

8.1 RATE OF REACTION

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Introduction

1. Explain what is meant by the term *rate of reaction*. [1]
2. Calculate the reaction rate for 0.0440 g of ethyl ethanoate ($\text{CH}_3\text{COOC}_2\text{H}_5$) formed 1.00 min from a reaction mixture of 400 cm^3 . (ans= $2.08 \times 10^{-5}\text{ mol dm}^{-3}\text{ s}^{-1}$)

1. The rate of the reaction between a reactive metal and an excess of a dilute acid is investigated. The total volume of hydrogen gas produced is recorded every 30 seconds for 3 minutes.

time / s	total volume of hydrogen gas / cm^3
0	0
30	64
60	105
90	132
120	151
150	161
180	167

The average rate of reaction during the first 30 seconds is P.

The average rate of reaction during the last 30 seconds is Q.

What is the value of $P - Q$?

- A $1.21\text{ cm}^3\text{ s}^{-1}$
- B $1.93\text{ cm}^3\text{ s}^{-1}$
- C $2.13\text{ cm}^3\text{ s}^{-1}$
- D $3.43\text{ cm}^3\text{ s}^{-1}$

2. 20.0 cm^3 of hydrogen peroxide decomposes to water and oxygen in the presence of a suitable catalyst. 160 cm^3 of oxygen, measured at room conditions, is produced in 5.00 minutes. What is the average rate of decomposition of hydrogen peroxide during this reaction period?

- A $2.22 \times 10^{-5}\text{ mol s}^{-1}$
- B $4.44 \times 10^{-5}\text{ mol s}^{-1}$
- C $1.76 \times 10^{-4}\text{ mol s}^{-1}$
- D $2.67 \times 10^{-3}\text{ mol s}^{-1}$

3. According to collision theory, state two conditions that particles need to for an effective collision to occur. [1]

The effect of concentration and pressure changes

4. An increase in concentration means there are more particles per unit volume.

In terms of collisions, explain how this increases the rate of reaction. [1]

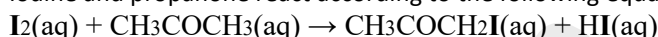
3. 4.0g of powdered calcium carbonate, $M_r = 100$, are added to 100 cm³ of 0.10 mol dm⁻³ hydrochloric acid. The volume of carbon dioxide produced is recorded every 30 seconds.

time/s	30	60	90	120	150	180	210	240
Total volume of carbon dioxide given off/cm ³	40	70	88	101	110	116	120	120

Which row of the table is correct?

	why rate of the reaction changes with time	why the reaction stops
A	fewer collisions between reacting molecules occur	the calcium carbonate is used up
B	fewer collisions between reacting molecules occur	the hydrochloric acid is used up
C	more collisions between reacting molecules occur	the calcium carbonate is used up
D	more collisions between reacting molecules occur	the hydrochloric acid is used up

4. Iodine and propanone react according to the following equation.



If the concentration of propanone is increased, keeping the total reaction volume constant, the initial rate of the reaction also increases.

What could be the reason for this?

- A** A greater proportion of collisions are successful at the higher concentration.
B The particles are further apart at the higher concentration.
C The particles have more energy at the higher concentration.
D There are more collisions per second between particles at the higher concentration.

5. A large excess of marble chips is reacted with 25 cm³ of 1.0 mol dm⁻³ hydrochloric acid at 40°C. How is the result different when the reaction is repeated with 60 cm³ of 0.5 mol dm⁻³ hydrochloric acid at 40°C?

- A** The reaction is faster and more of the products are made when the reaction is complete.
B The reaction is faster and less of the products are made when the reaction is complete.
C The reaction is slower and more of the products are made when the reaction is complete.
D The reaction is slower and less of the products are made when the reaction is complete.

6. A student carries out four experiments to investigate the rate of reaction between 3.0 g of calcium carbonate and hydrochloric acid.



experiment 1 CaCO₃ powder + 2.0 mol dm⁻³ HCl at 35 °C

experiment 2 CaCO₃ powder + 2.0 mol dm⁻³ HCl at 35 °C

experiment 3 large chips of CaCO₃ + 1.0 mol dm⁻³ HCl at room temp

experiment 4 large chips of CaCO₃ + 1.0 mol dm⁻³ HCl at 35 °C

The student collects the CO₂(g) and times how long it takes to produce the same volume of gas for each experiment.

