**Review study the physicochemical properties of ionic liquids and its tremendous significant**

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**Abstract**

Ionic liquid is defined as a salt with a melting point below the boiling point of water. Ionic liquids are also referred to as molten salts, designer solvents, neoteric solvents, and ionic fluids. The majority of ionic liquids are made up of inorganic anions and organic cations. This review examines the various physicochemical characteristics of ionic liquids as well as their incredibly important aspects.This review is focus on the physicochemical properties of ionic liquids and significant of ionic liquids.

Keyword: Ionic liquid, catalyst, Biocatalytic Reactions in Ionic Liquids.

**1.Introduction**

The “Ionic liquids” what are they? Simply said, an ionic liquid is any liquid that is made completely of ions. Ionic liquids that are fluidlike at or near room temperature might be referred to as room-temperature ionic liquids using the same logic. Ionic liquid and room-temperature ionic liquid will both be utilized interchangeably throughout this dissertation. Salts are high melting solids, as is widely known They are extremely toxic and corrosive when in their liquid condition, which is typically well above 500 °C. However, the ionic environments that these liquid salts, commonly referred to as molten salts, offer might present special media for organic reactions and separation procedures.

The salts' uses are severely constrained by the high temperatures needed to transform them into a fluid-like condition. Such media cannot be used for synthetic transformations. A salt that has a melting point lower than the boiling point of water is said to be an ionic liquid [1]. Salts that melt below 100 °C have been referred to as ionic liquids (ILs). ILs melts with melting points lower than room temperature are typically referred to as room temperature ionic liquids (RTILs). Ionic liquids are also referred to as molten salts, designer solvents, neoteric solvents, and ionic fluids. The majority of ionic liquids are made up of inorganic anions and organic cations. ILs are electrolytes that exclusively include cations and anions and produce liquid electrolytes. The cation should ideally be unsymmetrical, meaning that the alkyl groups should differ, in order to be liquid at ambient temperature. Ionic liquids' polarity and hydrophilicity/hydrophobicity can be adjusted by choosing the right cation and anion combination. Ionic liquids have the characteristic that has made them known as "designer solvents" Ionic liquids are used in a variety of reactions as solvents. The “ionic liquid” One of the twelve guiding principles of green chemistry states that the usage of auxiliary materials like solvents and separation agents should be minimised and, when essential, made harmless [2]. Numerous solvents, in particular chlorinated hydrocarbons, have poisonous and dangerous qualities that raise serious environmental issues such atmospheric emissions and water effluent contamination. It is understood that using unconventional solvents as alternatives to conventional, environmentally harmful solvents can greatly minimise waste solvent production and, consequently, the adverse effects on the environment. Ionic liquids have shown the most promise among the non-conventional solvents of interest discussed above. Similar to the majority of non-aqueous electrolytes, ionic liquids (ILs) often exhibit a broad electrochemical window of stability and a respectable ionic conductivity. Since their expanding use doesn't cause air pollution, ILs hold promise as many, environmentally friendly reaction media that are anticipated to offer an alluring substitute for traditional volatile organic solvents (VOSs) in contemporary synthetic organic chemistry.

**2. Definitions**

An ionic liquid is defined as a salt with a melting point below the boiling point of water. The term ionic liquids (ILs) have been used to describe salts that melt below 100 °C. Whereas, the term room temperature ionic liquids (RTILs) are usually reserved for ILs melts with melting points below room temperature.

**3. History**

Ionic liquids were utilized for some organic transformation two decades ago by a small number of researchers as an alternative to routinely used volatile organic solvents. ILs have been referred to as effective molecular and/or environmentally friendly solvents with particular physicochemical and thermal properties [3]. ILs are known as fused/molten/liquid organic salts, etc. because they are ions and liquid at room temperature or below 100 C. Ammonium salts, which have lower melting points than room temperature, were first presented in 1914. Analogs of pyridinium were later reported. These ammoniums and pyridinium ionic liquids appear to satisfy every need for an appropriate ionic medium. Using binary and tertiary systems, as illustrated in Table 1.2, is another strategy for lowering the melting points of inorganic salts. It seemed quite promising to employ aluminum (III) chloride (m.p. 192 oC). Although the melting point values decrease dramatically, they are still high enough to make these systems useful as reaction media. However, it shows that low melting point systems made entirely of inorganic components are theoretically possible. In the 1980s, at that time, the phrase "ionic liquid" gained more traction to define organic salts with a liquid range and a melting point below 100 0C.

**4. Properties of ionic liquids**

**4.1 Melting points**

The “Ionic liquids” (ILs) solid-liquid transition temperatures can (ideally) drop as low as -100 °C. DSC, or differential scanning calorimetry, is the most effective technique for determining the transition temperatures. NMR, X-ray scattering, and cold-stage polarising microscopy are some more techniques that have been employed. Numerous ionic liquids display thermal behaviour that is relatively complex. When the liquid state is cooled in a normal IL, glass forms because the solidification kinetics are slow. After cooling from a liquid, the low-temperature region is often not limited by the phase diagram liquidus line but instead extends to a lower temperature limit determined by the glass transition temperature. Salt mixing and lattice-destabilizing additives like organic solutes exacerbate this tendency. After cooling, glass solidification temperatures are kinetic transitions rather than precise measurements of melting or heating Tg values [4]. Thermodynamic data must be acquired in heating mode to obtain reliable findings. As a result, to obtain reliable transition data, extensive equilibration durations with small samples that enable fast cooling are needed to quench non-equilibrium states in mixes. Metastable glasses typically develop in molten salts. One notable example of a low glass transition temperature is salts of 1-alkyl-3-methylimidazolium, which typically have glass transition temperatures between -70 and -90 °C. Samples typically go through an exothermic transition when heated from a glassy condition, which causes crystallisation and eventually melting.

