Higher Chemistry: Unit 2 – Chemical Changes and Structure

Revision of Controlling the Rate

Part 1 – Collision Theory, Activation Energy and Energy Distribution

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Learning Outcomes

The lesson will help you revise the following topics

1. Collision Theory
2. Factors affecting rate of reaction
3. Activation Energy
4. Kinetic Energy Distribution

Success Criteria

You will have been successful in this lesson if you:

1. Read the summary given (do not copy these notes – you already have them)
2. Watch the links provided
3. Complete questions provided
4. EXTENSION: There is a further reading section to help you gain more depth of understanding for this section. There are also suggested questions for you to try from the blue book of revision questions.

If you have any questions about the content of this lesson, you should ask your class teacher either through your class MS team or via email. The teams will be monitored through the week and someone will get back to you as soon as they can.

Links to Prior Knowledge

You may wish to revise the following to help you understand this lesson:

Higher chemistry – Unit 1 Part C – Controlling the Rate of Reaction

You may wish to have a copy of the data booklet handy for this lesson. Download or print a copy of the Higher Chemistry Data Booklet from MS Teams or the SQA website - https://www.sqa.org.uk/sqa/files_ccc/ChemistryDataBooklet_NewH_AH-Sep2016.pdf

Do not copy the notes below – these are a summary of the printed notes you already have for this unit.

WATCH: Click on the link for a recorded lesson for this topic:

RECORDED LESSON from Ms Hastie

Part C – Controlling the Rate (Part 1)

1. Collision Theory

Factors affecting reaction rate

For a chemical reaction to occur, reactant particles…

1. must collide with enough energy to react (the activation energy)

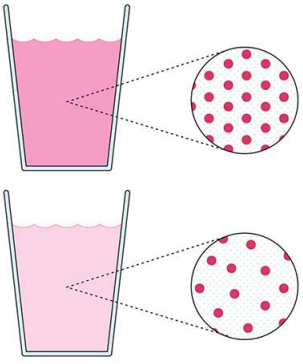
AND

2. must have the correct collision geometry (correct orientation in space).

Rate of reaction is affected by the following factors:

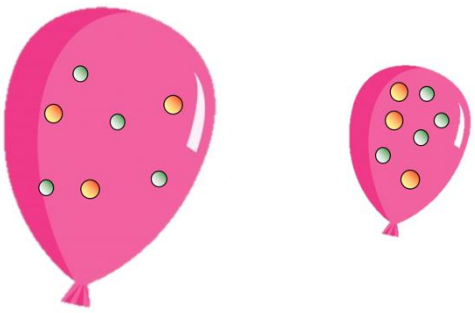
1. Concentration

Increasing the concentration of a solution, increases the number of particles in a given volume. This results in **more collisions, therefore increases reaction rate.**



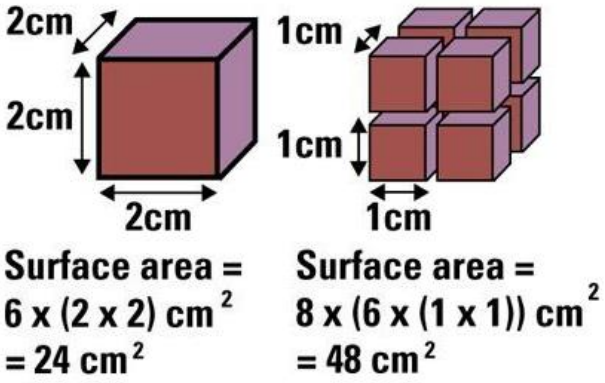
2. Pressure

Increasing the pressure in a reaction involving gases, reduces the volume for particles to move around in. This results **in more collisions, therefore increases reaction rate.**



3. Surface Area / Particle Size

Reactions of solids can only take place at the surface of the solid. Smaller particles have a larger surface area. This results in **more collisions, therefore increases the reaction rate.**



4. Temperature

Particles must collide with a **minimum energy** to react, called the **activation energy**. Heating particles gives them more kinetic energy, causing **an increase in the number of particles with energy greater than the activation energy**. This results in a greater chance of successful collisions, therefore increases reaction rate.

Calculations involving rate of reaction

The rate of reaction can be found using the following equation:

$$\text{Rate} = \frac{1}{time}$$

The unit for rate is s^{-1} (per second)

Example 1.

Toby carried out the iodine clock reaction at two different temperatures. The results are in the table below.

Temp (°C)	Time (s)	Rate (s^{-1})
40	35	
60	12	

Use the information in the table to calculate the rate of reaction at 40°C and 60°C, respectively.

