Reaction Rates

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Chemical Reaction

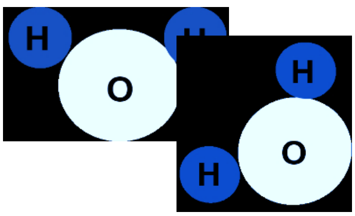
A **chemical process** where **reactants** (starting chemical) are **CHANGED** into **products** (end chemical).

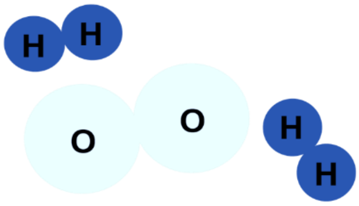
This CHANGE involves:

- The **INTRA-molecular bonds** in the reactants break & new bonds form to produce the products.
- **Change in the energy** of the system

REACTANT/S → **PRODUCT/S**

The atoms get *re-arranged* during a chemical reaction





Atoms:
H – 4 atoms
O – 2 atoms

Molecules:
H_2O – 2 molecules
H_2 – 0 molecules
O_2 – 0 molecules

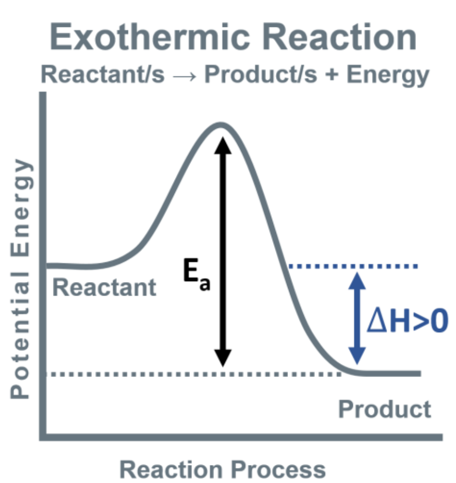
Atoms:
H – 4 atoms
O – 2 atoms

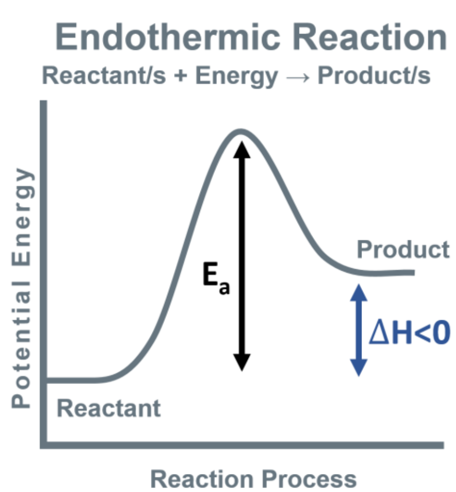
Molecules:
H_2O – 0 molecules
H_2 – 2 molecules
O_2 – 1 molecules

Number of atoms are conserved and **type of molecules change**

Energy Changes in Chemical Reactions

Energy gets **absorbed** and **released** when bonds break and form.
Energy changes which occur during a chemical reaction can be represented using a **POTENTIAL ENERGY DIAGRAM**





The minimum energy needed for a reaction to take place is called **ACTIVATION ENERGY (E_a)**

The net change in energy (amount of heat transferred) for a chemical is called **ENTHALPY CHANGE ΔH**