**4.1.1 The upper limit “Decomposition Temperature”**

The thermal decomposition temperature of the ionic liquid frequently acts as the upper limit of the liquidus range because the majority of ionic liquids are non-volatile. Contrary to molten salts, which form tight ion-pairs in the vapour phase, the reduced Coulombic interactions between ions energetically restrict the ion-pair formation required for salt volatilization, leading to low vapour pressures. Due to the IL's breakdown rather than vaporisation, this leads to severe upper temperature constraints. The nature of ionic liquids, which contain organic cations, places a restriction on the upper stability temperatures; pyrolysis normally occurs between 350 and 450 °C if no other lower temperature breakdown pathways are present. The volatilization of the component fragments and total mass loss are typical effects of decomposition [5].

**4.1.2 Effect of Ion Sizes on the Melting Points**

It is well known that the specific characteristics of ionic liquids are influenced by the choice of anion and cation. An ionic liquid's structure has a direct impact on two characteristics, its melting point and liquidus ranges. The reasons behind the drive to lower battery electrolyte melting points have already been covered. Utilising the changes in these aspects allows for the creation of ionic liquids with a variety of characteristics [6]. The charge, size, and distribution of charge on the corresponding ions are the main factors affecting the melting points of the salts as general classes. However, even little changes in the geometry of the uncharged, covalent portions of the ions can have a sizable effect on the melting points of the salts within a given salt series.

**4.1.2.1 Anion size**

Increases in anion size lead to decreases in salt melting temperatures by reducing the Coulombic attraction contributions to the crystal's lattice energy and raising ion covalency. Ionic liquid melting points often drop as anion size decreases.

**4.1.2.2 Cation size**

The “melting points” of the salts are significantly influenced by the sizes and forms of the cations in ionic liquids. Large ions typically result in reductions in melting points, to put it simply.

**4.1.3 Imidazolium salts**

Changes in the substitution patterns of imidazolium rings, such as substitution at the C (2,4,5)-positions on an imidazolium ring, can have a significant impact on the melting points of imidazolium salts in addition to simple symmetry shifts or H-bonding interactions. The melting temperatures of the salts are increased, for example, by substitution at the C (2)-position of the imidazolium ring. This is not usually an obvious or straightforward result, but it may be caused by structural changes to cations that result in aromatic stacking or methyl-interactions between cations. The environment of the ions may change as a result of the addition of additional capabilities. Most frequently, additional characteristics like ether groups increase the number of contacts and hence elevate melting points [7].

**4.2 Viscosity of “Ionic Liquids”**

The cause of a fluid's viscosity, which manifests externally as the fluid's reluctance to flow, is internal friction. Viscosity-wise, fluids fall into two basic categories: Newtonian and non-Newtonian. Newtonian fluids have a constant viscosity independent of the rate of strain. Low-molecular-weight pure liquids are among the Newtonian fluids. Non-Newtonian fluids don't have a constant viscosity under strain; instead, they either get thicker or get thinner [8].

………………..(1)

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|  | Where  F= | [force](https://www.google.com/search?sca_esv=560585411&sxsrf=AB5stBieomw33FVEoidll5FdR2Otdkr0cg:1693197369916&q=Force&stick=H4sIAAAAAAAAAOPgE-LQz9U3SDIqrlICs4wqk420tLKTrfRTU0qTE0sy8_P00_KLcktzEq2gtEJmbmJ6qkJiXnF5atEjRmNugZc_7glLaU1ac_IaowoXV3BGfrlrXklmSaWQGBcblMUjxcUFt4BnESurW35RcioAzfn824AAAAA&sa=X&ved=2ahUKEwiHzpLew_6AAxVHzjgGHefCB_8Q24YFegQIHhAC) |
|  | µ= | viscosity of the fluid |
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**4.3 Density measurement**

To quantify density precisely with a limited sample size, use a pycnometer. A pycnometer can be used to accurately measure the bottom of the meniscus in glassware that has been calibrated with aqueous solutions that may have somewhat different surface tensions. The two most common types of pycnometers are the Ostwald-Sprengel and the Weld, or stopper, pycnometer. These devices are normally composed of glass, with a reservoir attached to a capillary or capillaries with fiducial markings. After being weighed empty, the pycnometer is filled with the test fluid, and thermal equilibrium is allowed to develop. The pycnometer is weighed after the liquid from above the fiducial marks has been removed. To determine the accurate volume, pycnometers must be calibrated before use. The density is then calculated by dividing the mass of the fluid by the volume of the pycnometer.

……….(2)

Where;

P= Density

M=Mass

V=Volume

**4.3.1 Ionic liquid densities**

Ionic liquid densities seem to be the physical characteristic least susceptible to changes in temperature. during instance, a 50.0:50.0 mol% [EMIM]Cl/AlCl3 only experiences a 0.3% drop in density during a 5-degree temperature change from 298 to 303 K. Additionally, it appears that contaminants have a much less significant impact than in the case of viscosity. It has been demonstrated that the density can vary depending on the substituents on the imidazolium cation in the “Chloroaluminate ionic liquids”. increased anion mass corresponds to increased ionic liquid density within a succession of non-halo aluminate ionic liquids carrying the same cation species. The densities of the non-haloaluminate ionic liquids are also affected by the type of organic cation. Like with haloaluminate ionic liquids, the density decreases as the size of the cation increases.

**4.4 Solubility**

Regarding the stoichiometric chemical synthesis and catalytic processes, ionic liquids (ILs) play a crucial role in the solubilities of both organic molecules and metal salts. In order to effectively separate and isolate products, it is necessary for reagents, products, and catalysts to have varied solubilities in the solvent [9]. In addition, the reagents and catalysts must be sufficiently soluble in the solvent. In addition to requiring knowledge of solute solubility in ionic liquids (ILs), evaluating the relative merits of a particular ionic liquid (IL) for chemical or separation processes also requires knowledge of relative solubility and partitioning data about the preference of the solutes for ionic liquids (ILs) phases relative to extractants. However, there isn't much systematic evidence on these qualities in the literature. Solutes and solvents are commonly classified as immiscible in a particular ionic liquid (IL) based on the observation that two phases arise rather than employing compositional analysis to pinpoint the limits of solubility or co-miscibility.

