

**CO₂ CAPTURE AND PROTOTROPISM WITHIN
ALTERNATE SOLVENT MEDIA**

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**DEPARTMENT OF CHEMISTRY
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ALTERNATE SOLVENT MEDIA

by

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Dedicated to
My Parents

CERTIFICATE

This is to certify that the thesis entitled, “**CO₂ Capture and Prototropism within Alternate Solvent Media**”, being submitted by **Ms. Bhawna** to the **Indian Institute of Technology Delhi** for the award of the degree of **Doctor of Philosophy** in Chemistry is a record of bonafide research work carried out by her. She has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard.

The results contained in this dissertation have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

Date:

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ABSTRACT

The significant potential of alternate solvents including DESs, ILs, and liquid polymers/surfactants as environmentally-benign solubilizing media and their peculiar and beguiling features coupled to their wide range of applications in various industries and academia make them solvents of utmost importance. In this context, the present thesis provides a detailed description of these solvents along with their application in studying specific research problems, to widen the scope of these alternate solvent.

The thesis titled '**CO₂ Capture and Prototropism within Alternate Solvent Media**' is focused towards understanding the behavior of alternate solvent media such as deep eutectic solvents (DESs), ionic liquids (ILs), and surfactants/liquid polymers for CO₂ capture and prototropism. The thesis includes the preparation of new choline chloride-based eutectic mixtures and a detailed study of their ability to capture CO₂ in the absence and presence of different superbases. Moreover, low-cost solvent systems, e.g., surfactant and liquid polymer are also investigated for their CO₂ capture ability. The thesis also features a detailed investigation of prototropism within judiciously selected DESs and ILs. A range of DESs and ILs having different structures are used to explore and comprehend the nature of interactions between a prototropic probe and these solvent media.

The thesis has been divided into seven chapters. Chapter 1 (Background and Introduction) provides summarized information about liquid polymers/surfactants, DESs, and ILs solvent systems that are prepared and investigated in the current work. It also includes a brief overview of the existing gaps associated with the current research along with possible options for bridging the gaps. The ultimate/overall objective of the current research work is to explore and establish DESs, ILs, and surfactants/liquid polymers as environmentally-benign replacements to conventional media for CO₂ capture and to investigate prototropism therein.

Chapter 2 titled ‘Materials and Methodologies’ highlights the specifications involved in the purchase, preparation, purification, and storage of chemicals as well as techniques used during the investigation. Specifically, UV-Vis molecular absorbance, steady-state and time-resolved fluorescence, FTIR absorbance, Raman spectroscopy, ^{13}C NMR, density, and dynamic viscosity measurements are employed to obtain the essential information.

Chapter 3 titled ‘CO₂ Capture by Liquid Polymers and Surfactants’, common and popular liquid surfactants and polymers are explored for their CO₂ absorption and retention abilities under ambient conditions. Specifically, three Tween (Tween 20, Tween 40, and Tween 80), TX-100, TX-114, and one Pluronic (P84) series liquid surfactants, and three PEG (PEG 200, PEG 400, and PEG 600), and two PEI (PEI 800 and PEI 25000) family liquid polymers are found to capture an appreciable amount of CO₂ in the presence of superbase. The reaction of electron-rich centers of hydroxyl/amine functionality of the liquid surfactant/polymer with the electron-deficient center of CO₂ is facilitated by the superbase. DBN superbase is found to afford more effective capture of CO₂ within the liquid surfactants/polymers investigated as compared to DBU and TBD. Except for PEGs, the efficiency of CO₂ capture is directly correlated to the number of moles of hydroxyl/amine groups present; inter-PEG H-bonding in PEG200 having relatively smaller polymer chain results in partial unavailability of hydroxyl groups to interact with added CO₂. The presence of water within the liquid surfactant/polymer renders the CO₂ uptake by the media faster due to decreased viscosity, the efficiency of CO₂ capture is decreased due to favorable back reaction and H-bonding between added water and hydroxyl of surfactant/polymer. The superbase-added liquid surfactants/polymers exhibit excellent CO₂ capture-expulsion reversibility with alternate CO₂-N₂ addition as well. Inexpensive, benign, and readily-available common and popular liquid surfactants/polymers are shown to have the potential for effective and easy storage and release of CO₂.

