

## CHAPTER 6 QUESTIONS

### Multiple-Choice Questions

Use the following information to answer questions 1-4.

A multi-step reaction takes place with the following elementary steps:

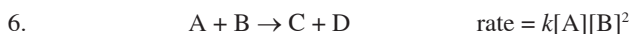


- What is the overall balanced equation for this reaction?
    - $2A + B + 2C + D \rightarrow C + D + B + E$
    - $A + B \rightarrow B + E$
    - $A + 2C \rightarrow D + E$
    - $2A + C \rightarrow E$
  - What is the function of species B in this reaction?
    - Without it, no reaction would take place.
    - It is a reaction intermediate which facilitates the progress of the reaction.
    - It is a catalyst which changes the overall order of the reaction.
    - It lowers the overall activation energy of the reaction.
  - If step II is the slow step for the reaction, what is the overall rate law?
    - Rate =  $k[A]^2[B]$
    - Rate =  $k[A][C]$
    - Rate =  $k[A][B]$
    - Rate =  $k[A]/[D]$
  - Why would increasing the temperature make the reaction rate go up?
    - It is an endothermic reaction that needs an outside energy source to function.
    - The various molecules in the reactions will move faster and collide more often.
    - The overall activation energy of the reaction will be lowered.
    - A higher fraction of molecules will have the same activation energy.
-



At 600 K,  $\text{SO}_2\text{Cl}_2$  will decompose to form sulfur dioxide and chlorine gas via the above equation. If the reaction is found to be first order overall, which of the following will cause an increase in the half life of  $\text{SO}_2\text{Cl}_2$ ?

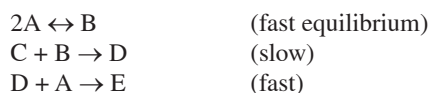
- (A) Increasing the initial concentration of  $\text{SO}_2\text{Cl}_2$
- (B) Increasing the temperature at which the reaction occurs
- (C) Decreasing the overall pressure in the container
- (D) None of these will increase the half life.



What are the potential units for the rate constant for the above reaction?

- (A)  $\text{s}^{-1}$
- (B)  $\text{s}^{-1}\text{M}^{-1}$
- (C)  $\text{s}^{-1}\text{M}^{-2}$
- (D)  $\text{s}^{-1}\text{M}^{-3}$

7. The following mechanism is proposed for a reaction:



Which of the following is the correct rate law for complete reaction?

- (A)  $\text{Rate} = k[\text{C}]^2[\text{B}]$
- (B)  $\text{Rate} = k[\text{C}][\text{A}]^2$
- (C)  $\text{Rate} = k[\text{C}][\text{A}]^3$
- (D)  $\text{Rate} = k[\text{D}][\text{A}]$



The reaction above takes place with all of the reactants and products in the gaseous phase. Which of the following is true of the relative rates of disappearance of the reactants and appearance of the products?

- (A) NO appears at twice the rate that NOCl disappears.
- (B) NO appears at the same rate that NOCl disappears.
- (C) NO appears at half the rate that NOCl disappears.
- (D)  $\text{Cl}_2$  appears at the same rate that NOCl disappears.

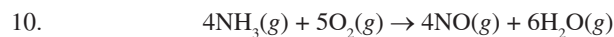


When the reaction given above takes place in a sealed isothermal container, the rate law is

$$\text{Rate} = k[\text{H}_2][\text{I}_2]$$

If a mole of  $\text{H}_2$  gas is added to the reaction chamber and the temperature remains constant, which of the following will be true?

- (A) The rate of reaction and the rate constant will increase.
- (B) The rate of reaction and the rate constant will not change.
- (C) The rate of reaction will increase and the rate constant will decrease.
- (D) The rate of reaction will increase and the rate constant will not change.



The above reaction will experience a rate increase by the addition of a catalyst such as platinum. Which of the following best explains why?

- (A) The catalyst causes the value for  $G$  to become more negative.
- (B) The catalyst increases the percentage of collisions that occur at the proper orientation in the reactant molecules.
- (C) The catalyst introduces a new reaction mechanism for the reaction.
- (D) The catalyst increases the activation energy for the reaction.