**4.5 “Extraction & Separations”**

Studies of extractions and separations provide the partitioning data—information on the relative solubilities of solutes between two phases—needed to create systems in which a solute is either immobilised in one phase or removed from another phase in a selective manner. Investigations into liquid/liquid separation of metal ions mostly concentrate on aqueous/organic two-phase systems, with implications for the extraction and concentration of metal ions in the organic phase. Regarding ionic liquids (ILs) /aqueous partitioning, there is a lot of interest in the use of ionic liquids (ILs) for the immobilisation of transition metal catalysts, the reprocessing of nuclear fuel and waste, and the recovery of metals from waste water in mining. With the exception of the most hydrophobic cations, most metal ions' hydrated natures lower their affinity for the less-polar extraction phases in ionic liquids (ILs) systems where hydrated metal ions do not partition into the ionic liquids (ILs) from water. The affinity of meta ions for less polar phases can be improved by changing the hydration environments of the metal ions, either with organic ligands that give more hydrophobic areas around the metal or with inorganic anions that form softer, more extractable anionic complexes with the metal. To ensure the complete removal of the metal ions from the aqueous phase, the complexant and metal complex should continue to exist in the hydrophobic phase [10]. This makes it difficult to find extractants that quantitatively partition into the ionic liquids (ILs) phase while still readily complexing target metal ions. It is also difficult to determine the ideal conditions for selectively extracting a given metal ion species from aqueous streams containing inorganic complexing ions.

**4.6 The Solubilities of gas**

Despite the importance of gas solubilities in ionic liquids (ILs), there haven't been many studies on the topic published as of this writing. the stoichiometric technique used to gauge different gases' solubilities in distinct ionic liquids (ILs). Henry's law provided the constants for H2 in two ionic liquids (ILs).

**4.7 Separations of gas**

Ionic liquids (ILs), on the other hand, are perfect for use as solvents for gas separations. Since they are non-volatile, they cannot evaporate and contaminate the gas stream. This is important if supported liquid membranes or conventional absorbers are used with selected solvents [11]. The ability to differentiate between two gases in conventional absorbers exclusively depends on their relative solubilities (relation of Henry's law constants). Additionally, ILs are particularly appealing for supported liquid membranes because to their potential for being highly stable. Because the liquid gradually evaporates, conventional liquids employed in supported liquid membranes eventually deteriorate. Furthermore, this finite evaporation rate limits the maximal membrane thickness. This suggests that the net flux across the membrane has decreased. These problems might be resolved by using a non-volatile liquid. In the absence of assisted transport (such as the complexation of CO2 with amines to form carbamates), gas permeability through supported liquid membranes depends on both solubility and diffusivity. It is possible to calculate the flux of one gas in respect to the other using a simplified solution-diffusion model.

**4.8 Electrochemical Properties of Ionic Liquids**

Ionic liquids are desirable as solvents for studying electrochemical processes because they have a number of characteristics. A wide range of inorganic, organic, and organometallic compounds can be solvated by them, and they frequently have broad electrochemical potential windows, decent electrical conductivity, and solvent transport capabilities.

**4.9 Ionic Conductivity**

When choosing a solvent for an electrochemical application, a solvent's ionic conductivity is crucial. Ionic conductivity can be measured using a wide range of DC and AC techniques.

**4.10 Transport Properties**

The transport characteristics of an ionic liquid's ionic constituents have a significant impact on how well it behaves as an electrolyte. These transport properties relate to the rate and mode of ion movement (individually, in pairs, or in aggregates). For instance, the amount and mobility of charge carriers affect conductivity. If highly mobile yet neutral ion-pairs predominate in an ionic liquid, there will be few available charge carriers and a low conductivity. The two metrics that are typically used to evaluate the transport properties of electrolytes are the ion-diffusion coefficients and the ion-transport numbers. The diffusion coefficient is a measurement of the rate of ion movement in a solution, whereas the transport number is a measurement of the percentage of charge carried by that ion in the presence of an electric field [12].

**4.11 Liquid crystals**

Liquid-crystalline phases can be produced by a wide variety of ionic liquids. Usually, this is done by adding longer, linear alkyl groups to the cation to make it more amphiphilic. The salts have relatively low melting temperatures that are close to ambient temperature when the alkyl chain length (Cn) is short (n 10), and when n > 12 they display liquid crystal mesomorphism.

**4.12 Electrical conductivity**

How quickly an electrical current can flow through a material or how easily electrical charge may be transferred across it is determined by the substance's electrical conductivity. High value materials are those that easily conduct electricity and do not easily retain an electrical charge. This performance suggests that certain batteries might make excellent use of this material as an electrolyte (Heiken, 1991) [13].

**4.13 Micelle formation in ionic liquids**

Surface tension data were used to calculate surfactant CMC values. It has been demonstrated that the solvatophobic interactions of the ionic liquids with the hydrocarbon part of the surfactants cause the surfactants to dissolve in ionic liquids to reduce their surface tension [14]. The CMC values of surfactants have been determined using a wide variety of techniques. To find the CMC values, many physicochemical parameters are often monitored for changes.

**5. Ionic liquids (ILs) applications**

Ionic liquids have their unique features, ILs have been highlighted as the green option in chemistry while yet having the capacity to dissolve a wide variety of organic and inorganic molecules. Ionic liquids (ILs) have unique physicochemical characteristics and excellent application possibilities. Researchers from all around the world are very interested in surface active ILs as a unique class of surfactants, and this interest has increased as a result of their propensity to self-assemble. These ILs have been shown to exhibit surface activity when dissolved in water, which is shown by a drop in surface tension. It is noteworthy that the ILs can form micellar nano-aggregates in aqueous solution and have characteristics that are similar to those of surface-active (SA) agents. Ionic liquids (ILs) have become intriguing and adaptable reaction media for a variety of bio-applications, most notably enzyme catalysis, as potential environmentally friendly solvents [15].

