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Review Worksheet

This worksheet serves to review concepts and calculations from first semester General Chemistry (CHM 150/151). Brief descriptions of concepts are included here. If you have trouble with any topics in this worksheet, you should reread the appropriate sections of the OpenStax textbook for more in-depth explanations.

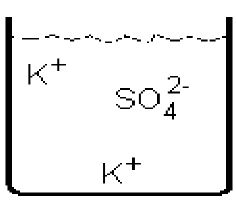
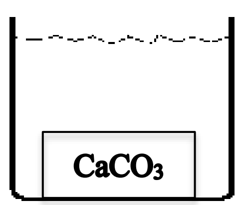
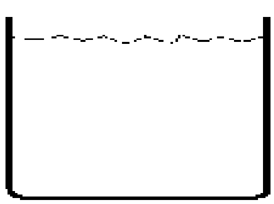
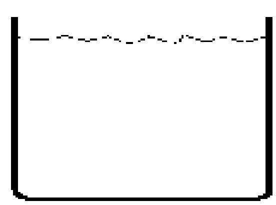
Solubility Rules and Molecular-Level Representations of Ionic Solutions

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. Ionic compounds in water will either dissociate (if soluble) or stick together (if insoluble). The solubility rules provided below may be used to predict whether an ionic compound is soluble or insoluble in water .

Solubility Rules for Ionic Compounds in Water

The **compound is SOLUBLE** if it has:	The **compound is INSOLUBLE** if it has:
1. Li^{+}, Na^{+}, K^{+}, NH_4^{+} ions (**ALWAYS!**)	5. Carbonate ion, CO_3^{2-}, **but** Rule 1 ions
2. Acetate ion ($C_2H_3O_2^{-}$), nitrate ion (NO_3^{-}), or perchlorate ion (ClO_4^{-})	6. Chromate ion, CrO_4^{2-}, **but** Rule 1 ions
3. Halide ions (X^{-}): chloride ion (Cl^{-}), bromide ion (Br^{-}), or iodide ion (I^{-}), ***but*** AgX, PbX_2, Hg_2X_2 are **insoluble**	7. Phosphate ion, PO_4^{3-}, **but** Rule 1 ions
4. Sulfate ion (SO_4^{2-}), ***but*** $CaSO_4$, $SrSO_4$, $BaSO_4$ are **insoluble**	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**

Drawings of substances in solution will often be used to explain how molecules and compounds behave in solutions and reactions. For each ionic compound listed below write the chemical formula and draw a representation of the compound in water. The first two have been completed as examples. (2 pt each formula and 2 pts each drawing = 8 pts total)

1. potassium sulfate formula K_2SO_4  	2. calcium carbonate formula $CaCO_3$ 
3. **silver chromate** formula ____________ 	4. **sodium phosphate** formula _____________ 

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Chemical Reactions in Solution

Three common types of chemical reactions *(OpenStax text, sections 4.2)* that take place in solution are:

1. precipitation
2. acid-base neutralization
3. oxidation-reduction (redox)

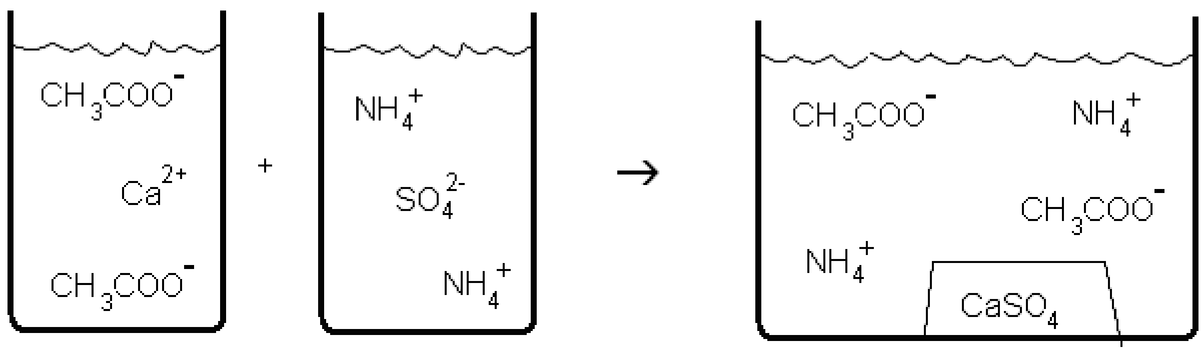
For the following set of reactants, indicate the type of reaction (No Reaction, Precipitation, Acid-Base Neutralization, or Oxidation-Reduction). If there is no reaction write NR for the type but you still must complete the reactions and molecular-level drawings. Then write and balance the molecular, 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). Note that you should draw water molecules if they are part of the reaction.

