No outside paper is allowed. Use the reverse side of your answer paper as scratch. Always show the set up before calculating your math problems. Write your questions clearly and using the correct units to get full points. For multiple choice and similar problems, show the calculation on the reverse page to get partial points. The last page contains a periodic table and some important (constants. \( T \_F = i K \_F \ m; \ P_\text{A} = X_\text{A} P_\text{A} \).

Total points = 46 + 56 + 8 = 110.

**ESSAY.** Write your answer in the space provided or on a separate sheet of paper.

1) You need a buffer of \( \text{pH} = 4.5 \) and you are given a 5.0L of 0.05M sodium benzoate solution. How much benzoic acid \((C_6H_5COOH)\) would you mix to get the right buffer? \( K_a \) of benzoic acid is \( 6.3 \times 10^{-5} \). (6 pts)

\[
\text{pH} = 4.5 \Rightarrow -\log [H^+] \Rightarrow [H^+] = 10^{-\text{pH}} = 10^{-4.5} = 3.16 \times 10^{-5}
\]

\[
\text{C}_6\text{H}_5\text{COOH} \rightleftharpoons \text{C}_6\text{H}_5\text{COO}^- \text{H}^+ \\
K_a = \frac{[\text{C}_6\text{H}_5\text{COO}^-][\text{H}^+]}{[\text{C}_6\text{H}_5\text{COOH}]} \Rightarrow \text{so } \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{K_a} = \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{3.16 \times 10^{-5}}
\]

Amount of \( \text{C}_6\text{H}_5\text{COOH} \) to be added in SL Soln

\[
= 5.0L \times \frac{0.025 \text{ mol/L} \times 122.12 \text{ g/L Acid}}{1 \text{ mol L Acid}} = 15.3 \text{ g C}_6\text{H}_5\text{COOH}
\]

2) 0.82g \( \text{ZnCl}_2 \) is dissolved in 255mL of 0.15 M NaCN solution. Using \( K_f \) for \( \text{Zn(CN)}_4^{2-} = 4.2 \times 10^{19} \).

(a) Calculate the concentrations of \( \text{CN}^- \) and \( \text{Zn(CN)}_4^{2-} \) in the solution (2 x 4 pts)

\[
\text{Zn}^{2+} + 4 \text{ CN}^- \rightleftharpoons \text{Zn(CN)}_4^{2-}
\]

\[
\text{0.0} \times 10^{-3} \text{ mol Zn}^{2+} \text{ will require 4(0.0} \times 10^{-3} \text{ mol) CN}^- \text{, leaving 0.014 mol CN}^- \text{ behind)}
\]

\[
\text{0.6382 mol CN}^- \text{ - 4(0.0} \times 10^{-3} \text{ mol CN}^- \text{) = 0.014 mol) to produce}
\]

\[
0.0 \times 10^{-3} \text{ mol Zn(CN)}_4^{2-}
\]

\[
[\text{CN}^-] = \frac{0.014 \text{ mol}}{0.255 \text{ L}} = 0.055 \text{ M}
\]

\[
[\text{Zn(CN)}_4^{2-}] = \frac{0.0 \times 10^{-3} \text{ mol}}{0.255 \text{ L}} = 0.024 \text{ M}
\]
(c) Calculate the concentration of Zn$^{2+}$ in the solution (8 pts)?

\[
Zn^{2+} \text{(aq)} + 4 \text{CN}^- \text{(aq)} \rightarrow Zn(\text{CN})_4^{2-} \text{(aq)}
\]

\[
K_f = \frac{[Zn(\text{CN})_4^{2-}]}{[Zn^{2+}][\text{CN}^-]^4}
\rightarrow [Zn^{2+}] = \frac{[Zn(\text{CN})_4^{2-}]}{K_f [\text{CN}^-]^4}
\]

\[
[Zn^{2+}] = \frac{0.024}{(4.2 \times 10^{19})(0.055)^4}
\rightarrow [Zn^{2+}] = 6.2 \times 10^{-17} M
\]

3) If $K_{sp}$ of calcium phosphate, $Ca_3(PO_4)_2$, in water is $1.0 \times 10^{-33}$, then what is its solubility in water in mol/L (8 pts)?