Chapter 4 titled ‘Superbase-Added Choline Chloride-Based Deep Eutectic Solvents for CO₂ Capture and Sequestration’ describes the potential usage of DESs as inexpensive and environmentally-benign liquid media for CO₂ capture. CO₂ sequestration and release ability of DES systems composed of salt choline chloride mixed with hydrogen bond donors (HBDs) urea, ethylene glycol, and MEA are assessed in the absence and presence of three superbases: DBN, DBU, and TBD, respectively. The addition of superbase is found to significantly increase the CO₂ capture ability of the DESs. It is found that the overall efficiency of CO₂ capture is the best with superbase DBN as compared to DBU or TBD. ¹³C-NMR, FTIR and Raman spectroscopic measurements reveal that a major part of the CO₂ binds covalently to the electron-rich functionalities present on the components of the DES with superbase assisting this association. The reversibility of the captured CO₂ is assessed by introducing N₂ gas into the CO₂ captured superbase-added DES system and by heating at high temperatures. Intramolecular excimer intensity of BPD and steady-state fluorescence anisotropy of R6G fluorescence probes effectively monitor the CO₂ capture process as the viscosity of the superbase-added DES increases as more-and-more CO₂ is captured. The efficiency, effectiveness, and robustness of superbase-added DES-based systems towards CO₂ capture and sequestration are amply highlighted.

Chapter 5 titled ‘Norharmane Prototropism in Choline Chloride-Based Deep Eutectic Solvents’ explores the suitability of DESs in exploring and understanding prototropic behavior of norharmane. Specifically, prototropic behavior of β-carboline, commonly named as norharmane (9H-pyrido[3,4-b]indole), is investigated in eight different DESs prepared using ChCl with eight different H-bond donors (HBDs) to ascertain their role in controlling prototropism within DESs. In the ground-state, DESs with HBDs glycerol and ethylene glycol support both neutral and cationic forms of norharmane, however, within DESs constituted of HBDs urea, 1,4-butane-diol, and acetamide, respectively, only the neutral form exists.

Within the remaining three DESs with HBDs tetraethylene glycol, 3-phenylpropionic acid, and malonic acid, respectively, only cationic form is supported. As the cationic form is preferred more over the neutral form of norharmane in the excited-state, DESs with HBDs tetraethylene glycol, 3-phenylpropionic acid, and malonic acid, respectively, support only the cationic form in the excited-state. DES with glycerol also supports only the cationic form in the excited-state, DES with ethylene glycol, acetamide, and 1,4-butane-diol support both cationic and neutral forms. The DES with urea as the HBD is the only DES that supports only the neutral form in the excited state. Excited-state intensity decay data confirms the presence of different prototropic forms of norharmane within investigated DESs with distinct decay times for the neutral and cationic forms. Correlation between the common empirical solvent polarity parameter, E_T^N , along with Kamlet-Taft parameters, H-bond donating acidity (α), and H-bond accepting basicity (β), of the DESs and the relative presence of the norharmane prototropic forms is established.

Chapter 6 titled ‘Prototropic Behavior of Norharmane in Ionic Liquid’ explores the role of ILs having different anionic and cationic components as novel solvent media on prototropic behavior of norharmane. UV–vis molecular absorbance and steady-state/time-resolved fluorescence are employed to acquire more information about the ground- and excited-state prototropism, respectively. Nine ILs are used for the investigation that are judiciously selected on the basis of the availability of acidic proton in the cationic part of IL. Experimental outcomes have shown the dependence of norharmane prototropic species on the structural constituent of both cation and anion of the ILs. The role of the acidity imparted via the cation of an IL plays a crucial role in deciding the prototropic behavior of the probe norharmane in ILs. Further, for ILs having similar acidity cations, the Lewis basicity (viz., water-miscibility) of the anionic counterpart of the IL controls the relative presence of the different prototropic forms. ILs as designer solvents to control the prototropic forms of a solute is clearly established.

