IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

6.1 Chemical Kinetics

6.1.1 Collision Theory / 6.1.2 Rate of Reaction / 6.1.3 Measuring Rates / 6.1.4 Activation Energy / 6.1.5 Rate Experiments / 6.1.6 Explaining Rates / 6.1.7 Maxwell-Boltzmann Curves / 6.1.8 Energy Profiles & Catalysis

Easy (4 questions)	/33
Medium (5 questions)	/50
Hard (4 questions)	/39
Total Marks	**/122**

Scan here to return to the course
or visit savemyexams.com

Easy Questions

1 (a) Describe kinetic theory in relation to energy and temperature.

.....

.....

(2 marks)

(b) State what is required for a collision to result in a reaction.

.....

.....

(2 marks)

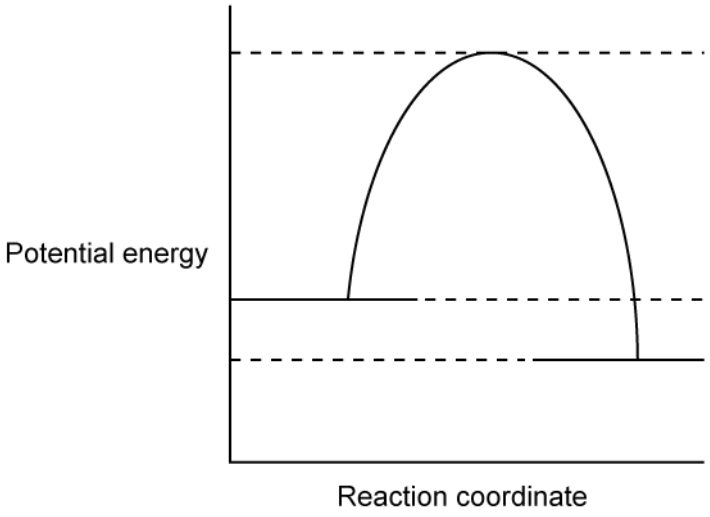
(c) State the meaning of activation energy (Ea).

.....

.....

(2 marks)

(d) Label the activation energy on the energy profile diagram below.



.....

(1 mark)

State three ways of monitoring concentration changes in a reaction.

2 (a) **(3 marks)**

A reaction is monitored by measuring the volume of a gas produced every 10 seconds. State an appropriate unit to use.

(b) **(1 mark)**

Sketch a graph to show the volume of gas produced during the course of an experiment against the time taken.

(c) **(4 marks)**

State the effect that increasing concentration has on the rate of a reaction.

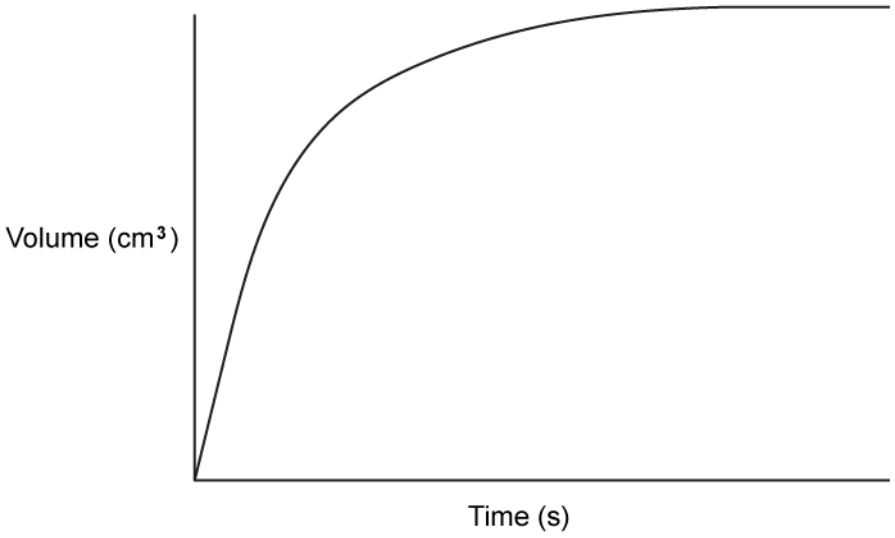
(d) **(1 mark)**

3 (a) State the effect that increasing temperature has on the rate of a reaction.

