CHEM 101A – TOPIC B
SOLUTION STOICHIOMETRY

WHAT YOU SHOULD BE ABLE TO DO WHEN YOU HAVE FINISHED THIS TOPIC:
1) Predict and write net ionic equations for the following reaction types:
   a) Acid-base reactions involving OH\(^{-}\) reacting with a strong or a weak acid.
   b) Acid-base reactions involving NH\(_3\) reacting with a strong or a weak acid.
   c) Formation of a weak acid from H\(^{+}\) and an anion.
   d) Precipitation reactions, including reactions of NH\(_3\) with metal ions to form insoluble hydroxides.
   e) Reactions of carbonates and bicarbonates with acids to form CO\(_2\).
2) Identify an ionic compound as soluble or insoluble in water, based on the solubility rules.
3) Determine any one of the molarity of a solution, the mass of solute, and the volume of solution, given the other two.
4) Solve dilution problems.
5) Carry out material balances for reactions in aqueous solution.

READING ASSIGNMENT:
Chapter 4: sections 4.1 through 4.9. (We will not cover redox reactions in Chem 101A.)
Supplemental handout: “Properties and Reactivity of Inorganic Compounds for Chem 101A”

RELEVANT PROBLEMS: (these will not be collected and graded, but you are expected to be able to do them)
(6\(^{th}\) edition): Chapter 4, problems 15, 17, 19, 25, 27, 31, 35, 39, 43 (parts a, b and c), 47, 49, 71, 83 and 89.
(5\(^{th}\) edition): Chapter 4, problems 13, 19, 21, 25, 27, 31, 37, 41 (parts a, b and c), 43, 45, 69, 81 and 85.

ADDITIONAL RELEVANT PROBLEMS: (answers available on the Chem 101A web site)
1) 24.5 mL of 0.0752 M Ba(OH)\(_2\) is mixed with 31.8 mL of 0.0883 M HCl. Write the balanced net ionic equation for the reaction that occurs, and carry out a material balance.
2) When 62.4 mL of 0.131 M Na\(_2\)CrO\(_4\) is mixed with 55.3 mL of 0.248 M AgNO\(_3\), a dark red precipitate forms. Write the balanced net ionic equation for the reaction that occurs, and carry out a material balance.

A set of practice problems on net ionic equations is available on the web site.

THE REQUIRED HOMEWORK ASSIGNMENT STARTS ON THE NEXT PAGE.
1) Which of the following compounds are soluble in water?
   a) K$_2$SO$_4$  b) BaSO$_4$  c) H$_2$SO$_4$  d) Fe$_2$(SO$_4$)$_3$
   e) (NH$_4$)$_2$CO$_3$  f) Ag$_2$CO$_3$  g) FeCO$_3$  h) CuCO$_3$

2) List all of the solute species that are present in each of the following solutions, and state whether the concentration of each species should be high (close to or equal to 0.1 M) or low (much less than 0.1 M). Note that CH$_3$OH is a nonelectrolyte.
   a) 0.1 M HNO$_3$  b) 0.1 M HNO$_2$  c) 0.1 M CH$_3$OH

3) List all of the major solute species and their molar concentrations in a 0.25 M solution of sodium sulfate.

4) A 5.317 g sample of Na$_2$CO$_3$ is dissolved in enough water to make 170.0 mL of solution.
   a) What is the molarity of the solution?
   b) How much additional water must be added to this solution in order for its concentration to be reduced to 0.125 M?
   c) What mass of solid Na$_2$SO$_4$ must be added to the solution in part b to raise the concentration of Na$^+$ to 0.400 M? Assume that adding Na$_2$SO$_4$ does not affect the volume of the solution.

5) a) What mass of potassium phosphate is required to prepare 250.0 mL of a 0.210 M solution?
   b) What are the molar concentrations of K$^+$ and PO$_4^{3-}$ ions in this solution?
   c) If you add an additional 500.0 mL of water to this solution, what will the molarity of potassium ions be?

6) A 250.0 mL sample of aqueous solution contains an unknown amount of dissolved NaBr. Excess aqueous Pb(NO$_3$)$_2$ is then added to this solution and a precipitate forms.
   a) What is the chemical formula of the precipitate?
   b) Write the net ionic equation for the precipitation reaction.
   c) If the mass of precipitate recovered was 3.006 grams, what was the molar concentration of Br$^-$ ions in the original solution?