**5.1 Ionic liquids (ILS) as reaction media**

Neutral ILs have been referred to as "environmentally benign solvents" because of their simple recyclable makeup, good thermal stability, and low vapour pressure. These ILs have been employed as superior and reusable catalysts for a number of processes, such as the Heck reaction (Park & Alper, 2003), the Bischler-Napierlaski cyclisation (Judeh et al., 2002) [16], and the Beckmann rearrangement (Ren et al., 2001) [17].

**5.2 Hydrophobic ionic liquid recycling**

The ease of recycling ILs is extensively acknowledged in the written literature. This is unquestionably the case for some IL-containing biphasic systems, particularly for hydrophobic ILs like [PF6]- and [(CF3SO2)2N]-ILs [Wu et al. 2009] [18]. Liquid-liquid extraction has been employed in palladium coupling procedures to recycle the catalyst and the IL solvent [Handy & Zhang, 2001]; [19] These ILs' capacity for recycling is aided by the fact that several important organic solvents, including diethyl ether, are insoluble in them. While byproducts contained in water-immiscible ILs can be washed out using water with minimal IL loss, products and residual organics can be recovered using an organic solvent due to their lack of solubility Birdwell et al. (2006) [20] created a centrifugal solvent-extraction contactor recycle method that was successfully used for separation of dispersions containing immiscible organic IL/hydrocarbon/and aqueous systems in order to offer significant advantages over conventional technologies for extraction processes.

**5.3 The “Hydrophilic ionic-liquid recycling”**

Hydrophobic ILs can be extracted with water to segregate water-soluble solutes into the aqueous phase, whereas hydrophilic ILs generally cannot be extracted in this way. Research in this area is still in its early stages, and recovery of hydrophilic ionic liquids (ILs) is more challenging than recovery of hydrophobic ILs.

**5.4 The Membrane technology for “Ionic-liquid (ILs)” recovery**

Volatile solutes have been selectively removed from Ionic-liquid (ILs) using membrane techniques, which have been used to generate exact separation of undesired components. In order to recycle ILs from water, Haerens et al. (2010) studied the use of pressure-driven membrane technologies, nano-filtration, reverse osmosis, and pervaporation. The findings of these tests were compared to those described in the literature using Ethaline200, a deep eutectic composed of choline chloride (a quaternary amine salt) and ethylene glycol. Osmotic pressure was discovered to be a limitation of reverse osmosis or nano-filtration when utilised for concentrating ionic liquid (ILs). [Haerens et al., 2010] investigated the potential of pervaporation but found that the excessive water content had limited applicability. Pervaporation can be employed for low water levels even when the flow is very low because of the presence of ionic liquids (ILs), which decreases the activity of the water and therefore the flux through the membrane. Due to the enormous membrane area requirement, pervaporation would be highly unfeasible [Haerens et al, 2010] [21]. The most important of all performance benefits is that only distillation processes can provide a comparable level of fluid purity for the removal of salt and other materials in the ionic size range. Since distillation cannot be used to recycle ILs from non-volatile compound/IL complexes, this method is crucial. Therefore, research into innovative membrane treatment methods is required for IL recovery. It can be challenging to separate, recover, and reuse ILs from particular process mixes because they have a high viscosity that is often 2-3 orders of magnitude higher than water [Wu et al. 2009].

**5.5 The CO2 cycloaddition catalysed by immobilized ILs**

Simple filtration can be used to quickly and easily remove heterogeneous catalysts from reaction mixtures. Immobilising IL catalysts on solid substrates can boost this benefit. The impregnation procedure is one simple way to immobilise. Using this technique, Wang et al. [22] produced silica gel-supported ammonium and imidazoilium IL catalysts. Similar to this, Zhu et al. [23] created a [Chol]Cl-urea IL catalyst supported by a molecular sieve. In these formulations, the IL and the support components were dissolved in a methanol- or acetone-based solution, and the solvent was then removed. These supported IL catalysts could be recycled numerous times without significantly losing their activity for the PC synthesis under solventless conditions, despite the fact that the active ingredient of IL over them was fixed on the surface of the support by weak physical adsorption. Inorganic materials made of silica, mesoporous silicates, aluminosilicate, and alumina can also covalently immobilise ILs. On the latter, inorganic materials that have been treated with alkyl halides—typically propylchloride—can be immobilised and quaternized with matching amine, phosphine, or pyridine. Imidazole is fixed on the altered support when alkali compounds are present, resulting in imidazolium-based immobilised IL that is then quaternized with alkyl halides. Immobilising ILs on solid materials has the advantages of making the catalyst separation process easier and allowing continuous operation in a fixed-bed flow reactor. The application of silica-immobilized phosphonium-based IL for a flow reactor was initially covered by Takahashi et al. For more than 1000 hours, they synthesised PC using 10 MPa of CO2. But throughout the reaction run, the selectivity to PC was kept over 99.9%. Unfortunately, the reaction temperature has to be raised from the initial 90°C to 160°C in order to maintain a yield above 80%, which increases the likelihood that some IL may leach off the support.

**5.6 The “Ionic liquids” used in batteries**

Quaternary ammonium (Mastumoto, 2001) [24], pyridinium (Xiao & Malhotra, 2005) [25], pyrrolidinium (Forsyth, 2001) [26], pyrazolium (Alarco, 2004) [27], imidazolium (Ito, 2000) [28], and [BF4]- and [PF6]- anions are the most researched ILs for application in batteries. Numerous physical and chemical properties of ILs that might be employed for electrolysis, electrochemical deposition, and the manufacture of batteries were revealed by Hagiwara and Ito in 2000 (Hagiwara & Ito, 2000). According to studies by Stracke and colleagues using ILs as electrolytes in hazardous compound-free Leclanché batteries, better ionic conductivities were associated with higher Leclanché battery potentials (Stracke, 2009) [29].