.....

(1 mark)

(b) Sketch a line on the graph to show the same reaction occurring at a higher temperature.



.....

.....

.....

(3 marks)

(c) State two variables that need to be controlled when investigating the effect of temperature on rate in the following reaction:

$$2HCl\ (aq) + Mg\ (s) \rightarrow MgCl_2\ (aq) + H_2\ (g)$$

.....

.....

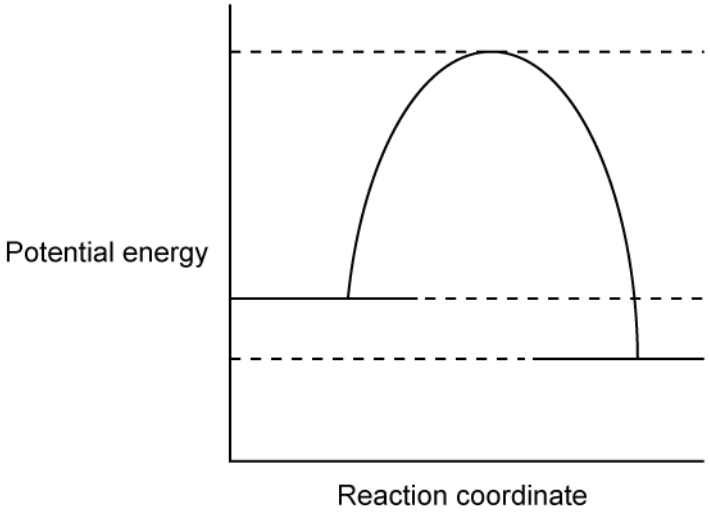
(2 marks)

(d) Suggest an appropriate piece of equipment to use to measure the volume of H_2 gas produced in the reaction between HCl and Mg.

.....

(1 mark)

4 (a) Sketch a line on the potential energy profile diagram to show the pathway for the same reaction, but with a catalyst.

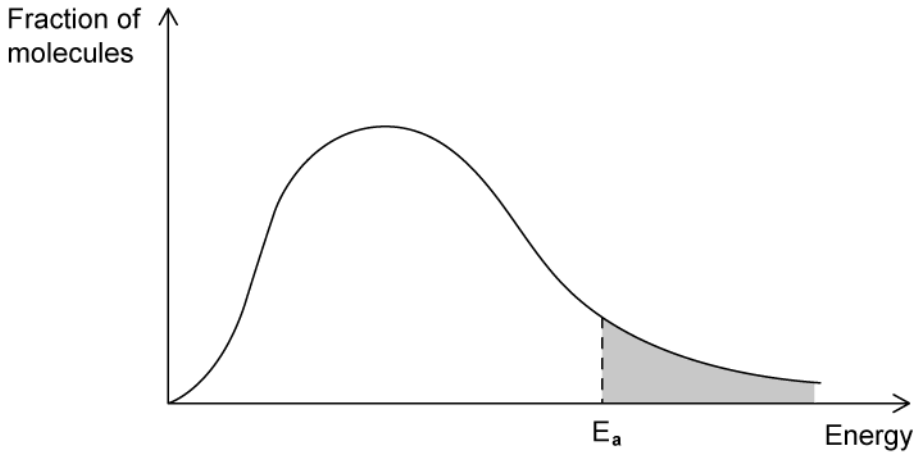


(2 marks)

(b) Explain how catalysts work.

(3 marks)

(c) Maxwell-Boltzmann distribution is shown below:



i) Draw a line on the Maxwell-Boltzmann curve below to show the effect of adding a catalyst.

