

APOLLO

How fast? The rate of chemical change

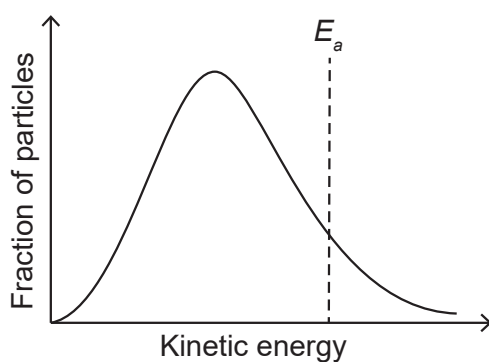
HL

Chemistry

First assessment 2025

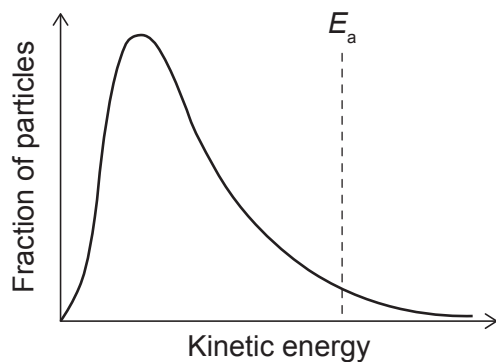
24 questions | questions

28. Consider the following Maxwell-Boltzmann distribution.

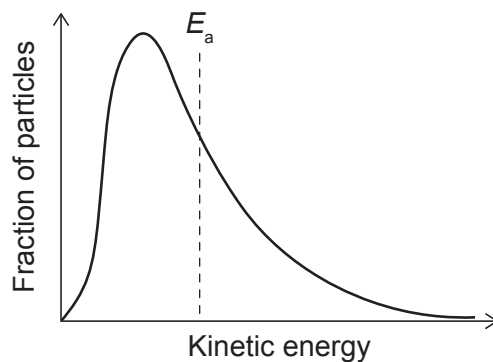


Which represents the distribution and value of activation energy at a lower temperature?

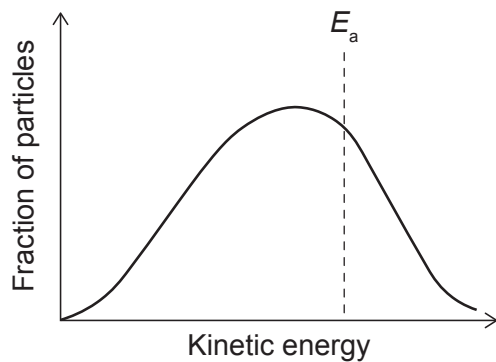
A.



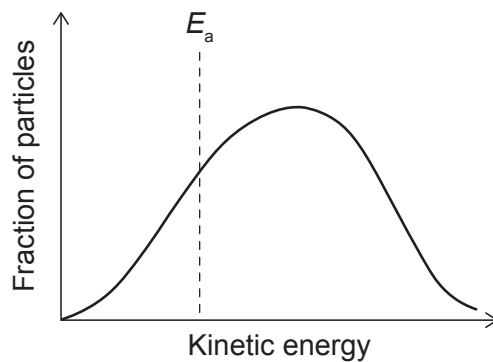
B.



C.



D.



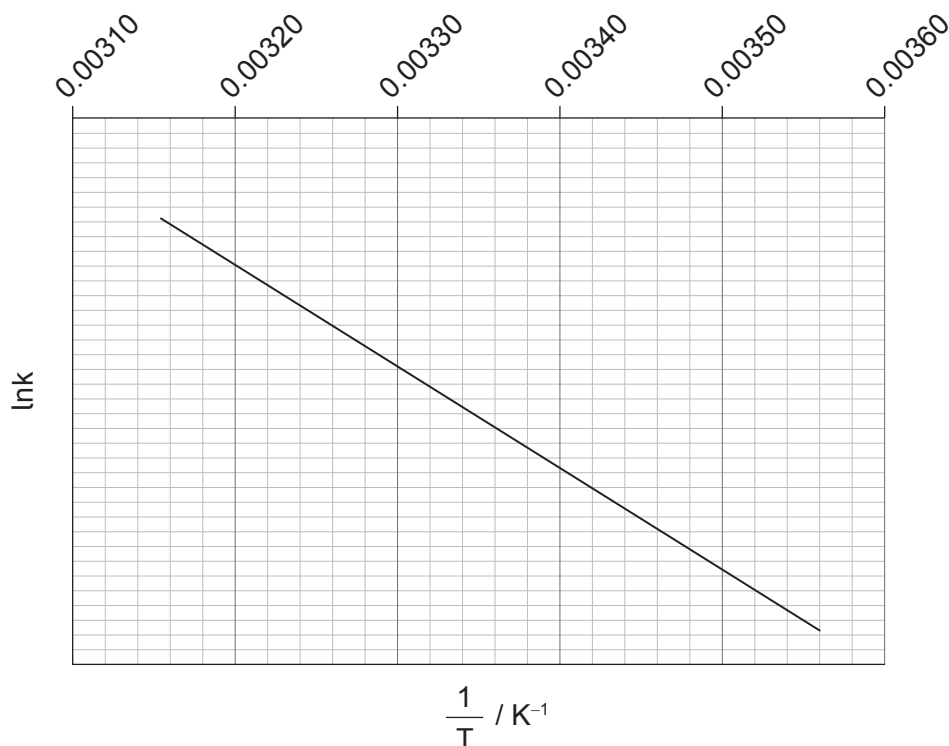
30. The following results were obtained from the acid-catalysed reaction between iodine, I_2 , and propanone, CH_3COCH_3 .