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

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

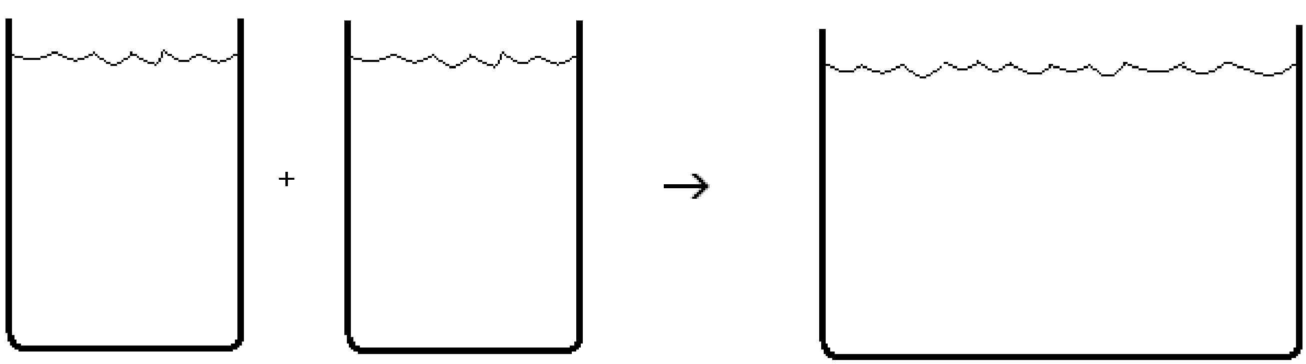


nitric acid and strontium hydroxide Reaction type (1 pt): ____________________

Molecular (3 pts):____

Ionic (4 pts):____

Net Ionic (2 pts):____



1 pt 1 pt 2 pts

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Review of Common Definitions / Calculations

A brief summary of some useful definitions and relationships is given below; if you need an in-depth review of these concepts, refer to the sections listed below in your online textbook: OpenStax General Chemistry (https://cnx.org/contents/havxkyvS@12.1:uXg0kUa-@5/Introduction). The review problems that follow will give you practice on some of the types of calculations that are used in this lab course. In general, when solving numerical problems make sure to show your work including units and express your final answer with the proper number of significant figures.

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

Example. *Molar mass of KOH = 56.11 g/mol; thus, 56.11 g KOH =* ***1.00 mole KOH***

Molarity: The concentration of a solution is commonly reported in units of Molarity (M). Refer to OpenStax (section 3.3) for additional information. The molarity of a solution is calculated using the moles of solute divided by the volume of solution:

$$\mathbf{M} = \frac{\text{moles solute}}{\text{liters solution}}$$

Example: What is the concentration of a solution made by adding 32.6 g NaCl to 875 mL of solution?

Moles solute: 32.6 g x (1 mol / 58.44 g NaCl) = 0.55784 mol NaCl

M = 0.55784 mol / 0.875 L = **0.638 M** (3 sig figs because of the mass and volume)

Diluting Solutions: Since only water is added during the dilution of aqueous solutions, the moles of solute before dilution (M ·V) equal the moles of solute after dilution (M·V) leading to $M_1 \cdot V_1 = M_2 \cdot V_2$. V_2 is always the total volume of solution (initial solution + water, or other solutions). To calculate the volume of water added, simply subtract the initial volume (V_1) from the final volume (V_2). Note that any unit of volume (mL, drops, cm^3, etc.) can be used in place of liters, if the units are the same. The following formula can be used to solve all **dilution problems**:

$$\mathbf{M_1V_1 = M_2V_2}$$

Example: What is the final concentration of 25.0 mL of a 0.15 M NaCl solution that is added to 150.0 mL of water?

M_1 = 0.15 M, V_1 = 25.0 mL; V_2 = total volume (25.0 mL + 150.0 mL) = 175.0 mL

$M_2 = M_1V_1 / V_2$ = (0.15 M x 25.0 mL) / 175.0 mL = **0.021 M**

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?

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

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

Titration (Solution Stoichiometry): You must consider the balanced chemical reaction and set up the appropriate conversion factors to solve solution stoichiometry and titration problems. **NOTE: Do not use the dilution formula ($M_1V_1 = M_2V_2$) for these problems!** Refer to OpenStax (section 4.5) for additional information.