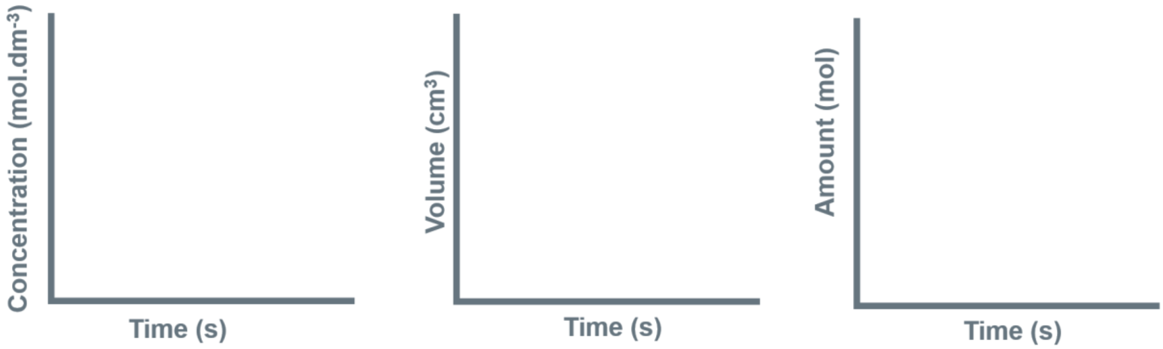
Reaction Rates

Measures the speed of the chemical reaction, determining how **fast** or **slow** it is.

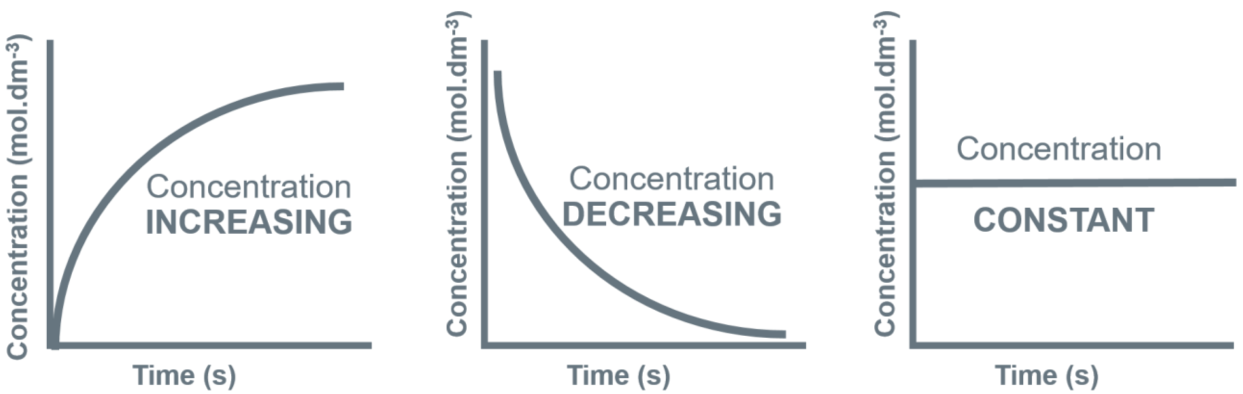
It is defined as the change in concentration of reactants or products per unit time.

$$\text{REACTION RATE} = \frac{\Delta\text{CONCENTRATION of reactants or products}}{\Delta\text{TIME}} = \text{mol dm}^{-3}\text{s}^{-1}$$

Graph Types



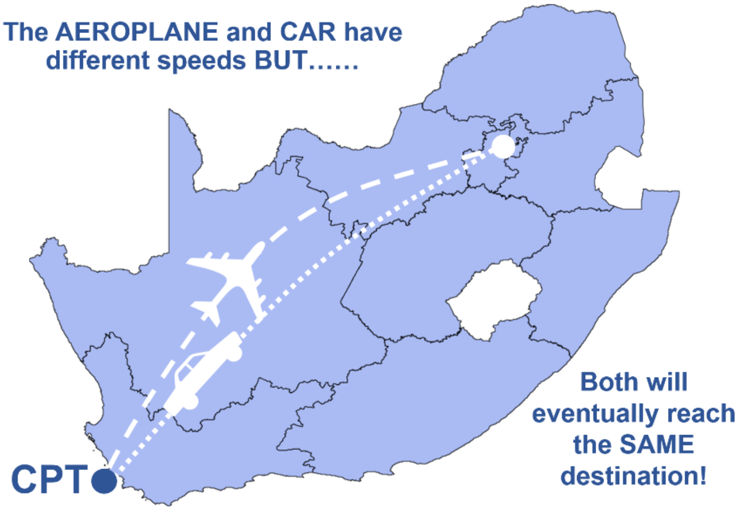
Graph Trends



REMEMBER…

Reaction rates ONLY affect the speed of the reaction

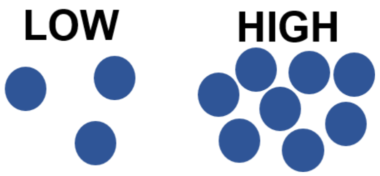
It does NOT change the end state of the reaction (amount of product made)



