Chapter 18
Practice Test

1. Reactions that may proceed in a forward or reverse reaction are called _____reversible_____ reactions. They eventually reach a point where the forward and reverse reactions occur at the same _____rate_____. This point is called _____equilibrium_____. Once the reactions reach this point, the _____concentrations_____ of reactants and products become _____constant_____, but rarely equal.

2. An _____equilibrium expression_____ is a ratio of products to reactants at _____equilibrium_____. Its value is represented by the symbol _____K_eq_____. The ratio is expressed by placing the _____concentrations of products_____ in the numerator and the _____concentrations of reactants_____ in the denominator. The _____coefficients_____ from the balanced equation are used as _____exponents_____. Because their concentrations never change at a given temperature, _____solids_____ and _____liquids_____ are not included in the _____equilibrium expression_____.

3. Write the equilibrium expression for each of the following unbalanced equations.
   a. \( \text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{HCl}(\text{g}) \)
   b. \( \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \)
   c. \( \text{S}_8(\text{s}) + 8\text{O}_2(\text{g}) \rightleftharpoons 8\text{SO}_2(\text{g}) \)
   d. \( \text{NH}_4\text{NO}_2(\text{s}) \rightleftharpoons \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \)

4. From the data provided below, calculate the value of the equilibrium constant for the reaction.
   a. \( \text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{HCl}(\text{g}) \); \([\text{H}_2] = [\text{Cl}_2] = 1.0 \times 10^{-2} \); \([\text{HCl}] = 1.0 \times 10^{-4} \)
   b. \( \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \); \([\text{N}_2] = 4.4 \times 10^{-2} \); \([\text{H}_2] = 1.2 \times 10^{-1} \); \([\text{NH}_3] = 3.4 \times 10^{-3} \)

5. To check if reaction has reached equilibrium a _____reaction quotient_____, represented by the symbol _____Q_____, may be calculated. If _____Q < K_eq_____, then the reaction will continue to proceed forward, if _____Q > K_eq_____, the reaction will proceed in reverse, and if _____Q = K_eq_____, the reaction is at equilibrium.

6. For the reaction \( \text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g}) \), \( K_{eq} = 0.2 \). At a particular time, the following concentrations are measured; \( [\text{N}_2\text{O}_4] = 2.0 \, \text{M} \), \( [\text{NO}_2] = 0.2 \, \text{M} \). Is this reaction at equilibrium? If not, in which direction will the reaction proceed?

7. For the reaction \( 2\text{ICl}(\text{g}) \rightleftharpoons \text{I}_2(\text{g}) + \text{Cl}_2(\text{g}) \), \( K_{eq} = 0.11 \). At a particular time, the following concentration are measured; \( [\text{ICl}] = 2.5\, \text{M} \), \( [\text{I}_2] = 2.0\, \text{M} \), \( [\text{Cl}_2] = 1.2\, \text{M} \). Is this reaction at equilibrium? If not, in which direction will the reaction proceed?
8. Name the 3 stresses that may be applied to a chemical equilibrium to cause it to shift.
   - temperature
   - pressure or volume
   - concentration

   When a system at equilibrium is subjected to a stress (a change in concentration, temperature, or pressure), the equilibrium will shift in the direction that tends to counteract the effect of the stress.

10. For the reaction below, mark whether the stress listed will cause the reaction to move forward or in reverse.
    \[ \text{Zn(s) + 2HCl(l) \rightleftharpoons ZnCl}_2(l) + H}_2(g); \Delta H = -235kJ \]
    a. Increase Heat
    b. Increase Pressure
    c. Increase [H\textsubscript{2}]
    d. Increase [Zn]
    e. Increase [ZnCl\textsubscript{2}]
    f. Increase [HCl]
    g. Decrease [HCl]
    h. Decrease [ZnCl\textsubscript{2}]
    i. Decrease [H\textsubscript{2}]
    j. Decrease Pressure
    k. Decrease Heat

11. What is the common-ion effect? Shift in equilibrium that occurs because the concentration of an ion that is part of the equilibrium is changed. For example, if you dissolve MgCl\textsubscript{2} in water, this is what happens:
    \[ \text{MgCl}_2(s) \rightleftharpoons \text{Mg}^{2+}(aq) + 2\text{Cl}^-(aq) \]
    Ions of both Mg\textsuperscript{2+} and Cl\textsuperscript{-} would be floating around in the water. If you then add a second solution that has NaCl [NaCl(s) \rightleftharpoons Na\textsuperscript{+}(aq) + Cl\textsuperscript{-}(aq)], the added Cl\textsuperscript{-} would cause the above reaction to shift in reverse and MgCl\textsubscript{2}(s) would precipitate out of the solution. The “common ion” affects the equilibrium of one of the reactions (LeChatelier’s Principle).

12. Solution formation also reaches a dynamic equilibrium. The formation of a solution can be described using a dissociation equation. In these equations, the reactant is always a solid and the products are always aqueous ions. The solubility of a substance can be described using a solubility product expression, which is just an equilibrium expression for a dissolution reaction. In these expressions there will never be a denominator. Like K\textsubscript{sp}, the value of K\textsubscript{sp} is temperature dependent.

