Practice Questions Section 3.4

Reactions Involving Precipitates

1. For each of the following,

   - predict the products of the double displacement reaction and write a balanced equation.
   - use a table of solubilities to predict whether or not a precipitate forms. Identify any precipitates in your balanced equation (part a); also identify products that remain in solution.
   - if a precipitate occurs, write a balanced net ionic equation for the reaction.

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   a. $CuSO_{4\,(aq)} + 2\ NaOH_{(aq)}$

   b. $CaS_{(aq)} + (NH_4)_3PO_{4\,(aq)}$

   c. $MgBr_{2\,(aq)} + H_2SO_{4\,(aq)}$

2. We wish to separate the cations from a mixture containing the following solutions:

   $Ra(NO_3)_2$, $Mg(NO_3)_2$, and $AgNO_3$

   In order to do so we are given the following separate solutions:

   K_2SO_4, K_2S, and KOH

   In what order should we add the separate solutions in order to remove the cations by selective precipitation? List the precipitates that form, in the proper order.

Practice Questions Section 3.4

Reactions Involving Precipitates Answers

1. For each of the following,

   - predict the products of the double displacement reaction and write a balanced equation.
   - use a table of solubilities to predict whether or not a precipitate forms. Identify any precipitates in your balanced equation (part a); also identify products that remain in solution.
   - if a precipitate occurs, write a balanced net ionic equation for the reaction.

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a. $CuSO_{4\,(aq)} + 2\ NaOH_{(aq)}$

Solution

Predict the possible products of the reaction and write a balanced equation. Be sure to correctly determine the correct formulas of the products before balancing the equation.:

$$CuSO_{4\,(aq)} + 2\ NaOH_{(aq)} \rightarrow Cu(OH)_{2\,(s)} + Na_2SO_{4\,(aq)}$$

Check a table of solubilities to see if the compounds $Cu(OH)_2$ and Na_2SO_4 are soluble or have low solubility. Compounds that are soluble (Na_2SO_4) will remain in solution, and are identified by the (aq) in the balanced equation. Compounds with a low solubility ($Cu(OH)_2$) will come out of solution and form solid precipitates, indicated by the (s) in the balanced equation.

Since a reaction does occur, we determine what the spectator ions are in the equation. It may help you to write out all aqueous species in their long form. Solids, however, remain together as a compound:

$$Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ Na^+_{(aq)} + 2\ OH^-_{(aq)} \rightarrow Cu(OH)_{2\,(s)} + 2\ Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

Notice that $Na_2SO_{4\,(aq)}$ becomes $2\ Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

The spectator ions are $Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$. Remove them to get the net ionic equation:

$$\mathbf{Cu^{2+}_{(aq)} + 2\ OH^-_{(aq)} \rightarrow Cu(OH)_{2\,(s)}}$$ **ANSWER**

b. $CaS_{(aq)} + (NH_4)_3PO_{4\,(aq)}$

Solution

Predict the products and write a balanced equation:

$$3\ CaS_{(aq)} + 2\ (NH_4)_3PO_{4\,(aq)} \rightarrow Ca_3(PO_4)_{2\,(s)} + 3\ (NH_4)_2S_{(aq)}$$

Use a table of solubilities to determine that the product $Ca_3(PO_4)_2$ is insoluble and will thus form a solid precipitate (s), while $(NH_4)_2S$ remains in solution (as indicated by (aq)).

Remove spectator ions to produce the net ionic equation. With practice you will see that both S^{2-} and NH_4^+ are spectator ions and you will not need to write the long form of the equation.

Long form:

$$3Ca^{2+}_{(aq)} + 3S^{2-}_{(aq)} + 6NH_4^+{}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Ca_3(PO_4)_{2\,(s)} + 6NH_4^+{}_{(aq)} + 3\ S^{2-}_{(aq)}$$

Net Ionic Equation

$$\mathbf{3Ca^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)} \rightarrow Ca_3(PO_4)_{2\,(s)}}$$ **ANSWER**

c. $MgBr_{2\,(aq)} + H_2SO_{4\,(aq)}$

Solution

Balanced Equation:

$$MgBr_{2\,(aq)} + H_2SO_{4\,(aq)} \rightarrow MgSO_{4\,(aq)} + 2\ HBr_{(aq)}$$

A table of solubilities tells us that both $MgSO_4$ and HBr are soluble compounds. Thus no precipitate forms and there is **NO REACTION**. All ions remain in solution.

We may indicate there is no reaction as follows:

$$\mathbf{MgBr_{2\,(aq)} + H_2SO_{4\,(aq)} \rightarrow NR}$$ **ANSWER**

2. We wish to separate the cations from a mixture containing the following solutions:

$Ra(NO_3)_2$, $Mg(NO_3)_2$, and $AgNO_3$

In order to do so we are given the following separate solutions:

K_2SO_4, K_2S, and KOH

In what order should we add the separate solutions in order to remove the cations by selective precipitation? List the precipitates that form, in the proper order.

Solution

Begin by recognizing the spectator ions that we can ignore.

In the cation solutions, nitrate, NO_3^-, is the spectator in all cases as it will never form a precipitate.

In the separate solutions, the potassium ion, K^+, is an alkali ion which likewise always forms soluble solutions.

Prepare a chart to help identify precipitates that will form. "ppt" indicates an insoluble precipitate; "sol" indicates a soluble compound that remains dissolved as ions.

	Ag^+	Ra^{2+}	Mg^{2+}
SO_4^{2-}	ppt	ppt	sol
S^{2-}	ppt	sol	sol
OH^-	ppt	sol	ppt

Read your chart carefully! We are adding the negative anions one at a time, so we read the across the rows (not down the columns):

SO_4^{2-} forms two precipitates, with Ag^+ and Ra^{2+} so it cannot be used first.

S^{2-} forms only one precipitate, with Ag^+ to form $Ag_2S_{(s)}$. It could be used first.

OH^- forms two single precipitates, with Ag^+ and Mg^{2+} so it cannot be used first

The solution:

To summarize our solution:

1. First add K_2S to remove Ag^+ , forming the preciptate $Ag_2S_{(s)}$
2. We could remove the next cation in either order:
   a. by adding K_2SO_4 to remove Ra^{2+}, forming $RaSO_{4(s)}$
   b. or by adding KOH to remove Mg^{2+}, forming $Mg(OH)_{2\,(s)}$