AQA Chemistry Unit 8

Rates and Equilibrium

Crompton House Chemistry

I am able to:

		Learn it	Revise it
1	I can explain how the following factors affect the rate of reaction: pressure, concentration, surface area, temperature, and catalyst		
2	I can calculate the rate of reaction from a graph using a tangent		
3	I can explain what is meant by the term reversible reaction and explain how the dynamic equilibrium of a reversible reaction can be affected by temperature and pressure changes.		

DODDLE QUIZZES

AQA Calculating reaction rates ____________%

AQA Catalyst ____________%

AQA Factors affecting reaction rate ____________%

AQA Reversible Reactions ____________%

AQA Rates of Reaction Practical Quiz ____________%

Kerboodle Extension Quizzes

Positive Points/postcards for completion

C8 Homework: Rates and Equilibrium 1 ____________%

C8 Homework: Rates and Equilibrium 2 ____________%

C8 Progress Quiz: Rates of reaction 1` ____________%

C8 Progress Quiz: Rates of reaction 2 ____________%

C8 Checkpoint quiz: Rates and Equilibrium ____________%

Self-Reflection

WWW:

EBI:

Checked by Teacher:

Date:

Chapter 8: Rates and equilibrium 1

Knowledge organiser

Rates of reaction

The **rate of a reaction** is how quickly the reactants turn into the products.

To calculate the rate of a reaction, you can measure:

- how quickly a reactant is used up

$$\text{mean rate of reaction} = \frac{\text{quantity of reactant used}}{\text{time taken}}$$

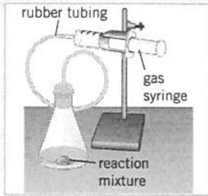
- how quickly a product is produced.

$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

For reactions that involve a gas, this can be done by measuring how the mass of the reaction changes or the volume of gas given off by the reaction.

Volume of gas produced

The reaction mixture is connected to a gas syringe or an upside down measuring cylinder. As the reaction proceeds the gas is collected.



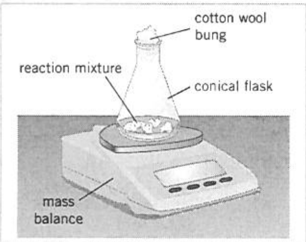
The rate for the reaction is then:

$$\text{rate} = \frac{\text{volume of gas produced}}{\text{time taken}}$$

Volume is measured in cm^3 and time in seconds, so the unit for rate is cm^3/s.

Change in mass

The reaction mixture is placed on a mass balance. As the reaction proceeds and the gaseous product is given off, the mass of the flask will decrease.



The rate for the reaction is then:

$$\text{rate} = \frac{\text{change in the mass}}{\text{time taken}}$$

The mass is measured in grams and time is measured in seconds. Therefore, the unit of rate is g/s.

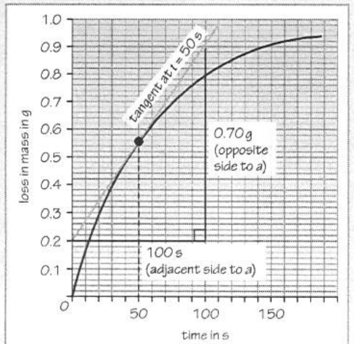
Calculating rate from graphs (HT only)

The results from an experiment can be plotted on a graph.

- A steep gradient means a high rate of reaction – the reaction happens quickly.
- A shallow gradient means a low rate of reaction – the reaction happens slowly.

Mean rate at specific time

To obtain the rate at a specific time draw a **tangent** to the graph and calculate its **gradient**.

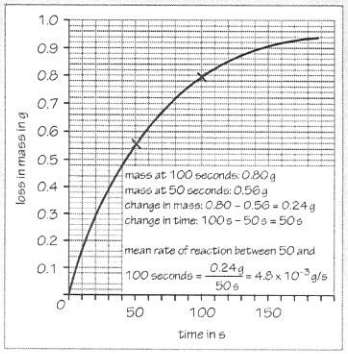


Rate at 50 s = $\frac{0.70\,g}{100\,s}$ = 0.007 g/s

The gradient is the change in y divided by the change in x for a right-angled triangle drawn from the tangent.

