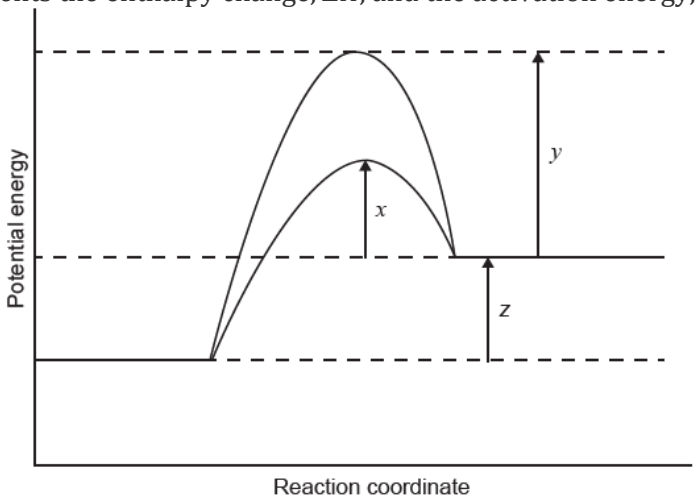
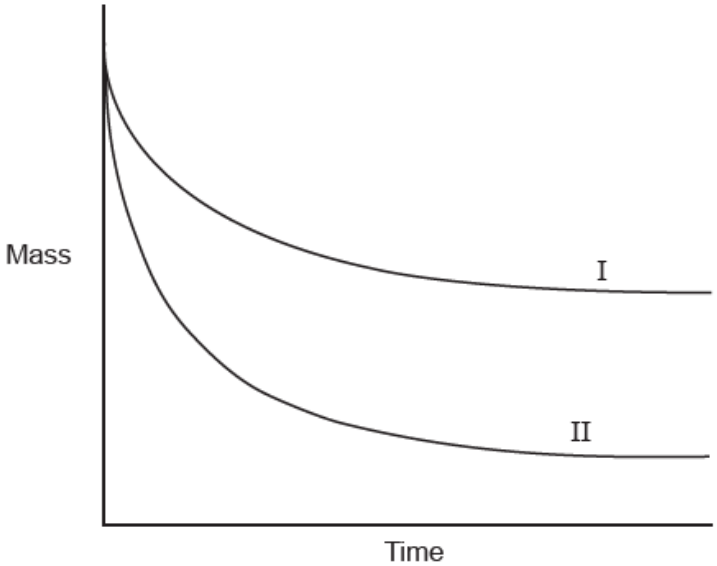
# IB Topics 6 & 16 Multiple Choice Practice

**1.** The diagram shows the energy profile for a catalysed and uncatalysed reaction.
Which represents the enthalpy change, $\Delta H$, and the activation energy, $E_a$, for the **catalysed** reaction?




| | $\Delta H$ | $E_a$ (catalysed reaction) |
|---|---|---|
| A. | $z$ | $x + z$ |
| B. | $z$ | $z + y$ |
| C. | $-z$ | $x$ |
| D. | $z + x$ | $x$ |

**2.** Excess magnesium powder was added to a beaker containing hydrochloric acid, HCl (aq).
The mass of the beaker and its contents was recorded and plotted against time (line I).




Which change could give line II?
A. Doubling the mass of powdered Mg
B. Using the same mass of Mg ribbon
C. Increasing the temperature
D. Using the same volume of more concentrated HCl

**3.** Copper catalyses the reaction between zinc and dilute sulfuric acid.

$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

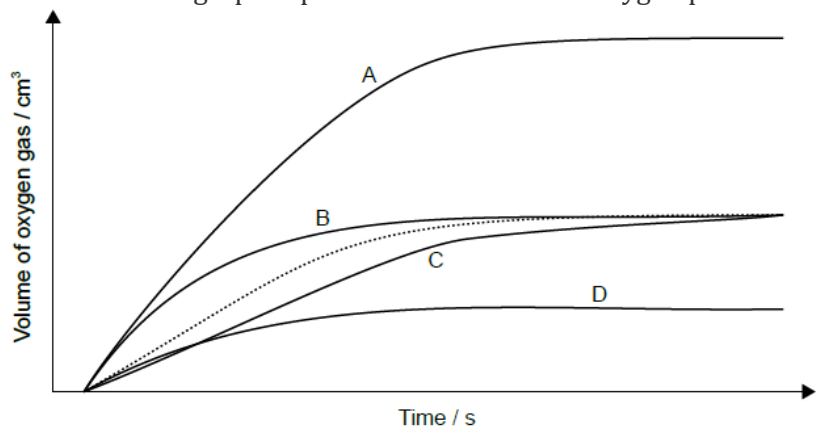
Why does copper affect the reaction?

A. Decreases the activation energy
B. Increases the activation energy
C. Increases the enthalpy change
D. Decreases the enthalpy change

**4.** 100 $cm^3$ of 10% hydrogen peroxide solution decomposes at 298 K to form water and oxygen.

$H_2O_2(aq) \rightarrow H_2O(l) + \frac{1}{2}O_2(g)$

The dotted line graph represents the volume of oxygen produced.




Which graph represents the decomposition of an equal volume of a 20% solution under the same conditions?

**5.** Which change does **not** increase the initial rate of reaction when $CaCO_3(s)$ is added to excess HCl(aq)?

A. Decrease in the size of the $CaCO_3(s)$ particles
B. Increase in the temperature of the reaction mixture
C. Increase in the concentration of HCl(aq), keeping the same volume
D. Increase in the volume of HCl(aq), keeping the same concentration

**6.** Which methods can be used to monitor the progress of this reaction?

I. Change in colour of this reaction mixture
II. Change in mass of this reaction mixture
III. Change in volume of gas evolved

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**7.** The rate expression for the reaction X (g) + 2Y (g) → 3Z (g) is rate = $k[X]^0 [Y]^2$

By which factor will the rate of reaction increase when the concentrations of X and Y are both increased by a factor of 3?

A. 6
B. 9
C. 18
D. 27

**8.** Which pair of statements explains the increase in rate of reaction when the temperature is increased or a catalyst is added?

| | Increasing temperature | Adding a catalyst |
|---|---|---|
| A. | average kinetic energy of particles increases | activation energy increases |
| B. | enthalpy change of reaction decreases | average kinetic energy of particles increases |
| C. | average kinetic energy of particles increases | activation energy decreases |
| D. | activation energy increases | enthalpy change of reaction decreases |

**9.** The table gives rate data for the reaction in a suitable solvent.

$C_4H_9Br + OH^- \rightarrow C_4H_9OH + Br^-$

| Initial $[C_4H_9Br]$ / mol dm$^{-3}$ | Initial $[OH^-]$ / mol dm$^{-3}$ | Initial rate of reaction / mol dm$^{-3}$ s$^{-1}$ |
|---|---|---|
| 0.02 | 0.02 | $2.0 \times 10^{-3}$ |
| 0.04 | 0.02 | $4.0 \times 10^{-3}$ |
| 0.02 | 0.04 | $2.0 \times 10^{-3}$ |
| 0.04 | 0.04 | $4.0 \times 10^{-3}$ |

Which statement is correct?

