

REVIEW STUDY THE PHYSICOCHEMICAL PROPERTIES OF IONIC LIQUIDS AND ITS TREMENDOUS SIGNIFICANT

Abstract

An ionic liquid is a salt that has a melting point lower than the boiling point of water. Other names for ionic liquids include molten salts, designer solvents, neoteric solvents, and ionic fluids. Ionic liquids are mostly composed of inorganic anions and organic cations. This review looks at the many physicochemical properties of ionic liquids as well as some of their key features. The physicochemical characteristics and importance of ionic liquids are the main topics of this review.

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

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I. 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.

II. DEFINITIONS

Salts with melting points below the boiling point of water are referred to as ionic liquids. The term "ionic liquids" (ILs) refers to salts that melt at lower temperatures than 100 °C. This is in contrast to the term "room temperature ionic liquids" (RTILs), which is commonly used to describe IL melts having melting points lower than room temperature.

III. 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 °C). 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 °C.

IV. PROPERTIES OF IONIC LIQUIDS

1. Melting points (MP): 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 T_g values [4]. In order to produce accurate results, thermodynamic data must be collected while heating. In order to quench non-equilibrium states in mixtures, lengthy equilibration times with tiny samples that enable quick cooling are required in order to collect valid transition data. Glasses that are metastable usually form in molten salts. Salts of 1-alkyl-3-methylimidazolium are one well-known example of a low glass transition temperature, with typical glass transition temperatures between -70 and -90 °C. Samples usually undergo an exothermic transition when heated from a glassy state, which results in crystallisation and subsequently melting.

- **The upper limit “Decomposition Temperature”** : Since most ionic liquids are non-volatile, their thermal breakdown temperature typically serves as the top limit of the liquidus range. The lower Coulombic interactions between ions energetically restrict the ion-pair formation necessary for salt volatilization, resulting in low vapour pressures, in contrast to molten salts, which form tight ion-pairs in the vapour phase. This causes severe upper temperature limitations since the IL breaks down instead of vaporising. The upper stability temperatures of ionic liquids, which contain organic cations, are constrained by their nature; pyrolysis often happens between 350 and 450 °C if no alternative lower temperature breakdown pathways are present.

Decomposition typically has two common side effects: volatilization of the component fragments and total mass loss [5].

- **The effect of Ion Sizes on the Melting Points:** It is well known that the anion and cation choices affect the distinctive properties of ionic liquids. The ionic liquid's melting point and liquidus ranges are directly influenced by the substance's structure. Why lowering the melting points of battery electrolytes makes sense has already been discussed. It is possible to create ionic liquids with a range of properties by utilising differences in these variables [6]. The charge, size, and distribution of charge on the corresponding ions are the main factors affecting the melting points of the salts as generic classes. However, even little changes to the geometry of the uncharged, covalent sections of the ions can have a big impact on the melting temperatures of the salts in a particular salt series.
 - **Anion Size :** Increasing ion covalency and lowering the Coulombic attraction contributions to the crystal's lattice energy result in lower salt melting temperatures as anion size increases. Ionic liquids often melt at lower temperatures as the size of the anion gets smaller.
 - **Cation Size:** The "melting points" of the salts in ionic liquids are significantly influenced by the sizes and forms of the cations. Simply said, high ions frequently result in decreases in melting points.
 - **Imidazolium Salts:** Along with obvious symmetry shifts or H-bonding interactions, 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 effect on the melting points of imidazolium salts. For example, substitution increases the melting point of the salts at the C (2)-position of the imidazolium ring. Although it could be caused by cation structural changes that result in aromatic stacking or methyl-interactions between cations, this is not always an obvious or straightforward outcome. The environment of the ions may change as a result of the addition of new capabilities. Ether groups are the most common modifications because they increase melting points by adding more connections [7].
2. **Viscosity of “Ionic Liquids (ILs)” :** Internal friction is the root cause of a fluid's viscosity, which shows itself externally as the fluid's resistance to flow. Fluids can be divided into Newtonian and non-Newtonian groups based on their viscosity. The viscosity of Newtonian fluids is constant and unaffected by the rate of strain. Among the Newtonian fluids are pure liquids with low molecular weight. Under strain, non-Newtonian fluids don't maintain their viscosity; instead, they either become thicker or thinner [8].

$$F = \mu A \frac{u}{y} \dots \dots \dots (1)$$

Where

- F= force
 μ = viscosity of the fluid
 A= area of each plate
 u/y= rate of shear deformation

