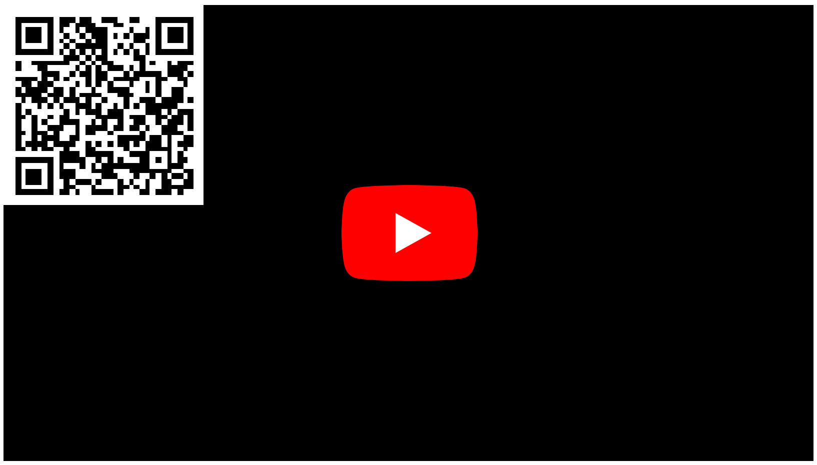
6.12: Chemical Properties

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:

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

Below is a video of this reaction.

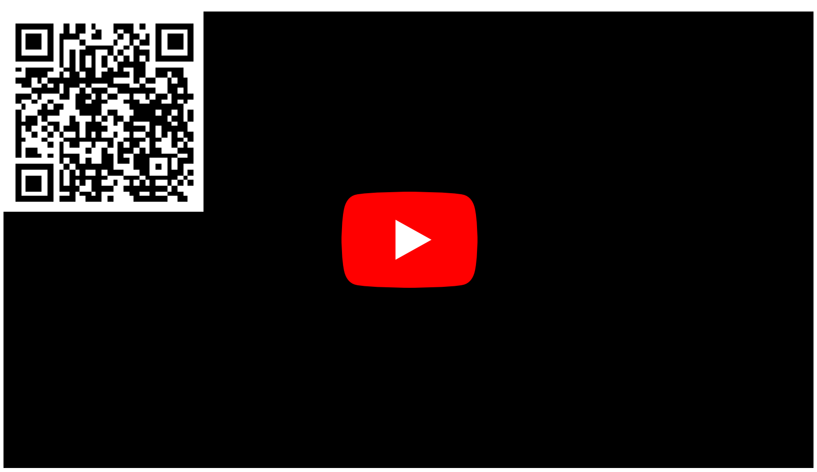


The solution of $BaCl_2$ is clear and colorless, but when H_2SO_4 is added through the the thin glass tube, the contents become white and opaque, as insoluble $BaSO_4$(*s*) come out of solution.

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:

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

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:

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

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^-:

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

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

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

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

$$\mathrm{Na_2O} + \mathrm{H_2O} \rightarrow 2\mathrm{Na^+}(aq) + 2\mathrm{OH^-}(aq)$$

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:

$$\mathrm{LiH}(s) + \mathrm{H_2O} \rightarrow \mathrm{Li^+}(aq) + \mathrm{OH^-}(aq) + \mathrm{H_2}(g)$$

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

$$\mathrm{F^-} + \mathrm{H_2O} \rightarrow \mathrm{HF} + \mathrm{OH^-}$$

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