

Task Specific Ionic Liquids (TSILs) used as Reaction Media and Catalyst

Chandan Kumar

Department of Chemistry, Deoghar College, Deoghar, Jharkhand, India

Corresponding Author's Email: chandankumar78@yahoo.com

Abstract

Task-specific ionic liquids (TSILs) have gained more attentiveness in recent years due to its specific physical as well as chemical properties. They are employed in many specific reactions of synthetic organic chemistry due to their distinctive nature. They also serve as a good catalyst in many reactions due to their excellent catalytic properties. The ionic liquids consist of unique properties, including very low vapor pressure, reusability, more thermal stability and distinct structural characteristics. These properties make them more multifaceted and green solvents. The applications of ionic liquids segregate them from the other conventional solvents used in synthesis. The ionic properties of ionic liquid furnish a special solvent environment for several reactions of synthesis. Ionic liquids also appear as a remarkable material due to its special characteristics such as low flammability, less volatility and ability to dissolve in a large number of organic and inorganic substances. This review is an attempt to propose some developments in the area of TSIL in regard to catalysis and reaction media for the synthesis of organic compounds.

Keywords: *Catalysis; Ionic Liquids; Organic Synthesis; Task Specific Liquids*

Introduction

In the last few decades, ionic liquids (ILs) received more attention in catalysis and reaction media for synthetic reactions. They have wide application in pharmaceuticals, biomedicines, lubrication technology, electrochemistry and industries that carry out the synthesis of a large number of compounds (Zhuo *et al.*, 2014; Greer *et al.*, 2020). The use of ILs is a greener process in the manufacturing of a large number of compounds due to their noticeable features, including low vapor pressure, low in flammability, reusability, low melting point, low boiling point and thermal stability. They are treated as green solvents due to acting with less harmful emissions and low effluent discharge in organic synthesis processes. However, many chemical industry processes have been or still are highly polluting the environment. Moreover, their ability to dissolve in a range of organic and inorganic compounds makes them a significant material. Although the term "ionic liquids" has been popular in recent years, the history of ionic liquids most likely was initiated by Paul Walden in 1914. He reported the synthesis and various properties of the ionic liquid [EtNH₃][NO₃]. Later on, Gorden (1969) critically studied the ionic liquids. Wilkes and coworkers (1982) reported many significant reactions and referred to them as a green solvent. The first effective use of an ionic liquid, dialkylimidazolium chloroaluminate, as a catalyst in Friedel-Crafts acylation reactions was reported by Boon *et al.* (1986). The term "Task Specific Ionic Liquids" (TSILs) was introduced to describe the characteristics of ionic liquids by Davis (2004). He significantly reviewed the various syntheses of TSILs and their applications in catalytic reactions and synthetic organic chemistry. TSILs are the type of ionic liquids structured and designed to perform specific actions or tasks in synthetic reactions. In recent years, TSILs, a class of ionic liquids, have received more attention in synthetic reactions because of their specific characteristics. Winkel *et al.* (2008) reported the asymmetric synthesis involving the utilization of task-specific chiral ionic liquids. In our previous review (Chaturvedi *et al.*, 2014; Kumar, 2025), the catalytic properties and application of

Application of Chemical and Biological Sciences for Sustainable Future

Task-Specific Ionic Liquids in Catalysis

ionic liquid. This review is an attempt to explain some developments of TSIL and their use in reaction media and catalysis.

TSILs as Reaction Media and Catalyst

Task-specific ionic liquids (TSILs) are also referred to as functionalized ionic liquids. They are specific salts having functional groups for specialized tasks/reactions that act as versatile solvents as well as catalysts to perform many reactions. They have focused applications in the specific reactions. TSILs furnish properties like high stability, great solubility in most reactants, and superior selectivity for reactions. They are treated as green solvents because they involve less environmentally harmful reactions than the conventional organic synthesis. Bellina *et al.* (2009) had prepared ionic liquids shown in Fig. 1 that carried glycerylimidazolium. They extensively studied their physicochemical features such as thermal stability, hydrogen bonding, and conductivity. It has been demonstrated that ionic liquid has application in Heck reaction and the palladium-catalyzed coupling reactions.

