POGIL: Who Are the Players?

Name: **Group Members:**

Objective:

Develop and utilize solubility rules for common ions in water.
Write simple net ionic equations for double replacement reactions.
Correctly predict the products of a double replacement reaction.
Write net ionic equations given the reactant salts.

Text Reference: Chang and Goldsby (*Chemistry: The Essential Concepts,* McGraw-Hill, 2014) pp. 100-104.

New Concepts:

- An *aqueous* solution is a solution with water as the solvent.
- A compound is said to be *soluble* if it readily dissolves in water and does not *precipitate* if left undisturbed for an extended period of time.
- A *spectator ion* is an ion that is present during a reaction but does not take part in the reaction.
- A *net ionic equation* is an equation that shows only the ions that undergo changes during a chemical reaction. (Spectator ions are omitted from net ionic equations.)
- *Dissociation* is the separation of an ionic salt into its ion, usually in water.
- A *precipitate* is the insoluble solid that remains after an aqueous reaction has occurred.

Model: Rules of Solubility in Aqueous Solutions

Several solid compounds are placed in water to determine if they are soluble in water. The results are shown in the chart below. An **X** indicates the compound **DOES NOT** readily dissolve in water. If it does dissolve, no mark is made.

The top row shows the cation in the compound. The far left column shows the anion in the compound. For example, magnesium hydroxide is insoluble, magnesium bromide is soluble, and silver chloride is insoluble.

Table I – This table represents an overview of the solubility of selected salts in water

	NH_4^+	Li^+	Na^+	K^+	Mg^{2+}	Ca^{2+}	Sr^{2+}	Ba^{2+}	Ag^+	Pb^{2+}	Hg_2^{2+}	Fe^{2+}	Cu^{2+}	Zn^{2+}
NO_3^{1-}														
$C_2H_3O_2^{1-}$									X					
Cl^{1-}									X	X	X			
Br^{1-}									X	X	X			
I^{1-}									X	X	X			
SO_4^{2-}						X	X	X	X	X				
OH^{1-}					X				X	X	X	X	X	X
S^{2-}					X	X	X	X	X	X	X	X	X	X
CO_3^{2-}					X	X	X	X	X	X	X	X	X	X
PO_4^{3-}					X	X	X	X	X	X	X	X	X	X

Reviewing the Model:

1. Is calcium carbonate soluble or insoluble? _____

2. Is silver bromide soluble or insoluble? _____

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3. Is iron (II) sulfate soluble or insoluble? _____

4. For what cations and anions are the compounds *always soluble* in water?

5. (a) For what anions are most of the compounds *usually soluble*?

   (b) For those that usually form soluble compounds, which cations result in the formation of insoluble compounds? List each cation separately.

6. For what anions are most of their compounds *usually insoluble*?

Exercises:

7. In discussion with your classmates and your teacher, record some key rules that will help you determine the solubility of most compounds you will encounter in this course.

8. Using your rules from question 7, indicate whether the following compounds are soluble (S) or insoluble (I). Double-check your answers by consulting the table in the model. (Revise your rules if necessary.)

(a) calcium carbonate	(b) strontium hydroxide	(c) silver chloride	(d) silver iodide
(e) calcium sulfate	(f) potassium nitrate	(g) sodium phosphate	(h) barium acetate
(i) iron(III) nitrate	(j) lead(II) carbonate	(k) copper(II) hydroxide	(l) magnesium phosphate

Model II: Net Ionic Equations

When a soluble salt is placed in water it *dissociates*, separates into its ions. For example, NaCl is soluble:

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Example I: **sodium nitrate reacts with potassium acetate in an aqueous solution**

In *double displacement reactions*, two ionic compounds react and switch ions, in an aqueous situation.

$$NaNO_3 + KC_2H_3O_2 \rightarrow KNO_3 + NaC_2H_3O_2$$

According to this "pencil and paper" reaction, potassium nitrate and sodium acetate are produced. However, if this reaction is actually carried out in an aqueous solution, nothing appears to happen.

If we investigate this system using the concept of net ionic equations, we can see why nothing appears to happen. First, write all of the compounds in the equations, showing all the ions present when the reaction is carried out in water. This is called a *complete ionic equation*.

$$Na^+_{(aq)} + NO_3^-{}_{(aq)} + K^+_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow K^+_{(aq)} + NO_3^-{}_{(aq)} + Na^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

Next we cross out any ions that are present on both the reactant side and the product side of the reaction.

$$\cancel{Na^+_{(aq)}} + \cancel{NO_3^-{}_{(aq)}} + \cancel{K^+_{(aq)}} + \cancel{C_2H_3O_2^-{}_{(aq)}} \rightarrow \cancel{K^+_{(aq)}} + \cancel{NO_3^-{}_{(aq)}} + \cancel{Na^+_{(aq)}} + \cancel{C_2H_3O_2^-{}_{(aq)}}$$

The ions we cross out, which are the same on both sides, are called *spectator ions*; they are just "standing around watching", hence the term spectator.

Both of the compounds on the left hand side of the reaction and the right hand side of the reaction are soluble. Therefore, no solid precipitate forms and *no reaction occurs (NVR)*. The ions are all simply floating around together in the solution.

Example 2: **strontium nitrate solution reacts with potassium sulfate solution**

Molecular Equation: Predict products and write the complete molecular equation

$$Sr(NO_3)_2 + K_2SO_4 \rightarrow 2\ KNO_3 + SrSO_4$$

Complete Ionic Equation: Write soluble compounds as ions and insoluble compounds (precipitates) in the combined form.

$$Sr^{2+}_{(aq)} + 2\ NO_3^-{}_{(aq)} + 2\ K^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow 2\ K^+_{(aq)} + 2\ NO_3^-{}_{(aq)} + SrSO_4\ _{(s)}$$

Cross out spectator ions.

$$Sr^{2+}_{(aq)} + \cancel{2\ NO_3^-{}_{(aq)}} + \cancel{2\ K^+_{(aq)}} + SO_4^{2-}{}_{(aq)} \rightarrow \cancel{2\ K^+_{(aq)}} + \cancel{2\ NO_3^-{}_{(aq)}} + SrSO_4\ _{(s)}$$

Net Ionic Equation: Everything that participates in the reaction gets recorded in the net ionic equation.

$$Sr^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow SrSO_4\ _{(s)}$$

In this example, writing a net ionic equation is useful because it indicates those chemical species that participate in the actual chemical reaction and form an insoluble product.

Reviewing the Model:

9. In Model II, Example 1, what are the spectator ions?

10. In Model II, Example 2, what ions are spectators?

11. In Model II, Example 2, what precipitate is formed?

12. Why is there no reaction when solutions $NaNO_3$ and $KC_2H_3O_2$ are mixed?

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Exercises:

13. Use the steps shown in Model II Example 2 to help you write the net ionic equations for each of the following reaction situations. Make sure your net ionic equation is properly balanced and labeled with state symbols.

    (a) $Fe(C_2H_3O_2)_3 + Ca(OH)_2 \rightarrow$

    (b) $KI + Pb(NO_3)_2 \rightarrow$

    (c) a solution of barium hydroxide is added to a solution of potassium nitrate

    (d) dilute potassium sulfide is added to aqueous barium chloride

14. In Model II, Example1, solutions of sodium nitrate and potassium acetate are mixed together forming all soluble products. If the product solution were evaporated to dryness, name all the compounds that *might* be found in the container.

POGIL inspiration: David Hanson's Foundations of Chemistry