Chapter 7 titled ‘Conclusions and Future Prospects’ presents the summary of the overall investigation and also the scope of the work done. In brief, it is concluded that the addition of a superbase to DESs, surfactants, and liquid polymers can result in a considerable increment in their CO₂ uptake efficiency. Moreover, DESs and ILs as solubilizing media have significant role in controlling the existence of various prototropic forms of a probe, norharmane in both ground- and excited-states. The overall outcomes of this work may help establish choline chloride-based DESs, ILs, and liquid polymers/surfactants as environmentally-benign solubilizing media with potential applications in both academia and industry.

सार

पर्यावरण, सौम्य सॉल्यूबिलिंग मीडिया और उनके अजीबोगरीब और भ्रामक विशेषताओं के रूप में डेस, आईएलएस, और तरल पॉलिमर / सर्फेक्टेंट सहित वैकल्पिक सॉल्वेंट्स की महत्वपूर्ण क्षमता विभिन्न उद्योगों और शिक्षाविदों में उनके विस्तृत अनुप्रयोगों के लिए युग्मित विशेषताएं हैं जो उन्हें अत्यधिक महत्व के सॉल्वेंट्स बनाते हैं। वर्तमान थीसिस इन वैकल्पिक विलायक के दायरे को व्यापक बनाने के लिए विशिष्ट शोध समस्याओं का अध्ययन करने में उनके आवेदन के साथ इन सॉल्वेंट्स का विस्तृत विवरण प्रदान करता है।

वैकल्पिक सॉल्वेंट मीडिया के भीतर सीओ₂ कैप्चर एंड प्रोटोट्रोपिज्म नामक थीसिस वैकल्पिक सॉल्वेंट मीडिया जैसे डीप यूटेक्टिक सॉल्वेंट्स (डीएसएस), आयनिक तरल पदार्थ (आईएलएस) और सीओ₂ कैप्चर और प्रोटोट्रोपिज्म के लिए सर्फेक्टेंट/लिक्विड पॉलिमर के व्यवहार को समझने की दिशा में केंद्रित है। थीसिस में नए कोलीन क्लोराइड आधारित यूटेक्टिक मिश्रण की तैयारी और विभिन्न सुपरबेस की अनुपस्थिति और उपस्थिति में सीओ₂ को पकड़ने की उनकी क्षमता का विस्तृत अध्ययन शामिल है। इसके अलावा, कम लागत वाले सॉल्वेंट सिस्टम, जैसे, सर्फेक्टेंट और लिक्विड पॉलिमर की भी उनकी सीओ₂ कैप्चर क्षमता के लिए जांच की जाती है। थीसिस में विवेकपूर्ण रूप से चयनित डीईएसएस और आईएलएस के भीतर प्रोटोट्रोपिज्म की विस्तृत जांच भी है। विभिन्न संरचनाओं वाले डीएसएस और आईएलएस की एक श्रृंखला का उपयोग प्रोटोट्रोपिक जांच और इन विलायक मीडिया के बीच बातचीत की प्रकृति का पता लगाने और समझने के लिए किया जाता है।

थीसिस को सात अध्यायों में बांटा गया है। **अध्याय 1 (पृष्ठभूमि और परिचय)** तरल बहुलक/सर्फेक्टेंट, डेस और आईएलएस सॉल्वेंट सिस्टम के बारे में संक्षेप में जानकारी प्रदान करता है जो वर्तमान कार्य में तैयार और जांच की जाती है। इसमें अंतराल को पाटने के लिए संभावित विकल्पों के साथ-साथ वर्तमान अनुसंधान से जुड़े मौजूदा अंतरालों का संक्षिप्त अवलोकन भी शामिल है। वर्तमान अनुसंधान कार्य का अंतिम/समग्र उद्देश्य सीओ₂ कैप्चर के लिए पारंपरिक मीडिया