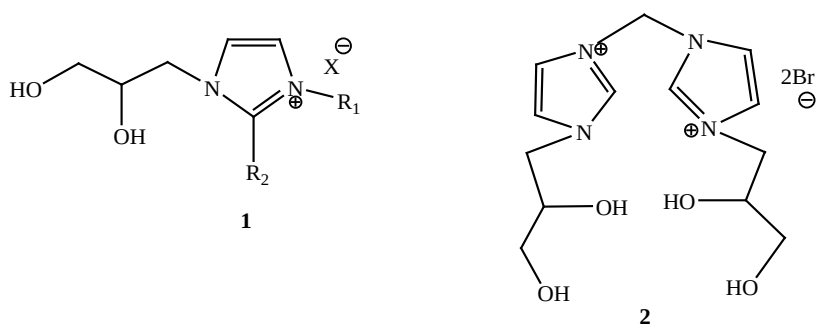
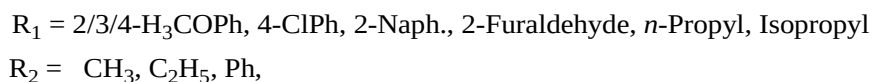
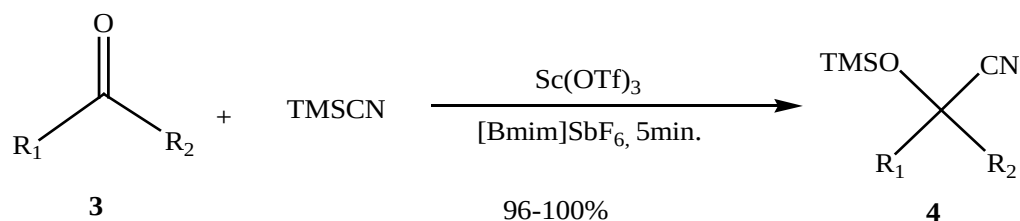


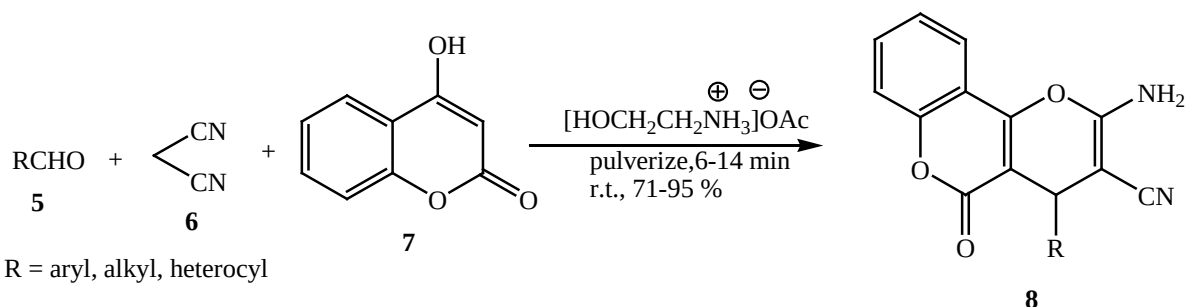
Figure 1: Glycerylimidazolium

Park *et al.* (2009) applied scandium triflate as a catalyst in the cytosilylation reaction of carbonyl compound **3** to yield compound **4**. When the ionic liquid 1-butyl-3-methylimidazolium antimony hexafluoride [Bmim]SbF₆ was used as a catalyst in this reaction, it was found that the product formed easily (**Scheme 1**). It was revealed that ionic liquid increased the catalytic activity of the reaction effectively. It was suggested this was due to the increase of Lewis acidity of IL and anion exchange between scandium triflate and ionic liquid.

