Rates of reaction

Rate of a chemical reaction:

Is the amount of a reactant used up or product produced in a reaction per unit time

FACTORS THAT AFFECT A CHEMICAL REACTION

There are about four factors that affect a chemical change/reaction. These are:
1. A catalyst
2. Temperature
3. Concentration
4. Pressure
5. Surface area of the reactants

1. **Concentration:**
   If the concentration of the reactant is increased, frequent molecular collisions will increase leading to increase in the rate reaction.
2. **Temperature:**
   Increasing the **temperature increases reaction rates** because of the disproportionately large **increase** in the number of high energy collisions. It is only these collisions (possessing at least the activation energy for the **reaction**) which result in a **reaction**.

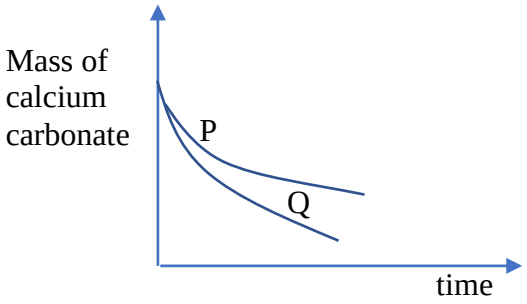
3. **Surface area:**
   Increasing the **surface area** of a solid reactant exposes more of its particles to attack. This results in an **increased** chance of collisions between reactant particles, so there **are** more collisions in any given time and the **rate of reaction increases**. The surface of a solid can be increased by crushing a substance into a powder or by reducing its particle size.

4. **Pressure:**
   This affects gaseous reactions since gases unlike solids are compressible. Increasing pressure on gases brings reactant particles close to each other increasing the frequency of collision and hence the rate of reaction. Pressure can be increased by decreasing the volume of the container. For example, in the Haber process, a large yield of ammonia is obtained from high pressure as per the following reaction.

5. **Catalyst:** increases the rate of reaction by lowering activation energy or energy barrier to the reaction.
   By definition
   A catalyst is substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.

Exercise

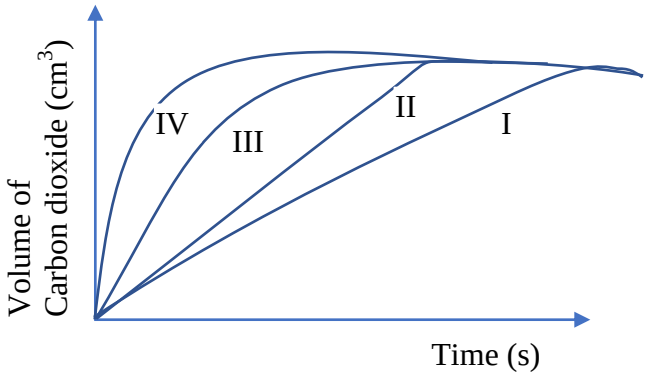
1 Curve in the graph below shows the variation in mass of calcium carbonate powder with time when it reacted with excess hydrochloric acid at room temperature



To obtain curve Q, one would keep all conditions the same except

A. Increase the concentration of the acid
B. Increase the mass of the carbonate powder
C. Reduce temperature
D. Use the same mass of marble chips

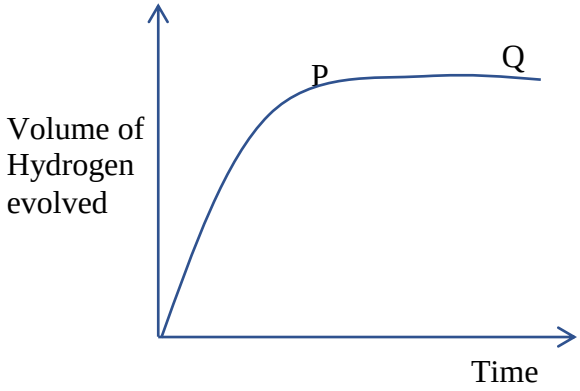
2. The figure below shows the graphs obtained when equal amounts of marble chips of different sizes were reacted with excess 2M hydrochloric acid at room temperature.



Which one of the graphs represents the reaction of marble chips with the smallest particle size?

A. I
B. II
C. III
D. IV

3. The graph below shows the variation in the volume of hydrogen evolved with time when excess zinc was reacted dilute sulphuric acid using copper (II) sulphate as a catalyst



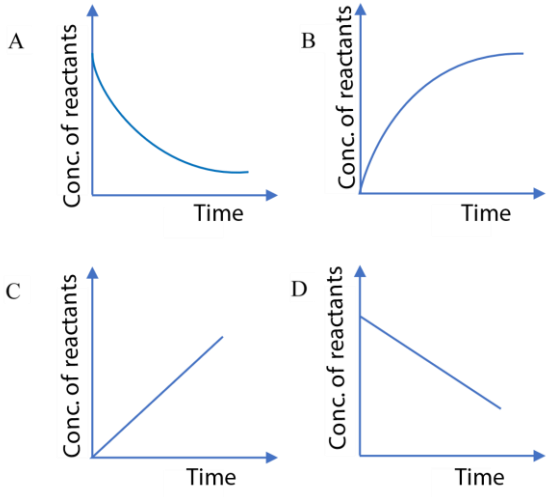
Which one of the following is the best explanation for the shape of the graph between P and Q?

