9.3: Equilibrium Applications (Exercises)

These are homework exercises to accompany Chapter 9 of the University of Kentucky's LibreText for CHE 103 - Chemistry for Allied Health. Answers are below the questions.

Questions

9.1: Acid and Base Strength

(click here for solutions)

Q9.1.1

Describe the difference between a strong acid and a weak acid.

Q9.1.2

Describe the difference between a strong base and a weak base.

Q9.1.3

Identify each of the following as a strong acid, weak acid, strong base, or weak base.

a. HCl
b. NaOH
c. KOH
d. HNO_2
e. HNO_3
f. HF
g. NH_3
h. $Ba(OH)_2$
i. CH_3CH_2COOH

Q9.1.4

Write an equation representing the behavior of each substance in question 3. Pay attention to the type of arrow used in the equation.

Q9.1.5

A solution is prepared by dissolving 15.0 grams of NaOH in enough water to make 500.0 mL of solution. Calculate the pH of the solution.

Q9.1.6

A solution is prepared by dissolving 22.0 grams of HCl in enough water to make 300.0 mL of solution. Calculate the pH of the solution.

9.2: Buffers

(click here for solutions)

Q9.2.1

What is a buffer?

Q9.2.2

What is the purpose of a buffer?

Q9.2.3

Determine whether or not each of these pairs can act as a buffer.

a. HCl/Cl^-
b. HF/F^-
c. H_2SO_4/HSO_4^-
d. HSO_4^-/SO_4^{2-}

e. H_2O/NaOH
f. HNO_2/KNO_2
g. HCl/NaOH

Q9.2.4

Write the formula of the conjugate base needed to form a buffer with each of the following weak acids.

a. $HClO_3$
b. $H_2PO_4^-$
c. CH_3COOH

Q9.2.5

Write the formula of the conjugate acid needed to form a buffer with each of the following weak bases.

a. NH_3
b. CH_3NH_2

Q9.2.6

Describe buffer capacity.

Answers

9.1: Acid and Base Strength

Q9.1.1

A strong acid completely dissociates into ions and a weak acid doesn't completely dissociate into ions.

Q9.1.2

A strong base is a base (metal with an -OH) group that dissociates completely into ions. A weak base is a proton acceptor but not ll of the molecules will accept a proton.

Q9.1.3

Identify each of the following as a strong acid, weak acid, strong base, or weak base.

a. HCl is a strong acid. See list of 6 strong acids.
b. NaOH is a strong base. It has a metal with an -OH group.
c. KOH is a strong base. It has a metal and an -OH group.
d. HNO_2 is a weak acid. The formula starts with H but it's not water so it's an acid. Recognize it is weak because it is not on the list of 6 strong acids.
e. HNO_3 is a strong acid. The formula starts with H but it's not water so it's an acid. See the list of 6 strong acids.
f. HF is a weak acid. the formula starts with H but it's not water so it's an acid. Recognize it is weak becauce it is not on the list of 6 strong acids.
g. NH_3 is a weak base. Amines are weak bases.
h. $Ba(OH)_2$ is a strong base. It has a metal with an -OH group.
i. CH_3CH_2COOH is a weak base. It has a carboxylic acid functional group so it's an acid. Carboxylic acids are all weak (also, not on the list of 6 strong acids).

Q9.1.4

Write an equation representing the behavior of each substance in question 3. Pay attention to the type of arrow used in the equation.

a. $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$
b. $NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$
c. $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$
d. $HNO_2(aq) \rightleftharpoons H^+(aq) + NO_2^-(aq)$
e. $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
f. $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$
g. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

h. $Ba(OH)_2(aq) \rightarrow Ba^{2+}(aq) + 2OH^{-}(aq)$
i. $CH_3CH_2COOH(aq) \rightleftharpoons H^{+}(aq) + CH_3CH_2COO^{-}(aq)$

Q9.1.5

NaOH is a strong base and completely dissociates (see reaction). Since it completely dissociates, the concentration of NaOH equals the concentration of OH^-. We need to calculate the concentration of NaOH.