5 Factors which Change Reaction Rates

HINT: A clever way to remember concepts/lists is to use a fun acronym. A good for the 5 factors is (a.C.C.i.D.e.N.T)

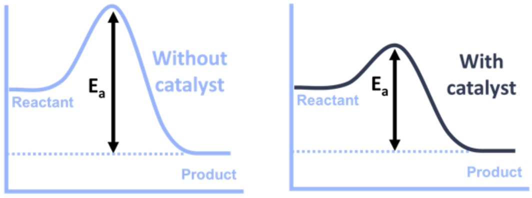
CONCENTRATION



An increase in the concentration of reactants (gaseous and aqueous solutions) leads to:

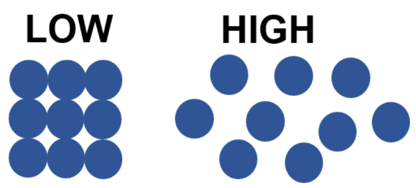
↑ **Collision Frequency**

CATALYST



It **lowers the Activation Energy** providing an alternative route for the chemical reaction

DIVISION OF STATE



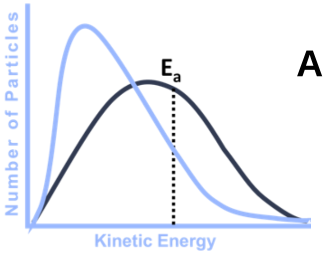
Increasing the surface area of solid reactants leads to:

↑ **Collision Frequency**

NATURE OF REACTANT

Some reactants are more reactive than others, undergoing a chemical change quicker.

TEMPERATURE



A temperature increase causes an **increase in the E_k of the particles** this leads to

↑ **Collision Frequency**

↑ **Number of Successful Collisions per unit time**

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ASTRON ENERGY

The calcium carbonate ($CaCO_3$) in antacid tablets reacts with dilute hydrochloric acid (HCℓ) according to the following balanced equation:

$$CaCO3(s) + 2HCℓ(aq) \rightarrow CaCℓ2(aq) + CO2(g) + H2O(ℓ) \quad \Delta H < 0$$

5.1 Is the above reaction EXOTHERMIC or ENDOTHERMIC? Give a reason for the answer. (2)

Exothermic because ΔH is negative, indicating energy is released

An antacid tablet of mass 2 g is placed in HCℓ(aq). After 30 s the mass of the tablet was found to be 0,25 g.

5.2 Calculate the average rate (in $g \cdot s^{-1}$) of the above reaction. (3)

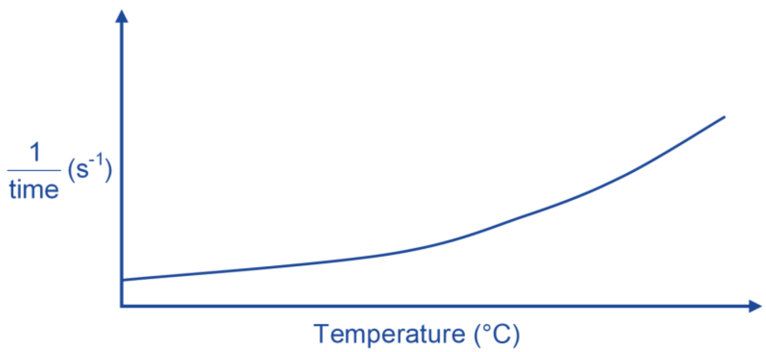
It is not specified the system is closed, so mass is used instead of concentration to calculate reaction rate

$$\mathbf{rate}=\Delta m/\Delta t=(0.25-2)g/(30-0)s=-0.06\ g[.s]^{(-1)}$$

A negative reaction rate indicates the reactant is being used up

Therefore the average rate for the above reaction where the reagent is being used up is 0,06 g.s-1

The reaction rate of similar antacid tablets with excess HCℓ(aq) of concentration 0,1 mol·dm-3 at DIFFERENT TEMPERATURES is measured. The graph below was obtained.