Rate at 40°C = $\frac{1}{35}$ = **0.029 s^{-1}**

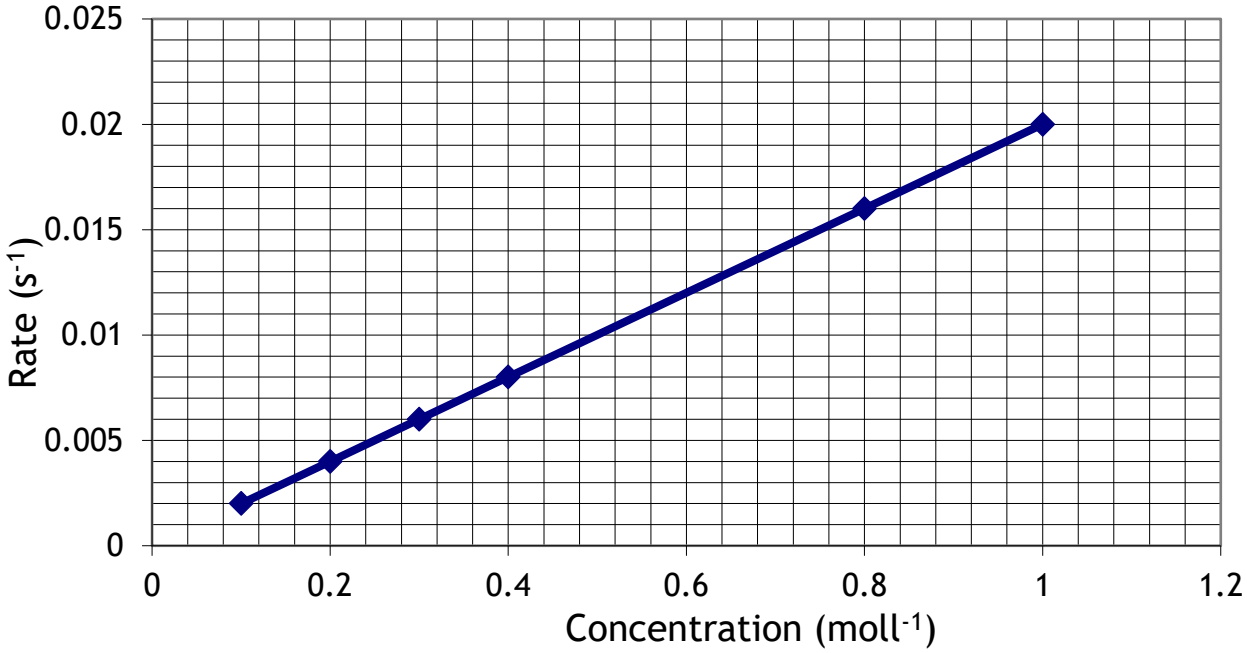
Rate at 60°C = $\frac{1}{12}$ = **0.083 s^{-1}**

Alternatively, if you know the rate of reaction, you can use this same equation to calculate the time for the reaction:

$$\text{Rate} = \frac{1}{time} \qquad \text{therefore,} \qquad \text{time} = \frac{1}{rate}$$

Example 2.

Grace carried out the iodine clock reaction at a number of different concentrations and plotted a graph of her results.



Use the graph to calculate the time taken for the reaction when a concentration of 0.6 mol l^{-1} was used.