Experiment	Initial $[CH_3COCH_3]$ ($mol\ dm^{-3}$)	Initial $[I_2]$ ($mol\ dm^{-3}$)	Initial $[H^+]$ ($mol\ dm^{-3}$)	Relative initial rate $mol\ dm^{-3}\ s^{-1}$
1	0.56	0.56	0.56	5.6×10^{-3}
2	0.28	0.56	0.28	1.4×10^{-3}
3	0.56	0.28	0.56	5.6×10^{-3}
4	0.56	0.56	0.28	2.8×10^{-3}

Which row gives the correct order of reaction for each reactant?

	CH_3COCH_3	I_2	H^+
A.	1	0	1
B.	1	1	0
C.	0	0	2
D.	0	1	1

31. The acid-catalysed reaction between iodine, I_2 , and propanone, CH_3COCH_3 , was carried out at various temperatures to find the activation energy. The following graph was obtained from the processed data, and the slope was calculated to be -6400 .



Which expression gives the activation energy for this reaction?

$$\ln k = \frac{-E_a}{RT} + \ln A$$

- A. $\frac{-6400 \times 1000}{R} \text{ kJ mol}^{-1}$
- B. $\frac{6400 \times R}{1000} \text{ kJ mol}^{-1}$
- C. $\frac{-6400 \times R}{1000} \text{ kJ mol}^{-1}$
- D. $\frac{6400 \times 1000}{R} \text{ kJ mol}^{-1}$

— 11 —

4420-0201

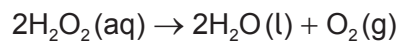
24. Which are units for rate of reaction?

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

— 11 —

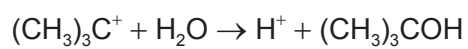
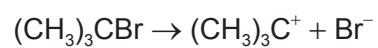
2225-0219

25. Which changes increase the rate of the reaction?



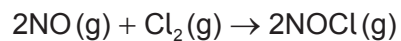
- I. Introducing a catalyst
 - II. Increasing concentration of $\text{H}_2\text{O}_2(\text{aq})$
 - III. Increasing pressure
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

26. Which species is an intermediate in the following reaction mechanism?



- A. $(\text{CH}_3)_3\text{C}^+$
- B. Br^-
- C. H_2O
- D. H^+

27. What is the overall reaction order?



[NO] / mol dm ⁻³	[Cl ₂] / mol dm ⁻³	Rate
0.10	0.10	2.5×10^{-6}
0.10	0.20	5.0×10^{-6}
0.20	0.10	10.0×10^{-6}

- A. Zero order
- B. First order
- C. Second order
- D. Third order

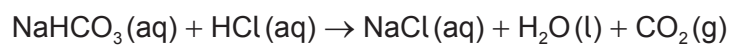
— 16 —

Turn over
4445-0219

28. What is true of rate constants of elementary reactions?

- A. Always increase with temperature
- B. Only increase with temperature for endothermic reactions
- C. Never vary with temperature
- D. Only decrease with temperature for endothermic reactions

26. Which apparatus can be used to monitor the progress of this reaction?



- I. A pH meter
 - II. A gas syringe
 - III. A colorimeter
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

27. Compounds **P** and **Q** were mixed together at various concentrations and the initial rate of each reaction was measured.

Experiment	[P] mol dm ⁻³	[Q] mol dm ⁻³	Initial rate of reaction (mol dm ⁻³ s ⁻¹)
1	0.20	0.15	0.50
2	0.10	0.15	0.25
3	0.20	0.30	1.00

What are the orders of reaction with respect to **P** and **Q**?

	Order with respect to P	Order with respect to Q
A.	1	1
B.	1	2
C.	2	1
D.	1	0

— 11 —

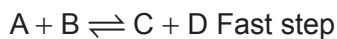
2225-0213

28. What are the units for the rate constant, k , in the following expression?

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

- A. $\text{mol}^2 \text{dm}^{-6} \text{s}^{-1}$
- B. $\text{mol dm}^{-3} \text{s}^{-1}$
- C. $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$
- D. $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$

8. The mechanism of an exothermic reaction between A and B consists of two steps.



- (a) (i) State the products of the reaction.