A. The rate expression is rate = $k$ $[C_4H_9Br]$ $[OH^-]$.

B. The rate increases by a factor of 4 when the $[OH^-]$ is doubled.

C. $C_4H_9Br$ is a primary halogenoalkane.

D. The reaction occurs via $S_N1$ mechanism.

**10.** What are the units for the rate constant, $k$, in the expression?

Rate = $k$ $[X]^2[Y]$

A. mol$^2$ dm$^{-6}$ s$^{-1}$

B. mol$^{-1}$ dm$^3$ s$^{-1}$

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

D. mol$^{-2}$ dm$^6$ s$^{-1}$

**11.** Which is the first step in the CFC-catalysed destruction of ozone in UV light?

A. $CCl_2F_2 \rightarrow CClF_2^+ + Cl^-$

B. $CCl_2F_2 \rightarrow \bullet CClF_2 + Cl\bullet$

C. $CCl_2F_2 \rightarrow CCl_2F^+ + F^-$

D. $CCl_2F_2 \rightarrow \bullet CCl_2F + F\bullet$

**12.** Which is true of an Arrhenius plot of $\ln k$ ($y$-axis) against $\frac{1}{T}$?

A. The graph goes through the origin.

B. The activation energy can be determined from the gradient.

C. The intercept on the $x$-axis is the activation energy.

D. The intercept on the $y$-axis is the frequency factor, A.

**13.** Which is correct about reaction mechanisms?

A. A species that is zero order does not take part in the reaction.

B. A catalyst does not take part in the reaction.

C. Reactants in a fast step before the slow step are included in the rate expression.

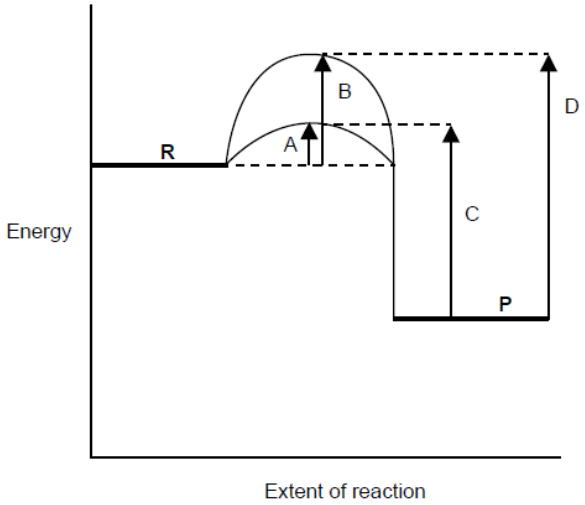
D. Reactants in a fast step after the slow step are included in the rate expression.

**14.** Which conditions must be met for a reaction to take place?

I. Reactants collide with sufficient energy.
II. Reactants collide with correct orientation.
III. Reactants must be in the same state.

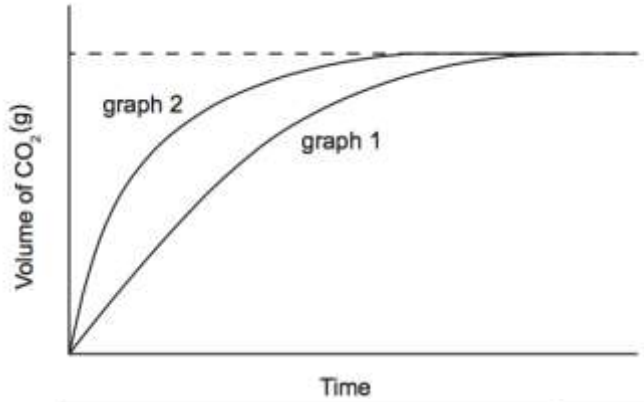
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**15.** For the reaction **R** → **P**, which letter represents the activation energy for the catalysed **reverse** reaction?




**16.** Graph 1 shows a plot of volume of $CO_2(g)$ against time for the reaction of $CaCO_3(s)$ with 1.00 moldm$^{-3}$HCl (aq). The acid is the limiting reagent and entirely covers the lumps of $CaCO_3(s)$.

Which set of conditions is most likely to give the data plotted in graph 2 when the same mass of $CaCO_3(s)$ is reacted with the same volume of HCl(aq) at the same temperature?




| | Size of lumps | Concentration of acid / mol dm$^{-3}$ |
|---|---|---|
| A. | larger | 1.00 |
| B. | smaller | 0.05 |
| C. | smaller | 1.00 |
| D. | larger | 0.05 |

**17.** Which experimental methods could be used to observe the progress of the following reaction?

$Cr_2O_7^{2-}(aq) + 6I^-(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3I_2(aq) + 7H_2O(l)$

I. Change in colour
II. Change in mass
III. Change in electrical conductivity

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**18.** The data shows the effect of changing reactant concentrations on the rate of the following reaction at 25°C. $F_2(g) + 2ClO_2(g) \rightarrow 2FClO_2(g)$

| Initial $[F_2(g)]$ / mol dm$^{-3}$ | Initial $[ClO_2(g)]$ / mol dm$^{-3}$ | Initial rate of reaction / mol dm$^{-3}$ s$^{-1}$ |
|---|---|---|
| 0.100 | 0.010 | $1.20 \times 10^{-3}$ |
| 0.100 | 0.030 | $3.60 \times 10^{-3}$ |
| 0.150 | 0.010 | $1.80 \times 10^{-3}$ |

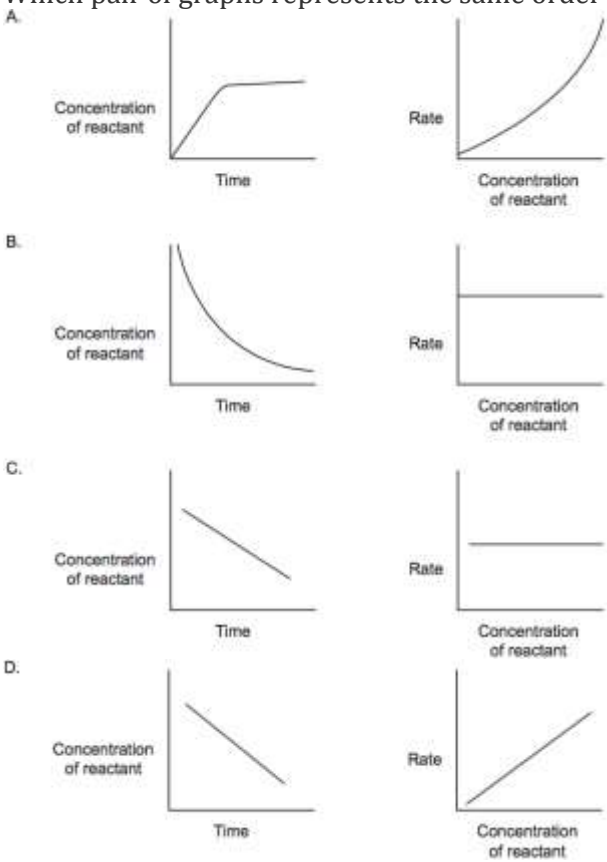
Which is correct for the order of reaction with respect to the fluorine concentration and the overall order of reaction?

| | Order with respect to $[F_2(g)]$ | Overall order |
|---|---|---|
| A. | 2 | 1 |
| B. | 2 | 2 |
| C. | 1 | 1 |
| D. | 1 | 2 |

**19.** Which statement describes the characteristics of a transition state relative to the potential energy of the reactants and products?

A. It is an unstable species with lower potential energy.
B. It is an unstable species with higher potential energy.
C. It is a stable species with lower potential energy.
D. It is a stable species with higher potential energy.

