# National 5 Chemistry

## Unit 1:

### Chemical Changes & Structure

### Topic 1: Reaction Rates

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<th>Checked</th>
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<td></td>
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</table>
Learning Outcomes

Assumed Knowledge - Met in Earlier Courses

Chemical Reactions

- In all chemical reactions new substances are formed
- In many chemical reactions there is a change in appearance
- In many chemical reactions there is a detectable energy change
- Reactions that release energy are described as exothermic
- Reactions that take in energy are described as endothermic
- Precipitation is the reaction of two solutions to form an insoluble solid called a precipitate - use of Solubility Table in Data Booklet.

Chemical Tests

- Test for hydrogen: burns with a squeaky pop
- Test for oxygen: glowing splint relights
- Test for carbon dioxide: lime water turns cloudy / milky
- Test for acid: indicator turns red / orange
- Test for alkali: indicator turns purple / blue

Elements

- Everything in the universe is made from about 100 elements
- Every element is made up of small particles called atoms.
- Elements cannot be broken down into simpler substances
- Atoms of different elements are different.
- There is a different symbol for every element

Periodic Table

- The periodic table is how chemists classify elements.
- A column of elements in this table is called a group.
- Elements in the same group have similar chemical properties.
- Important groups include: Group 1 - alkali metals (reactive)
  Group 7 - halogens (reactive non-metals)
  Group O - noble gases (very unreactive)
- The transition metals are an important block of elements between groups 2 & 3
- Most elements are solids, a few are gases and two, bromine and mercury, are liquids.
Compounds

- Compounds are formed when elements react with each other and join together
- To separate the elements in a compound requires a chemical reaction

Mixtures

- Mixtures are formed when two or more substances are mingled together without reacting. They are not joined
- Separating the substances in a mixture does not involve a chemical reaction
- Air is a mixture of many gases (some elements, some compounds):
  - nitrogen, oxygen, carbon dioxide, water vapour, noble gases
- Air is mainly nitrogen (~78%) and oxygen (~21%)

Solvents, Solutes and Solutions

- A solvent is the liquid in which a substance dissolves
- A solute is the substance (solid, liquid or gas) that dissolves in a liquid
- A solution is a liquid with something dissolved in it
- A dilute solution has a small amount of solute compared to solvent
- A concentrated solution has a large amount of solute compared to the solvent
- A saturated solution can dissolve no more solute, it is ‘full-up’
- Water is the most common solvent

Rates of Reactions

- Decreasing particle size (smaller lumps) speeds up chemical reactions
- Increasing temperature speeds up chemical reactions
- Increasing concentration speeds up chemical reactions
- Using a catalyst speeds up some chemical reactions

Catalysts

- Catalysts speed up some reactions
- Catalysts are not used up during reactions
- Catalysts can be recovered and used again at the end of reactions
- Catalysts in living things (biological catalysts) are called enzymes
- Catalysts in the same state as the reactants are called homogeneous
- Catalysts in a different state from the reactants are called heterogeneous
1.1 Reaction Rates

This lesson revises the factors which can affect the speed of a reaction, methods used to measure the speed of a reaction and their graphical representation.

Factors

The rate of a chemical reaction is the speed of the reaction. It can be effected by:-

- Temperature
  
  As you incr the temp of the reacting chemicals the reaction gets fa

- Concentration
  
  If any of your reacting chemicals are solu then increasing the conc of the solution will make the reaction fa

- Surface area (Particle Size)
  
  If any of your reacting chemicals are solids then breaking the solid into sma lumps will increase the sur area of the solid and make the reaction fa.

- Catalysts
  
  For some reactions it is possible to find an extra ingredient that allows the reacting chemicals to react fa than normal but will not be us up during the reaction.
One of the most important uses of **cat** is to help **control poll**ution, in particular, **exh fumes** from cars which contain **pois**onous chemicals, **can causing** chemicals and gases that help form **ac rain**.