What could be the correct times for the four experiments? (ANS: B)

	experiment 1 /s	experiment 2 /s	experiment 3 /s	experiment 4 /s
A	5	10	30	95
B	5	10	95	30
C	5	30	95	10
D	95	30	10	5

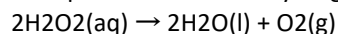
7. In reaction 1, a student measures the initial rate of production of $\text{CO}_2(\text{g})$ when $\text{CuCO}_3(\text{s})$ is added to 50 cm^3 of $0.1 \text{ mol dm}^{-3} \text{ HNO}_3(\text{aq})$.

In reaction 2, the student repeats the experiment using 50 cm^3 of $0.5 \text{ mol dm}^{-3} \text{ HNO}_3(\text{aq})$ and the same mass of $\text{CuCO}_3(\text{s})$.

In reaction 1 and reaction 2, the acid is in excess and samples of the same CuCO_3 powder are used.
Which row is correct?

	rate of reaction 1 rate of reaction 2	initial number of effective collisions in reaction 1 per second initial number of effective collisions in reaction 2 per second
A	greater than 1	greater than 1
B	greater than 1	less than 1
C	less than 1	greater than 1
D	less than 1	less than 1

8. An aqueous solution of hydrogen peroxide is placed in a flask and decomposes, as shown.



The total volume of oxygen gas evolved is 180 cm^3 after 90 seconds, measured under room conditions.

The rate of the reaction is calculated using the equation shown.

$$\text{rate} = \frac{\text{change in moles of H}_2\text{O}_2}{\text{time}}$$

What is the average rate of the reaction, measured in mol min^{-1} , over the duration of the experiment?

A 8.33×10^{-5}

B 1.67×10^{-4}

C 0.0050

D 0.010

9. Why does the rate of a gaseous reaction increase when the pressure is increased at a constant temperature?

A More particles have energy that exceeds the activation energy.

B The particles have more space in which to move.

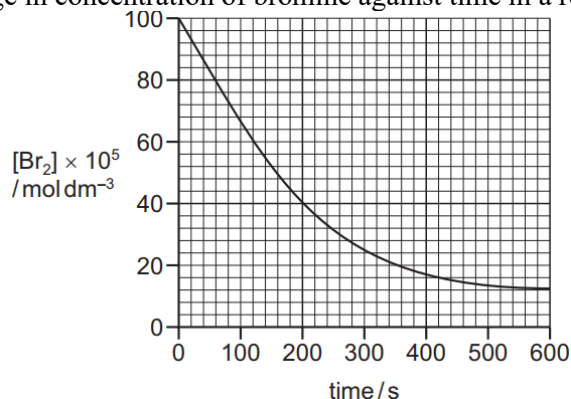
C The particles move faster.

D There are more frequent collisions between particles.

5. Aqueous bromine reacts with methanoic acid to form hydrogen bromide and carbon dioxide gas. $\text{Br}_2(\text{aq}) + \text{HCO}_2\text{H}(\text{aq}) \rightarrow 2\text{HBr}(\text{aq}) + \text{CO}_2(\text{g})$

This reaction can be followed by measuring the concentration of bromine present in the mixture at regular time intervals.

The graph shows the change in concentration of bromine against time in a reaction carried out at 20°C .



- (i) Use the graph to calculate the average rate of reaction at 20°C during the first 600s. State the units of this rate of reaction. [2]
- (ii) The experiment is repeated at a temperature of 40°C. This relatively small increase in temperature produces a large increase in reaction rate.
Sketch a graph, on the same axes, to show the expected results when repeating the experiment at 40°C. [1]
- (iii) The rate of reaction increases when the frequency of successful collisions between reactant particles increases.
Explain why an increase in temperature produces this effect. [2]

