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Review Article

A REVIEW OF GREEN SOLVENT IONIC LIQUIDS: AS A FUTURE SOLVENT

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ABSTRACT

Currently, chemists seem more fascinated with exploiting less hazardous green solvent ionic liquids for countering the detrimental consequence of organic solvents on the environment. Ordinarily, ionic liquids having salt-like structures comprise cations and anions. Ionic liquids alleviate various enzyme-catalyzed reactions having excellent yields, increasing capacities and functions, enhancing recyclability, increasing stability, recovery, and cost-effectiveness, and these are cardinal elements for applications in industry. Furthermore, growing nanotechnology, polymer, electrochemistry, environmental chemistry, pharmaceutical medicinal chemistry or pharmaceutical chemistry, and biochemistry in the area of ionic liquids have been flourished among investigators. Ionic liquids-supported materials and techniques are excellent for efficient and sustainable procedures. Because of their assignment as designer solvents, through which the physio-chemical dimensions of an Ionic liquid can be adjusted for better functioning for peculiar applications. The review delivers the gradual improvement, growth or development, or progress and prospects of ionic liquids and their physicochemical properties as well as examples of applications in a unified fashion.

Keywords: Ionic liquids, Physio-chemical properties, Separation Science, Nanomaterials, Ionanofluids, Fossil fuel cleaner.

1. INTRODUCTION

Magical chemical ionic liquids, having unique tunable properties with a variety of applications in every field have attracted tremendous attention from scientists ecumenically. The history of liquids effectively started in 1914 when the inception of the first ionic liquid (IL) ethyl ammonium nitrate ([$EtNH_3$] [NO_3] with a melting point of 12°C was reported. Years later, a procession of remarkable related ionic liquids has been revealed unusually, have established enormous pursuit in the chemical industry as well as in academia because of their tremendous greener properties and exist as a liquid at below 100°C temperature. Ionic liquids (ILs) have no boundary between organic and inorganic materials because of their tunable properties. Furthermore, target-specific ionic liquids with tunable properties can be designed by changing cation-anion combinations. Examples of several normally employed cationic constituents are pyrrolidinium [1], imidazolium cations [2], ammonium cations [3], pyridinium cations [4], phosphonium cations [5], and piperidinium cations [6] with variant substituents and anionic constituents tetrafluoroborate anions, alkyl sulphonate anions, alkyl tosylate anions, and hexafluorophosphate anions for production of ILs. As a result, ILs have many advantages over the traditional organic solvents (Table1) such as very low volatility, trifling vapor pressure [7], less hazardous, inflammability [8], solubility, and more environmental compatibility, viscosity [9], high chemical and thermal stability [10], prominent ionic conductivity [11-14]. Usually, the viscosity of ILs relies on and enhances with increasing hydrogen bonding, van der Waals forces, length of the alkyl chain, and degree of fluorination or anion. Furthermore, normally, at room temperature, ILs's viscosity has a scope between 10 and 500 mPa. [15-18].

2. PHYSIO-CHEMICAL PROPERTIES OF IONIC LIQUIDS

Remarkably, some of their canonical dimensions are [19-29]:

- Potentiality to solvate numerous organic, organo-metallic, and inorganic substances.
- Prominent polarity.
- Loose-fitting coordinating large-size ions.

- In general, very low vapor pressures as well as low volatility.
- Thermal constancy up to 300°C approximately.
- Eminent thermal conductance and an enormous electrochemical window.
- Liquid windows of ILs are up to 200°C to empower broad kinetic control.
- Nonaqueous polar options to phase transfer procedures.
- They have been acknowledged as universal solvents.
- They are capable to solvate still gases such as H_2, CO_2, O_2, and CO. They have been applied under supercritical CO_2.
- In ILs, the dissolubility deciding components are anions and cations from which these are framed.
- They do not coordinate with macrocycle metal complexes such as enzymes, etc. chiefly, the ionic properties of ILs enhance the rate of reactions.
- They are stable and can be stored without decomposition for a long time.
- ILs have found extensive use in the control of stereo selectivity.
- The viscosity of imidazolium-modified ILs can be controlled by modifications in branching.
- They have melting point preferably below 100°C.
- The dielectric constant of ILs has been implied to <30.