Mean rate between two points in time

To get the mean rate of reaction between two points in time:



Collision theory

For a reaction to occur, the reactant particles need to collide. When the particles collide, they need to have enough energy to react or they will just bounce apart. This amount of energy is called the **activation energy**.

You can increase the rate of a reaction by:

- increasing the **frequency of collisions**
- increasing the energy of the particles when they collide.

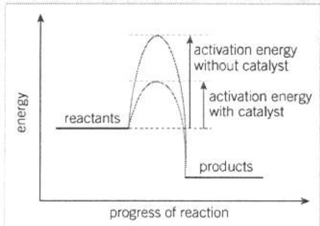
Factors affecting rate of reaction

Condition that increases rate	How is this condition caused?	Why it has that effect
increasing the temperature	Heat the container in which the reaction is taking place.	1 particles move faster, leading to more frequent collisions 2 particles have more energy, so more collisions result in a reaction note that these are two *separate* effects
increasing the concentration of solutions	Use a solution with more solute in the same volume of solvent.	there are more reactant particles in the reaction mixture, so collisions become more frequent
increasing the pressure of gases	Increase the number of gas particles you have in the container or make the container smaller.	less space between particles means more frequent collisions
increasing the surface area of solids	Cut the solid into smaller pieces, or grind it to create a powder, increasing the surface area. Larger pieces decrease the surface area.	only reactant particles on the surface of a solid are able to collide and react; the greater the surface area the more reactant particles are exposed, leading to more frequent collisions

Catalysts

Some reactions have specific substances called **catalysts** that can be added to increase the rate. These substances are not used up in the reaction.

A catalyst provides a different reaction pathway that has a lower activation energy. As such, more particles will collide with enough energy to react, so more collisions result in a reaction.



Chapter 8: Rates and equilibrium 2
Knowledge organiser

Reaction conditions

The conditions of a reaction refer to the external environment of the reaction. When the reaction occurs in a closed system, you can change the conditions by:

- changing the concentration of one of the substances
- changing the temperature of the entire reaction vessel
- changing the pressure inside the vessel.

Le Châtelier's principle (HT only)

At equilibrium, the amount of reactants and products is constant. In order to change the amounts of reactant and product at equilibrium the *conditions* of the reaction must be changed. The closed system will then counteract the change by favouring either the forward reaction or the reverse reaction. This is known as **Le Châtelier's principle**.

For example, lowering the concentration of the product in the system causes the forward reaction to be **favoured** to increase the concentration of the product.

Changing concentrations (HT only)

Change	Effect	Explanation
decrease concentration of product	favours the forward reaction	opposes the change by making *less* reactant and *more* product
increase concentration of product	favours the reverse reaction	opposes the change by making *more* reactant and *less* product
decrease concentration of reactant	favours the reverse reaction	opposes the change by making *more* reactant and *less* product
increase concentration of reactant	favours the forward reaction	opposes the change by making *less* reactant and *more* product

Changing temperature (HT only)

Change	Effect	Explanation
increase temperature of surroundings	favours the endothermic reaction	opposes the change by decreasing the temperature of the surroundings
decrease temperature of surroundings	favours the exothermic reaction	opposes the change by increasing the temperature of the surroundings

Changing pressure (HT only)

Change	Effect	Explanation
increase the pressure	favours the reaction that results in fewer molecules	decreasing the number of molecules within the vessel opposes the change because it decrease pressure
decrease the pressure	favours the direction that results in more molecules	increasing the number of molecules within the vessel opposes the change because it increase pressure

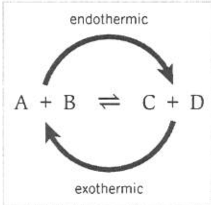
Key terms

Make sure you can write a definition for these key terms.

activation energy *catalyst* *collision* *collision theory* *closed system* *conditions* *dynamic equilibrium* *frequency of collision* *gradient* *Le Châtelier's principle* *rate of reaction* *reversible reaction* *tangent*

Reversible reactions

In some reactions, the products can react to produce the original reactants. This is called a **reversible reaction**. When writing chemical equations for reversible reactions, use the $\rightleftharpoons$ symbol.



