

# *CH 221 Fall 2021:*

# **“Net Ionic Reactions”** *(in class) Lab - Instructions*

**Note: This is the lab for section 01 and H1 of CH 221 only.**

- *If you are taking section W1 of CH 221, please use this link:*

<http://mhchem.org/s/6b.htm>

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*Step One:*

**Print this lab!** You will need a printed (hard copy) version of pages I-6-2 through I-6-11 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

*Step Two:*

**Bring the printed copy of the lab with you on Wednesday, October 27.** During lab in room AC 2507, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

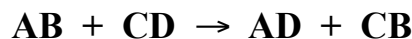
*Step Three:*

Complete the lab work and calculations on your own, then **turn it in** (*pages I-6-8 through I-6-11 only*) **at the beginning of recitation to the instructor on Wednesday, November 3.** The graded lab will be returned to you the following week during recitation.

*If you have any questions regarding this assignment, please email ([mike.russell@mhcc.edu](mailto:mike.russell@mhcc.edu)) the instructor! Good luck on this assignment!*

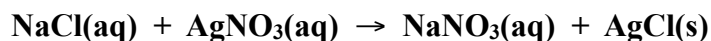
## Net Ionic Reactions in Aqueous Solutions

Double replacements are among the most common of the simple chemical reactions. Consider the hypothetical reaction:



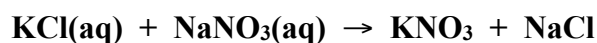
where AB exists as A<sup>+</sup> and B<sup>-</sup> ions in solution and CD exists as C<sup>+</sup> and D<sup>-</sup> ions in solution. As the ions come in contact with each other, there are six possible combinations that might conceivably cause a chemical reaction. Two of these combinations are the meeting of ions of like charge; that is, A<sup>+</sup> with C<sup>+</sup> and B<sup>-</sup> with D<sup>-</sup>. Since particles with like electrical charges repel each other, no reaction will occur. Two other possible combinations are those of the original two compounds; that is A<sup>+</sup> with B<sup>-</sup> and C<sup>+</sup> with D<sup>-</sup>. This combination would lead to no change. Thus the only possibilities for chemical reaction are the combination of each of the positive ions with the negative ion of the other compound; that is, A<sup>+</sup> with D<sup>-</sup> and C<sup>+</sup> with B<sup>-</sup>.

*Example 1:* When solutions of sodium chloride and silver nitrate are mixed, the combination of silver cations and chloride anions form silver chloride, which precipitates and settles to the bottom of the container. Note that the states of matter are included: (aq) substance is soluble in water; (s) substance is insoluble in water (solid precipitate)



This combination – the **molecular equation** - of chemicals is referred to as a **precipitation reaction** since an insoluble solid, AgCl, is present as a product.

*Example 2:* When solutions of potassium chloride and sodium nitrate are mixed, the equation for the hypothetical double replacement reaction is:

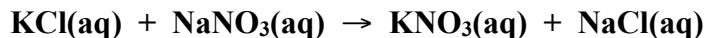


But has there been a reaction? Double replacement reactions occur when one of the following is formed as a product of the reaction:

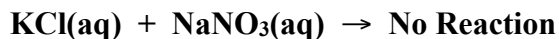
- an **insoluble solid** (precipitate) - check the solubility table in this lab report. If a solid has formed, this is called a **precipitation reaction**.
- a **gas** - for example, CO<sub>2</sub> (from H<sub>2</sub>CO<sub>3</sub>), SO<sub>2</sub> (from H<sub>2</sub>SO<sub>3</sub>), or NH<sub>3</sub> (from NH<sub>4</sub>OH). If a gas has formed, this is called a **gas forming reaction**.
- water** from an acid (source of H<sup>+</sup>) and a base (source of OH<sup>-1</sup>). If water forms from an acid and a base (along with an ionic "salt"), this is called an **acid-base reaction**.