[1]

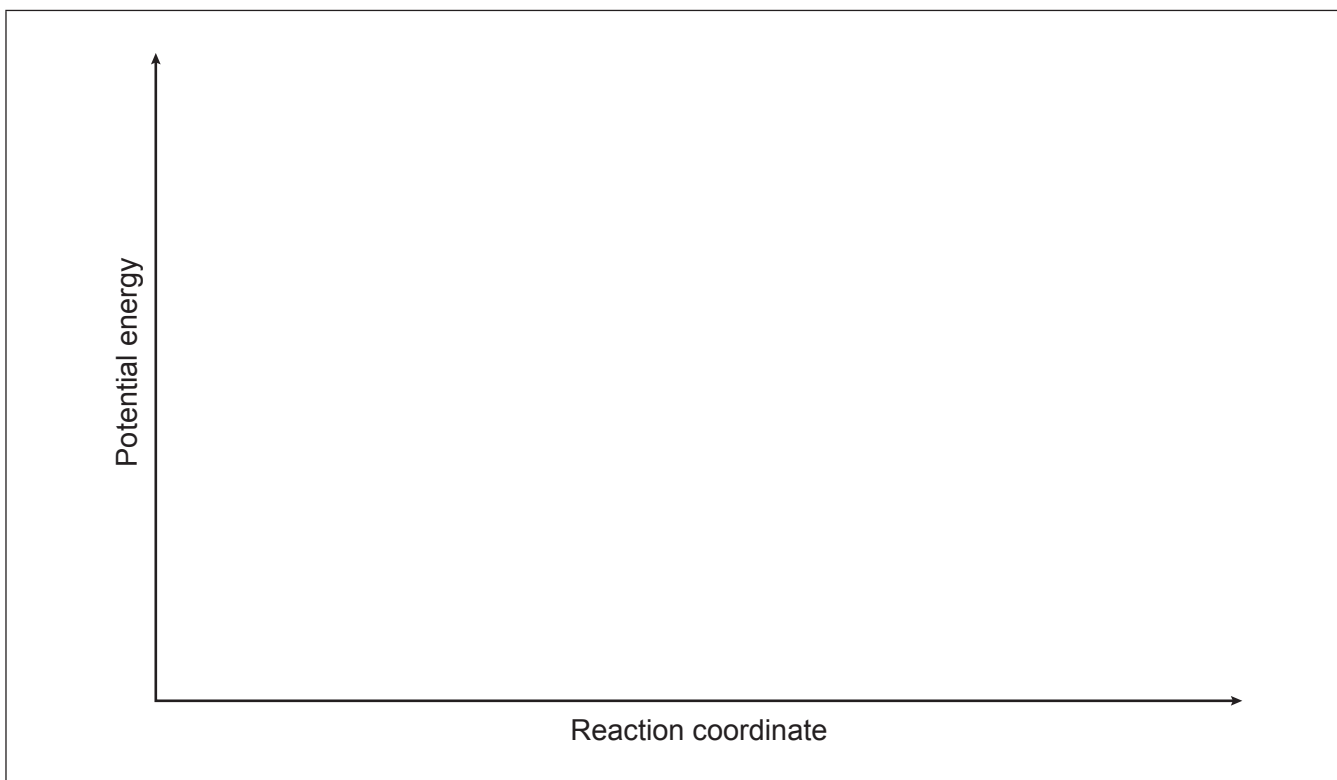
.....

.....

.....

- (ii) Sketch the energy profile for this reaction. Include labels for reactants, products, transition state(s) and intermediate(s).

[3]



- (iii) Deduce the rate equation of the reaction.

[2]

.....

.....

.....

.....

(This question continues on the following page)



(Question 8 continued)

- (b) Explain, using collision theory, how an increase in temperature increases the reaction rate. [3]

.....

.....

.....

.....

.....

.....

.....