**Exh fumes** normally **poll**ut the air with a mixture of **unburnt oil** and **pet**rol, **carbon monox**ide and **oxides of nitr**ogen. The **cat**alyst chamber converts these into **harmless gases** by helping them to react with each other and **oxy**gen from the air.

**Nitr**ogen, **oxy**gen, **wat vapour** and **car dioxide** are produced and released into the air instead.

**Cat**alysts make use of very expensive **Tran**sition **Metals** like **platinum**.

Many **cat**alysts simply provide a **surf**ace onto which **mol**ecules can be **adsorbed**, **weakened**, **reacted** more easily and then **released**.

**e.g**

\[
\text{NH}_3 + \text{O}_2 \rightarrow \text{NO} + \text{H}_2\text{O}
\]

(*Try balancing this equation*)

The **cat**alyst remains **unch**anged by the process and **none of the catalyst is used up** - **sa am**ount at the end as you started with.

Other **catalysts** quite definitely **take part** in a reaction and **appear** to **cha**nge. Eg, **pink cobalt (II) chloride** turns **green** whilst **spe**ed up the reaction between **rochelle salt & hydrogen peroxide**.

However, the **pink** colour **ret**urns when the reaction stops so ....

The **catalyst** remains **unch**anged by the process and **none of the catalyst is used up - sa am**ount at the end as you started with.
Following Progress of a Reaction

① Measure the *quantity* of a *product* being *produced* at *regular time intervals*.

*eg* in the reaction between *magnesium* and *hydrochloric acid*:

\[ \text{Mg}(s) + 2\text{HCl}(aq) \rightarrow \text{MgCl}_2(aq) + \text{H}_2(g) \]

an 'easy option' is to measure the *volume* of hydrogen gas.

② Measure the *quantity* of a *reactant* being *used up* at *regular time intervals*.

*eg* in the reaction between *magnesium* and *hydrochloric acid*:

\[ \text{Mg}(s) + 2\text{HCl}(aq) \rightarrow \text{MgCl}_2(aq) + \text{H}_2(g) \]

a 'difficult option' would be to measure the *concentration* of hydrochloric acid.

③ Time how long it takes for a certain *quantity* of *product* to be *produced* or how long it takes for a certain *quantity* of *reactant* to be *used up* - set an 'end-point' for the reaction.

*eg* in the reaction between *sodium thiosulfate* and *hydrochloric acid* the solid *precipitate* of *sulfur powder* would be difficult to measure directly.

Instead we set an 'end-point' for the reaction.
Any reaction that produces a gas which can escape into the room will lose weight.

An electronic balance can be used to measure the weight of chemicals and apparatus and the total weight of gas produced can be calculated by subtracting from the starting weight.

Different sizes of marble lumps were compared using this apparatus and it was found that:

small lumps react faster than medium lumps react faster than large lumps

A number of different methods can be used to measure the volume of a gas produced during a chemical reaction.

The easiest and most common method is to collect the gas in an upturned measuring cylinder filled with water.

As the gas goes in it pushes the water out allowing the volume of gas to be measured using the scale on the measuring cylinder.

Different concentrations of hydrochloric acid were compared using this apparatus and it was found that:

more concentrated (1M) acid reacts faster than less concentrated (0.5M)

Many reactions produce solid precipitate and go cloudy, but most do so immediately.

If, however, the reaction is slow enough, we can use a simple technique involving a cross drawn on a piece of paper to measure the rate of the reaction.

The rate of this reaction was measured at different temperatures and it was found that:

higher the temperature the faster the reaction
A student investigated the amount of the biological catalyst, catalase, in different vegetables. Catalase breaks down hydrogen peroxide solution to produce water and oxygen.

The experiment was repeated to find out if increasing the concentration of hydrogen peroxide solution would speed up the reaction.

Complete the labelling of the diagram to show how she would make her second experiment a fair test.

A catalyst speeds up the following reaction:

\[ \text{hydrogen peroxide} \rightarrow \text{water} + \text{oxygen} \]

The grid shows reactions carried out using the same mass of catalyst with two different concentrations of hydrogen peroxide.

