The two possible products of a double-displacement reaction between $(NH_4)_2S$ and $Cd(NO_3)_2$ are ammonium nitrate, NH_4NO_3, and cadmium sulfide, CdS. The question marks indicate that the states are unknown.

$$(NH_4)_2S(aq) + Cd(NO_3)_2(aq) \longrightarrow 2NH_4NO_3(?) + CdS(?)$$

To decide whether a precipitate can form, you must know the solubilities of these two compounds. Consulting **Table 1,** you can see that NH_4NO_3 is soluble in water. However, CdS is insoluble. You can therefore predict that when solutions of ammonium sulfide and cadmium nitrate are combined, ammonium nitrate will not precipitate and cadmium sulfide will. As illustrated in **Figure 3,** crystals of CdS form when the solutions are mixed. In the following equation, the designations (*aq*) and (*s*) show that $NH_4NO_3(aq)$ remains in solution and $CdS(s)$ precipitates.

$$(NH_4)_2S(aq) + Cd(NO_3)_2(aq) \longrightarrow 2NH_4NO_3(aq) + CdS(s)$$

Net Ionic Equations

Reactions of ions in aqueous solution are usually represented by net ionic equations rather than formula equations. *A* **net ionic equation** *includes only those compounds and ions that undergo a chemical change in a reaction in an aqueous solution.* To write a net ionic equation, you first convert the chemical equation into an overall ionic equation. All soluble ionic compounds are shown as dissociated ions in solution. The precipitates are shown as solids. The precipitation of cadmium sulfide described previously can be shown by the following overall ionic equation.

$$Cd^{2+}(aq) + 2NO_3^-(aq) + 2NH_4^+(aq) + S^{2-}(aq) \longrightarrow CdS(s) + 2NO_3^-(aq) + 2NH_4^+(aq)$$

Notice that the aqueous ammonium ion, $NH_4^+(aq)$, and the aqueous nitrate ion, $NO_3^-(aq)$, appear on both sides of this equation. Therefore, they have not undergone any chemical change and are still present in their original form. *Ions that do not take part in a chemical reaction and are found in solution both before and after the reaction are* **spectator ions.**

To convert an ionic equation into a net ionic equation, the spectator ions are canceled on both sides of the equation. Eliminating the NH_4^+ and NO_3^- ions from the overall ionic equation above gives the following net ionic equation.

$$Cd^{2+}(aq) + S^{2-}(aq) \longrightarrow CdS(s)$$

This net ionic equation applies not only to the reaction between $(NH_4)_2S$ and $Cd(NO_3)_2$ but also to *any* reaction in which a precipitate of cadmium sulfide forms when the ions are combined in solution. For example, it is also the net ionic equation for the precipitation of CdS when $CdSO_4$ and H_2S react.

extension

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