Use the information in the graph to answer the following questions.

5.4 Write down ONE controlled variable for this investigation. (1)

In this experiment the independent variable is temperature (we choose the value) and the dependent variable is time (system response).

Controlled variables include concentration of acid, size / mass / surface area of the tablet.

5.5 Write down a conclusion that can be made from the graph. (2)

Time is used to determine reaction rate (1/$time$)

Therefore from the graph it can be concluded reaction rate increases with temperature.

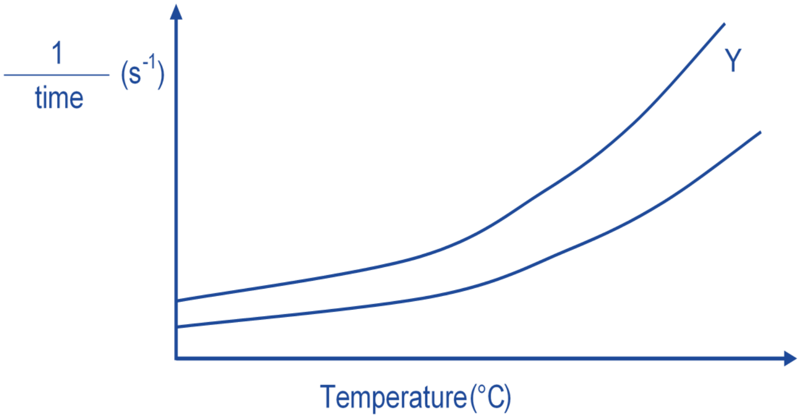
5.6 Use the collision theory to fully explain the answer to QUESTION (3)

An increase in temperature increases the average kinetic energy which means the molecules move faster and have sufficient kinetic energy ($E_k > E_a$).

This results in more effective collisions per unit time/second.

5.7 Redraw the graph above in the ANSWER BOOK.

On the same set of axes, sketch the curve that will be obtained if HCℓ(aq) of concentration 0,2 mol·dm^{-3} is now used. Label this curve **Y**. (2)



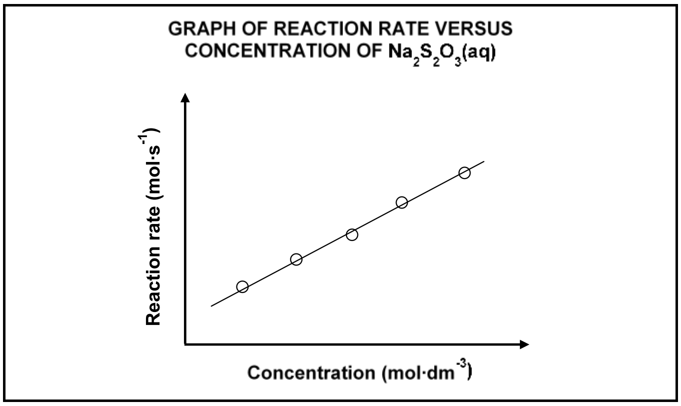
Past Exam Question — Paper 2, May/June 2019, Q.5

Learners use the reaction of a sodium thiosulphate solution with dilute hydrochloric acid to investigate several factors that affect the rate of a chemical reaction.
The balanced equation for the reaction is:

$$Na_2S_2O_3(aq) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + SO_2(g) + S(s) + H_2O(\ell)$$