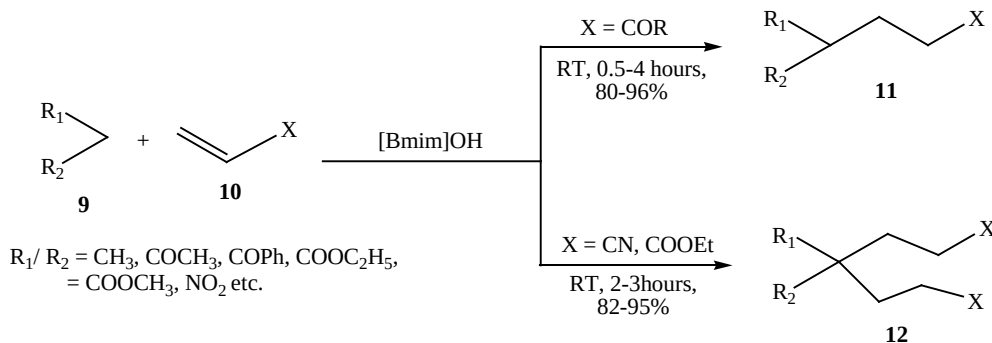


Scheme 1

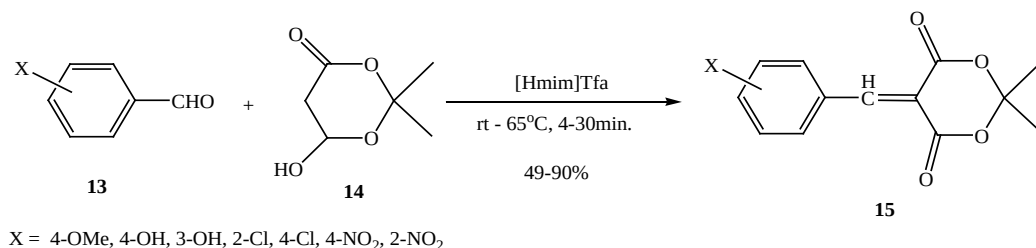
Shaterian and Honarmand (2011) reported that task-specific ionic liquid [HOCH₂CH₂NH₃]⁺[OAc]⁻ is a reusable and effective catalyst for one-pot synthesis of dihydropyrano[3,2-c]chromene derivatives **8**. This synthesized product was produced with the condensation of 4-hydroxycoumarin **7**, various aldehydes **5**, and malononitrile **6**. This reaction occurs in a combinatorial fashion. The reaction at room temperature gave excellent yield (**Scheme 2**).

**Scheme 2**

The distinct selectivity of task-specific ionic liquid, 1-butyl-3-methylimidazolium hydroxide [Bmim]OH, was reported by Ranu and Banerjee (2005) in a well-known Michael addition reaction. They conducted the reaction of active methylene compounds **9** with conjugated ketones/esters/nitriles **10**. They suggested that vinyl ketones and chalcones yield mono-addition product **11**, while the unsaturated esters and nitriles yield *bis*-addition product **12**. These reactions were carried out at room temperature and give excellent quantitative yields (**Scheme 3**).

**Scheme 3**

Darvatkar *et al.* (2006) conducted the Knoevenagel condensation consisting of Meldrum's acid **14** with a range of aldehydes **13**. They used the different kinds of ionic liquids, such as 1-butyl-3-methylimidazolium hexafluoroborate [Bmim]PF₆, 1-methylimidazolium trifluoroacetate [Hmim]Tfa, 1-butyl-3-methylimidazolium tetrafluoroborate [Bmim]BF₄, and 1-hexyl-3-methylimidazolium tetrafluoroborate [Hmim]BF₄ in this reaction. The corresponding derivatives of ylidene **15** were produced (**Scheme 4**). They observed that at room temperature, use of ionic liquid [Hmim]Tfa as a catalyst yields product effectively. The utilization of ionic liquids, the product produced easily, was reused.