In this reaction:

- A and B can react to form C and D – the forward reaction
- C and D can react to form A and B – the reverse reaction.

The different directions of the reaction have opposite energy changes.

If the forward reaction is *endothermic*, the reverse reaction will be *exothermic*.

The same amount of energy is transferred in each direction.

Equilibrium

In a **closed system** no reactants or products can escape. If a reversible reaction is carried out in a closed system, it will eventually reach **dynamic equilibrium** – a point in time when the forward and reverse reactions have the same rate.

At dynamic equilibrium:

- the reactants are still turning into the products
- the products are still turning back into the reactants
- *the rates of* these two processes are *equal*, so overall the amount of reactants and products are constant.

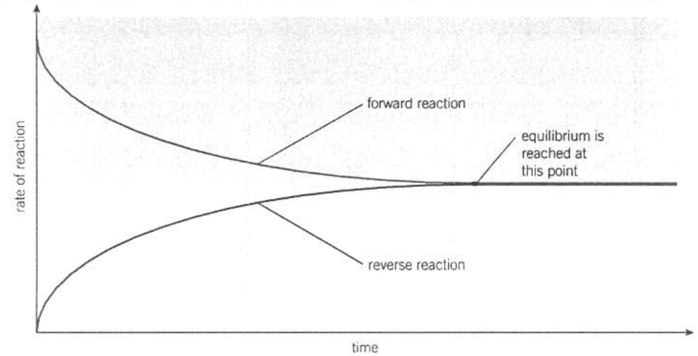
Dynamic equilibrium

At dynamic equilibrium the amount of reactant and product are constant, but not necessarily equal.

You could have a mixture of reactants and products in a 50:50 ratio, in a 75:25 ratio, or in any ratio at all. The **conditions** of the reaction are what change that ratio.

How dynamic equilibrium is reached

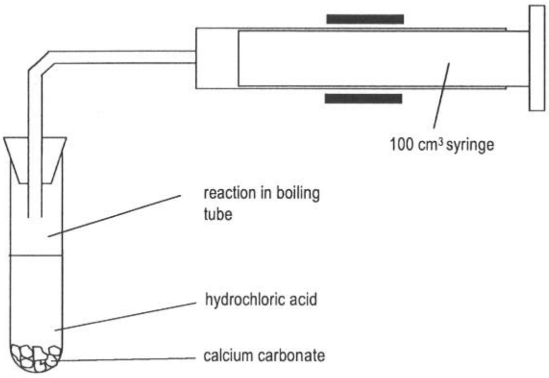
Progress of reaction	start of reaction	middle of reaction	at dynamic equilibrium
Amount of A + B	high	decreasing	constant
Frequency of collisions A + B	high	decreasing	constant
Rate of forward reaction	high	decreasing	same as rate of reverse reaction



Progress of reaction	start of reaction	middle of reaction	at dynamic equilibrium
Amount of C + D	zero	increasing	constant
Frequency of collisions C + D	no collisions	increasing	constant
Rate of reverse reaction	zero	increasing	same as rate of forward reaction

REACTION RATES 1

Calcium carbonate reacts with hydrochloric acid to form carbon dioxide gas which can be collected in a gas syringe. Kate reacted hydrochloric acid with an excess of calcium carbonate. She measured the volume of gas formed at 10 second intervals. Her results are shown in the table.



