The University of Zambia
School of Natural Sciences
Chemistry Department
2020/21 ACADEMIC YEAR TERM

CHE1000 - INTRODUCTORY CHEMISTRY

TUTORIAL SHEET 11: **August 2021**

TOPIC: ACID-BASE EQUILIBRIUM, BUFFERS AND SOLUBILITY

Acid-Base Equilibrium

1. Write the dissociation reaction and the corresponding Ka equilibrium expression for each of the following acids in water.
   (i) HCN
   (ii) HOC_6H_5
   (iii) $C_6H_5NH_3^+$

2. For each of the following aqueous reactions, **identify** the acid, the base, the conjugate base, and the conjugate acid.
   (i) $H_2O + H_2CO_3 \rightleftharpoons H_3O^+ + HCO_3^-$
   (ii) $C_5H_5NH^+ + H_2O \rightleftharpoons C_5H_5N + H_3O^+$
   (iii) $HCO_3^- + C_5H_5NH^+ \rightleftharpoons H_2CO_3 + C_5H_5N$

3. At 40 ^oC the values of K_w is 2.92 $x10^{-14}$.
   (i) Calculate the $[H^+]$ and $[OH^-]$ in pure water at 40 ^oC.
   (ii) What is the pH of pure water at 40 ^oC?
   (iii) If the hydroxide ion concentration in solution is 0.10 M, what is the pH at 40^oC?
4. A student prepared 0.10M acetic acid solution and experimentally measured its pH to be 2.88. Calculate K_a for acetic acid and determine its percent dissociation.

5. Consider a weak base like, NH_3 in water:
   (i) Write the base ionization constant, K_b expression.
   (ii) Write the equation to calculate the pK_b of this base given above.
   (iii) Using the above base dissociation process, show that $K_b \times K_a = K_w$ for this base and its conjugate acid.

6. Calculate the:
   (i) pH of 1.0 $x\ 10^{-3}$M HCl solution
   (ii) percentage ionization of 0.75 M HF. $K_a = 7.2\ x10^{-4}$.
   (iii) pH of 1.5 M NaF solution. $K_a = 7.2\ x10^{-4}$.
   (iv) pH of a 0.25 M NH_3 solution. K_b of NH_3 is $1.8\ x10^{-5}$.
   (v) pH of a 0.10 M NH_4Cl solution. The K_b value for the NH_3 is 1.8×10^{-5}
   (vi) pH of 0.100M CH_3COOH solution [$K_a(CH_3COOH) = 1.8 \times 10^{-5}$].

7. Consider the following list of salts which salts are neutral, acidic, or basic?
   (i) $Al(NO_3)_3$
   (ii) $NaC_2H_3O_2$
   (iii) Predict whether the aqueous solution of NH_4CN with acidic or basic. K_a (HCN) = 4.9 x 10^{-10}; K_b (NH_3) = 1.8 x10^{-5}.
8. The following values of K_w as a function of temperature are as follows:

Temperature (^oC)	K_w
0	$1.14x10^{-15}$
25	$1.00x10^{-14}$
35	$2.09x10^{-14}$
40	$2.92x10^{-14}$
50	$5.47x10^{-14}$

   (i) Is the autoionization of water exothermic or endothermic? Explain your answer.
   (ii) Calculate $[H^+]$ and $[OH^-]$ in a neutral solution at 50 ^{o}C.

9. For propanoic acid (CH_3CH_2COOH), $K_a = 1.30\ X10^{-5}$. Determine the concentration of all species and the pH of a 0.100M solution.

10. Calculate the percentage dissociation of the acid in each of the following solutions:
   (i) 0.50 M Acetic acid
   (ii) 0.050M Acetic acid
   (iii)0.0050M Acetic acid

11. The pH of a sample of gastric juice in a person's stomach is 2.1.
   (i) Calculate the pOH, $[H^+]$, and $[OH^-]$
   (ii) The pH of a 1.00 x 10^{-2} M solution of cyanic acid (HOCN) is 2.77 at 25^{o}C. Calculate K_a for HOCN from this result.