के लिए पर्यावरण की दृष्टि से सौम्य प्रतिस्थापन के रूप में डीएसएस, आईएलएस, और सर्फेक्टेंट/लिक्रिड पॉलिमरका पता लगाना और स्थापित करना और उसमें प्रोटोटोपिज्म की जांच करना है। 'सामग्री और पद्धतियों' शीर्षक वाले अध्याय 2 में रसायनों की खरीद, तैयारी, शुद्धिकरण और भंडारण के साथ-साथ जांच के दौरान उपयोग की जाने वाली तकनीकों में शामिल विनिर्देशोंपर प्रकाश डाला गया है। विशेष रूप से, यूवी-विस आणविक अवशोषण, स्थिर-राज्य और समय-हल फ्लोरेसेंस, एफटीआर अवशोषण, रमन स्पेक्ट्रोस्कोपी, ¹³सी एनएमआर, घनत्व और गतिशील चिपचिपाहट माप आवश्यक जानकारी प्राप्त करने के लिए नियोजित हैं।

अध्याय 3 शीर्षक "सीओ₂ कैप्चर बाय लिक्विड पॉलिमर और सर्फेक्टेंट", परिवेशी परिस्थितियों में उनके सीओ₂ अवशोषण और प्रतिधारण क्षमताओं के लिए आम और लोकप्रिय तरल सर्फेक्टेंट और पॉलिमर का पता लगाया जाता है। विशेष रूप से, तीन ट्विन (ट्विन 20, ट्विन 40, और ट्विन 80), टीएक्स -100, टीएक्स -114, और एक प्लुरोनिक (पी 84) श्रृंखला तरल सर्फेक्टेंट, और तीन खूंटी (खूंटी 200, खूंटी 400, और खूंटी 600), और दो पी (पी 800 और पी 25000) परिवार तरल बहुलकसुपरबेस की उपस्थिति में सीओ₂ की एक प्रशंसनीय राशि पर कब्जा करने के लिए पाए जाते हैं। सीओ₂ के इलेक्ट्रॉन की कमी वाले केंद्र के साथ तरल सर्फेक्टेंट/बहुलक की हाइड्रोक्सिल/अमीन कार्यक्षमता के इलेक्ट्रॉन समृद्ध केंद्रों की प्रतिक्रिया₂ सुपरबेस द्वारा सुगम है। डीबीएन सुपरबेसडीबीयू और टीबीडी की तुलना में जांच किए गए तरल सर्फेक्टेंट/पॉलिमर के भीतर सीओ₂ का अधिक प्रभावी कब्जा करने के लिए पाया जाता है। पीईजी के अलावा, सीओ₂ कैप्चर की दक्षता सीधे तौर पर हाइड्रोक्सिल/अमीन समूहों के मॉल की संख्या से सहसंबद्ध है; पीईजी 200 में अंतर-खूंटी एच-बॉन्डिंग के परिणामस्वरूप अपेक्षाकृत छोटे बहुलक श्रृंखला के परिणामस्वरूप हाइड्रोक्सिल समूहों की आंशिक अनुपलब्धता के परिणामस्वरूप अतिरिक्त सीओ₂ के साथ बातचीत करने के लिए। यह तरल सर्फेक्टेंट/बहुलक के भीतर पानी कीपी रेसेंस मीडिया द्वारा सीओ₂ तेज को तेजी से प्रस्तुत करता है क्योंकि चिपचिपाहट में कमीआई है, अनुकूल बैक रिएक्शन और सर्फेक्टेंट/बहुलक के अतिरिक्त पानी