Time (s)	Volume of gas (cm^3)
0	0
10	16
20	26
30	33
40	40
50	45
60	49
70	50
80	50
90	50

1 Plot a graph showing volume of carbon dioxide formed against time.

2 How much gas was given off after:

a 12 s ……………… **b** 26 s ……………… **c** 55 s ………………

3 **a** Work out the rate of reaction at 0 seconds by drawing a tangent to the curve at 0 seconds and working out the gradient. Give the units for the reaction rate.

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b Work out the rate of reaction at 30 seconds by drawing a tangent to the curve at 30 seconds and working out the gradient. Give the units for the reaction rate.

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c Explain why the rate of reaction is lower at 30 seconds than at 0 seconds (use collision theory).

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4 **a** When does the reaction stop? ……………………………………………………………………………

b Explain why the reaction stops. ……………………………………………………………………………

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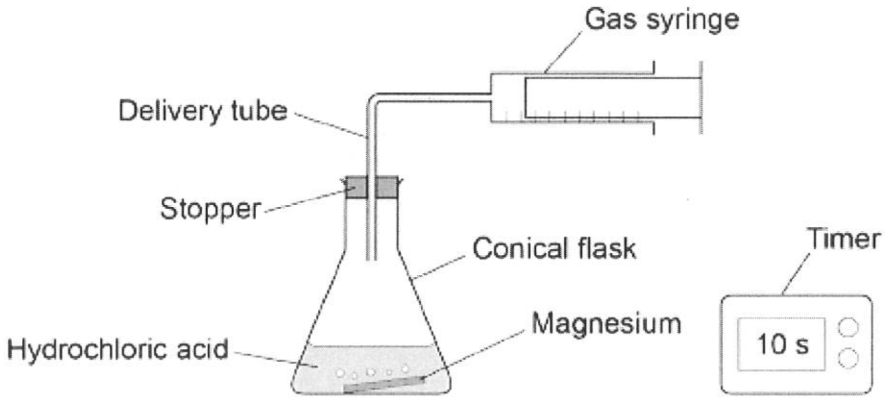
Area	Strength	To develop	Area	Strength	To develop	Area	Strength	To develop
Done with care and thoroughness			Suitable best fit line			Gives units		
Good SPG			Can read points off graph			Can explain why rate changes		
Suitable scales chosen			Draws suitable tangents			Can work out when reaction stops		
Axes are labelled with units			Chooses points well apart			Can explain why reaction stops		
Points plottted			Finds gradients correctly					

Exam Questions

Q1. A student investigated the reaction between magnesium and excess hydrochloric acid.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Pour 50 cm^3 of hydrochloric acid into a conical flask.
2. Add a piece of magnesium.
3. Insert stopper and delivery tube and start a timer.
4. Collect the gas produced in a gas syringe.
5. Record the volume of gas produced every 20 seconds for 2 minutes.
6. Repeat steps 1 to 5 with higher concentrations of hydrochloric acid.

(a) Give the independent variable and **one** control variable in this investigation.

Independent variable ______________________________

Control variable ______________________________

(2)

The table below shows the results from the first experiment using hydrochloric acid with a low concentration.