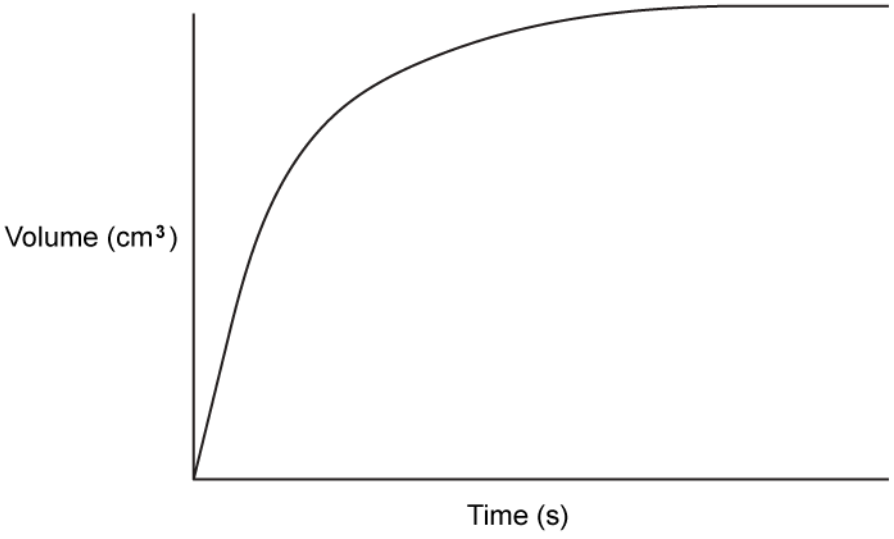
ii) Shade in the area representing the number of particles that can react with the catalyst present.

.....

.....

(2 marks)

(d) Sketch a line on the graph to show the same reaction occurring with a catalyst.



(3 marks)

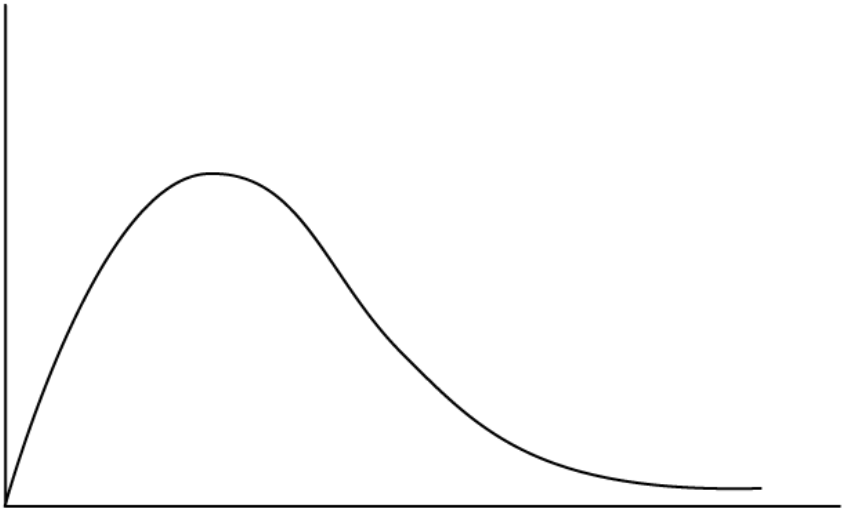
Medium Questions

1 (a) In any chemical reaction, the particles will all be moving around in different directions, at different speeds, with different amounts of energy.

A Maxwell-Boltzmann distribution is a graph which shows the distribution of energy amongst particles within a chemical reaction.

Figure 1 below shows the Maxwell-Boltzmann distribution in a sample of a gas at a fixed temperature, T_1.

Figure 1



i) Label the x and y axes of the graph.

ii) Sketch a distribution for this same sample of gas, at a higher temperature, and label it as T_2.

(4 marks)

(b) State why a Maxwell-Boltzmann distribution curve always starts at the origin and what the area under the curve represents.

.....

.....

(2 marks)

(c) Chemical reactions take place at different speeds. For a chemical reaction to take place, particles must collide with each other in the correct orientation and with sufficient energy.

i) Explain why most collisions between particles in the gas phase do not result in a reaction taking place.

ii) State and explain one way that the rate of reaction could be increased, other than by increasing the temperature.