और हाइड्रोक्सिल के बीच एच-बॉन्डिंग के कारण सीओ₂ कैप्चर की दक्षता कम हो जाती है। सुपरबेस-वर्धित तरल सर्फेक्टेंट/पॉलिमर वैकल्पिक सीओ₂ अतिरिक्त के साथ उत्कृष्ट सीओ₂ कैप्चर-निष्कासन रिवर्सिबिलिटी भी प्रदर्शित करते हैं। सस्ती, सौम्य, और आसानी से उपलब्ध आम और लोकप्रिय तरल सर्फेक्टेंट/पॉलिमर को प्रभावी और आसान भंडारण और सीओ₂ की रिहाई की क्षमता दिखाई जाती है।

अध्याय 4 शीर्षक “सुपरबेस-जोड़ा कोलीन क्लोराइड-आधारित डीप यूटेक्टिक सॉल्वेंट्स फॉर सीओ₂ कैप्चर एंड ज़ब्ती” में डीएसएस के संभावित उपयोग को सीओ₂ कैप्चर के लिए सस्ती और पर्यावरण की दृष्टि से सौम्य तरल मीडिया के रूप में वर्णित किया गया है। सीओ₂ ज़ब्ती और नमक कोलीन क्लोराइड से बना डेस प्रणालियों की रिलीज क्षमता हाइड्रोजन बांड दाताओं (एचबीडी)यूरिया, एथिलीन ग्लाइकोल, और विदेश मंत्रालय के साथ मिश्रित तीन सुपरबेस की अनुपस्थिति और उपस्थिति में मूल्यांकन किया जाता है: डीबीएन, डीबीयू और टीबीडी, क्रमशः। सुपरबेस के अलावा डीईएसएसकी सीओ₂ कैप्चर क्षमता में काफी वृद्धि पाई जाती है। यह पाया गया है कि डीबीयू या टीबीडी की तुलना में सुपरबेस डीबीएन के साथ सीओ₂ कैप्चर की समग्र दक्षता सबसे अच्छी है।¹³सी-एनएमआर, एफटीआर और रमन स्पेक्ट्रोस्कोपिक माप से पता चलता है कि सीओ₂ का एक प्रमुख हिस्सा इस संघ की सहायता करने वाले सुपरबेस के साथ डीईएस के घटकों पर मौजूद इलेक्ट्रॉन-समृद्ध कार्यक्षमताओं को सहसंबद्ध करता है। कब्जा कर लिया सीओ₂ की रिवर्सिबिलिटी सीओ₂ में एन₂ गैसशुरू करने के द्वारा मूल्यांकन किया जाता है, सुपरबेस-एडेड डेस सिस्टम पर कब्जा कर लिया और उच्च तापमान पर हीटिंग द्वारा। आर6जी फ्लोरेसेंस प्रोबके बीपीडी और स्थिर-राज्य फ्लोरेसेंस एनिसोट्रोपी की इंटरमोल्यूलर एक्सीमर तीव्रता प्रभावी रूप से सीओ₂ कैप्चर प्रक्रिया की निगरानी करती है क्योंकि सुपरबेस-वर्धित डेस की चिपचिपाहट बढ़ जाती है क्योंकि अधिक से अधिक सीओ₂ पर कब्जा कर लिया जाता है। सीओ₂ कैप्चर और ज़ब्ती की ओरसुपरबेस-एडेड डेस-आधारित प्रणालियों की ई-फिशिएंसी, प्रभावशीलता और मजबूती को पर्याप्त रूप से हाइलाइट किया गया है।