A. A layer of insoluble oxide formed on zinc sulphate
B The reaction become faster
C. Sulphuric acid was used up
D. the catalyst was used up

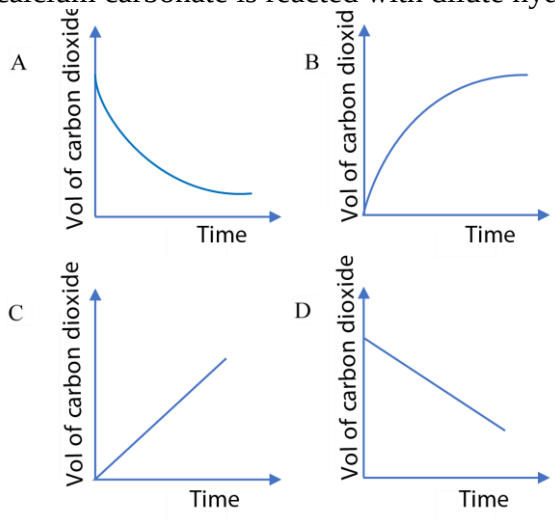
4. Hydrogen peroxide decomposes according to the following equation

$2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$

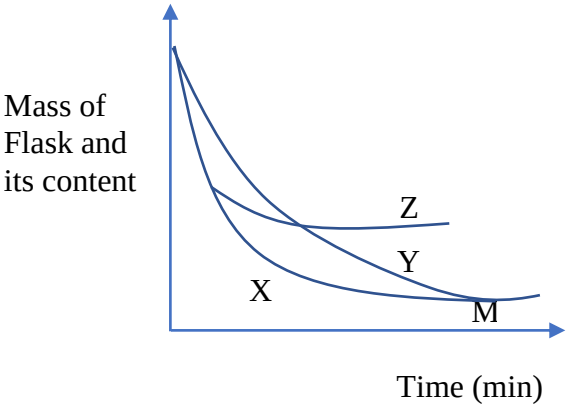
Which one of the following graphs represent, how the concentration of the reactants varies with time during the reaction?



5. Which one of the following graphs shows the variation of the volume of carbon dioxide evolved with time when calcium carbonate is reacted with dilute hydrochloric acid



6. Curve Y in diagram shows the results that were obtained during the investigation of the rate of the reaction between iron and dilute hydrochloric acid under normal conditions. Curve X and Z were obtained when some conditions of the experiment were changed.



(a) (i) List **three** condition that were changed to obtain curve **X** (3marks)

(ii) State what point M represent (½ mark)

(b) Some conditions you have listed in (a)(i) were changed to obtained curve Z.

(i) State the condition changed (01mark)

(ii) Give a reason for your answer

7. Sodium thiosulphate reacts with hydrochloric acid according to the following equation

$S_2O_3^{2-}(aq) + 2H^+(aq) \longrightarrow H_2O(l) + SO_2(g) + S(s)$

(a) State what would be observed if dilute hydrochloric acid is added to sodium thiosulphate solution (½ mark)

(b) The rate of reaction with dilute acids is affected by the concentration of sodium thiosulphate.

(i) State one other factor other than concentration that can affect the rate of reaction (½ mark)

(ii) Briefly explain the effect of the factor you have state in (b)(i) on the rate of reaction. (02mark)

(iii) Describe an experiment can be carried out in the laboratory to show the effect of the factor on have stated in (b)(i) on the rate of reaction. Diagram not required) (6 ½ marks)

8. State and explain the effect of each of the following conditions on the rate of chemical reaction.

(a) Particle size (04marks

(b) Concentration of reactants (05 msrks)

(c) Temperature (06marks)

9. The table shows the variation in the concentration of sodium thiosulphate with time.

Time (s)	200	100	40	20	10
Concentration of thiosulphate ($moldm^{-3}$)	0.05	0.09	0.15	0.20	0.25
$^{1}/_{concentration}$of thiosulphate ($mold^{-1}m^{-3}$)					

(i) Determine the values of $^{1}/_{concentration}$of thiosulphate, copy the table and enter your answer in the space provided in the table. (01mark)

(ii) Plot a graph of $^{1}/_{concentration}$of thiosulphate (vertical axis) against time (horizontal axis. (03marks)

(iii) State any conclusion that can be drawn from the shape of the graph. (1 ½ marks)

10. (a) (i) Write an equation for the reaction between dilute nitric acid and calcium carbonate (1 ½ mark)

(ii) State how temperature can affect the rate of reaction in (a)(i) above (01mark)

(iii) Give a reason why a large surface area of calcium carbonate can speed up rate of reaction in (a)(i) (2 marks)

(b) Magnesium can react with hydrochloric acid to form hydrogen. State the conditions and write equation for the reaction (2 ½ marks)

(c) The table below shows the volume of hydrogen evolved when various lengths of magnesium ribbon were reacted with fixed volume of hydrochloric acid

Length of ribbon (cm)	1.0	2.0	3.0	5.0	6.0
Volume of hydrogen (cm^3/min)	2.2	3.6	5.2	9.2	10.8

(i) Plot a graph of volume of hydrogen (vertical axis) against length of magnesium ribbon (horizontal axis) (5marks)

(ii) Explain the shape of the graph you have drawn. (2marks)

(iii) Using your graph, determine the rate of reaction if 4.0cm of magnesium ribbon was used (01mark)

11. Oxygen is formed from hydrogen peroxide in the

presence of Manganese dioxide according to the following equation

$2H_2O_2(aq) \xrightarrow{MnO_2} 2H_2O(l) + O_2(g)$

(a) In an experiment, a certain volume of hydrogen peroxide was used to prepare oxygen at room temperature. With the aid of a suitable diagram describe how the following can be determined.