12. Write out the stepwise K_a reactions for the diprotic acid H_2SO_3.

13. Arsenic acid (H_3AsO_4) is a triprotic acid with Kw = 5 x10^{-3}, K_{a2} = 8x10^{-8}; and K_{a3} = 6 x10^{-10}. Calculate [H+],$[OH^-]$, $[H_3AsO_4]$, $[H_2AsO_4^-]$, $[HAsO_4^{2-}]$, and $[AsO_4^{3-}]$ in 0.20M arsenic acid.

14. Phosphoric acid is common ingredient in traditional cola drinks. It is added to enhance taste. Assuming that in cola drinks the concentration of phosphoric acid is 0.007M, calculate the pH in this solution.

15. For each reaction, identify the **Lewis** acid and base
   (i) $Ni_2^+(aq) + 6NH_3(aq) \longrightarrow Ni(NH_3)_6^{2+}$
   (ii) $H^+(aq) + H_2O(aq) \rightleftharpoons H_3O^+(aq)$

Buffers

1. Calculate the pH of a solution containing 0.20M CH_3COOH and 0.30 M CH_3COONa. [K_a of $CH_3COOH = 1.8 \times 10^{-5}$]

2. What would be the pH of 0.20 M solution, if no salt was present in question (b) above?

3. How would you prepare a phosphate buffer with a pH of 7.40.

4. Calculate the pH of the following buffer solutions:
   (i) 0.10 M acetic acid /0.25M sodium acetate
   (ii) 0.25 M acetic acid/0.10 M sodium acetate

5. Consider a solution that contains both C_5H_5N and $C_5H_5NH^+NO_3^-$. Calculate the ratio $[C_5H_5N]/C_5H_5NH^+]$ if the solution has the following pH values:
   (i) pH = 4.50 (ii) pH = 5.23

6. Consider the titration of 40.0 mL of 0.200 M $HClO_4$ by 0.100 M KOH. Calculate the pH of the resulting solution after the following volumes have been added:
   (i) 0.00 mL (ii) 10.00 mL (iii) 40.0 mL

7. Explain why the equivalence point is greater than 7 in a weak acid and a strong base titration.

8. Calculate the pH in the titration of 25.0 cm^3 of 0.15 cm^3 acetic acid by NaOH after the addition of:
   (i) 10.0 ml of 0.150 M NaOH
   (ii) 35.0 ml of 0.150 M NaOH

9. Which of the following are buffer systems
   (i) KH_2PO_4/H_3PO_4
   (ii) $NaClO_4/HClO_4$
   (iii) C_5H_5NHCl/ C_5H_5N
   ($C_5H_5N=K_b=1.7x\ 10^{-9}$)
   (iv) HCO_3^-/CO_2^-
   (v) HOCl/KOCl
   (vi) H_2NNH_2/H_2NNH

Solubility Product

1. A Solution is prepared by adding 750.0 mL of 4.00×10^{-3} M $Ce(NO_3))_3$ to 300 mL of 2.00×10^{-2} M KIO_3. Will $Ce(IO_3)_3$ ($K_{sp}=1.9 \times 10^{-10}$) precipitate from this solution?

2. A solution contains 1.0×10^{-5}M Na_3PO_4 what is the minimum concentration of silver nitrate ($AgNO_3$) that would cause precipitation of solid Ag_3PO_4 ($K_{sp}= 1.8 \times 10^{-18}$)

3. The solubility of $Zn(OH)_2$ is 1.0×10^{-5} at 25 ^oC. Calculate the pH of a solution of a saturated solution of $Zn(OH)_2$ at 25 ^oC

4. What is the concentration of copper ion (Cu^+) and Iodide ions (I^-) in a saturated copper iodide (CuI) solution. $K_{sp}(CuI) = 5.1 \times 10^{-12}$).

5. Will a precipitate of Barium sulphate form when 200 cm^3 of 0.0040 M $BaCl_2$ is added to exactly 600 cm^3 of 0.0080M K_2SO_4? $K_{sp}(BaSO_4)= 1.1 \times 10^{-10}$.