.....

.....

.....

(3 marks)

(d) Give one reason why a reaction may be slow at room temperature.

.....

(1 mark)

2 (a) State the meaning of the term *rate of reaction*.

.....

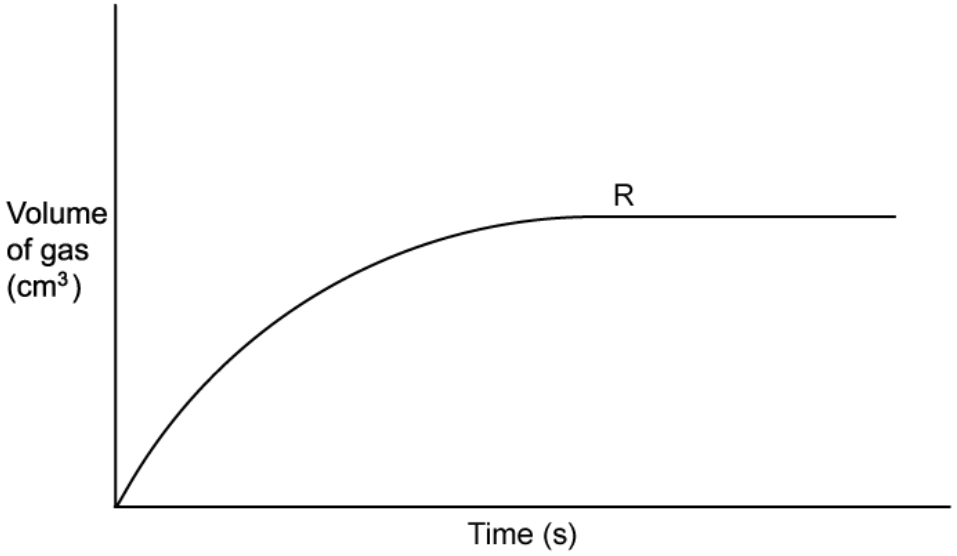
(1 mark)

(b) A group of students were completing a practical, investigating the factors which affect the rate of the chemical reaction shown below.

A (s) + B (aq) → C (g)

The students collected the gas produced and plotted the graph shown in **Figure 1**.

Figure 1



i) State and explain what the letter R represents on the students graph in **Figure 1.**

ii) In the original reaction above, the students used 0.5 g of **A** and 50 cm^3 of 1.0 mol dm^{-3} **B**.

Sketch a curve on the graph to show how the total volume of gas collected would change if the students still used 0.5 g of **A,** but used 50 cm^3 of 2.0 mol dm^{-3} of **B**.

.....

.....

(3 marks)

(c) Explain why the gradient of the curve in part (b) decreases as the time of the reaction progresses.

(2 marks)

(d) Another way to increase the rate of reaction is to increase the temperature.

Explain why a small increase in temperature has a large effect on the initial rate of a chemical reaction.

(2 marks)

3 (a) The decomposition of hydrogen peroxide into water and oxygen is a very slow chemical reaction.

Write the equation for the decomposition of hydrogen peroxide.

.....

(1 mark)

(b) The rate of decomposition of hydrogen peroxide can be found by collecting and measuring the volume of gas formed at specific time intervals.

i) Draw a labelled diagram to show the apparatus that you would use to collect and measure the volume of gas formed during this reaction.

ii) Explain how you would use the results to determine the initial rate of the reaction.

.....

.....

.....

.....

.....

(5 marks)

(c) The decomposition of hydrogen peroxide is a slow reaction, so a catalyst is often added to speed up the rate of the reaction. Catalysts are used in many chemical reactions to increase the rate.

The following shows a two-step reaction mechanism of a chemical reaction, where a catalyst, **X** is used.