(i) The volume of oxygen evolved (5 ½ marks)

(ii) The rate of evolution of oxygen (03marks)

(b) In another experiment one half of volume of hydrogen peroxide in (a) was diluted with equal volume of water. On the same axes draw graphs to show the variation of volume of oxygen with time in (a) and (b). (03marks)

(c) Oxygen produced from $200cm^3$ of 0.5M hydrogen peroxide solution was reacted completely with magnesium. (3 ½ marks)

Calculate the mass of magnesium that reacted

12. (a) Define the term rate of reaction (02marks)

(b) The table below shows variation of hydrogen evolved with time when dilute hydrochloric acid was added to excess zinc.

Volume of hydrogen (cm^3)	0	20	35	46	56	72	79	79
Time (s)	0	10	20	30	40	60	80	90

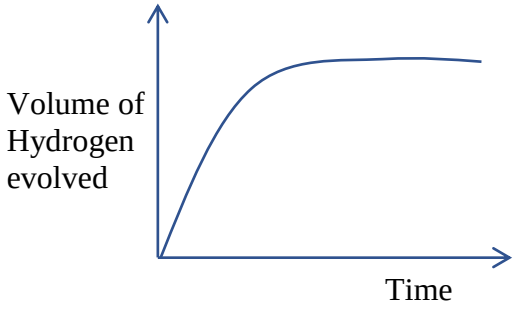
Plot a graph of volume hydrogen evolved against time (05mrks)

(c) Using the graph determine the time taken to collect $60cm^3$ of hydrogen gas (01mark)

(d) (i) Draw tangents on your graph at points when the time is 20 and 60 seconds and determine the gradient of each tangent. (04marks)

(ii) Compare the rate of reaction at 20 and 60seconds. Explain your answer (03marks)

13. The graph in figure below shows the variation of volume of hydrogen evolved with time when excess magnesium was added to $100cm^3$ of 1.0M sulphuric at room temperature.



(a) Calculate the number of moles of hydrogen ions that is

contained in $100cm^3$ of

(i) A 0.5M H_2SO_4 (01mark)

(ii) A 1.0M H_2SO_4 (01mark)

(b) (i) Sketch on the same axes of the graph in figure above the graph that would be obtained if the same mass of magnesium was added to $100cm^3$ of a 0.5M sulphuric acid at room temperature. (01mark)

(ii) Mark on the graph the times the two reactions have reached completion. (01mark)

(iii) Compare the time the reaction took to reach completion when 0.5M sulphuric acid was used to that when 1.0M sulphuric acid was used (01mark0

14. (a) Describe an experiment to show how surface area can affect the rate of reaction between calcium carbonate and 2M hydrochloric acid. Your answer **must** include: 11 ½

- A labelled diagram of apparatus
- Sketch of expected graph
- Mention how the graph can be used to reach a conclusion.

(b) Briefly explain why, when 4M hydrochloric acid was used instead of the 2M acid, the rate of reaction was faster. Explain this observation. (2½ marks)

(c) State one other factor than mentioned above that can affect the rate of reaction between hydrochloric acid and calcium carbonate (01mmark)

15. (a) What is meant by the rate of reaction? (02marks)

(b) State how the following factors affect the rate of a chemical reaction:

(i) Temperature

(ii) Surface area of the reactants

(c) The table below shows the volume of hydrogen collected at various time intervals when magnesium was reacted with a 2M hydrochloric acid

Time (s)	0	1	2	3	4	5	6	7
Volume of hydrogen collected (cm^3)	0	25	45	60	70	75	77	77

(i) Plot a graph of volume of hydrogen versus time (04 marks)

(ii) Determine the rate of reaction at 3 seconds (02marks)

(iii) Determine the volume of hydrogen evolved at 3.5 seconds (01mark)

(d) State how the rate of reaction at 3 seconds would be affected if a 1M hydrochloric acid was used (02marks)

16. When a certain volume of 0.1M hydrochloric acid was reacted at room temperature with excess iron fillings, $120cm^3$ of the gas were produced.

(a) Draw a labelled diagram to show how the rate of reaction was determined

(b) Write equation for the reaction that took place

(c) Calculate the

(i) Volume of hydrochloric acid required to produce $120cm^3$ of the gas

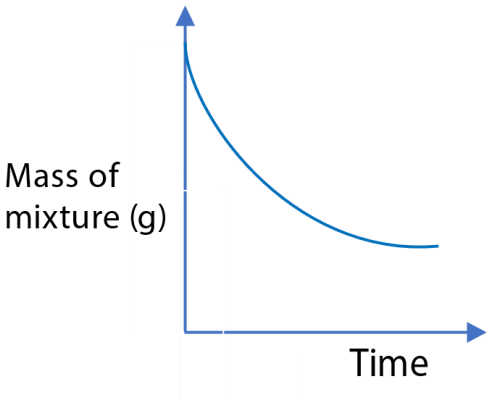
(ii) The mass of iron filling that reacted

(d) Draw a sketch graph of the volume of the gas against time

(e) State how the rate of reaction would change if the reaction was carried out at a temperature above room temperature

17. (a) State the factors that can affect the rate of chemical reaction.