**5.7 Ionic liquid as solvent and co-catalyst**

Ionic liquids like chloroaluminate or chlorostannate melts are widely used as a co-catalyst as well as a solvent in transition metal catalysis. They are created by a Lewis acid and halide salt reacting. This is due to the fact that the catalyst complex is highly affected by the Lewis acidity or basicity, which is perpetually present (at least latently). The neutral catalyst precursor is frequently transformed into the equivalent cationic active form using the Lewis acidity of an ionic liquid [30]. There is a good possibility that the catalyst system will be activated in a mildly acidic ionic liquid due to the enhanced electrophilicity of the catalytic centre, which results in increased catalytic activity (as in the majority of olefin oligomerization processes, for example).

**5.8 The “Ionic liquid” as solvent and ligand precursor**

An ionic liquid's cation and anion can serve as ligands or ligand precursors for a transition metal complex that is dissolved there. If the catalytic centre is cationic, the anions of the ionic liquid may, to some extent, act as ligands depending on their degree of coordination. The anion of the ionic liquid has actually been sufficiently shown to replace the anion of a cationic transition metal complex, if different. The majority of ionic liquid anions used in catalysis are chosen to interact with the catalytic centre as little as possible, but this situation may drastically change if the ionic liquid's anion goes through breakdown processes. For instance, fluoride ions are released when an ionic liquid's hexafluorophosphate anion hydrolyzes when it comes into touch with water. These fluoride ions serve as strong ligands and catalyst poisons in numerous transition metal complexes. Because catalytic interactions with anionic transition metal complexes are still not very common in ionic liquids, the situation is a little bit different in terms of the cation of the ionic liquid. However, a transition metal immersed in an ionic liquid can function as a ligand precursor for an imidazolium molecule [31]. Three alternative methods have been used to observe its transformation into a ligand during reaction conditions: (1) Deprotonating the imidazolium cation yields metal-carbene complexes; (2) Oxidatively adding the imidazolium cation to the metal centre yields metal-carbene complexes; and (3) Dealkylating the imidazolium cation yields metal-imidazole complexes.

**5.9 The “Ionic liquid” as solvent & transition metal catalyst**

For procedures that are often catalysed by AlCl3, like catalytic Friedel-Crafts alkylation or stoichiometric Friedel-Crafts acylation, acidic chloroaluminate ionic liquids have already been used as both solvents and catalysts. Similar reactions between Lewis-acidic transition metal complexes and organic halide salts can result in complex anions. For instance, a Friedel-Crafts acylation method based on an acidic chloroferrate ionic liquid catalyst has been patented by Seddon and colleagues. However, not all ionic liquids that function as transition metal catalysts are based on conventional Lewis acids. recently described the ionic liquid [BMIM][Co(CO)4]. By metathesising [BMIM]Cl and Na[Co(CO)4], a vivid blue-green liquid was created It served as a catalyst to convert the matching 2-bromoketones into ketones. In general, it seems like a good idea to incorporate an active transition metal catalyst into the anion of an ionic liquid when a high catalyst concentration is required [32].

**5.10 Significant of The “Ionic Liquids” in Transition Metal Catalysis**

**5.10.1 Hydrogenation**

Ionic liquid hydrogenation processes that are catalysed by transition metals are generally quite promising. One the one hand, there are a lot of well-known ionic hydrogenation catalysts out there. On the other hand, it appears that good reaction rates can be reached due to the solubility of many alkenes and the availability of hydrogen in many ionic liquids. In this regard, it is interesting that the availability of hydrogen is influenced by both its ease of transfer from the gas phase into the melt and its solubility under equilibrium conditions. The latter aspect is very important because it has been found that hydrogen migrates into ionic liquids quite quickly. The miscibility gap between the saturated reaction products and the ionic liquid is generally large, hence a biphasic method is typically practical. In 1995, the de Souza and Chauvin groups looked into the first successful hydrogenation reactions in ionic liquids [33]. De Souza and colleagues looked at the hydrogenation of cyclohexene in 1-n-butyl-3-methylimidazolium ([BMIM]) tetrafluoroborate under the influence of Rh.

**5.10.2 Oxidation reactions**

Ionic liquid catalytic oxidation techniques have only recently been investigated. This comes as a bit of a surprise considering the well-known oxidation stability of ionic liquids from electrochemical research and the substantial commercial significance of oxidation reactions. Additionally, the ionic liquid's nonvolatile feature is a significant advantage for the reaction's safety in oxygen oxidation reactions. While the use of volatile organic solvents may be constrained by the potential for explosive combinations in the gas phase, this problem is not present when a nonvolatile ionic liquid is used as the solvent. According to Ley et al., an ammonium perruthenate catalyst that was dissolved in [NEt4] Br and [EMIM][PF6] catalysed the oxidation of alcohols [34]. N-methylmorpholine or oxygen the authors discuss straightforward product recovery using solvent extraction and the potential for recycling the ionic catalyst solution while employing N-oxide as the oxidant. Abu-Omar et al. described the oxidation of alkenes and allylic alcohols using the urea-H2O2 adduct (UHP) as the oxidant and methyltrioxorhenium (MTO) dispersed in [EMIM][BF4] as the catalyst. The ionic liquid totally dissolved both MTO and UHP. It was discovered that conversions were influenced by the olefin's reactivity and the olefinic substrate's solubility in the reactive layer. In general, it was discovered that the epoxidation process's reaction rates were comparable to those found in conventional solvents.

