Ionic Liquids: An Environmentally Friendly Alternative

By Kim Anderson, Ph.D., [TC]²

Introduction

Non-aqueous systems can either reduce or completely eliminate the amount of water used in textile processing. Reducing the amount of water in a textile process provides environmental benefits as well as cost savings. Not only are water and energy conserved in a non-aqueous process, but operating costs may be less expensive than in conventional processes. Recent research has shown that ionic liquids have the potential to be used in place of water in some textile processes.

The textile industry is believed to be one of the biggest consumers of water. On average, an estimated 200 liters of water is needed to process 1 kilogram of textile material. The development of ionic liquids that exhibit useful and unique properties has created a huge untapped potential for commercial applications to increase operating efficiencies of many chemical production operations—including the processing of textiles.

Textile Dyeing

Textile dyes are organic compounds—compounds that are carbon based. In the dyeing process, dyes are dissolved in a solvent, usually water. Once the dyes are in solution, they are absorbed by the textile fiber, passing into the interior of the material by a process called diffusion. The process of transferring the dye from solution to the fiber is called exhaustion. One hundred percent exhaustion means that there is no dye left in the dye bath; however, 100% exhaustion is challenging to achieve. The wastewater generated in the textile dyeing process can be difficult to treat because it is contaminated not only with residual dye but dispersing agents and surfactants as well.

An alternative to using water as a solvent in the dyeing process of textiles is to use ionic liquids. Because of their unique set of properties not exhibited in any other material, they have gained overwhelming interest in the past decade. The term "room temperature ionic liquids" has been assigned to organic salts that are liquid at ambient conditions.

By definition, ionic liquids are low melting salts with melting temperatures around 100º C. Like common salts, they consist of 100% cations (positively charged ions) and anions (negatively charged ions). These two components can be varied to design ionic liquid solvents for a specific end use, or to possess a particular set of properties. Properties such as melting point, viscosity, density, and hydrophobicity can be varied. In addition, ionic liquids have unique dissolving properties in the presence of organic compounds, therefore they can replace conventional solvents in many applications.

Ionic liquids have excellent stability over a wide temperature range and are neither volatile nor readily flammable which gives them advantages when used in a production environment. Due to their non-volatility, they are considered to have a low impact on the environment and human health. Another advantage to using ionic liquids is that they have negligible vapor pressure at room temperature, therefore they will not volatilize— making them recoverable for reuse. In addition, they do not emit volatile organic compounds (VOCs).

Cellulose Regeneration

Cellulose has immense importance as a renewable material. In the textile industry renewable cellulose is used to manufacture a variety of fibers including rayon, acetate, triacetate and Lyocell®. However, out of the 40 billion tons renewed each year, only about 2 million tons are used for further processing. The main obstacle is the lack of suitable solvents for the chemical dissolution process.

Cellulose is non-soluble in water as well as conventional organic solvents because of its well-developed intermolecular hydrogen bonding. Because cellulose burns as opposed to melting when exposed to high heat, it cannot be processed via melt spinning.

In order to process cellulose the solvent must either cause a chemical derivatization (a technique used to transform a chemical compound into a product of similar chemical structure) or physical dissolution of the cellulose.

Cellulose processing has traditionally been complex and expensive compared to other synthetic fiber processes. The viscose method is used to process 95% of the cellulose. Although there have been improvements to the method in the last 20 years, more than 2 tons of auxiliaries (carbon disulphide, sodium hydroxide and sulfuric acid) and significant volumes of fresh water are required to produce one ton of cellulose fiber. Although 70-75% of the carbon disulphide can be recycled, the process is complex.

The process of regenerating the cellulose can be greatly simplified by the use of ionic liquids which serve as the solvent and can be almost entirely recycled. In addition, the concentration of cellulose obtained in the viscose method ranges from 8-12% weight. Using selected ionic liquids has produced cellulose concentrations of 20% weight.

Conclusion

Ionic liquids have been coined "green solvents" because they are excellent solvents for a broad range of organic compounds. By varying an ionic liquid, the solvent properties can be tailored to create an almost infinite set of "designer solvents."

The field of ionic liquids is growing at a rate that was unpredictable even five years ago. In 2006 there were over 2000 papers published. As ionic liquids start to leave academic labs and find their way into a wide variety of industrial applications, challenges will arise. For one—the concepts and paradigms of ionic liquids are new and still not fully accepted in the wider community. It is hard for conservative scientists to throw away many years of tried and true concepts that they have become so familiar with.

And just how green are ionic liquids? Although attempts have been made to define "green chemistry," the term remains vague—allowing researchers to apply "green" to a wide variety of chemical processes. Ionic liquids are safer solvents compared to standard organic solvents because they are non-flammable, have low vapor pressure at room temperature and can be reused. The major concerns are the unknown toxicity of ionic liquids to humans and the environment.

The investigation of ionic liquids has led to a more environmentally friendly way to dye fibers and regenerate cellulose. It remains to be seen how environmentally friendly ionic liquids will be regarded once widely used by industry. Some of the disadvantages of ionic liquids are poor biodegradability, therefore biodegradability must be "built-in" in the design stage. Some ionic liquids are toxic to micro-organisms. A truly green ionic liquid would need to be sustainable, easy and clean to prepare, non-toxic and biodegradable.

References

EPA Publication, Environmental Guidelines for the Textile Dyeing and Finishing Industry. June 1998.

Hermanutz, Frank and Frank Meister and Eric Uerdingen. New Developments in the Manufacture of Cellulose Fibers with Ionic Liquids. "Chemical Fibers International," 2006.

Marsh, Kenneth and Alex Deev and Alex C-T Wu and Emma Tran and A. Klamt. Room Temperature Ionic Liquids as Replacement for Conventional Solvents – A Review. "Korean Journal of Chemical Engineering. Featured Review", 2002

Miller, Sean. Developments in Textile Colorants. "Textile Outlook International," January-February 2007.

Crombie, Janet. Ionic liquids toxic to fish. "Chemical Science." October 2005

West, Andrew. Promising a greener future. "Chemistry World." March 2005.

August 2008