(b) A mixture of a known mass of magnesium and a certain volume of 2M hydrochloric acid were put in a conical flask and the mass of the mixture was recorded at various intervals. The results of the experiment are shown in the graph below.



On the same axes, draw a graph that would be obtained when same mass of magnesium was reacted with the same volume of 1M hydrochloric acid.

(c) 5.0g of calcium carbonate was reacted with $20cm^3$ of 2M hydrochloric acid.

(i) Write equation for the reaction between hydrochloric acid and calcium carbonate

(ii) The mass of calcium carbonate that was left.
(Ca = 40, C = 12, O =16)

18. (a) (i) What is the rate of reaction?

(ii) How does the particle size affect rate of reaction? Explain your answer

(b) The table of results shows the time taken for sulphur to form when various concentrations of sodium thiosulphate were used.

Concentration of $S_2O_3^{2-}$ (M)	0.2	0.6	0.8	1.2	1.6
Time for sulphur to form (s)	60	20	15	10	7.5
$^1/_t$ (s^{-1})	0.017	0.05	0.07	0.10	0.13

Plot a graph of $^1/_t$ on vertical axis against concentration of thiosulphate.

(c) (i) Explain the relationship between the rate of the reaction and $^1/_t$.

(ii) Deduce from the graph, how the rate of reaction varies with the concentration of thiosulphate.

(d) Name one reagent that you would use to test for sulphur dioxide and state what would be observed if the reagent was used.

19. In an experiment to determine the rate of reaction between zinc and sulphuric acid, dilute sulphuric acid was reacted with zinc granules to which some copper II sulphate solution was added. The volume of hydrogen gas evolved at various

Time in minutes	0	5	10	15	20	25	30
Vol. of gas in cm^3	0	10	21	26.5	31.5	32	32

(a) (i) What is the role copper (II) sulphate solution?

(ii) Write ionic equation for the reaction above

(iii) Explain what would happen to the reaction if zinc granules were replaced with zinc powder.

(b) (i) Plot the graph of volume of hydrogen evolved (vertical) against time (horizontal axis)

(ii) Describe how you would determine the rate of reaction at 12 minutes.

(iii) Compare the rate of reaction at 12 minutes with that at 20 minutes. Give reason for your answer

(iv) What happens to the shape of the after 24 minutes? Explain your answer

Marking guide

1. A 2. D 3. C 4. A 5. D

6. (a) (i) Note that - the rate of reaction in curve X is higher than in curve Y,
   - The initial and final mass in X and Y is the same implying that the mass of iron was not changed

   Thus, to increase the rate of reaction
   - temperature was increased
   - particle size of iron was reduced
   - the concentration acid was increased

   (b) (i) The concentration of the acid was reduce

   (ii) The initial mass is the same but final mass in Z is higher suggesting that not all the iron reacted due to insufficient acid in the volume added.

7. (a) Yellow solid and chocking gas

   (b) (i) Temperature

   (ii) The temperature increases the rate of reaction by increasing the rate of collision high energetic molecules.

   (iii) Two experiments are curried out using equal volumes of thiosulphate and acid of the same concentration.

   In one experiment the temperature of thiosulphate is kept at room temperature while for the other the temperature is raised to 60^0C.

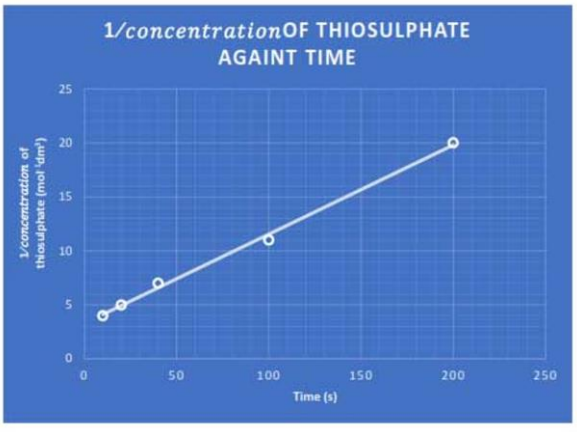
   When acid is added to thiosulphate, the yellow suspension form earlier in thiosulphate solution at 60^0C that that at room temperature. This indicates that the reaction is faster at higher temperature than at low temperature.

8. Refer to page 1

9. (i)

Time (s)	200	100	40	20	10
Concentration of thiosulphate ($moldm^{-3}$)	0.05	0.09	0.15	0.20	0.25
$1/_{concentration}$ of thiosulphate ($mold^{-1}m\text{-}^{3}$)	20	11	7	5	4

   (ii)



   (ii) Rate of reaction increases as concentration increase
   (Note that the recipricol of concentration is dilution, and dilute solution takes long to form cloudness)

10. (a) (i) $CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(s) + CO_2(g) + H_2O(l)$

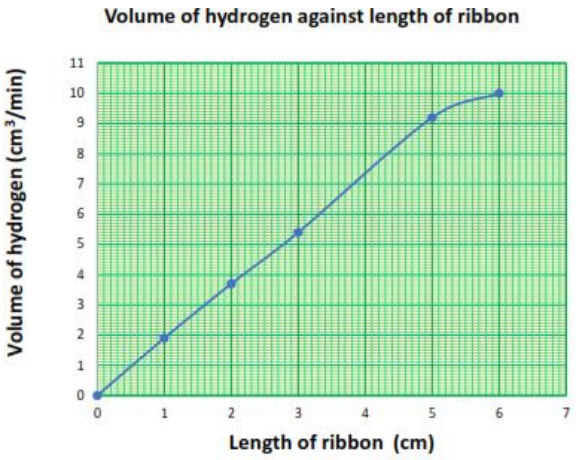
(ii) Temperature increases the rate of reaction

