</td>
<td>

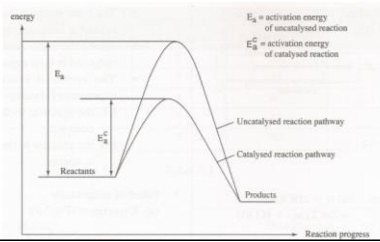
- The same mass of Zinc (limiting reagent) is used in both experiments.<br>- Hence the same volume of hydrogen is collected in both experiments.<br>- The speed of reaction in Experiment II is higher because:<br>➢ The reaction took a shorter time to complete<br>➢ The gradient to the curve at time = 0 is steeper.</td>
</tr>
<tr>
<td>Temperature</td>
<td><u>Increasing the Temperature</u><br>- At higher temperatures, reacting particles have more kinetic energy to move around faster and more vigorously.<br>- More collisions per unit time would produce a higher frequency of effective collisions.</td>
<td>

- <u>Reaction</u><br>$Na_2S_2O_3$ (aq) + 2$HCl$ (aq) → 2$NaCl$ (aq) + S (s) + $H_2O$ (l) + $SO_2$ (g)<br>- Temperature of reactant solution is changed.<br>- 50cm$^3$ of 0.01M Sodium</td>
<td>

<table>
<tr><th>Experiment</th><th>Temp/ $^0$C</th><th>Time Taken/ s</th></tr>
<tr><td>I</td><td>30</td><td>80</td></tr>
<tr><td>II</td><td>35</td><td>60</td></tr>
</table></td>
</tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>Thiosulphate was measured into a conical flask.<br>- $5cm^3$ of 1M HCl was measured into a test tube.<br>- The two solutions were heated to $30^0C$ in a water bath.<br>- The acid solution was then poured into the conical flask and the mixture shaken.<br>- The flask was placed on a cross marked on a piece of paper.<br>- A stop-watch was started, to record the time take for the cross to disappear.<br>- The experiment was repeated with the same volumes and concentration of Sodium Thiosulphate and Hydrochloric Acid but at different temperatures, i.e. $35^0C$, $40^0C$, $45^0C$ and $50^0C$</td>
<td><table><tr><td>III</td><td>40</td><td>46</td></tr><tr><td>IV</td><td>45</td><td>37</td></tr><tr><td>V</td><td>50</td><td>29</td></tr></table>- The same mass of sulphur is precipitated in each experiment.<br>- The higher the temperature, the shorter the time of reaction, i.e. speed of reaction increases with temperature.<br>- The speed of reaction in Experiment V is the highest because it takes the shortest time to complete.</td>
</tr>
<tr>
<td>Catalyst</td>
<td><u>Addition of a catalyst</u><br>- A catalyst is a chemical substance which alters the speed of reaction without itself being changed chemically at the end of the reaction.<br>- A catalyst speeds up reactions by providing an alternative reaction mechanism, i.e. an alternative reaction pathway for the reaction to take place.<br>- This alternative pathway has a lower activation energy.</td>
<td>
<br>- <u>Reaction</u><br>$2H_2O_2$ (aq) → $2H_2O$ (l) + $O_2$ (g)<br>- The catalyst, Manganese (IV) Oxide, $MnO_2$, catalyses the decomposition of Hydrogen Peroxide into Water and</td>
<td>
<br>- The same amount of Hydrogen Peroxide is used in both experiments.<br>- Hence, the volume of Oxygen</td>
</tr>
</table>

- Hence more reactant particles will have sufficient energy to overcome the lower activation energy.
- This will produce more effective collisions per unit time to increase the speed of reaction.
- Different reactions need different types of catalysts, i.e. each catalyst is specific to a particular reaction (e.g. Iron → Haber Process)
- A catalyst does not change the amount of products of reaction, it only allows the products to be obtained in a shorter time.




Oxygen.

| Experiment I | Experiment II |
|---|---|
| 50cm$^3$ 1M $H_2O_2$ | 50cm$^3$ 1M $H_2O_2$ |
| No catalyst | 0.1g $MnO_2$ |
| Room Temp | Room Temp |

- 50cm$^3$ of 1M Hydrogen Peroxide was measured into a conical flask.
- The flask was stoppered and a stop watch started.
- The volume of Oxygen given out was measured every 30s.
- The experiment was repeated using the same volume and concentration of Hydrogen Peroxide with 0.1g of Manganese (VI) Oxide

collected n both experiments is the same.

- The speed of reaction is higher in Experiment II because:
  - ➢ The reaction took a shorter time to complete.
  - ➢ The gradient to the curve at time = 0 is steeper.

## D Enzymes

- Enzymes are biological catalysts which speed up reactions in living things.
- Enzymes are made inside animals and plants.
- Each enzyme is a chemical substance which:
  - ➢ Is made of a protein
  - ➢ Speeds up just one particular reaction.
  - ➢ Works best at one particular temperature
  - ➢ Is destroyed by extreme temperatures, i.e. too hot or too cold.
- Many chemical reactions in plants and animals use enzymes.
- Without enzymes, life would be impossible.

- The digestion of food involves many enzymes:
  - Ptyalin: Found in saliva, speeds up the digestion of food in the mouth.
  - Gastric Juice: Contains several enzymes for the digestion of food in the stomach
- Industrial uses of Enzymes:
  - Addition to detergents
  - Used to make meat tougher
  - Used to convert sugars to alcohol (Fermentation, using the enzyme in yeast)
  - Antibiotics that kill harmful bacteria, produced by enzymes in fungi (e.g. Penicillin)