- 3. The "Density measurement" :** To measure density precisely and with a small sample size, use a pycnometer. The bottom of the meniscus can be carefully measured with a pycnometer in glassware that has been calibrated with aqueous solutions that may have slightly different surface tensions. The two types of pycnometers that are most frequently used are the Ostwald-Sprengel and the Weld, or stopper, pycnometer. Usually made of glass, these devices have a reservoir connected to a capillary or capillaries with a fiducial mark. The pycnometer is weighed empty, filled with the test fluid, and thermal equilibrium is then permitted. Following the removal of the liquid from above the fiducial markings, the pycnometer is weighed. Pycnometers must be calibrated before to use to provide an accurate volume measurement. After that, the density is computed by dividing the fluid's mass by the pycnometer's volume.

$$P = \frac{m}{V} \dots \dots \dots (2)$$

Where;

- P= Density
 M=Mass
 V=Volume

- **Ionic Liquid Densities :** Ionic liquid densities seem to be the physical characteristic least susceptible to changes in temperature. For instance, across a 5-degree temperature range from 298 to 303 K, the density of a 50.0:50.0 mol% [EMIM]Cl/AlCl₃ barely falls by 0.3%. Contaminants also seem to have a much lower effect than viscosity. The density of "Chloroaluminate ionic liquids" can be changed by the substituents on the imidazolium cation, which has been proven. A collection of non-halo aluminate ionic liquids transporting the same cation species exhibit increased ionic liquid density in response to an increase in anion mass. The kind of organic cation has an impact on the non-haloaluminate ionic liquids' densities as well. The density decreases as the cation size increases, just like haloaluminate IL.
- 4. Solubility :** In stoichiometric chemical synthesis and catalytic processes, ionic liquids (ILs) are crucial for the solubilities of both organic molecules and metal salts. To effectively separate and isolate the products, reagents, products, and catalysts must all have differing solubilities in the solvent [9]. Furthermore, the solvent-soluble requirements for the catalysts and reagents must be met. The relative merits of a particular ionic liquid (IL) for chemical or separation processes must be evaluated in addition to the

solute solubility in ionic liquids (ILs). This requires knowledge of the relative solubility and partitioning data about the preference of the solutes for ionic liquids (ILs) phases relative to extractants. However, the literature offers little systematic support for these characteristics. Instead of using compositional analysis to determine the boundaries of solubility or co-miscibility, it is more common to classify solutes and solvents as immiscible in a specific ionic liquid (IL) based on the observation that two phases form.

5. **“Separations & Extraction”** : Studies of extractions and separations provide the partitioning data—information on the relative solubilities of solutes between two phases—that are necessary to create systems in which a solute is either immobilised in one phase or selectively removed from another phase. Studies on the liquid-liquid separation of metal ions have implications for the extraction and concentration of metal ions in the organic phase, and their main focus is on aqueous/organic two-phase systems. 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 mine waste water has garnered a lot of interest. The hydrated natures of the majority of metal ions, with the exception of the most hydrophobic cations, reduce their affinity for the less polar extraction phases in ionic liquid systems, where hydrated metal ions do not partition into the ionic liquids from water. Metal ions' affinity for less polar phases can be increased by altering the hydration environments of the metal ions, either by using organic ligands that create more hydrophobic regions around the metal or by using inorganic anions that create softer, more extractable anionic complexes with the metal [10].
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).
7. **Separations of Gas** : Ionic liquids (ILs), however, are the best type of solvent to utilise when separating gases. They are non-volatile, which means they cannot evaporate and contaminate the gas stream. This is essential [11] when using supported liquid membranes or conventional absorbers with specific solvents. Only the link between the Henry's law constants and the solubilities of two gases can be utilised to discriminate between them in conventional absorbers. Additionally, ILs are particularly appealing for supported liquid membranes because of their extraordinary stability. Conventional liquids employed in supported liquid membranes eventually deteriorate as a result of the liquid's slow evaporation. This limited evaporation rate also limits the maximum membrane thickness. This demonstrates a reduction in the net flux across the membrane. To solve these problems, a non-volatile liquid might be utilised. In the absence of assisted transport (such as the complexation of CO₂ with amines to produce carbamates), gas permeability through supported liquid membranes depends on both solubility and diffusivity. The flow of one gas in relation to the other can be calculated using a simplified solution-diffusion model.

