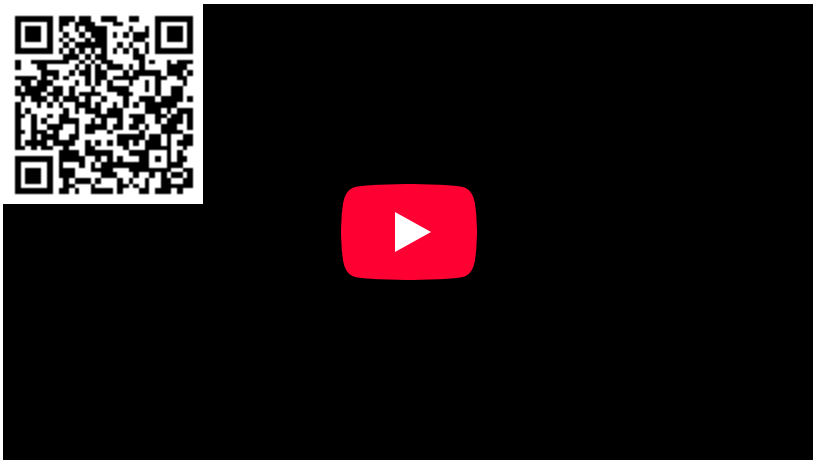
6.12: Chemical Properties

The most important chemical characteristic of ionic compounds is that *each ion has its own properties*. *Such properties are different from those of the atom from which the ion was derived*. In other words, an Na^+ ion is quite different from an Na atom, and a Cl^- ion is unlike an isolated Cl atom or either of the Cl atoms in a Cl_2 molecule. You eat a considerable quantity of Na^+ and Cl^- ions in table salt every day, but Na atoms or Cl_2 molecules would be quite detrimental to your health. The unique chemical properties of each type of ion are quite evident in aqueous solutions. Most of the reactions of $BaCl_2(aq)$, for example, can be classified as reactions of the Ba^{2+} (aq) ion or the $Cl^-(aq)$ ion. If sulfuric acid, H_2SO_4, is added to a solution of $BaCl_2$, the solution turns milky and very fine crystals of $BaSO_4(s)$ eventually settle out. The reaction can be written as:

$$Ba^{2+}(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2H^+(aq)$$

Below is a video of this reaction.

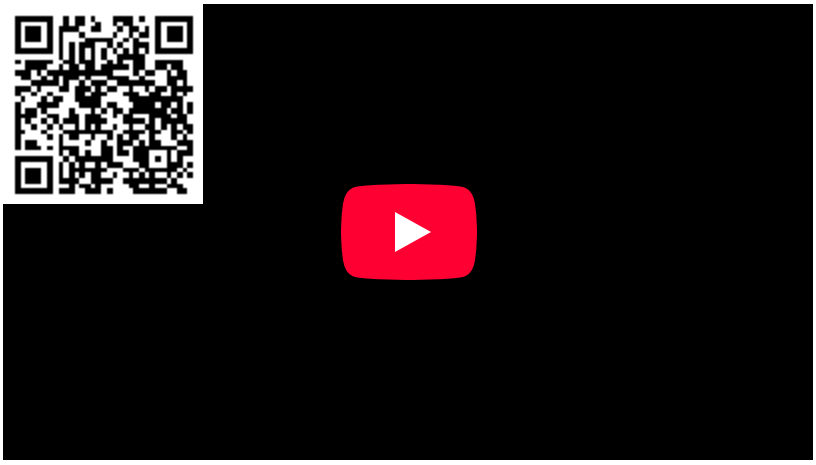


The solution of $BaCl_2$ is clear and colorless, but when H_2SO_4 is added through the the thin glass tube, the contents become white and opaque, as insoluble $BaSO_4(s)$ come out of solution.

This reaction is characteristic of the *barium ion*. It will also occur if H_2SO_4 is added to solutions such as $BaI_2(aq)$ or $BaBr_2(aq)$ which contain barium ions but no chloride ions. By contrast, if a solution of silver nitrate, $AgNO_3$, [which contains silver ions, Ag^+ (aq)] is added to a $BaCl_2$ solution, a reaction characteristic of the *chloride ion* occurs. A white curdy precipitate of $AgCl(s)$ forms according to the equation:

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

Other ionic solutions containing chloride ions, such as $LiCl(aq)$, $NaCl(aq)$, or $MgCl_2(aq)$, give an identical reaction. Below is a video of the reaction of a sodium chloride solution with a silver nitrate solution.



Both the NaCl(aq) solution and the $AgNO_3$(aq) solution begin clear and colorless. When the NaCl(aq) solution is added to the $AgNO_3$(aq) solution, a cloudy white precipitate of AgCl(s) is formed. The same result would have occurred had $BaCl_2$ been used, as the reaction is only between the Ag^+ and $Cl^–$ ions, as seen:

$$Ag^+(aq) + Cl^–(aq) \rightarrow AgCl(s)$$

Many binary ionic solids not only dissolve in water, they also react with it. When the compound contains an anion such as $N^{3–}$, $O^{2–}$, or $S^{2–}$, which has more than one negative charge, the reaction with water produces hydroxide ions, $OH^–$:

$$O^{2–} + H_2O \rightarrow OH^–(aq) + OH^–(aq)$$

$$S^{2–} + H_2O \rightarrow HS^–(aq) + OH^–(aq)$$

$$N^{3–} + 3H_2O \rightarrow NH_3(aq) + 3OH^–(aq)$$

Thus, when sodium oxide, Na_2O, is added to water, the resulting solution contains sodium ions and hydroxide ions but no oxide ions:

$$Na_2O + H_2O \rightarrow 2Na^+(aq) + 2OH^–(aq)$$

The hydride ion also reacts with water to form hydroxide ions. When lithium hydride, LiH, is dissolved in water, for example, the following reaction occurs:

$$LiH(s) + H_2O \rightarrow Li^+(aq) + OH^–(aq) + H_2(g)$$

Note that hydrogen gas is evolved in this reaction. Lithium hydride crystals provide a very compact, if somewhat expensive, method for storing hydrogen.

Among the *halide ions* ($F^–$, $Cl^–$, $Br^–$, $I^–$) only the fluoride ion shows any tendency to react with water, and that only to a limited extent. When sodium fluoride is dissolved in water, for example, faint traces of hydroxide ion can be detected in the solution owing to the reaction

$$F^– + H_2O \rightarrow HF + OH^–$$

With sodium chloride, by contrast, no such reaction occurs.
