LESSON 121 CLASSWORK

# How Balanced Equilibrium Calculations

Name ____________________

Date __________ Period ______

## Purpose

To explore how the total acid concentration, the $H^+$ and $A^-$ concentrations, and the value of K are related to one another.

## Part 1: Equilibrium Constant Equation

Use the data in the table to answer the questions below. Remember that the brackets, [ ], indicate concentrations in mol/L the equilibrium mixture.

| # | Solution | Formula | Solution molarity | [HA] | $[H^+]$ | $[A^-]$ | *K* | pH |
|---|---|---|---|---|---|---|---|---|
| 1 | Hydrochloric acid | HCl | 0.10 M | ~0 M | 0.10 M | 0.10 M | 40 | 1.0 |
| 2 | Nitric acid | $HNO_3$ | 0.10 M | ~0 M | 0.10 M | 0.10 M | 200 | 1.0 |
| 3 | Nitrous acid | $HNO_2$ | 0.10 M | 0.093 M | 0.0072 M | 0.0072 M | 0 00056 | 2.1 |
| 4 | Formic acid | HCOOH | 0.10 M | 0.096 M | 0.0042 M | 0.0042 M | 0.00018 | 2.4 |
| 5 | Benzoic acid | $C_6H_5COOH$ | 0.10 M | 0.098 M | 0.0024 M | 0.0024 M | 0.000063 | 2.6 |
| 6 | Acetic acid | $CH_3COOH$ | 0.10 M | 0.099 M | 0.0013 M | 0.0013 M | 0.000018 | 2.9 |
| 7 | Hydrogen sulfide | $H_2S$ | 0.10 M | 0.10 M | 0.00010 M | 0.00010 M | $1.0\times10^{-7}$ | 4.0 |
| 8 | Hypochlorous acid | HOCl | 0.10 M | 0.10 M | 0.000054M | 0.000054M | $3.0\times10^{-8}$ | 4.3 |

1. Why are the concentrations of cations and ions in each solution equal to one another?

2. Explain why $[H^+]$ is equal to the solution molarity for acids #1 and #2.

3. Explain why [HA] is approximately equal to the solution concentration for all acids except for #1 and #2.

## Part 2: Calculating K for the dissolution a weak acid in water

The equation below relates the equilibrium constant, *K*, and the concentrations of HA, $H^+$, and $A^-$ in an equilibrium mixture of a weak acid dissolved in water.

$$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$$

$$K = \frac{[H^+][A^-]}{[HA]}$$

$[H^+]$ at equilibrium is known by measuring the pH.

$[A^-] = [H^+]$ for a weak acid dissolved in water. For every $H^+$ ion, there is one $A^-$ ion.

[HA] ≈ solution molarity. The equilibrium concentration of HA is approximately equal ("≈")

**1.** Use the values given in the table from Part 1 to answer these questions for solution #5, benzoic acid.

**a.** Write the chemical equation for the reversible dissociation of benzoic acid, $C_6H_5COOH$.

**b.** What is the value of $[H^+]$?

**c.** What is the value of $[A^-] = [C_6H_5COO^-]$?

**d.** What is the value of $[HA] = [C_6H_5COOH]$?

**e.** Is [HA] ≈ the solution molarity?

**f.** Plug these values into the equilibrium constant equation to calculate *K*. You can use the solution molarity for [HA].

$$K = \frac{[H^+][A^-]}{[HA]}$$

2. Use the values given in the table from Part I to answer the questions for solution #8, hypochlorous acid.

**a**. Write the chemical equation for the reversible dissociation of hypochlorous acid , HOCl.

**b**. What is the value of $[H^+]$?

**c.** What is the value of $[A^-] = [NO^{2-}]$?

**d**. What is the value of [HA]?

**e.** Plug these values into the equilibrium constant equation to calculate *K*.

$$K = \frac{[H^+][A^-]}{[HA]}$$

## Part 3: Using K to calculate the pH value

The equilibrium constant equation can be rearranged to solve for the pH of a weak acid, HA, dissolved in water.

$$K = \frac{[H^+][A^-]}{[HA]}$$

For an acid dissolved in water: $[H^+] = [A^-]$

Substitute for [A-]:

$$K = \frac{[H^+]^2}{[HA]}$$

Solve for $[H^+]$:

$$[H^+]^2 = K[HA]$$

$$[H^+] = \sqrt{K[HA]}$$

$$pH = -\log[H^+]$$

1. Consider 0.010 M acetic acid, $CH_3COOH$.

   a. How do you expect the pH to compare to the value for 0.10 M acetic acid given in the table above?

   b. What value for *K* should you use to calculate the pH of 0.010 M $CH_3COOH$?

   c. What is the $H^+$ concentration in a 0.010 M acetic acid, $CH_3COOH$, solution? (Hint: use the equation on the previous page to solve for $H^+$.)

   d. What is pH?

2. **Making Sense** What values are related by the equilibrium constant equation for the dissociation of a weak acid?