Based on the following experimental data, what is the rate law for the hypothetical reaction given above?

| Experiment | [A] (M) | [B] (M) | Initial Rate of Formation of C (mol/L·sec) |
|------------|---------|---------|--------------------------------------------|
| 1          | 0.20    | 0.10    | $3 \times 10^{-2}$                         |
| 2          | 0.20    | 0.20    | $6 \times 10^{-2}$                         |
| 3          | 0.40    | 0.20    | $6 \times 10^{-2}$                         |

- (A)  $\text{Rate} = k[\text{A}]$
- (B)  $\text{Rate} = k[\text{A}]^2$
- (C)  $\text{Rate} = k[\text{B}]$
- (D)  $\text{Rate} = k[\text{A}][\text{B}]$

12. A solution of  $\text{Co}^{2+}$  ions appears red when viewed under white light. Which of the following statements is true about the solution?

- (A) A spectrophotometer set to the wavelength of red light would read a high absorbance.
- (B) If the solution is diluted, the amount of light reflected by the solution will decrease.
- (C) All light with a frequency that is lower than that of red light will be absorbed by it.
- (D) Electronic transmissions within the solution match the wavelength of red light.

13.



Based on the following experimental data, what is the rate law for the hypothetical reaction given above?

| Experiment | [A] (M) | [B] (M) | Initial Rate of Formation of C (M/sec) |
|------------|---------|---------|----------------------------------------|
| 1          | 0.20    | 0.10    | $2.0 \times 10^{-6}$                   |
| 2          | 0.20    | 0.20    | $4.0 \times 10^{-6}$                   |
| 3          | 0.40    | 0.40    | $1.6 \times 10^{-5}$                   |

- (A) Rate =  $k[A]$   
 (B) Rate =  $k[A]^2$   
 (C) Rate =  $k[B]$   
 (D) Rate =  $k[A][B]$

14.

| Time (Hours) | [A] M |
|--------------|-------|
| 0            | 0.40  |
| 1            | 0.20  |
| 2            | 0.10  |
| 3            | 0.05  |

Reactant A underwent a decomposition reaction. The concentration of A was measured periodically and recorded in the chart above. Based on the data in the chart, which of the following is the rate law for the reaction?

- (A) Rate =  $k[A]$   
 (B) Rate =  $k[A]^2$   
 (C) Rate =  $2k[A]$   
 (D) Rate =  $\frac{1}{2}k[A]$

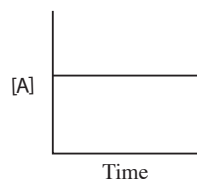
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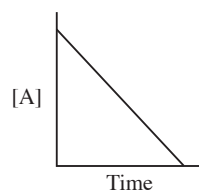
$$\text{rate} = k[A]^2$$

Which of the following graphs may have been created using data gathered from the above reaction?

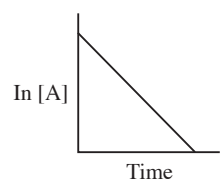
(A)



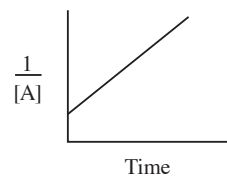
(B)



(C)



(D)



16. After 44 minutes, a sample of  ${}^{44}_{19}\text{K}$  is found to have decayed to 25 percent of the original amount present. What is the half-life of  ${}^{44}_{19}\text{K}$ ?

- (A) 11 minutes
- (B) 22 minutes
- (C) 44 minutes
- (D) 66 minutes

## Free-Response Questions

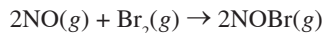


The following results were obtained in experiments designed to study the rate of the reaction above:

| Experiment | Initial Concentration (mol/L) |      | Initial Rate of Disappearance of A (M/sec) |
|------------|-------------------------------|------|--------------------------------------------|
|            | [A]                           | [B]  |                                            |
| 1          | 0.05                          | 0.05 | $3.0 \times 10^{-3}$                       |
| 2          | 0.05                          | 0.10 | $6.0 \times 10^{-3}$                       |
| 3          | 0.10                          | 0.10 | $1.2 \times 10^{-2}$                       |
| 4          | 0.20                          | 0.10 | $2.4 \times 10^{-2}$                       |

- (a) Determine the order of the reaction with respect to each of the reactants, and write the rate law for the reaction.
- (b) Calculate the value of the rate constant,  $k$ , for the reaction. Include the units.
- (c) If another experiment is attempted with [A] and [B], both 0.02-molar, what would be the initial rate of disappearance of A?
- (d) The following reaction mechanism was proposed for the reaction above:
- $$A + B \rightarrow C + D$$
- $$D + B \rightarrow C$$
- (i) Show that the mechanism is consistent with the balanced reaction.
- (ii) Show which step is the rate-determining step, and explain your choice.