STEP 1: $W + X \rightarrow Y + Z$

STEP 2: $Y + W \rightarrow Z + A + X$

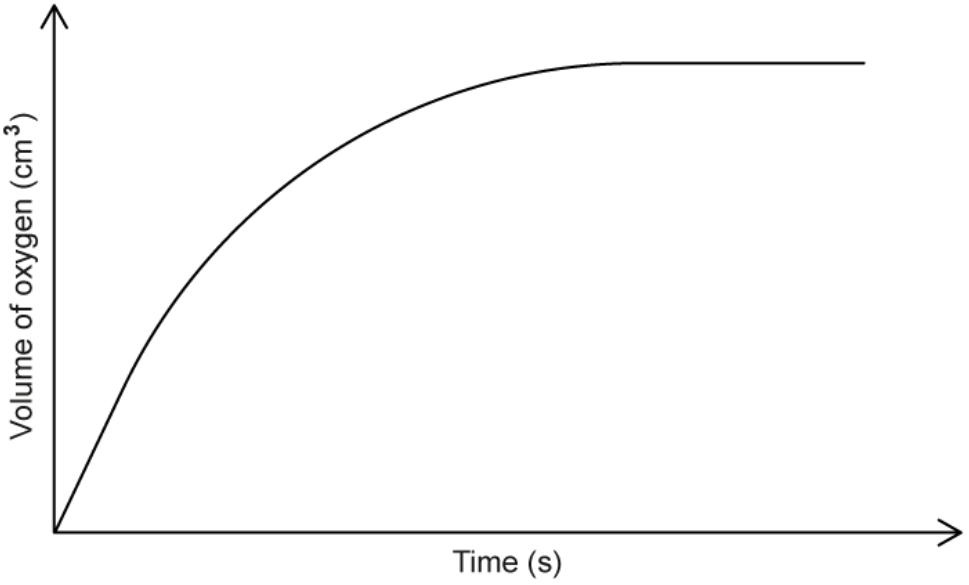
OVERALL REACTION: $2W \rightarrow 2Z + A$

Give a reason, other than the rate of reaction increasing, why it can be deduced from the three equations above that X is a catalyst.

(1 mark)

(d) The graph shown below represents the decomposition of hydrogen peroxide.

Figure 1



The graph starts to level out as the reaction slows down.

State why the rate of the reaction slows down over time.

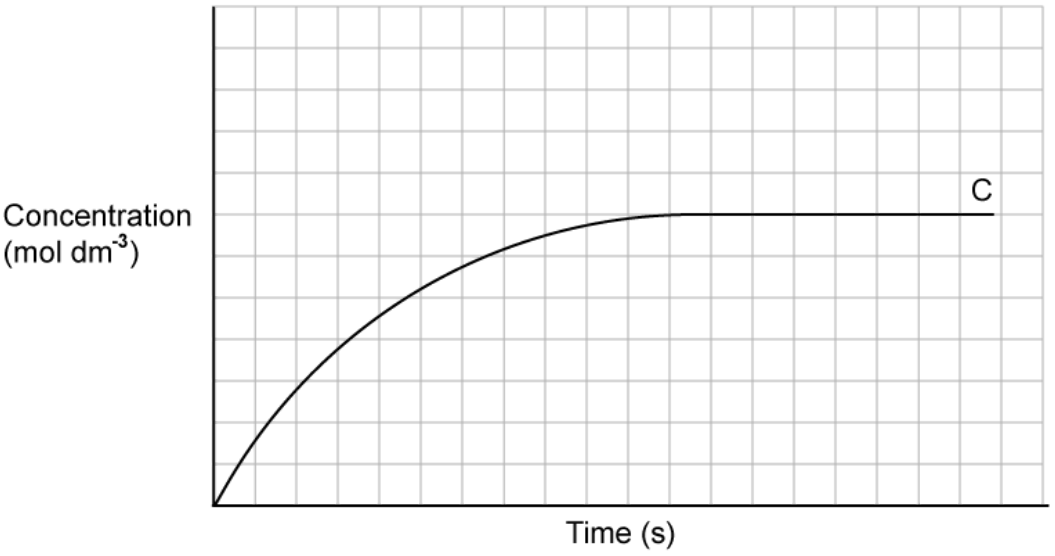
(1 mark)

4 (a) During the following reaction, **A** and **B** react together to produce **C**.

$$\mathbf{A + 2B \rightleftharpoons C}$$

Figure 1 shows the production of C over time.

