Chemistry 132.E.1. Double Replacement Reactions

The most common reaction between two ionic substances dissolved in water is called a **double replacement reaction**. The general form of a double replacement reaction is as follows:

$$AX + BY \rightarrow AY + BX \quad (1)$$

where A and B are cations and X and Y are anions. Double replacement reactions involve the formation of a solid product called a **precipitate**. On the other hand, some ionic compounds do not react when mixed together. If no precipitate is formed, then we can conclude that no reaction occurred.

An example of a double replacement reaction involves the reaction between barium nitrate ($Ba(NO_3)_2(aq)$) and sodium sulfate ($Na_2SO_4(aq)$):

$$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2\ NaNO_3(aq) \quad (2)$$

This equation states that when aqueous solutions of $Ba(NO_3)_2$ and Na_2SO_4 are mixed, a precipitate of barium sulfate ($BaSO_4$) is formed.

Procedure

Normally you would go into the laboratory and actually perform the following reactions to observe the formation of a precipitate, however, it is just as easy to do using prepared tables and there is less chemical waste that needs to be disposed of properly.

To do this exercise, you must pick two chemicals that you want to mix from Table 1. One ionic compound must be from the top row and the other must be from the left column. For example, you could choose barium nitrate solution and sodium phosphate solution. When these two solutions are mixed, a precipitate is formed (as indicated by ppt). If two ionic solutions are mixed and no precipitate forms, this is indicated by NR (no reaction). An example of this would be the combination of barium nitrate and sodium chloride.

It is your responsibility to determine the identity of the solid formed when precipitation occurs and to write a balanced equation for the reaction (when there is no reaction, you cannot write an balanced chemical equation because no new products were formed). First you must write a word equation that follows the format of a double replacement reaction above (Equation 1). For example, for barium nitrate and sodium phosphate you get:

$$\text{barium nitrate} + \text{sodium phosphate} \rightarrow \text{barium phosphate} + \text{sodium nitrate} \quad (3)$$

Using the word equation, you can write chemical equations for each of the species and balance the equation:

$$3\ Ba(NO_3)_2(aq) + 2\ Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2\,(?) + 6\ NaNO_3\,(?) \quad (4)$$

At this point, we are unsure whether the barium phosphate or the sodium nitrate is the precipitate. In order to decide which of these compounds causes the precipitate, we need to use a solubility chart (Table 2). From the chart, we can see that sodium nitrate is soluble in water (as indicated by Aq) and barium phosphate forms a precipitate in water (as indicated by ppt). We can then identify the precipitate as "barium phosphate" on the data sheet and complete the balanced equation:

$$3\ Ba(NO_3)_2(aq) + 2\ Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2\ (s) + 6\ NaNO_3\ (aq) \qquad (5)$$

The data sheet includes a completed row for barium nitrate and examples of word and chemical equations are shown on the worksheet. What this exercise entails is you writing a word equation and a balanced chemical equation for the other 22 reactions that resulted in the formation of a precipitate.

Table 1: Possible double replacement reactions.

	Sodium sulfate $Na_2SO_4(aq)$	Sodium phosphate $Na_3PO_4(aq)$	Sodium nitrate $NaNO_3(aq)$	Sodium hydroxide NaOH (aq)	Sodium chloride NaCl (aq)	Sodium carbonate $Na_2CO_3(aq)$
Barium nitrate $Ba(NO_3)_2$ (aq)	white ppt Barium sulfate	white ppt Barium phosphate	NR	NR	NR	white ppt Barium carbonate
Calcium chloride $CaCl_2$ (aq)	white ppt	white ppt	NR	white ppt	NR	white ppt
Chromium (III) chloride $CrCl_3$ (aq)	NR	violet ppt	NR	yellow ppt	NR	NR
Cobalt (II) nitrate $Co(NO_3)_2$ (aq)	NR	pink ppt	NR	pink ppt	NR	red ppt
Copper (II) sulfate $CuSO_4$ (aq)	NR	blue ppt	NR	blue ppt	NR	light blue ppt
Manganese (II) sulfate $MnSO_4$ (aq)	NR	pink ppt	NR	pink ppt	NR	NR
Potassium chloride KCl (aq)	NR	NR	NR	NR	NR	NR
Silver (I) nitrate $AgNO_3$ (aq)	white ppt	white ppt	NR	white ppt	white ppt	yellow ppt
Zinc (II) sulfate $ZnSO_4$ (aq)	NR	white ppt	NR	white ppt	NR	white ppt

Table 2. Solubilities of Ionic Compounds. Ppt = Insoluble. Aq = Soluble

Ions	Carbonate	Chloride	Hydroxide	Nitrate	Phosphate	Sulfate
Barium	Ppt	Aq	Aq	Aq	Ppt	Ppt
Calcium	Ppt	Aq	Ppt	Aq	Ppt	Ppt
Chromium	Aq	Aq	Ppt	Aq	Ppt	Aq
Cobalt	Ppt	Aq	Ppt	Aq	Ppt	Aq
Copper	Ppt	Aq	Ppt	Aq	Ppt	Aq
Manganese	Aq	Aq	Ppt	Aq	Ppt	Aq
Potassium	Aq	Aq	Aq	Aq	Aq	Aq
Silver	Ppt	Ppt	Ppt	Aq	Ppt	Ppt
Sodium	Aq	Aq	Aq	Aq	Aq	Aq
Zinc	Ppt	Aq	Ppt	Aq	Ppt	Aq

1. Word Equation barium nitrate + sodium sulfate → barium sulfate + sodium nitrate

Balanced Equation $Ba(NO_3)_2\ (aq) + Na_2SO_4\ (aq) \rightarrow BaSO_4\ (s) + 2\ NaNO_3\ (aq)$

2. Word Equation barium nitrate + sodium phosphate → barium phosphate + sodium nitrate

Balanced Equation $3\ Ba(NO_3)_2\ (aq) + 2\ Na_3PO_4\ (aq) \rightarrow Ba_3(PO_4)_2\ (s) + 6\ NaNO_3\ (aq)$

3. Word Equation barium nitrate + sodium carbonate → barium carbonate + sodium nitrate

Balanced Equation $Ba(NO_3)_2\ (aq) + Na_2CO_3\ (aq) \rightarrow BaCO_3\ (s) + 2\ NaNO_3\ (aq)$

4. Word Equation _____

Balanced Equation _____

5. Word Equation _____

Balanced Equation _____

6. Word Equation _____

Balanced Equation _____

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