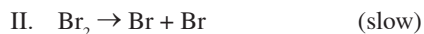
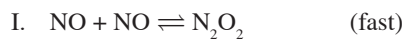
2.



The following results were obtained in experiments designed to study the rate of the reaction above:

| Experiment | Initial Concentration (mol/L) |                    | Initial Rate of Appearance of NOBr (M/sec) |
|------------|-------------------------------|--------------------|--------------------------------------------|
|            | [NO]                          | [Br <sub>2</sub> ] |                                            |
| 1          | 0.02                          | 0.02               | $9.6 \times 10^{-2}$                       |
| 2          | 0.04                          | 0.02               | $3.8 \times 10^{-1}$                       |
| 3          | 0.02                          | 0.04               | $1.9 \times 10^{-1}$                       |

- (a) Write the rate law for the reaction.  
 (b) Calculate the value of the rate constant,  $k$ , for the reaction. Include the units.  
 (c) In experiment 2, what was the concentration of NO remaining when half of the original amount of Br<sub>2</sub> was consumed?  
 (d) Which of the following reaction mechanisms is consistent with the rate law established in (a)? Explain your choice.



3.



Dinitrogen pentoxide gas decomposes according to the equation above. The first-order reaction was allowed to proceed at 40°C and the data below were collected.

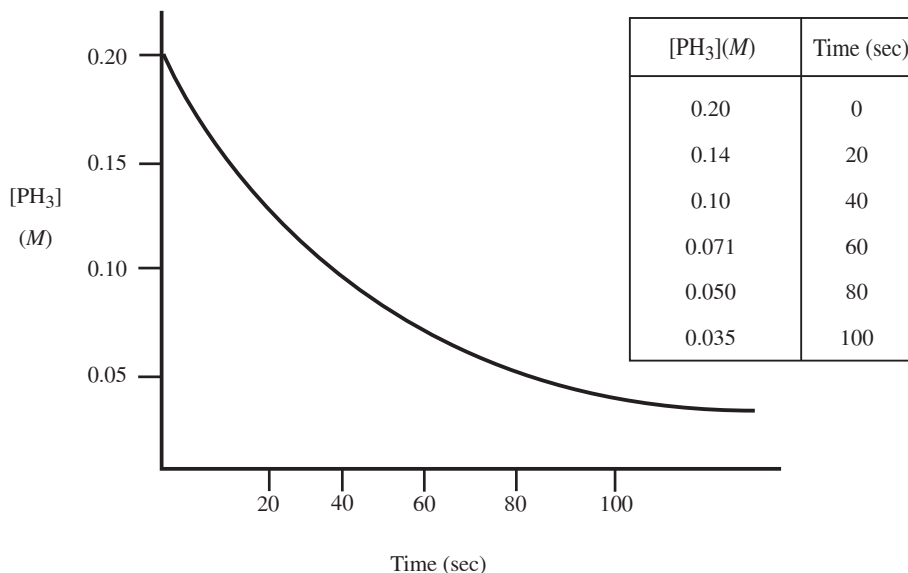
| [N <sub>2</sub> O <sub>5</sub> ] (M) | Time (min) |
|--------------------------------------|------------|
| 0.400                                | 0.0        |
| 0.289                                | 20.0       |
| 0.209                                | 40.0       |
| 0.151                                | 60.0       |
| 0.109                                | 80.0       |

- (a) Calculate the rate constant for the reaction using the values for concentration and time given in the table. Include units with your answer.  
 (b) After how many minutes will [N<sub>2</sub>O<sub>5</sub>] be equal to 0.350 M?  
 (c) What will be the concentration of N<sub>2</sub>O<sub>5</sub> after 100 minutes have elapsed?  
 (d) Calculate the initial rate of the reaction. Include units with your answer.  
 (e) What is the half-life of the reaction?

