# Practice Questions Topic 6 Kinetics *[79 marks]*

1. Which is a correct unit for expressing the rate of a reaction? *[1 mark]*

   A. $\mathrm{mol\,dm^{-3}s^{-1}}$

   B. $\mathrm{mol\,dm^{-3}s}$

   C. $\mathrm{mol\,s}$

   D. $\mathrm{mol^{-1}dm^{3}s^{-1}}$

2. Which change increases the rate of a chemical reaction? *[1 mark]*

   A. Increasing the size of solid reactant particles

   B. Decreasing the concentration of aqueous reactants

   C. Increasing the surface area of a solid reactant

   D. Decreasing the pressure of gaseous reactants

3. Consider the following reaction between hydrogen peroxide, hydrogen ions and iodide ions. *[1 mark]*

$$\mathrm{H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)}$$

   Which changes could be used to investigate the rate of this reaction?

   I. Electrical conductivity

   II. Mass of solution

   III. Colour intensity

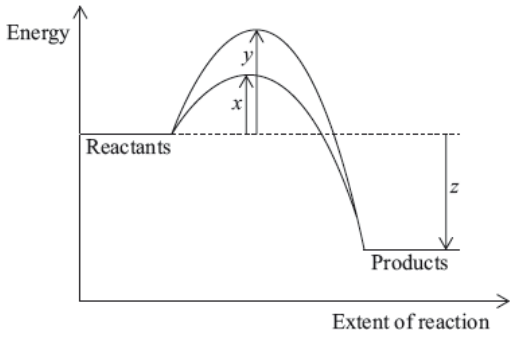
   A. I and II only

   B. I and III only

   C. II and III only

   D. I, II and III

4. The diagram below shows the energy changes for a reaction with and without a catalyst. Which symbols represent the activation energy, $E_a$, and the enthalpy change, $\Delta H$, for the reaction with a catalyst? *[1 mark]*




| | $E_a$ (with a catalyst) | $\Delta H$ |
|---|---|---|
| A. | $x$ | $z$ |
| B. | $y$ | $z$ |
| C. | $z$ | $x$ |
| D. | $y - x$ | $z$ |