5.1 Define reaction rate. (2)
Three investigations (I, II and III) are carried out.

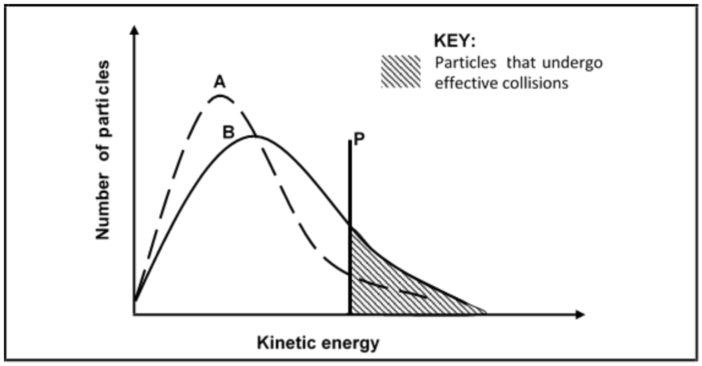
5.2 **INVESTIGATION I**
The results obtained in INVESTIGATION I are shown in the graph.



For this investigation, write down the:
5.2.1 Dependent variable (1)
5.2.2 Conclusion that can be drawn from the results (2)

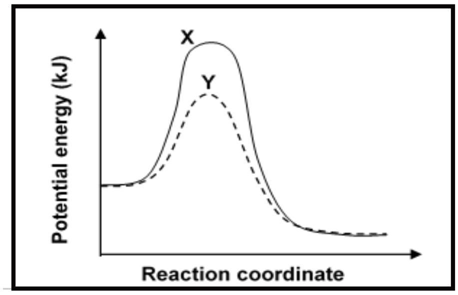
5.3 INVESTIGATION II

The Maxwell-Boltzmann distribution curves, A and B, below represent the number of particles against kinetic energy for the reaction at two different temperatures.



5.3.1 What does line P represent? (1)
5.3.2 Which curve (A or B) was obtained at the higher temperature? (1)
5.3.3 Explain, in terms of the collision theory, how an increase in temperature influences the rate of a reaction. (4)

5.4 INVESTIGATION III
The potential energy diagrams, X and Y, below represent the reaction under two different conditions.



Give a reason why curve Y differs from curve X. (1)

Past Exam Question

Paper 2, Oct/Nov 2018, Q.5

The reaction of zinc and EXCESS dilute hydrochloric acid is used to investigate factors that affect reaction rate. The balanced equation for the reaction is:

$$Zn(s) + 2HC\ell(aq) \rightarrow ZnC\ell_2(aq) + H_2(g)$$

The reaction conditions used and the results obtained for each experiment are summarised in the table below.

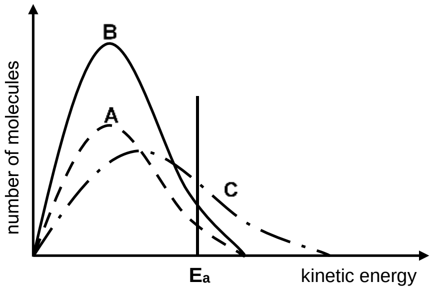
The same mass of zinc is used in all the experiments. The zinc is completely covered in all reactions. The reaction time is the time it takes the reaction to be completed.

EXPERIMENT	CONCENTRATION OF HCℓ (mol·dm^{-3})	VOLUME OF HCℓ (cm^3)	STATE OF DIVISION OF Zn	TEMPERATURE OF HCℓ (°C)	REACTION TIME (min)
1	2,0	200	powder	25	7
2	1,5	200	granules	25	14
3	5,0	200	powder	25	5
4	1,5	400	granules	25	**x**
5	2,0	200	powder	35	4

5.1 Experiment 1 and experiment 5 are compared. Write down the independent variable. (1)
5.2 Define reaction rate. (2)
5.3 Write down the value of x in experiment 4. (2)

Past Exam Question — Paper 2, Oct/Nov 2018, Q.5

5.4 The Maxwell-Boltzmann energy distribution curves for particles in each of experiments 1, 3 and 5 are shown below.



Identify the graph (A or B or C) that represents the following:

5.4.1 Experiment 3 – Give a reason for the answer. (2)

5.4.2 Experiment 5 – Give a reason for the answer. (2)

5.5 Experiment 6 is now conducted using a catalyst and the SAME reaction conditions as for Experiment 1.

5.5.1 What is the function of the catalyst in this experiment? (1)

5.5.2 How will the heat of reaction in experiment 6 compare to that in experiment 1? Choose from: GREATER THAN, EQUAL TO or LESS THAN. (1)

5.6 Calculate the average rate of the reaction (in mol·min-1) with respect to zinc for experiment 2 if 1,5 g of zinc is used. (4)

Past Exam Question — Paper 2, May/June 2018, Q.5

Two experiments are carried out to investigate one of the factors that affects the reaction rate between magnesium and dilute hydrochloric acid. The balanced equation below represents the reaction that takes place.

$$Mg(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2(g)$$

In experiment 1 a certain mass of magnesium ribbon reacts with EXCESS dilute hydrochloric acid. In experiment 2 magnesium powder of the same mass as the magnesium ribbon, reacts with the same volume of excess dilute hydrochloric acid. The concentration of the acid is the same in both experiments.

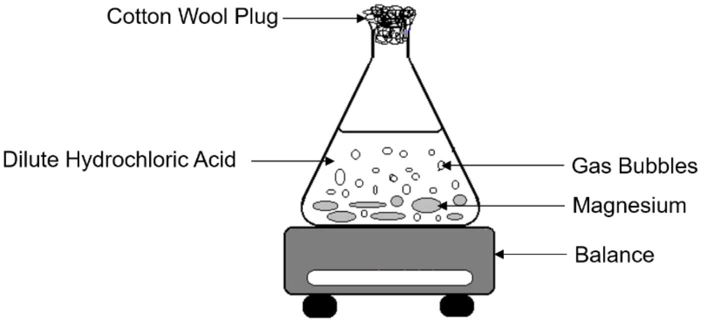
The apparatus below is used for the investigation.

5.1 Define reaction rate. (2)

5.2 For this investigation, write down the:

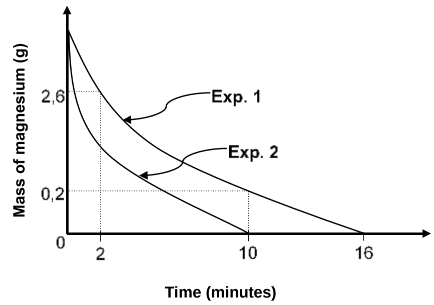
5.2.1 Independent variable (1)

5.2.2 Control variable (1)



CONTINUED — Paper 2, May/June 2018, Q.5

The change in mass of magnesium is calculated and recorded in 2-minute intervals for both experiments. The results obtained are shown in the graph below (NOT drawn to scale).



5.3 Use the information on the graph to:

5.3.1 Calculate the volume of hydrogen gas produced in experiment 1 from t = 2 minutes to t = 10 minutes
Take the molar gas volume as 25 dm3·mol-1. (5)

5.3.2 Calculate the initial mass of magnesium used if the average rate of formation of hydrogen gas in experiment 2 was 2,08 x 10-4 mol·s-1 (5)

5.4 Use the collision theory to explain why the curve of experiment 2 is steeper than that of experiment 1. (3)

Past Exam Question — Paper 2, Oct/Nov 2016, Q.5

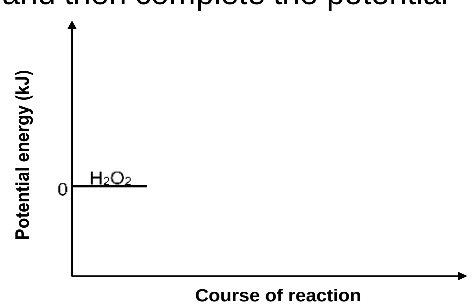
Hydrogen peroxide, H2O2, decomposes to produce water and oxygen according to the following balanced equation:

$$2H_2O_2(\ell) \rightarrow 2H_2O(\ell) + O_2(g)$$

5.1 The activation energy (EA) for this reaction is 75 kJ and the heat of reaction (ΔH) is –196 kJ.
5.1.1 Define the term activation energy. (2)
5.1.2 Redraw the set of axes below in your ANSWER BOOK and then complete the potential energy diagram for this reaction.