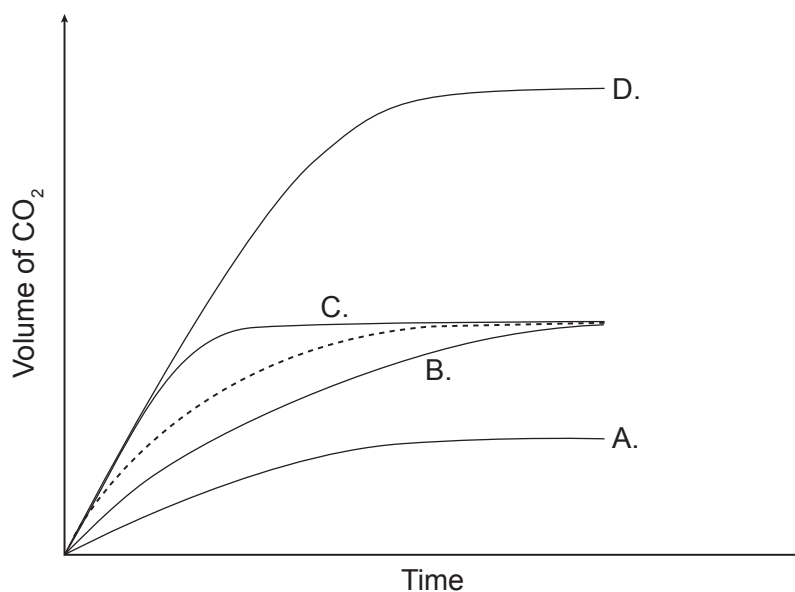
**Turn over**

— 20 —

4440-0221

27. The dotted line represents the volume of carbon dioxide evolved when excess calcium carbonate is added into 100 cm^3 of 1.0 mol dm^{-3} of hydrochloric acid.

Which graph represents the production of carbon dioxide when excess calcium carbonate is added to the 200 cm^3 of 0.25 mol dm^{-3} of hydrochloric acid?



28. Which reaction has the lowest activation energy?

- A. $\text{Cl}_2(\text{g}) \rightarrow 2\text{Cl}(\text{g})$
- B. $\text{HCl}(\text{g}) \rightarrow \text{H}(\text{g}) + \text{Cl}(\text{g})$
- C. $\text{HCl}(\text{g}) \rightarrow \text{H}^+(\text{g}) + \text{Cl}^-(\text{g})$
- D. $2\text{H}(\text{g}) \rightarrow \text{H}_2(\text{g})$

— 18 —

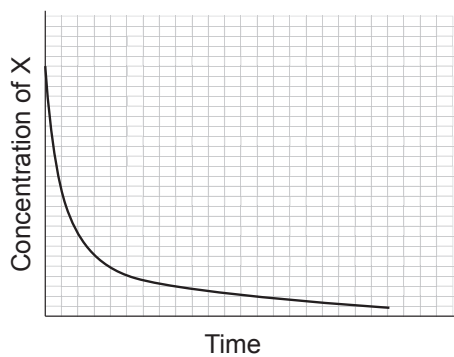
0025-0207

29. Consider the following equation:

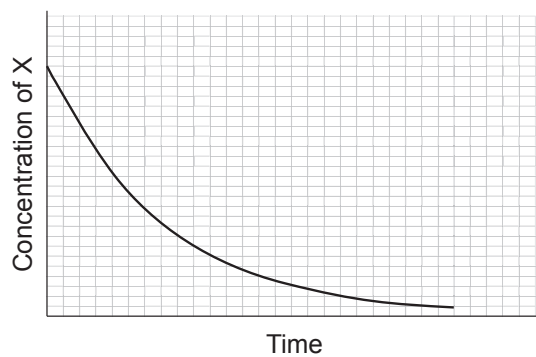


Which graph shows that the reaction is first order with respect to X?

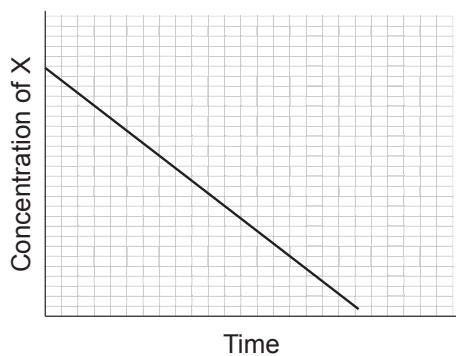
A.



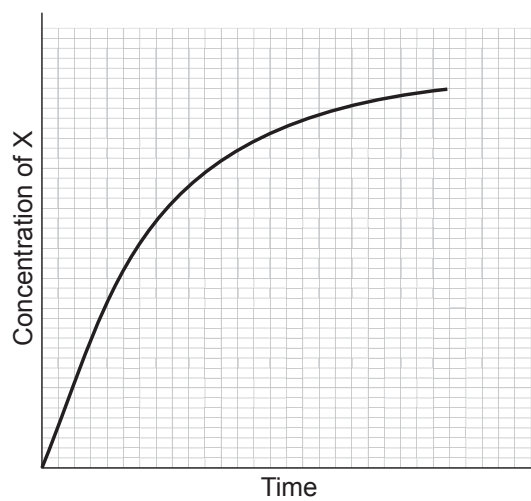
B.



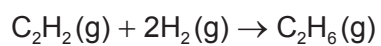
C.



D.

