Name: _____
Section: _____

CHM152LL Solution Chemistry Worksheet

Many chemical reactions occur in solution. Solids are often dissolved in a solvent and mixed to produce a chemical reaction that would not occur if the solids themselves were directly mixed together. This worksheet will review the solution process, several different types of chemical reactions in solution with focus on molecular-level pictures of the reactions, and end with a review of calculations commonly used in the laboratory.

Solutions & Solubility Rules: When a solute is dissolved in a solvent we call the mixture a solution. If the solvent is water, the mixture is an aqueous solution. The following solubility rules are for ionic species in water as the solvent.

Solubility Rules for Ionic Compounds in Water

The **compound is SOLUBLE** if it has:

1. Li^+, Na^+, K^+, NH_4^+ ions (**ALWAYS!**)
2. Acetate ion, $C_2H_3O_2^-$, Nitrate ion, NO_3^- , or perchlorate ion ClO_4^-
3. Halide ions (X^-): Chloride ion (Cl^-), bromide ion (Br^-), or iodide ion (I^-), ***but*** AgX, PbX_2, Hg_2X_2 are **insoluble**
4. Sulfate ion (SO_4^{2-}), ***but*** $CaSO_4$, $SrSO_4$, $BaSO_4$ are **insoluble**

The **compound is INSOLUBLE** if it has:

5. Carbonate ion, CO_3^{2-}, **but** Rule 1 ions
6. Chromate ion, CrO_4^{2-}, **but** Rule 1 ions
7. Phosphate ion, PO_4^{3-}, **but** Rule 1 ions
8. Sulfide ion, S^{2-}, **but** Rule 1 ions and CaS, SrS, BaS are **soluble**
9. Hydroxide ion, OH^-, **but** Rule 1 ions, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$ are **soluble**

Watch the animations at the following links (sound is needed for the 2nd one) to answer the following two questions:

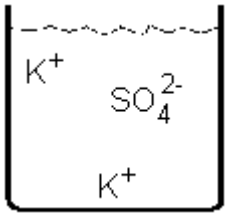
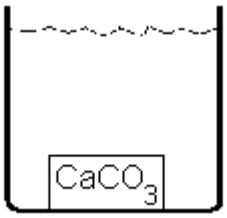
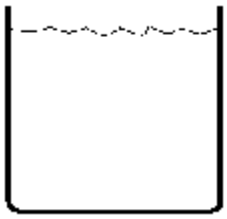
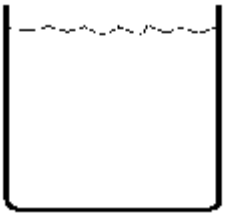
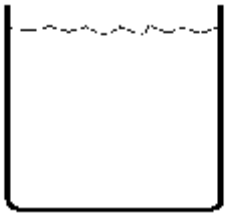
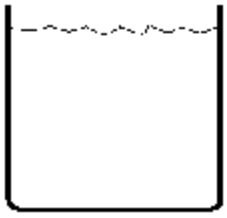
1. http://www.northland.cc.mn.us/biology/Biology1111/animations/dissolve.html
2. http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/molvie1.swf
3. http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/thermochem/solutionSalt.html

Question1: When sodium chloride dissolves in water explain how the water molecules arrange themselves around the chloride ions. Draw a picture of a **chloride ion** surrounded by 2 water molecules.

Question 2: Now explain why the water molecules arrange themselves like that. Discuss the **polarity** of the water molecule in your answer.

Molecular-Level Representations of Ionic Solutions

For each ionic compound listed below write the chemical formula and draw a representation of the compound in water. Do not show the water molecules. The first two have been completed as examples.

1. potassium sulfate formula___K_2SO_4_____ 	2. calcium carbonate formula___$CaCO_3$____ 	3. lithium phosphate formula_____ 
4. ammonium sulfide formula_____ 	5. silver iodide formula_____ 	6. barium hydroxide formula_____ 

Chemical Reactions in Solution

Three common types of chemical reacitons that take place in solution are:

1. precipitations reactions *(text section 4.4)*
2. acid base neutralization reactions *(text section 4.5)*
3. single replacement reactions, a type of redox reaction *(text section 4.6)*

To review precipitation reactions watch the following animation:
http://preparatorychemistry.com/Bishop_precipitation_frames.htm

Question 1: What are the **formulas** for the four **reactant ions** involved in the above animation?

