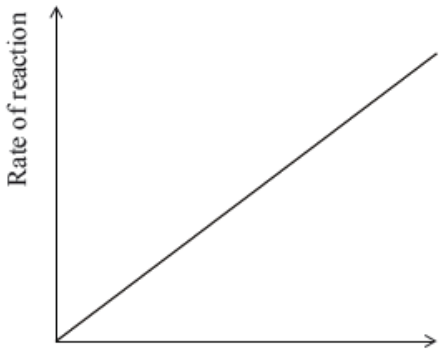
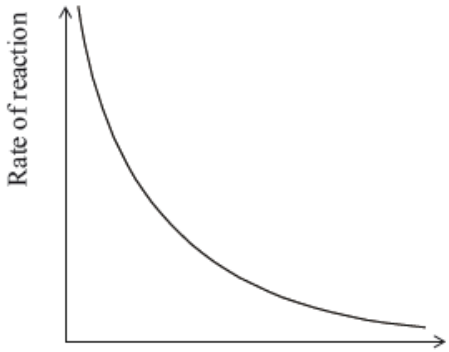
HL Paper 1

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

A.



B.



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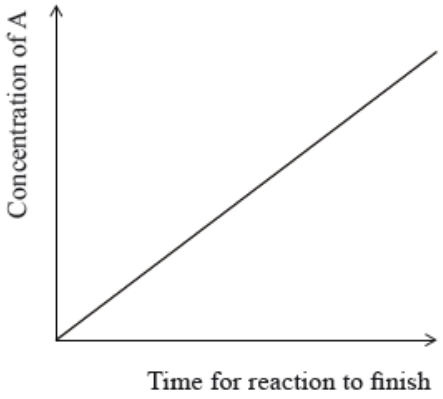

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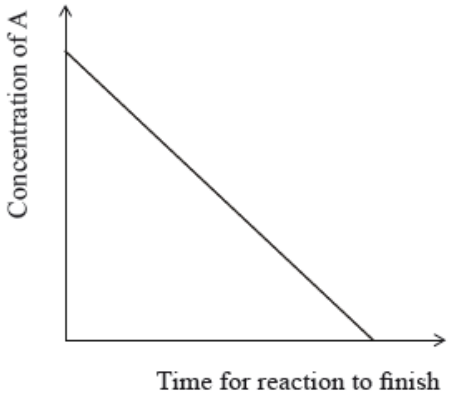


Which is correct about reaction mechanisms?

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.

What are correct labels for the Maxwell–Boltzmann energy distribution curves?

	x-axis	*y*-axis
A.	progress of reaction	energy
B.	energy	progress of reaction
C.	probability density	kinetic energy
D.	kinetic energy	probability density

What are the units of the rate constant for a zero-order reaction?

A. s

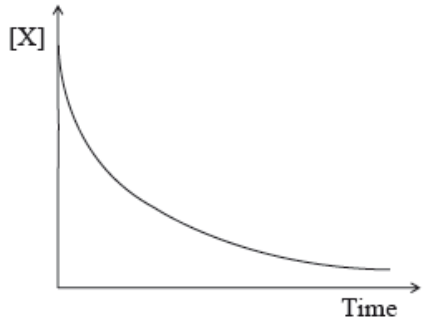
B. s^{-1}

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

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

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

A.



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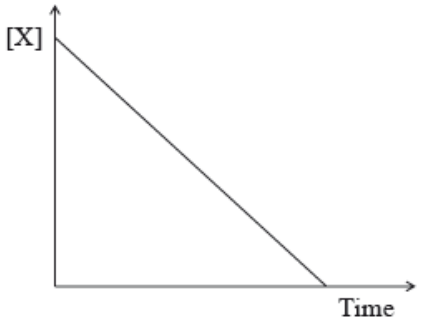

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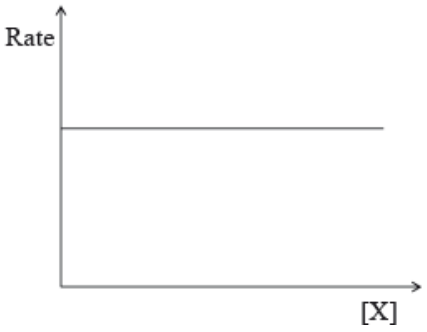
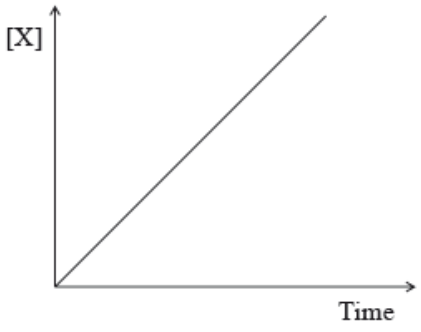


D.