- 8. Electrochemical Properties of Ionic Liquids :** Ionic liquids are a good choice for electrochemical process research because of a variety of properties. They frequently exhibit wide electrochemical potential windows, respectable electrical conductivity, and solvent transport capabilities, and they can solvate a wide variety of inorganic, organic, and organometallic compounds.
- 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.
- 10. Transport Properties:** The transport characteristics of the ionic components have a big impact on how an ionic liquid behaves when used as an electrolyte. These transportation traits relate to the direction and speed of ion transit (solute, in pairs, or in aggregates). The amount and mobility of charge carriers, for instance, have an impact on conductivity. In an ionic liquid, if highly mobile yet neutral ion-pairs dominate, there will be few accessible charge carriers and a low conductivity. To evaluate the transport characteristics of electrolytes, two metrics are typically used: ion-diffusion coefficients and ion-transport numbers. In contrast to the diffusion coefficient, which measures the speed at which ions travel in a solution, the transport number quantifies the amount of charge that an ion carries while it is in the presence of an electric field [12].
- 11. Liquid Crystals:** Many different ionic liquids can form liquid-crystalline phases. Typically, this is accomplished by increasing the cation's amphiphilicity by adding longer, linear alkyl groups. When the alkyl chain length (C_n) is short ($n < 10$), the melting points of the salts are relatively low and near to room temperature. When $n > 12$, however, they exhibit liquid crystal mesomorphism.
- 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 [13].
- 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.

V. IONIC LIQUIDS (ILS) APPLICATIONS

Ionic liquids (ILs) are special in that they can dissolve a wide range of organic and inorganic molecules while also being environmentally friendly. ILs have their own special characteristics. The physicochemical properties of ionic liquids (ILs) are distinctive, and they

have several potential uses. Surface active ILs are a distinct class of surfactants that have drawn significant interest from researchers all around the world. This interest has grown as a result of their ability to self-assemble. The surface activity of these ILs, as indicated by a decrease in surface tension, has been demonstrated. Notable features of the ILs include their ability to form micellar nano-aggregates in aqueous solution and their resemblance to surface-active (SA) agents in these regards. Ionic liquids (ILs) have emerged as fascinating and flexible reaction media for several bio-applications, most notably enzyme catalysis, as possible green solvents [15].

- 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].
- 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 $[\text{PF}_6]$ - and $[(\text{CF}_3\text{SO}_2)_2\text{N}]$ -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 products and residual organics can be recovered using an organic solvent due to their insolubility, byproducts contained in water-immiscible ILs can be washed away using water with little IL loss. In order to provide significant advantages over traditional technologies for extraction processes, Birdwell et al. (2006) [20] It was effectively used to separate dispersions including immiscible organic IL/hydrocarbon/and aqueous systems using a centrifugal solvent-extraction contactor recycling technique.
- 3. The Membrane Technology for "Ionic-Liquid (ILs)" Recovery :** In order to provide a precise separation of undesirable components, membrane techniques have been utilised to selectively extract volatile solutes from ionic liquids (ILs). Haerens et al. (2010) In order to recycle ILs from water, research was done on the utilisation of pressure-driven membrane technologies, nano-filtration, reverse osmosis, and pervaporation. The outcomes of these studies were compared to those described in the literature using ethaline200, a deep eutectic made 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].

4. **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. **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 imidazolium ionic liquids (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. Despite the fact that the active ingredient of IL over them was fixed on the surface of the support by poor physical adsorption, these supported IL catalysts could be recycled several times without appreciably losing their activity for the PC synthesis under solventless circumstances. ILs can also be covalently immobilised in inorganic materials comprised of silica, mesoporous silicates, aluminosilicate, and alumina. 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.

6. **The “Ionic Liquid (ILs)” as Solvent and Co-Catalyst** : Ionic liquids are frequently utilised as a co-catalyst and a solvent in transition metal catalysis, such as melts of chloroaluminate or chlorostannate. They are created through the fusion of a Lewis acid and halide salt. The Lewis acidity or basicity, which is always present (at least latently), has a substantial impact on the catalyst complex, which is why. Utilising the Lewis acidity of an ionic liquid, the neutral catalyst precursor is normally converted into the

equivalent cationic active form [24]. The enhanced electrophilicity of the catalytic centre, which leads to increased catalytic activity (as in the majority of olefin oligomerization processes, for example), increases the likelihood that the catalyst system will be activated in a mildly acidic ionic liquid.