time $= \frac{1}{Rate} = \frac{1}{0.012}$

= 83s

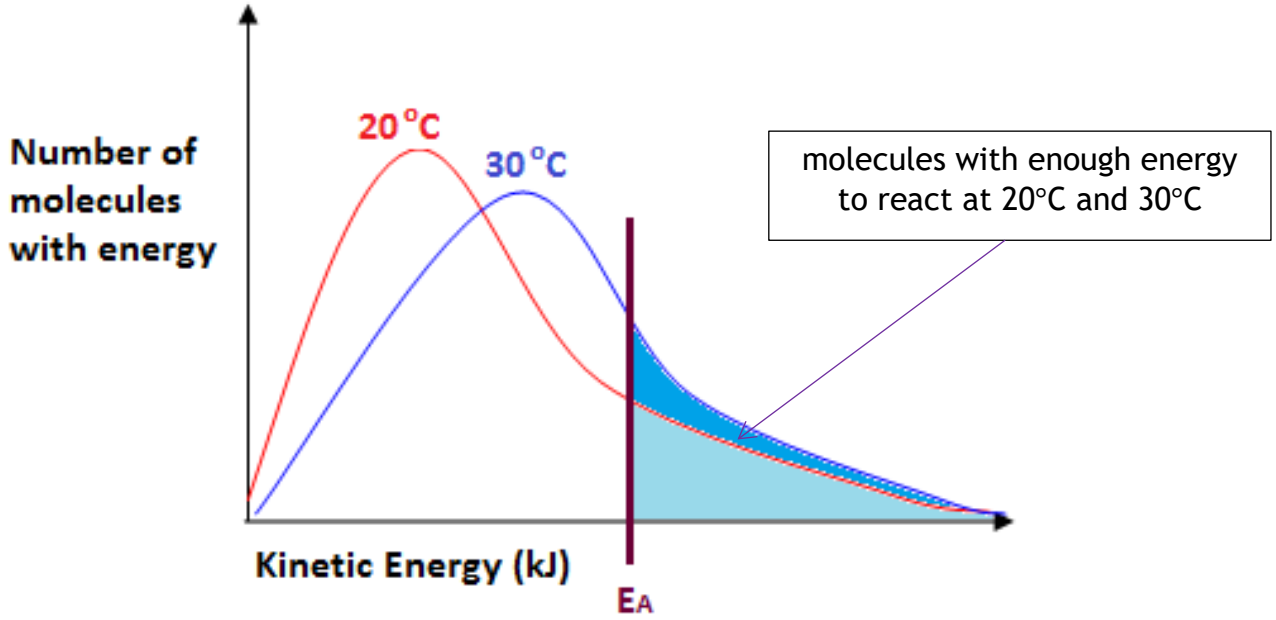
2. Kinetic Energy Distribution and Activation Energy

Activation energy and energy distribution

The **activation energy, E_A, is the minimum kinetic energy required by colliding particles before a reaction may occur.**

It is important to note that this does not guarantee a successful collision (particles also need the correct collision geometry).

Using an energy distribution graph, it is possible to show the proportion of molecules that have energy greater than the activation energy, E_A, and therefore may be able to take part in successful collisions.



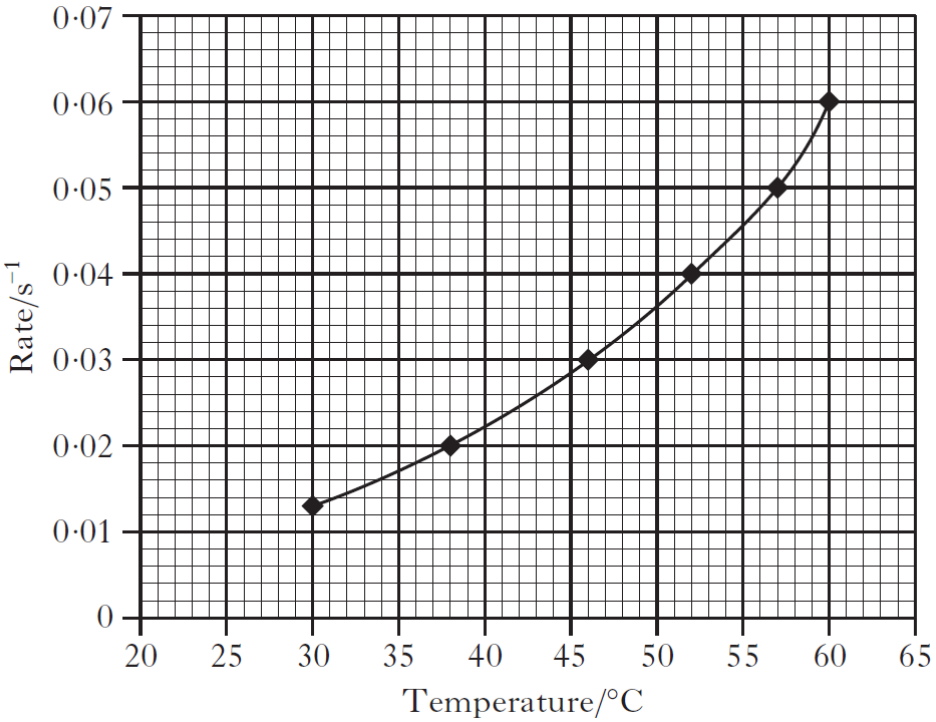
At 20°C **only a small number of molecules have enough energy to react**, meaning the reaction rate would be **slow**.

At 30°C, more particles now have energy greater than the activation energy, meaning the reaction rate will be **faster**.

Activation energy is not affected by the change in temperature and does not change position.

Example of a calculation showing that a small rise in temperature results in a **large** increase in reaction rate.