3. APPLICATIONS OF IONIC LIQUIDS

On account of their fascinating properties, ILs have been exploited in a wide area of applications which are listed below [30-54]:

Medium extraction [30], physico-chemical procedures [31], ILs as a medium for many reactions [31], in the modification of the mobile phase of HPLC [32], metals electrodeposition, and semiconductors in ILs [33], in the analysis of chemicals [34], dye-sensitized solar cells [35, 36], in the nuclear fuel chain: extraction and electrodeposition [37], nuclear-supported separations [38],oil shale treating [39], separation of petrochemical relevance [40], development of functional nanoparticles as well as different inorganic nanostructures [41], ILs as mediums for electrochemistry [42], ILs as mediums in polymerization procedures [43], chemical as well as biochemical conversions [44], materials chemistry [45], ILs as a biocatalyst, or biocatalysts in ILs [46-55], utilization as green catalysts, chromatographic actions; ILs have been depicted as immense per-formances in separation techniques [56], as separators for extraction of metal ions, Ionic liquids modified sensing-Chemo-sensing has been examined by employing ILs and detected the fast reduction in viscosity, in spectroscopy; The applications of ILs in mass spectroscopy are speedily raising after being accomplished by Armstrong's group.

These are some of the universal applications of ILs. Several applications that are associated with oil as well as with the gas industry comprise:

Removal of sulfur from fuels, naphthenic acids extraction, removal of nitrogen from gasoline, utilization as a demulsifiers agent, eliminate contamination, selective gas extraction and mercury elimination in natural gas, production of Biofuels, in improving oil recovery, CO_2 is captivating and sequestrant, application as asphaltene and wax retardant, recovery of heavy oils or bitumen with ILs and in oil fields, deep eutectic media is being extended.

Ionic liquids (ILs) have come out into view as a mesmerizing green reusable substitute for toxic, dangerous, combustible, and extremely volatile organic compounds [58-63]. ILs are widely exploited in chemistry, nanotechnology [64, 65], engineering [66-68], biotechnology [69-74], pharmaceutical industries [75-80]. ILs have many exertion like as natural fibers processing, carbon dioxide capture [81-83], separation, battery [84, 85], biofuel formation, extraction [86], biological activities, solvents [87, 88], catalysis [89-92], fuel cells [93] and biomedical uses [94]. Several reports have included a total or partial degradation of the epoxy thermoset polymers as well as utilized the end productions for making functional materials for various applications [95-98]. Other approaches applied by many investigators include chemical decomposition by the base or acid reactions [99-101] or by the implementation of a catalyst for degradation of the Epoxy-resin [102-105].

4. IONIC LIQUIDS AND IONIC SALTS

Ionic liquids are magnificently distinct from ionic salts such as NaCl [106]. Ionic salts exist as solid at room temperature and have electrostatics interaction with normally metallic cations and non-metallic anions. On the whole, ionic materials such as NaCl can be in a liquid or molten state at high temperatures so can not be used in organic synthesis. Whereas, ionic liquids, a category of ionic salts which have melting points below 100°C, are soluble in organo-metallic as well as inorganic-organic compounds and are used in organic synthesis [107].

Table 1: Comparison between Ionic liquids and organic solvents [57]

Serial Number	Property	Ionic liquids	Organic solvents
1	Number of solvents	More than 1,000,000	More than 1000
2	Applicableness	Multifunctional	One work
3	Catalytic capability	Frequent and tunable	Uncommon
4	Chiral Property	Frequent and tunable	Uncommon
5	Refractive Index	From 1.5 to 2.2	From 1.3 to1.6
6	Viscosity (cP)	From 22 to 40,000	From 0.2 to 100
7	Polar property	Employ doubtable conceptions of polarity	Employ traditional conceptions of polarity
8	Density (g/cm^3)	From 0.8 to 3.3	From 0.6 to 1.7
9	Recyclability	Economical clamant	Green clamant
10	The capability of being tuned	The almost limitless scope entails designed solvents	The narrow scope of solvents accessible
11	Solvency	Potent Solvency	Feeble Solvency
12	Inflammability	Generally inflammable	Generally flammable
13	Monetary Value	Mostly low-priced	Mostly from two to hundreds of times than that of organic solvents
14	Vapor pressure	Worthless vapor pressure	Follow the Clausius-Claperon equation