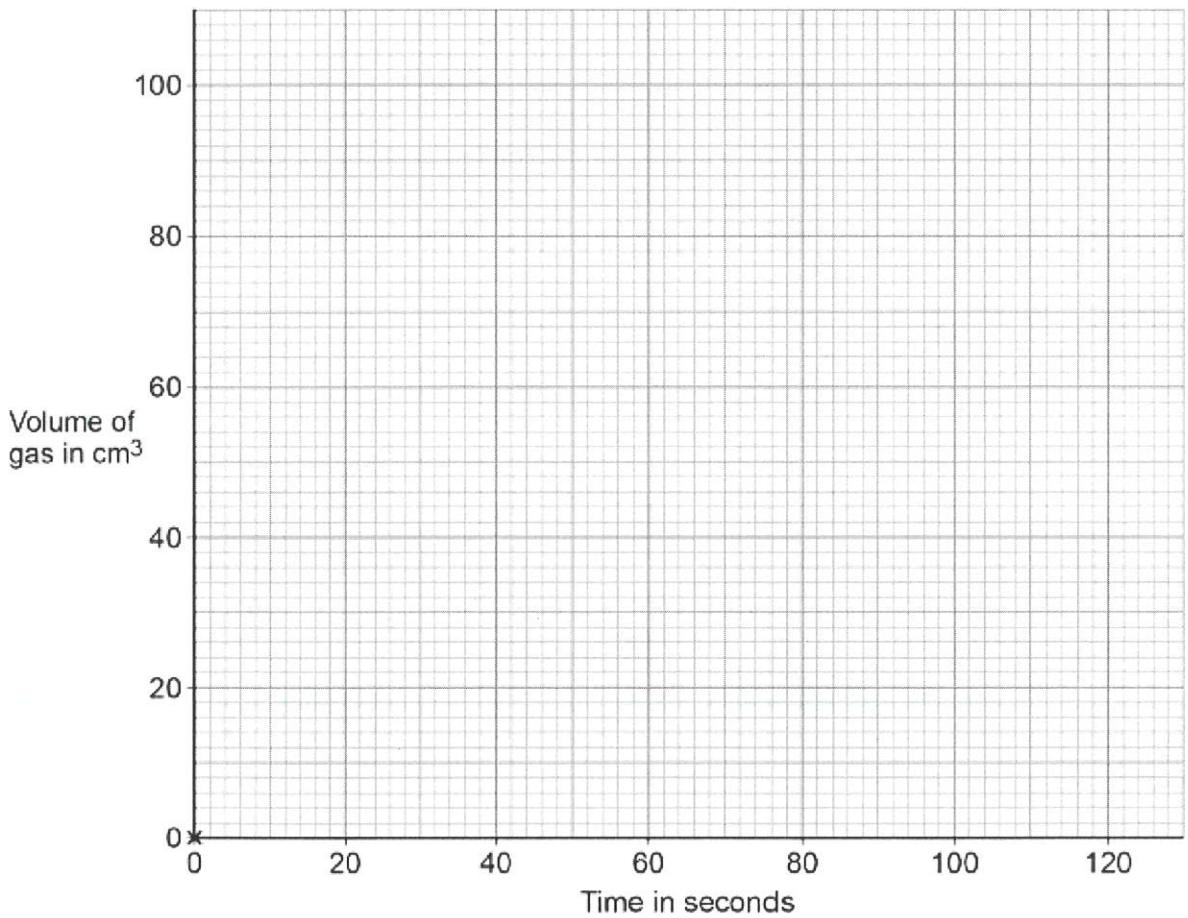
Time in seconds	0	20	40	60	80	100	120
Volume of gas in cm^3	0	48	72	90	97	98	98

(b) Complete **Figure 2**.

You should:

- plot the data from the table above (the point 0,0 has been plotted for you)
- draw a line of best fit.

Figure 2



(3)

(c) How does the **rate** of this reaction change with time?

Use the table above.

Tick (✓) **one** box.

The rate decreases. ☐

The rate increases. ☐

The rate stays the same. ☐

(1)

(d) The student repeated the experiment using hydrochloric acid with a higher concentration.

Which statement is correct?

Tick (✓) **one** box.

The activation energy for the reaction was higher. ☐

The magnesium reacted more quickly. ☐

The reaction finished at the same time. ☐

The total volume of gas collected was smaller. ☐

(1)

(e) Temperature also affects the rate of the reaction.

Explain how increasing the temperature affects the **rate** of the reaction.

You should refer to particles and collisions.