5. Which factors can increase the rate of a chemical reaction? *[1 mark]*

I. Increasing the pressure in gaseous reactions

II. Increasing the temperature in gaseous reactions

III. Increasing the particle size of a solid in a reaction

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

6. Which piece of equipment could **not** be used in an experiment to measure the rate of this reaction? *[1 mark]*

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

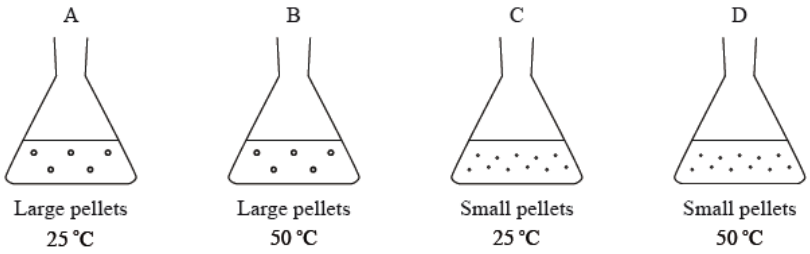
A. A colorimeter

B. A gas syringe

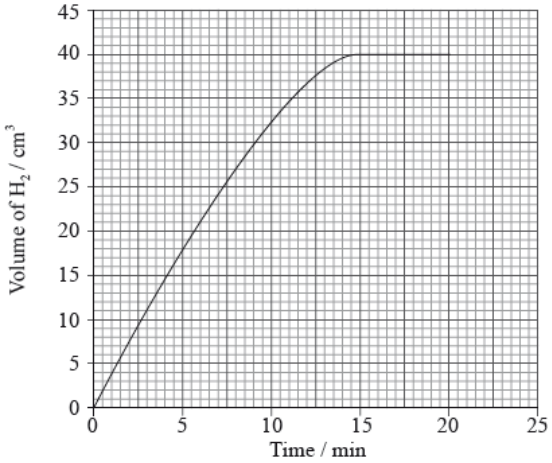
C. A stopwatch

D. A pH meter

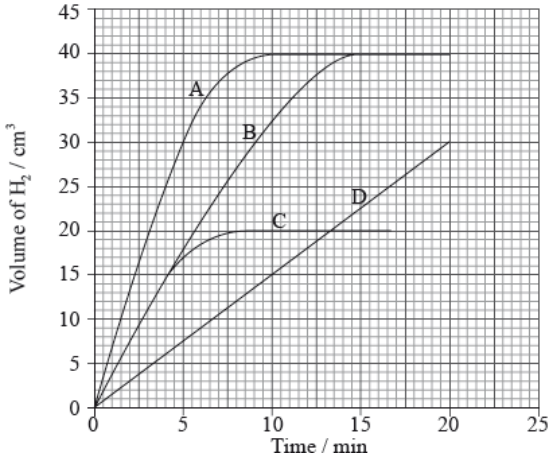
7. In which flask will the reaction between 2.0 g of magnesium carbonate and 25 $cm^3$ 1.0 mol $dm^{-3}$ hydrochloric acid occur most rapidly? *[1 mark]*



8. A piece of zinc was added to aqueous nitric acid and the volume of hydrogen gas produced was measured every minute. The results are plotted on the graph below. *[1 mark]*




Which graph would you expect if the same mass of powdered zinc was added to nitric acid with the same concentration?




9. Which changes increase the rate of the reaction below? *[1 mark]*

$$C_4H_{10}(g) + Cl_2(g) \rightarrow C_4H_9Cl\ (l) + HCl(g)$$

I. Increase of pressure

II. Increase of temperature

III. Removal of HCl(g)

A. I and II only

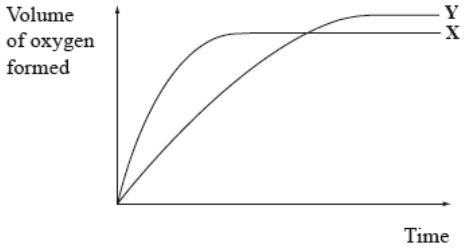
B. I and III only

C. II and III only

D. I, II and III

10. Curve **X** on the graph below shows the volume of oxygen formed during the catalytic decomposition of a $1.0\ \text{mol dm}^{-3}$ solution of hydrogen peroxide. *[1 mark]*

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




Which change would produce the curve **Y**?

A. Adding water

B. Adding some 0.1 mol dm–3 hydrogen peroxide solution

C. Using a different catalyst

D. Lowering the temperature

11. Which are appropriate units for the rate of a reaction? *[1 mark]*

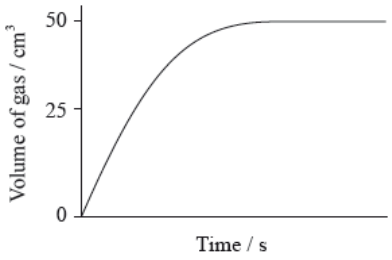
A. $\text{mol dm}^{-3}\text{s}^{-1}$

B. $\text{mol dm}^{-3}\text{s}$

C. $\text{mol dm}^{-3}$

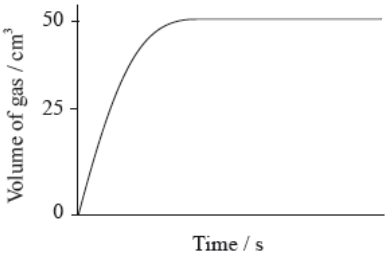
D. s

12. A student added 0.20 g of calcium carbonate powder to $100\ \text{cm}^3$ of $1.0\ \text{mol dm}^{-3}$ hydrochloric acid (an excess) and measured the volume of the gas that was evolved. The graph of the results is shown below. *[1 mark]*




Which graph would be obtained if 0.20 g of calcium carbonate powder is added to $100\ \text{cm}^3$ of $0.5\ \text{mol dm}^{-3}$ hydrochloric acid (an excess)?

A.

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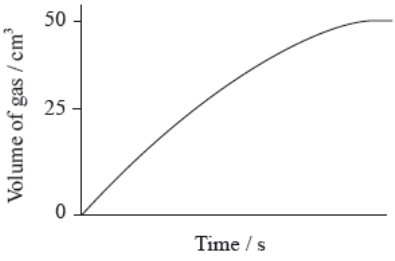


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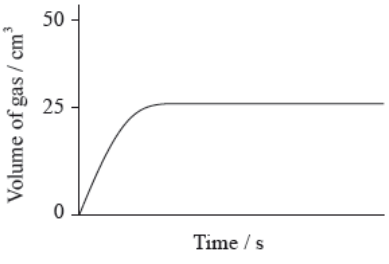
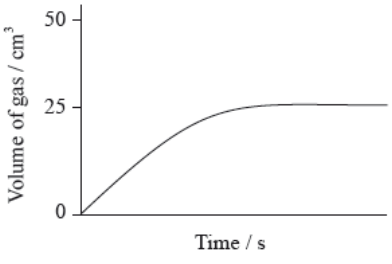



D.