Hashim carried out the iodine clock reaction at a number of different concentrations and plotted a graph of his results.



Use the graph to determine the temperature rise required to double the rate of reaction.

Temp at rate of 0.02 s^{-1} = 38°C
Temp at rate of 0.04 s^{-1} = 52°C

ΔT = 52-38 = <u>14°C</u>

Double check:
Temp at rate of 0.03 s^{-1} = 46°C
Temp at rate of 0.06 s^{-1} = 60°C

ΔT = 46-60 = <u>14°C</u>

Answer = **<u>14°C</u>**

Learning Outcomes

You should have now revised:

1. Collision Theory
2. Factors affecting rate of reaction
3. Activation Energy
4. Kinetic Energy Distribution

Further Reading

To learn more about proteins, try the following online resources:

BBC Bitesize: https://www.bbc.co.uk/bitesize/guides/z2gccdm/revision/1

Read prevision pages (optional) and **TRY THE END TOPIC TEST**

Scholar: Log in through GLOW

Higher Chemistry → Chemistry in Society → Topics 2-3

Read through the exercises and **TRY THE END TOPIC TESTS**

Evans2 chem web: https://www.evans2chemweb.co.uk/login/index.php#

Username: snhs password: giffnock

Select any teacher → revision material → CfE Higher → Unit 2: Nature's Chemistry in Society → Controlling the Rate

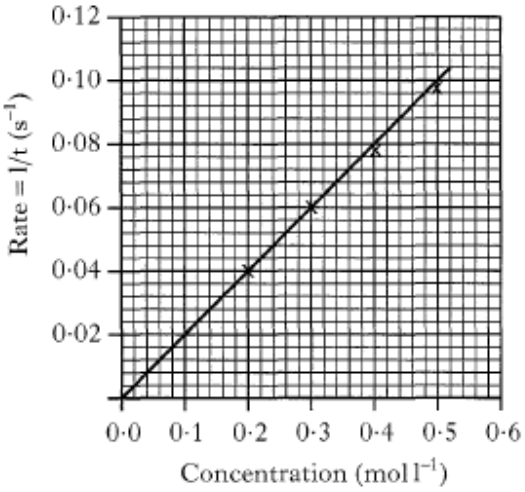
Check your understanding – Answers the questions below in you class jotter

Revision of Controlling the Rate of Reaction Questions

1. A student investigated the effect of changing the concentration of a reactant on the rate of chemical reaction.

When a concentration of 0.3 mol l^{-1} is used, the time of reaction, in seconds, is

A 0.06
B 3.33
C 16.67
D 10.0



2. Excess zinc was added to 100cm^3 of hydrochloric acid, concentration 1 $moll^{-1}$. Graph I refers to this reaction.

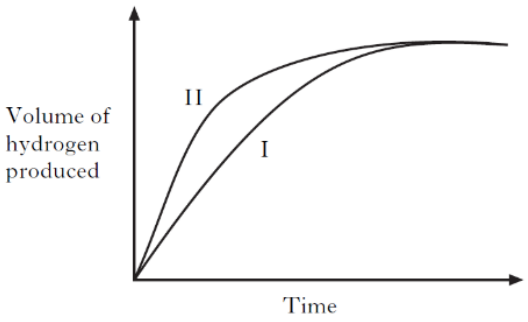
Graph II could be for:

A Excess zinc reacting with 100cm^3 of hydrochloric acid concentration 2 $moll^{-1}$

B Excess zinc reacting with 100cm^3 of sulfuric acid concentration 1 $moll^{-1}$

C Excess zinc reacting with 100cm^3 of hydrochloric acid concentration 0.5 $moll^{-1}$

D Excess magnesium reacting with 100cm^3 of hydrochloric acid concentration 1 $moll^{-1}$

