# Equilibrium Constant Practice Problems

**1. Write equilibrium expressions for the following reactions.**

a. $NH_4HS(g) \leftrightarrow NH_3(g) + H_2S(g)$

$$K_{eq} = \frac{[NH_3][H_2S]}{[NH_4HS]}$$

b. $4HCl(g) + O_2(g) \leftrightarrow 2Cl_2(g) + 2H_2O(g)$

$$K_{eq} = \frac{[Cl_2]^2[H_2O]^2}{[HCl]^4[O_2]}$$

c. $PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$

$$K_{eq} = \frac{[Cl_2][PCl_3]}{[PCl_5]}$$

d. $CuSO_4{\cdot}3H_2O(s) + 2H_2O(g) \leftrightarrow CuSO_4{\cdot}5H_2O(s)$

$$K_{eq} = \frac{1}{[H_2O]^2}$$

**2. At 793 K, the equilibrium constant for the reaction $NCl_3(g) + Cl_2(g) \leftrightarrow NCl_5(g)$ is 39.3.**

a. Do products or reactants dominate in this equilibrium?

Products dominate ($K_{eq} > 1$)

b. If the equilibrium constant for this reaction were less than 1, would the reactants or products be dominant?

Reactants dominate ($K_{eq} < 1$)

**3. At 773 K, the reaction $2NO(g) + O_2(g) \leftrightarrow 2NO_2(g)$ produces the following concentrations: $[NO] = 3.49\times10^{-4}M$; $[O_2] = 0.80M$; $[NO_2] = 0.25M$.**

a. What is the equilibrium constant expression for the reaction?

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]}$$

b. What is the equilibrium constant for the reaction?

$$K_{eq} = \frac{[0.25]^2}{[3.49\times10^{-4}]^2[0.80]} = 6.4\times10^5$$

**4. If you wished to maximize the products of the following reactions, which concentrations would you lower or raise?**

a. $H_2(g) + Br_2(g) \leftrightarrow 2HBr(g)$

$$K_{eq} = \frac{[HBr]^2}{[H_2][Br_2]}$$

- Add $H_2$ or $Br_2$

or

- Remove $HBr$

b. $CO_2(g) + H_2(g) \leftrightarrow CO(g) + H_2O(g)$

$$K_{eq} = \frac{[H_2O][CO]}{[CO_2][H_2]}$$

- Add $CO_2$ or $H_2$

or

- Remove $CO$ or $H_2O$

c. $SO_2(g) + NO_2(g) \leftrightarrow SO_3(g) + NO(g)$

$$K_{eq} = \frac{[SO_3][NO]}{[SO_2][NO_2]}$$

- Add $SO_2$ or $NO_2$

or

- Remove $SO_3$ or $NO$

d. $C(s) + CO_2(g) \leftrightarrow 2CO(g)$

$$K_{eq} = \frac{[CO]^2}{[C][CO_2]}$$

- Add $CO_2$

or

- Remove $CO$

5. **For each reaction, state whether increasing or decreasing the volume of the reaction vessel would yield more product at equilibrium. Give the reason for your choice.**

a. $N_2O_4(g) \leftrightarrow 2NO_2(g)$

$K_{eq} = \frac{[NO_2]^2}{[N_2O_4]}$

↑ Volume = ↑ $NO_2$

(Pressure ↓ = More moles)

b. $2SO_3(g) \leftrightarrow 2SO_2(g) + O_2(g)$

$K_{eq} = \frac{[SO_2]^2[O_2]}{[SO_3]^2}$

↑ Volume = ↑ $SO_2$ ; ↑ $O_2$

(Pressure ↓ = More moles)

c. $CH_4(g) + 2O_2(g) \leftrightarrow CO_2(g) + 2H_2O(g)$

$K_{eq} = \frac{[CO_2][H_2O]^2}{[CH_4][O_2]^2}$

(No effect = Same # moles on both sides)

d. $2CO(g) + O_2(g) \leftrightarrow 2CO_2(g)$

$K_{eq} = \frac{[CO_2]^2}{[CO]^2[O_2]}$

↓ Volume = ↑ $CO_2$

(Pressure ↑ = Less moles)

6. **What effect would an increase in temperature have on these reactions at equilibrium? Why?**

a. Heat + $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$

↑ Temp. = Favors forward rxn

(Right consumes heat = Less stress)

b. $CH_4(g) + 2O_2(g) \leftrightarrow CO(g) + 2H_2O$ + heat

↑ Temp. = Favors reverse rxn

(Left consumes heat = Less stress)

c. $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$ + heat

↑ Temp. = Favors reverse rxn

(Left consumes heat = Less stress)

d. Heat + $CH_4(g) \leftrightarrow C(s) + 2H_2(g)$

↑ Temp. = Favors forward rxn

(Right consumes heat = Less stress)

**7. Phosphorous pentachloride decomposes to phosphorous trichloride according to this equation: $PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$. At equilibrium, $[PCl_5] = 1.00M$ and $[Cl_2] = 3.16\times10^{-2}M$.**

a. Write the expression for determining the concentration of $PCl_3$.

$$K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]} \rightarrow [PCl_3] = K_{eq}\left(\frac{[PCl_5]}{[Cl_2]}\right)$$

b. What is the equilibrium concentration of $PCl_3$? Use: $K_{eq} = 1.00\times10^{-3}$.

$$[PCl_3] = (1.00\times10^{-3})\left(\frac{1.00}{3.16\times10^{-2}}\right) = 3.16\times10^{-2} M$$

**8. The solubility product constant ($K_{sp}$) of $Ag_2SO_4$ is $1.2\times10^{-5}$.** $Ag_2SO_4(s) \leftrightarrow 2Ag^+(aq) + SO_4^{-2}(aq)$

a. How would you estimate the molar solubility of $SO_4^{2-}$ without actually calculating it?

$K_{sp} = [Ag^+]^2[SO_4^{-2}] = 1.2\times10^{-5}$

Cube root = $10^{-1}$ or $10^{-2}$

b. What is the calculated molar solubility of $SO_4^{2-}$? $2\,Ag^+ : 1\,SO_4^{-2} \rightarrow S = 2s$

#1 Substitute terms into Ksp (solve for s)

#2 $K_{sp} = (2s)^2(s) = 4s^3 = 1.2\times10^{-5}$

$s^3 = 3.0\times10^{-6}$

$s = 1.4\times10^{-2} = [SO_4^{-2}]$