7. The “Ionic Liquid (ILs)” as Solvent and Ligand Precursor : The cation and anion of an ionic liquid may act as ligands or ligand precursors for a dissolved transition metal complex. Depending on how coordinated they are, the anions of the ionic liquid could serve as ligands to some extent if the catalytic centre is cationic. It has been sufficiently demonstrated that the anion of an ionic liquid may, if it differs, take the place of the anion of a cationic transition metal complex. The bulk of ionic liquid anions used in catalysis are chosen to interact with the catalytic centre as little as possible; however, if the ionic liquid's (ILs) anion passes through breakdown processes, this scenario may radically change. For instance, when an ionic liquid and water come into contact, the hexafluorophosphate anion hydrolyzes and releases fluoride ions. 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. The ligand precursor for an imidazolium molecule can, however, be a transition metal submerged in an ionic liquid [25]. 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.

8. The “Ionic Liquid” As Solvent & Transition Metal Catalyst : For procedures that are often catalysed by $AlCl_3$, like catalytic Friedel-Crafts alkylation or stoichiometric Friedel-Crafts acylation, acidic chloroaluminate ionic liquids have already been used as both solvents and catalysts. Lewis-acidic transition metal complexes and organic halide salts have similar mechanisms for the synthesis of complex anions. A Friedel-Crafts acylation method based on an acidic chloroferrate ionic liquid catalyst, for instance, has been the subject of a patent issued by Seddon and colleagues. Ionic liquids that serve as catalysts for transition metals, however, are not always based on typical Lewis acids. It was recently reported on the ionic liquid $[BMIM][Co(CO)_4]$. A vibrant blue-green liquid was produced by metathesising $[BMIM]Cl$ and $Na[Co(CO)_4]$. It acted as an initiator for the ketonization of the corresponding 2-bromoketones. When a high catalyst concentration is desired, it generally appears like a good idea to add an active transition metal catalyst to the anion of an ionic liquid [26].

9. Significant of the “Ionic Liquids” in Transition Metal Catalysis

- **Hydrogenation Reactions:** In general, the hydrogenation processes involving "ionic liquids (ILs)" and transition metals show great promise. On the one hand, ionic hydrogenation catalysts are common and well-known. However, it appears that good

reaction rates can be attained given the solubility of many alkenes and the availability of hydrogen in many ionic liquids. It is noteworthy in this regard that the amount of hydrogen available depends on both the solubility of hydrogen under equilibrium conditions and the simplicity with which it may be integrated into the melt. The latter is essential since it has been found that hydrogen migrates into ionic liquids extremely quickly. Additionally, a biphasic method is typically feasible because the miscibility difference between the saturated reaction products and the ionic liquid is frequently significant. In 1995, the de Souza and Chauvin groups looked into the first efficient methods of ionic liquid hydrogenation [27]. De Souza and associates investigated the influence of Rh on the hydrogenation of cyclohexene in 1-n-butyl-3-methylimidazolium ([BMIM]) tetrafluoroborate.

- **Oxidation Reactions:** Catalytic oxidation processes based on ionic liquids have just lately been studied. Given the well-known oxidation stability of ionic liquids from electrochemical research and the enormous commercial impact of oxidation reactions, this comes as a bit of a surprise. The reaction's nonvolatile nature is a crucial benefit for safety in oxygen oxidation procedures. While the possibility of explosive mixtures in the gas phase may limit the use of volatile organic solvents, this issue is not present when a nonvolatile ionic liquid is employed as the solvent. According to Ley et al., an ammonium perruthenate catalyst that was dissolved in [NEt₄] Br and [EMIM][PF₆] was responsible for catalysing the oxidation of alcohols [28]. N-methylmorpholine or oxygen When N-oxide is utilised as the oxidant, the authors explore both the viability of reusing the ionic catalyst solution and facile product recovery using solvent extraction. In addition, the oxidation of alkenes and allylic alcohols employing the catalyst methyltrioxorhenium (MTO) distributed in [EMIM][BF₄] and the urea-H₂O₂ adduct (UHP) as the oxidant. Both MTO and UHP were completely dissolved by the ionic liquid. It was shown that the olefinic substrate's solubility in the reactive layer and the olefin's reactivity have an impact on conversions. Overall, it was discovered that the reaction rates of the epoxidation process were comparable to those of conventional solvents.
- **Hydroformylation :** A tried-and-true method for effective catalyst separation and recycling in hydroformylation is biphasic catalysis. The Ruhrchemie-Rhône-Poulenc process technically implements this concept by using water as the catalyst phase in Rh-catalyzed hydroformylation operations. Sadly, this method is limited to C₂-C₅-olefins because higher olefins have a low water solubility. But there is commercial interest in hydroformylating a number of higher olefins.
- **The Immobilization of Catalysts in “Ionic Liquids” (ILs):** There are two proven strategies to use ionic liquids in organic or catalytic reactions. Ionic liquid serves as both the catalyst and the reaction solvent in the first case. Lewis acidic ionic liquids, such as acidic chloroaluminates, serve as both the solvent for the carbenium ions and the active catalytic species in acid-catalyzed reactions. AlCl₃ is an example of an inorganic Lewis acid that, in this circumstance, does not dissolve in the organic phase.