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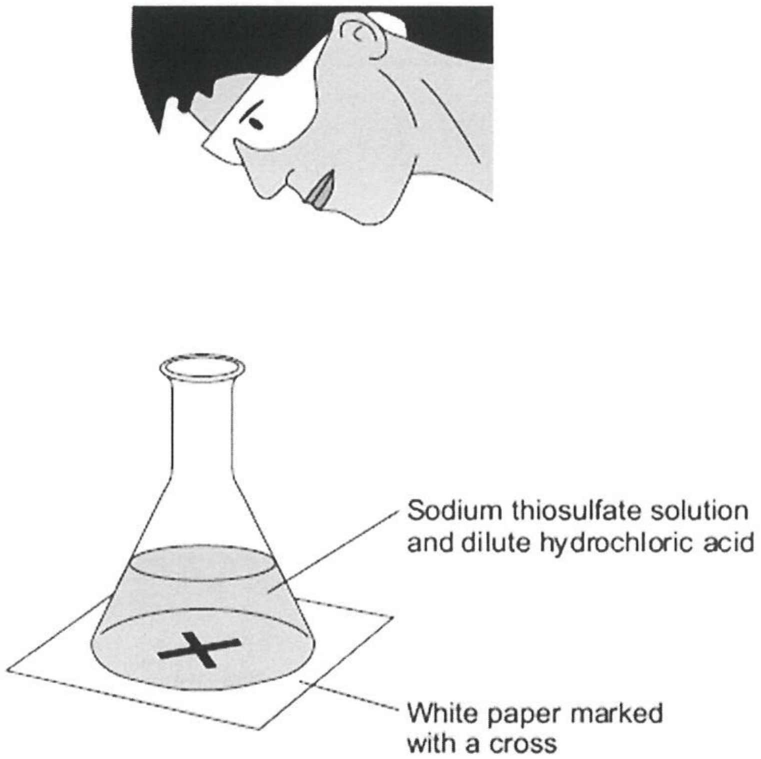
(3)

(Total 10 marks)

Q2. A student investigated the rate of reaction between sodium thiosulfate solution and dilute hydrochloric acid, as shown in **Figure 1**.

Figure 1



The reaction produced a precipitate, which made the mixture turn cloudy.

The student timed how long it took until she could no longer see the cross.

She calculated the rate of the reaction.

(a) The equation for the reaction is:

$$Na_2S_2O_3(aq) + 2\ HCl(aq) \longrightarrow 2\ NaCl(aq) + S(s) + SO_2(g) + H_2O(l)$$

Name the product that made the mixture go cloudy.

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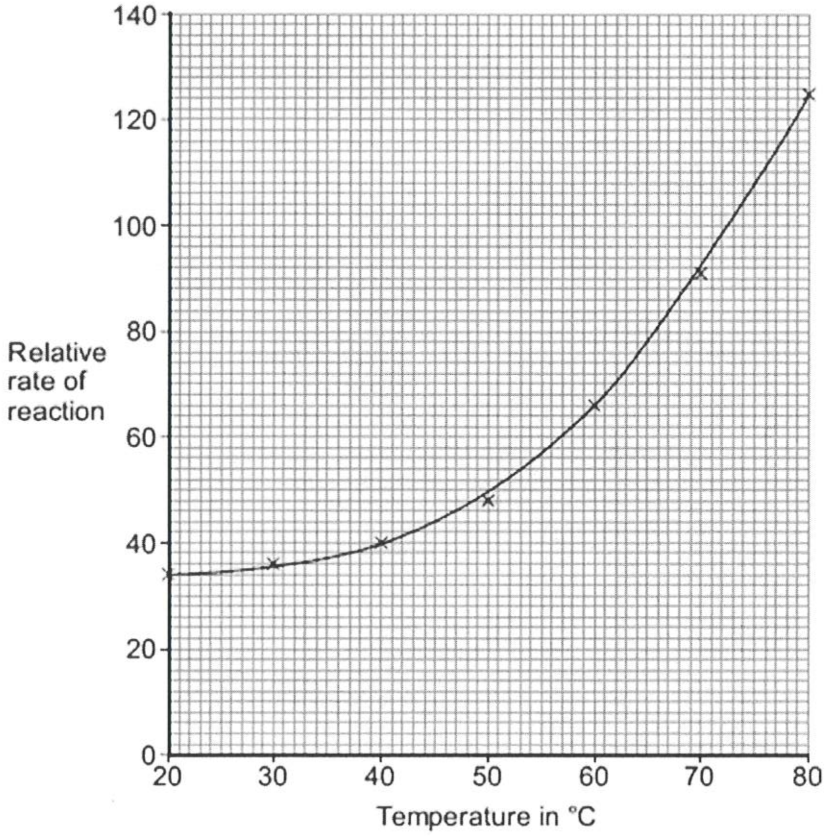
(1)