A student investigated the effect of concentration on the rate of reaction between magnesium and sulphuric acid. In each case she used the same mass of magnesium ribbon and timed how long it took for the magnesium to disappear.

The results are shown.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Volume of 2 mol/l sulphuric acid/cm³</th>
<th>Volume of water/cm³</th>
<th>Total volume/cm³</th>
<th>Time/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>20</td>
<td>0</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>15</td>
<td>20</td>
<td>35</td>
<td>65</td>
</tr>
</tbody>
</table>

(a) (i) Complete the table to show the volume of water the student should have used in experiment 2.

How did the speed of the reaction in experiment 2 compare with the speed of the reaction in experiment 1?

(b) Magnesium reacts with dilute sulphuric acid to produce magnesium sulphate and hydrogen gas. State the test for hydrogen gas.

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<tr>
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<th>Volume of water/cm³</th>
<th>Total volume/cm³</th>
<th>Time/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>20</td>
<td>0</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>15</td>
<td>20</td>
<td>35</td>
<td>65</td>
</tr>
</tbody>
</table>

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How did the speed of the reaction in experiment 2 compare with the speed of the reaction in experiment 1?

(b) Magnesium reacts with dilute sulphuric acid to produce magnesium sulphate and hydrogen gas. State the test for hydrogen gas.
Q5. Two students investigated the reaction between magnesium and dilute hydrochloric acid.

(a) Identify the two experiments which could be used to show the effect of concentration on the speed of reaction.

A B C
D E F

(b) Identify the experiment with the fastest speed of reaction.

Q6. A student investigated the reaction between marble chips and excess dilute hydrochloric acid.

Which of the following would not affect the rate of the reaction?

A Increasing the volume of the acid
B Decreasing the size of the marble chips
C Decreasing the concentration of the acid
D Increasing the temperature of the acid

Q7. Two students investigated the reaction between magnesium and dilute hydrochloric acid.

(a) Identify the two experiments which could be used to show the effect of concentration on the speed of reaction.

(b) Identify the experiment with the fastest speed of reaction.

Q8. The reaction between sodium persulphate and potassium iodide was investigated to show the "Effect of Concentration on Reaction Rate".

The Iodine Scavenger is there to react with the iodine produced meaning that the starch cannot turn blue-black until the Scavenger is used up. In effect, it acts like a a 'finishing line' that the reaction must reach. Once the finishing line is reached, there is a dramatic change in colour.

The results obtained during this PPA are shown in the table.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Volume of sodium persulphate (cm³)</th>
<th>Volume of water (cm³)</th>
<th>Reaction time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>126</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>0</td>
<td>162</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>0</td>
<td>210</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0</td>
<td>336</td>
</tr>
</tbody>
</table>

(a) Complete the results table to show the volumes of water used in experiments 2, 3 and 4.

(b) How was the end-point of the reaction determined?

(c) Apart from using a timer, what allowed the accurate measurement of reaction times?
1.2 Reaction Progress

This lesson topic deals with some ways of following the progress of a chemical reaction.

**Progress of a Reaction**  
The aim of the following experiment is to follow the progress of a reaction by recording the volume of gas produced at regular intervals.

The reaction involves magnesium and hydrochloric acid, which react to form magnesium chloride and hydrogen gas.

\[
magnesium \quad + \quad \text{hydrochloric acid} \quad \rightarrow \quad MgCl_2 \quad + \quad H_2
\]

**Time Table**

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Time (s)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A *sha* slope - many reactions are slow to get started

B *st* slope - fast reaction rate

C *sha* slope - reaction starts to slow down as chemicals are used up (their concentrations fall)

D *le* slope - reaction has stopped. One of the chemicals has been used up completely
Calculating the Rate

This activity examines how the rate of a reaction can be calculated from a progress graph.

**Rate of reaction** is the change in quantity of a reactant or product per unit of time.

\[
\text{average rate} = \frac{\text{change in quantity}}{\text{change in time}}
\]

The unit used for rate depends on the quantity of the reactant/product that is being measured, and the time scale for the reaction.