Indicate the value of the potential energy of the following on the y-axis:
- Activated complex
- Products

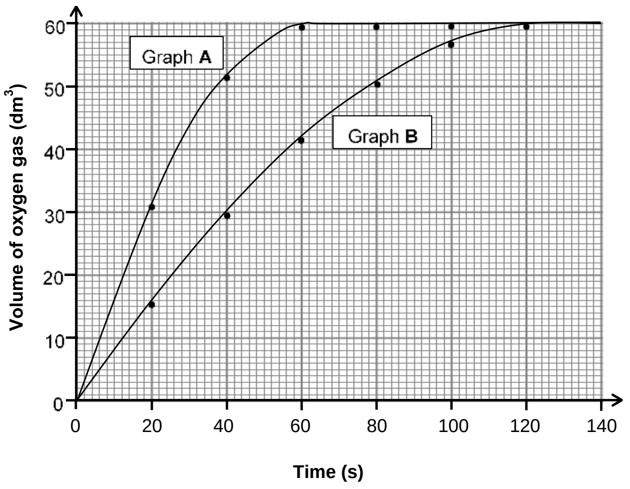
(The graph does NOT have to be drawn to scale.)



When powdered manganese dioxide is added to the reaction mixture, the rate of the reaction increases.

5.1.3 On the graph drawn for QUESTION 5.1.2, use broken lines to show the path of the reaction when the manganese dioxide is added. (2)
5.1.4 Use the collision theory to explain how manganese dioxide influences the rate of decomposition of hydrogen peroxide. (3)

5.2 Graphs **A** and **B** below were obtained for the volume of oxygen produced over time under different conditions.



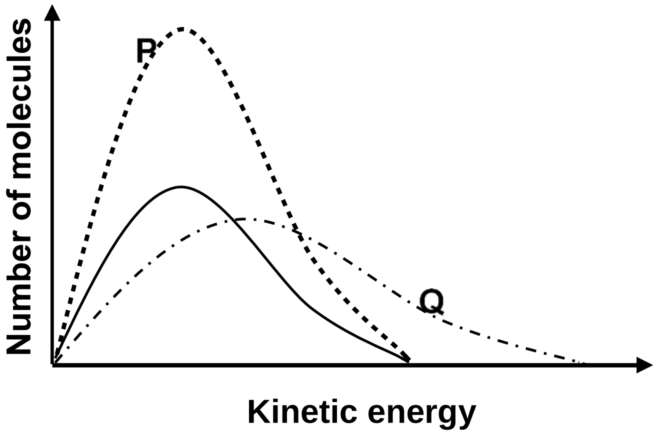
5.2.1 Calculate the average rate of the reaction (in $dm^3 \cdot s^{-1}$) between t = 10 s and t = 40 s for graph **A**. (3)

5.2.2 Use the information in graph A to calculate the mass of hydrogen peroxide used in the reaction. Assume that all the hydrogen peroxide decomposed. Use 24 $dm^3 \cdot mol^{-1}$ as the molar volume of oxygen. (4)

5.2.3 How does the mass of hydrogen peroxide used to obtain graph B compare to that used to obtain graph A? Choose from GREATER THAN, SMALLER THAN or EQUAL TO. (1)

5.3 Three energy distribution curves for the oxygen gas produced under different conditions are shown in the graph below.

The curve with the solid line represents 1 mol of oxygen gas at 90 °C.



Choose the curve (**P** or **Q**) that best represents EACH of the following situations:

5.3.1 1 mol of oxygen gas produced at 120 °C. (1)

5.3.2 2 moles of oxygen gas produced at 90 °C (1)