Figure 1



i) Sketch a graph to show what happens to **A** and **B** during the progress of the reaction.

ii) On your graph, write the letter **E** at the point at which an equilibrium is first established.

.....

.....

(2 marks)

(b) In the reaction in part (a), large pieces of **A** were used.

Use collision theory to explain what would happen to the rate of the reaction if powdered **A** was used instead of large pieces.

.....

.....

(3 marks)

(c) In a different reaction, gaseous W and X were added together to produce Y and Z as shown in the equation below:

$2W\,(g) + X\,(g) \rightarrow Y\,(g) + 2Z\,(g)$

A catalyst was added to speed up the rate of reaction.

i) Sketch a Maxwell-Boltzmann distribution on the axes below in **Figure 2** to show the distribution of molecular energies at a constant temperature with **and** without a catalyst.
Use E_a to label the activation energy without a catalyst and E_c to label the activation energy with a catalyst.

ii) Explain what your distribution shows.

Figure 2

(6 marks)

(d) Some changes were made individually to the experiment completed in part (c).

Consider your Maxwell-Boltzmann distribution curve from part (c). For each of the changes in parts (i), (ii) and (iii) below, state and explain the effect that the change would have on:

- The area under the curve
- The value of the most probable energy of the molecules (E_{mp})
- The proportion of molecules with energy greater than or equal to E_a

i) The temperature of the original reaction is increased, but no other changes are made.

ii) The number of molecules in the original reaction mixture is increased, but no other changes are made.

iii) A catalyst is added to the original reaction mixture, but no other changes are made.

(6 marks)

5 (a) Iodine reacts with propanone in an acid catalyzed reaction, according to reaction equation below.

$$CH_3COCH_3\ (aq) + I_2\ (aq) \rightarrow CH_3COCH_2I\ (aq) + H^+\ (aq) + I^-\ (aq)$$

Suggest how the change in concentration of iodine could be used to determine the rate of the above reaction.

.....

(1 mark)

(b) A group of students completed the iodination of propanone reaction using the same acid catalyst, but with different concentrations. The results achieved are shown in the table below:

Table 1

Concentration of acid, $[H^+]$ / $moldm^{-3}$	Relative Rate of Iodination Reaction
0.100	0.0046
0.200	0.0092
0.300	0.0138

Use the table to state and explain the relationship between the concentration of acid used in the reaction and the rate.

.....

.....

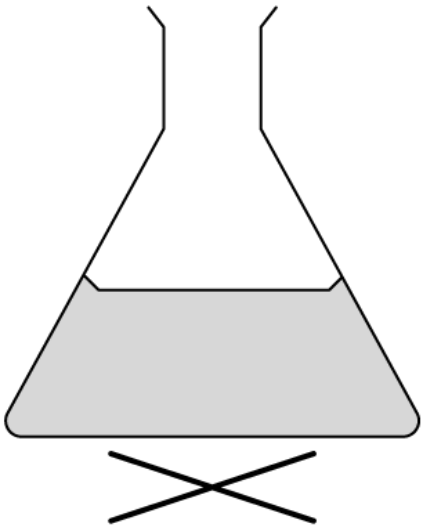
(2 marks)

(c) Sodium thiosulfate and hydrochloric acid will react together readily, as shown by the equation below:

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + S + SO_2 + H_2O$$

This reaction is often referred to as the 'disappearing cross' experiment. The cross disappears when viewed from above because the solution turns cloudy as a sulfur precipitate is formed, covering the cross.

Figure 1



The speed of the reaction can be increased, by raising the temperature of the sodium thiosulfate solution in the reaction. The thiosulfate solution is heated to different temperatures before the acid is added, and the time it takes for the cross to disappear is recorded. The times can then be compared.

Suggest one reason why the value for the rate of reaction when a higher temperature was used may be less accurate than at a lower temperature.