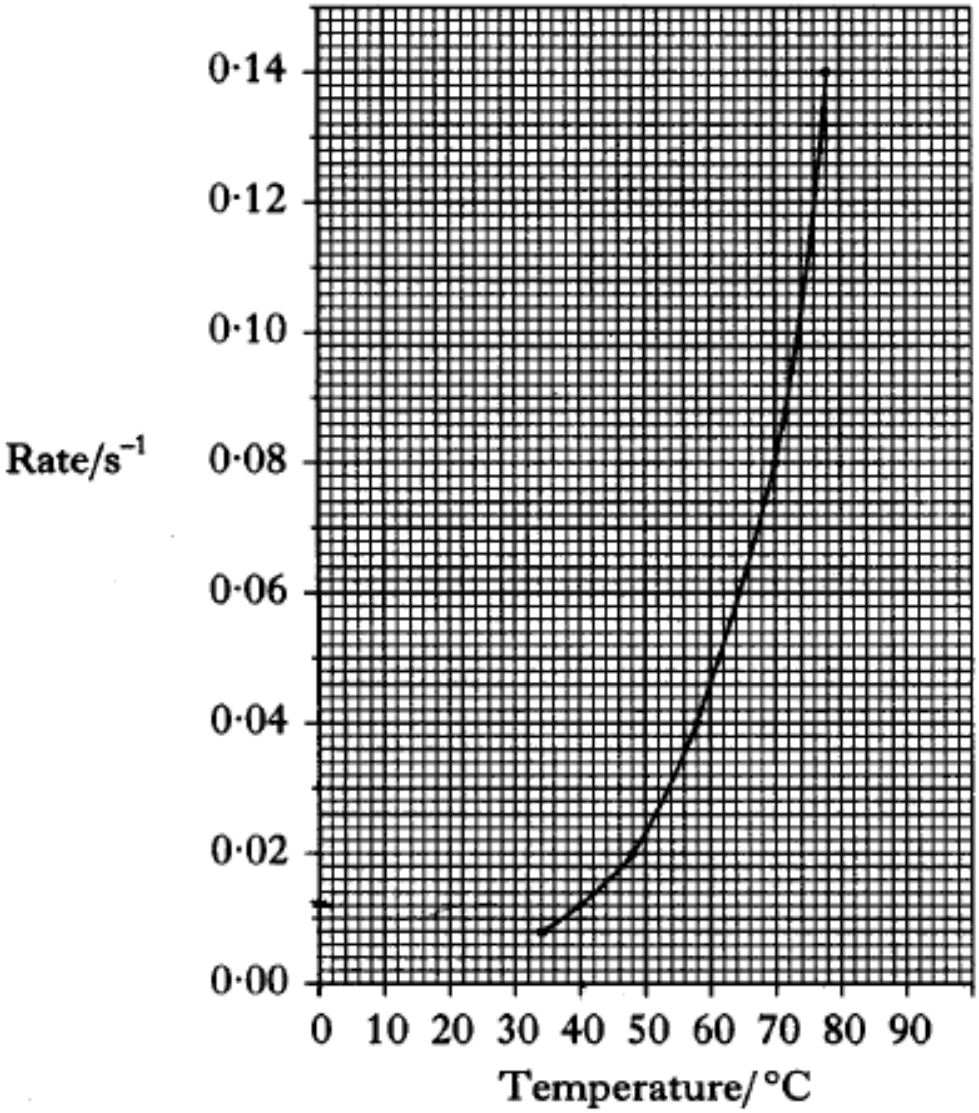


3. Two identical samples of zinc were added to an excess of two solutions of sulphuric acid, concentrations 2 $moll^{-1}$ and 1 $moll^{-1}$ respectively. Which of the following would have been the same for the two samples?

A The total mass lost
B The total time for the reaction
C The initial reaction rate
D The average rate of evolution of gas.

Questions 4 and 5 refer to the graph below

The results of the effect of temperature on the reaction rate of the reaction between oxalic acid and acidified potassium permanganate are plotted in the graph below.



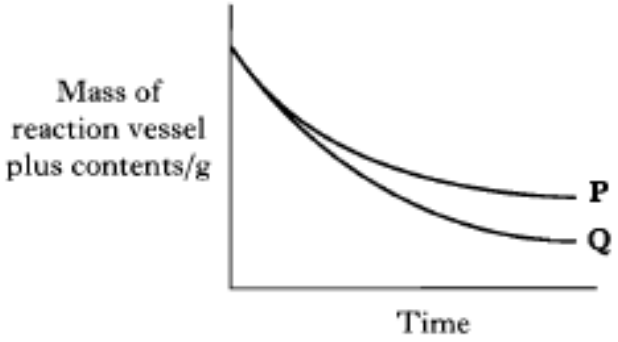
4. The time taken, in seconds, for the reaction at 70ºC was

A 0.8
B 8
C 1.25
D 12.5

5. The temperature, in ˚C, required to double the rate of reaction was approximately

A 6
B 12
C 18
D 24

6. When copper carbonate reacts with excess acid, carbon dioxide is produced. The curves shown were obtained under different conditions.