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}
3.00×10^{-1}	2.00×10^{-1}	1.89×10^{-2}
3.00×10^{-1}	4.00×10^{-1}	1.89×10^{-2}
6.00×10^{-1}	4.00×10^{-1}	7.56×10^{-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

Consider the following reaction.

$$2\mathrm{NO(g)} + 2\mathrm{H_2(g)} \rightarrow \mathrm{N_2(g)} + 2\mathrm{H_2O(g)}$$

A proposed reaction mechanism is:

$$\begin{aligned} &\mathrm{NO(g)} + \mathrm{NO(g)} \rightleftharpoons \mathrm{N_2O_2(g)} && \textit{fast} \\ &\mathrm{N_2O_2(g)} + \mathrm{H_2(g)} \rightarrow \mathrm{N_2O(g)} + \mathrm{H_2O(g)} && \textit{slow} \\ &\mathrm{N_2O(g)} + \mathrm{H_2(g)} \rightarrow \mathrm{N_2(g)} + \mathrm{H_2O(g)} && \textit{fast} \end{aligned}$$

What is the rate expression?

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

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

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

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

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

$$\mathrm{Br_2(g)} + 2\mathrm{NO(g)} \rightarrow 2\mathrm{NOBr(g)}$$

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	1.0×10^{-6}
0.20	0.10	4.0×10^{-6}
0.20	0.40	4.0×10^{-6}

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

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

C. $\text{rate} = k[\mathrm{Br_2}]^2$

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

Consider the following reaction.

$$5\text{Br}^-(\text{aq}) + \text{BrO}_3^-(\text{aq}) + 6\text{H}^+(\text{aq}) \rightarrow 3\text{Br}_2(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$$

The rate expression for the reaction is found to be:

$$\text{rate} = k[\text{Br}^-][\text{BrO}_3^-][\text{H}^+]^2$$

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

D. A change in concentration of Br^- or BrO_3^- does not affect the rate of the reaction.

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

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.

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

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

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

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

Which statements are correct?

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

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

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

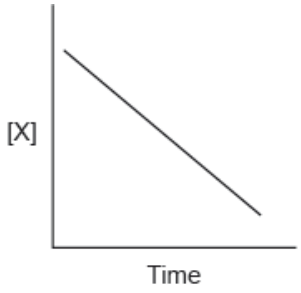
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

When X reacts with Y to give Z, the following graph is plotted. What can be deduced from the graph?



A. The concentration of X is directly proportional to time.

B. The reaction is first order overall.

C. The reaction is zero order with respect to X.

D. The reaction is first order with respect to X.

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

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

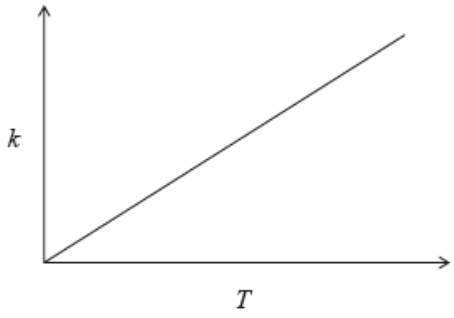
A. *A*
B. E_a
C. *R*
D. *T*

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 $= k[CH_3COCH_3][H^+][I_2]^0$	$dm^3\,mol^{-1}\,s^{-1}$

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.