5. APPLICATIONS OF IONIC LIQUIDS

5.1. Applications in separation science

Outstanding holdings of IL, ability to synthesize with different solubility in water as well as in organic solvents such as methanol or ethanenitrile makes their use in separation technique newsworthy. Due to the viscous nature, ILs have been utilized in chromatography as an additive and after adding High-Performance Liquid Chromatography solvents viscosities of ILs reduced [108, 109]. In a special separation technique capillary electrophoresis (CE), ILs are used as background electrolytes as well as additives. Additionally, ILs modify the capillary wall and electrophoretic separations [110-112]. ILs are also used in the separation of flavonoids from phenolic compounds and imidazolium ionic liquid, and carprofen, naproxen, ketoprofen, and suprofen from (C_4mim) (NTf_2). Natural product researchers are using ILs as a green method to extract and isolate from plants-like alkaloids, flavonoids, terpenoids, and phenolics [113-116].

5.2. Environmental acceptable green extraction techniques

Conventionally, scientists ordinarily utilize hazardous volatile organic compounds (VOCs) in extraction techniques to have organic extracts like soxhlet, distillation, percolation, maceration, distillation, and infusion. On the other hand, all green chemistry scientists have long attempted for replacing conventional methods which have an environmental impact with green methods such as supercritical fluid extraction, ultrasound-assisted extraction, microwave-assisted extraction, high-speed homogenization, and pulsed electric field, and pressurized solvents. ILs scale down solvent uptake and extraction time. Supercritical fluid extraction has fantabulous extraction properties but high operational costs than ILs [117-121].

5.3. Role of ionic liquids as a catalyst for the preparation of biodiesel

Negligible vapor pressure, high thermal stability, phase transition behavior, solubility and miscibility with reactants, acidity and basicity, switchable ionic liquids as green solvents, ionic liquids in biodiesel synthesis, catalyst, solvent for enzyme-catalyzed transesterification, catalyst support, recycling of ionic liquids, ionic liquids recovery, deep eutectic solvents (DES) such as choline chloride, a peculiar category of ILs regarded as a new generation of ionic liquids that form hydrogen bonding. Additionally, hydrogen-bonding interactions in deep eutectic solvents (DES) are energetically favorable as a result of more solubility. Researchers have used a combination of deep eutectic solvents and ILs in biodiesel preparation [122,123].

5.4. Protein solubility and stability in ionic liquids

Many publications on protein solubility and consistency have been published in aqueous solution but in some cases solvation and constancy of proteins in water are pocket-size and these difficulties can be subdued by using ILs as co-solvents with an aqueous medium in two-phase systems or as dexterous ILs [124-126] and also ameliorate the separation effectiveness of essential biomolecules like carbohydrates, amino acids, alkaloids, proteins, antibiotics, and various solvents [127, 128]. The stability of a protein is important for the purification and extraction process for their diligence because alterations in the protein surroundings can modify its pure form. Classical methods of protein refinement like liquid-liquid extraction, electrophoresis, and chromatography, have convinced disadvantages admitting huge prices, time uptake, deprivation in biological functions, and insufficiency of lustiness. Ionic liquid-based aqueous biphasic systems can get over these disadvantages [129-132]. IL-supported aqueous state extraction for protein separation is a desirable alternative.

5.5. Biocatalysis in the presence of ionic liquids

The foremost booming study of biocatalysis in presence of ILs is done in 2000 [133]. Functions and consistency of a vast figure of enzymes for example tremendously employed lipases [134-137], oxidoreductases, proteases [138, 139], and alcohol dehydrogenases, and compatibility with other enzymes have been measured. The functioning of enzymes in ILs is stimulated by numerous components such as anions which can form hydrogen bonding with enzymes and make configurational modifications, cations that have the power to form van der waals interactions, the alkyl chain extension enhance enzyme constancy, as well as viscosity, hydrophobicity that can be elevated by an alkyl chain, lengthened, affects the folding or refolding of enzymes [140-143].