Using the solubility table (see below) we find both KNO<sub>3</sub> and NaCl are water-soluble (aqueous, or *aq* for short) products. There is no precipitate, gas or water from this combination. Thus in Example 2, we conclude that even though we can write an equation for a double replacement reaction, no reaction occurs. We simply end up with a solution containing four kinds of ions - Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup>, and NO<sub>3</sub><sup>-</sup>.

Thus the **molecular equation** is more properly written:



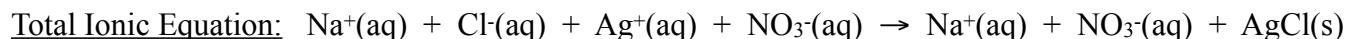
but in terms of “if something happens”, we should write:



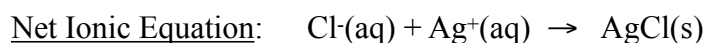
Aqueous solutions of sodium chloride and silver nitrate will undergo double replacement reaction to produce a white precipitate of silver chloride and aqueous sodium nitrate. What would happen if we just mixed solid silver nitrate and solid sodium chloride together? No apparent reaction occurs. Thus the water performs some necessary function that allows the reaction to proceed. When ionic compounds are dissolved in water, the ions separate and become surrounded by water molecules. This frees the ions from the crystal lattice, allowing them to move throughout the solution and react with appropriate ions of opposite charge.

To clarify what reaction occurs between ions in electrolyte solutions, we write **total ionic equations**. In this type of equation, compounds are written in the form in which they are predominately present in water. Most notably, soluble compounds (aq) are written as ions in solution. Others (s, l, g) are written in their molecular form.

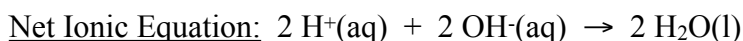
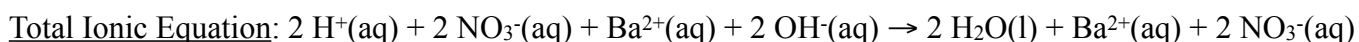
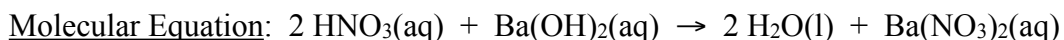
For example, if we write the total ionic equation for the double replacement precipitation reaction (See Example 1) we get the following:



Note that during the course of reaction, there has been no change in the  $\text{Na}^+$  and  $\text{NO}_3^-$  ions. These unreacted ions (**spectator ions**) can be left out of the total ionic equation to yield the **net ionic equation**. Net ionic equations tell us only what is actually changing during reaction.



Another example is illustrated below for the reaction of nitric acid and a dilute aqueous solution of barium hydroxide (an **acid-base reaction**):



This is an example of an **acid-base reaction**.

We will use the following solubility table in CH 221:

## CH 221 Solubility Table for Ionic Compounds

### SOLUBLE COMPOUNDS

Almost all salts of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{NH}_4^+$

Salts of nitrate,  $\text{NO}_3^-$   
chlorate,  $\text{ClO}_3^-$   
perchlorate,  $\text{ClO}_4^-$   
acetate,  $\text{CH}_3\text{CO}_2^-$

### EXCEPTIONS

Almost all salts of  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$

Halides of  $\text{Ag}^+$ ,  $\text{Hg}_2^{2+}$ ,  $\text{Pb}^{2+}$

Compounds containing  $\text{F}^-$

Fluorides of  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Pb}^{2+}$

Salts of sulfate,  $\text{SO}_4^{2-}$

Sulfates of  $\text{Ca}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Pb}^{2+}$

### INSOLUBLE COMPOUNDS

Most salts of carbonate,  $\text{CO}_3^{2-}$   
phosphate,  $\text{PO}_4^{3-}$   
oxalate,  $\text{C}_2\text{O}_4^{2-}$   
chromate,  $\text{CrO}_4^{2-}$

Most metal sulfides,  $\text{S}^{2-}$

Most metal hydroxides and oxides

### EXCEPTIONS

Salts of  $\text{NH}_4^+$  and the alkali metal cations

*Note: Use this table for all CH 221 solubility questions!*

The following examples should help you understand how the solubility table works and also how to complete the written part of this assignment.