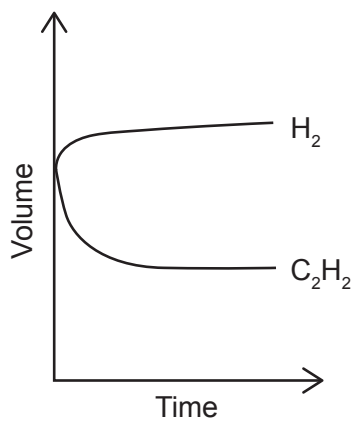


25. The volume of ethyne as it reacts with hydrogen is shown in the graphs.

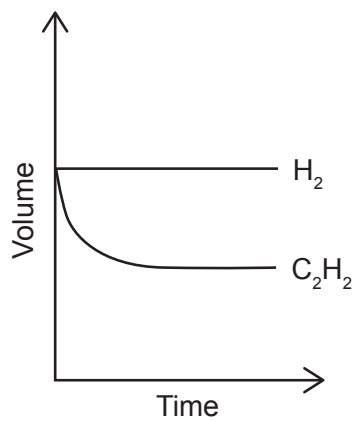


Which graph shows how the volume of hydrogen changes with time?

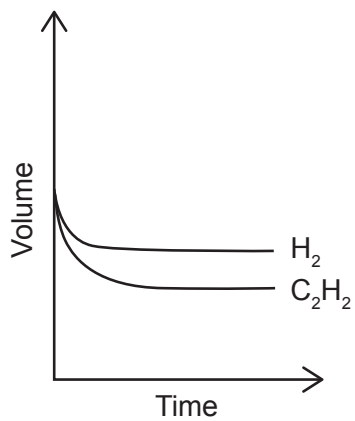
A.



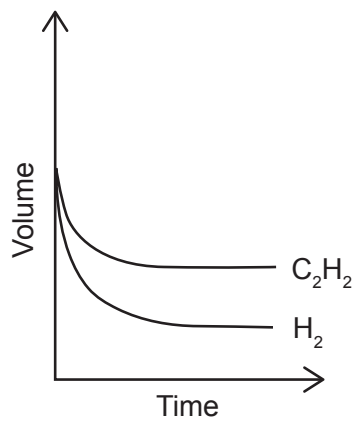
B.



C.



D.



— 11 —

0020-0219

26. The reaction between bromine and nitrogen(II) oxide follows a two-step mechanism.



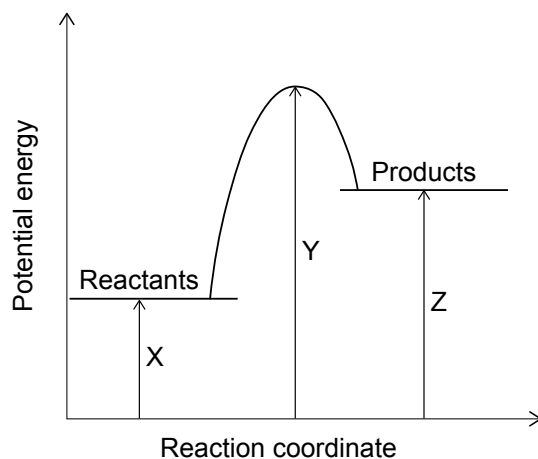
What is the rate equation?

- A. Rate = $k[\text{Br}_2][\text{NO}]$
- B. Rate = $k[\text{Br}_2][\text{NO}]^2$
- C. Rate = $k[\text{Br}_2][\text{NO}]^2[\text{NOBr}_2]$
- D. Rate = $k[\text{NOBr}]^2$

27. Which statement about catalysts is correct?

- A. Catalysts increase the kinetic energy of reacting particles.
- B. Catalysts affect endothermic reactions more than exothermic reactions.
- C. Catalysts increase reaction rate and are used up in a reaction.
- D. Catalysts alter the mechanism of a reaction.

26. The diagram shows the energy profile of a reaction.



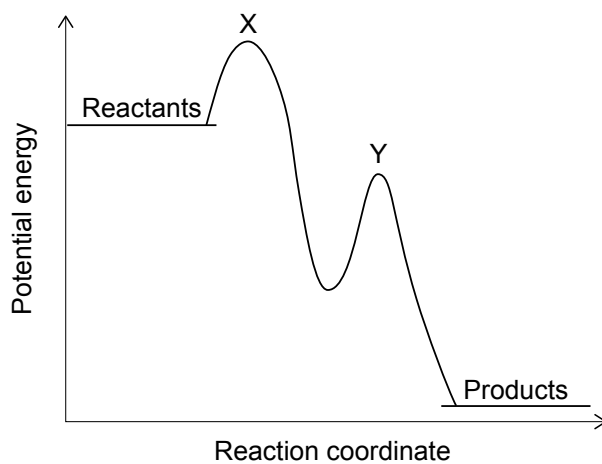
Which combination is correct?