Question 2: Why don't the carbonate and nitrate ions "stick" together in the animation?

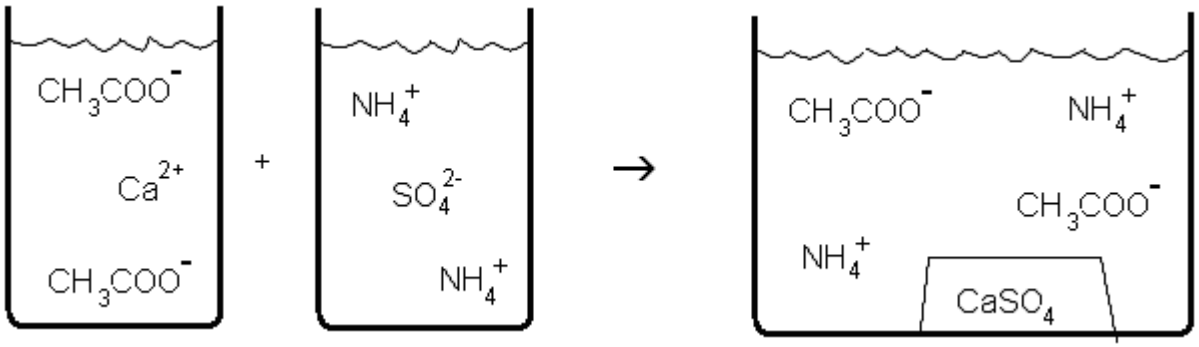
Question 3: Write the **net ionic equation** for the reaction in the animation.

Example: 1. **calcium acetate and ammonium sulfate** Reaction type: _precipitation__

Molecular: $Ca(CH_3COO)_2(aq) + (NH_4)_2SO_4(aq) \rightarrow CaSO_4(s) + 2\ NH_4CH_3COO(aq)$

Ionic: $Ca^{2+}(aq) + 2\ CH_3COO^-(aq) + 2\ NH_4^+(aq) + SO_4^{2-}(aq) \rightarrow CaSO_4(s) + 2\ CH_3COO^-(aq) + 2\ NH_4^+(aq)$

Net Ionic: $Ca^{2+}(aq) + SO_4^{2-}(aq) \rightarrow CaSO_4(s)$



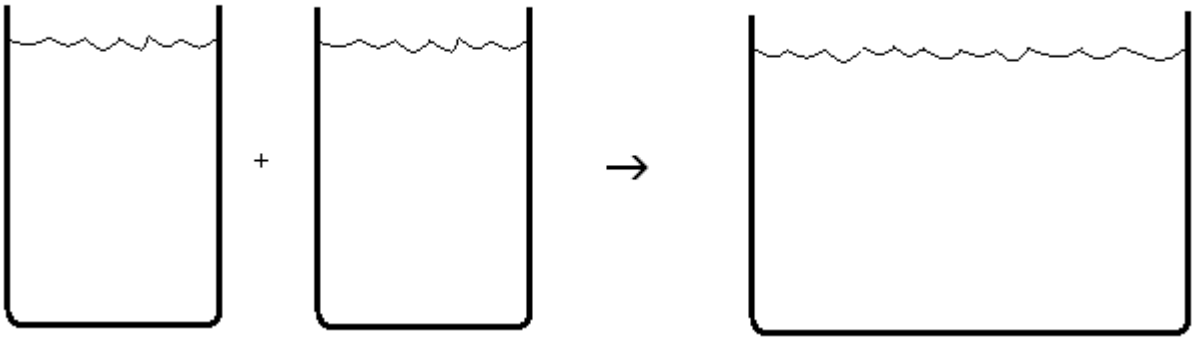
We can write and balance these chemicals reactions using molecular equations, ionic equations, and net ionic equations. *(text section 4.3)* For the following sets of reactants, write and balance the molecular, ionic and net ionic equations (including all phases, using the Solubility Rules on page 1) and draw a molecular-level representation of each reactant and the products in the provided beakers (based on the **ionic equation** you wrote). Also indicate the type of reaction; if there is no reaction write NR for the type but still complete the reactions and molecular-level drawings. The first problem is already completed as an example. **Draw the water molecules if they are part of the reaction, but do not draw solvent water molecules.**