*Example:* Is  $\text{PbSO}_4$  soluble in water? What species are present in a water solution?

*Answer:* To solve, notice how  $\text{PbSO}_4$  has a sulfate ion ( $\text{SO}_4^{2-}$ ). Most salts of sulfate are soluble (i.e. they dissolve in water, or are (aq)), but salts of sulfate with a  $\text{Pb}^{2+}$  ion are an exception to this rule. Hence,  $\text{PbSO}_4$  is insoluble (it does not dissolve in water), and we would write  $\text{PbSO}_4$  in water as  $\text{PbSO}_4(\text{s})$ . Indeed,  $\text{PbSO}_4(\text{s})$  is the only species present in a water solution.

*Example:* Is  $\text{Li}_2\text{S}$  soluble in water? What species are present in a water solution?

*Answer:* To solve, notice how  $\text{Li}_2\text{S}$  has a sulfide ion ( $\text{S}^{2-}$ ). Most salts of sulfide are insoluble (i.e. they do not dissolve in water, or are (s)), but salts of alkali metals (which includes  $\text{Li}^+$ ) are an exception to this rule. Hence,  $\text{Li}_2\text{S}$  is soluble (it *does* dissolve in water), and we would write  $\text{Li}_2\text{S}$  in water as  $\text{Li}_2\text{S}(\text{aq})$ .

Further, because  $\text{Li}_2\text{S}$  dissolves in water, we should really write it as the dissociation ions – i.e. the molecular  $\text{Li}_2\text{S}$  dissociates into lithium and sulfide ions. The species which are present in a water solution of  $\text{Li}_2\text{S}(\text{aq})$  are  $2 \text{Li}^+(\text{aq})$  and  $\text{S}^{2-}(\text{aq})$  (molecular  $\text{Li}_2\text{S}$  does not exist in water.)

*Example:* Describe  $\text{CaCO}_3$ ,  $\text{RbMnO}_4$  and  $\text{TiCrO}_4$  in terms of their solubility in water.

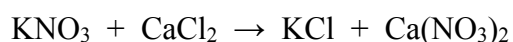
*Answer:* Use the solubility table to answer these types of questions:

- **$\text{CaCO}_3$**  has a carbonate ion, and calcium is not an alkali metal or ammonium, so  $\text{CaCO}_3$  is insoluble in water. We would write it as  $\text{CaCO}_3(\text{s})$ .
- **$\text{RbMnO}_4$**  has an alkali metal ion (rubidium), so by default, all alkali metals are water soluble (no exceptions, at least in CH 221!) So we would write this species as  $\text{RbMnO}_4(\text{aq})$  or, as dissolve ions, we would write it as  $\text{Rb}^+(\text{aq})$  and  $\text{MnO}_4^-(\text{aq})$ .
- **$\text{TiCrO}_4$**  has a chromate ion, and titanium is not an alkali metal or ammonium, so  $\text{TiCrO}_4$  is insoluble in water. We would write it as  $\text{TiCrO}_4(\text{s})$ .

*Example:* Write the balanced molecular equation and net ionic reaction that occurs between potassium nitrate and calcium chloride in water. Classify this reaction type.

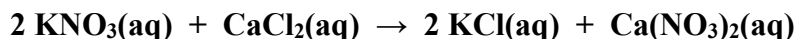
*Answer:* First, we need the chemical equations for potassium nitrate and lithium chloride. They are  $\text{KNO}_3$  and  $\text{CaCl}_2$ . Notice the ionic charges on the cations and anions:  $\text{K}^+$ ,  $\text{NO}_3^{-1}$ ,  $\text{Ca}^{2+}$ ,  $\text{Cl}^{-1}$ .