.....

(1 mark)

(d) Collision theory can be used to explain why different factors affect the rate of a chemical reaction.

Describe collision theory.

.....

.....

.....

(3 marks)

Hard Questions

1 (a) A group of students planned how to investigate the effect of changing the concentration of H_2SO_4 on the initial rate of reaction with magnesium:

$$Mg\,(s) + H_2SO_4\,(aq) \rightarrow MgSO_4\,(aq) + H_2\,(g)$$

They decided to measure how long the reaction took to complete when similar masses of magnesium were added to acid.

Two methods were suggested:

Method 1 - Use small pieces of magnesium ribbon, an excess of acid and record the time taken for the magnesium ribbon to disappear

Method 2 - Use large strips of magnesium ribbon, an excess of magnesium and record the time taken for bubbles to stop forming

Deduce, giving a reason, which of method 1 and method 2 would be the least affected if the masses of magnesium ribbon used varied slightly between each experiment.

.....

.....

(2 marks)

(b) Neither method in part a) actually allows the initial rate to be calculated. Outline a method that would allow the calculation of initial rate.

.....

.....

(2 marks)

(c) The reaction is to be conducted across a few weeks.

State a factor that has a significant effect on reaction rate, which could vary between experiments across the weeks and therefore needs to be controlled.

(1 mark)

(d) One group collected the following data using 1.50 mol dm^{-3} acid:

Trial	Time/ s (± 0.01 s)
1	91.56
2	98.33
3	72.08
4	89.41

i) Comment on the use of the uncertainty when calculating the mean.

ii) Calculate the mean time for the set of results.

(4 marks)

2 (a) When investigating the reaction between sulfuric acid and calcium carbonate, it was observed that a small increase of temperature of around 10 ^{o}C caused a doubling in the rate of the reaction.

Sketch and label Maxwell-Boltzmann curve for the two temperatures T and T+10, and use this diagram to help to explain this effect of temperature on rate.

(5 marks)

Why do some collisions at high temperatures still not result in the formation of the product?

(b) **(2 marks)**

(c) Identify and explain another factor that affects the number of particles present in a solution with sufficient energy to react.

(3 marks)

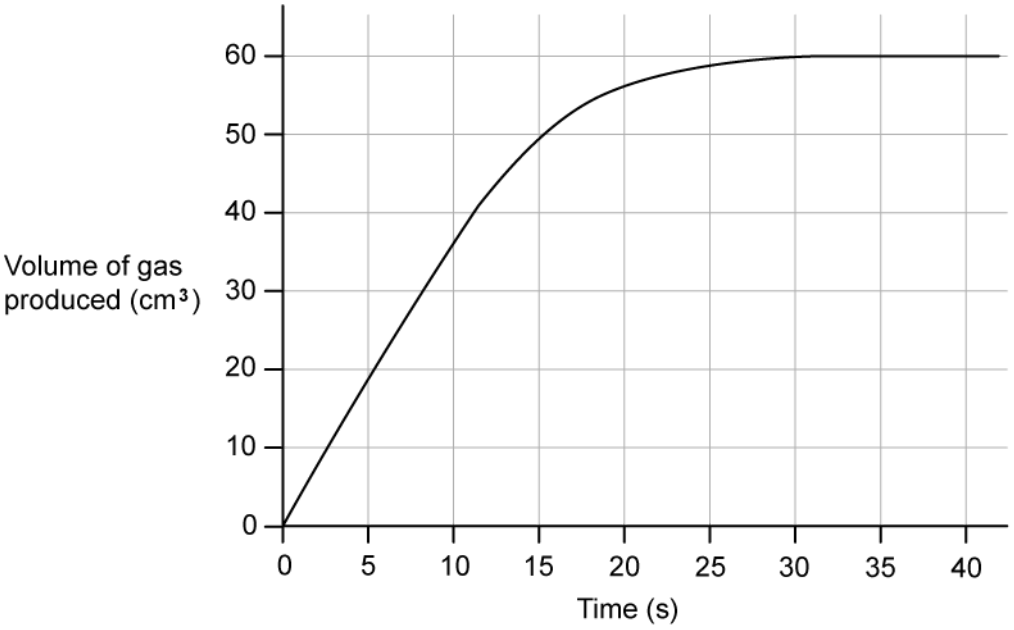
(d) Some groups investigating the effect of temperature on rate stirred their reactions, some did not.

