

# Chapter *1*

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## *Importance and Possibility of Ionic Liquids*

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### 1.1 IONIC LIQUIDS

Ionic liquids are the salts having very low melting temperature. Ionic liquids have received great interests recently because of their unusual properties as liquids. These unique properties of ionic liquids have already been mentioned in some books, so we do not repeat them here more than simply summarize them in Table 1.1. Note these are entirely different properties from those of ordinary molecular liquids. The most important properties of electrolyte solutions are nonvolatility and high ion conductivity. These are essentially the properties of advanced (and safe) electrolyte solutions that are critical to energy devices put in outdoor use. Safety is more an issue than performance these days, and is taken into account in the trends in the materials developed for practical. Thus more developments in ionic liquids are expected to be seen in the future. The nonvolatile electrolyte solution will change the performance of electronic and ionic devices. These devices will become safer and have longer operational lives. But, more interesting, they will be composed of organic ions, and these organic compounds will have unlimited structural variations because of the easy preparation of many components. So there are unlimited possibilities open to the new field of ionic liquids. The most compelling idea is that ionic liquids are “designable” or “fine-tunable.” So we can easily expect explosive developments in fields using these remarkable materials.

**TABLE 1.1 Basic Characteristics of Organic Ionic Liquids**

Low melting point	<ul style="list-style-type: none"> <li>• Treated as liquid at ambient temperature</li> <li>• Wide usable temperature range</li> </ul>
Non-volatility	<ul style="list-style-type: none"> <li>• Thermal stability</li> <li>• Nonflammability</li> </ul>
Composed by ions	<ul style="list-style-type: none"> <li>• High ion density</li> <li>• High ion conductivity</li> </ul>
Organic ions	<ul style="list-style-type: none"> <li>• Various kinds of salts</li> <li>• Designable</li> <li>• Unlimited combination</li> </ul>

## 1.2 IMPORTANCE OF IONIC LIQUIDS

Ionic liquids are salts that melt at ambient temperature. The principles of physical chemistry involved in the great difference between solution properties of molecular solvents and molten salts have already been introduced and summarized in a number of books. Thousands of papers have already been published on their outstanding characteristics and effectiveness for a variety of fields. Thus, as was mentioned above, in this book we take the most important point that these ionic salts are composed of organic ions and explore the unlimited possibility of creating extraordinary materials using molten salts.

Because ionic liquids are composed of only ions, they show very high ionic conductivity, nonvolatility, and nonflammability. The nonflammable liquids with high ionic conductivity are practical materials for use in electrochemistry. At the same time the nonflammability and nonvolatility inherent in ion conductive liquids open new possibilities in other fields as well. Because most energy devices can accidentally explode or ignite, for motor vehicles there is plenty of incentive to seek safe materials. Ionic liquids are being developed for energy devices. It is therefore important to have an understanding of the basic properties of these interesting materials. The ionic liquids are multi-purpose materials, so there should be considerable (and unexpected) applications. In this book we, however, will not venture into too many other areas. Our concern will be to assess the possible uses of ionic liquids in electrochemistry and allied research areas.

## 1.3 POTENTIAL OF IONIC LIQUIDS

At present most of the interest in ionic liquids is centered on the design of new solvents. While the development of “new solvents” has led the direction of possible applications for ionic liquids, there is more potential for development electrochemical applications.

Electrochemistry basically needs two materials: electro conductive materials and ion conductive materials. Ionic liquids open the possibility of improving ion conductive materials. The aqueous salt solution is one of the best electrolyte solutions

for electrochemical studies. However, because water is volatile, it is impossible to use this at wide temperature range or on a very small scale. Many other organic polar solvents have been used instead of water to prepare electrolyte solutions. They, however, have more or less the same drawback, depending on the characteristics. The material known to be a nonvolatile ion conductor is the polymer electrolyte. Polymers do not vaporize but decompose at higher temperatures; the vapor pressure at ambient temperature is zero. Polymer electrolytes are considered a top class of electrolytes except for the one drawback: relatively low ionic conductivity.

Some of the literature has included statements that the ionic liquids are thermally stable and never decompose. This kind of statement has led to a misunderstanding that the ionic liquids are never vaporized and are stable even when on fire. Are the ionic liquids indestructable? The answer is no. However, while inorganic salts are entirely stable, the thermal stability of organic salts depends largely on their structure. Since most recently reported ionic liquids are organic compounds, their degradation begins at the weakest covalent bond. Nevertheless, ionic liquids are stable enough for ordinary use at temperatures of 200° to 300°C. So it is not difficult to design novel ionic liquids that can be decomposed at certain temperature or by certain trigger. It is also possible to design unique catalysts (or catalytic systems) that can decompose target ionic liquids. Some catalysts such as metal oxides or metal complexes have the potential to become excellent catalysts for the decomposition of certain ionic liquids under mild conditions. The post-treatment technologies of ionic liquids should therefore also be developed along with the work on the design of ionic liquids.

At the present time there has been little progress in this area. Although post-treatment technologies are beyond the scope of this book, we do attempt to give ideas on the various future developments in ionic liquid technologies as well as in electrochemistry. This book is dedicated to introducing, analyzing, and discussing ionic liquids as nonvolatile and highly ion conductive electrolyte solutions. The astute reader will find the future prospects for ionic liquids between the lines in all chapters of this book.