**5.10.3 Hydroformylation**

Biphasic catalysis is a tried-and-true technique for efficient catalyst separation and recycling in hydroformylation. Technically, this idea is put into practise in the Ruhrchemie-Rhône-Poulenc process, which uses water as the catalyst phase in Rh-catalyzed hydroformylation processes. Due to the low water solubility of higher olefins, this technique is regrettably restricted to C2-C5-olefins. However, there is business interest in the hydroformylation of several higher olefins.

**5.10.4 “Dimerization & Oligomerization” reactions**

In dimerization and oligomerization processes, ionic liquids have previously demonstrated themselves to be a very promising solvent class for converting tried-and-true catalytic systems into biphasic catalysis. In oligomerization chemistry, biphasic catalysis is not a brand-new concept. On the other hand, the oligomerization of ethylene was the first catalytic, biphasic process to occur commercially. The process was first patented in the late 1960s and is known as the "Shell Higher Olefins Process (SHOP)" in those documents. Despite the fact that 1,4-butanediol is the catalyst phase in the SHOP, it was later found that several very desirable catalyst systems for dimerization and oligomerization were incompatible with polar organic solvents or water [35].

**5.10.5 Immobilization of Catalysts in Ionic Liquids**

There are two basic approaches that have been established for using ionic liquids in organic or catalytic reactions. Ionic liquid serves as both the catalyst and the reaction solvent in the first case. In acid-catalyzed reactions, Lewis acidic ionic liquids like acidic chloroaluminates act as both solvents for the carbenium ions and active catalytic species. AlCl3 is an example of an inorganic Lewis acid that does not dissolve in the organic phase under this situation. In the second method, the homogeneous catalyst is placed in the ionic liquid, which serves as a "liquid support" for it.

**5.11 Industrial use of ionic liquids**

A higher cost-effectiveness is undoubtedly one important factor. This may happen as a result of increased reaction speeds and selectivity, which are connected to more effective catalyst recovery and higher environmental compatibility. Of course, the price of ionic liquids may be a barrier to their development. The cost of the ionic liquid must be compared to that of present chemicals or catalysts, and if it is shown to have a long enough lifetime, then its initial cost is probably not an important factor. For instance, in Difasol technology, the cost of the ionic liquid is lower than the cost of the catalyst components when stated in terms of the amount of octene generated. It is also important to take into account the industrial production of ionic liquids [36]. For use in electrochemical devices (like capacitors), some ionic liquids have previously been commercialised. The extrapolation of chloroaluminate laboratory preparations to a large scale was found to be simple. In the presence of protons, these chloroaluminate salts are corrosive liquids. Similar to aluminium chloride, they create hydrochloric acid when exposed to moisture. However, this can be prevented by including a proton scavenger, such as derivatives of alkylaluminum.

**5.12 The Multiphasic Catalysis with Ionic Liquids in Combination with Compressed CO2**

**5.12.1 The “Catalytic Reaction” with Subsequent Product Extraction**

The initial use, which involved a catalytic reaction in an ionic liquid and a subsequent extraction step using scCO2, was disclosed by Jessop et al. in 2001 [37]. These authors described two different asymmetric hydrogenation methods using [Ru (OAc)2(tolBINAP)] as a catalyst that was dissolved in the ionic liquid [BMIM][PF6]. The asymmetric hydrogenation of tiglic acid was carried out with exceptional yield and selectivity in a [BMIM][PF6]/water biphasic combination. After the reaction was complete, the product was extracted using scCO2 to prevent contamination of the catalyst or ionic liquid. Similar to this, the asymmetric hydrogenation of isobutylatropic acid produced the anti-inflammatory drug ibuprofen. Here, the reaction was carried out in a [BMIM][PF6]/MeOH combination, again followed by product extraction with scCO2) to get more information on these hydrogenation processes [38].

**Role in “Electrodeposition” of less noble elements**

**5.13 The “Aluminium Electrodeposition”**

Ex situ techniques, potential step experiments, and conventional electrochemical techniques like cyclic voltammetry have all been used in numerous articles to study Al electrodeposition from chloroaluminate ionic liquids. Al deposition was only ever observed in acidic environments, and the deposits' quality was always thought to be superior to that of deposits created by organic solutions. Al is a granular metal, and the cluster size varies with current density, with greater current densities typically producing smaller crystals. When the liquid is combined with toluene or benzene that has been dried, mirror-bright deposits have been observed. Organic substances acting as brighteners are probably present [39]. These effects have long been known to occur since organic substances like crystal violet are often utilised in aqueous electroplating processes to produce brilliant coatings of Cu, Ag, etc. Another advantage of the miscibility of the chloroaluminates with toluene, xylene and other organic solvents is the simple removal of the liquid from the samples following electrodeposition. As a result, clean substrates can be prepared from aqueous solutions almost as quickly.

**5.14 Free Radical Polymerization**

The polymer industry relies heavily on free radical polymerization to create a wide variety of polymers. It is employed in bulk, solution, and aqueous procedures for the addition polymerization of vinyl monomers such as styrene, vinyl acetate, tetrafluoroethylene, methacrylates, acrylates, (meth)acrylonitrile, and (meth)acrylamides. The chemical is simple to use and is unaffected by contaminants or numerous functional groups [40].

**6. Conclusion**

The “Ionic liquids” (ILs) hold certain beneficial properties; their use in everyday life becomes nearly indispensable. The wide applications of the “Ionic liquids” (ILs) such as the “Ionic liquids” (ILs) are among the most essential ingredients encountered in Free Radical Polymerization, Role in “Electrodeposition” of less noble elements, Catalytic Reaction, Industrial use of ionic liquids, Oxidation reactions, these are the main applications of the “Ionic liquids” (ILs).

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**AUTHORS CONTRIBUTION**

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**NOTES**

All authors declare no competing financial interest.

**CONFLICTS OF INTEREST**

There are no conflicts to declare.