**20.** Which pair of graphs represents the same order of reaction?

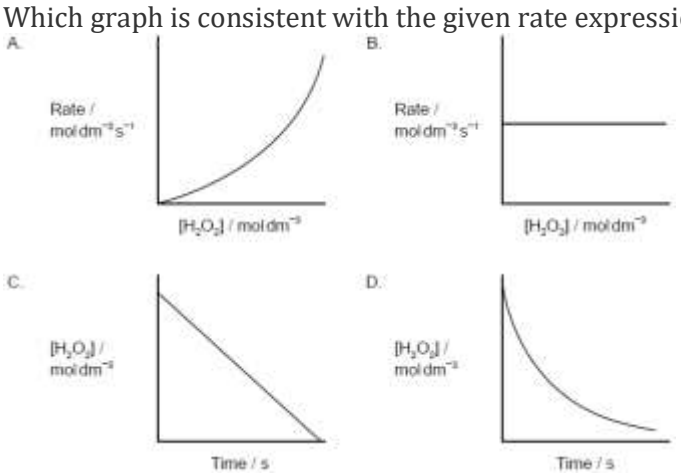



**21.** Decomposition of hydrogen peroxide in an aqueous solution proceeds as follows.

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

The rate expression for the reaction was found to be: rate = $k$ $[H_2O_2]$.

Which graph is consistent with the given rate expression?




**22.** Which of the terms in the Arrhenius equation takes into account the orientation of the molecules?

$$k = Ae^{\frac{-E_a}{RT}}$$

A. $A$
B. $E_a$
C. $R$
D. $T$

**23.** Which variable is best to use when determining the rate of decomposition of hydrogen peroxide?

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

A. Volume of solution
B. Volume of gas
C. pH of solution
D. Conductivity of solution

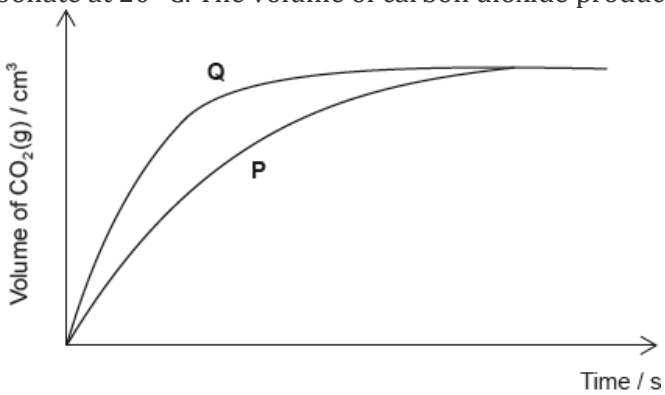
**24.** Nitrogen gas reacts with hydrogen gas according to the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\ \text{kJ}$$

Why is the rate of reaction slow at room temperature?
A. The activation energy of the forward reaction is high.
B. The activation energy of the forward reaction is low.
C. The equilibrium constant is very small.
D. The rate of the reverse reaction is greater than the rate of the forward reaction.

**25.** Which is a correct unit for expressing the rate of a reaction?
A. $\text{mol dm}^{-3}\text{s}^{-1}$
B. $\text{mol dm}^{-3}\text{s}$
C. $\text{mol s}$
D. $\text{mol}^{-1}\ \text{dm}^{3}\text{s}^{-1}$

**26.** $100\ \text{cm}^3$ of a $1.00\ \text{mol dm}^{-3}$ solution of hydrochloric acid is added to 2.00 g of small pieces of calcium carbonate at 20 °C. The volume of carbon dioxide produced against time is plotted to give curve **P**.




Which change will produce curve **Q**, given that calcium carbonate is always the limiting reagent?
A. Increasing the volume of the hydrochloric acid to $200\ \text{cm}^3$
B. Increasing the mass of calcium carbonate to 4.00 g
C. Increasing the concentration of the hydrochloric acid to $2.00\ \text{mol dm}^{-3}$
D. Replacing the 2.00 g of small pieces of calcium carbonate with 2.00 g of larger pieces of calcium carbonate

**27.** Which statement about a first-order reaction is correct?
A. The reactant concentration decreases linearly with time.
B. The reactant concentration decreases exponentially with time.
C. The rate of reaction remains constant as the reaction proceeds.
D. The rate of reaction increases exponentially as the reaction proceeds.

**28.** Consider the rate expression:

$$\text{Rate} = k[\text{X}][\text{Y}]$$

Which change decreases the value of the rate constant, $k$?
A. Increase in the reaction temperature
B. Decrease in the reaction temperature
C. Increase in the concentration of X and Y
D. Decrease in the concentration of X and Y

**29.** What are the units of the rate constant for a zero-order reaction?
A. s
B. $\text{s}^{-1}$
C. $\text{mol}^{-1}\ \text{dm}^3\ \text{s}^{-1}$
D. $\text{mol}\ \text{dm}^{-3}\ \text{s}^{-1}$

**30.** The hydrolysis of tertiary bromoalkanes with a warm dilute aqueous sodium hydroxide solution proceeds by a two-step $\text{S}_\text{N}1$ mechanism.
Step I: $\text{R} - \text{Br} \rightarrow \text{R}^+\text{Br}^-$
Step II: $\text{R}^+ + \text{OH}^- \rightarrow \text{R} - \text{OH}$
Which description of this reaction is consistent with the above information?

| | Step I | Step II | Rate expression |
|---|---|---|---|
| A. | fast | slow | rate = $k$[R–Br] |
| B. | slow | fast | rate = $k$[R–Br] |
| C. | fast | slow | rate = $k$[R–Br][OH⁻] |
| D. | slow | fast | rate = $k$[R–Br][OH⁻] |

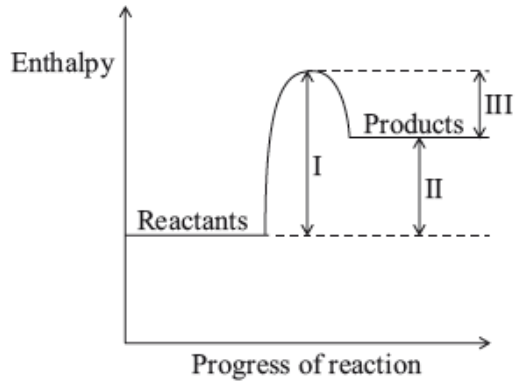
**31.** Consider the following reaction between hydrogen peroxide, hydrogen ions and iodide ions.

$$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow \text{I}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$$

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

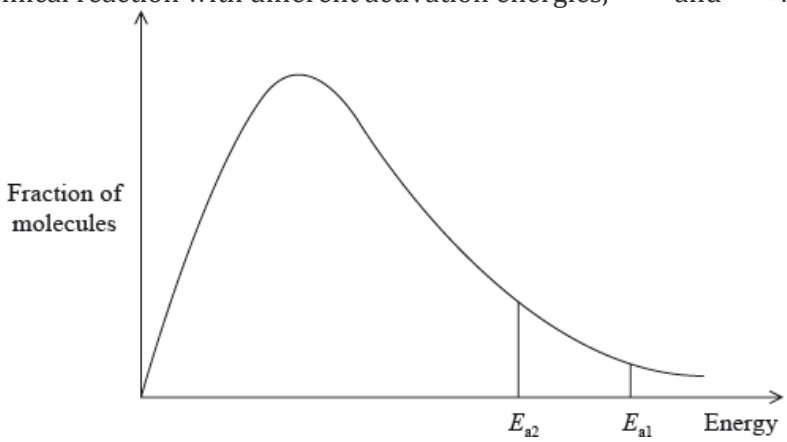
**32.** Which quantity can be changed by the use of a catalyst?

A. I and II only
B. I and III only
C. II and III only
D. I, II and III



**33.** Why does the rate of a reaction increase when the temperature is increased?
I. The activation energy decreases.
II. There are more particles with energy equal to or greater than the activation energy.
III. The frequency of collisions between particles increases.
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

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




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.

