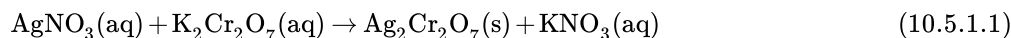


10.5.1: Precipitation Reactions

Learning Objectives

- To identify a precipitation reaction and predict solubility.

A precipitation reaction is a type of double displacement reaction that yields an insoluble product—a precipitate—when two solutions are mixed. When a colorless solution of silver nitrate is mixed with a yellow-orange solution of potassium dichromate, a reddish precipitate of silver dichromate is produced.



This unbalanced equation has the general form of an exchange reaction:



Thus precipitation reactions are a subclass of exchange reactions that occur between ionic compounds when one of the products is insoluble. Because both components of each compound change partners, such reactions are sometimes called **double-displacement reactions**. Precipitation reactions are used to isolate metals that have been extracted from their ores, and to recover precious metals for recycling.



Video: Mixing potassium dichromate and silver nitrate together to initiate a precipitation reaction (Equation [10.5.1.1](#)).

Just as important as predicting the product of a reaction is knowing when a chemical reaction will *not* occur. Simply mixing solutions of two different chemical substances does *not* guarantee that a reaction will take place. For example, if 500 mL of aqueous NaCl solution is mixed with 500 mL of aqueous KBr solution, the final solution has a volume of 1.00 L and contains $\text{Na}^+(\text{aq})$, $\text{Cl}^-(\text{aq})$, $\text{K}^+(\text{aq})$, and $\text{Br}^-(\text{aq})$. As you will see in (Figure 10.5.1.1), none of these species reacts with any of the others. When these solutions are mixed, the only effect is to dilute each solution with the other.

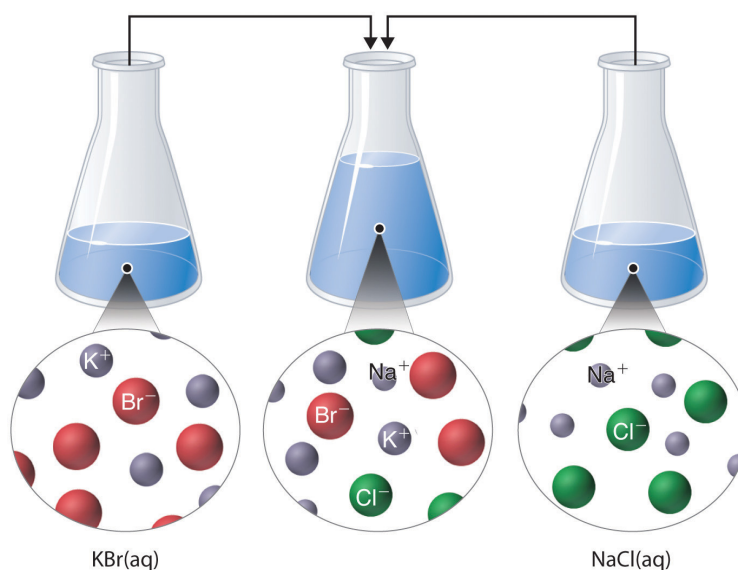


Figure 10.5.1.1: The Effect of Mixing Aqueous KBr and NaCl Solutions. Because no net reaction occurs, the only effect is to dilute each solution with the other. (Water molecules are omitted from molecular views of the solutions for clarity.)

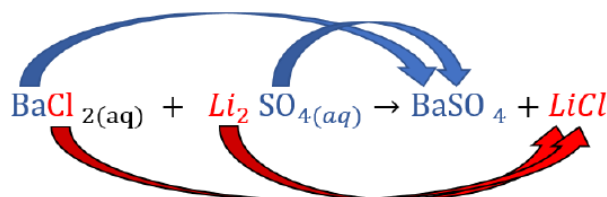
Predicting Precipitation Reactions

Previously, we had discussed the [prediction of double replacement reactions](#) without considering solubility. Now that we have learned how to use solubility rules, we will revisit double replacement reactions with this new knowledge. The steps for predicting the result of a double replacement reaction are essentially the same as before, but with an additional step included for using the solubility rules.

We will go through the same examples as previously, but adding the additional staff of using solubility rules. When a reaction does occur, we will obtain the same result but with the additional information of which of the products is solid and which is aqueous. If the reaction does not occur, we are now able to determine that using the solubility rules when we were not able to do so earlier.

Predict what will happen when aqueous solutions of barium chloride and lithium sulfate are mixed.

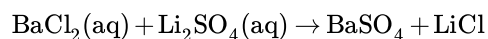
Change the partners of the anions and cations on the reactant side to form new compounds (products):



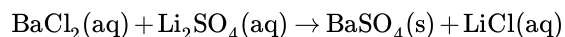
Because barium chloride and lithium sulfate are strong electrolytes, each dissociates completely in water to give a solution that contains the constituent anions and cations. Mixing the two solutions *initially* gives an aqueous solution that contains Ba^{2+} , Cl^- , Li^+ , and SO_4^{2-} ions. The only possible exchange reaction is to form LiCl and BaSO_4 .