Explain the effect of stirring upon the rate of the reaction.

(2 marks)

3 (a) 0.5 g of magnesium reacts with 50 cm^3 of 0.01 $moldm^{-3}$ nitric acid. Magnesium is in excess.

A graph monitoring the volume of hydrogen gas produced is shown below:



i) Calculate the mean rate of reaction over the first 15 seconds of the reaction

[1]

ii) Calculate the actual rate of reaction at 15 seconds

[3]

iii) Explain the difference in values for rate

[1]

.....

.....

.....

.....

.....

(5 marks)

(b) Compare the expected rate and progress of the reaction if 25 cm^3 of 0.2 mol dm^{-3} nitric acid was used instead of 50 cm^3 of 0.1 mol dm^{-3} nitric acid.

(3 marks)

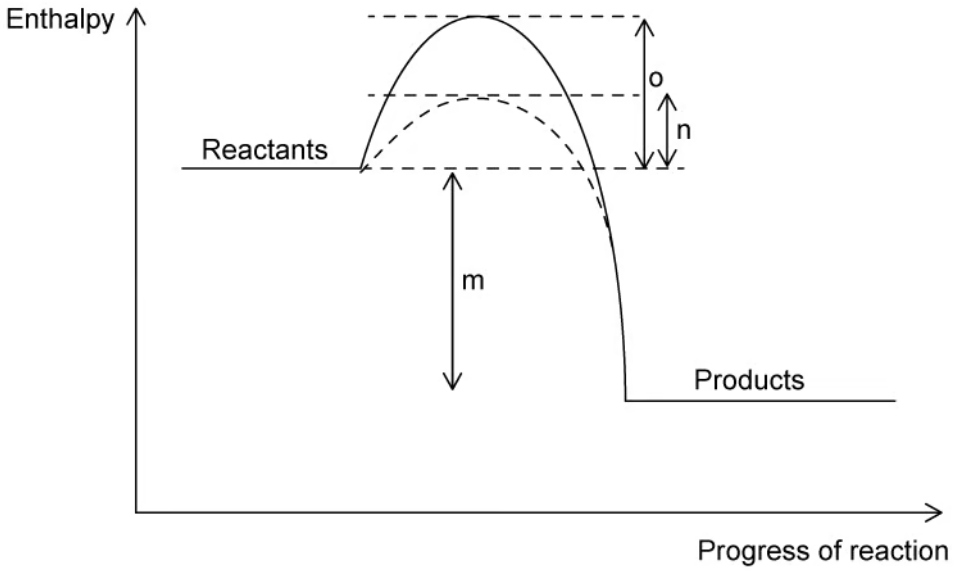
(c) Suggest one change to the reaction that could be made to produce more hydrogen gas in total and explain your choice.

(2 marks)

(d) Suggest why it is often better to study a slower reaction instead of a faster one.

(2 marks)

4 (a) The following energy profile diagram shows the pathways for both a catalysed and uncatalysed reversible reaction:



Identify the letter(s) representing the activation energy for the catalysed reverse reaction.

(1 mark)

(b) State and explain the effect that this catalyst will have on the equilibrium yield.

(2 marks)

(c) Vehicles with combustion engines usually have catalytic convertors added to catalyse the oxidation of carbon monoxide into carbon dioxide and to catalyse the reduction of nitrogen oxides to nitrogen. These catalysts are usually rhodium or platinum.

Leaded fuels were phased out as they were found to poison these catalysts, binding irreversibly to the metal surface.

Explain the problems for drivers of the catalysts being poisoned.

.....

(2 marks)

(d) Suggest a situation in which using a catalyst would not be appropriate.

.....

(1 mark)