5.3: Just Because You Can Write It Doesn't Mean That It Will Happen

The fact that a balanced chemical equation can be written does not necessarily mean that the chemical reaction that it represents will occur. As an example, it is known that a number of metals will react with acid to release elemental hydrogen gas and produce a metal salt. For example, if iron wire, Fe, is placed into a solution of sulfuric acid, H_2SO_4, H_2 gas is evolved,

$$\mathrm{Fe(s) + H_2SO_4(aq) \rightarrow H_2(g) + FeSO_4(aq)} \tag{5.3.1}$$

leaving $FeSO_4$ salt in solution. The copper salt, $CuSO_4$, is also known to exist. So one might believe that it could be prepared by reacting copper metal with H_2SO_4:

$$\mathrm{Cu(s) + H_2SO_4(aq) \rightarrow H_2(g) + CuSO_4(aq)} \tag{5.3.2}$$

This equation is balanced and it looks like it could occur. But, placing copper metal into a solution of H_2SO_4 in the laboratory results in — nothing. The reaction simply does not occur. The lesson here is that a balanced chemical equation is not sufficient reason to conclude that a reaction will take place.

Since $CuSO_4$ is known to exist, there has to be a way to prepare it. There are, in fact several ways. One pathway to the preparation of this salt starting with copper metal is to first react the copper with oxygen at a relatively high temperature to produce copper oxide:

$$\mathrm{2\,Cu(s) + O_2(g) \rightarrow 2\,CuO(s)} \tag{5.3.3}$$

The CuO product reacts with sulfuric acid to give $CuSO_4$ salt:

$$\mathrm{CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)} \tag{5.3.4}$$

Alternate Reaction Pathways in Green Chemistry

Much of the science of green chemistry involves making decisions about alternative chemical reactions to choose a reaction or reaction sequence that provides maximum safety, produces minimum byproduct, and utilizes readily available materials. Consider two ways of preparing iron sulfate, $FeSO_4$. This chemical is commonly used to treat (clarify) water because when it is added to water and air is bubbled through the water, it produces $Fe(OH)_3$, a gelatinous solid that settles in the water and carries suspended mud and other particles with it. Consider two possible ways of making $FeSO_4$. The first of these was shown earlier and consists of the reaction of iron metal with sulfuric acid:

$$\mathrm{Fe(s) + H_2SO_4(aq) \rightarrow H_2(g) + FeSO_4(aq)} \tag{5.3.5}$$

leaving $FeSO_4$ salt in solution. The copper salt, $CuSO_4$, is also known to exist. So one might believe that it could be prepared by reacting copper metal with H_2SO_4:

$$\mathrm{Cu(s) + H_2SO_4(aq) \rightarrow H_2(g) + CuSO_4(aq)} \tag{5.3.6}$$

This equation is balanced and it looks like it could occur. But, placing copper metal into a solution of H_2SO_4 in the laboratory results in — nothing. The reaction simply does not occur. The lesson here is that a balanced chemical equation is not sufficient reason to conclude that a reaction will take place.

Since $CuSO_4$ is known to exist, there has to be a way to prepare it. There are, in fact several ways. One pathway to the preparation of this salt starting with copper metal is to first react the copper with oxygen at a relatively high temperature to produce copper oxide:

$$\mathrm{2\,Cu(s) + O_2(g) \rightarrow 2\,CuO(s)} \tag{5.3.7}$$

The CuO product reacts with sulfuric acid to give $CuSO_4$ salt:

$$\mathrm{CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)} \tag{5.3.8}$$

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$$\mathrm{Fe(s) + H_2SO_4(aq) \rightarrow H_2(g) + FeSO_4(aq)} \tag{5.3.9}$$

A second pathway would be to react iron oxide, FeO, with sulfuric acid:

$$\mathrm{FeO(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2O(aq)} \tag{5.3.10}$$

Which of these reactions would be the better choice? Both would work. The first reaction generates elemental H_2 gas as a byproduct. That has a potential downside because elemental hydrogen is highly explosive and flammable and could cause an explosion or fire hazard. But, in a contained reaction vessel that allowed for capture of H_2, the elemental hydrogen could be put to use as a fuel or reacted directly in a fuel cell to produce electricity (Section 3.2 and Figure 3.2). Furthermore, scrap iron metal and waste sulfuric acid are common materials that should be recycled and the synthesis of $FeSO_4$ by the direct reaction of the two can prepare a useful material from the two recyclable substances.

The second reaction (5.3.6) also gives the desired product. Its only byproduct is innocuous water. And there is no hazard from elemental hydrogen. In principle, the FeO required could be made by reacting scrap iron metal with oxygen from the air.

$$\mathrm{2\,Fe + O_2 \rightarrow 2\,FeO} \tag{5.3.11}$$

but in practice the reaction tends to produce other oxides of iron, particularly Fe_2O_3 and Fe_3O_4.