The change from P to Q could be brought about by:

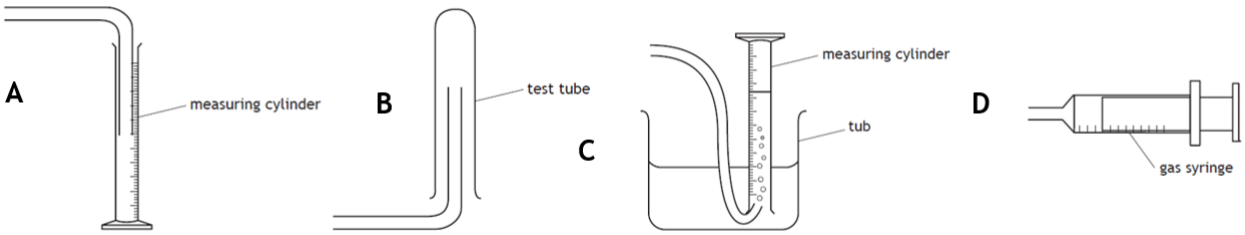
A increasing the concentration of the acid
B increasing the mass of copper carbonate
C decreasing the particle size of the copper carbonate
D adding a catalyst.

7. The relative rate of a reaction which reached completion in 1 minute and 40 seconds is

A 0.010 s^{-1}
B 0.714 s^{-1}
C 0.010 min^{-1}
D 0.714 min^{-1}

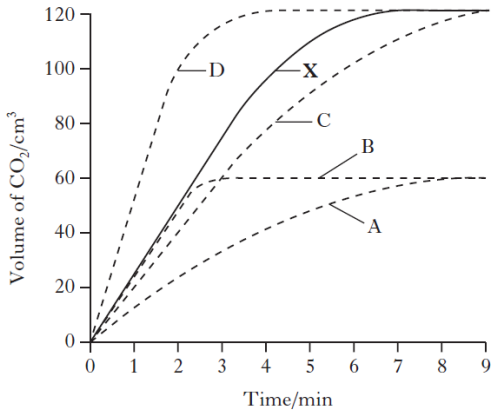
8. Sulfur dioxide gas is denser than air and is very soluble in water.

Which of the following diagrams shows the most appropriate apparatus for collecting and measuring the volume of sulfur dioxide given off in a reaction?

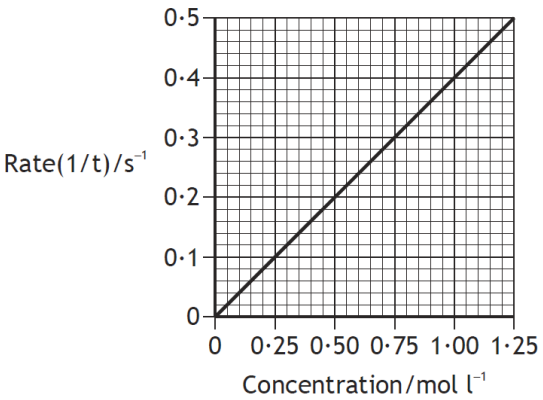


9. Graph **X** was obtained when 1 g of calcium carbonate powder reacted with excess dilute hydrochloric acid at 20 °C.

Which curve (**A-D**) would best represent the reaction of 0·5 g lump calcium carbonate with excess of the same dilute hydrochloric acid?



10. The graph shows how the rate of a reaction varies with the concentration of one of the reactants.



(a) Calculate the reaction time, in seconds, when the concentration of the reactant was 0.5 mol l^{-1}. **(1)**

(b) At what concentration, in mol l^{-1}, did the reaction last 2 seconds? **(1)**

11. A student carried out three experiments involving the reaction of excess magnesium ribbon with dilute acids. The rate of hydrogen production was measured in each of the three experiments.

Experiment	Acid
1	100 cm^3 of 0·10 mol l^{-1} sulphuric acid
2	50 cm^3 of 0·20 mol l^{-1} sulphuric acid
3	100 cm^3 of 0·10 mol l^{-1} hydrochloric acid

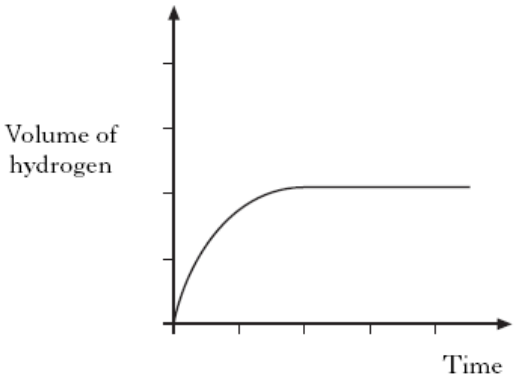
(a) Write an equation for the reactions occurring in experiment 1. **(1)**

(b) State **two** conditions necessary for a collision to be successful **(2)**

(c) Draw a labelled diagram of the reaction between magnesium ribbon and hydrochloric acid, showing how the volume of gas was measured. **(1)**

(d) The curve obtained from Experiment 1 is drawn on the graph on the right.