Both hydrolases enzymes as lipases have mostly habituated in reactions transesterification, perhydrolysis, ammonolysis, polyester synthesis [144-151], proteases such as thermolysin have applied commonly in peptide synthesis [152], chymotrypsin has been used in transesterification [153-156], esterase has exploited in transesterification [157], glycosidase like as galactosidase has employed in N-acetyllactosamine synthesis and oxidoreductases for examples formate dehydrogenase in the regeneration of NADH [158], baker's yeast in reduction of ketones, peroxidases in the oxidation of guaiacol, laccase C in the oxidation of syringaldazine [159-161], have been expended, hold back natural functions with ionic liquids. In many reactions, proteases and lipases show enantioselectivity in ILs [162].

5.6. Ionic liquids as a fossil fuel cleaner

For the expeditious formation of cleaner fossil fuels, ILs possess various anion and cation additions that have been programmed to efficaciously draw out sulfur chemical compounds likewise dibenzothiophene out of fossil fuels under atmospheric considerations. On account of its extremely noxious and destructive nature, the quantity of H_2S is hard to govern in natural gas, and the quantity of H_2S should be less than $6mg/m^{3.}$ Consequently, the establishment of ILs for withdrawing H_2S has appealed to modernize attention freshly. Many kinds of ILs have been examined for their dissolubility of H_2S, and their functioning. The dissolubility and discrimination of H_2S are due to attractions in anions and H_2S, favorable prominent CO_2 concentrations. Chemists have reported that imidazolium-based ionic liquids can be employed as an extraordinary excerption to remove the sulfur from liquid fuels, and dibenzothiophene [163,164].

5.7. Ionic liquids and polysaccharide cellulose

Polysaccharide cellulose-supported kinds of stuff have been exercised in the global industries [165] and have fascinating attributes like biological harmony, biodegradability, best solubility, recyclable, chemical as well as thermal constancy [166, 167]. Because cellulose is indissoluble in traditional solutions, current research universally proposes to discover novel, effective, and green solvents for biomass such as cellulose, so attempts have concentrated on the exploitation of ionic liquids for receiving solubility of cellulose. Currently, a research report has found the association between the dissolution and the degree of polymerization (DP) of cellulose [168], and the dissolution of cellulose can be decreased with the enhancing DP.

5.8. Role of ionic liquids in nanomaterials

The stability of nanomaterials in the various solvents has been essential for beautifying versatile usage in divergent areas. Moreover, the solution works a cardinal function in altering and calibrating the physiochemical attributes of the nanomaterials [169, 170]. Imidazolium-supported ILs have been depicted for ameliorating dimensions of the nanomaterials such as carbon nanotubes [171], and offer surface monotony of nanoparticles without throwing away properties like no alteration in nanoparticle size as well as in size dispersion, allowing for reusability as catalysis, and comfortably separation from the reaction solutions [171]. According to reference, imidazolium-supported ILs have behaved as capping agents [172,173]. IL-nanomaterial composites

1-butyl-3-methylimidazolium tetrafluoroborate has been applied to make IL-ZnO composites to increase the potent capacity of dasatinib and doxorubicin for breast antitumor curatives [174]. 1-ethyl-3-methylimidazolium methanesulfonate stabilized PbS, CdS nanoparticles [175,176].

Graphene oxide-supported ionic liquids methods have been developed to find out traces of Hg in water [177]. Moreover, carbon quantum dots capped with imidazolium-supported ILs by pyrolysis have been groomed and presently, citrate-based ILs have been applied to develop the Ag nanoparticles capped with IL [178], and nanosheets. According to Okoli, [179] the sole function of ILs is the generation of best attribute metal alloy nanoparticles to raise catalytic functions. Imidazolium modified ILs such as 1-methacryloyloxypropyl-3-methylimidazolium bromide [180] for Al_2O_3, TiO_2, Fe_3O_4, 1-butyl-3-methylimidazolium methyl sulfate [181] for ZnSe with 70-100 nm size, PbS from 1-n-butyl-3-methylimidazolium hexafluorophosphate with 100 nm size [182], 1-alkyl-3-methylimidazolium N- bis(trifluoromethane sulfonyl) [183] for Ni with 4.9–5.9 nm size, n- butyltrimethylammonium N-bis(trifluoromethylsulfonyl)imide [184] for Au in rage 140nm, 1-n-butyl-3-methyl trifluoromethane sulfonate for Ir with 2.4-2.6 nm size, were applied to synthesis nanoparticle [185].