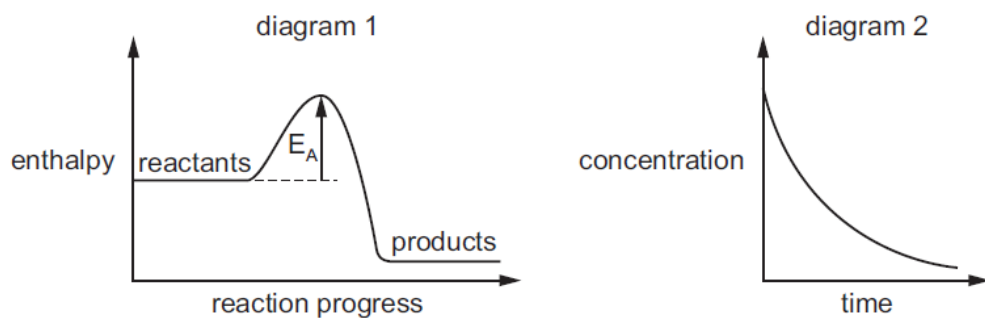
10. Two chemicals, X and Y, react together in solution to give product Z.

The rate of formation of product Z at the start of the reaction was measured in five experiments, 1–5, using various concentrations of X and Y. The results are shown.

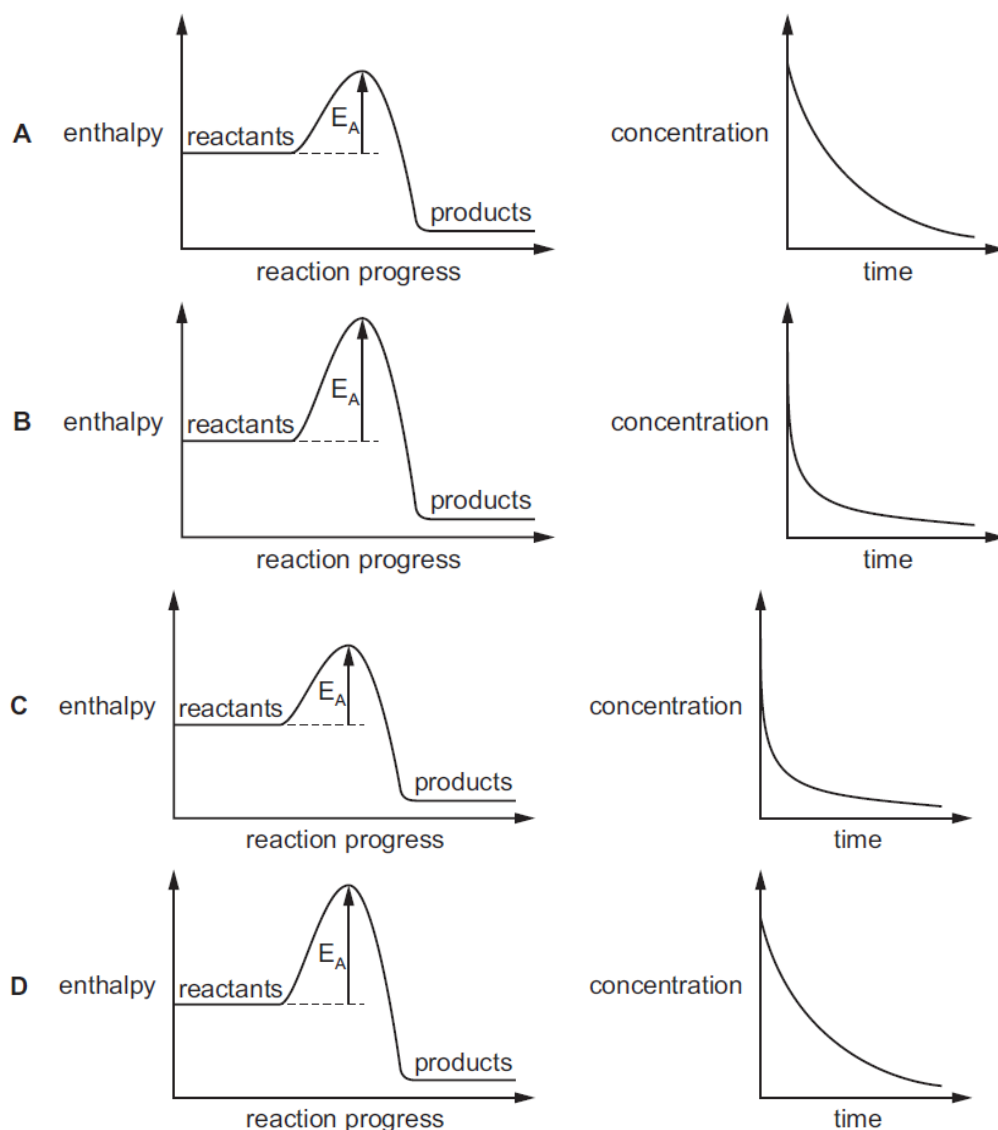
experiment number	starting concentration of X / mol dm ⁻³	starting concentration of Y / mol dm ⁻³	rate of formation of Z at the start / mol dm ⁻³ s ⁻¹
1	0.10	0.10	0.0001
2	0.10	0.20	0.0004
3	0.10	0.40	0.0016
4	0.20	0.10	0.0001
5	0.40	0.10	0.0001

Which statement is correct?