Correct the formulas of the products based on the charges of the ions.

No need to correct the formula as both compounds already have their charges balanced.

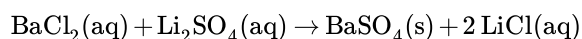


Refer to the solubility rules table to determine insoluble products which will therefore form a precipitate.



[Table 7.5.1](#) from the previous section shows that LiCl is soluble in water, but BaSO_4 is not soluble in water.

Balance the equation:



Although soluble barium salts are toxic, BaSO_4 is so insoluble that it can be used to diagnose stomach and intestinal problems without being absorbed into tissues. An outline of the digestive organs appears on x-rays of patients who have been given a “barium milkshake” or a “barium enema”—a suspension of very fine BaSO_4 particles in water.



Figure 10.5.1.2: An x-ray of the digestive organs of a patient who has swallowed a “barium milkshake.” A barium milkshake is a suspension of very fine BaSO_4 particles in water; the high atomic mass of barium makes it opaque to x-rays. (Public Domain; Glitzy queen00 via Wikipedia).

✓ Example 10.5.1.1

Predict what will happen if aqueous solutions of rubidium hydroxide and cobalt(II) chloride are mixed.

Solution

Steps	Example
Change the partners of the anions and cations on the reactant side to form new compounds (products).	$\text{RbOH}_{(\text{aq})} + \text{CoCl}_{2(\text{aq})} \rightarrow \text{RbCl} + \text{Co}(\text{OH})_2$
Correct the formulas of the products based on the charges of the ions.	$\text{RbOH}(\text{aq}) + \text{CoCl}_2(\text{aq}) \rightarrow \text{RbCl} + \text{Co}(\text{OH})_2$
Refer to the solubility rules table to determine insoluble products which will therefore form a precipitate.	$\text{RbOH}(\text{aq}) + \text{CoCl}_2(\text{aq}) \rightarrow \text{RbCl}(\text{aq}) + \text{Co}(\text{OH})_2(\text{s})$
Balance the equation.	Coefficients already balanced. $\text{RbOH}(\text{aq}) + \text{CoCl}_2(\text{aq}) \rightarrow \text{RbCl}(\text{aq}) + \text{Co}(\text{OH})_2(\text{s})$

✓ Example 10.5.1.2

Predict what will happen if aqueous solutions of strontium bromide and aluminum nitrate are mixed.

Solution

Steps	Example
Change the partners of the anions and cations on the reactant side to form new compounds (products).	$\text{SrBr}_{2(\text{aq})} + \text{Al}(\text{NO}_3)_3(\text{aq}) \rightarrow \text{SrNO}_3 + \text{AlBr}_3$

Steps	Example
Correct the formulas of the products based on the charges of the ions.	$\text{SrBr}_2(\text{aq}) + \text{Al}(\text{NO}_3)_3(\text{aq}) \rightarrow \text{Sr}(\text{NO}_3)_2 + \text{AlBr}_3$
Refer to the solubility rules table to determine insoluble products which will therefore form a precipitate.	$\text{SrBr}_2(\text{aq}) + \text{Al}(\text{NO}_3)_3(\text{aq}) \rightarrow \text{Sr}(\text{NO}_3)_2(\text{aq}) + \text{AlBr}_3(\text{aq})$ According to Table 7.5.1 from the previous section, both AlBr_3 (rule 4) and $\text{Sr}(\text{NO}_3)_2$ (rule 2) are soluble.
If all possible products are soluble, then no net reaction will occur.	$\text{SrBr}_2(\text{aq}) + \text{Al}(\text{NO}_3)_3(\text{aq}) \rightarrow$ NO REACTION

? Exercise 10.5.1.2

Using the information in [Table 7.5.1](#) from the previous section, predict what will happen in each case involving strong electrolytes.

- An aqueous solution of strontium hydroxide is added to an aqueous solution of iron(II) chloride.
- Solid potassium phosphate is added to an aqueous solution of mercury(II) perchlorate.
- Solid sodium fluoride is added to an aqueous solution of ammonium formate.
- Aqueous solutions of calcium bromide and cesium carbonate are mixed.

Answer a

$\text{Fe}(\text{OH})_2$ precipitate is formed.

Answer b

$\text{Hg}_3(\text{PO}_4)_2$ precipitate is formed.

Answer c

No Reaction.

Answer d

CaCO_3 is precipitate formed.

Summary

In a **precipitation reaction**, a subclass of exchange reactions, an insoluble material (a **precipitate**) forms when two electrolyte solutions are mixed. To predict the product of a precipitation reaction, all species initially present in the solutions are identified, as are any combinations likely to produce an insoluble salt.

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