7) An unknown solid compound containing Pb$^{2+}$ ion was mixed with 15 mL of 2.0 M HNO$_3$. The mixture bubbled profusely. After complete reaction, it was found that 0.020 moles of CO$_2$ were produced and the original solid was completely consumed.
   a) What is the chemical formula of the unknown solid?
   b) Write a balanced net ionic equation for this reaction.
   c) Calculate the mass of the original unknown solid.

8) Write the balanced net ionic equations for the reactions that will occur when the following are mixed. If no reaction will occur, write "No Reaction."
   a) 0.1 M Na$_2$CO$_3$ and 0.1 M NiCl$_2$
   b) 0.05 M AgNO$_3$ and 0.05 M K$_3$PO$_4$
c) 0.50 M MgCl$_2$ and 0.25 M (NH$_4$)$_2$SO$_4$

d) 0.25 M NaOH and 0.50 M HCl

e) 0.50 M Na$_3$PO$_4$ and 0.30 M K$_2$S

f) 1.5 M HC$_2$H$_3$O$_2$ and 1.5 M KOH
g) 0.082 M Ba(OH)$_2$ and 0.23 M HNO$_3$
h) equal volumes of 0.25 M H$_3$PO$_4$ and 0.25 M NaOH
i) 0.25 M H$_3$PO$_4$ and excess 0.25 M NaOH
j) solid Cu(OH)$_2$ and excess 2.0 M HCl

k) solid Fe(OH)$_3$ and excess 3.0 M HC$_2$H$_3$O$_2$
l) 0.25 M Cr(NO$_3$)$_3$ and excess 1.0 M NH$_3$
m) 0.050 M H$_3$PO$_4$ and 0.075 M NH$_3$

n) 0.075 M HClO and 0.050 M NH$_3$ (HClO is a weak acid)
o) 0.10 M NaHCO$_3$ and excess 0.050 M H$_2$SO$_4$
p) equal volumes of 0.10 M Na$_2$CO$_3$ and 0.10 M HCl
q) 0.10 M Na$_2$CO$_3$ and excess 0.10 M HCl
r) solid CaCO$_3$ and excess 2.0 M HNO$_3$

9) When solutions of K$_2$CrO$_4$ and AgC$_2$H$_3$O$_2$ are mixed, a precipitate forms.
   a) What is the chemical formula of the precipitate?
   b) Write a net ionic equation for the reaction that occurred.

10) When solid MgCO$_3$ is added to 3 M H$_2$SO$_4$, the solid bubbles vigorously and eventually
dissolves completely. When solid BaCO$_3$ is added to 3 M H$_2$SO$_4$, the solid also bubbles
vigorously, but it does not appear to dissolve at all. Explain this difference.

11) Carry out a material balance for the reaction that occurs when 27.1 mL of 0.170 M
Mg(NO$_3$)$_2$ is mixed with 36.3 mL of 0.210 M NaOH.

12) Carry out a material balance for the reaction that occurs when 18.25 mL of 0.252 M
HBr is combined with 0.150 g of Zn(OH)$_2$ solid.

13) Potassium hydrogen phthalate, KHC$_8$H$_4$O$_4$, is an ionic compound that dissociates into K$^+$ and
HC$_8$H$_4$O$_4^-$ when it dissolves in water. The HC$_8$H$_4$O$_4^-$ ion is an acid and reacts with hydroxide ion
as follows:

\[ \text{HC}_8\text{H}_4\text{O}_4^-(aq) + \text{OH}^-(aq) \rightarrow \text{C}_8\text{H}_4\text{O}_4^{2-}(aq) + \text{H}_2\text{O}(l). \]

A chemist dissolves a 0.8280 g sample of KHC$_8$H$_4$O$_4$ (MM: 204.20 g/mol) in 50.00 mL of water
and titrates the solution with a NaOH solution. The chemist needs 30.96 mL of the NaOH
solution to reach the endpoint of the titration.

The chemist then measures out 15.45 mL of a solution of H$_2$C$_4$H$_4$O$_4$ (succinic acid, a
diprotic acid) and titrates it with the same NaOH solution, requiring 25.23 mL of the NaOH to
reach the endpoint. Using this information, calculate the molarity of the H$_2$C$_4$H$_4$O$_4$ solution.