

16.10: Green Chemistry to Combat Terrorism

As *safe* and *sustainable* chemistry, green chemistry has an important role to play in the war on terrorism. When safe chemistry is practiced, hazards and hazardous substances that might be stolen or diverted for use in attacks are not made or used in large quantities. The successful practice of green chemistry means that chemical products do what they are supposed to do and are used in minimum quantities. With green chemistry, materials and processes that are likely to result in violent reactions, fires, high pressures, and other extreme conditions are avoided and auxiliary substances and flammable materials are not used.

Green chemistry minimizes energy consumption, thereby reducing energetic, high-temperature processes that might be susceptible to sabotage. With its emphasis on biological processes, where applicable, green chemical processes are carried out under the mild, low temperature, toxic-substance-free, inherently less hazardous conditions conducive to biochemical reactions. By reducing demand for energy and raw materials, green chemistry reduces reliance on uncertain sources that are controlled by potentially hostile populations and therefore are inherently subject to disruption and blackmail.

The practice of green chemistry requires exacting process control combined with real-time, in-process monitoring techniques. These are conditions that resist sabotage. In addition, green chemistry uses passive safety systems that function by default in the event of failure of or deliberate damage to intricate control systems. An example of such a system is gravity-fed cooling water for nuclear reactors that will continue to flow even if the pumps for the cooling system pumps fail.

The chemical industry and related enterprises continue to implement green chemistry practices to reduce hazards and vulnerabilities to attack. For example, a DuPont chemical facility in Texas now makes methyl isocyanate, the agent of the catastrophic 1984 Bhopal, India, disaster, on site so that it does not have to store large quantities of this dangerous chemical.

As noted in Section 16.6, liquified and pressurized elemental chlorine, the first “poison gas” to be employed in warfare, has a high potential for terrorist attack because of its toxicity, volatility, and widespread shipping and storage. Alkaline aqueous solutions of hypochlorite ion, OCl^- , are widely used for bleaching and disinfection. Because liquified Cl_2 is the most economical form in which to ship chlorine, the common practice has been to react the elemental substance with base to produce hypochlorite:



Maintained in a basic state, the equilibrium of this reaction lies to the right so that the equilibrium concentration of Cl_2 in solution remains very low. Both Cl_2 and NaOH are made by passing a direct electrical current through a solution of NaCl where the reaction at the cathode is



and that at the anode is the following (where e^- represents the electron)



The chlorine gas produced at the anode can be reacted with the basic NaOH solution generated at the cathode to produce sodium hypochlorite (Reaction 16.8.1), which is produced, stored, and used as aqueous solutions. Many water treatment plants have started using relatively safe sodium hypochlorite solutions in place of toxic, reactive liquid chlorine formerly stored in large pressurized tanks on site. A potential problem in storing sodium hypochlorite solutions is their decomposition to produce elemental oxygen,



a process catalyzed by traces of transition metal ions such as Cu^{2+} . This results in a loss of product and a potentially hazardous buildup of oxygen and pressure.

By 2010 the Clorox company, a major world supplier of chlorine-based bleach announced that it would no longer be using liquid chlorine to make sodium hypochlorite, but would be shipping relatively concentrated aqueous solutions of sodium hypochlorite and diluting them to the strength required for bleaching. A reasonable alternative to using liquid chlorine or solutions of sodium hypochlorite for larger installations, such as major metropolitan water treatment plants, would be to have relatively small installations for the electrolysis of sodium chloride solutions which would make sodium hypochlorite directly on site. Such a facility might fit well with an industrial ecosystem in which several users of sodium hypochlorite would be clustered in close proximity.

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