Writing Precipitation Equations

This page shows the procedure for predicting whether mixing two aqueous solutions of ionic compounds will lead to a precipitation reaction and shows you how to write complete and net ionic equations for the reactions that take place. The following is a typical problem.

Predict whether a precipitate will form when water solutions of silver nitrate, AgNO₃(aq), and sodium sulfide, Na₂S(aq), are mixed. If there is a precipitation reaction, write the complete and net ionic equation that describes the reaction.

Tip-off – When you are asked to predict whether a precipitation reaction takes place when two aqueous solutions of ionic compounds are mixed and to write complete and net ionic equations for the reaction, if it takes place.

General Steps

Step 1: Determine the formulas for the possible products using the general double displacement equation. (Remember to consider ion charges when writing your formulas.)

\[ AB + CD \rightarrow AD + CB \]

Step 2: Predict whether either of the possible products is water insoluble. If either possible product is insoluble, a precipitation reaction takes place, and you will continue with step 3. If neither is insoluble, write “No reaction”.

Step 3: Follow these steps to write the complete equation.

Write the formulas for the reactants separated by a “+”.

Separate the formulas for the reactants and products with a single arrow.

Write the formulas for the products separated by a “+”.

Write the physical state for each formula.

1) The insoluble product will be followed by (s).

2) Water-soluble ionic compounds will be followed by (aq).

Balance the equation.

Step 4: Follow these steps to write the net ionic equation.

Write the complete ionic equation by describing water-soluble ionic compounds as separate ions and insoluble ionic compounds with a complete formula.

Eliminate the formulas for the ions that are unchanged in the reaction (the spectator ions).

Rewrite what is left after the spectator ions are removed.

Balance the equation.
**EXAMPLE 1 – Predicting Precipitation Reactions:** Predict whether a precipitate will form when water solutions of silver nitrate, AgNO₃(aq), and sodium sulfide, Na₂S(aq), are mixed. If there is a precipitation reaction, write the complete and net ionic equation that describes the reaction.

**Solution:**

**Step 1:** Determine the possible products using the general double displacement equation.

AB + CD → AD + CB

In AgNO₃, Ag⁺ is A, and NO₃⁻ is B. In Na₂S, Na⁺ is C, and S²⁻ is D. The possible products from the mixture of AgNO₃(aq) and Na₂S(aq) are Ag₂S and NaNO₃. (Remember to consider charge when you determine the formulas for the possible products.)

AgNO₃(aq) + Na₂S(aq) to Ag₂S and NaNO₃

**Step 2:** Predict whether either of the possible products is water insoluble.

According to our solubility guidelines, most sulfides are insoluble, and compounds with Ag⁺ are not listed as an exception. Therefore, Ag₂S would be insoluble. Because compounds containing Na⁺ and NO₃⁻ are soluble, NaNO₃ is soluble.

**Step 3:** Write the complete equation. (Don’t forget to balance the equation.)

2AgNO₃(aq) + Na₂S(aq) → Ag₂S(s) + 2NaNO₃(aq)

**Step 4:** Write the net ionic equation.

Write the complete ionic equation, describing the aqueous ionic compounds, AgNO₃(aq), Na₂S(aq) and NaNO₃(aq), as ions. Describe the solid with a complete formula.

2Ag⁺(aq) + 2NO₃⁻(aq) + 2Na⁺(aq) + S²⁻(aq)
→ Ag₂S(s) + 2Na⁺(aq) + 2NO₃⁻(aq)

The nitrate and sodium ions have the same form on each side of the equation, so they are eliminated as spectator ions.

2Ag⁺(aq) + S²⁻(aq) → Ag₂S(s)

**EXAMPLE 2 – Predicting Precipitation Reactions:** Predict whether a precipitate will form when water solutions of barium chloride, BaCl₂(aq), and sodium sulfate, Na₂SO₄(aq), are mixed. If there is a precipitation reaction, write the complete and net ionic equation that describes the reaction.

**Solution:**

**Step 1:** Determine the possible products using the general double displacement equation.

AB + CD → AD + CB
In $\text{BaCl}_2$, $A$ is $\text{Ba}^{2+}$, and $B$ is $\text{Cl}^−$. In $\text{Na}_2\text{SO}_4$, $C$ is $\text{Na}^+$, and $D$ is $\text{SO}_4^{2−}$. The possible products from the reaction of $\text{BaCl}_2(\text{aq})$ and $\text{Na}_2\text{SO}_4(\text{aq})$ are $\text{BaSO}_4$ and $\text{NaCl}$. (Remember to consider charge when you determine the formulas for the possible products.)

$\text{BaCl}_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4 + \text{NaCl}$

**Step 2:** Predict whether either of the possible products is water insoluble.

According to our solubility guidelines, most sulfates are soluble, but $\text{BaSO}_4$ is an exception. It is insoluble and would precipitate from the mixture. Because compounds containing $\text{Na}^+$ and $\text{Cl}^−$ are soluble, $\text{NaCl}$ is soluble.

**Step 3:** Write the complete equation. (Don’t forget to balance the equation.)

$\text{BaCl}_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{NaCl}(\text{aq})$

**Step 4:** Write the complete ionic equation, describing the aqueous ionic compounds as ions. Describe the solid as a complete formula.

$$\text{Ba}^{2+}(\text{aq}) + 2\text{Cl}^−(\text{aq}) + 2\text{Na}^+(\text{aq}) + \text{SO}_4^{2−}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{Na}^+(\text{aq}) + 2\text{Cl}^−(\text{aq})$$

The chloride and sodium ions have the same form on each side of the equation, so they are eliminated as spectator ions.

$$\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2−}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$$

This is the reaction used in industry to form barium sulfate, which is used in paint preparations and in x-ray photography.