\[
Ca_3(PO_4)_2 \rightarrow 3Ca^{2+} + 2PO_4^{3-}
\]

\[
K_{sp} = (3s)^3 \cdot (2s)^2 = 27s^3 \cdot 4s^2 = 108s^5
\]

So $1 \times 10^{-33} = 108s^5$$\Rightarrow s^5 = \frac{10^{-33}}{108} = 9.259 \times 10^{-36}$

\[
(s^5)^{1/5} = (9.259 \times 10^{-36})^{1/5} \Rightarrow s = 9.85 \times 10^{-8} M
\]
4) Calculate the vapor pressure at 25 °C of a solution made by dissolving 50.0mL of glycerin in 500.0mL of water. Glycerin (C$_3$H$_8$O$_3$) is a nonvolatile nonelectrolyte with a density of 1.26g/mL at 25 °C, and vapor pressure of pure water at 25 °C is 23.8 torr (8 pts).

Moles of C$_3$H$_8$O$_3$ = (50 mL C$_3$H$_8$O$_3$) $\frac{1.26 g C_3H_8O_3}{1 mL C_3H_8O_3} \times \frac{1 mol C_3H_8O_3}{92.1 g C_3H_8O_3}$ = 0.684 mol

Moles of H$_2$O = 500 mL H$_2$O $\times \frac{1 g H_2O}{1 mL H_2O} = \frac{18 g H_2O}{18 g H_2O} = 27.8$ mol

Mole fraction of solvent, $X_{H_2O} = \frac{27.8}{27.8 + 0.684} = 0.976$

From Raoult's law $P_{H_2O} = X_{H_2O} \cdot P^0_{H_2O} = 0.976 \times 23.8$ torr

= 23.2 torr

5) An aqueous solution of hydrochloric acid contains 36% HCl by mass.

(a) Calculate the mole fraction of HCl in the solution (4 pts)

36% HCl means the solution has 36 g HCl in 100 g solution. Remaining is water = 100 - 36 g = 64 g

Moles of HCl = $\frac{36 g HCl}{36.5 g HCl}$ = 0.99 mol HCl

Moles of H$_2$O = $\frac{64.5 g H_2O}{18.0 g H_2O}$ = 3.6 mol H$_2$O

So $X_{HCl} = \frac{0.99}{0.99 + 3.6} = 0.22$

(b) Calculate the molality of HCl in the solution (4 pts)

$\text{Molality} = \frac{\text{moles of HCl}}{\text{wt. of H$_2$O in kg}} = \frac{0.99}{64 g \times \frac{1 kg}{1000 g}}$

= 0.99 mol

$\frac{0.064 kg}{15$ molal

= 15 molal
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question (4 pts each).

6) The process of solute particles being surrounded by solvent particles is known as 
   A) agglutination
   B) agglomeration
   C) salutation
   D) dehydration
   E) solvation

7) At 20°C, an aqueous solution that is 24.00% by mass in ammonium chloride has a density of 1.0674 g/mL. What is the molarity of ammonium chloride in the solution? The formula weight of NH₄Cl is 53.50 g/mol.
   A) 0.0445
   B) 4.79
   C) 5.90
   D) 22.5
   E) 0.479

8) A supersaturated solution
   A) is one with a higher concentration than the solubility
   B) must be in contact with undissolved solid
   C) is one that has been heated
   D) exists only in theory and cannot actually be prepared
   E) is one with more than one solute

9) In which of the following aqueous solutions would you expect AgCl to have the lowest solubility?
   A) 0.020 M BaCl₂
   B) 0.020 KCl
   C) 0.015 NaCl
   D) 0.020 AgNO₃
   E) pure water

10) The concentration of iodide ions in a saturated solution of lead (II) iodide is $\frac{M}{1.4 \times 10^{-8}}$. The solubility product constant of PbI₂ is $1.4 \times 10^{-8}$. The concentration of iodide ions is
   A) $1.5 \times 10^{-3}$
   B) $1.4 \times 10^{-8}$
   C) $3.0 \times 10^{-3}$
   D) $3.5 \times 10^{-9}$
   E) $3.8 \times 10^{-4}$

11) Formation of solutions where the process is endothermic can be spontaneous provided that
   A) the solvent is water and the solute is a gas
   B) they are accompanied by another process that is exothermic
   C) they are accompanied by an increase in disorder
   D) they are accompanied by an increase in order
   E) the solvent is a gas and the solute is a solid
12) Which of the following could be added to a solution of acetic acid to prepare a buffer?
   A) hydrochloric acid
   B) sodium hydroxide
   C) more acetic acid
   D) nitric acid
   E) None of the above can be added to an acetic acid solution to prepare a buffer.