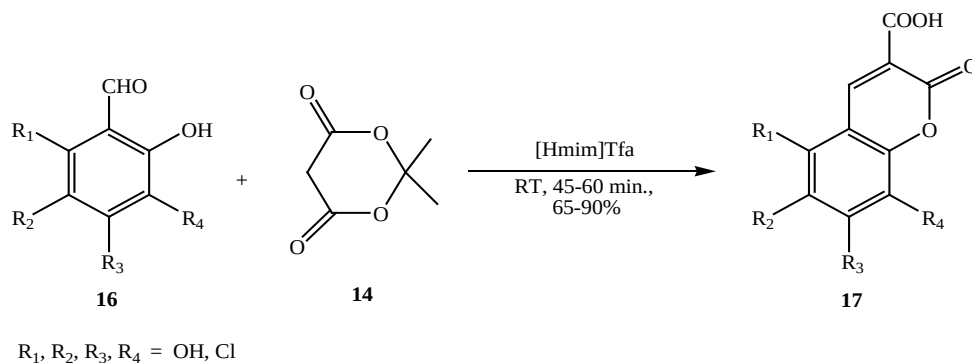
**Scheme 4**

Darvatkar and their associates (2008) had again used TSIL [Hmim]Tfa in the reaction of *o*-hydroxy aryl aldehydes **16** and Meldrum's acid **14**. The derivatives of coumarin-3-carboxylic acid **17** were produced

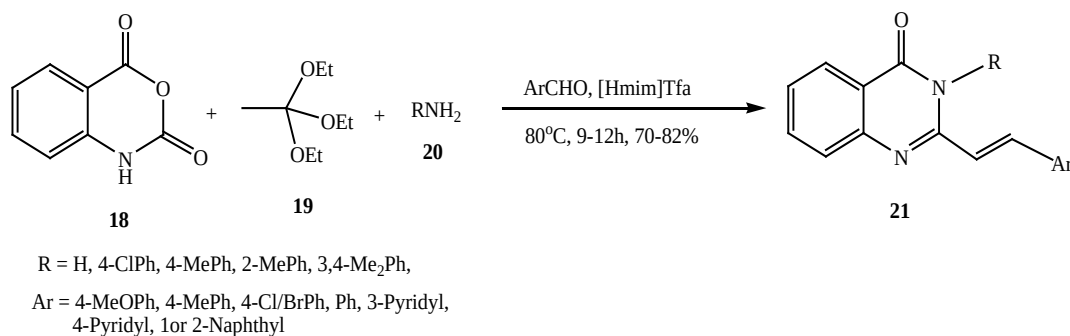
Application of Chemical and Biological Sciences for Sustainable Future

Task-Specific Ionic Liquids in Catalysis

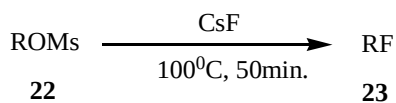
effectively. They conducted this reaction at room temperature and produced the product in good yield (**Scheme 5**). They concluded that the use of this ionic liquid acts as an effective catalyst.

**Scheme 5**

Dabiri *et al.* (2008) used [Hmim]Tfa as a TSIL in a reaction of isatoic anhydride **18**, triethyl orthoformate **19**, and amine derivatives **20**. This reaction produced 2-styryl-4(3H)-quinazolines (**21**) in the presence of different substituted aromatic aldehydes. The reaction was carried out at 80°C, and the product yield was satisfactory (**Scheme 6**).

**Scheme 6**

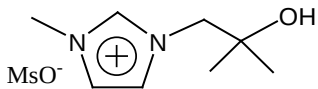
Shinde *et al.* (2008) reported the effect of ionic liquid and alcohol in nucleophilic substitution reactions. This reaction involved the conversion of mesylates **22** to the corresponding fluoro-substituted compound **23** in the presence of cesium fluoride at 100°C (**Scheme 7**). It was found that the combination of tertiary butanol and ionic liquid accelerated the reaction effectively, as shown in Table 1. The advantage of this reaction is very few side products. It was suggested that the weak hydrogen bond of HF reduces nucleophilicity and decreases the basic character of fluoride, which leads to fewer side products.