13. Which statement about the kinetic theory is **not** correct? *[1 mark]*

A. The particles in ice vibrate about fixed points.

B. The particles in steam have more energy than the particles in ice.

C. All the particles in water have the same amount of energy at 298 K.

D. Evaporation of water occurs at all temperatures between 273 K and 373 K when the atmospheric pressure is 101 kPa.

14. What is the best definition of *rate of reaction*? *[1 mark]*

A. The time it takes to use up all the reactants

B. The rate at which all the reactants are used up

C. The time it takes for one of the reactants to be used up

D. The increase in concentration of a product per unit time

15. Which factors can affect reaction rate? *[1 mark]*

I. The state of the reactants

II. The frequency of the collisions between particles

III. The average kinetic energy of the particles

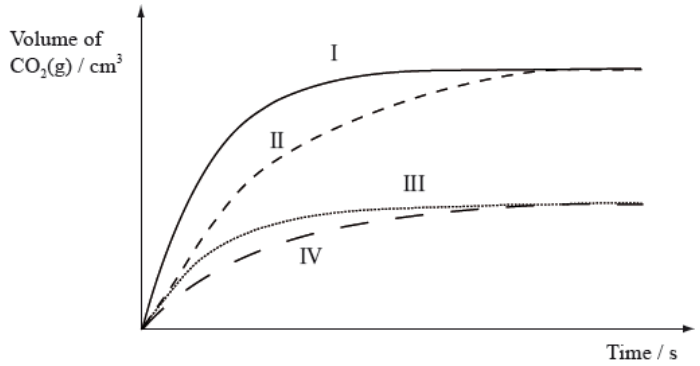
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. Equal masses of powdered calcium carbonate were added to separate solutions of hydrochloric acid. The calcium carbonate was in excess. The volume of carbon dioxide produced was measured at regular intervals. Which curves best represent the evolution of carbon dioxide against time for the acid solutions shown in the table below. *[1 mark]*




| | 25 $cm^3$ of 2 mol $dm^{-3}$ HCl | 50 $cm^3$ of 1 mol $dm^{-3}$ HCl | 25 $cm^3$ of 1 mol $dm^{-3}$ HCl |
|---|---|---|---|
| A. | I | III | IV |
| B. | I | IV | III |
| C. | I | II | III |
| D. | II | I | III |

17. Consider the reaction between magnesium and hydrochloric acid. Which factors will affect the reaction rate? *[1 mark]*

I. The collision frequency of the reactant particles

II. The number of reactant particles with $E \geqslant E_a$

III. The number of reactant particles that collide with the appropriate geometry

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

18a. Define the term *rate of reaction*. *[1 mark]*

18b. State an equation for the reaction of magnesium carbonate with dilute hydrochloric acid. *[1 mark]*

18c. The rate of this reaction in (a) (ii), can be studied by measuring the volume of gas collected over a period of time. Sketch a graph which shows how the volume of gas collected changes with time. *[1 mark]*

18d. The experiment is repeated using a sample of hydrochloric acid with double the volume, but half the concentration of the original acid. Draw a second line on the graph you sketched in part (a) (iii) to show the results in this experiment. Explain why this line is different from the original line. *[4 marks]*

Nitrogen monoxide reacts at 1280 °C with hydrogen to form nitrogen and water. All reactants and products are in the gaseous phase.

18e. The kinetics of the reaction were studied at this temperature. The table shows the initial rate of reaction for different concentrations of each reactant. *[4 marks]*

Deduce the order of the reaction with respect to NO and $\mathrm{H_2}$, and explain your reasoning.

18f. Deduce the rate expression for the reaction. *[1 mark]*

18g. Determine the value of the rate constant for the reaction from Experiment 3 and state its units. *[2 marks]*

The gas-phase decomposition of dinitrogen monoxide is considered to occur in two steps.

$$\text{Step 1:}\quad \mathrm{N_2O(g)} \xrightarrow{k_1} \mathrm{N_2(g) + O(g)}$$

$$\text{Step 2:}\quad \mathrm{N_2O(g) + O(g)} \xrightarrow{k_2} \mathrm{N_2(g) + O_2(g)}$$

The experimental rate expression for this reaction is rate $= k[\mathrm{N_2O}]$.