(iii) Increase in surface area increases the rate of reaction by increasin the probability of contact between the liquid and the solid

(b) (i) Heat

Contentration of hydrogen

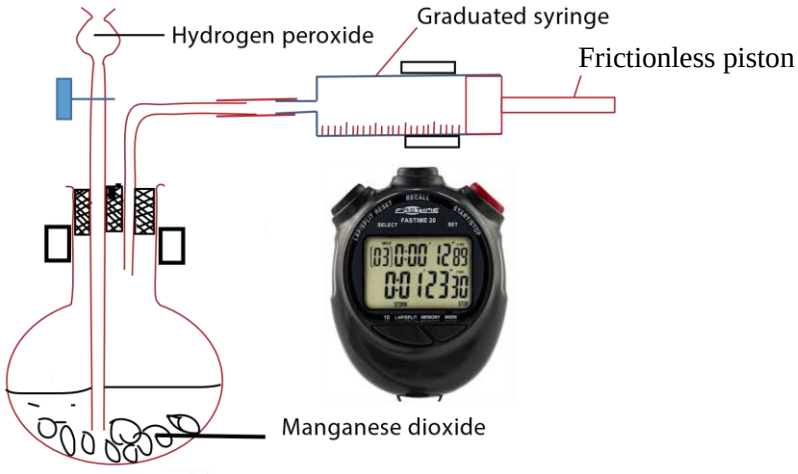
(c) (i)



(ii) The rate of production of hydrogen increases with the lengnt of magnesium ribblon up to 5cm when the acid become insufficient that increase in rate decreases.

(iii) At 4.0 cm the rate is 7.3cm^3/minute

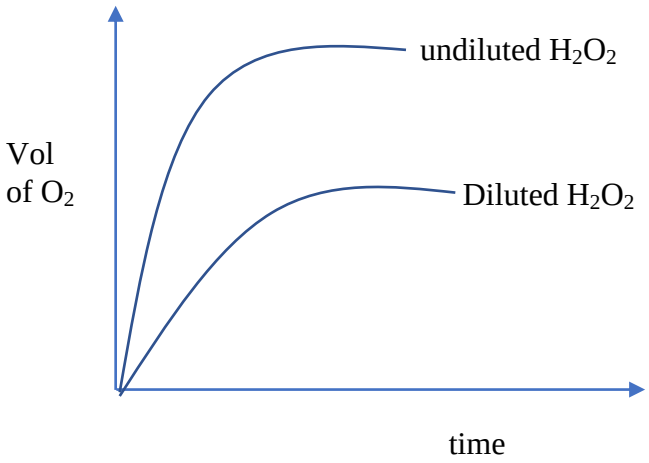
11. (a) The setup is as shown below



Hydrogen peroxide is added to manganese (IV) oxide and immediately stop clock started. The amount ox oxygen produced in graduated syringe in a given time is noted.

(ii) Rate of production of oxygen $= \frac{volume\ of\ oxygen}{time}$

(b)



Note that dulution of hydrogen peroxide reduces the rate of production of oxygen and the maximum volume of oxygen produced.

(c) Mole of hydrogen peroxide = $\frac{200\ x\ 0.5}{1000} = 0.1 moles$

Moles of hydrogen produced

2mole of hydrogen peroxide produce 1 mole of oxygen

⇨ 0.1 mole of hydrogen peroxide produce $\frac{0.1\ x\ 1}{2} = 0.05 moles$

Mole of magnesium that reacted

$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

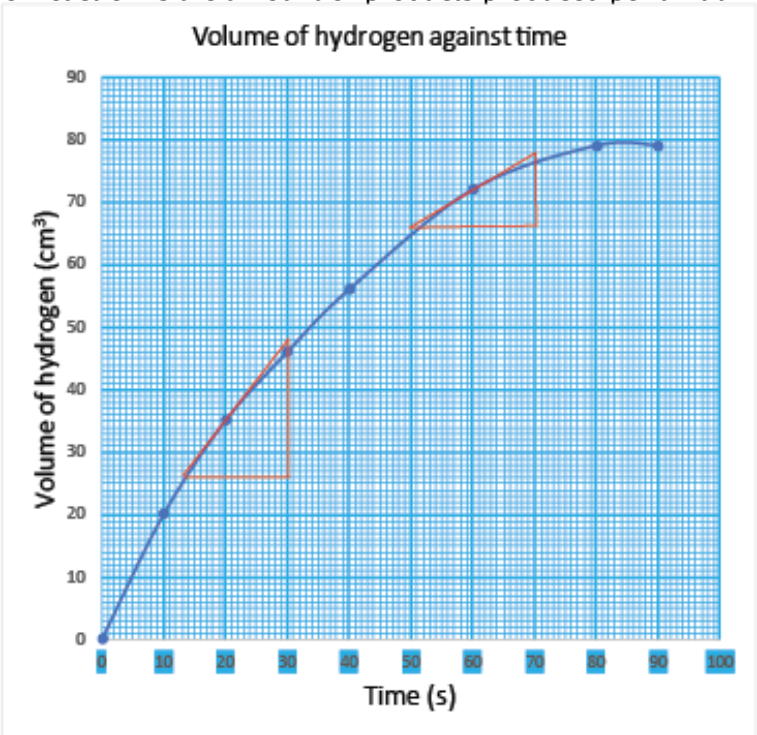
From equation

2 mole of O_2 react with (2x24 = 48g of magnesium

⇨ 0.05mole of O_2 react with $\frac{48\ x0.05}{2} = 1.2g$

12 (a) Rate of reaction is the amount of products produced per unit time

(b)



(d) (i) At 20 second

Rate = $\frac{47-26}{30-13} = 1.3\ cm^3/s$

At 60 seconds

Rate = $\frac{78-66}{70-50} = 0.6\ cm^3/s$

(ii) The rate at 20 seconds is higher than at 60 seconds because the concentration of the reactants decrease as time goes on.