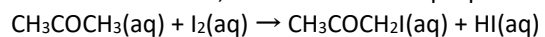
- A The rate of the reaction is directly proportional to the concentration of reagent X.
 B The rate of the reaction is directly proportional to the concentration of reagent Y.
 C The rate of the reaction is **not** affected by the concentration of reagent X.
 D The rate of the reaction is **not** affected by the concentration of reagent Y.
11. Diagram 1 shows the reaction pathway for a reaction.
 Diagram 2 shows a graph of the concentration of reactant against time for the same reaction.



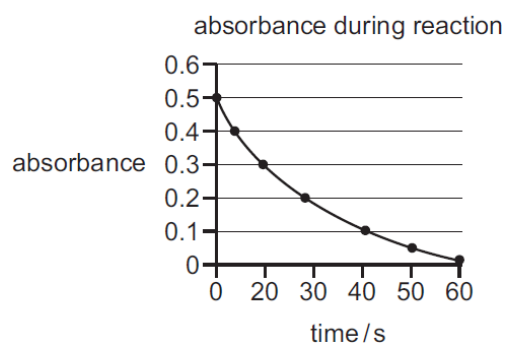
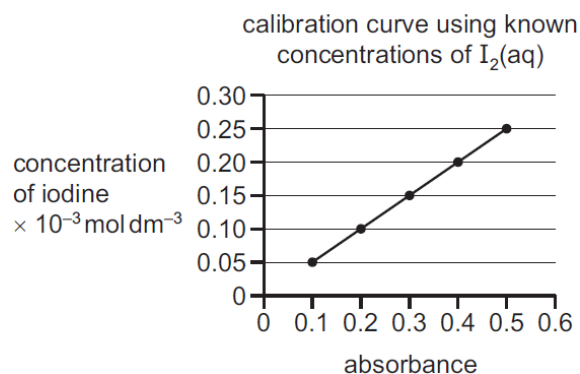
Which diagrams, drawn to the same scale, show the effect of increased temperature on this reaction?



12. In acidic conditions, iodine reacts with propanone in a substitution reaction.



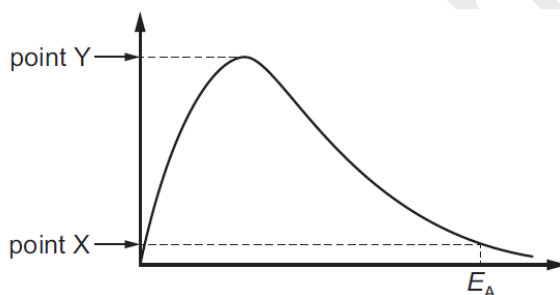
The kinetics of the reaction are investigated using a colorimeter. As the I_2 reacts, the yellow/brown colour of the $\text{I}_2(\text{aq})$ fades to colourless, changing the absorbance of the solution. Known concentrations of $\text{I}_2(\text{aq})$ are used to prepare a calibration curve graph and the absorbance is then measured as the reaction proceeds.



What is the rate of reaction at 20 s?

- A** $5 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1}$
B $1 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$
C $5 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$
D $1 \times 10^{-2} \text{ mol dm}^{-3} \text{ s}^{-1}$

13. The diagram shows a Boltzmann distribution curve. The axes are not labelled.



Points X and Y are points on the vertical axis. What is represented by both points X and Y?

	point X	point Y
A	number of molecules with energy equal to E_A	largest number of molecules with the same energy
B	number of molecules with energy equal to or greater than E_A	largest number of molecules with the same energy
C	number of molecules with energy equal to E_A	the amount of energy of the greatest number of molecules
D	number of molecules with energy equal to or greater than E_A	the amount of energy of the greatest number of molecules

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