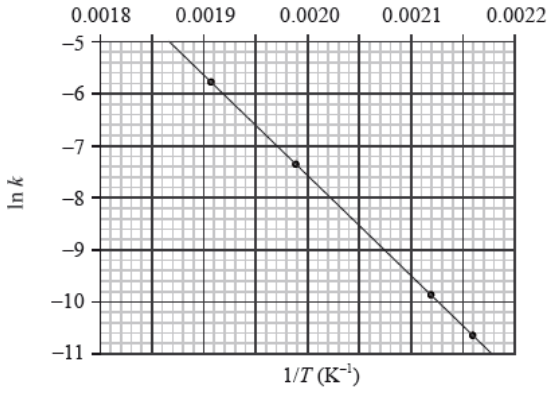
18h. Identify the rate-determining step. *[1 mark]*

18i. Identify the intermediate involved in the reaction. *[1 mark]*

The conversion of $\mathrm{CH_3NC}$ into $\mathrm{CH_3CN}$ is an exothermic reaction which can be represented as follows.

$$\mathrm{CH_3{-}N{\equiv}C} \rightarrow \text{transition state} \rightarrow \mathrm{CH_3{-}C{\equiv}N}$$

This reaction was carried out at different temperatures and a value of the rate constant, $k$, was obtained for each temperature. A graph of $\ln k$ against $1/T$ is shown below.




18j. Define the term *activation energy*, $E_\mathrm{a}$. *[1 mark]*

18k. Construct the enthalpy level diagram and label the activation energy, $E_a$, the enthalpy change, $\Delta H$, and the position of the transition state. *[3 marks]*

18l. Describe qualitatively the relationship between the rate constant, $k$, and the temperature, $T$. *[1 mark]*

18m. Calculate the activation energy, $E_a$, for the reaction, using Table 1 of the Data Booklet. *[4 marks]*

19. Which unit could be used for the rate of a chemical reaction? *[1 mark]*

A. mol

B. $\mathrm{mol\,dm^{-3}}$

C. $\mathrm{mol\,dm^{-3}s^{-1}}$

D. $\mathrm{dm^3}$

20. Which of the following can **increase** the rate of a chemical reaction? *[1 mark]*

I. Increasing the temperature

II. Adding a catalyst

III. Increasing the concentration of reactants

A. I and II only

B. I and III only

C. II and III only

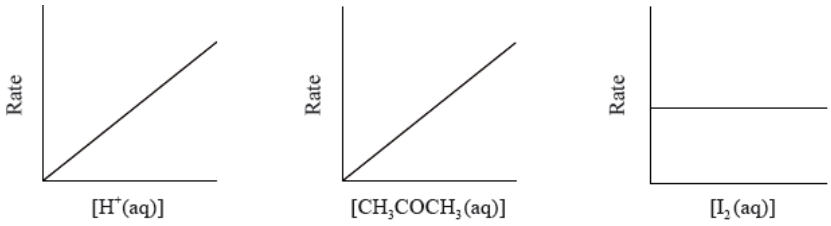
D. I, II and III

Alex and Hannah were asked to investigate the kinetics involved in the iodination of propanone. They were given the following equation by their teacher.

$$\mathrm{CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+(aq)} CH_2ICOCH_3(aq) + HI(aq)}$$

Alex's hypothesis was that the rate will be affected by changing the concentrations of the propanone and the iodine, as the reaction can happen without a catalyst. Hannah's hypothesis was that as the catalyst is involved in the reaction, the concentrations of the propanone, iodine and the hydrogen ions will all affect the rate.

They carried out several experiments varying the concentration of one of the reactants or the catalyst whilst keeping other concentrations and conditions the same. Their results are shown graphically below.




21. (a) Discuss whether either Alex's or Hannah's hypothesis is correct. *[8 marks]*

(b) Explain why the reaction rate will increase with increasing temperature.

(c) (i) This reaction uses a catalyst. Sketch and annotate the Maxwell-Boltzmann energy distribution curve for a reaction with and without a catalyst on labelled axes below.

(ii) Describe how a catalyst works.