5.9. Electrochemical applications of ionic liquids

Application of early acknowledged IL-supported activity has been done in 1996. The intrinsic conductance of ILs builds ILs desirable for varied uses in electrochemistry like as chromium electroplating of scionix procedure [186-188], providing a securer option for toxicity of chromium (IV) salts, in reinforced current power, exempt from cracked, rusting resistive coatings, in a diverse metal procedures employment such as metal plating and metal polishing [189-192].

Various commercial ILs have launched demand in batteries for ameliorating protection, enhanced eminent-voltage steadiness, in ion-Li batteries work as an electrolyte [193, 194]; and also, in Zn modified air batteries, Zn based Br batteries [195-198], gas sensors, supercapacitors, cheap option for crystalline silicon-based cells, in photovoltaic cells which are dye sensitive [199-201]. Various companies are acknowledged to employ the ILs's electrochemical attributes like as IoLiTec as well as C-Tech Innovation for aluminum plating, BASF has applied imidazolium modified ILs to aluminum plating, and Xtalic has employed nanoscale aluminum metal alloy plating [200, 202-206].

5.10. The function of ionic liquids in alkylation

According to recent reports, ILs are an appropriate and securer substitute to invent gasoline from lower hydrocarbons by alkylation [207], however, in the conventional methods alkylation procedure is made up of catalytic action of corrosive acids. In cooperation with QUILL, Chevron started the study of ILs for catalyzing alkylation as a catalyst in 1999 and performed research establishment with their ISOALKYTM discipline for five years long till 2010 for perfecting chemical reaction circumstances [208-210]. The unit of ISOALKYTM which is authenticated by Honeywell UOP takes a lower quantity of catalyst because of their more prominent capability than based-acid operations, enhanced production yield, and attributes with analogous manufacturing as well as operating prices, and also in magnanimous technical applications [211-213].

5.11. The activity of ionic liquids as a capture

In 2005, wind products accounted that they had generated a novel technique to collect and transfer hazardous gases which are broadly applied in the electrochemical industry for doping silicon [214, 215]. Cooperation with investigators in PETRONAS and QUILL resulted in the exploitation of a new technique of withdrawing mercury (Hg) from natural gas currents, with an extraordinarily less execution period [216-220]. Springing up the concern in supported ionic liquids phase (SILP) modified catalyst process headed to the research of proportion synthesis process [221].

5.12. Utility of ionic liquids in coating

The traditional synthesis process involves the dissolution of catalyst in proper solution adopted by the add-on of IL and a poriferous catalyst-based substance and sequential separation of the solvent. Extraction should be done slowly to assuring dispersal of the catalyst as well as IL throughout the poriferous base. According to documented reports, SILP modified substances can be manifoldly produced by employing a fluidized bed spray-based coating, through which supported substances are liquified by applying managed temperature inert gases, catalyst dissolution, and IL in a dissolution is consecutively sprinkled on the support, likewise, this procedure can be applied to prepare ionic liquid supported solid catalyst, incorporating a conventional catalyst covered with a fine film of IL. In addition, this process has been commercially exploited for a hydrogenation procedure, also impacting activity [222-225].