**35.** Which change increases the rate of a chemical reaction?
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

**36.** Which is **not** affected by an increase in temperature?
A. Rate of reaction
B. Collision frequency
C. Collision geometry
D. % of molecules with $E \geq E_a$

**37.** Consider the following reaction between nitrogen monoxide and oxygen.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

The reaction occurs in two steps:

Step 1: $NO(g) + NO(g) \rightleftharpoons N_2O_2(g)$ *fast*

Step 2: $N_2O_2(g) + O_2(g) \rightarrow 2NO_2(g)$ *slow*

What is the rate expression for this reaction?

A. Rate $= k[NO]^2$

B. Rate $= k[NO][O_2]$

C. Rate $= k[NO]^2[O_2]$

D. Rate $= k[NO][O_2]^2$

**38.** What happens to the rate constant, *k*, and the activation energy, $E_a$, as the temperature of a chemical reaction is increased?

| | Value of *k* | Value of $E_a$ |
|---|---|---|
| A. | increases | increases |
| B. | unchanged | increases |
| C. | decreases | unchanged |
| D. | increases | unchanged |

**39.** X and Y react according to the equation $2X + Y \rightarrow Z$. The reaction can be described by the following mechanism:

$X + X \rightarrow X_2$ slow

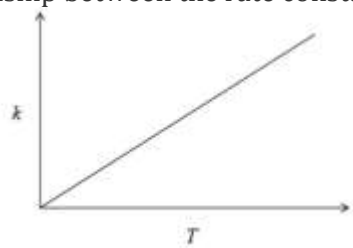
$X_2 + Y \rightarrow Z$ fast

What is the order of the reaction with respect to X and Y?

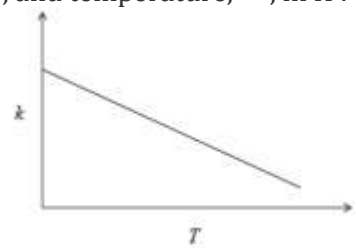
| | X | Y |
|---|---|---|
| A. | First | Zero |
| B. | First | First |
| C. | Second | Zero |
| D. | Second | First |

**40.** The rate constant for a reaction is determined at different temperatures. Which diagram represents the relationship between the rate constant, $k$, and temperature, $T$, in K ?

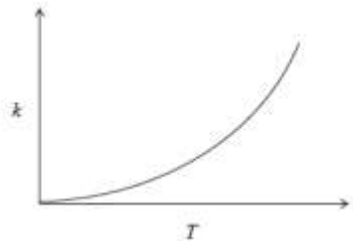
A.



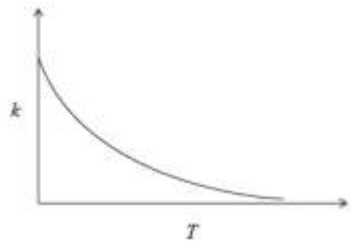

B.




C.



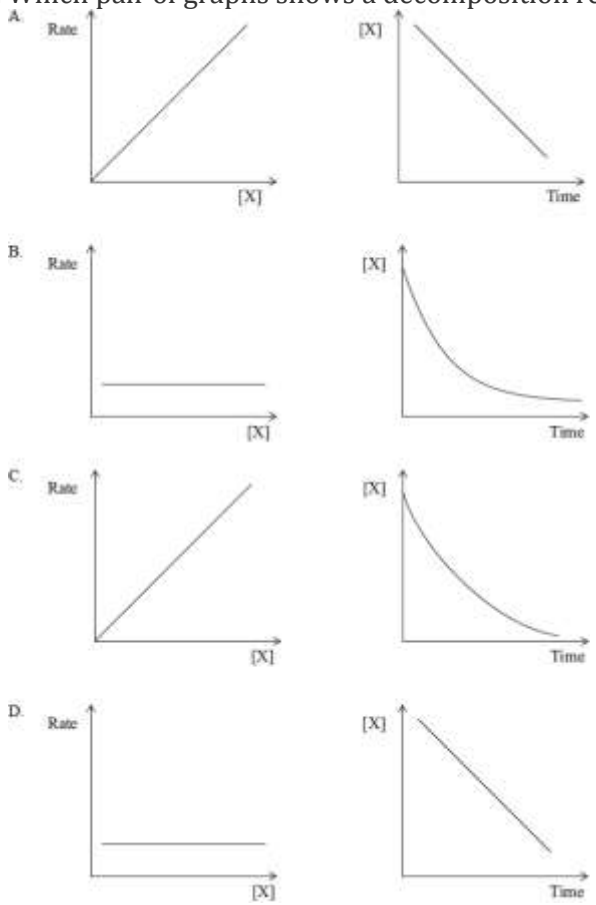

D.



**41.** Which combination shows a second-order rate expression with the correct rate constant units?

| | Rate expression | $k$ units |
|---|---|---|
| A. | rate $= k[NH_3][BF_3]$ | $mol\,dm^{-3}\,s^{-1}$ |
| B. | rate $= k[N_2O_5]$ | $s^{-1}$ |
| C. | rate $= k[N_2O_5]$ | $dm^3\,mol^{-1}\,s^{-1}$ |
| D. | rate $= k[CH_3COCH_3][H^+][I_2]^0$ | $dm^3\,mol^{-1}\,s^{-1}$ |

**42.** Which pair of graphs shows a decomposition reaction of $X$ that obeys first-order kinetics?




**43.** Which statements explain why a catalyst is used in the Contact process (shown below)?

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

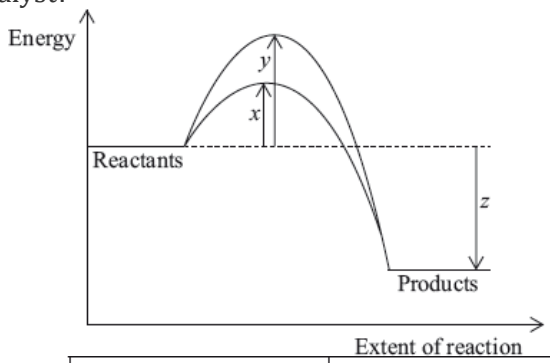
I. A catalyst lowers the activation energy.
II. A catalyst moves the position of equilibrium towards the product.
III. A catalyst allows the same rate to be achieved at a lower temperature.
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**44.** Which factors can increase the rate of a chemical reaction?

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

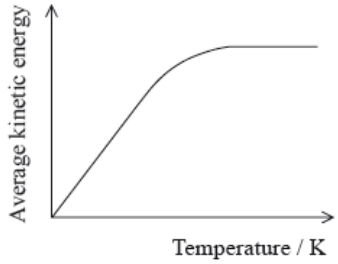
**45.** The diagram below shows the energy changes for a reaction with and without a catalyst. Which symbols represent the activation energy, $E_a$, and the enthalpy change, $\Delta H$, for the reaction with a catalyst?



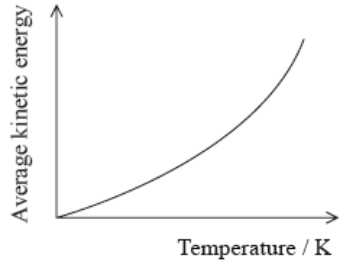

| | $E_a$ (with a catalyst) | $\Delta H$ |
|---|---|---|
| A. | $x$ | $z$ |
| B. | $y$ | $z$ |
| C. | $z$ | $x$ |
| D. | $y - x$ | $z$ |

**46.** Which graph best represents the relationship between the average kinetic energy of molecules of a gas and temperature in K?

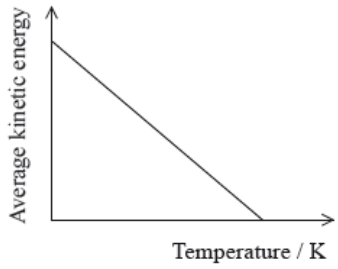
A.