- e.g. weight loss (electrical balance) g/s, g/min, g/hour
- gas volume (syringe) ml or cm³, cm³/s etc.
- concentration (colourimeter) moles/litre, moles/l/s etc.

The reaction between sulphuric acid and magnesium produces hydrogen gas. The progress of the reaction can be monitored by measuring the volume of gas produced. The **Progress Graph**, below, can be used to calculate the rate of this reaction at different stages.
Chemical Changes & Structure

The rate will be at a maximum near the beginning of the reaction, (when the concentrations of the reactants are at their highest level), will usually drop quite steadily (as the reactant concentrations decrease) and will eventually reach zero (once one of the reactants is used up completely.)
Comparing Reaction Progress

Ex 1 - Higher Temperature

The purpose of this activity is to add another labelled line to each of the progress graphs.

Both reactions have used the same mass of zinc, with the same particle size, with the same volume and concentration of hydrochloric acid.

**lower temperature**

The reaction has finished when the volume reached its maximum value:

\[ \text{maximum volume} = \text{cm}^3 \]

The end-point of the reaction came after minutes.

The starting slope of the reaction can be measured/estimated using

\[ \text{average rate} = \frac{\text{change in quantity}}{\text{change in time}} \]

For example:

after 2 minutes

\[ \text{volume} = \text{cm}^3 \]

\[ \text{Average Rate} = \quad / \quad 2 \]

\[ = \text{cm}^3 \text{ min}^{-1} \]

**higher temperature**

The final volume of the reaction will be smaller / the same / larger.

The end-point of the reaction will be sooner / the same / later.

The starting slope of the reaction will be shallower / the same / steeper.
Both reactions have used the same mass of marble, with the same particle size, with the same volume of hydrochloric acid at the same temperature.

lower concentration

The reaction has finished when the mass reached its minimum value:-

minimum mass = g

The end-point of the reaction came after minutes.

The starting slope of the reaction can be measured/estimated using

average rate = \frac{\text{change in quantity}}{\text{change in time}}

For example:

after 0 min mass = 199.6 g
after 2 min mass = g

\[ \Delta \text{mass} = 199.6 - = \quad g \]

Average Rate = / 2 = g min\(^{-1}\)

higher concentration

The final mass of the reaction will be smaller / the same / larger

The end-point of the reaction will be sooner / the same / later

The starting slope of the reaction will be shallower / the same / steeper
Ex 3 - Smaller Amount

Both reactions have used the same par size, with the same vol and same conc of hydrochloric acid at the same temp.

1 g of marble
The reaction has finished when the volume reached its maximum value:
maximum volume = 100 cm$^3$
The end-point of the reaction came after minutes.

0.5 g of marble
The final volume of the reaction will be halved / the same / doubled
The end-point of the reaction will be sooner / the same / later
The starting slope of the reaction will be shallower / the same / steeper

Ex 4 - Catalysed Reaction
The catalysed reaction will be the faster reaction and will produce more gas over the same time interval: the slope will be steeper.
The catalysed reaction will finish first.

Both reactions have used the same ma of zinc, with the same par size, with the same vol and conc of sulphuric acid at the same temperature, so the final volume of gas will be the same.
Chemical Changes & Structure

Q1.

Rapid inflation of airbags in cars is caused by the production of nitrogen gas. The graph gives information on the volume of gas produced over 30 microseconds.

<table>
<thead>
<tr>
<th>Volume of nitrogen gas produced (litres)</th>
<th>Time (microseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

(a) (i) Calculate the average rate of reaction between 2 and 10 microseconds.

(ii) At what time has half of the final volume of nitrogen gas been produced?

Q2.

Hydrogen peroxide solution decomposes to give water and oxygen.

\[ 2\text{H}_2\text{O}_2(aq) \rightarrow 2\text{H}_2\text{O}(l) + \text{O}_2(g) \]

The graph shows the results of an experiment carried out to measure the volume of oxygen gas released.