	Activation energy of forward reaction	Activation energy of reverse reaction
A.	X	Z
B.	$Y - X$	$Y - Z$
C.	Y	Y
D.	$Y - X$	$Z - X$

Turn over

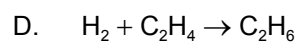
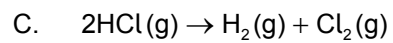
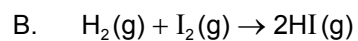
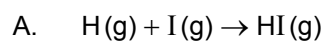
- 27.** What is the main reason for an increase in rate of reaction when the temperature is raised?
- A. A greater proportion of collisions are successful.
 - B. Particles collide more frequently.
 - C. The bonds in the reactants are weakened.
 - D. The activation energy of the reaction decreases.

29. Which statement is correct about points X and Y on the energy profile diagram?



- A. X is a transition state and Y is an intermediate.
- B. X is an intermediate and Y is a transition state.
- C. X and Y are transition states.
- D. X and Y are intermediates.

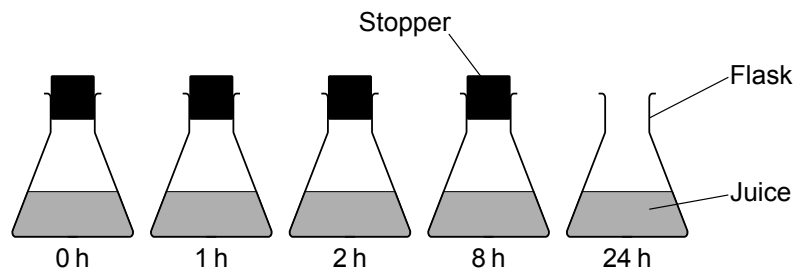
31. Which reaction would be expected to have the largest Arrhenius (pre-exponential) factor, A , at constant temperature?



Section B

Answer **all** questions. Answers must be written within the answer boxes provided.

2. A student investigates the effect of exposure to the air on the ascorbic acid (vitamin C) concentration in a specific orange juice. Equal volumes of orange juice are sealed into identical flasks and placed in a refrigerator for two weeks. The samples in the refrigerator are exposed to the air by removing the stopper for a different number of hours each day as shown.



- (a) Identify **two** variables that are controlled. [1]

.....

.....

- (b) The concentration of ascorbic acid is determined by titration with a standard iodine solution. Every few days, 10.00 cm^3 of orange juice is removed from each sample, diluted to 100.0 cm^3 , and titrated.

- (i) Suggest why the juice is diluted before titration. [1]

.....

.....

- (ii) Identify a possible systematic error with this method regarding the sample that is exposed for zero hours. [1]

.....

.....

- (iii) Suggest how an additional flask could be set up to verify whether the systematic error in (ii) has occurred. [1]

.....

.....

(This question continues on the following page)



12EP07

Turn over

(Question 2 continued)

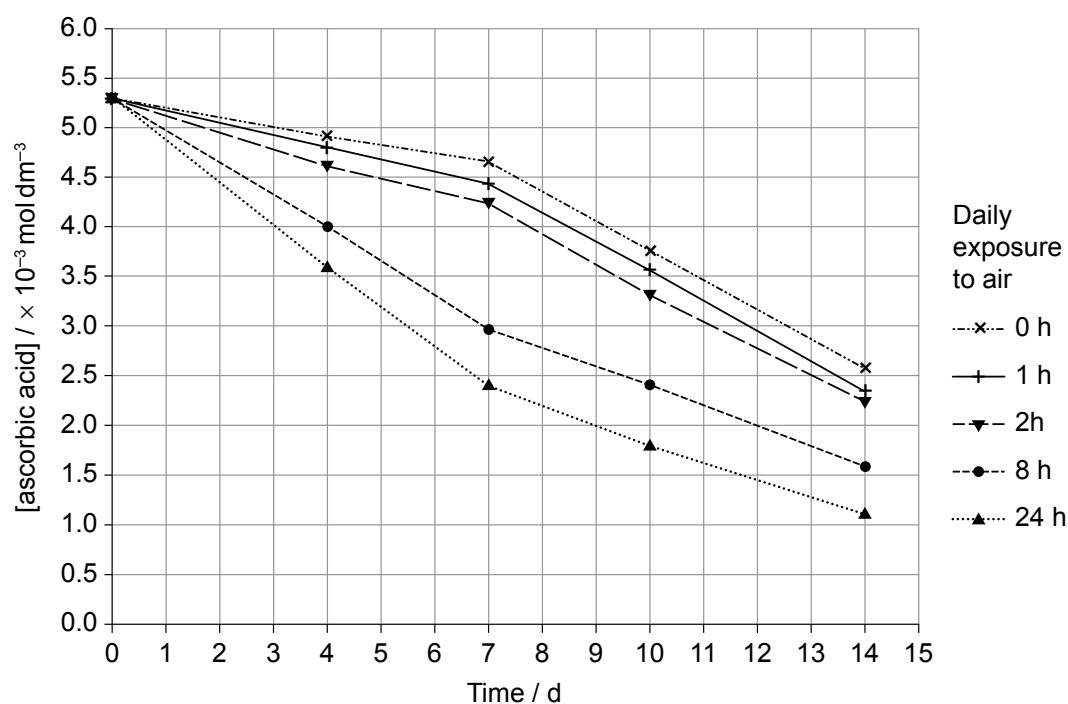
- (c) The following data are collected during a titration.