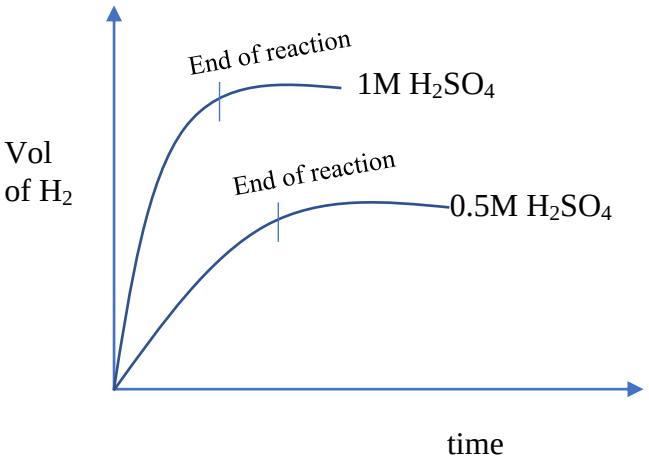
13 (a) (i) 1000cm^3 contain 0.5 moles

⇨ 100 cm^3 cotains $\frac{0.5\ x\ 100}{1000} = 0.05 moles$

(ii) 1000cm^3 contain 1 moles

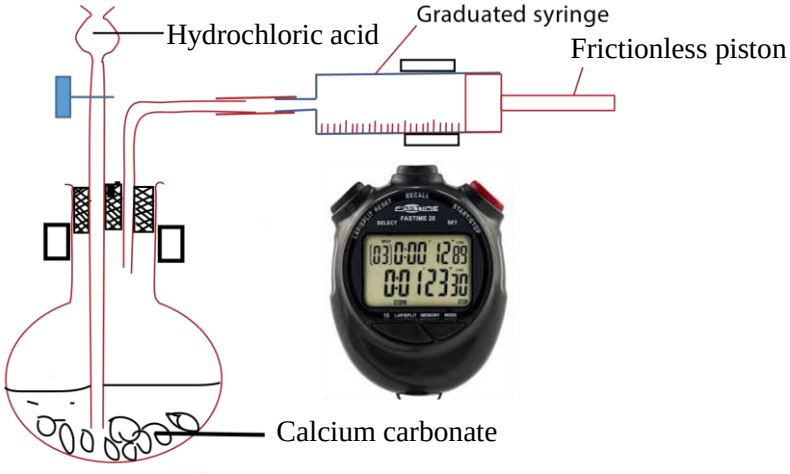
100 cm^3 cotains $\frac{1\ x\ 100}{1000} = 0.1 moles$

(i) & (ii)



(i) The reaction with 0.5M sulphuric acid takes longer because the reaction is slower. Since the concentration of aicd is lower.

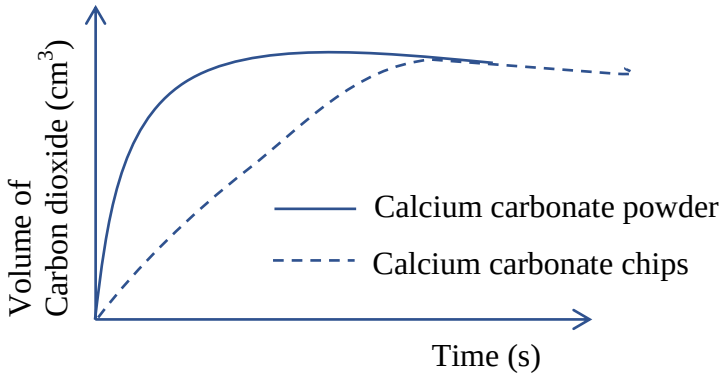
14 Experiment set up is shown below



Two experiements are carried out using equal masses of calcium carbonate chips and calcium carbonate power and equal volumes of acid.

In each case the volume of carbon dioxide produced at intervals of time is

measured.
A plot of the graph of the volume of carbon dioxide by calcium carbonate chips and calcium carbonate powder with time is given below



Conclusion
The graphs whow that the rate of reaction is higher with calcium carbonate poweder than with chips.

(b) The rate of reaction is higher with 4M hydrochloric acid than 2M hydrochloric acid because high concentration of the acid increases the rate of collision between calcium carbonate molecules and acid molecules.

