



## Ionic Liquids: Transforming the Landscape of Pharmaceutical Formulations

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The development of any effective pharmaceutical formulation is dependent majorly on the solubility and the bioavailability of the drug. Majority of the marketed drugs suffer from poor water solubility, limiting their therapeutic potential. This is where the role of ionic liquids becomes essential. Ionic liquids have emerged as a promising tool for addressing the solubility, delivery and bioavailability challenges in pharmaceutical sciences.

Ionic liquids are salts that melt below 100°C. These are composed of organic cations with varied alkyl chain lengths and organic or inorganic anions. The presence of these bulky groups leads to the liquid or viscous states of these highly useful compounds. Ionic liquids have a marked presence in various domains of science and technology on an industrial level, be it in surface chemistry, as catalytic agents, in energy storage and capture, space sciences, etc. Pharmaceutical industry is an emerging field where the use of ionic liquids is becoming prevalent with time.

Ionic liquids are increasingly finding applications in the pharmaceutical field because of their unique and tunable properties. By carefully selecting the cation and anion, ionic liquids can be designed to improve the solubility and stability of poorly water-soluble drugs, which is a major challenge in drug formulation. They have also been explored as green solvents in drug synthesis, helping to reduce the use of volatile organic solvents and making processes more sustainable. In some cases, active pharmaceutical ingredients can be converted into ionic liquid forms, enhancing bioavailability and minimizing polymorphism issues. Additionally, certain ionic liquids exhibit intrinsic antimicrobial activity, opening

possibilities for dual-functional drug delivery systems. Owing to their versatility, ionic liquids are gradually emerging as promising tools in modern pharmaceutical development.

In addition to improving formulations, ionic liquids are being explored as more sustainable alternatives in pharmaceutical processing. They can replace volatile organic solvents in certain synthesis and purification steps, making manufacturing safer and environmentally friendlier. Some ionic liquids even show inherent antimicrobial or antiviral properties, creating opportunities for multifunctional therapeutic systems. Although challenges such as toxicity evaluation, regulatory approval, and large-scale production still need careful consideration, ongoing research continues to highlight their strong potential. With further refinement, ionic liquids may play a meaningful role in the next generation of pharmaceutical technologies.

It is equally important to address the challenges and future outlook associated with the use of ionic liquids in pharmaceuticals. Although they offer many advantages, concerns related to toxicity and long-term biocompatibility must be carefully evaluated before clinical application. Regulatory approval can also be complex, as ionic liquids often do not fit neatly into traditional excipient or solvent categories. In addition, issues such as large-scale production, cost-effectiveness, and environmental impact need thoughtful consideration to ensure practical feasibility.

Looking ahead, systematic toxicity studies, rational molecular design, and the development of greener, biodegradable ionic

liquids will be crucial for wider acceptance. Collaboration between chemists, formulation scientists, toxicologists, and regulatory experts can help bridge existing gaps. With continued research and responsible design strategies, ionic liquids have the potential to move from experimental systems to reliable components of next-generation pharmaceutical technologies.