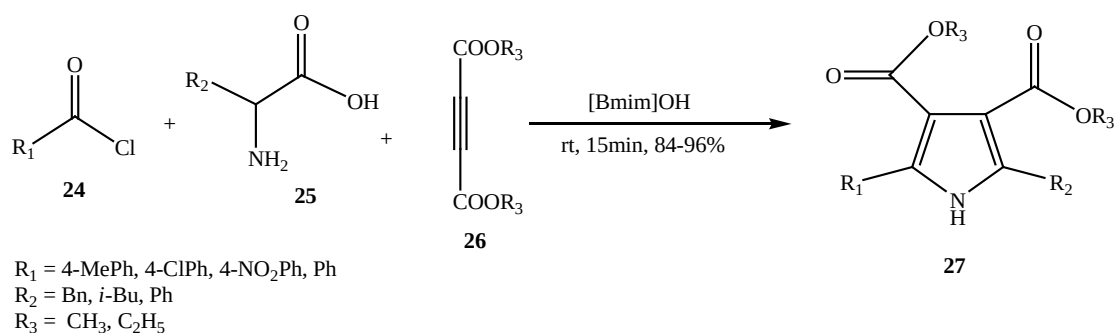
$\text{R} = \text{2-Naphthyloxypropane, protected steroids and protected glycosides}$

Scheme 7

Table 1: Effect of Solvent and IL on Nucleophilic Fluorination

Solvent/Ionic liquid	Equivalent	Yields in %
Tertiary Butanol	0.5	22
[Bmim]OMs	0.5	30
Tertiary Butanol: [Bmim]OMs	0.5:0.5	37
	0.5	97

Yavari and Kowsari (2008) utilized 1-butyl-3-methylimidazolium hydroxide [Bmim]OH, an ionic liquid, as a catalyst for the condensation reaction of acid chlorides **24**, dialkyl acetylene dicarboxylates **26** and amino acids **25** in aqueous solution. The pyrrole derivatives were formed with sufficient yields. They studied this reaction with ten different types of ionic liquids, in which [Bmim]OH was most effective. At 80°C, pyrrole derivatives have good yield. It was reported that benzoyl chloride having an electron-withdrawing substituent reacts faster (**Scheme 8**).

**Scheme 8**

Conclusion

Ionic liquids are generally molten salts, which are composed entirely of ions, consisting mainly of organic or inorganic cations and anions. Ionic liquids are referred to as a green solvent due to their low vapor pressure, being environmentally less harmful, low volatility and recycling properties. They have characteristics to dissolve in most of the organic and organic compounds, making them fabulous for many reactions. They have noticeable catalytic properties in most of the synthesis. Task-specific ionic liquids are a type of ionic liquid that performs specific tasks for several synthetic reactions and has wide applications.

Acknowledgement

The author expresses sincere thanks to his friends for their valuable suggestion and support. The author also extends his gratitude to Deoghar College, India, for encouragement.

References

- Bellina, F., Bertoli, A., Melai, B., Scalesse, F., Signori, F., & Chiappe, C. (2009). Synthesis and properties of glycerylimidazolium based ionic liquids: a promising class of task-specific ionic liquids. *Green Chemistry*, 11(5), 622-629. <https://doi.org/10.1039/B821927C>
- Boon, J. A., Levisky, J. A., Pflug, J. L., & Wilkes, J. S. (1986). Friedel-Crafts reactions in ambient-temperature molten salts. *The Journal of Organic Chemistry*, 51(4), 480-483. <https://doi.org/10.1021/jo00354a013>

Task-Specific Ionic Liquids in Catalysis

Chaturvedi, D., Kumar, C., Zaidi, S., & Chaturvedi, A. K. (2014). Task specific ionic liquids: Reaction selectivity in organic synthesis. *J. Org. Biomol. Chem*, 2, 51-79.