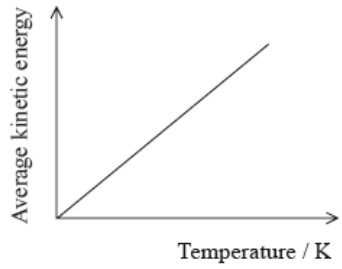

B.




C.




D.



**47.** Which statement best describes and explains the effect of a catalyst on the rate of a chemical reaction?
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.

**48.** Which statements explain the increase in the rate of a reaction when the temperature is increased?
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

**49.** Consider the following reaction mechanism.

Step 1 $H_2O_2 + I^- \rightarrow H_2O + IO^-$ slow
Step 2 $H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-$ fast

Which statement correctly identifies the rate-determining step and the explanation?
A. Step 2 because it is the faster step
B. Step 1 because it is the slower step
C. Step 1 because it is the first step
D. Step 2 because it is the last step

**50.** The following experimental rate data were obtained for a reaction carried out at temperature *T*.

$$A(g) + B(g) \rightarrow C(g) + D(g)$$

| Initial [A(g)] / mol dm$^{-3}$ | Initial [B(g)] / mol dm$^{-3}$ | Initial rate / mol dm$^{-3}$ s$^{-1}$ |
|---|---|---|
| $3.00\times10^{-1}$ | $2.00\times10^{-1}$ | $1.89\times10^{-2}$ |
| $3.00\times10^{-1}$ | $4.00\times10^{-1}$ | $1.89\times10^{-2}$ |
| $6.00\times10^{-1}$ | $4.00\times10^{-1}$ | $7.56\times10^{-2}$ |

What are the orders with respect to A(g) and B(g)?

| | Order with respect to A(g) | Order with respect to B(g) |
|---|---|---|
| A. | zero | second |
| B. | first | zero |
| C. | second | zero |
| D. | second | first |

**51.** Consider the following proposed two-step reaction mechanism at temperature T.

Step 1: $2NO_2(g) \xrightarrow{k_1} NO(g) + NO_3(g)$ *Slow*

Step 2: $NO_3(g) + CO(g) \xrightarrow{k_2} NO_2(g) + CO_2(g)$ *Fast*

Which statements are correct?

I. The overall reaction is $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$.

II. Step 1 is the rate-determining step of the reaction.

III. The rate expression for Step 1 is rate $= k_1[NO_2]^2$.

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**52.** For the gas phase reaction:

$$A(g) + B(g) \rightarrow C(g)$$

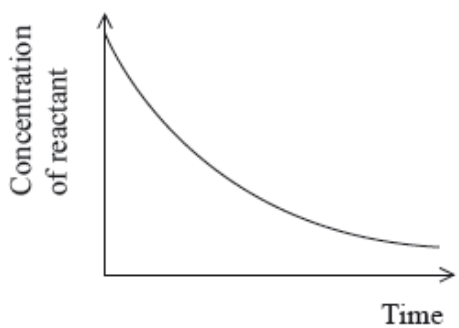
the experimentally determined rate expression is: rate $= k[A][B]^2$

By what factor will the rate change if the concentration of A is tripled and the concentration of B is halved?

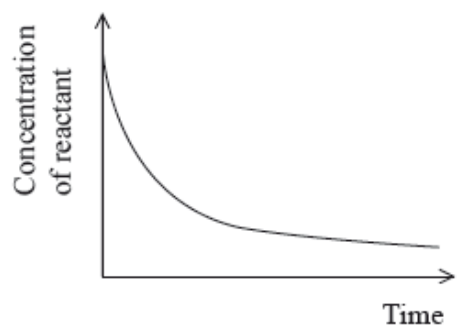
A. 0.75
B. 1.5
C. 6
D. 12

**53.** Which graph best represents a second-order reaction?

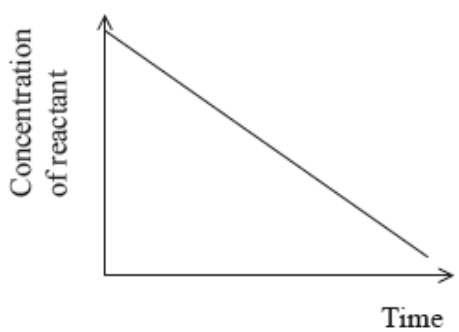
A.



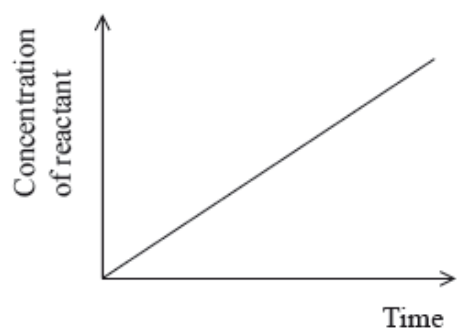

B.



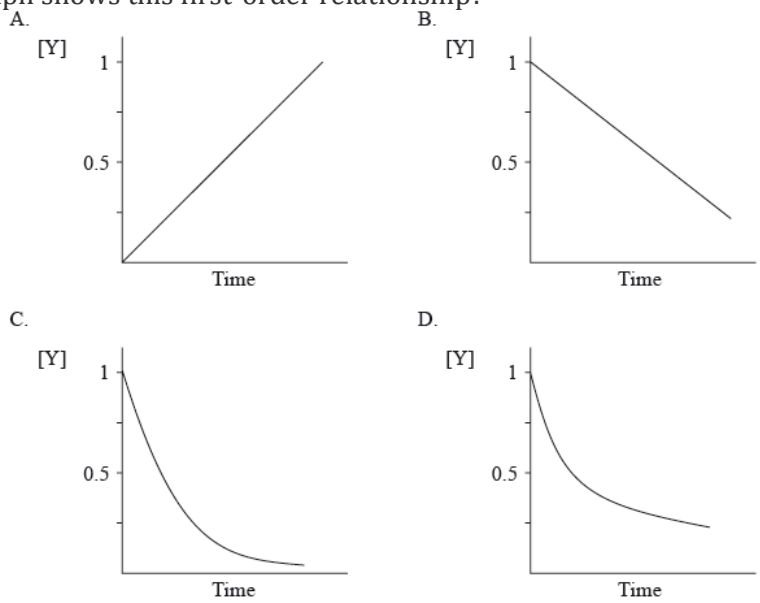

C.




D.



**54.** Experimental data shows that a reaction in which Y is a reactant is first order with respect to Y. Which graph shows this first-order relationship?




**55.** Which statement about a reaction best describes the relationship between the temperature, $T$, and the rate constant, $k$?

A. As $T$ increases, $k$ decreases linearly.
B. As $T$ increases, $k$ decreases non-linearly.
C. As $T$ increases, $k$ increases linearly.
D. As $T$ increases, $k$ increases non-linearly.