(b) The student investigated the effect of changing the temperature of the sodium thiosulfate solution on the rate of reaction.

She plotted her results on a graph, as shown in **Figure 2**.

Figure 2



Describe the trends shown in the student's results.

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(2)

(c) The student then investigated the effect of changing the concentration of sodium thiosulfate solution on the rate of the reaction.

(i) Suggest **two** variables the student would need to control to make sure that her results were valid.

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(2)

(ii) From this investigation the student correctly concluded:

'As the concentration of sodium thiosulfate solution doubles, the rate of reaction doubles.'

Explain the student's conclusion in terms of particles.

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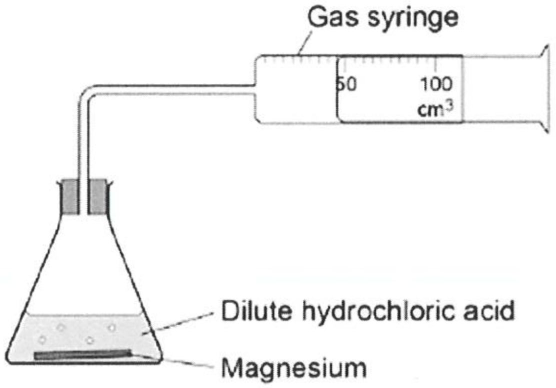
(3)
(Total 8 marks)

Q3. A student investigated the rate of the reaction between magnesium and dilute hydrochloric acid.

The student used the apparatus shown in **Figure 1** to collect the gas produced.

Figure 1



(a) Outline a plan to investigate how the rate of this reaction changed when the concentration of the hydrochloric acid was changed.

- Describe how you would do the investigation and the measurements you would make.
- Describe how you would make it a fair test.

You do **not** need to write about safety precautions.

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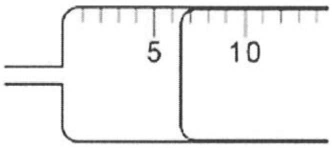
(6)

(b) **Figure 2** shows the gas syringe during one of the experiments.

Figure 2



What is the volume of gas collected?