5.13. Use of ionic liquids in polymer chemistry

ILs having eminent optical limpidity with less hazing work as additives such as antistatic additives for ameliorating neatness, and enhancing security. ILs have harmony with many usual working methods or techniques as well as polymers [226-229]. According to Evonik, ILs as an auxiliary dissipate additive for uniformly reinforcing water-modified pigments in water as well as solvent-modified paints and stopping sedimentation [230,231]. Moreover, IoLiTec is acknowledged for making and conveying its investigation and exploitation of IL modified functioning additives to a broad kind of utilizations: diffusing agents, optic brighteners, neatness additives, formation of inorganic substances having definite particle sizes on a commercial scale, and preparation of alcohols on the pilot-scale [222, 232, 233]. In natural fiber welding procedures, ILs have been exploited to procedure natural fiber materials for making congealable networks to sustain the original polymer structure [234-236]. The qualities of the novel material, as well as the magnitude of the welding procedure, have been governed by time, temperature/heat, pressure or ionic liquids nature, quantity, and placement [237]. Trouble in recyclate of plastic is being accepted as a challenge by ILs modified technique and the mainsail problem overcome by plastics recycling because it is frequently much economy to landfill, and incinerate waste matters [238].

5.14. Ionic liquids as active ingredients of pharmaceutical preparations

Crystal polymorphism and less solubility are the most considerable difficulty in the pharmaceutic industry [239-243]. ILs have been depicted as a substitute for conventional drug delivery systems for increasing dissolubility and consistency. Currently produced reports have proved that many ILs hold protein structures [244] so ILs are assured as a stabilizing media to protein remedies [245-248] and also are capable to substitute water and more expensive lyophilic substances in protein supported pharmaceutical formulations. According to currently published reports, ILs have a destructive effect on bacterial and fungal growth, due to this ILs can be used for removing pathogenic micro-organisms tolerant to antibiotics and different medicines [249, 250]. There are numerous illustrations of exploiting ILs in medicinal chemistry, disinfectant detergents [251], as constituents of drugs, tumor treatment [252-254], and novel bioactive substances such as antiseptics [255-258], to oppose microbial biofilms which have various bacteria [259]. Benzalkonium and ammonium supported ILs auspicious action against fungi and bacteria peculiarly for Streptococcus mutans. Various ILs have broad-spectrum actions to oppose pathogenic micro-organisms [259]. Another major trouble regarding the bioavailability of drugs is difficulty in traveling across biological membranes because of the prominent hydrophilic nature and this drawback can be overcome by the proper choice of different active cations and anions to combine these with hydrophilic ones, also by the coating of ILs [259, 260]. Employing ILs as constituents of drugs demands organized determination of toxicological attributes and cytotoxicity [261,262]. Moreover, by exploiting ILs as constituents of pharmaceutical formulations, the osmotic coefficient potency should be precisely determined. Phosphates, as well as choline, have been picked out as initiating.

5.15. Selection of ionic liquids and preparation of ionanofluids

For heat transfer-supported uses, ILs can be chiefly picked out grounded on their physical properties (Table 2) especially of eminent thermal conductance, heat capacity, negligible viscosity, and dissolubility in water. Applications and properties of prominent functioning ionanofluids (INF) depend on the processes by which they are formed. The formation process of high functioning ionanofluids is a one-step process and a two-step process. In a one-step process, nanomaterials to ionanofluids are established directly without supported ILs, and seldomly employed. However, in a generally employed two-step process, ionanofluids are usually developed by using nanomaterials supported ILs, after that homogeneousness is chiefly developed by ultrasonication.

Several kinds of nanomaterials like graphene, carbon nanotubes, and imidazolium-modified ionic liquids have been exploited for the grooming of ionanofluids. The formation process of ionanofluids is quite free from ambiguity, however, it has a stimulating interest in verifying thoroughly uniform dispersal of nanoparticles and long-time constancy of developed ionanofluids. Stability of developed ionanofluids can be ameliorated by adding sonication and surface-active agents and in other manners by surfacing treatment or alteration of nanoparticles. It is essential to notice that specific alertness should be devoted to ultrasonic ionanofluids because beyond normal limits sonication can devolve the substance in both physical and chemical conditions, evaporate substance ionanofluids, and in the alteration of concentration of nanomaterials. Surfactants have been also suggested not to exercise because they can degenerate or can get dormant at average and higher temperatures. Determination of stability of ionanofluids admits measuring Zeta potential, SEM, TEM investigation thermophysical properties of ILs and INFs used on convective heat transfer applications [263-265].