**56.** Carbon monoxide and nitrogen dioxide react to form carbon dioxide and nitrogen monoxide according to the following equation.

$$\mathrm{CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)}$$

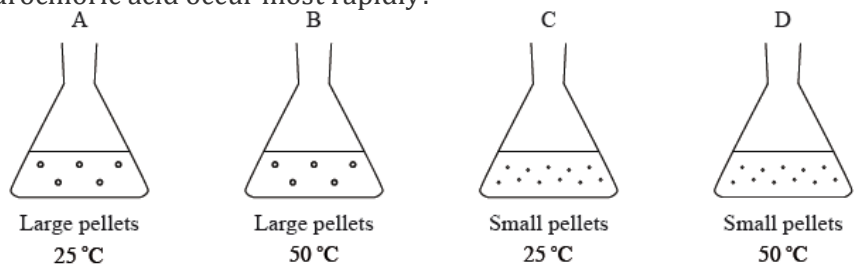
The reaction occurs in a series of steps. The equation for the rate-determining step is given below.
$\mathrm{2NO_2(g) \rightarrow NO_3(g) + NO(g)}$
What is the rate expression for this reaction?
A. rate $= k[\mathrm{CO(g)}][\mathrm{NO_2(g)}]$
B. rate $= k[\mathrm{NO_2(g)}]^2$
C. rate $= k[\mathrm{NO_3(g)}][\mathrm{NO(g)}]$
D. rate $= k[\mathrm{CO_2(g)}][\mathrm{NO(g)}]$

**57.** Which piece of equipment could **not** be used in an experiment to measure the rate of this reaction?

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

A. A colorimeter
B. A gas syringe
C. A stopwatch
D. A pH meter

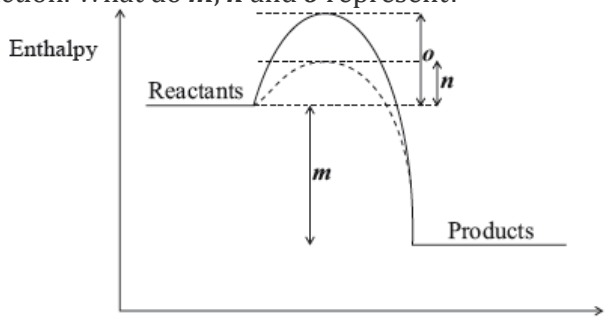
**58.** In which flask will the reaction between 2.0 g of magnesium carbonate and 25 $cm^3$ 1.0 mol $dm^{-3}$ hydrochloric acid occur most rapidly?




**59.** Which are appropriate units for the rate of a reaction?

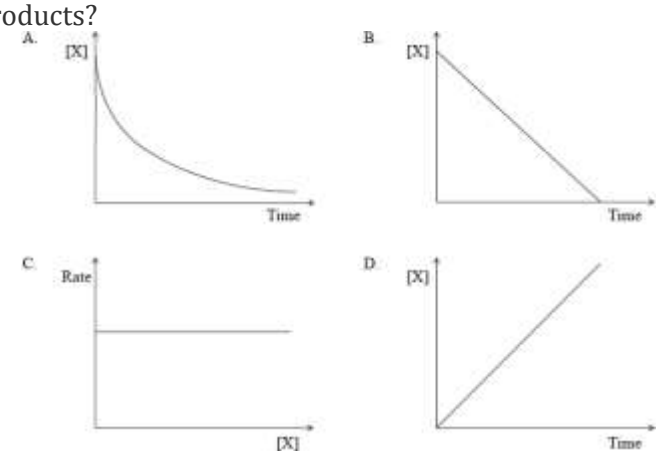
A. $mol\ dm^{-3}\ s^{-1}$
B. $mol\ dm^{-3}\ s$
C. $mol\ dm^{-3}$
D. s

**60.** The following enthalpy level diagram shows the effect of the addition of a catalyst on a chemical reaction. What do ***m***, ***n*** and ***o*** represent?

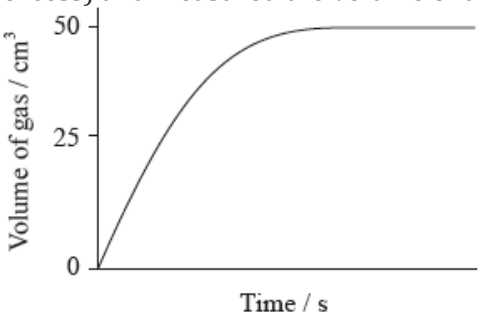



| | *m* | *n* | *o* |
|---|---|---|---|
| A. | $\Delta H$ | $E_a$ (without a catalyst) | $E_a$ (with a catalyst) |
| B. | $E_a$ (with a catalyst) | $\Delta H$ | $E_a$ (without a catalyst) |
| C. | $E_a$ (with a catalyst) | $E_a$ (without a catalyst) | $\Delta H$ |
| D. | $\Delta H$ | $E_a$ (with a catalyst) | $E_a$ (without a catalyst) |

**61.** Which graph represents a reaction that is second order with respect to X for the reaction X $\rightarrow$ products?

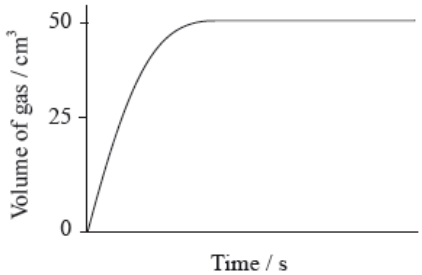


**62.** A student added 0.20 g of calcium carbonate powder to $100\ \mathrm{cm^3}$ of $1.0\ \mathrm{mol\,dm^{-3}}$ hydrochloric acid (an excess) and measured the volume of the gas that was evolved. The graph of the results is shown below.

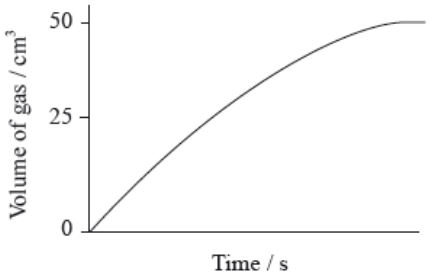



Which graph would be obtained if 0.20 g of calcium carbonate powder is added to $100\ \mathrm{cm^3}$ of $0.5\ \mathrm{mol\,dm^{-3}}$ hydrochloric acid (an excess)?

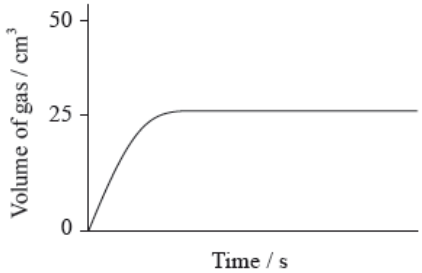
A.



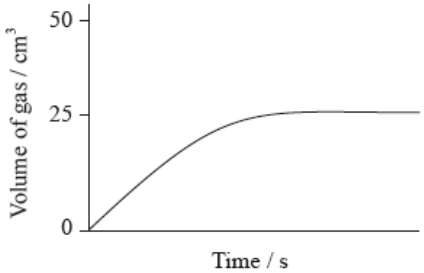

B.




C.




D.




**63.** Which statement about the kinetic theory is **not** correct?

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.

**64.** Which statements describe the action of a catalyst?

I. It does **not** alter the $\Delta H$ for a reaction.
II. It increases the $E_a$ for the reaction.
III. It alters the mechanism (pathway) of a reaction.
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**65.** Consider the reaction between gaseous iodine and gaseous hydrogen.

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

Why do some collisions between iodine and hydrogen **not** result in the formation of the product?
A. The $I_2$ and $H_2$ 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.

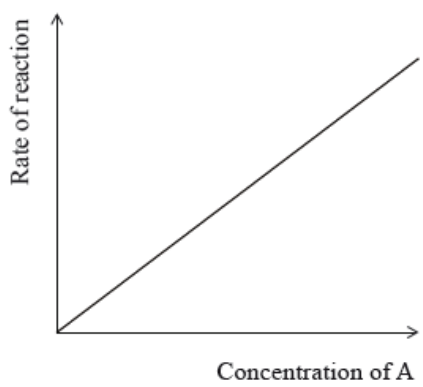
**66.** The reaction below represents the Haber process for the industrial production of ammonia.