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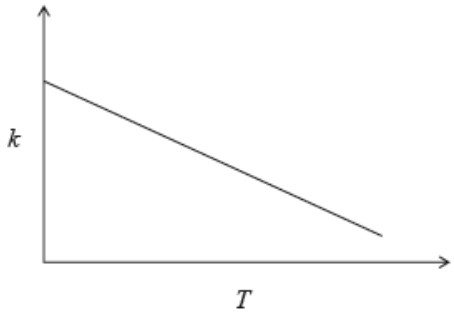
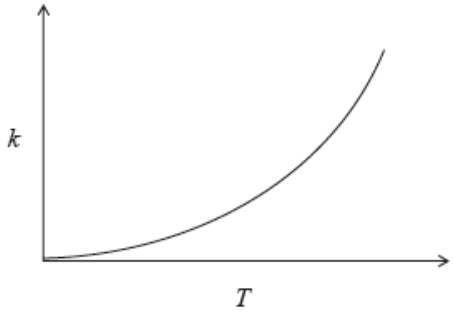


C.



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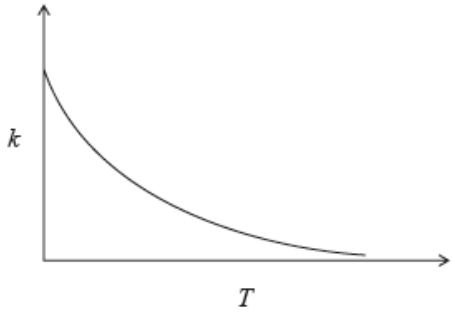


Consider the following reaction between nitrogen monoxide and oxygen.

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

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 $= k[NO][O_2]^2$

Which statement is correct?

A. The value of the rate constant, *k*, is independent of temperature and is deduced from the equilibrium constant, K_c.

B. The value of the rate constant, *k*, is independent of temperature and the overall reaction order determines its units.

C. The value of the rate constant, *k*, is temperature dependent and is deduced from the equilibrium constant, K_c.

D. The value of the rate constant, *k*, is temperature dependent and the overall reaction order determines its units.

Consider the following reaction mechanism.

$$\begin{array}{lll} \text{Step 1} & \mathrm{H_2O_2 + I^- \rightarrow H_2O + IO^-} & \text{slow} \\ \text{Step 2} & \mathrm{H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-} & \text{fast} \end{array}$$

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

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

$$\text{Rate} = k\,[\mathrm{X}]^2[\mathrm{Y}]$$

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

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

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

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

Consider the following reaction.

$$\mathrm{2P + Q \rightarrow R + S}$$

This reaction occurs according to the following mechanism.

$$\begin{array}{ll} \mathrm{P + Q \rightarrow X} & slow \\ \mathrm{P + X \rightarrow R + S} & fast \end{array}$$

What is the rate expression?

A. rate $= k[\mathrm{P}]$

B. rate $= k[\mathrm{P}][\mathrm{X}]$

C. rate $= k[\mathrm{P}][\mathrm{Q}]$

D. rate $= k[\mathrm{P}]^2[\mathrm{Q}]$

What is the effect of increasing temperature on the rate constant, *k*?

A. The rate constant does not change.

B. The rate constant decreases linearly.

C. The rate constant increases exponentially.

D. The rate constant increases proportionally with temperature.

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.

For the gas phase reaction:

$$\mathrm{A(g)} + \mathrm{B(g)} \rightarrow \mathrm{C(g)}$$

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

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

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

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

The reaction occurs in a series of steps. The equation for the rate-determining step is given below.

$\mathrm{2NO_2(g)} \rightarrow \mathrm{NO_3(g)} + \mathrm{NO(g)}$

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 $= k[\mathrm{CO_2(g)}][\mathrm{NO(g)}]$

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.

The rate expression for a reaction is:

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

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.

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.

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	1.0×10^{-3}	1.0×10^{-3}	2.0×10^{-4}
2	2.0×10^{-3}	1.0×10^{-3}	2.0×10^{-4}
3	2.0×10^{-3}	2.0×10^{-3}	4.0×10^{-4}

Which relationship represents the rate expression for the reaction?