Redraw the graph and add curves to show the results obtained for Experiment 2 and Experiment 3.
Label each curve clearly. **(2)**



12. The reaction between iodide ions, $I^-_{(aq)}$, and persulfate ions, $S_2O_8^{2-}{}_{(aq)}$, was used to investigate the effect of changing concentration on rate of reaction. The relative rate of the reaction was determined by mixing the reactants in a beaker and recording the time taken for the mixture to change colour. The results of the investigation are shown in the table.

Experiment	Concentration of $I^-_{(aq)}$ / mol l^{-1}	Concentration of $S_2O_8^{2-}{}_{(aq)}$ / mol l^{-1}	Time / s	Relative rate / s^{-1}
1	0.04	0.05	241	0.00415
2	0.06	0.05	180	0.00556
3	0.08	0.05		0.00819
4	0.1	0.05	103	0.00971

(a) The instructions state that a dry beaker must be used for each experiment. Suggest a reason why the beaker should be dry. **(1)**

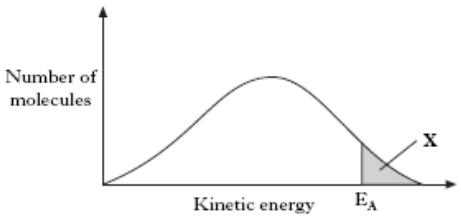
(b) Calculate the time, in seconds, for the reaction in experiment 3. **(1)**

(c) Explain why decreasing the concentration of iodide ions lowers the reaction rate. **(1)**

Total = 20

Revision of Collision Theory and Energy Distribution Questions

1. In area X



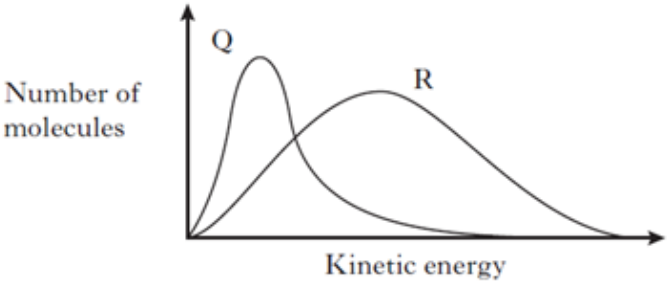
A Molecules always form an activated complex
B No molecules have the energy to form an activated complex
C All molecules have the energy to form an activated complex
D Collisions between molecules are always successful in forming products

2. A small increase in temperature results in a large increase in rate of reaction. The **main** reason for this is that

A more collisions are taking place
B the enthalpy change is lowered
C the activation energy is lowered
D many more particles have energy greater than the activation energy.

3. Which line in the table is correct for curves Q and R in the graph shown below?

	Curve Q	Curve R
A	1 mol of O_2 at 50°C	2 mol of O_2 at 100°C
B	1 mol of O_2 at 100°C	2 mol of O_2 at 100°C
C	2 mol of O_2 at 50°C	1 mol of O_2 at 100°C
D	2 mol of O_2 at 100°C	1 mol of O_2 at 100°C

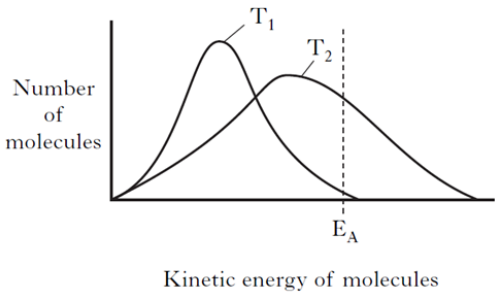


4. In a reaction involving gases, an increase in temperature results in
A an increase in activation energy.
B an increase in the enthalpy change.
C a decrease in the activation energy.
D more molecules per second forming an activated complex.