22. Consider the reaction between gaseous iodine and gaseous hydrogen. *[1 mark]*

$$\mathrm{I_2(g) + H_2(g) \rightleftharpoons 2HI(g)} \quad \Delta H^{\ominus} = -9\ \mathrm{kJ}$$

Why do some collisions between iodine and hydrogen **not** result in the formation of the product?

A. The $\mathrm{I_2}$ and $\mathrm{H_2}$ molecules do not have sufficient energy.

B. The system is in equilibrium.

C. The temperature of the system is too high.

D. The activation energy for this reaction is very low.

23. The reaction below represents the Haber process for the industrial production of ammonia. *[1 mark]*

$$\mathrm{N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)} \quad \Delta H^{\ominus} = -92\ \mathrm{kJ}$$

The optimum conditions of temperature and pressure are chosen as a compromise between those that favour a high yield of ammonia and those that favour a fast rate of production. Economic considerations are also important.

Which statement is correct?

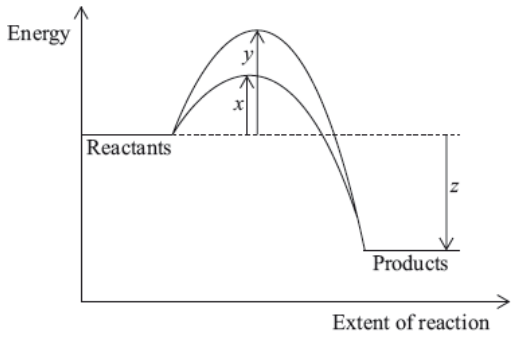
A. A higher temperature would ensure higher yield and a faster rate.

B. A lower pressure would ensure a higher yield at a lower cost.

C. A lower temperature would ensure a higher yield and a faster rate.

D. A higher pressure would ensure a higher yield at a higher cost.

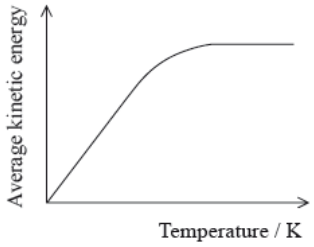
24. The diagram below shows the energy changes for a reaction with and without a catalyst. Which symbols represent the activation energy, $E_a$, and the enthalpy change, $\Delta H$, for the reaction with a catalyst? *[1 mark]*




| | $E_a$ (with a catalyst) | $\Delta H$ |
|---|---|---|
| A. | $x$ | $z$ |
| B. | $y$ | $z$ |
| C. | $z$ | $x$ |
| D. | $y - x$ | $z$ |

25. Which graph best represents the relationship between the average kinetic energy of molecules of a gas and temperature in K? *[1 mark]*

A.

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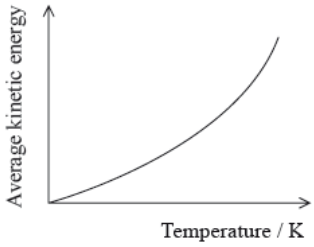


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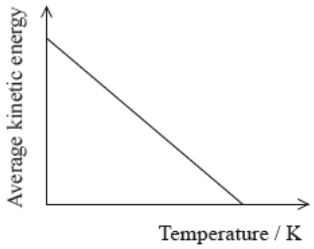


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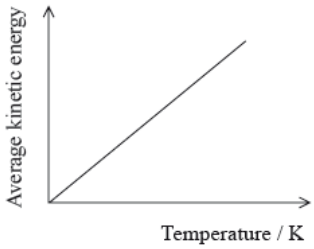

26. Which statement best describes and explains the effect of a catalyst on the rate of a chemical reaction? *[1 mark]*

A. The rate increases because the frequency of collisions between particles increases.

B. The rate increases because more colliding particles have the energy needed to react.

C. The rate increases because the activation energy increases.

D. The rate increases because more molecules are present.

27. Which statements explain the increase in the rate of a reaction when the temperature is increased? *[1 mark]*

I. More particles have energy greater than the activation energy.

II. The frequency of collisions increases.

III. The activation energy decreases.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Reaction kinetics can be investigated using the iodine clock reaction. The equations for two reactions that occur are given below.

Reaction A: $\mathrm{H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)}$

Reaction B: $\mathrm{I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)}$

Reaction B is much faster than reaction A, so the iodine, $\mathrm{I_2}$, formed in reaction A immediately reacts with thiosulfate ions, $\mathrm{S_2O_3^{2-}}$, in reaction B, before it can react with starch to form the familiar blue-black, starch-iodine complex.