4. The decomposition of phosphine occurs via the pathway below:



A scientist observing this reaction at 250 K plots the following data:



- (a) (i) What order is this reaction? Why?  
(ii) What would the concentration of the PH<sub>3</sub> gas be after 120 sec?
- (b) If the rate of disappearance of PH<sub>3</sub> is  $2.5 \times 10^{-3} \text{ M/s}$  at  $t = 20 \text{ s}$ :  
(i) What is the rate of appearance of P<sub>4</sub> at the same point in time?  
(ii) How will the rate of appearance of P<sub>4</sub> change as the reaction progresses forward?
- (c) The experiment is repeated with the same initial concentration of phosphine, but this time the temperature is set at 500 K. How and why would the following values change, if at all?  
(i) The half-life of the phosphine  
(ii) The rate law  
(iii) The value of the rate constant



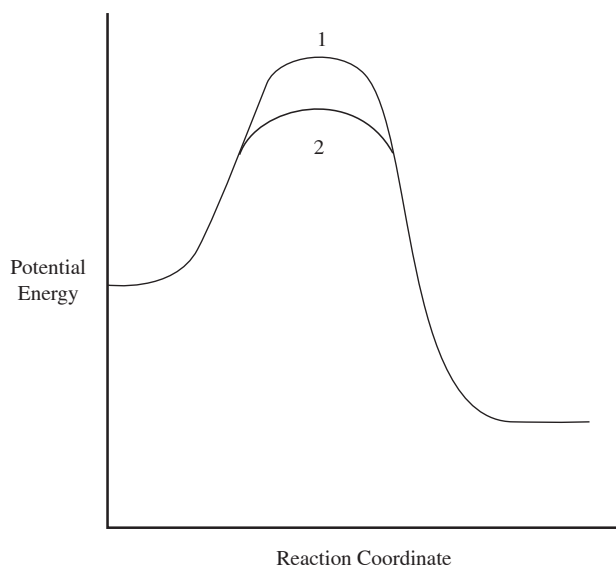
The reaction above is second order with respect to A and zero order with respect to B. Reactants A and B are present in a closed container. Predict how each of the following changes to the reaction system will affect the rate and rate constant, and explain why.

- (a) More gas A is added to the container.  
(b) More gas B is added to the container.  
(c) The temperature is increased.  
(d) An inert gas D is added to the container.  
(e) The volume of the container is decreased.



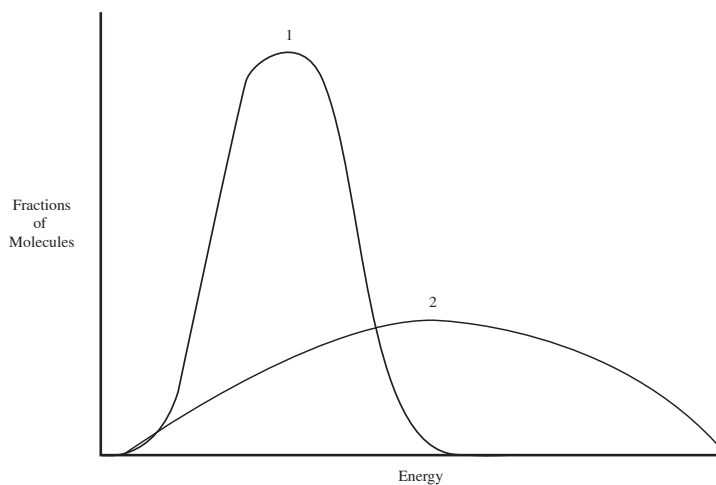
6. Use your knowledge of kinetics to answer the following questions. Justify your answers.

(a)



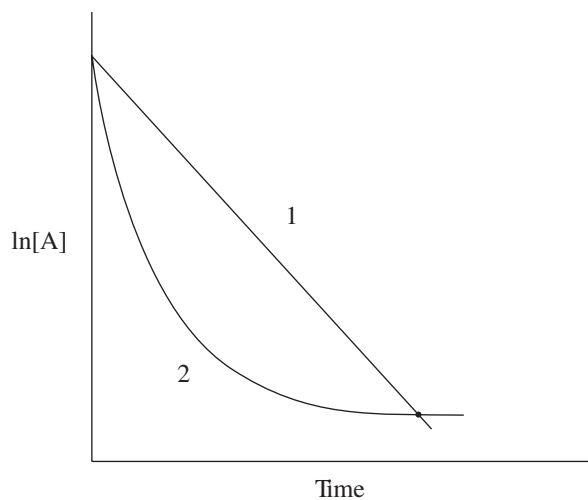
The two lines in the diagram above show different reaction pathways for the same reaction. Which of the two lines shows the reaction when a catalyst has been added?

(b)

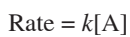


Which of the two lines in the energy distribution diagram shows the conditions at a higher temperature?