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

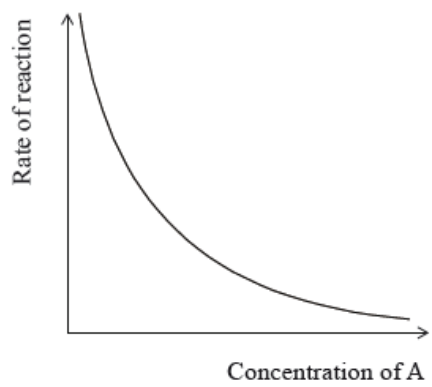
The optimum conditions of temperature and pressure are chosen as a compromise between those that favour a high yield of ammonia and those that favour a fast rate of production. Economic considerations are also important.
Which statement is correct?
A. A higher temperature would ensure higher yield and 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.

**67.** Which graph represents a reaction that is first order with respect to reactant A.

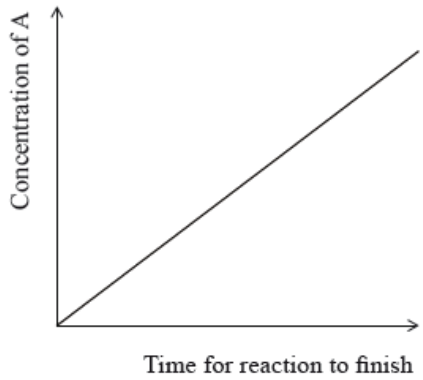
A.



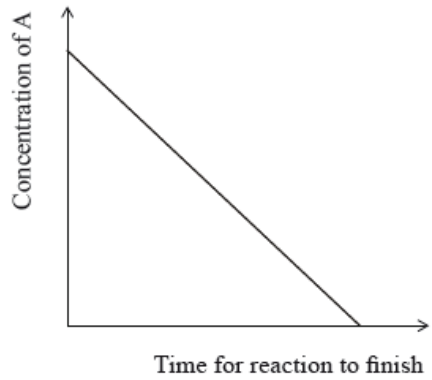

B.




C.

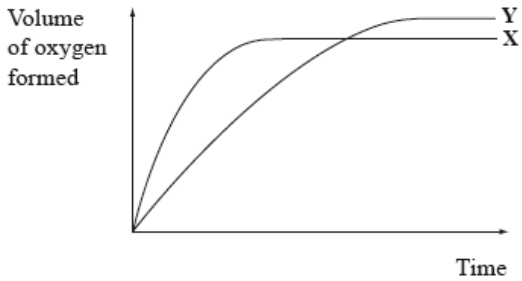



D.



**68.** Curve **X** on the graph below shows the volume of oxygen formed during the catalytic decomposition of a $1.0\ \mathrm{mol\,dm^{-3}}$ solution of hydrogen peroxide.

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




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

**69.** Bromine and nitrogen(II) oxide react according to the following equation.

$$Br_2(g) + 2NO(g) \rightarrow 2NOBr(g)$$

Which rate equation is consistent with the experimental data?

| $[Br_2]$ / mol dm$^{-3}$ | [NO] / mol dm$^{-3}$ | Rate / mol dm$^{-3}$s$^{-1}$ |
|---|---|---|
| 0.10 | 0.10 | $1.0\times10^{-6}$ |
| 0.20 | 0.10 | $4.0\times10^{-6}$ |
| 0.20 | 0.40 | $4.0\times10^{-6}$ |

A. $\text{rate} = k[Br_2]^2[NO]$
B. $\text{rate} = k[Br_2][NO]^2$
C. $\text{rate} = k[Br_2]^2$
D. $\text{rate} = k[NO]^2$

**70.** Which step is the rate-determining step of a reaction?
A. The step with the lowest activation energy
B. The final step
C. The step with the highest activation energy
D. The first step

**71.** Sodium carbonate and hydrochloric acid react according to the equation below.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow CO_2(g) + 2NaCl(aq) + H_2O(l)$$

Which conditions will produce the fastest initial rate with 2.0 g of powdered sodium carbonate?
A. $100\ \mathrm{cm^3}$ of $1.0\ \mathrm{mol\,dm^{-3}}$ hydrochloric acid at 323 K
B. $50\ \mathrm{cm^3}$ of $2.0\ \mathrm{mol\,dm^{-3}}$ hydrochloric acid at 323 K
C. $100\ \mathrm{cm^3}$ of $1.0\ \mathrm{mol\,dm^{-3}}$ hydrochloric acid at 348 K
D. $50\ \mathrm{cm^3}$ of $2.0\ \mathrm{mol\,dm^{-3}}$ hydrochloric acid at 348 K

**72.** The rate information below was obtained for the following reaction at a constant temperature.

$2NO_2(g) + F_2(g) \rightarrow 2NO_2F(g)$

| $[NO_2]$ / mol dm$^{-3}$ | $[F_2]$ / mol dm$^{-3}$ | Rate / mol dm$^{-3}$ s$^{-1}$ |
|---|---|---|
| $2.0\times10^{-3}$ | $1.0\times10^{-2}$ | $4.0\times10^{-4}$ |
| $4.0\times10^{-3}$ | $1.0\times10^{-2}$ | $8.0\times10^{-4}$ |
| $4.0\times10^{-3}$ | $2.0\times10^{-2}$ | $1.6\times10^{-3}$ |

What are the orders of the reaction with respect to $NO_2$ and $F_2$?

A. $NO_2$ is first order and $F_2$ is second order

B. $NO_2$ is second order and $F_2$ is first order

C. $NO_2$ is first order and $F_2$ is first order

D. $NO_2$ is second order and $F_2$ is second order

**73.** Consider the following reaction. $2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$

A proposed reaction mechanism is:

$NO(g) + NO(g) \rightleftharpoons N_2O_2(g)$ *fast*

$N_2O_2(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g)$ *slow*

$N_2O(g) + H_2(g) \rightarrow N_2(g) + H_2O(g)$ *fast*

What is the rate expression?