<table>
<thead>
<tr>
<th>Volume of oxygen gas (cm³)</th>
<th>Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
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<tr>
<td>25</td>
<td>25</td>
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<td>30</td>
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<tr>
<td>35</td>
<td>35</td>
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<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Calculate the average rate of reaction between 0 and 20 seconds.

Q3.

Zinc reacts with dilute hydrochloric acid producing hydrogen gas.

The rate of reaction between zinc and dilute hydrochloric acid can be followed by measuring the volume of gas given off during the reaction.

Results

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>Volume of gas (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>58</td>
</tr>
<tr>
<td>40</td>
<td>72</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

b) Calculate the average rate at which gas is given off during the first 40 seconds of the reaction.

\[ \frac{\text{cm}^3}{\text{s}} \]

c) Why would increasing the concentration of the acid increase the rate of the reaction?

a) (i) Plot a line graph of the results of the reaction.

(ii) Predict the volume of gas which would have been given off after 60 seconds.

\[ \text{cm}^3 \]
Learning Outcomes Topic 1

Knowledge Met in this Section

Measuring Reaction Rates

- Reactions can be followed by measuring changes in concentration, mass or volume of reactants or products.
- Rates of reaction can be increased by:
  - increasing the temperature of the reactants
  - increasing the concentration of a reacting solution
  - increasing the surface area (decreasing particle size) of a reacting solid
  - using a catalyst

- The progress of a reaction can be shown graphically.
- Graphs can be used to show the end-point of a reaction.
- Graphs can be used to show the effect of changes in reaction conditions.
- Graphs can be used to show the effect of changes in reaction quantities.
- The average rate of a reaction can be calculated from initial and final quantities and the time interval.
- The average rate at any stage of a reaction can be calculated from change in quantities and the time interval.

\[
\text{average rate} = \frac{\Delta \text{ quantity}}{\Delta \text{ time}}
\]

- The rate of a reaction can be shown to decrease over time by calculating the average rate at different stages of the reaction.
Q1. Which of the following elements has similar properties to argon?

A) Fluorine  
B) Krypton  
C) Potassium  
D) Zinc

Q2. Which of the following would not be evidence of a chemical reaction when the solid is added to the solution?

A) A colour change  
B) A gas being given off  
C) The temperature rising  
D) The solid disappearing

Q3. Which line in the table shows the approximate composition of air?

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Oxygen</th>
<th>Carbon dioxide</th>
<th>Noble gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>78</td>
<td>21</td>
<td>0.03</td>
</tr>
<tr>
<td>B</td>
<td>21</td>
<td>78</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>D</td>
<td>0.03</td>
<td>78</td>
<td>1</td>
</tr>
</tbody>
</table>

Q4. Vinegar is prepared by dissolving ethanoic acid in water. Which term describes the water used when making the vinegar?

A) Solute  
B) Saturated  
C) Solvent  
D) Solution

Q5. Vinegar is prepared by dissolving ethanoic acid in water. Which line in the table identifies the solute, solvent and solution?

<table>
<thead>
<tr>
<th>Solute</th>
<th>Solvent</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>water</td>
<td>ethanoic acid</td>
</tr>
<tr>
<td>B</td>
<td>water</td>
<td>vinegar</td>
</tr>
<tr>
<td>C</td>
<td>ethanoic acid</td>
<td>water</td>
</tr>
<tr>
<td>D</td>
<td>vinegar</td>
<td>water</td>
</tr>
</tbody>
</table>

Q6. Which of the following elements is an alkali metal?

A) Aluminium  
B) Calcium  
C) Copper  
D) Sodium

Q7. Lemonade can be made by dissolving sugar, lemon juice and carbon dioxide in water. In lemonade, the solvent is

A) water  
B) sugar  
C) lemon juice  
D) carbon dioxide

Q8. Which line in the table correctly shows how the concentration of a solution changes by adding more solute or by adding more solvent?

