Chem 1C, Sum 09, FH, Lab Quiz 1

Name: KEY

Read questions carefully to understand what is being asked. If you have doubt, feel free to ask your instructor. Use the reverse side of your answer paper as scratch. Use attached periodic table and important constants chart. (Total pts. = 92)

SHORT ANSWER: Show all your calculations using appropriate set up and units.

1) You need a buffer of pH = 4.5 and you are given a 5.0L of 0.05M sodium benzoate solution. How much benzoic acid (C₆H₅COOH) would you mix to get the right buffer?

Ka of benzoic acid is 6.3 x 10⁻⁵ (8 pts).

\[
pH = pK_a + \log \left( \frac{[\text{Conj Base}]}{[\text{Acid}]} \right)
\]

\[
4.5 = -\log (6.3 \times 10^{-5}) + \log \left( \frac{0.05}{[\text{Acid}]} \right)
\]

\[
4.5 = 4.2 + \log \left( \frac{0.05}{[\text{Acid}]} \right)
\]

\[
\log \left( \frac{0.05}{[\text{Acid}]} \right) = 4.5 - 4.2 = 0.3
\]

\[
\frac{0.05}{[\text{Acid}]} = 10^{0.3} = 1.99
\]

\[
[\text{Acid}] = \frac{0.05}{1.99} = 0.025 M
\]

So [C₆H₅COOH] should be 0.025 M in SL soln to make a buffer.

\[
e_{p} \text{pH} = 4.5
\]

1) 15.3 g

2) 250mL of a buffer of pH 12.25 was made by dissolving Na₂HPO₄ and Na₃PO₄ in water. If the concentration of Na₃PO₄ is 0.4 M, what mass of Na₂HPO₄ is present. (Kₐ₃ = 4.2 x 10⁻¹³) (6 pts.)

Using Henderson-Hasselbalch eqn

\[
pH = pK_a + \log \left( \frac{[\text{Conj Base}]}{[\text{Acid}]} \right)
\]

Here, the acid-base equlib is HPO₄²⁻ → PO₄³⁻ (aq) + H⁺(aq),

Acid is HPO₄²⁻ and base PO₄³⁻.

So 12.25 = -log \left( 4.2 \times 10^{-13} \right) + log \left( \frac{[PO₄³⁻]}{[HPO₄²⁻]} \right)

\[
= 12.38 + \log \left( \frac{0.4 \text{ M}}{[\text{HPO}_4^{2-}]} \right)
\]

\[
\log \left( \frac{[\text{HPO}_4^{2-}]}{0.4 \text{ M}} \right) = 12.25 - 12.38 = -0.13
\]

\[
\frac{[\text{HPO}_4^{2-}]}{0.4 \text{ M}} = 10^{-0.13} = 0.7413
\]

\[
[\text{HPO}_4^{2-}] = \frac{0.4 \text{ M}}{0.7413} = 0.5396 \text{ M} = [\text{Na}_2\text{HPO}_4]
\]

Mass of Na₂HPO₄ needed to make 0.5396 M soln:

\[
\frac{0.5396 \text{ M} \times \text{mol Na}_2\text{HPO}_4 \times 141.96 \text{ g} \text{ Na}_2\text{HPO}_4}{1 \text{ mol Na}_2\text{HPO}_4} = 19.15 \text{ g}
\]

2) 19.15 g
3) A 0.0723 M aqueous ammonia (NH₃) solution shows a pH of 10.50. Calculate the pK₆ of ammonia. (6 pts.)

\[ pH = 10.5, \text{ so } pOH = 14 - pH = 14 - 10.5 = 3.5, \text{ then } [OH^-] = 10^{-3.5} = 3.16 \times 10^{-4} \text{ M} \]

Ammonia dissociates in water as follows:

\[ \text{NH}_3(aq) + H_2O(l) \rightleftharpoons \text{NH}_4^+(aq) + OH^-(aq) \]

\[ I = 0.0723 \text{ M} \]

\[ [\text{OH}^-] = \frac{3.16 \times 10^{-4}}{3.16 \times 10^{-4}} = 1 \text{ M} \]

So \( K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = \frac{(3.16 \times 10^{-4})^2}{0.0723 - 3.16 \times 10^{-4}} \]

\[ r = \text{p}K_b = -\log(1.4 \times 10^{-5}) = 5.85 \]

4) 25.0 mL of an 0.0723 M aqueous ammonia solution was titrated with 17.71 mL of a 0.102 M HCl solution. The pH at the neutralization point was 5.33. Calculate the K₆ of ammonia from these data (10 pts.).