2. **hydrochloric acid and barium hydroxide** Reaction type: _____

Molecular:_____

Ionic:_____

Net Ionic:_____



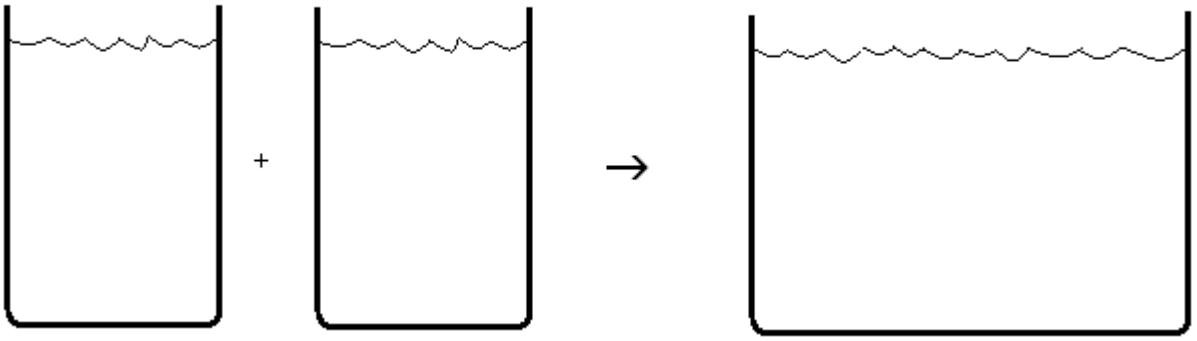
4. **aluminum and zinc nitrate** – watch phases and oxidation numbers!!!

Reaction type: _____

Molecular:_____

Ionic:_____

Net Ionic:_____

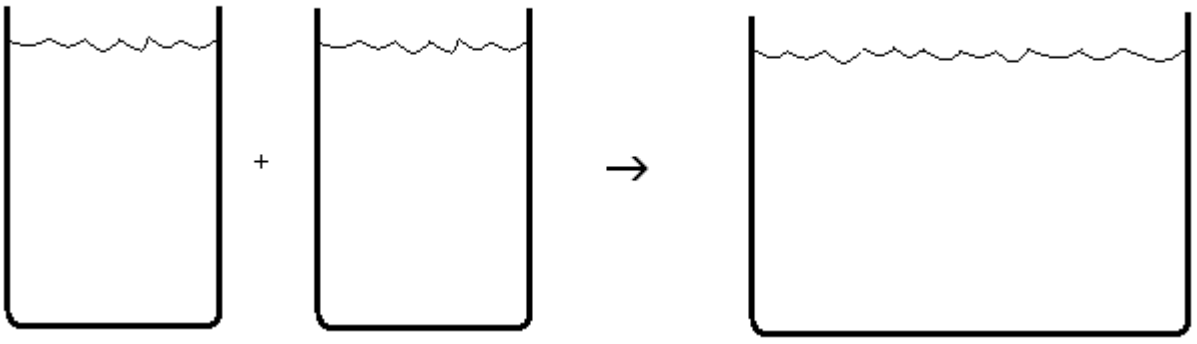


4. **magnesium perchlorate and copper(II) chloride** Reaction type: _____

Molecular:_____

Ionic:_____

Net Ionic:_____



CHM 152LL: Review of Common Lab Calculations

A brief summary of some useful relationships is given below; if you need an in-depth review of these relationships, refer to the McMurry Fay textbook sections listed in the margins. The review problems that follow will give you practice on some of the types of calculations that are used in this lab course. Use the conversion-factor method to solve these problems, and apply the rules for significant figures.

Sections 3.4: Molar Mass: the mass in grams of one mole of a substance; units = g/mol.

Example: Molar mass of NaOH = 40.0 g/mol; thus, 40.0 g NaOH = 1.00 mole NaOH

Sections 3.7: Molar Concentration: For a solution, molarity is the number of moles of solute per liter of solution; that is, M = mol of solute/L of solution.