Dabiri, M., Baghbanzadeh, M., & Delbari, A. S. (2008). Novel and efficient one-Pot tandem synthesis of 2-Styryl-Substituted 4 (3 H)-Quinazolinones. *Journal of Combinatorial Chemistry*, 10(5), 700-703. <https://doi.org/10.1021/cc800067g>

Darvatkar, N. B., Deorukhkar, A. R., Bhilare, S. V., & Salunkhe, M. M. (2006). Ionic liquid-mediated Knoevenagel condensation of Meldrum's acid and aldehydes. *Synthetic communications*, 36(20), 3043-3051. <https://doi.org/10.1080/00397910600775218>

Darvatkar, N. B., Deorukhkar, A. R., Bhilare, S. V., Raut, D. G., & Salunkhe, M. M. (2008). Ionic liquid-mediated synthesis of coumarin-3-carboxylic acids via knoevenagel condensation of meldrum's acid with ortho-hydroxyaryl aldehydes. *Synthetic Communications®*, 38(20), 3508-3513. <https://doi.org/10.1080/00397910802162967>

Davis Jr, J. H. (2004). Task-specific ionic liquids. *Chemistry letters*, 33(9), 1072-1077. <https://doi.org/10.1246/cl.2004.1072>

Gorden, J. E. (1969). *Techniques and Methods of Organic and Organometallic Chemistry*. Dekker, New York, NY., 1, 51-188.

Greer, A. J., Jacquemin, J., & Hardacre, C. (2020). Industrial applications of ionic liquids. *Molecules*, 25(21), 5207. <https://doi.org/10.3390/molecules25215207>

Kumar, C. (2025). Ionic liquids and its application in organic synthesis. In *Harmonising Chemical and Biological Sciences for Sustainable Development* (pp. 150–155). Lincoln University College. <https://doi.org/10.31674/book.2025hcbssd014>

Park, B. Y., Ryu, K. Y., Park, J. H., & Lee, S. G. (2009). A dream combination for catalysis: highly reactive and recyclable scandium (III) triflate-catalyzed cyanosilylations of carbonyl compounds in an ionic liquid. *Green chemistry*, 11(7), 946-948. <https://doi.org/10.1039/B900254E>

Ranu, B. C., & Banerjee, S. (2005). Ionic liquid as catalyst and reaction medium. The dramatic influence of a task-specific ionic liquid, [bmIm] OH, in michael addition of active methylene compounds to conjugated ketones, carboxylic esters, and nitriles. *Organic letters*, 7(14), 3049-3052. <https://doi.org/10.1021/ol051004h>

Shaterian, H. R., & Honarmand, M. (2011). Task-specific ionic liquid as the recyclable catalyst for the rapid and green synthesis of dihydropyrano [3, 2-c] chromene derivatives. *Synthetic Communications*, 41(23), 3573-3581. <https://doi.org/10.1080/00397911.2010.519594>

Shinde, S. S., Lee, B. S., & Chi, D. Y. (2008). Synergistic effect of two solvents, tert-alcohol and ionic liquid, in one molecule in nucleophilic fluorination. *Organic letters*, 10(5), 733-735. <https://doi.org/10.1021/ol702679d>

Walden, P. (1914). Molecular weights and electrical conductivity of several fused salts. *Bull. Acad. Imper. Sci.(St. Petersburg)*, 1800, 405. <https://ci.nii.ac.jp/naid/10025720020/>

Wilkes, J. S., Levisky, J. A., Wilson, R. A., & Hussey, C. L. (1982). Dialkylimidazolium chloroaluminate melts: a new class of room-temperature ionic liquids for electrochemistry, spectroscopy and synthesis. *Inorganic Chemistry*, 21(3), 1263-1264. <https://doi.org/10.1021/ic00133a078>

Winkel, A., Reddy, P. V. G., & Wilhelm, R. (2008). Recent advances in the synthesis and application of chiral ionic liquids. *Synthesis*, 2008(07), 999-1016. <https://doi.org/10.1055/s-2008-1066986>

Yavari, I., & Kowsari, E. (2008). Task-specific basic ionic liquid: a reusable and green catalyst for one-pot synthesis of highly functionalized pyrroles in aqueous media. *Synlett*, 2008(06), 897-899. <https://doi.org/10.1055/s-2008-1042912>

Zhuo, Y., Cheng, H. L., Zhao, Y. G., & Cui, H. R. (2024). Ionic liquids in pharmaceutical and biomedical applications: A review. *Pharmaceutics*, 16(1), 151. <https://doi.org/10.3390/pharmaceutics16010151>