**Reference**

1. Wang, H., Gurau, G., and Rogers, R.D. (2014) Structures and Interactions of Ionic Liquids, Structure and bonding (Berlin, Ger.), vol. 151, pp. 79–105

2. Hunt, P.A. (2006) The simulation of imidazolium-based ionic liquids. Mol. Simul., 32 (1), 1–10.

3. welton T., Ionic liquids: a brief history, [Biophys Rev.](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5988633/) 2018, 691–706. <https://doi.org/10.1007%2Fs12551-018-0419-2>

4. Earle, M.J., Esperanca, J., Gilea, M.A. et al. (2006) The distillation and volatility of ionic liquids. Nature, 439, 831.

5.Girard, G.M.A., Hilder, M., Zhu, H. et al. Electrochemical and physicochemical properties of small phosphonium cation ionic liquid electrolytes with high lithium salt content. Phys. Chem. Chem. Phys., 17 (14), (2015), 8706–8713.

6. José O. Valderrama, Richard A. Campusano,Melting properties of molten salts and ionic liquids. Chemical homology, correlation, and prediction,Comptes Rendus Chimie, Volume 19, Issue 5, 2016, Pages 654-664, <https://doi.org/10.1016/j.crci.2016.02.002>.

7.Wilkes, J.S. and Zaworotko, M.J. (1992) Air and water stable 1-ethyl-3- methylimidazolium based ionic liquids. J. Chem. Soc., Chem. Commun., (13), 965–967.

8. Novak, J. and Britton, M.M. (2013) Magnetic resonance imaging of the rheology of ionic liquid colloidal suspensions. Soft Matter, 9 (9), 2730–2737.

9. Carlos E. S. Bernardes, Kyrylo Klimenko, and José N. Canongia Lopes, Water Solubility Trends in Ionic Liquids: The Quantitative Structure–Property Relationship Model versus Molecular Dynamics., The Journal of Physical Chemistry B **2021** 125 (41), 11491-11497,

10. Baba Y., Kubota F., Kamiya N., Gota M., Recent Advances in Extraction and Separation of Rare-Earth Metals Using Ionic Liquids, Journal of chemical engineering of Japan., 44,679-685, (2011).

11. Xinxin Han and Daniel W. Armstrong., Ionic Liquids in Separations., J. ACS, **2007** 40 (11), 1079-1086.

12. Mojtaba Shamsipur, Ali Akbar Miran Beigi, Mohammad Teymouri, Sayed Mahdi Pourmortazavi, Mohsen Irandoust, Physical and electrochemical properties of ionic liquids 1-ethyl-3-methylimidazolium tetrafluoroborate, 1-butyl-3-methylimidazolium trifluoromethanesulfonate and 1-butyl-1-methylpyrrolidinium bis(trifluoromethylsulfonyl)imide, Journal of Molecular Liquids, Volume 157, Issue 1, 2010,Pages 43-50, <https://doi.org/10.1016/j.molliq.2010.08.005>.

13. Edward J. Maginn, Atomistic Simulation of the Thermodynamic and Transport Properties of Ionic Liquids., J. ACS., **2007** 40 (11), 1200-1207, <https://doi.org/10.1021/ar700163c>

14. Zsombor Miskolczy, Krisztina Sebők-Nagy, László Biczók, Sinem Göktürk, Aggregation and micelle formation of ionic liquids in aqueous solution, Chemical Physics Letters,

Volume 400, Issues 4–6, 2004, Pages 296-300, <https://doi.org/10.1016/j.cplett.2004.10.127>.

15. Marr, P.C. and Marr, A.C. Ionic liquid gel materials: applications in green and sustainable chemistry. Green Chem., 18 (1), 105–128. (2016).

16. Zaher M.A. Judeh, Chi Bun Ching, Jie Bu, Adam McCluskey, The first Bischler–Napieralski cyclization in a room temperature ionic liquid, J. Tetrahedron Letters, Volume 43, Issue 29, 2002, Pages 5089-5091, <https://doi.org/10.1016/S0040-4039(02)00998-X>

17. Rex X Ren, Larisa D Zueva, Wei Ou, Formation of ε-caprolactam via catalytic Beckmann rearrangement using P2O5 in ionic liquids, J. Tetrahedron Letters, Volume 42, Issue 48, 2001, Pages 8441-8443, <https://doi.org/10.1016/S0040-4039(01)01850-0>.

18. [Bo Wu](https://chemistry-europe.onlinelibrary.wiley.com/authored-by/Wu/Bo), [WeiWei Liu](https://chemistry-europe.onlinelibrary.wiley.com/authored-by/Liu/WeiWei), [YuMei Zhang Dr.](https://chemistry-europe.onlinelibrary.wiley.com/authored-by/Zhang/YuMei), [HuaPing Wang](https://chemistry-europe.onlinelibrary.wiley.com/authored-by/Wang/HuaPing), Do We Understand the Recyclability of Ionic Liquids?., chem. euro. Journal,15, 1804-1810., 2009.

[https://doi.org/10.1002/chem.200801509](https://doi.org/10.1002/chem.200801509   )

19. Scott T. Handy and Xiaolei Zhang, Organic Synthesis in Ionic Liquids:  The Stille Coupling, J. Organic Letters **2001,** 3 (2), 233-236, [https://doi.org/10.1021/ol0068849.](https://doi.org/10.1021/ol0068849.%20%20)

20. Joseph F. Birdwell Jr., Joanna McFarlane, Rodney D. Hunt, Huimin Luo, David W. DePaoli, Denise L. Schuh & Sheng Dai (2006) Separation of Ionic Liquid Dispersions in Centrifugal Solvent Extraction Contactors, J. Separation Science and Technology, 41:10, 2205-2223,  <https://doi.org/10.1080/01496390600745719>

21. [Kurt Haerens](https://pubs.rsc.org/en/results?searchtext=Author%3AKurt%20Haerens),   [Stephanie Van Deuren](https://pubs.rsc.org/en/results?searchtext=Author%3AStephanie%20Van%20Deuren),  [Edward Matthijs](https://pubs.rsc.org/en/results?searchtext=Author%3AEdward%20Matthijs)  and  [Bart Van der Bruggen](https://pubs.rsc.org/en/results?searchtext=Author%3ABart%20Van%20der%20Bruggen),   Challenges for recycling ionic liquids by using pressure driven membrane processes,. J. **Green Chem.,** 2010,**12**, 2182-2188. <https://doi.org/10.1039/C0GC00406E>

22. J.Q. wang., X-D. Yue., F. Cai, L-N. He., "Solventless synthesis of cyclic carbonates from carbon dioxide and epoxides catalyzed by silica-supported ionic liquids under supercritical conditions, Catal. Commun. 8. 2007. 167-172.

