Ridding your clothing of a stain can be a very difficult task. Getting rid of the stain is not a matter of removing the molecules like detergents. The stained molecules are changed chemically so they no longer reflect light in just the same way as before. This process is called decolorizing or bleaching. Natural stains as well as some dyes produced from grass come from chemical compounds called chromophores. Chromophores can absorb light at specific wavelengths and therefore cause colors.¹

Ordinary household bleach, sodium hypochlorite (NaClO), acts on a stain through the chemical process called oxidation reduction, or redox reaction. Oxidation is generally defined as losing electrons and reduction as gaining elections. The two processes oxidation and reduction occur together; thus one compound is reduced in the process of oxidizing another. Chlorine bleaches are oxidizing agents; when chlorine reacts with water, it produces hydrochloric acid and atomic oxygen. The oxygen reacts easily with the chromophores to remove electrons from the molecule, chemically changing the structure of the molecule and the physical properties that cause the color are changed.¹

Chlorine bleaches work efficiently and inexpensively. However sometimes oxidation with chlorine bleaches involve addition of chlorine atoms to the colored stain molecules rather than just elimination of electrons. The addition of chlorine to the waste stream can lead to the formation of hazardous byproducts, such as dioxins. Dioxins are a group of hundreds of similarly structured compounds that have the ability to bioaccumulate. The main sources of dioxins come from waste burning and forest fires, but dioxins can also be added to the environment by industrial processes that use chlorine, like textile and paper manufacturing. Exposure to large amounts of dioxins can cause a condition known as chloracne. Chloracne is a severe skin disease causing lesions to appear on the face and upper body. High exposures to dioxins have also been linked to increase cancer threats. Their tendency to linger in the environment has prompted the U.S. Environmental Protection Agency to work with industry to find ways to limit their usage.²

Chlorine on the large scale is deadly to an environment. Other alternatives or nonchlorine bleaches are available. The nonchlorine bleaches contain hydrogen peroxide or solids like perborate or percarbonate that react with water to release hydrogen peroxide. Hydrogen peroxide decomposes into oxygen gas and water, shown in Equation 1.¹

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\ce{H2O2 -> 1/2O2 + H2O}\label{1}\]

In the process of decomposing, H₂O₂ releases free radicals, highly reactive intermediates that oxidize other molecules by removing electrons from them. If these other molecules are colored stains or pigments, the chemical changes occurring from their oxidation may change their physical properties, making them colorless.¹

Hydrogen peroxide is a greener and more environmentally friendly alternative to the chlorine bleaching reagents. However, the challenge to replacing chlorine bleaches with hydrogen peroxide comes with two problems. The peroxide oxidation process can be indiscriminate; any molecule can react with the free radicals. The second problem with the use of hydrogen peroxide is the requirement of higher temperatures and pressures with longer reactions times to attain the same results as with chlorine bleaching. In manufacturing, this leads to higher costs for energy, equipment, and labor.¹

This problems led researchers at Carnegie Mellon University to develop molecules called tetraamido macrocyclic ligands (TAML) to function as catalysts in the hydrogen peroxide bleaching reaction. Their addition allows for the reaction to proceed at much lower temperatures and pressures and obtain higher reaction selectivity.³ TAML-activated H₂O₂ is an
ideal example of green chemistry at work. It is made from naturally occurring biochemicals, reduces energy costs, and reduces chlorine pollution.

From ChemPRIME: 11.17: Common Oxidizing Agents

References


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