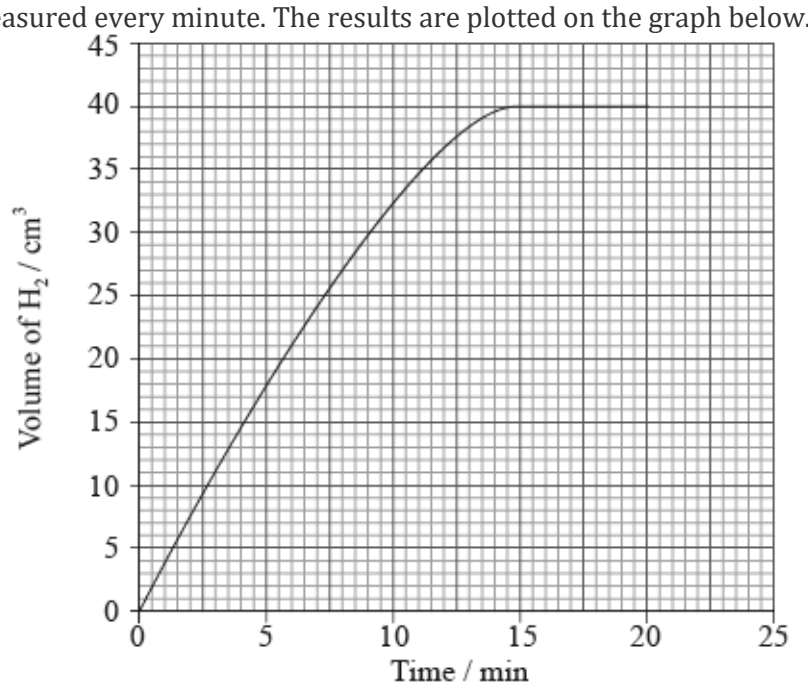
A. $\text{rate} = k[H_2][NO]^2$

B. $\text{rate} = k[N_2O_2][H_2]$

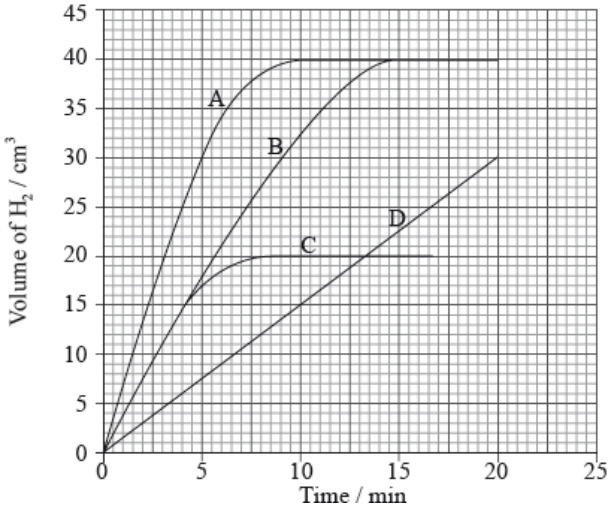
C. $\text{rate} = k[NO]^2[H_2]^2$

D. $\text{rate} = k[NO]^2[N_2O_2]^2[H_2]$

**74.** 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.



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




**75.** Which changes increase the rate of the reaction below?

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

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

**76.** Which unit could be used for the rate of a chemical reaction?
A. mol
B. $mol\ dm^{-3}$
C. $mol\ dm^{-3}s^{-1}$
D. $dm^3$

**77.** Which of the following can **increase** the rate of a chemical reaction?
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

**78.** Consider the following reaction. $2P + Q \rightarrow R + S$
This reaction occurs according to the following mechanism.

$P + Q \rightarrow X$ *slow*

$P + X \rightarrow R + S$ *fast*

What is the rate expression?

A. rate $= k[P]$
B. rate $= k[P][X]$
C. rate $= k[P][Q]$
D. rate $= k[P]^2[Q]$

**79.** What happens when the temperature of a reaction increases?
A. The activation energy increases.
B. The rate constant increases.
C. The enthalpy change increases.
D. The order of the reaction increases.

**80.** The following data were obtained for the reaction between gases A and B.

| Experiment | Initial [A] / mol dm$^{-3}$ | Initial [B] / mol dm$^{-3}$ | Initial rate / mol dm$^{-3}$ min$^{-1}$ |
|---|---|---|---|
| 1 | $1.0\times10^{-3}$ | $1.0\times10^{-3}$ | $2.0\times10^{-4}$ |
| 2 | $2.0\times10^{-3}$ | $1.0\times10^{-3}$ | $2.0\times10^{-4}$ |
| 3 | $2.0\times10^{-3}$ | $2.0\times10^{-3}$ | $4.0\times10^{-4}$ |

Which relationship represents the rate expression for the reaction?
A. $\text{rate} = k[\text{B}]^2$
B. $\text{rate} = k[\text{A}]^2$
C. $\text{rate} = k[\text{A}]$
D. $\text{rate} = k[\text{B}]$

**81.** Hydrochloric acid is reacted with large pieces of calcium carbonate, the reaction is then repeated using calcium carbonate powder. How does this change affect the activation energy and the collision frequency?

| | Activation energy | Collision frequency |
|---|---|---|
| A. | increases | increases |
| B. | stays constant | increases |
| C. | increases | stays constant |
| D. | stays constant | stays constant |

**82.** Which statement is true about using sulfuric acid as a catalyst in the following reaction?

$$\text{CH}_3\text{–CO–CH}_3(\text{aq}) + \text{I}_2(\text{aq}) \xrightarrow{\text{H}^+(\text{aq})} \text{CH}_3\text{–CO–CH}_2\text{–I(aq)} + \text{HI(aq)}$$

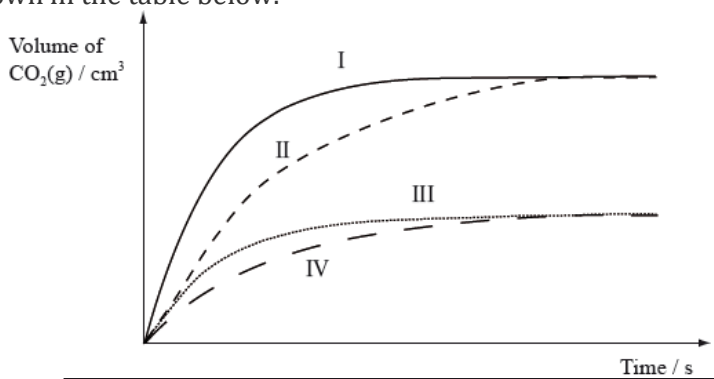
I. The catalyst increases the rate of reaction.
II. The catalyst lowers the activation energy for the reaction.
III. The catalyst has been consumed at the end of the chemical reaction.
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**83.** What is the best definition of *rate of reaction*?
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

**84.** Which factors can affect reaction rate?

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

**85.** 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.




| | 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 |

**86.** Consider the reaction between magnesium and hydrochloric acid. Which factors will affect the reaction rate?

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

**87.** The activation energy of a reaction may be determined by studying the effect of a particular variable on the reaction rate. Which variable must be changed?

A. pH
B. Concentration
C. Surface area
D. Temperature

**88.** Consider the following reaction.

$$5Br^-(aq) + BrO_3^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

The rate expression for the reaction is found to be:

$$\text{rate} = k[Br^-][BrO_3^-][H^+]^2$$

Which statement is correct?
A. The overall order is 12.
B. Doubling the concentration of all of the reactants at the same time would increase the rate of the reaction by a factor of 16.
C. The units of the rate constant, $k$, are $\text{mol dm}^{-3}\text{s}^{-1}$.
D. A change in concentration of $Br^-$ or $BrO_3^-$ does not affect the rate of the reaction.

**89.** The rate expression for a reaction is:

$$\text{rate} = k[X][Y]$$

Which statement is correct?
A. As the temperature increases the rate constant decreases.
B. The rate constant increases with increased temperature but eventually reaches a constant value.
C. As the temperature increases the rate constant increases.
D. The rate constant is not affected by a change in temperature.

| | | | | |
|---|---|---|---|---|
| **1.** A | **2.** D | **3.** A | **4.** A | **5.** D |
| **6.** D | **7.** B | **8.** C | **9.** D | **10.** D |
| **11.** B | **12.** B | **13.** C | **14.** A | **15.** C |
| **16.** C | **17.** B | **18.** D | **19.** B | **20.** C |
| **21.** D | **22.** A | **23.** B | **24.** A | **25.** A |
| **26.** C | **27.** B | **28.** B | **29.** D | **30.** B |
| **31.** B | **32.** B | **33.** C | **34.** C | **35.** C |
| **36.** C | **37.** C | **38.** D | **39.** C | **40.** C |
| **41.** D | **42.** C | **43.** B | **44.** A | **45.** A |
| **46.** D | **47.** B | **48.** A | **49.** B | **50.** C |
| **51.** D | **52.** A | **53.** B | **54.** C | **55.** D |
| **56.** B | **57.** B | **58.** D | **59.** A | **60.** D |
| **61.** A | **62.** B | **63.** C | **64.** B | **65.** A |
| **66.** D | **67.** A | **68.** B | **69.** C | **70.** C |
| **71.** D | **72.** C | **73.** A | **74.** A | **75.** A |
| **76.** C | **77.** D | **78.** C | **79.** B | **80.** D |
| **81.** B | **82.** A | **83.** D | **84.** D | **85.** C |
| **86.** D | **87.** D | **88.** B | **89.** C | |