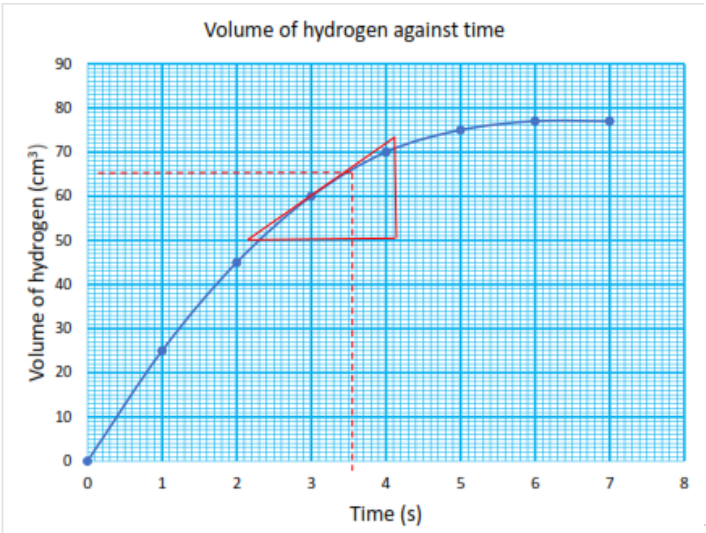
(c) Catalyst

15 (a) The rate of reaction produce in a unit time

(b) (i) **Temperature**
Increasing the temperature increases reaction rates because of the disproportionately large increase in the number of high energy collisions. It is only these collisions (possessing at least the activation energy for the reaction) which result in a reaction.

(ii) **Surface area**:
Increasing the surface area of a solid reactant exposes more of its particles to attack. This results in an increased chance of collisions between reactant particles, so there are more collisions in any given time and the rate of reaction increases. The surface of a solid can be increased by crushing it into a powder.

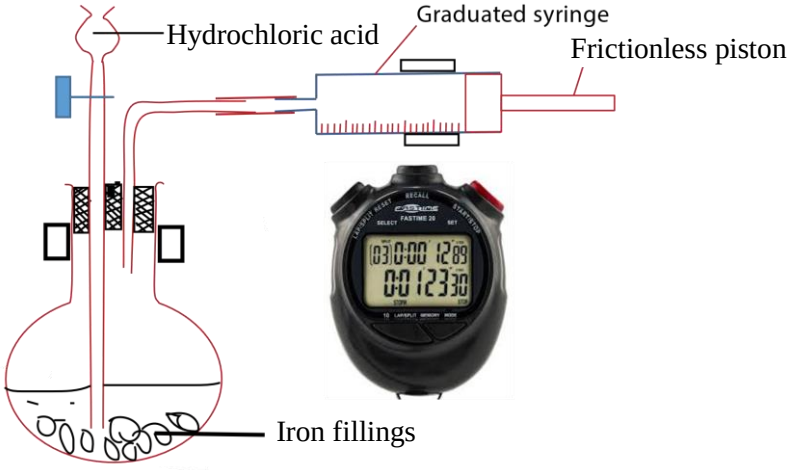
(c) (i)



(ii) Rate at 3.0 s = $\frac{77-60}{5.1-2,7} = \frac{17}{2.4} = 7cm^3$

(d) Would decrease

16 (a) Experiment set up is shown below



Hydrochloric acid is added to iron fillings and immediately a stop clock is sterted and the volume (V) of hydrogen is recorded in a given time (t)

Rate = $\frac{V\ (cm^3)}{t\ (s)}$

(b) $Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$

(c) (i) Moles of HCL that reacted

24000cm^3 at room temperature of hydrogen require 2 moles of hydrogen

120cm^3 of hydrogen will require $\frac{2\ x\ 120}{24000} = 0.01cm^3$

Volume of hydrochloric acid

Remember that molarity is the moles in 1000 cm^3

⇨ 0.1moles of HCl are contained in1000cm^3

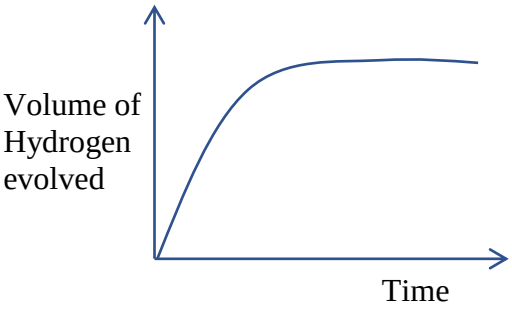
And 0.01mole of HCl will be in $\frac{1000\ x\ 0.01}{0.1} = \mathbf{100}\boldsymbol{cm^3}$

(ii) Mass of iron fillings

2moles of HCl react with 56g

⇨ 0.01 mole of HCl react with $\frac{56\ x\ 0.01}{2} = 0.28g$

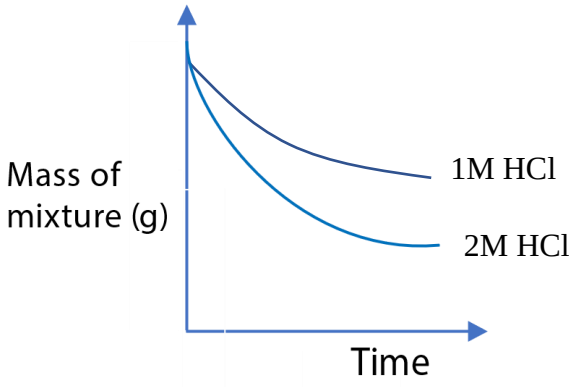
(d) A graph of volume of hydrogen liberated against time



(e) The rate increases

17 (a) - temperature
- concentration
- catalyst
- surface area

(b)



Note that the rate is slower with 1M HCl due to reduced concentration.

