Chemistry 192
Problem Set 3
Spring, 2018

1. Problem 3, page 782, textbook

2. Calculate the pH and pOH of the following solutions of strong acids or bases:

   (a) 0.0125 M $HCl_{(aq)}$
   Answer: pH=1.903, pOH=12.10

   (b) 0.0460 M $NaOH_{(aq)}$
   Answer: pOH=1.337, pH=12.66

   (c) 1.75 $\times 10^{-8}$ M $HCl_{(aq)}$
   Answer: pOH=7.04, pH=6.96

   (d) 1.75 $\times 10^{-8}$ M $NaOH_{(aq)}$
   Answer: pH=7.04, pOH=6.96

3. Problem 14, page 782, textbook
   Answer: pOH=2.297, pH=11.70

4. Problem 19, page 782, textbook
   Answer: pOH=3.796, pH=10.20

5. Problem 20, Page 782, textbook
   Answer: pOH=1.71, pH=12.29

6. Calculate the volume of a 0.100 M aqueous KOH solution that must be added to 100. ml of a 0.100 M aqueous HCl solution to obtain a solution having a pH=2.000.
   Answer: V=81.8 mL

7. Given that sodium hydroxide is a strong base, calculate the pH of an aqueous 7.5 $\times$ 10^{-8} M sodium hydroxide solution. **Answer**: 7.16

8. Calculate the pH and percent ionization of a 2.00 M aqueous HCN solution given that for the reaction

$$HCN_{(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + CN^-_{(aq)},$$

$K_a = 4.1 \times 10^{-10}$.
Answer: pH=4.54

9. The pK_a of phenol (C_6H_5OH) when acting as a weak acid in aqueous solution is 9.99. Calculate the pH of a 2.0 M phenol solution.
Answer: pH=4.84

10. When a 0.072 M aqueous solution of benzoic acid reacts

$$C_6H_5COOH_{(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + C_6H_5COO^-_{(aq)}$$

the pH is found to be 2.68. Calculate the pK_a for the reaction.
Answer: p$K_a = 4.20$

11. Formic acid (HCOOH) is a monoprotic acid with acid dissociation reaction

$$HCOOH_{(aq)} + H_2O_{(\ell)} \rightleftharpoons HCOO^-_{(aq)} + H_3O^+_{(aq)}.$$

The pH of a 1.20×10^{-3} M formic acid solution is found to be 3.41. Calculate K_a and pK_a for formic acid.
Answer: p$K_a = 3.73$

12. Dimethylamine ionizes according to the reaction

$$(CH_3)_2NH_{(aq)} + H_2O_{(\ell)} \rightleftharpoons (CH_3)_2NH^+_{2(aq)} + OH^-_{(aq)}$$

A 0.95 M solution of dimethylamine is found to have a pH of 12.32. Calculate the pK_b of the reaction.
Answer: p$K_b = 3.32$

13. Hydrofluoric acid ($HF_{(aq)}$) is formed when gas-phase hydrogen fluoride ($HF_{(g)}$) is dissolved in water according to the reaction

$$HF_{(aq)} + H_2O_{(\ell)}) \rightleftharpoons F^-_{(aq)} + H_3O^+_{(aq)}$$

The pK_a of hydrofluoric acid is 3.18. Calculate the pH of a solution that forms when 0.25 grams of gas-phase HF are dissolved in water to make 1.2 L of solution. Approximations do not work for this problem. **Answer**: pH=2.66

14. Ethylamine, $C_2H_5NH_2$, is a weak base in aqueous solution. The pH of a 1.0 M aqueous ethylamine solution is measured to be 12.32. Calculate the pK_b of ethylamine.
Answer: pK_b=3.35

15. The two values for the pK_a of hydrosulfuric acid according to the reactions

$$H_2S_{(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + HS^-_{(aq)}$$

$$HS^-_{(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + S^{2-}_{(aq)}$$

are respectively 7.00 and 19.0. Calculate the concentrations of all species present in a 0.0100 and 0.00100 M aqueous solution of hydrosulfuric acid.
Answer: 0.0100 M $[H_3O^+]=[HS^-] = 3.16 \times 10^{-5}$, $[H_2S]$=0.0100 M, $[S^{2-}]=1.00 \times 10^{-19}$

16. When phthalic acid combines with water, two equilibrium reactions occur

$$H_2C_8H_4O_{4(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + HC_8H_4O^-_{4(aq)} \qquad K_{a1} = 1.1 \times 10^{-3}$$

and

$$HC_8H_4O^-_{4(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + C_8H_4O^{2-}_{4(aq)} \qquad K_{a2} = 3.9 \times 10^{-6}$$

Calculate the pH and concentrations of all species present in a 0.010 M phthalic acid solution.
Answer: pH=2.55, $3.9 \times 10^{-6} = [C_8H_4O_4^{2-}]$

17. Germanic acid (H_2GeO_3) is a diprotic acid with pK_a's for the two protons in aqueous solution given by p$K_{a,1} = 9.01$ and p$K_{a,2} = 12.30$. Calculate the equilibrium concentrations of $HGeO^-_{3(aq)}$, $GeO^{2-}_{3(aq)}$ and $H_3O^+_{(aq)}$ and the pH for a 1.50 M aqueous solution of germanic acid. Approximations work for this problem.
Answer: pH=4.42, $[HGeO_3^-] = 3.8 \times 10^{-5}$ M,$[GeO_3^{2-}] = 5.0 \times 10^{-13}$ M

18. Selenic acid (H_2SeO_4) is a diprotic acid. Like sulfuric acid, the first proton is essentially 100% ionized in aqueous solution. The second proton dissociates according to the reaction

$$HSeO^-_{4(aq)} + H_2O_{(\ell)} \rightleftharpoons SeO^{2-}_{4(aq)} + H_3O^+_{(aq)}$$

with a p$K_a = 1.92$. Consider a 0.10 M solution of selenic acid. Calculate the equilibrium concentrations of $HSeO_4^-$ and SeO_4^{2-}, and the pH of the solution at equilibrium. Approximations work for the dissociation equilibrium.
Answer:$[SeO_4^{2-}] = 1.2\times10^{-2}$ M, $[HSeO_4^-]$= 0.10 M (to two significant figures), $[H_3O^+]$= 0.11 M, pH=0.96