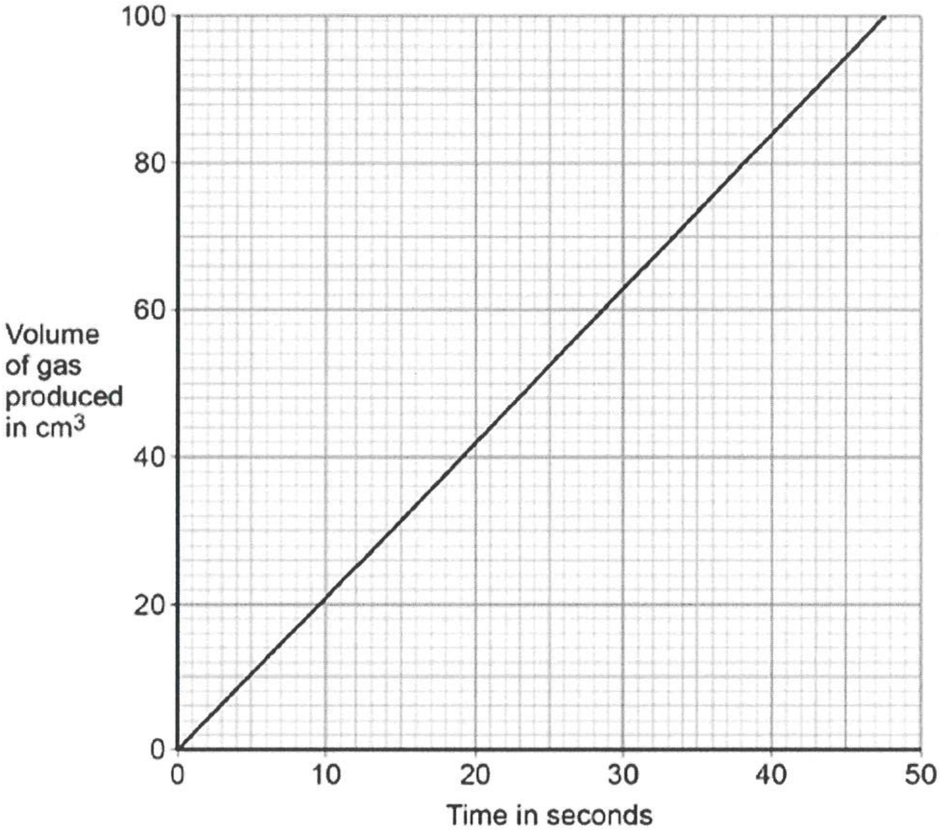
Tick **one** box.

5.3 cm^3	☐	6.5 cm^3	☐
6.0 cm^3	☐	7.0 cm^3	☐

(1)

(c) **Figure 3** shows the student's results for one concentration of hydrochloric acid.

Figure 3



The table below shows the student's results when the concentration was two times greater than the results on **Figure 3**

Time in seconds	Volume of gas produced in cm^3
0	0
10	35
15	52
20	80
30	87

Plot the results in the table above on the grid in **Figure 3**.
Draw a line of best fit.

(3)

(d) Give **one** conclusion about how the rate of reaction changed when the concentration of hydrochloric acid was changed.

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(1)
(Total 11 marks)

HIGHER TIER ONLY

Q4. This question is about equilibrium.

(a) Describe how a reaction reaches equilibrium.

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(2)

Nitrogen dioxide gas reacts to form dinitrogen tetroxide gas.

The reaction is reversible.

The equation for the reaction is:

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$$

(b) Explain the effect on the equilibrium position of increasing the pressure.

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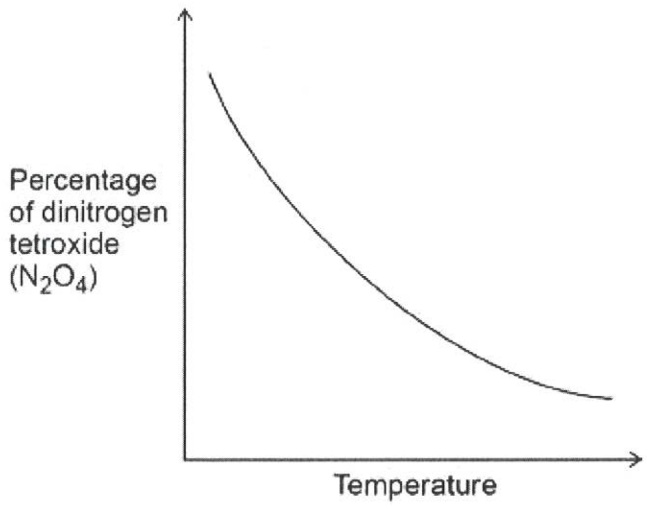
(2)

(c) The graph below shows the change in the percentage of dinitrogen tetroxide (N_2O_4) in the equilibrium mixture as the temperature of the equilibrium mixture is changed.



Explain the effect on the equilibrium position of increasing the temperature.

Use the graph above.

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(3)
(Total 7 marks)