Table 2: Thermophysical properties of ionic liquids expanded as basis fluids for ionanofluids

Ionic Liquid	Thermophysical Property	Thermophysical Property's value	Condition	Reference
1-butyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide [C_4mim] [NTf_2]	Viscosity (mPa·s)	99.6	298 K	[266]
	Density (kg/m^3)	1.436	298 K	[267]
	Thermal Conductivity (W/m K)	0.126	300 K	[268]
	Heat Capacity (kJ/kg·K)	1.352	298 K	[269]
1-hexyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide [C_6mim] [NTf_2]	Viscosity (mPa·s)	70.5	298 K	[270]
	Density (kg/m^3)	1.372	298 K	[271]
	Thermal Conductivity (W/m K)	0.122	293 K	[272]
	Heat Capacity (kJ/kg·K)	1.426	298 K	[271]
1-n-butyl-3-methylimidazoliumtrifluoromethanesulfonate [C_4mim] [CF_3SO_3]	Viscosity (mPa·s)	76.0	298 K	[273]
	Density (kg/m^3)	1.306	293 K	[274]
	Thermal Conductivity (W/m K)	0.142	293 K	[272]
	Heat Capacity (kJ/kg·K)	1.484	298 K	[275]
1-butyl-methylimidazolium hexafluorophosphate [C_4mim] [PF_6]	Viscosity (mPa·s)	257.0	298 K	[273]
	Density (kg/m^3)	1.372	293 K	[274]
	Thermal Conductivity (W/m K)	0.145	293 K	[276]
	Heat Capacity (kJ/kg·K)	1.432	308 K	[276]
1-hexyl-3-methylimidazolium hexafluorophosphate [C_6mim] [PF_6]	Viscosity (mPa·s)	485.8	298 K	[277]
	Density (kg/m^3)	1.293	298 K	[277]
	Thermal Conductivity (W/m K)	0.142	293 K	[274]
	Heat Capacity (kJ/kg·K)	1.358	293 K	[277]
1-n-butyl-3-methylimidazolium dicyanamide [C_4mim] [DCA]	Thermal Conductivity (W/m K)	0.176	298 K	[278]
	Heat Capacity (kJ/kg·K)	1.827	296 K	[279]
1-ethyl-3-methyl imidazoliumethylsulfate [C_2mim [$EtSO_4$]	Viscosity (mPa·s)	125.4	293 K	[280]
	Density (kg/m^3)	1.236	298 K	[280]
	Thermal Conductivity (W/m K)	0.1706	293.4 K	[281]
	Heat Capacity (kJ/kg·K)	1.57	293 K	[282]
1-n-butyl-3-methylimidazolium bis(trifluoromethanesulfonylimid) [C_4mim][$(CF_3SO_2)_2N$]	Viscosity (mPa·s)	51.1	313 K	[283]
	Density (kg/m^3)	1.426	313 K	[283]
	Thermal Conductivity (W/m K)	0.1114	293.4 K	[281]
	Heat Capacity (kJ/kg·K)	1.373	313 K	[283]
1-hexyl-3-methylimidazolium tetrafluoroborate [C_6mim] [BF_4]	Viscosity (mPa·s)	250.0	298 K	[284]
	Density (kg/m^3)	1.149	298 K	[284]
	Thermal Conductivity (W/m K)	2.21	298 K	[284]
	Heat Capacity (kJ/kg·K)	0.166	298 K	[284]
1-Butyl-3-methylimidazolium tetrafluoroborate [C_4mim] [BF_4]	Viscosity (mPa·s)	85.37	303.15 K	[285]
	Density (kg/m^3)	1.198	303.15 K	[285]
	Thermal Conductivity (W/m K)	0.163	298 K	[272]
	Heat Capacity (kJ/kg·K)	1.614	298 K	[272]
1-Ethyl-3-methylimidazolium methanesulfonate [C_2mim] [CH_3SO_3]	Viscosity (mPa·s)	149.1	298 K	[286]
	Density (kg/m^3)	1.239	298 K	[286]
	Thermal Conductivity (W/m K)	0.190	298 K	[287]
	Heat Capacity (kJ/kg·K)	1.629	298 K	[287]
Butyltrimethylammoniumbis	Viscosity (mPa·s)	105.4	298 K	[288]