Example: For a 0.100 M NaOH solution, 0.100 mole NaOH is in 1.00 L of solution

Conversion factors can be constructed from these and other relations, and they can be "strung together" to solve a problem. For example, to calculate the number of grams of HNO_3 in 25.0 mL of 15.4 M HNO_3 solution, the setup and answer would be:

$$\text{g } HNO_3 = 25.0 \text{ mL } HNO_3 \text{ soln} \times \frac{15.4\, mol\ HNO_3}{1000\, mL\ HNO_3\ soln} \times \frac{63.0\, g\ HNO_3}{1\, mol\ HNO_3} = 24.3 \text{ g } HNO_3$$

Note: We substituted 1000mL for 1L so that mL would cancel out.

Ion Molarities: Soluble ionic compounds completely dissociate into ions in solution; to determine the molarity of individual ions, we must consider the stoichiometric relationship between the ionic compound and the number of ions formed in solution.

Example: What is the molarity of K^+ ions in a 0.20 M K_2CO_3 solution?

$$K_2CO_3(s) \rightarrow 2K^+(aq) + CO_3^{2-}(aq)$$

$$\frac{0.20\, mol\ K_2CO_3}{1\, L}\left(\frac{2\, mol\ K^+}{1\, mol\ K_2CO_3}\right) = \frac{0.40\, mol\ K^+}{1\, L} = 0.40 \text{ M } K^+$$

Section 3.8: Diluting Solutions: Since only water is added during the dilution of aqueous solutions, the moles of solute before dilution ($M_{init} \cdot L_{init}$) equal the moles of solute after dilution ($M_{fin} \cdot L_{fin}$) leading to $M_{init} \cdot L_{init} = M_{fin} \cdot L_{fin}$. To calculate the volume of water added, simply subtract the initial number of liters from the final number of liters. Note that any unit of volume can be used in place of liters. Hence, the following formula can be used to solve all dilution problems:

$$\mathbf{M_1V_1 = M_2V_2}$$

Sections 3.9 & 10: Solution Stoichiometry: You must consider the balanced chemical reaction and set up the appropriate conversion factors to solve solution stoichiometry and titration problems. Do no use the dilution formula for these problems!

Example. How many L of 0.164 M $Ca(OH)_2$ is needed to neutralize 25.00 mL of 0.458 M HCl solution?

$$Ca(OH)_2(aq) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + 2\ H_2O(l)$$

$$\text{L } Ca(OH)_2 = 25.00 \text{ mL}\left(\frac{1\, L}{1000\, mL}\right)\left(\frac{0.458\, moles\ HCl}{L}\right)\left(\frac{1\, mol\ Ca(OH)_2}{2\, mol\ HCl}\right)\left(\frac{1\, L}{0.164\, mol\ Ca(OH)_2}\right)$$

$$= 0.349 \text{ L } Ca(OH)_2$$

CHM 152LL: Lab Calculation Review Problems

1. Molar Mass: Calculate the number of moles in 75.0 g of lead(II) perchlorate trihydrate, $Pb(ClO_4)_2 \cdot 3H_2O$. For hydrates the water mass is **added** to the rest of the molecule's mass to get the total molar mass.

2. a) Ion Molarities: What is the molarity of Na^+ ions in a 0.25 M solution of Na_3PO_4?
   b) What is the molarity of PO_4^{3-} ions in this solution?

3. a) Dilution: How many mL of 6.00 M H_2SO_4 are needed to prepare 2.00 liters of 0.100 M H_2SO_4?
   b) How much water is added to prepare this solution?

4. Molar Concentration: How many moles of HCl are there in 25.8 mL of 0.593 M HCl?

5. Molar Concentration: How many grams of solid NaOH are required to prepare 0.500 liters of 0.100 M NaOH solution?

6. Solution Stoichiometry: How many mL of 0.0500 M H_2SO_4 are necessary to precipitate all the Ba^{2+} in 15.0 mL of 0.0200 M $BaCl_2$? (Write the balanced equation for the reaction, given $BaSO_4$ (s) is formed.)

7. Solution Stoichiometry: 60.0 mL of 0.100 M NaOH are required to neutralize 15.0 mL of H_2SO_4. What is the molarity of the H_2SO_4? (Write the balanced equation for the reaction.)