All of the reactions in this lab are “double displacement” – the reactant cations will switch places, forming new products. *The ionic charges will not change upon going from reactant to product.* Potassium and chloride will come together as  $\text{KCl}$  (only one  $\text{Cl}^{-1}$  for every one  $\text{K}^{+1}$ ), and calcium and nitrate will come together as  $\text{Ca}(\text{NO}_3)_2$  (two nitrates being needed for every calcium +2 ion.) Initially, the equation looks like this:



Notice the parentheses used for more than one polyatomic ion ( $\text{Ca}(\text{NO}_3)_2$ ) but parentheses are not used when only one polyatomic ion is used ( $\text{KNO}_3$ ).

We need to balance this reaction and add states of matter. Every compound with potassium (an alkali metal) or nitrate will dissolve in water;  $\text{CaCl}_2$  is also soluble in water (Ca is not Ag, Pb or Hg), leading to:

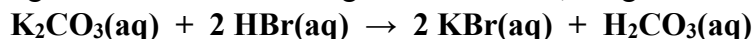


To *classify* this reaction, our options include: precipitate, acid-base, gas forming, or no reaction. Since no solids have formed, it is not a precipitation reaction. Water has not formed from an acid or base, so this is excluded; and  $\text{H}_2\text{CO}_3$  and  $\text{NH}_4\text{OH}$  have not formed (see next example), so gas forming is excluded. Indeed, all the reactants and products are (aq), so nothing really happens; classify this reaction as “**no reaction**.” Nothing needs to be written for a net ionic reaction because nothing happens!

*Example:* Write the balanced molecular equation and net ionic reaction that occurs between potassium carbonate and hydrobromic acid in water. Classify this reaction type.

*Answer:* First, we need the chemical equations for the reactants. They are  $\text{K}_2\text{CO}_3$  and  $\text{HBr}$ , and they make  $\text{K}^+$ ,  $\text{CO}_3^{2-}$ ,  $\text{H}^+$ ,  $\text{Br}^-$ . Performing a “double displacement” on these reactants – the reactant cations will switch places – we get:  $\text{K}_2\text{CO}_3 + \text{HBr} \rightarrow \text{KBr} + \text{H}_2\text{CO}_3$

Balancing this reaction and adding states of matter, we get:



At first, it looks like this is a “no reaction” classification – all states are aqueous – but **make sure you check for  $\text{H}_2\text{CO}_3$  and  $\text{NH}_4\text{OH}$**  – these two species are the hallmarks of the **gas forming reaction** since both are unstable compounds and further decompose to new products. ***Be watchful for  $\text{H}_2\text{CO}_3$  and  $\text{NH}_4\text{OH}$ !***

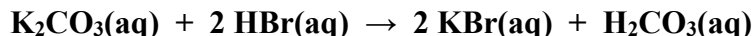
Carbonic acid ( $\text{H}_2\text{CO}_3$  breaks down into water and carbon dioxide, so really you should write:



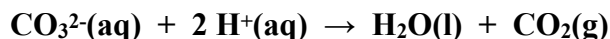
and ammonium hydroxide ( $\text{NH}_4\text{OH}$ ), which breaks down into water and ammonia, should be written:



So in this **gas forming** example,



should be written as a net ionic equation in the following manner:



## PROCEDURE and LAB REPORT:

Use the attached sheets to complete this week's lab. For each reaction,

- **Mix** 1.0 mL (20 drops) of each of the two indicated solutions (below) in a clean (but not necessarily dry) **small** test tube and record observations that might indicate a chemical change has occurred (**color, precipitate, bubbles of a gas, or heat released.**)
- Write the **balanced molecular equation** (double displacement or exchange reaction) for each reaction. Show **states of matter** (use the **solubility table in this lab report for your answers**) and **ionic charges (on ions, not molecules)** for all species.
- Write the **total ionic equation** and the **net ionic equation** for each reaction. Be sure to include all states of matter and ionic charges. If all the products are aqueous, no reaction has occurred, and you should write **no reaction** in place of the net ionic equation. Note that even if no reaction occurs, you will still be required to write a balanced molecular equation and the total ionic equation.
- Finally, **classify each reaction** as **precipitation, acid-base, gas forming or** (if nothing happened) **no reaction**. Remember that gas forming reactions often create unstable precursors (such as **H<sub>2</sub>CO<sub>3</sub>** (which creates CO<sub>2</sub>(g) and H<sub>2</sub>O(l)) and **NH<sub>4</sub>OH** (which creates NH<sub>3</sub>(g) and H<sub>2</sub>O(l)).)