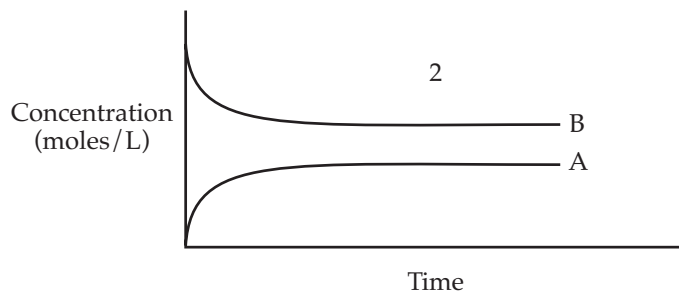
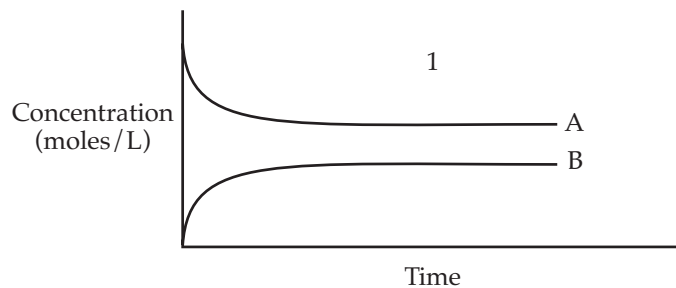
(c)



Which of the two lines in the diagram above shows the relationship of  $\ln[A]$  to time for a first order reaction with the following rate law?



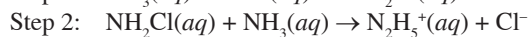
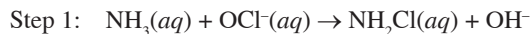
(d)



Which of the two graphs above shows the changes in concentration over time for the following reaction?



7. Hydrazine ( $\text{N}_2\text{H}_4$ ) can be produced commercially via the Raschig process. The following is a proposed mechanism:



- (a) (i) What is the equation for the overall reaction?  
(ii) Identify any catalysts or intermediates from the reaction mechanism.
- (b) The rate law for the reaction is determined to be  $\text{rate} = k[\text{NH}_3][\text{OCl}^-]$
- (i) Which elementary step is the slowest one? Justify your answer.  
(ii) If the reaction is measured over the course of several minutes, what would the units of the rate constant be?
8. The reaction between crystal violet (a complex organic molecule represented by  $\text{CV}^+$ ) and sodium hydroxide is as follows:



As the crystal violet is the only colored species in the reaction, a spectrophotometer calibrated to a specific wavelength can be used to determine its concentration over time. The following data was gathered:

| $[\text{CV}^+]$ (M)  | Time (s) |
|----------------------|----------|
| $5.5 \times 10^{-5}$ | 0        |
| $3.8 \times 10^{-5}$ | 60       |
| $2.6 \times 10^{-5}$ | 120      |
| $1.8 \times 10^{-5}$ | 180      |

- (a) (i) What is the rate of disappearance for crystal violet from  $t = 60$  s to  $t = 120$  s?  
(ii) If the solution placed in the spectrophotometer 30 s after mixing instead of immediately after mixing, how would that affect the calculated rate of disappearance for crystal violet in part (i)?
- (b) Given the path length of the cuvette is 1.00 cm and the molar absorptivity of the solution is  $26,000 \text{ cm}^{-1}\text{M}^{-1}$  at the wavelength of the spectrophotometer, what would the absorbance reading on the spectrophotometer be at  $t = 60$  s?

- (c) This reaction is known to be first order with respect to crystal violet. On the provided axes, graph a function of  $[CV^+]$  vs. time that will provide you with a straight line graph.



The following data was also gathered over the course of three experiments:

| Experiment | $[CV^+]_{\text{init}} (M)$ | $[OH^-]_{\text{init}} (M)$ | Initial rate of formation of CVOH (M/s) |
|------------|----------------------------|----------------------------|-----------------------------------------|
| 1          | $5.5 \times 10^{-5}$       | 0.12                       | $3.60 \times 10^{-7}$                   |
| 2          | $5.5 \times 10^{-5}$       | 0.24                       | $7.20 \times 10^{-7}$                   |
| 3          | $4.1 \times 10^{-5}$       | 0.18                       | ?                                       |

- (d) Write the rate law for this reaction.  
(e) What is the rate constant,  $k$ , for this reaction? Include units in your answer.  
(f) Determine the initial rate of formation of CVOH for experiment 3.