A. $\text{rate} = k[\mathrm{B}]^2$

B. $\text{rate} = k[\text{A}]^2$

C. $\text{rate} = k[\text{A}]$

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

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

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

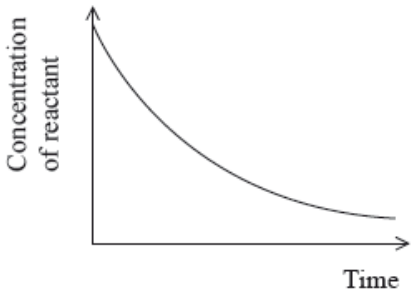
B. $CCl_2F_2 \rightarrow \bullet CClF_2 + Cl\bullet$

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

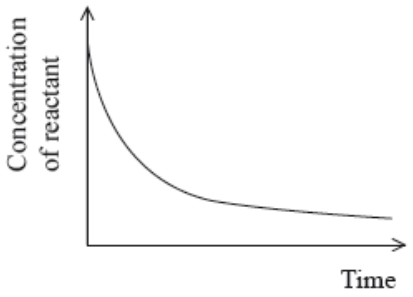
D. $CCl_2F_2 \rightarrow \bullet CCl_2F + F\bullet$

Which graph best represents a second-order reaction?

A.



B.



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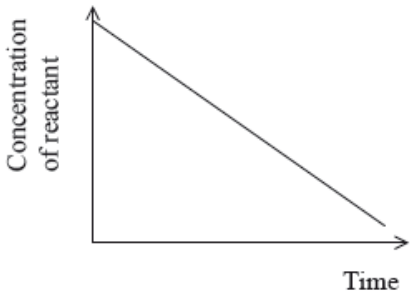
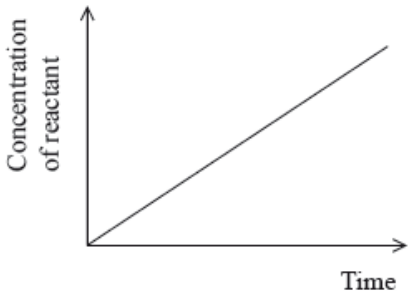


D.



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

The rate expression for the reaction X (g) + 2Y (g) → 3Z (g) is

$$\text{rate} = k[X]^0 [Y]^2$$

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

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	2.0×10^{-3}
0.04	0.02	4.0×10^{-3}
0.02	0.04	2.0×10^{-3}
0.04	0.04	4.0×10^{-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.

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

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

$\mathrm{X} + \mathrm{X} \rightarrow \mathrm{X_2}$ slow

$\mathrm{X_2} + \mathrm{Y} \rightarrow \mathrm{Z}$ 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

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

The hydrolysis of tertiary bromoalkanes with a warm dilute aqueous sodium hydroxide solution proceeds by a two-step $\mathrm{S_N1}$ mechanism.

Step I: $\mathrm{R - Br} \rightarrow \mathrm{R^+Br^-}$

Step II: $\mathrm{R^+ + OH^-} \rightarrow \mathrm{R - OH}$

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^-]

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.

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}
2.0×10^{-3}	1.0×10^{-2}	4.0×10^{-4}
4.0×10^{-3}	1.0×10^{-2}	8.0×10^{-4}
4.0×10^{-3}	2.0×10^{-2}	1.6×10^{-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

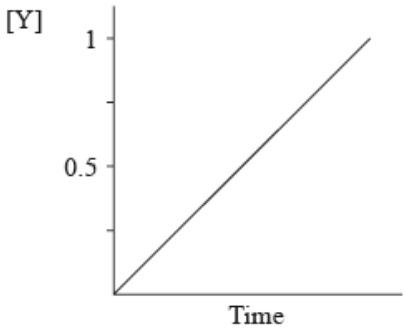
B. NO_2 is second order and F_2 is first order

C. NO_2 is first order and F_2 is first order

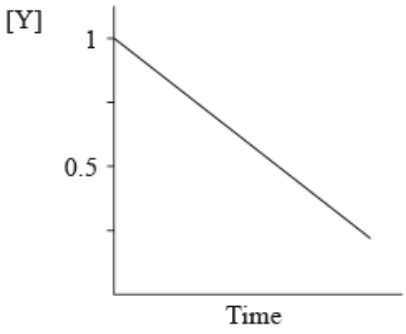
D. NO_2 is second order and F_2 is second order

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?

A.



B.