### The reactions:

1. Barium Nitrate + Magnesium Sulfate
2. Barium Nitrate + Hydrochloric Acid
3. Barium Nitrate + Sodium Carbonate
4. Iron(III) Chloride + Sodium Hydroxide
5. Iron(III) Chloride + Sodium Phosphate
6. Iron(III) Chloride + Magnesium Sulfate
  
7. Magnesium Sulfate + Sodium Hydroxide
8. Magnesium Sulfate + Sodium Carbonate
9. Ammonium Oxalate + Barium Nitrate
10. Hydrochloric Acid + Sodium Hydroxide
11. Hydrochloric Acid + Sodium Carbonate
12. Silver Nitrate + Potassium Chromate
  
13. Silver Nitrate + Iron(III) Chloride
14. Sodium Hydroxide + Ammonium Chloride
15. Sodium Hydroxide + Sulfuric Acid
16. Copper(II) Sulfate + Iron(III) Chloride
17. Copper(II) Sulfate + Sodium Phosphate
18. Acetic Acid + Sodium Carbonate

## Net Ionic Reactions *Worksheet*

Name:

Complete the following worksheet using the instructions provided. Remember to show states of matter and charges where appropriate. **M = Molecular Equation**, **T = Total Ionic Equation**, and **N = Net Ionic Equation**. This lab is due during recitation on Wednesday November 3.

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1. Barium Nitrate + Magnesium Sulfate Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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2. Barium Nitrate + Hydrochloric Acid Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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3. Barium Nitrate + Sodium Carbonate Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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4. Iron(III) Chloride + Sodium Hydroxide Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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5. Iron(III) Chloride + Sodium Phosphate Observations: \_\_\_\_\_



M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**        **acid-base**        **gas forming**        **no reaction**

6. Iron(III) Chloride + Magnesium Sulfate        Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**        **acid-base**        **gas forming**        **no reaction**

7. Magnesium Sulfate + Sodium Hydroxide        Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**        **acid-base**        **gas forming**        **no reaction**

8. Magnesium Sulfate + Sodium Carbonate        Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**        **acid-base**        **gas forming**        **no reaction**

9. Ammonium Oxalate + Barium Nitrate        Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**        **acid-base**        **gas forming**        **no reaction**

10. Hydrochloric Acid + Sodium Hydroxide        Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**       **acid-base**       **gas forming**       **no reaction**

11. Hydrochloric Acid + Sodium Carbonate       Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**       **acid-base**       **gas forming**       **no reaction**

12. Silver Nitrate + Potassium Chromate       Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**       **acid-base**       **gas forming**       **no reaction**

13. Silver Nitrate + Iron(III) Chloride       Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**       **acid-base**       **gas forming**       **no reaction**

14. Sodium Hydroxide + Ammonium Chloride       Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):*   **precipitation**       **acid-base**       **gas forming**       **no reaction**

15. Sodium Hydroxide + Sulfuric Acid       Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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16. Copper(II) Sulfate + Iron(III) Chloride      Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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17. Copper(II) Sulfate + Sodium Phosphate      Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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18. Acetic Acid + Sodium Carbonate      Observations: \_\_\_\_\_

M: \_\_\_\_\_

T: \_\_\_\_\_

N: \_\_\_\_\_

*Type of reaction (circle one):* **precipitation**      **acid-base**      **gas forming**      **no reaction**

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**Bonus!** On a *separate piece of paper*, add an original poem or short story of at least 50 words in length for extra credit... content will not be criticized, but the poem must be original, and short haikus written at the bottom of this page will not count (although the instructor will find them fun to read! ☺) Original music will also count!