WORKSHEET: SOLUTION EQUILIBRIUM (Weak acids and bases, buffers, Polyprotic acids, and Hydrolysis.)

SET A:

1. 40.00 ml of 0.350 M CH₃NH₂ is titrated with 0.280 M HCl until the end point is reached. Calculate the pH of the solution at the end point. (Kᵇ for CH₃NH₂ = 5.0 x 10⁻⁴)

Setup:

Answer: 5.74
2. How many moles of HNO₂ must be added to a 1.00 liter of 0.370 M NaNO₂ to give a buffer of pH = 4.20? (Ignore any volume change due to the addition of HNO₂) (Kₐ for HNO₂ is 4.5 x 10⁻⁴).

Setup:

Answer: 0.052 moles

3. a. Is NaHCO₃ (aq) acidic, basic, or neutral? You must show your work to justify your answer. (Kₐ₁ for H₂CO₃ = 4.3 x 10⁻⁷, Kₐ₂ for HCO₃⁻ = 4.8 x 10⁻¹¹)

Setup:

Answer: Kₐ₂ for HCO₃⁻ is larger than Kₐ₁ for HCO₃⁻. NaHCO₃ (aq) is basic.

b. Is NaHCO₃ (aq) a buffer? (You must show your work to prove that your answer is not a guess.)

Setup:

Answer: Yes
4. How many moles of NaOH must be added to a 1.00 liter of 0.230 M benzoic acid, \( \text{HC}_7\text{H}_5\text{O}_2 \), to produce a solution of pH = 4.50? (Ka for \( \text{HC}_7\text{H}_5\text{O}_2 \) = \( 6.3 \times 10^{-5} \))

Setup:

Answer: 0.15 mole

5. The \([\text{S}^2^-]\) concentration of a 0.150 M \( \text{H}_2\text{S} \) is adjusted to a value of \( 4.18 \times 10^{-8} \) moles/liter. What is the \([\text{H}^+]\) concentration?

\((\text{Ka}_1 \text{ for H}_2\text{S}= 8.9 \times 10^{-8}, \text{Ka}_2 \text{ for HS}^- \text{ is } 1.2 \times 10^{-13})\)

Setup:

Answer: \( 1.9 \times 10^{-7} \) M
6. What is the $[H^+]$ concentration of a solution made by adding 35.00 ml of 0.660 M $C_6H_5NH_2$ to 40.00 ml of 0.420 M HCl? ($K_b$ for $C_6H_5NH_2$ is $4.6 \times 10^{-7}$)

Setup:

Answer: $5.9 \times 10^{-8}$ M
7. Predict whether the following solutions are acidic, basic, or neutral. Write the equilibrium equations, and all calculations if needed, to justify your answer. (K_b for NH_3 is 1.8 \times 10^{-5}, K_a for HClO is 3.5 \times 10^{-8})

a. NH_4ClO
Setup:

Answer: K_b for ClO^- > K_a for NH_4^+, Basic

b. NaNO_2
Setup:

Answer: Basic

c. Ni(NO_3)_3
Setup:

Answer: Acidic

**SET B:**

1. How many moles of HCHO_2 must be added to a 1.00 liter of 0.400 M NaCHO_2 to give a buffer of pH=3.60? Ignore any volume change due to the addition of HCHO_2. (K_a for HCHO_2=1.8 \times 10^{-4})

Setup:

Answer: 0.55 mole
2.  a. Is Na₂HPO₄ (aq) a buffer? You must show your work to prove that your answer is not a guess.
   Setup:
   
   Answer: Yes

   b. Is Na₂HPO₄ acidic, basic, or neutral? You must show your work to justify your answer.
   Setup:
   Ka₃ for HPO₄²⁻ is 1.00 x 10⁻¹², Kₐ₂ for H₂PO₄⁻ is 6.2 x 10⁻⁸
   
   Answer: Kᵦ (for HPO₄²⁻) > Kₐ₃ (for HPO₄²⁻), Basic

3. What is the [H⁺] concentration of a solution made by titrating 30.00 ml of 0.7200 M C₆H₅NH₂ with 0.2500 M HCl until the equivalence point is reached? Kᵦ for C₆H₅NH₂ is 4.6 x 10⁻⁷.
   Setup:
   