13) The $K_{sp}$ for Zn(OH)$_2$ is $5.0 \times 10^{-17}$. Determine the molar solubility of Zn(OH)$_2$ in a buffer solution with a pH of 11.5.
   A) $5.0 \times 10^{-12}$
   B) $5.0 \times 10^{-17}$
   C) $5.0 \times 10^6$
   D) $1.2 \times 10^{-12}$
   E) $1.6 \times 10^{-14}$

14) Which below best describe(s) the behavior of an amphoteric hydroxide in water?
   A) With conc. aq. NaOH, its suspension dissolves.
   B) With conc. aq. HCl, its suspension dissolves.
   C) With both conc. aq. NaOH and conc. aq. HCl, its suspension dissolves.
   D) With conc. aq. NaOH, its clear solution forms a precipitate.
   E) With conc. aq. HCl, its clear solution forms a precipitate.

15) What change will be caused by addition of a small amount of HCl to a solution containing fluoride ions and hydrogen fluoride?
   A) The concentration of hydronium ions will increase significantly.
   B) The concentration of fluoride ion will decrease and the concentration of hydrogen fluoride will increase.
   C) The concentration of fluoride ions will increase as will the concentration of hydronium ions.
   D) The concentration of hydrogen fluoride will decrease and the concentration of fluoride ions will increase.
   E) The fluoride ions will precipitate out of solution as its acid salt.

16) The concentration of lead nitrate (Pb(NO$_3$)$_2$) in a 0.726 M solution is _______ molal. The density of the solution is 1.202 g/mL.
   A) 0.755
   B) 0.476
   C) 0.650
   D) 0.819
   E) 1.928

\[
0.726 \text{ M} = \frac{0.726 \text{ mol}}{1} \quad \Rightarrow \quad \text{Molarity} = \frac{\text{mol}}{\text{kg of solvent}}
\]

\[
= \frac{0.726 \text{ mol}}{1.1998 \text{ kg}} = 0.605
\]
17) The vapor pressure of pure water at 25 °C is 23.8 torr. What is the vapor pressure (torr) of water above a solution prepared by dissolving 18.0 g of glucose (a nonelectrolyte, MW = 180.0 g/mol) in 95.0 g of water? \[ \frac{P_{\text{H}_2\text{O}}}{P_{\text{H}_2\text{O}}} = \frac{x_{\text{H}_2\text{O}}}{x_{\text{H}_2\text{O}}} = 2.38 \times \frac{\frac{18}{180}}{\frac{18}{180}} = 2.38 \]
   A) 24.3  
   B) 23.8  
   C) 0.451  
   D) 0.443  
   E) 23.4

18) A solution is prepared by dissolving 0.60 g of nicotine (a nonelectrolyte) in water to make 12 mL of solution. The osmotic pressure of the solution is 7.55 atm at 25 °C. The molecular weight of nicotine is __________ g/mol.
   A) 28  
   B) 0.50  
   C) 43  
   D) 50  
   E) 160

19) Determine the freezing point (°C) of a 0.015 molal aqueous solution of MgSO₄. Assume i = 2.0 for MgSO₄. The molal freezing-point-depression constant of water is 1.86 °C/m.
   A) -0.17  
   B) 0.000  
   C) -0.084  
   D) -0.028  
   E) -0.056

TRUE/FALSE. Write 'T' if the statement is true and 'F' if the statement is false (2 pts each).

20) After swimming in the ocean for several hours, swimmers noticed that their fingers appeared to be very wrinkled. This is an indication that seawater is supertonic relative to the fluid in cells.
   20) F

21) The value of the boiling-point-elevation constant (Kₘ) depends on the identity of the solvent.
   21) T

22) The solubility of slightly soluble salts containing basic anions is proportional to the pH of the solution.
   22) F

23) The extent of ionization of a weak electrolyte is increased by adding to the solution a strong electrolyte that has an ion in common with the weak electrolyte.
   23) F