25 mL of 0.0723 M NH₃ solution is used. At neutralization point, 17.71 mL HCl added. pH = 5.33

Total volume at neutralization = 25 mL + 17.71 mL = 42.71 mL = 0.0427 L

So \( [\text{NH}_4^+] \) at equiv. pt. = \( \frac{0.0723 \text{ mole}}{L} \times 0.0427 \text{ L} = 0.0042 \text{ M} \)

Since \( \text{NH}_4^+ \) is formed from weak base \( \text{NH}_3 \) & strong acid HCl, \( \text{NH}_4^+ \) ion will hydrolyze at equiv. pt. giving H⁺ & pH = 5.33, \[ [H^+] = 10^{-5.33} = 4.68 \times 10^{-6} \]

\[ \text{I} = 0.042 \text{ M} \]

\[ E = -A.68 \times 10^{-6} \]

\[ E (0.042 - 4.68 \times 10^{-6}) = 4.68 \times 10^{-6} \]

So \( K_a = \frac{[\text{NH}_3][\text{H}_2\text{O}^+]}{[\text{NH}_4^+]} = \frac{(4.68 \times 10^{-6})(4.68 \times 10^{-6})}{0.042 - 4.68 \times 10^{-6}} \]

Since \( 4.68 \times 10^{-6} \) is very small compared to 0.042, we neglect the former. So \( K_a = \frac{(4.68 \times 10^{-6})^2}{0.042} = 5.17 \times 10^{-10} \)

So \( K_b = \frac{K_w}{K_a} = \frac{10^{-14}}{5.17 \times 10^{-10}} = 1.9 \times 10^{-4} \)
5) $K_{sp}$ of Ag$_2$CrO$_4$ in water at 20 °C is $1.9 \times 10^{-12}$ M. Calculate its solubility in gram per 0.1 L of solution (8 pts.).

Let solubility be $S$, then

$$
\text{Ag}_2\text{CrO}_4(s) \rightleftharpoons 2\text{Ag}^+(aq) + \text{CrO}_4^{2-}(aq)
$$

$$
-5

\therefore K_{sp} = (2S)^2 \cdot S = 4S^3 \Rightarrow 4S^3 = 1.9 \times 10^{-12}
$$

$$
\therefore S = 7.8 \times 10^{-5} \text{ M}
$$

So in 0.1 L, $S = \frac{7.8 \times 10^{-5} \text{ mol}}{1 \text{ L}} \times 0.1 \text{ L} \times \frac{331.8 \text{ g}}{1 \text{ mol} \text{ Ag}_2\text{CrO}_4} = 2.58 \times 10^{-3} \text{ g}$

6) Show your calculation to predict if a precipitate will form when 0.10 L of 8.0x10$^{-3}$ M Pb(NO$_3$)$_2$ is added to 0.40 L of 5.0 x 10$^{-3}$ M Na$_2$SO$_4$ solution. $K_{sp}$ of PbSO$_4$ = 6.3x10$^{-7}$ (8 pts.)

Final cone of Pb$^{2+}$ ion in the mixture = $\frac{8 \times 10^{-3} \text{ mol/L} \times 0.1 \text{ L}}{(0.11 + 0.41 \text{ L})} = 1.6 \times 10^{-3} \text{ M}$

$p$ Pb$^{2+}$ ion $n$ $SO_4^{2-}$ ion $\therefore \frac{8 \times 10^{-3} \text{ mol/L} \times 0.41 \text{ L}}{(0.11 + 0.41 \text{ L})} = 4 \times 10^{-3} \text{ M}$

$SO_4^{2-}$ ion $\Rightarrow$ for Pb$^{2+}$ ion $SO_4^{2-}$ = $1.6 \times 10^{-3} \times 4 \times 10^{-3} = 6.4 \times 10^{-6} = 0$

This value is greater than $K_{sp} (6.3 \times 10^{-7})$, so there will be precipitate.

7) For a 0.01 M HCl(aq) solution, the freezing point is -0.04 °C. Determine its van’t Hoff factor in water. ($K_f$ for water is -1.86 °C/m) (4 pts.).

$$\Delta T = i \cdot m \cdot K_f$$

(-0.04 - 0) = i \cdot (0.01) \cdot (-1.86)

$$i = \frac{-0.04 \degree C}{0.01 \degree C/\text{mol}} \neq 1.86 \degree C/\text{mol} = 2.15$$
8) In order to determine the molar mass of an unknown non-electrolyte through FP depression experiment, following data were collected: (1) Mass of test tube = 123.2 g. (2) Mass of test tube and cyclohexane = 132.11 g. (3) Mass of test tube, cyclohexane and unknown = 134.11 g. (4) FP of pure cyclohexane = 6.4 °C. (5) FP of the non-electrolyte in cyclohexane = 2.9 °C. Knowing the KFP for cyclohexane = –20 °C/m, calculate the molar mass of the non-electrolyte (10 pts.).