23. Zhu.T., Jiang, B. Han, J.Zhang, Y.Xie, X.ma, "Supported choline chloride/urea as a heterogeneous catalyst for chemical fixation of carbon dioxide to cyclic carbonates J. Green Chem. 9.(2007), 169-172. <https://doi.org/10.1039/B612164K>

24. Hajime Matsumoto, Hikari Sakaebe, Kuniaki Tatsumi, Preparation of room temperature ionic liquids based on aliphatic onium cations and asymmetric amide anions and their electrochemical properties as a lithium battery electrolyte, Journal of Power Sources, Volume 146, Issues 1–2, 2005, Pages 45-50, <https://doi.org/10.1016/j.jpowsour.2005.03.103>.

25. Ying Xiao, Sanjay V. Malhotra, Friedel-Crafts acylation reactions in pyridinium based ionic liquids, Journal of Organometallic Chemistry, Volume 690, Issue 15, 2005, Pages 3609-3613, <https://doi.org/10.1016/j.jorganchem.2005.04.047>.

26. D R MacFarlane M Forsyth., Structural studies of ambient temperature plastic crystal ion conductors.,  J. Phys.: Condens. Matter **13** 8257 (2001). **DOI** 10.1088/0953-8984/13/36/303

27. Pierre-Jean Alarco, Yaser Abu-Lebdeh, Nathalie Ravet, Michel Armand, Lithium conducting pyrazolium imides plastic crystals: a new solid state electrolyte matrix, j. Solid State Ionics, Volume 172, Issues 1–4, 2004, Pages 53-56, <https://doi.org/10.1016/j.ssi.2004.02.029>.

28. Kaori Ito, Naoko Nishina, Hiroyuki Ohno, Enhanced ion conduction in imidazolium-type molten salts, j. Electrochimica Acta, Volume 45, Issues 8–9, 2000, Pages 1295-1298, <https://doi.org/10.1016/S0013-4686(99)00335-7>.

29. M.P. Stracke, M.V. Migliorini, E. Lissner, H.S. Schrekker, J. Dupont, R.S. Gonçalves, Imidazolium ionic liquids as electrolytes for manganese dioxide free Leclanché batteries,J. Applied Energy, Volume 86, Issue 9, 2009, Pages 1512-1516, <https://doi.org/10.1016/j.apenergy.2008.11.014>.

30. Zhou, F., Izgorodin, A., Hocking, R.K. et al. (2012) Electrodeposited MnOx films from ionic liquid for electrocatalytic water oxidation. Adv. Energy Mater., 2 (8), 1013–1021.

31. [Andreas Taubert Dr.](https://onlinelibrary.wiley.com/authored-by/Taubert/Andreas), CuCl Nanoplatelets from an Ionic Liquid-Crystal Precursor, J. angewandte chemie. 116,40, 5494-5496. 2004.

32. [Peter Wasserscheid Dr.](https://onlinelibrary.wiley.com/authored-by/Wasserscheid/Peter), [Wilhelm Keim Prof.](https://onlinelibrary.wiley.com/authored-by/Keim/Wilhelm) Review Ionic Liquids—New “Solutions” for Transition Metal Catalysis, J. angewandte chemie. 39, 21, (2000), 3772-3789. <https://doi.org/10.1002/1521-3773(20001103)39:21%3C3772::AID-ANIE3772%3E3.0.CO;2-5>

33. Souza, M. O. D. (2014). Ionic liquids and catalysis. Journal of the Brazilian Chemical Society, 25, 2140-2150.

34. Habermann, J., Ponzi, S., & Ley, S. V. (2005). Organic chemistry in ionic liquids using non-thermal energy-transfer processes.J. Mini-Reviews in Organic Chemistry, 2(2), 125-137.

35. Einloft, S., Dietrich, F. K., De Souza, R. F., & Dupont, J. (1996). Selective two-phase catalytic ethylene dimerization by NiII complexes/AlEtCl2 dissolved in organoaluminate ionic liquids. Polyhedron, 15(19), 3257-3259.

36. Plechkova, N.V. and Seddon, K.R. (2008) Applications of ionic liquids in the chemical industry. Chem. Soc. Rev., 37 (1), 123–150

37. Brown, R.A., Pollet, P., McKoon, E., Eckert, C.A., Liotta, C.L. and Jessop, P.G., 2001. Asymmetric hydrogenation and catalyst recycling using ionic liquid and supercritical carbon dioxide. Journal of the American Chemical Society, 123(6), pp.1254-1255.

38. Reetz, Manfred T., Wolfgang Wiesenhöfer, Giancarlo Francio, and Walter Leitner. "Continuous flow enzymatic kinetic resolution and enantiomer separation using ionic liquid/supercritical carbon dioxide media." Advanced Synthesis & Catalysis 345, no. 11 (2003): 1221-1228.

39. Endres, Frank. "Ionic liquids: solvents for the electrodeposition of metals and semiconductors." ChemPhysChem 3.2 (2002): 144-154.

40. Svec, Frantisek. "Porous polymer monoliths: amazingly wide variety of techniques enabling their preparation." Journal of Chromatography A 1217.6 (2010): 902-924.

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