Final burette reading = $16.10 \pm 0.05 \text{ cm}^3$ Initial burette reading = $1.10 \pm 0.05 \text{ cm}^3$

Calculate the percentage uncertainty of the titre.

[1]

- (d) The following graph shows the student's results.



- (i) Calculate the average rate of decrease in ascorbic acid concentration for the 24 h sample over the period of 14 days, including units.

[2]

(This question continues on the following page)

12EP08

(Question 2 continued)

- (ii) The student's hypothesis is: "A lower ascorbic acid concentration will be found in juice exposed to the air for longer, due to oxidation of ascorbic acid by oxygen."

Discuss whether or not the data support the hypothesis.

[2]

.....
.....
.....
.....

- (iii) State the implications of the results of the experiment for avoiding loss of vitamin C in the storage of orange juice.

[1]

.....
.....

- (e) Suggest an extension to the investigation that would generate further recommendations for the storage of orange juice.

[1]

.....
.....



12EP09

Turn over

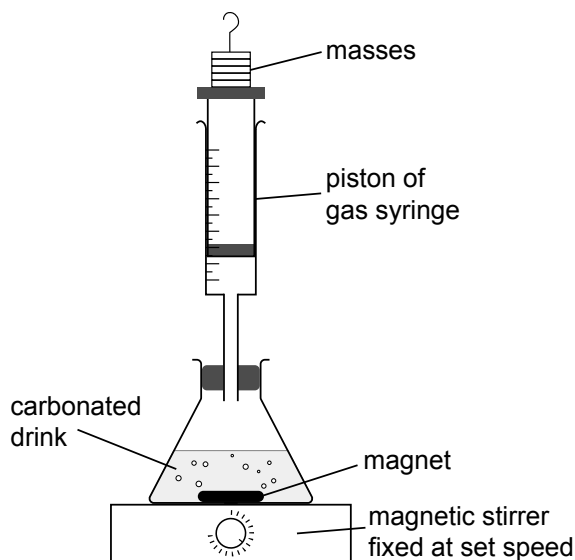


Section B

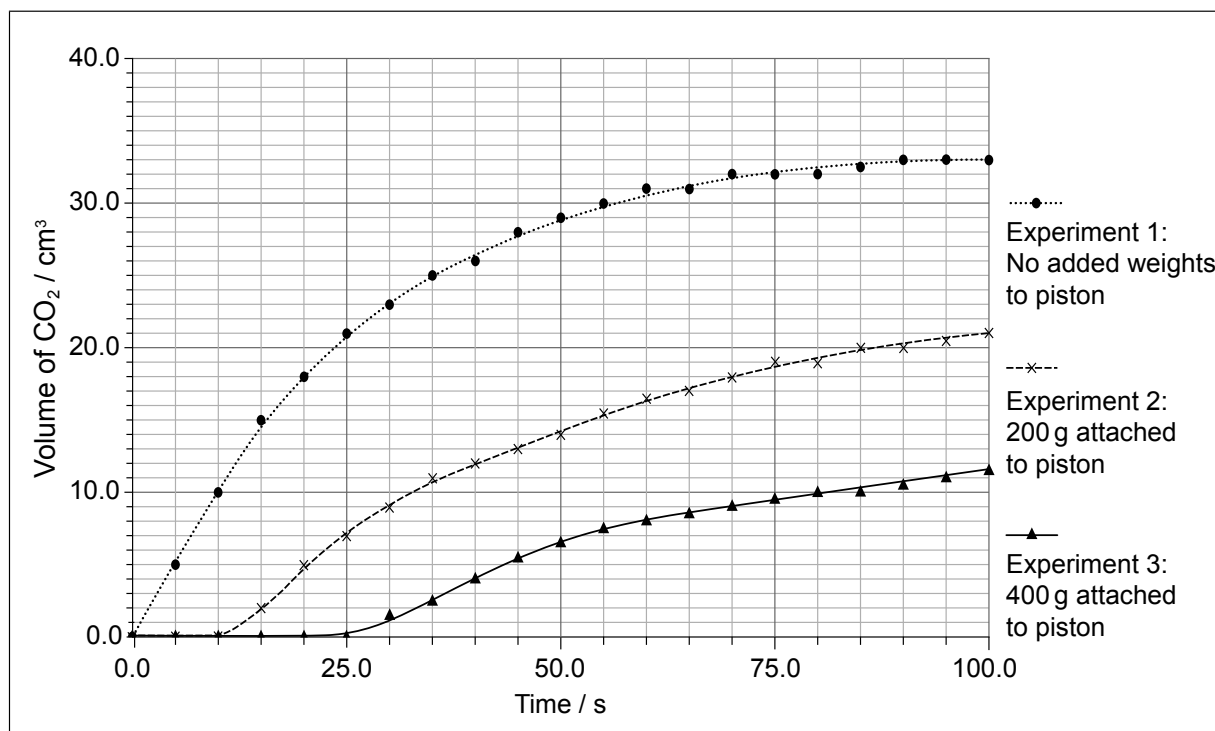
Answer **all** questions. Answers must be written within the answer boxes provided.