(c) (i) $CaCO_3(s) + 2HCl\ (aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

(ii) Moles of HCl
Remember molority is number of mole in $1000cm^3$ of solution
1000cm3 contain 2moles
20cm3 contain $\frac{2\ x\ 20}{1000} = 0.o4moles$
Moles of calcium carbonate that reacted
2mole of HCl that reacted
2moles of HCl react with 1 mole of $CaCO_3$
⇨ 0.04mole reacted with $\frac{0.04\ x\ 1}{2}$ = 0.02 moles of $CaCO_3$

Mass of $CaCO_3$ that reacted
Rfm of $CaCO_3$ = 40 + 12 + 16 x 3 = 100g

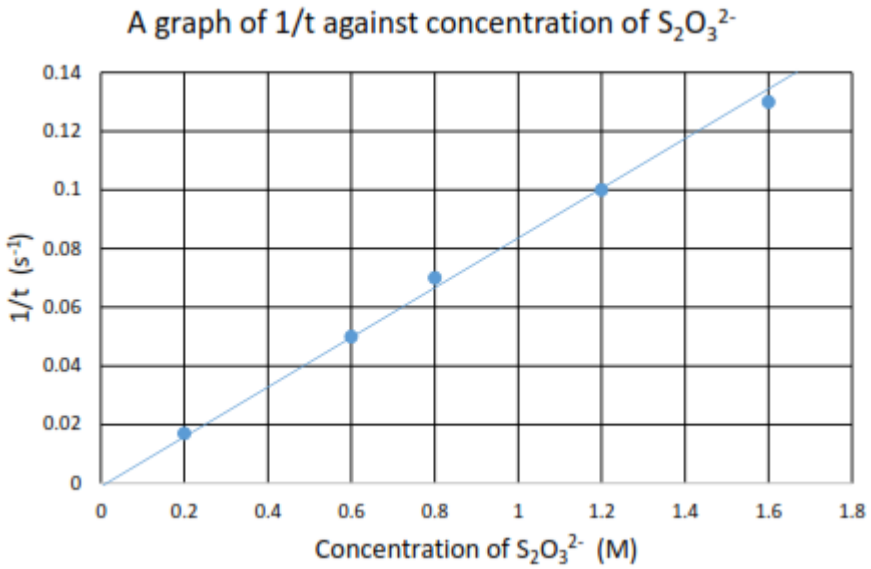
1 moles of $CaCO_3$ = 100g
0.2 moles = 0.02 x100 = 2g

Mass of $CaCO_3$ left = 5 -2 =3g

18 (a) (i) The rate of reaction is the amount of product produced or amount of reactants used up in agiven time

(ii) The smaller the particle sizes, the bigger the surface area and the faster the reaction due to increased chance of collision between the reactant.

(b)



(c) (i) 1/t is directly proportional to the rate of reaction

(ii) The rate is prortional to the concentration of thiosulphate ions

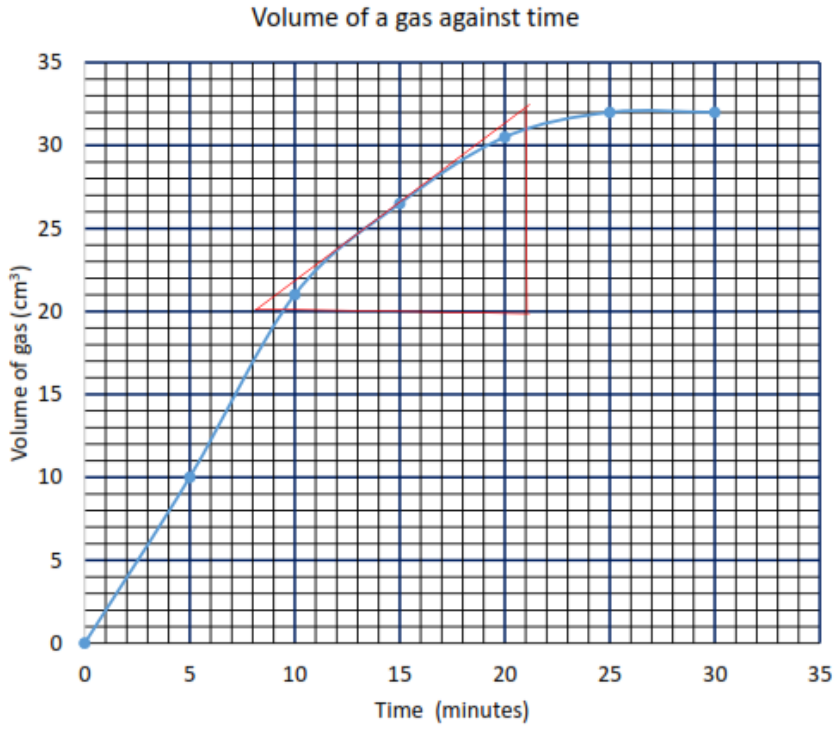
(d) Acidified potassium dichromate changes from orange to green

19 (a) (i) Catalyse the reaction

(ii) $Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$

(iii) The rate of reaction increase to increase in surface area and chances of collision of ractants

(b) (i)



(ii) Determine the gradient of the targent drawn at 12 minutes
i.e $\frac{32-20}{21-8} = \frac{12}{13} = 0.923cm^3min^{-1}$

(iii) The rate of reaction is higher at 12 minutes than at 20 minutes because at 20 minutes the amount of reactants has decreased

(iv) Became constant because the reactants are used.