In one experiment the reaction mixture contained:

5.0 ± 0.1 $\mathrm{cm^3}$ of 2.00 $\mathrm{mol\,dm^{-3}}$ hydrogen peroxide ($\mathrm{H_2O_2}$)

5.0 ± 0.1 $\mathrm{cm^3}$ of 1% aqueous starch

20.0 ± 0.1 $\mathrm{cm^3}$ of 1.00 $\mathrm{mol\,dm^{-3}}$ sulfuric acid ($\mathrm{H_2SO_4}$)

20.0 ± 0.1 $\mathrm{cm^3}$ of 0.0100 $\mathrm{mol\,dm^{-3}}$ sodium thiosulfate ($\mathrm{Na_2S_2O_3}$)

50.0 ± 0.1 $\mathrm{cm^3}$ of water with 0.0200 ± 0.0001 g of potassium iodide (KI) dissolved in it.

After 45 seconds this mixture suddenly changed from colourless to blue-black.

28a. The concentration of iodide ions, $\mathrm{I^-}$, is assumed to be constant. Outline why this is a valid assumption. *[1 mark]*

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28b. For this mixture the concentration of hydrogen peroxide, $H_2O_2$, can also be assumed to be constant. Explain why this is a valid assumption. *[2 marks]*

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28c. Explain why the solution suddenly changes colour. *[2 marks]*

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28d. The colour change occurs when $1.00 \times 10^{-4}\,\text{mol}$ of iodine has been formed. Use the total volume of the solution and the time taken, to calculate the rate of the reaction, including appropriate units. *[4 marks]*

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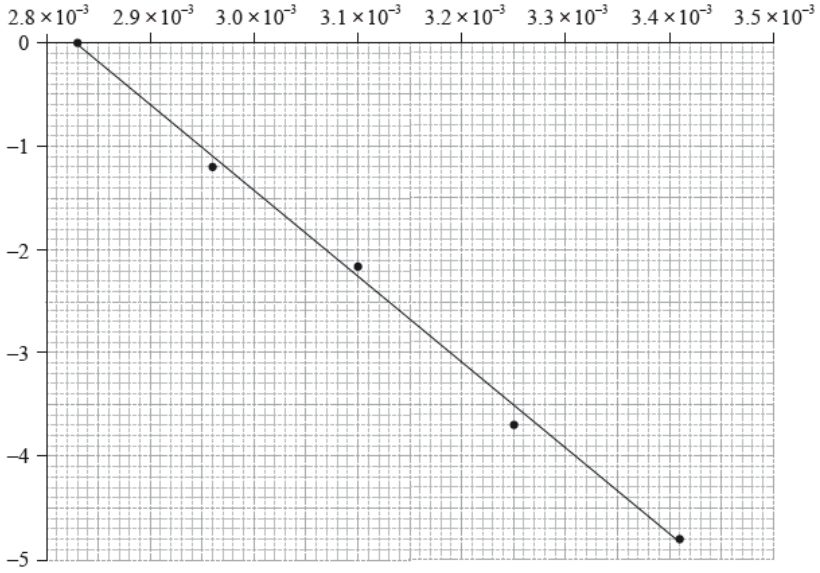
The activation energy can be determined using the Arrhenius equation, which is given in Table 1 of the Data Booklet. The experiment was carried out at five different temperatures. An incomplete graph to determine the activation energy of the reaction, based on these results, is shown below.




28e. State the labels for each axis. *[2 marks]*

*x*-axis:

*y*-axis:

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28f. Use the graph to determine the activation energy of the reaction, in $\mathrm{kJ\,mol^{-1}}$, correct to **three** significant figures. *[3 marks]*

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28g. In another experiment, 0.100 g of a black powder was also added while all other concentrations and volumes remained unchanged. The time taken for the solution to change colour was now 20 seconds. Outline why you think the colour change occurred more rapidly and how you could confirm your hypothesis. *[2 marks]*

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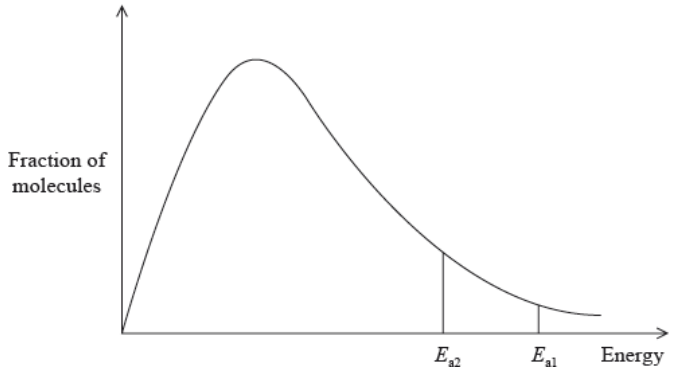
29. The diagram represents the Maxwell–Boltzmann energy distribution curve of the reactants for a chemical reaction with different activation energies, $E_{a1}$ and $E_{a2}$. *[1 mark]*




What is the reason why the rate of the reaction with activation energy $E_{a2}$ is greater?