13. Write the balanced dissociation equations for the following salts.
    a. CaCl\textsubscript{2} \[ \text{CaCl}_2(s) \rightleftharpoons \text{Ca}^{2+}(aq) + 2\text{Cl}^-(aq) \]
    b. (NH\textsubscript{4})\textsubscript{2}SO\textsubscript{4} \[ (\text{NH}_4)_2\text{SO}_4(s) \rightleftharpoons 2\text{NH}_4^+(aq) + \text{SO}_4^{2-}(aq) \]
    c. Na\textsubscript{2}I \[ \text{Na}_2\text{I}(s) \rightleftharpoons \text{Na}^+(aq) + \text{I}^-(aq) \]
    d. Al(NO\textsubscript{3})\textsubscript{3} \[ \text{Al(NO}_3)_3(s) \rightleftharpoons \text{Al}^{3+}(aq) + 3\text{NO}_3^-(aq) \]

14. Q\textsubscript{sp} is called the solubility product. If Q\textsubscript{sp} > K\textsubscript{sp}, the solution is supersaturated. If Q\textsubscript{sp} < K\textsubscript{sp}, the solution is unsaturated. If Q\textsubscript{sp} = K\textsubscript{sp}, the solution is saturated.

15. Write the dissociation equations and solubility product expressions for the following:
    a. SrSO\textsubscript{4} \[ \text{SrSO}_4(s) \rightleftharpoons \text{Sr}^{2+}(aq) + \text{SO}_4^{2-}(aq) \]
    \[ K\textsubscript{sp} = [\text{Sr}^{2+}][\text{SO}_4^{2-}] \]
    b. Al\textsubscript{2}(SO\textsubscript{4})\textsubscript{3} \[ \text{Al}_2(\text{SO}_4)_3(s) \rightleftharpoons 2\text{Al}^{3+}(aq) + 3\text{SO}_4^{2-}(aq) \]
    \[ K\textsubscript{sp} = [\text{Al}^{3+}]^2[\text{SO}_4^{2-}]^3 \]

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16. A sample of PbBr$_2$(s) is added to pure water and allowed to come to equilibrium at 25°C. The concentration of Pb$^{2+}$ is 0.0118M at equilibrium. What is the value of $K_{sp}$ for PbBr$_2$? (6.60 x 10$^{-6}$)

\[
PbBr_2 (s) \leftrightarrow Pb^{2+} (aq) + 2Br^- (aq)
\]

$K_{sp} = [Pb^{2+}][Br^-]^2$

The concentrations of Br$^-$ will be 2x the concentration of Pb$^{2+}$ because the mole ratio of Br$^-$ to Pb$^{2+}$ is 2:1

$K_{sp} = [0.0118][0.0236]^2$

$Ksp = 6.6 \times 10^{-6}$

17. A sample of BaSO$_4$(s) is added to pure water and allowed to come to equilibrium at 25°C. The concentration of Ba$^{2+}$ is 1.05 x 10$^{-5}$M at equilibrium. What is the value of $K_{sp}$ for BaSO$_4$? (1.1 x 10$^{-10}$)

\[
BaSO_4(s) \leftrightarrow Ba^{2+}(aq) + SO_4^{2-}(aq)
\]

$K_{sp} = [Ba^{2+}][SO_4^{2-}]$

The concentrations of Ba$^{2+}$ and SO$_4^{2-}$ will be equal because their mole ratio is 1:1

$K_{sp} = [1.05 \times 10^{-5}][1.05 \times 10^{-5}]$

$Ksp = 1.10 \times 10^{-10}$

18. What will be the equilibrium concentration of dissolved ions in a saturated solution of Pb(OH)$_2$ at 25°C? $K_{sp}$ for the reaction is 1.2 x 10$^{-15}$. ([Pb$^{2+}$] = 6.69 x 10$^{-6}$M and [OH$^-$] = 1.34 x 10$^{-4}$M)

\[
Pb(OH)_2(s) \leftrightarrow Pb^{2+}(aq) + 2OH^-(aq)
\]

$K_{sp} = [Pb^{2+}][OH^-]^2$

Setting the concentration of Pb$^{2+}$ to $x$, and the concentration of OH$^-$ to 2x, (the mole ratio of Pb$^{2+}$ to OH$^-$ is 1:2), we get the following:

$$1.2 \times 10^{-15} = [x][2x]^2$$
$$1.2 \times 10^{-15} = 4x^3$$
$$3.0 \times 10^{-16} = x^3$$
$$6.69 \times 10^{-6} = x$$

So, [Pb$^{2+}$] is 6.69 x 10$^{-6}$M and [OH$^-$] would be twice that or 1.34 x 10$^{-5}$M.

19. What will be the equilibrium concentration of dissolved ions in a saturated solution of SrSO$_4$ at 25°C? $K_{sp}$ for the reaction is 3.44 x 10$^{-7}$. ([Sr$^{2+}$] = [SO$_4^{2-}$] = 5.87 x 10$^{-4}$M)

\[
SrSO_4(s) \leftrightarrow Sr^{2+}(aq) + SO_4^{2-}(aq)
\]

$K_{sp} = [Sr^{2+}][SO_4^{2-}]$

Setting the concentration of Sr$^{2+}$ to $x$, and the concentration of SO$_4^{2-}$ also to $x$, (the mole ratio of Sr$^{2+}$ to SO$_4^{2-}$ is 1:1), we get the following:

$$3.44 \times 10^{-7} = [x][x]$$
$$3.44 \times 10^{-7} = x^2$$
$$5.87 \times 10^{-4} = x$$

So, [Sr$^{2+}$] is 5.87 x 10$^{-4}$M and [SO$_4^{2-}$] would be the same.