<table>
<thead>
<tr>
<th>Adding solute</th>
<th>Adding solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>concentration falls</td>
</tr>
<tr>
<td>B</td>
<td>concentration falls</td>
</tr>
<tr>
<td>C</td>
<td>concentration rises</td>
</tr>
<tr>
<td>D</td>
<td>concentration rises</td>
</tr>
</tbody>
</table>
**CONSOLIDATION QUESTIONS**

**Q1.**

Magnesium and zinc both react with hydrochloric acid. In which of the following experiments would the reaction rate be fastest?

**A**  
![Image](20°C)  
1 mol L⁻¹ hydrochloric acid  
zinc lump

**B**  
![Image](30°C)  
2 mol L⁻¹ hydrochloric acid  
magnesium lump

**C**  
![Image](30°C)  
1 mol L⁻¹ hydrochloric acid  
zinc powder

**D**  
![Image](40°C)  
2 mol L⁻¹ hydrochloric acid  
magnesium powder

**Q2.**

The following results were obtained in the reaction between marble chips and dilute hydrochloric acid.

<table>
<thead>
<tr>
<th>Time/minutes</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total volume of carbon dioxide produced/cm³</td>
<td>0</td>
<td>52</td>
<td>68</td>
<td>78</td>
<td>82</td>
<td>84</td>
</tr>
</tbody>
</table>

What is the average rate of production of carbon dioxide, in cm³ min⁻¹, between 2 and 8 minutes?

- **A** 5  
- **B** 26  
- **C** 30  
- **D** 41

**Q3.**

Chloromethane, CH₃Cl, can be produced by reacting methanol solution with dilute hydrochloric acid using a solution of zinc chloride as a catalyst.

\[ \text{CH}_3\text{OH(aq)} + \text{HCl(aq)} \xrightleftharpoons{} \text{ZnCl}_2(aq) \rightarrow \text{CH}_3\text{Cl(aq)} + \text{H}_2\text{O(l)} \]

The graph shows how the concentration of the hydrochloric acid changed over a period of time when the reaction was carried out at 20 °C.

Calculate the average rate, in mol l⁻¹ min⁻¹, in the first 400 minutes.

**Q4.**

Excess marble chips (calcium carbonate) were added to 25 cm³ of hydrochloric acid, concentration 2 mol l⁻¹.

Which of the following measurements, taken at regular intervals and plotted against time, would give the graph shown above?

- **A** Temperature  
- **B** Volume of gas produced  
- **C** pH of solution  
- **D** Mass of the beaker and contents
Hydrogen peroxide solution decomposes to give water and oxygen.

\[ 2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \]

The graph shows the results of an experiment carried out to measure the volume of oxygen gas released.

a) State the test for oxygen gas

b) What volume of gas was released after 20 seconds.

\[
\underline{\text{cm}^3}
\]

c) Calculate the average rate at which gas is given off during the first 20 seconds of the reaction.

\[
\underline{\text{cm}^3 \text{s}^{-1}}
\]

d) Draw a second line on the graph to show the effect of increasing the temperature of the hydrogen peroxide solution.

e) Draw a labelled diagram showing the apparatus that could have been used to obtain the results used to construct this graph.
Hydrogen gas can be produced in the laboratory by adding a metal to dilute acid. Heat energy is also produced in the reaction. A student measured the volume of hydrogen gas produced when zinc lumps were added to dilute hydrochloric acid.

a) State the term used to describe all chemical reactions that release heat energy ___________________

b) Plot these results as a line graph

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of hydrogen (cm³)</td>
<td>0</td>
<td>12</td>
<td>21</td>
<td>29</td>
<td>34</td>
<td>36</td>
<td>37</td>
<td>37</td>
</tr>
</tbody>
</table>

c) Calculate the average rate of reaction, in cm³ s⁻¹, between 10 and 30 seconds.  ___________________

d) Estimate the time taken, in seconds, for the reaction to finish.  ___________________

e) The student repeated the experiment using the same mass of zinc.

Plot a dotted line on your graph showing how the rate of the reaction would change if zinc powder was used instead of lumps.