A. More frequent collisions between the particles occur.

B. More energetic collisions between the particles occur.

C. A catalyst has been added.

D. The temperature is higher.

30. Which statements explain why a catalyst is used in the Contact process (shown below)? *[1 mark]*

$$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$$

I. A catalyst lowers the activation energy.

II. A catalyst moves the position of equilibrium towards the product.

III. A catalyst allows the same rate to be achieved at a lower temperature.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

31. Which is **not** affected by an increase in temperature? *[1 mark]*

A. Rate of reaction

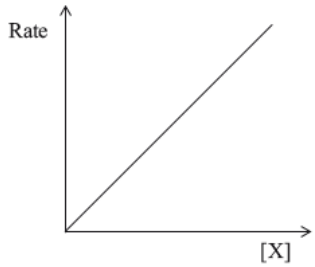
B. Collision frequency

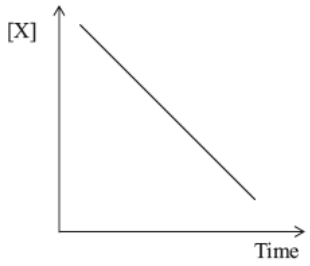
C. Collision geometry

D. % of molecules with $E \geq E_a$

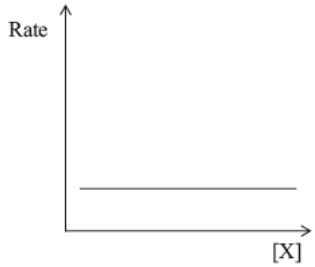
32. Which pair of graphs shows a decomposition reaction of $X$ that obeys first-order kinetics? *[1 mark]*

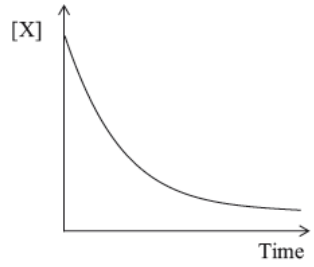
A.



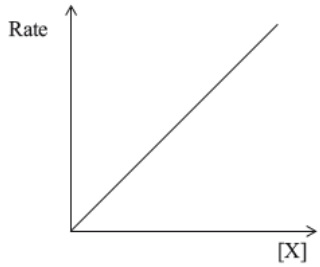



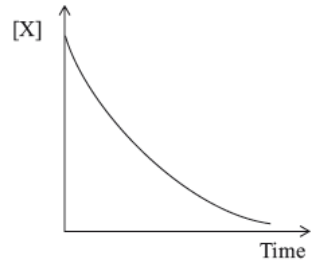

B.



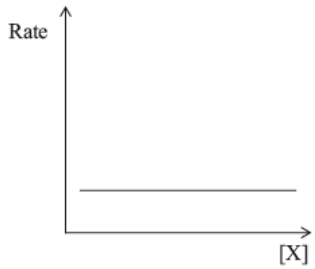



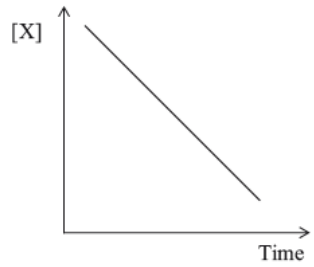

C.



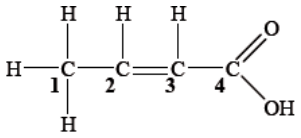




D.



33. Identify the hybridization of carbon atoms in this molecule *[1 mark]*




| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| A. | $sp^3$ | $sp^2$ | $sp^2$ | $sp^2$ |
| B. | $sp^2$ | $sp^2$ | $sp^2$ | sp |
| C. | $sp^3$ | sp | $sp^2$ | sp |
| D. | sp | $sp^2$ | sp | $sp^2$ |