

18

REACTION RATES AND EQUILIBRIUM

Practice Problems

In your notebook, solve the following problems.

SECTION 18.1 RATES OF REACTION

- List three ways that reaction rates can generally be increased.
- Ethyl acetate ($C_4H_8O_2$) reacts with a solution of sodium hydroxide (NaOH) in water to form sodium acetate ($C_2H_3O_2Na$) and ethyl alcohol (C_2H_6O). Suppose at $25^\circ C$ two moles of ethyl acetate react completely in four hours. How would you express the rate of reaction?
- How would the following actions likely change the rate of the reaction in problem 2?
 - the temperature is lowered to $4^\circ C$.
 - the concentration of sodium hydroxide in water is increased.
- Ethyl acetate and water are not miscible; thus, the reaction in problem 2 only occurs at the interface of the two liquids. What would be the effect on the reaction rate of adding a solvent to make the reaction homogeneous?

SECTION 18.2 REVERSIBLE REACTIONS AND EQUILIBRIUM

- Write the expression for the equilibrium constant for this reaction:

$$2N_2O_5(g) \rightleftharpoons 4NO_2(g) + O_2(g)$$
- Calculate the equilibrium constant for the reaction in problem 1 if the equilibrium concentrations are $[N_2O_5] = 0.50 \text{ mol/L}$, $[NO_2] = 0.80 \text{ mol/L}$, $[O_2] = 0.20 \text{ mol/L}$.
- How would the equilibrium position for the equation in problem 1 be affected by
 - an addition of O_2 to the reaction vessel?
 - a decrease in the pressure?

- The equilibrium constant for the reaction of nitrogen dioxide to form dinitrogen tetroxide is 5.6.

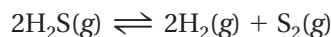
$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

In a one-liter container, the amount of N_2O_4 , at equilibrium, is 0.66 mol. What is the equilibrium concentration of NO_2 ?

- Write the equilibrium constant expression for each of the following reactions.

<ol style="list-style-type: none"> $4NO(g) + 2O_2(g) \rightleftharpoons 2N_2O_4(g)$ $2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$ 	<ol style="list-style-type: none"> $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$
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- What effect would an increase in pressure have on the equilibrium position of each reaction in problem 5?

- Which value of K_{eq} indicates most favorably for product formation, $K_{\text{eq}} = 1 \times 10^{12}$, $K_{\text{eq}} = 1.5$, or $K_{\text{eq}} = 5.6 \times 10^{-4}$?
- Hydrogen sulfide gas decomposes into its elements and establishes an equilibrium at 1400 °C.



A liter of this gas mixture at equilibrium contains 0.18 mol H_2S , 0.014 mol H_2 , and 0.035 mol S_2 . Calculate the equilibrium constant, K_{eq} , for this reaction.

SECTION 18.3 SOLUBILITY EQUILIBRIUM

- Write the solubility product expression for **a.** $\text{Ca}(\text{OH})_2$ and **b.** Ag_2CO_3 .
- What is the concentration of silver ions in a saturated solution of silver carbonate? The K_{sp} of Ag_2CO_3 is 8.1×10^{-12} .
- The equilibrium concentration of hydroxide ions in a saturated solution of iron(II) hydroxide is $1.2 \times 10^{-5}M$ at a certain temperature. Calculate the K_{sp} of $\text{Fe}(\text{OH})_2$ at this temperature.
- Strontium carbonate has a $K_{\text{sp}} = 9.3 \times 10^{-10}$ at 25°C. What is the concentration of strontium ions in a saturated solution of SrCO_3 ?
- What is the equilibrium concentration of silver ions at 25°C in a 1.0-L saturated solution of silver carbonate to which 0.20 mol of Na_2CO_3 has been added? The K_{sp} of Ag_2CO_3 is 8.1×10^{-12} at 25°C.
- Will a precipitate of PbSO_4 form when 400.0 mL of 0.0050M MgSO_4 is mixed with 600.0 mL of 0.0020M $\text{Pb}(\text{NO}_3)_2$? The K_{sp} of $\text{PbSO}_4 = 6.3 \times 10^{-7}$.
- Will precipitation of CaCO_3 occur when 500.0 mL of $4.2 \times 10^{-3}M$ CaCl_2 is mixed with 500.0 mL of $2.6 \times 10^{-3}M$ Na_2CO_3 ? The K_{sp} of CaCO_3 is 4.5×10^{-9} .
- Which of these compounds would not decrease the solubility of $\text{Mg}(\text{OH})_2$ when added to a saturated solution of the compound?

NaOH , MgCl_2 , NaCl , KOH

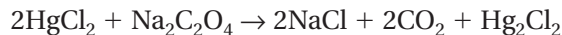
SECTION 18.4 ENTROPY AND FREE ENERGY

- When gently warmed, the element iodine will sublime:

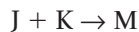
$$\text{I}_2(s) \rightarrow \text{I}_2(g)$$
 Is this process accompanied by an increase or decrease in entropy?
- Does entropy increase or decrease when air is cooled and liquefied (changed from a gas to a liquid)?
- Is the degree of disorder increasing or decreasing in these reactions?
 - $\text{H}_2(g) + \text{Br}_2(l) \rightarrow 2\text{HBr}(g)$
 - $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(s) \rightarrow \text{CuSO}_4(s) + 5\text{H}_2\text{O}(g)$
 - $2\text{XeO}_3(s) \rightarrow 2\text{Xe}(g) + 3\text{O}_2(g)$
- Classify each of these systems as always spontaneous (A), never spontaneous (N), or depends on the relative magnitude of the heat and entropy changes (D).
 - entropy decreases, heat is released
 - entropy decreases, heat is absorbed
 - entropy increases, heat is absorbed
 - entropy increases, heat is released

SECTION 18.5 THE PROGRESS OF CHEMICAL REACTIONS

- A first-order reaction has an initial reaction rate of $2.4 \text{ mol}/(\text{L}\cdot\text{s})$. What is the rate when one eighth the starting materials remain?
- It has been experimentally determined that the rate law for the reaction between mercury(II) chloride and sodium oxalate is third-order overall and first-order with respect to HgCl_2 . Write the rate law for this reaction.



- A combination reaction gave the following data. What is the rate law for this reaction?



Initial Concentration (mol/L)		Initial Rate (mol/L·s)
[J]	[K]	
0.30	0.50	0.080
0.60	0.50	0.160
0.60	0.25	0.080

- Iodide ion catalyzes the decomposition of hydrogen peroxide. The reaction is first-order in H_2O_2 . What is the value of the rate constant, k , if the initial rate is $0.00842 \text{ mol}/(\text{L}\cdot\text{s})$?

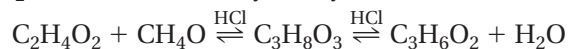
The initial concentration of H_2O_2 is 0.500 mol/L .



- A proposed reaction mechanism has two intermediates. How many elementary reactions are in this mechanism?
- The reaction $\text{A} + \text{B} \rightarrow \text{C}$ is first-order in A and B, second-order overall. Complete the following table:

Initial Concentration (mol/L)		Initial Rate (mol/L·s)
[A]	[B]	
0.50	0.50	0.020
0.50		0.040
0.25	1.0	

- The condensation of acetic acid ($\text{C}_2\text{H}_4\text{O}_2$) with methanol (CH_3O) to form methyl acetate ($\text{C}_3\text{H}_6\text{O}_2$) and water is catalyzed by HCl.



- How many elementary reactions are there in this condensation?
- Write the formula for the reaction intermediate(s).
- Write the rate law for this condensation.