\[ \text{wt. of cyclohexane (solvent)} = (132.11 - 123.2) \text{ g} = 8.91 \text{ g} = 0.00891 \text{ kg} \]

\[ \text{wt. of unknown (solute)} = (134.11 - 132.11) \text{ g} = 2.0 \text{ g} \]

\[ \frac{\Delta T_f}{T_f} = \frac{1}{k_f} \frac{m_{solute}}{m_{solvent}} \]

\[ \frac{(2.9 - 6.4)}{6.4} = \frac{1}{2} \frac{m_{unknown}}{0.00891 \text{ kg solven}} \]

\[ \frac{1}{2} \frac{m_{unknown}}{0.00891 \text{ kg solvent}} = \frac{2.20}{3.5 \times 0.00891} \]

\[ \frac{2.20}{3.5 \times 0.00891} = 2.9 \times 0.00891 \]

\[ \frac{2.20}{3.5 \times 0.00891} = 1282.67 \text{ g/mol} \]

MULTIPLE CHOICE. Select the one alternative that best completes the statement or answers the question (4 pts each).

9) Of the following solutions, which has the greatest buffering capacity?  

A) They are all buffer solutions and would all have the same capacity.  
B) 0.121 M HF and 0.667 M NaF  
C) 0.821 M HF and 0.217 M NaF  
D) 0.100 M HF and 0.217 M NaF  
E) 0.821 M HF and 0.909 M NaF  
F) a strong acid

10) A 1.35 M aqueous solution of compound X had a boiling point of 101.4 °C. Which one of the following could be compound X? The boiling point elevation constant for water is 0.52 °C/m.

A) KCl  
B) CH₃CH₂OH  
C) Na₃PO₄  
D) C₆H₁₂O₆  
E) CaCl₂

11) Which of the following aqueous solutions will have the highest boiling point?

A) 0.10 M Na₂SO₄  
B) 0.20 M glucose  
C) 0.10 M NaCl  
D) 0.10 M SrSO₄  
E) 0.25 M sucrose
Consider the following table of $K_{sp}$ values.

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>$K_{sp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium carbonate</td>
<td>CdCO₃</td>
<td>$5.2 \times 10^{-12}$</td>
</tr>
<tr>
<td>Cadmium hydroxide</td>
<td>Cd(OH)₂</td>
<td>$2.5 \times 10^{-14}$</td>
</tr>
<tr>
<td>Calcium fluoride</td>
<td>CaF₂</td>
<td>$3.9 \times 10^{-11}$</td>
</tr>
<tr>
<td>Silver iodide</td>
<td>AgI</td>
<td>$8.3 \times 10^{-17}$</td>
</tr>
<tr>
<td>Zinc carbonate</td>
<td>ZnCO₃</td>
<td>$1.4 \times 10^{-11}$</td>
</tr>
</tbody>
</table>

12) Which compound listed below has the greatest molar solubility in water?
A) Cd(OH)₂    B) AgI    C) CdCO₃    D) ZnCO₃    E) CaF₂

13) For which salt should the aqueous solubility be most sensitive to pH?
A) Ca(NO₃)₂    B) CaI₂    C) CaBr₂    D) CaF₂    E) CaCl₂

14) A 25.0 mL sample of a solution of an unknown compound is titrated with a 0.115 M NaOH solution. The titration curve above was obtained. The unknown compound is ________.
A) a weak acid    B) a strong base    C) a weak base    D) neither an acid nor a base

15) Colligative properties of solutions include all of the following except ________.
A) elevation of the boiling point of a solution upon addition of a solute to a solvent
B) depression of the freezing point of a solution upon addition of a solute to a solvent
C) an increase in the osmotic pressure of a solution upon the addition of more solute
D) the increase of reaction rates with increase in temperature
E) depression of vapor pressure upon addition of a solute to a solvent

16) The magnitudes of $K_f$ and of $K_b$ depend on the identity of the ________.
A) solute
B) solvent
C) solute and solvent
D) solution
E) solvent and on temperature
Extra point question: Calculate FP of a non-electrolyte (42 g, formula $\text{C}_10\text{H}_{18}\text{O}$) dissolved in 0.6 kg $\text{C}_2\text{H}_5\text{OH}$. FP of $\text{CH}_3\text{OH}$ = -63.5°C and $\text{Kg}$ = -4.68°C/m (8 pts).

<table>
<thead>
<tr>
<th>Compound</th>
<th>Concentration (m)</th>
<th>Specific Heat (J/g°C)</th>
<th>Solution Concentration (m)</th>
<th>Specific Heat (J/g°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C$_2$H$_5$OH</td>
<td>1.0</td>
<td>0.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH$_3$OH</td>
<td>0.2</td>
<td>0.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(D) If the solution freezes, the temperature decreases.