   Answer: 6.4 x 10⁻⁵
4. Predict whether each of the following solutions is acidic, basic, or neutral. Write the equilibrium equations, and all calculations if needed, to justify your answer. $K_b$ for NH$_3$ = $1.8 \times 10^{-5}$, $K_a$ for HCHO$_2$ is $1.8 \times 10^{-4}$.

a. NH$_4$CHO$_2$
Setup:

Answer: $K_a$ (for NH$_4^+$) > $K_b$ (for CHO$_2^-$), Acidic

b. Na$_2$S
Setup:

Answer: Basic

c. Cr(NO$_3$)$_3$
Setup:

Answer: Acidic

5. The C$_6$H$_6$O$_6^{2-}$, ascorbate ion, concentration of a 0.270 M ascorbic acid, is adjusted to a value of $8.5 \times 10^{-8}$ mole/liter. What is the [H$^+$] concentration? $K_{a1}$ for H$_2$C$_6$H$_6$O$_6$ is $7.9 \times 10^{-5}$ and $K_{a2}$ for HC$_6$H$_6$O$_6^-$ is $1.6 \times 10^{-12}$.

Setup:

Answer: $2.0 \times 10^{-5}$ M
6. How many moles of NaOH should be added to a 1.00 liter of 0.190 M HNO₂ to produce a solution of pH = 4.80? Assume there is no change in volume upon the addition of NaOH. \( K_a \) for HNO₂ is \( 4.5 \times 10^{-4} \).

Setup:

Answer: 0.18 mole
7) What is the pH of a solution made by mixing 25.00 ml of 0.440 M \( \text{CH}_3\text{NH}_3\text{Cl} \) and 37.00 ml of 0.200 M NaOH? \( K_b \) for \( \text{CH}_3\text{NH}_2 \) is \( 5.0 \times 10^{-4} \).

**Setup:**

**Answer:** pH = 11.00
SET C:

1. The oxalate ion concentration, C₂O₄²⁻, of 0.20 M H₂C₂O₄ is adjusted to a value of 3.00 x 10⁻³ M. What is the [H⁺] ion concentration in the solution? Kₐ₁ for H₂C₂O₄ is 5.6 x 10⁻² and Kₐ₂ for HC₂O₄⁻ is 5.1 x 10⁻⁵.

   Setup:

   Answer: 1.4 x 10⁻² M

2. Predict whether each of the following solutions is acidic, basic, or neutral. Write the equilibrium equations, and all calculations if needed, to justify your answer. Kₐ for HClO is 3.5 x 10⁻⁸, Kₐ for NH₃ is 1.8 x 10⁻⁵.

   a. NH₄ClO

   Setup:

   Answer: Kₐ for ClO⁻ > Kₐ for NH₄⁺ . Basic

   b. KCNO

   Setup:

   Answer: Basic

   c. Ni(ClO₄)₃

   Setup:

   Answer: Acidic
3. What is the pH at the equivalence point when 27.0 ml of 0.200 M CH₃NH₂ are titrated with 0.350 M HCl?

\[ K_b \text{ for } CH₃NH₂ \text{ is } 4.4 \times 10^{-4}. \]

Setup:

Answer: 5.76
4. How many ml of 0.250 M HF (aq) must be added to 500.0 ml of 0.300 M NaF to give a buffer of pH= 3.50? $K_a$ for HF is $6.8 \times 10^{-4}$.

**Setup:**

Answer: 282 ml
5. Find the pH of a solution made by mixing 25.0 ml of 0.0650 M benzylamine, C7H7NH₂, and 13.9 ml of 0.0500 M HCl. $K_b$ for C7H7NH₂ is $4.7 \times 10^{-10}$.

Setup:
6. A chemist wants to prepare a buffer of pH = 4.35. How many milliliters of 0.455 M acetic acid must be added to 465 ml of 0.0941 M NaOH solution to obtain such a buffer? Ka for HC₂H₃O₂ is 1.7 × 10⁻⁵.

Setup:

Answer: 351 ml
7. a. Is NaHC_2O_4 (aq) a buffer? You must show your work to prove that your answer is not a guess.
   Setup: Answer: Yes

   b. Is NaHC_2O_4 (aq) acidic, basic, or neutral? K_a1 for H_2C_2O_4 is 5.6 \times 10^{-2},
      K_a2 for HC_2O_4^- is 5.1 \times 10^{-5}. You must show your work to justify your answer.
   Setup: Answer: K_a2 for HC_2O_4^- > Kb for HC_2O_4^- , Acidic