The homogeneous catalyst is positioned in the "Ionic liquid (ILs)" in the second approach, which acts as a "liquid support" for it.

- **The “Dimerization & the Oligomerization” reactions :** Through the "dimerization and oligomerization" processes, ionic liquids have already demonstrated themselves to be a very promising solvent class for converting tried-and-true catalytic systems into biphasic catalysis. In the area of oligomerization chemistry, the concept of biphasic catalysis is not new. However, the first catalytic, biphasic process to occur in a commercial environment was the ethylene oligomerization. It was first patented in the late 1960s and is known in those documents as the "Shell Higher Olefins Process (SHOP)". Although 1,4-butanediol is the catalyst phase in the SHOP, it was later shown that a number of highly attractive catalyst systems for dimerization and oligomerization were incompatible with polar organic solvents or water [29].

10. 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 [30]. 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.

11. The “Multiphasic Catalysis” with “Ionic Liquids (ILs)” in Combination with Compressed CO₂, The “Catalytic Reaction” with Subsequent Product Extraction: The first use, which included a catalytic reaction in an ionic liquid and a subsequent extraction step using scCO₂, was published by Jessop et al. in 2001 [31]. These authors carried out two unique asymmetric hydrogenation processes using the catalyst [Ru(OAc)₂(tolBINAP)], which was dissolved in the ionic liquid [BMIM][PF₆]. In a biphasic combination of [BMIM][PF₆] and water, the asymmetric hydrogenation of tiglic acid was carried out with excellent yield and selectivity. To avoid contaminating the catalyst or ionic liquid once the reaction was finished, the product was extracted using scCO₂. Similar to this, the anti-inflammatory medication ibuprofen was created through asymmetric hydrogenation of isobutylatropic acid. To learn more about these hydrogenation processes, the reaction was conducted in the present instance in a [BMIM][PF₆]/MeOH mixture. The product was then extracted using scCO₂ [32].

12. The “Aluminium Electrodeposition (AE)” : Numerous papers have examined aluminium (Al) electrodeposition from chloroaluminate ionic liquids using ex situ methods, potential step experiments, and traditional electrochemical methods including cyclic voltammetry. Only acidic conditions have ever seen aluminium (Al) deposition, and the quality of these deposits has long been regarded to be superior to deposits made by organic solutions. The cluster size of the granular metal aluminium (Al) changes with the current density, with higher current densities often resulting in smaller crystals. Mirror-bright deposits have been seen when the liquid is mixed with dry toluene or benzene. There may be organic chemicals that function as brighteners [33]. Since organic materials like crystal violet are frequently used in aqueous electroplating techniques to create spectacular coatings of Cu, Ag, etc., these effects have long been known to occur. Another benefit of the chloroaluminates' miscibility with toluene, xylene, and other organic solvents is how simple it is to remove the liquid from the samples after electrodeposition. This enables the production of clean substrates from aqueous solutions to proceed almost as quickly.

13. Free Radical Polymerization: The polymer industry primarily relies on free radical polymerization to manufacture a broad range of polymers. For the addition polymerization of vinyl monomers such as styrene, vinyl acetate, tetrafluoroethylene, methacrylates, acrylates, (meth)acrylonitrile, and (meth)acrylamides, it is used in bulk, solution, and aqueous methods. The material is simple to use and unaffected by contaminants or several functional groups [34].

VI. CONCLUSION

The "ionic liquids" (ILs) have some advantageous qualities, making daily usage of them almost necessary. 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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