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

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

$$25.00\ mL\left(\frac{1\,L}{1000\,mL}\right)\left(\frac{0.458\ moles\,HCl}{L}\right)\left(\frac{1\ mol\,Ca(OH)_2}{2\,mol\,HCl}\right)\left(\frac{1\,L}{0.164\,mol\,Ca(OH)_2}\right) = \mathbf{0.349\ L\ Ca(OH)_2}$$

Thermodynamics Review: By convention, energy changes are based on the reactants and products in a chemical reaction which are referred to as the system. Everything else (the container, room, etc.) is called the surroundings. In a chemical process, the heat of reaction, also called the enthalpy of reaction, is the enthalpy of the products minus the enthalpy of reactants. In the equation below, standard heat of formation values (ΔH^o_f) are used for the reactants and products and n represents the number of moles based on the stoichiometric coefficients in a reaction. The standard heat of formation is the enthalpy change when 1 mole of a substance is formed from its elements in their standard states.

Enthalpy of reaction: $\Delta H^o_{rxn} = \Sigma n\Delta H^o_f$ (products) – $\Sigma n\Delta H^o_f$ (reactants)

For an exothermic reaction, heat flows from the system to the surroundings and it has a negative sign because the system has lost heat so it is at a lower state of energy. Conversely, an endothermic reaction has a positive sign because the system has gained energy from the surroundings.

Refer to OpenStax (section 5.3) for additional information.

Redox reactions and oxidation numbers: *A substance is oxidized when it loses electrons and is reduced when it gains electrons. An oxidizing agent causes a substance to be oxidized and is itself reduced. A reducing agent causes a substance to be reduced and is therefore oxidized.*

Example: $\overset{0}{Cu}\ (s) + 2\ \overset{+1}{Ag}\overset{+5}{N}\overset{-2}{O_3}\ (aq) \rightarrow 2\overset{0}{Ag}\ (s) + \overset{+2}{Cu}(\overset{+5}{N}\overset{-2}{O_3})_2\ (aq)$

Oxidation numbers are assigned above each element. To determine what is oxidized or reduced, we look for changes in oxidation numbers. Since Cu (s) increased from 0 to +2, it must have lost two electrons; thus, Cu was being oxidized. Ag^+ in $AgNO_3$ decreased from +1 to 0, so it gained one electron and was reduced. Note that we refer to the specific element as what is being oxidized or reduced; whereas we refer to the whole substance (compound, ion, or element) as being the oxidizing or reducing agent. Refer to OpenStax (section 4.2) for additional information.

Oxidized: ***Cu (s)*** Reduced: ***Ag^+ in $AgNO_3$ (aq)***

Oxidizing agent: ***$AgNO_3$ (aq)*** Reducing agent: ***Cu (s)***

Calculations. Make sure to show your set-ups for all calculations and express answers with the correct number of significant figures and appropriate units!

1. a) What is the molarity of aluminum ions in a 0.525 M solution of aluminum sulfate? (2 pts)

b) What is the molarity of sulfate ions in this solution? (2 pts)

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2. How many mL of 7.58 M $MgCl_2$ are needed to prepare 2.50 liters of 0.155 M $MgCl_2$? (3 pts)

3. How many grams of barium nitrate are required to prepare 2.25 liters of 0.366 M barium nitrate solution? (4 pts)

4. What is the molarity of a NaOH solution if 12.28 mL are needed to neutralize 27.75 mL of 0.1452 M H_2SO_4? (Write the balanced equation for the reaction first.) (5 pts)

5. Calculate the enthalpy of reaction (ΔH^o_{rxn}) for the balanced equation below using the given enthalpy of formation values. (4 pts)

$$C_6H_{12}O_6\ (s) \rightarrow 2\ C_2H_5OH\ (l) + 2\ CO_2\ (g)$$

Substance	**ΔH^o_f (kJ/mol)**
$C_6H_{12}O_6$ (s)	- 1275.0
C_2H_5OH (l)	- 277.6
CO_2 (g)	- 393.5

6. a) Assign oxidation numbers to each element in the following balanced equation (4 pts):

$$2\ PbS\ (s) + 3\ O_2\ (g) \rightarrow 2\ PbO\ (s) + 2\ SO_2\ (g)$$

Reactant Side			Product Side			
Pb	S	O	Pb	O in PbO	S	O in SO_2

b) Identify what element has been oxidized and which has been reduced in the reaction above. Also identify the oxidizing agent and the reducing agent. (4 pts)

Oxidized: ____________ Reduced: _______________

Oxidizing agent: ______________ Reducing agent: ____________