5. For any chemical, its temperature is a measure of

A the average kinetic energy of the particles that react
B the average kinetic energy of all the particles
C the activation energy
D the minimum kinetic energy required before reaction occur

6. Which of the following is the correct interpretation of energy distribution diagram below for a reaction as the temperature **decreases** from T_2 **to** T_1



	Activation energy (E_A)	Number of successful collisions
A	remains the same	increases
B	decreases	decreases
C	decreases	increases
D	remains the same	decreases

7. Which of the following **is not** affected when the temperature of a reaction is changed.

A The reaction rate
B The number of particles that have enough energy to react
C The number of successful collisions
D the activation energy

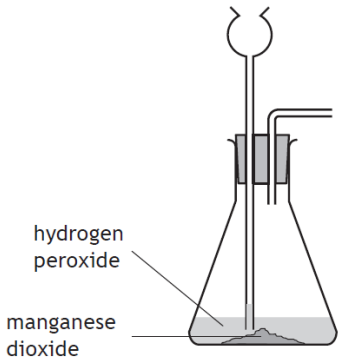
8. In which of the following will **both** changes result in an increase in the rate of a chemical reaction?

A A decrease in activation energy and an increase in the frequency of collisions.
B An increase in activation energy and a decrease in particle size.
C An increase in temperature and an increase in the particle size.
D An increase in concentration and a decrease in the surface area of the reactant particles.

9. Hydrogen peroxide, H_2O_2, gradually decomposes into water and oxygen.

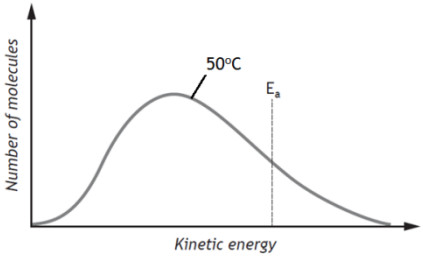
(a) Write a balanced equation for the decomposition of hydrogen peroxide. **(1)**

(b) The reaction goes faster when a catalyst, such as manganese dioxide, is added. Draw apparatus which would complete the diagram on the right to show how the oxygen gas produced could be collected and measured. (you do not need to redraw the flask) **(1)**



(c) The reaction can also be catalysed by adding potassium iodide instead of manganese dioxide. Describe an experiment to test which is the better catalyst. **(2)**

10. The graph shows the distribution of kinetic energies of particles in a molecule at **50°C**. The dotted line **Ea** represents the activation energy of the reaction.

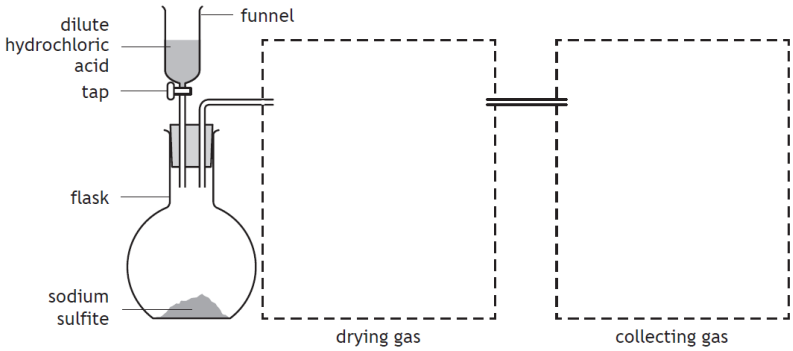


(a) What is meant by the term "activation energy"? **(1)**

(b) Copy the graph into your jotter and add a labelled line:
(i) to show the distribution of kinetic energies at **30°C.**
(ii)to show the distribution of kinetic energies at **70°C.** **(2)**

(c) Use your graph from (a) to explain why an increase in temperature results in an increase in reaction rate. **(1)**

11. Sulfur dioxide is a colourless, toxic gas that is soluble in water and more dense than air. One laboratory method for preparation of sulfur dioxide gas involves adding dilute hydrochloric acid to solid sodium sulfite. The sulfur dioxide gas produced is dried by bubbling the gas through concentrated sulphuric acid. The sulfur dioxide gas can then be collected.



In your jotter, draw apparatus suitable for drying the sulfur dioxide gas and apparatus suitable for collecting the gas. **(2)**

12. Theobromine, a compound present in chocolate, can cause illness in dogs and cats. To decide if treatment is necessary, vets must calculate the mass of theobromine consumed.

1·0 g of chocolate contains 1·4 mg of theobromine. Calculate the mass, in mg, of theobromine in a 17 g biscuit of which 28% is chocolate.
Show your working clearly. **(2)**

Total = 20

ANSWERS TO EXERCISES WILL BE POSTED ON WEDNESDAY FOR YOU TO CHECK YOUR WORK

EXTENSION WORK

Use the online learning link above if you would like to extend your knowledge on this topic. For more practise questions, use your Revision Questions for Higher Chemistry "Blue book":

Successful Collisions	page 1 Q1-7
Problem Solving: Factors affecting Rate	page 25 Q1-10