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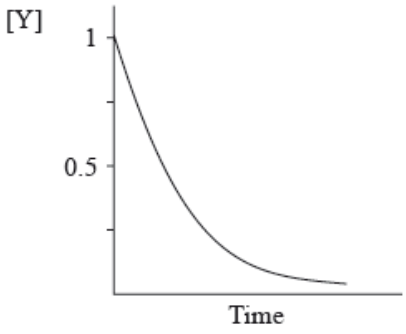

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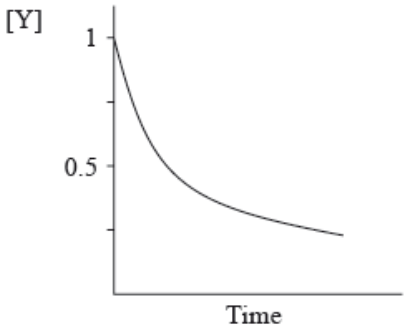


The reaction between NO_2 and F_2 gives the following rate data at a certain temperature.

$[NO_2]$ / mol dm^{-3}	$[F_2]$ / mol dm^{-3}	Rate / mol dm^{-3} min^{-1}
0.15	0.20	0.10
0.30	0.20	0.40
0.15	0.40	0.20

What is the overall order of reaction?

A. 3

B. 2

C. 1

D. 0

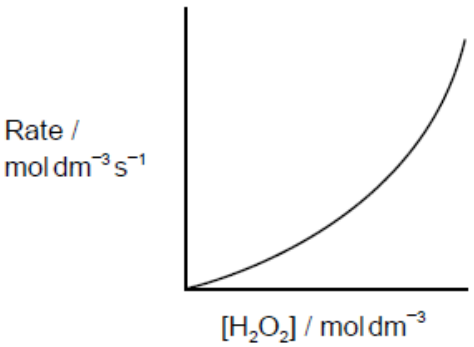
Decomposition of hydrogen peroxide in an aqueous solution proceeds as follows.

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

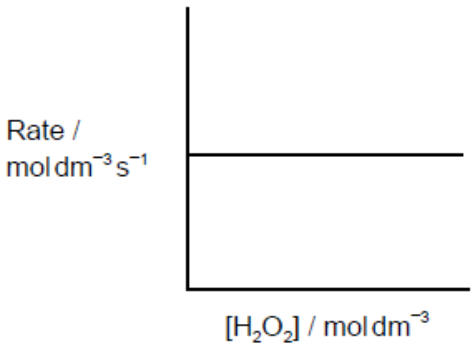
The rate expression for the reaction was found to be: rate = k $[H_2O_2]$.

Which graph is consistent with the given rate expression?

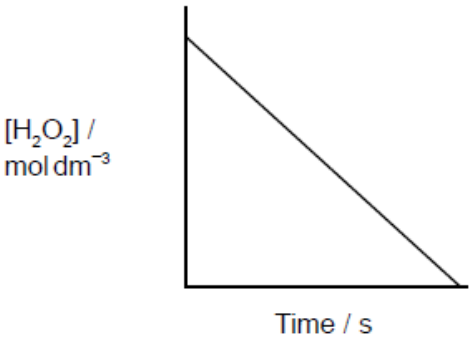
A.



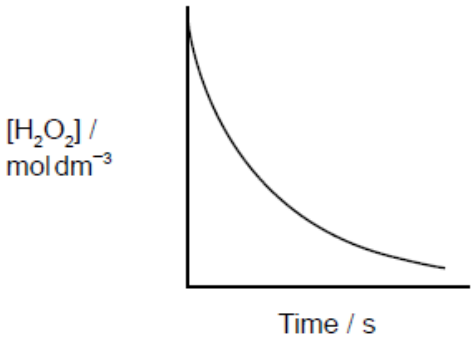
B.



C.



D.



