Paper Reference
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Edexcel GCE Chemistry (Nuffield)

Advanced Subsidiary

Unit Test 2: Passage for Section B

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BUILDING A BETTER BLEACH – A GREEN CHEMISTRY CHALLENGE

Your dark red T-shirt has turned everyone else's white washing pink. The problem is how do you remove the stain?

A stain is a colour where you don't want it, but stain removal is not actually removal at all. Instead the stain molecules are altered chemically so they no longer reflect light in the same way as before. We call it bleaching and chemistry is behind the process.

The active ingredient in household bleach, sodium hypochlorite (NaOCl), keeps white clothing white and your toilet sparkling, but how does the bleach act on stain molecules? Bleaching is an example of a redox reaction. The colour of the stain is a property caused by the chemical structure of its molecules. When the bleach removes electrons from a molecule, the chemical structure of the molecule is changed and properties like colour are altered. Any excess sodium hypochlorite is washed away in the rinse water. However, oxidation with such chlorine-based bleaches sometimes adds chlorine atoms to the stain molecules as well as removing electrons. This can lead to the formation of hazardous by-products such as dioxins, which can persist in the environment and accumulate in the food chain.

Non-chlorine bleaches to the rescue

If the release of chlorine-based bleaches on a large scale could be bad for the environment, what else can we use to get rid of the stains? Alternative non-chlorine bleaches are available. They contain hydrogen peroxide or other peroxide compounds. As hydrogen peroxide is a liquid it is not actually present in solid non-chlorine bleaches such as 'Oxi–Clean'. Solid non-chlorine bleaches contain ingredients like perborate or percarbonate – solid compounds which react with water to release hydrogen peroxide. Whilst removing stains, the hydrogen peroxide decomposes to release highly reactive free radicals. These oxidise other molecules by removing electrons or hydrogen atoms from them.

Hydrogen peroxide sounds like our ideal bleach. In addition to its use in household cleaners, stain removers and hair dyes, it is now used in the pulp and paper, textile and laundry industries. Best of all, hydrogen peroxide contains no chlorine atoms so produces no organochlorine pollutants. So why not stop using chlorine-based bleaches altogether?

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Turn over

The challenge of replacing traditional chlorine bleaches with hydrogen peroxide is twofold. Firstly, the peroxide oxidation process can be unselective. This means any molecules in the vicinity that are exposed to the hydrogen peroxide get exposed to free radicals, and some unwanted reactions might accompany the desired oxidation. Secondly, successful bleaching with hydrogen peroxide requires higher temperatures and pressures and longer reaction times than those needed for chlorine-based bleaches. On an industrial scale this means higher costs for energy, equipment and labour.

However, the Institute for Green Oxidation Chemistry at Carnegie Mellon University, in the USA, may have solved our bleaching problems. They have developed some heroic molecules called tetraamido macrocyclic ligands or TAML for short. These molecules function as catalysts in the hydrogen peroxide bleaching process and their presence allows the oxidation to proceed at much lower temperatures and pressures. Like all catalysts, they are not consumed in the process. This could make the process environmentally benign, meaning the materials used are made from renewable resources, the process consumes minimal energy resources and does not release polluting by-products into the environment.

So bleaching using TAML activated peroxide would be an ideal example of green chemistry in action. Made from naturally occurring biochemicals, TAML catalysts reduce energy costs and prevent pollution. In addition their highly selective nature means they can 'hunt and destroy' dye molecules in solution preventing dye transfer to other clothes, which may mean in the future TAML could protect you and your pink-clothed family from further laundry mishaps.

[613 words]

(Source: adapted from *Chem matters – Demystifying Everyday Chemistry* by Kathryn Parent, April 2004)