Chapter 6

Ionic Liquids as Sustainable Solvents for Eco-Friendly Industrial Applications

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ABSTRACT

Ionic liquids (ILs) are a family of adaptable, adjustable solvents that show a lot of promise for industrial and sustainable chemistry uses. They are excellent candidates to replace traditional volatile organic solvents due to their special physicochemical characteristics, which include low volatility, good thermal stability, and tunable solubility. The structure, production, and several uses of ILs are examined in this work, with a focus on their use in metal ion extraction, organic synthesis, catalysis, and nanoparticle synthesis. ILs' promise as green solvents is highlighted in this critical evaluation of their environmental impact, which also acknowledges issues

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with toxicity, difficulty of synthesis, and sustainability of the life cycle. This study emphasizes the importance that ILs play in promoting more sustainable industrial processes by incorporating them into chemical education and green chemistry practices.

INTRODUCTION

Ionic liquids (ILs) are a unique class of liquid materials that may be adjusted and have a remarkable set of features. An IL is defined historically and conventionally as a salt that stays molten at temperatures lower than 100 °C. Of these, room-temperature ionic liquids (RTILs) are especially pertinent for real-world uses because their melting points are lower than 25 °C. They differ from traditional molecular solvents in that they have a distinct set of properties due to their unique ion composition. Notably, ILs may be used as electrolytes in a variety of electrochemical systems due to their intrinsic conductivity and wide electrochemical window. Supercapacitors, batteries, and dye-sensitized solar cells (DSSCs) are a few examples of these uses. DSSCs are essential for energy conversion and storage, particularly as the use of renewable energy sources increases, (Rauber et al., 2018). ILs' low vapor pressure, which inhibits its evaporation into the environment and lowers operator exposure through gaseous emissions, is one of its main advantages. Furthermore, ILs can operate efficiently at high temperatures due to their generally great thermal stability. By reducing the possibility of igniting or explosion in the event of failure, this feature improves the safety of devices like batteries.

The capacity to modify the characteristics of ILs by adding functional groups or choosing particular cations and anions is one of their most amazing features. They are sometimes referred to as "task-specific fluids" or "designer solvents" (Plechkova & Seddon, n.d.) because of their versatility. Their phase behavior, which is frequently used in IL recycling procedures, can vary from extremely hydrophilic to extremely lipophilic. ILs are sometimes seen as a link between high-temperature molten salts and traditional molecular liquids due to their adaptability. ILs were commonly considered "green solvents" in the past (and sometimes even now), especially in contrast to conventional molecular solvents that were categorized as volatile organic compounds (VOCs). Their safety, non-volatility, and recyclability in chemical reactions served as the foundation for this impression. Even though these characteristics fit the guidelines for sustainable solvents, new research shows that, when considering their entire ecological impact, ILs are not always a more environmentally friendly option than VOCs, (Mir et al., 2025). Later on, this subject will be covered in more detail. However, the planned and cautious use of low-temperature molten salts can help make processes, devices, or reactions that use ILs more sustainable.

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