(trifluoromethylsulfonyl)imide [N4111] [NTf_2]	Density (kg/m^3)	1.392	298 K	[289]
	Thermal Conductivity (W/m K)	0.122	303 K	[289]
	Heat Capacity (kJ/kg·K	1.70	303 K	[289]
N-butyl-N-methylpyrrolidiniumbis(trifluoro methanesulfonyl)imide [C_4mpyrr [NTf_2]	Viscosity(mPa·s)	68	303 K	[290]
	Density (kg/m^3)	1.382	298 K	[291]
	Thermal Conductivity (W/m K)	0.124	303 K	[289]
	Heat Capacity (kJ/kg·K	1.58	303 K	[289]
1-Methylimidazolium tetrafluoroborate [HMIM] [BF_4]	Viscosity (mPa·s)	250	298 K	[292]
	Density (kg/m^3)	1.123	298 K	[293]
	Thermal Conductivity (W/m K)	0.166	298 K	[292]
	Heat Capacity (kJ/kg·K)	2.265	298 K	[292]
Trihexyltetradecylphosphoniumbis (trifluoromethylsulfonyl)imide [(C_6) 3PC14] [NTf_2]	Viscosity (mPa·s)	318	298 K	[294]
	Density (kg/m^3)	1.065	298 K	[295]
	Thermal Conductivity (W/m K)	0.137	298 K	[295]
	Heat Capacity (kJ/kg·K)	1.788	333 K	[295]
1-Ethyl-3-Methylimidazolium Diethyl Phosphate [EMIM] [DEP]	Viscosity (mPa·s)	274	298 K	[296]
	Density (kg/m^3)	1.148	298 K	[296]
	Thermal Conductivity (W/m K)	0.1749	303 K	[297]
	Heat Capacity (kJ/kg·K)	1.998	293 K	[297]
1-n-butyl-3-methylimidazolium chloride [C_4mim] [Cl]	Viscosity (mPa·s)	545	333 K	[298]
	Density (kg/m^3)	1.087	293 K	[298]
	Thermal Conductivity (W/m K)	0.176	293 K	[298]
	Heat Capacity (kJ/kg·K)	1.982	298 K	[299]
1-Ethyl-3-Methylimidazolium dicyanamide [EMIM] [DCA]	Viscosity (mPa·s)	13.2	300 K	[300]
	Density (kg/m^3)	1.1	298 K	[301]
Trihexyltetradecylphosphoniumph osphinate[$(C_6)_3$PC14)] [Phosph]	Thermal Conductivity (W/m K)	0.135	298 K	[295]
	Heat Capacity (kJ/kg·K)	2.12	298 K	[295]
1-butyl-3-methylimidazolium bromide[C_4mim] [Br]	Viscosity (mPa·s)	215	303 K	[298]
	Density (kg/m^3)	1.298	293 K	[298]
	Thermal Conductivity (W/m K)	0.16	293 K	[298]
	Heat Capacity (kJ/kg·K	1.421	298 K	[269]
1-butyl-3-methylimidazolium iodide[C_4mim] [I]	Viscosity (mPa·s)	379	303 K	[298]
	Density (kg/m^3)	1.489	293 K	[298]
	Thermal Conductivity (W/m K)	0.131	293 K	[298]
	Heat Capacity (kJ/kg·K	1.165	298 K	[302]

6. CONCLUSION

To respond to the harmful consequence of chemical substances on the natural world, institutional as well as industrial research concerns have transferred towards environment-friendly ILs with negligible vapor pressure, high thermal stability, phase transition behavior, solubility, and miscibility with reactants, acidity, and basicity, switchable ionic liquids as green solvents, ionic liquids in biodiesel synthesis, catalyst, solvent for enzyme-catalyzed transesterification, catalyst support, recycling of ionic liquids, ionic liquids recovery. Ionic liquids are not future solvents exclusively due to their green dimensions, however, that is not to express in words that belongings, like negligible flammability or worthless volatility, do not encourage the overall process. The concept is that ionic liquids are made up solely of ions has led to their future solvent applications with a large range of electro-chemical windows, prominent conductance, and high thermal stability.

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Conflicts of interest

The authors declare no conflict of interest

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