The data shows the effect of changing reactant concentrations on the rate of the following reaction at 25°C.

$$F_2\,(g) + 2ClO_2\,(g) \rightarrow 2FClO_2\,(g)$$

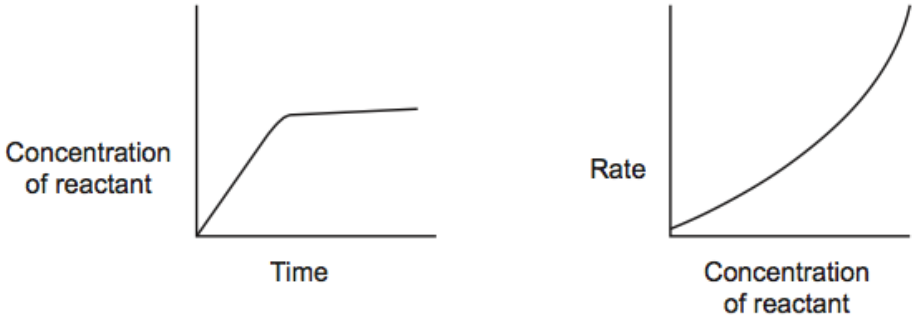
Initial $[F_2(g)]$ / mol dm^{-3}	Initial $[ClO_2(g)]$ / mol dm^{-3}	Initial rate of reaction / mol dm^{-3} s^{-1}
0.100	0.010	1.20×10^{-3}
0.100	0.030	3.60×10^{-3}
0.150	0.010	1.80×10^{-3}

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

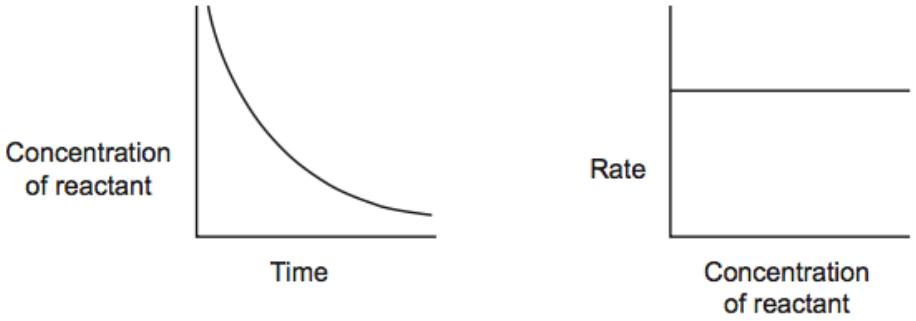
	Order with respect to $[F_2(g)]$	Overall order
A.	2	1
B.	2	2
C.	1	1
D.	1	2

Which pair of graphs represents the same order of reaction?

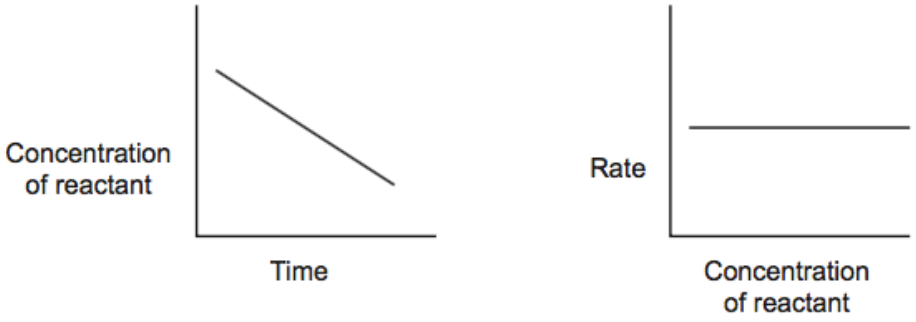
A.



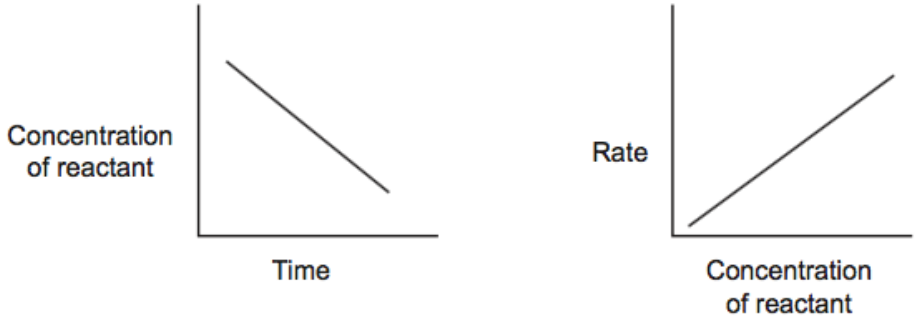
B.



C.



D.


Concentration of reactant
Time
Rate
Concentration of reactant