$NaOH(aq) \rightarrow Na^{+}(aq) + OH^{-}(aq)$

$15.0\ g\ \text{NaOH} \left(\frac{1\ mol}{40.00\ g}\right) = 0.375\ mol\ \text{NaOH}$

$M = \frac{mol\ solute}{L\ soln} = \frac{0.375\ mol}{0.500\ L} = 0.750\ M\ NaOH$

$[NaOH] = [OH^-] = 0.750\ M$

Use $[OH^-]$ to find pOH.

$p\text{OH} = -log[\text{OH}^-] = -log[0.750] = 0.125$

Now, convert from pOH to pH. Note that 14 is an exact number in this context so it does not affect significant figures.

$p\text{H} + p\text{OH} = 14$
$p\text{H} = 14 - p\text{OH}$
$p\text{H} = 14 - 0.125$
$p\text{H} = 13.875$

Q9.1.6

HCl is a strong acid and completely dissociates (see reaction). Since it completely dissociates, the concentration of HCl equals the concentration of H^+. We need to calculate the concentration of HCl.

$HCl(aq) \rightarrow H^{+}(aq) + Cl^{-}(aq)$

$22.6\ g\ \text{HCl} \left(\frac{1\ mol}{36.46\ g}\right) = 0.603\ mol\ \text{HCl}$

$M = \frac{mol\ solute}{L\ soln} = \frac{0.603\ mol}{0.300\ L} = 2.01\ M\ HCl$

$[HCl] = [H^+] = 2.01\ M$

$p\text{H} = -log[\text{H}^+] = -log[2.01] = -0.303$ (pH can be less than zero if it is a strong acid with a concentration greater than 1 M)

9.2: Buffers

Q9.2.1

A buffer is a weak acid and its conjugate base (or a weak base and its conjugate acid) that helps maintain the pH of a solution.

Q9.2.2

The purpose of a buffer is to resist change of pH in a solution.

Q9.2.3

a. HCl/Cl^- cannot because HCl is a strong acid.
b. HF/F^- can because HF is a weak acid and F^- is its conjugate base. It will be added to mixture as a salt (ionic compound) of F^- (i.e. NaF, KF, etc)
c. H_2SO_4/HSO_4^- cannot because H_2SO_4 is a strong acid.
d. HSO_4^-/SO_4^{2-} can because HSO_4^- is a weak acid and SO_4^{2-} is its conjugate base. Both compounds will be added to the mixture as salts (i.e. $NaHSO_4$ and Na_2SO_4).
e. $H_2O/NaOH$ cannot becase NaOH is a strong base and NaOH and H_2O are not a conjugate acid-base pair.
f. HNO_2/KNO_2 can because HNO_2 is a weak acid and KNO_2 contains its conjugate base. Note that KNO_2 is a strong electrolyte so it dissociates into K^+ and NO_2^-. HNO_2 and NO_2^- form a conjugate acid-base pair.
g. HCl/NaOH cannot because HCl is a strong acid, NaOH is a strong base, and they do not form a conjugate acid-base pair.

Q9.2.4

Write the formula of the conjugate base needed to form a buffer with each of the following weak acids.

a. ClO_3^- (or a salt such as $NaClO_3$)
b. HPO_4^{2-} (or a salt such as Na_2HPO_4)
c. CH_3COO^- (or a salt such as CH_3COONa)

Q9.2.5

Write the formula of the conjugate acid needed to form a buffer with each of the following weak acids.

a. NH_4^+ (or a salt such as NH_4Cl)
b. $CH_3NH_3^+$ (or a salt such as CH_3NH_3Cl)

Q9.2.6

Buffer capacity is the amount of acid or base that can be added to a buffer solution before it can no longer resist significant changes in the pH of the solution. Adding small amounts of acid or base will change the pH of a buffer by a small amount and the buffer continues to be effective. If larger amounts of acid or base are added, the buffer capacity is reached and the solution can no longer resist changes in pH.