3. A student investigates the effect of pressure on the volume of carbon dioxide gas released from a carbonated drink poured into a flask.

To alter the pressure on the carbonated drink, masses are placed on top of the piston of the gas syringe as shown.



The graph shows some of the data collected.



- (a) Determine, by annotating the graph, the initial rate of release of CO_2 in Experiment 1 in $\text{cm}^3 \text{s}^{-1}$. [2]

(This question continues on the following page)



(Question 3 continued)

- (b) Estimate the time at which the piston would begin to move if a 600 g mass is used. [1]

.....

.....

- (c) Suggest **two** reasons why the volume of CO₂ collected in the gas syringe is smaller when more masses are placed on top of the piston. [2]

.....

.....

.....

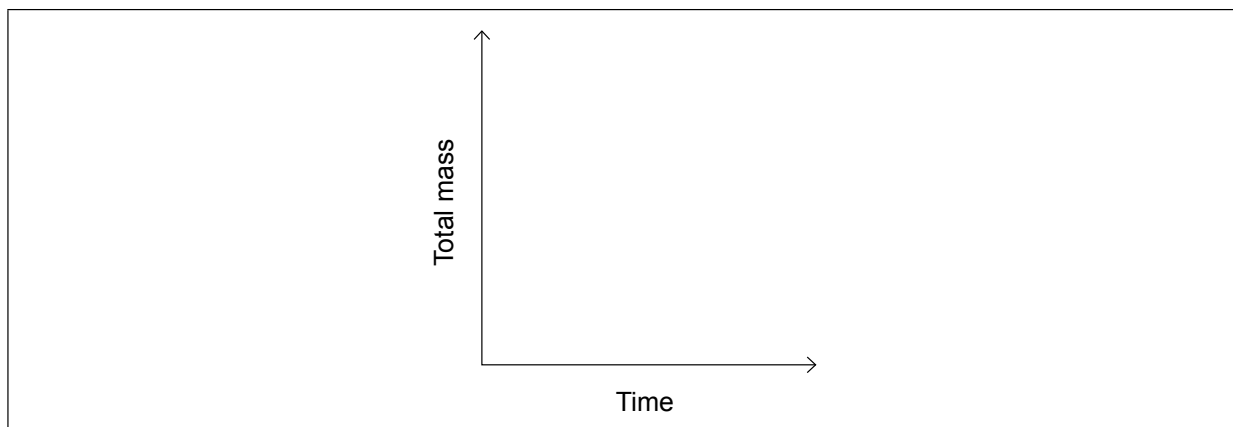
.....

- (d) Calculate the percentage decrease in the final volume of CO₂ per 100 g mass placed on the piston, using the results of Experiment 1 and Experiment 3 at 100 s. [1]

.....

.....

- (e) Sketch and give a reason for a graph of the total mass of the apparatus in Experiment 1 against time. [2]



.....

.....



12EP11

Disclaimer:

Content used in IB assessments is taken from authentic, third-party sources. The views expressed within them belong to their individual authors and/or publishers and do not necessarily reflect the views of the IB.

References:

- 1(c)** National Center for Biotechnology Information, 2020. *PubChem Compound Summary for CID 24526, Chlorine* [online] Available at: <<https://pubchem.ncbi.nlm.nih.gov/compound/Chlorine>> [Accessed 23 September 2020].
- 1(e)** Norlex, 2020. *Chlorine for water disinfection*. [online] Available at: <<https://norlexpoolspace.com/guidance/about-the-right-water-balance/safe>> [Accessed 23 September 2020].
- 1(f)(ii)** ResearchGate, 2015. *Distributions of chloramines as a function of pH*. [image online] Available at: <https://www.researchgate.net/figure/Distribution-of-chloramines-as-a-function-of-pH_fig8_273449675> [Accessed 23 September 2020].



12EP12