अध्याय 5 शीर्षक से “कोलिन क्लोराइड-आधारित डीप यूटेक्टिक सॉल्वेंट्स में नोहारमान प्रोटोट्रोपिज्म” नोरहारमेन के प्रोटोट्रोपिक व्यवहार की खोज और समझने में डीएसएस की उपयुक्तता की पड़ताल करता है। विशेष रूप से, β -कार्बोलिन के प्रोटोट्रोपिक व्यवहार, जिसे आमतौर पर नोरहारमेन (9H-pyrido [3,4-b] इंडोल) के रूप में नामित किया जाता है, आठ अलग-अलग एच-बॉन्ड दानदाताओं (एचबीडी) के साथ सीएचसीएल का उपयोग करके तैयार किए गए आठ अलग-अलग डीएसएस में जांच की जाती है ताकि डीओएस के भीतर प्रोटोट्रोपिज्म को नियंत्रित करने में उनकी भूमिका का पता लगाया जा सके। जमीन-राज्य में, एचबीडी ग्लाइसेरोल और एथिलीन ग्लाइकोल के साथ डीएसएस नोरहारमेन के तटस्थ और सेसिक रूपों का समर्थन करते हैं, हालांकि, एचबीडीएस यूरिया, 1,4-ब्यूटेन-डाइल और एसिटामाइड के गठित डीएसएस के भीतर क्रमशः केवल तटस्थ रूप मौजूद है।

एचबीडी टेट्राएथिलीन ग्लाइकोल, 3-फिनाइलप्रोपियोनिक एसिड और मैलोनिक एसिड के साथ शेष तीन डीएसएस के भीतर क्रमशः, केवल धनायनित रूप का समर्थन किया जाता है। चूंकि एंसिक रूप को उत्साहित-राज्य में नोरहारमेन के तटस्थ रूप पर अधिक पसंद किया जाता है, एचबीडीएस टेट्राएथिलीन ग्लाइकोल, 3-फिनाइलप्रोपियोनिक एसिड और मैलोनिक एसिड के साथ डीएसएस क्रमशः, उत्तेजित-राज्य में केवल धनायनित रूप का समर्थन करते हैं। ग्लिसेरोल के साथ डेस भी उत्तेजित-राज्य में केवल धनायनित रूप का समर्थन करता है, एथिलीन ग्लाइकोल, एसिटामाइड के साथ डेस, और 1,4-ब्यूटेन-डाइल दोनों धनायनित और तटस्थ रूपों का समर्थन करते हैं। एचबीडी के रूप में यूरिया के साथ डेस एकमात्र डेस है जो पूर्वसीआईटीई राज्य में केवल तटस्थ रूप का समर्थन करता है। उत्साहित-राज्य तीव्रता क्षय डेटा तटस्थ और धनायनित रूपों के लिए अलग क्षय समय के साथ जांच की डीएसएस के भीतर नोरहारमेन के विभिन्न प्रोटोट्रोपिक रूपों की उपस्थिति की पुष्टि करता है। सामान्य अनुभवजन्य विलायक ध्रुवीकरण पैरामीटर के बीच सहसंबंध, कामलेट-टैफ्ट पैरामीटर्स के साथ, एच-बॉन्ड दान करने वाली अम्लता $E_T^N(\alpha)$, और एच-बॉन्ड स्वीकार करने वाली बुनियादीता (β), डीएसएस की और नोरहारमेन प्रोटोट्रोपिक रूपों की सापेक्ष उपस्थिति स्थापित की गई है।

अध्याय 6 शीर्षक "आयनिक लिक्विड में नोरहारमेन का प्रोटोट्रोपिक व्यवहार" नोरहारमेन के प्रोटोट्रोपिक व्यवहार पर उपन्यास विलायक मीडिया के रूप में विभिन्न एनियोनिक और धनायनित घटकों वाले आईएलएस की भूमिका की पड़ताल करता है। यूवी-विस आणविक अवशोषण और स्थिर-राज्य/समय-संकल्पित फ्लोरेसेंस को क्रमशः जमीन और उत्साहित-राज्य प्रोटोट्रोपिज्म के बारे में अधिक जानकारी प्राप्त करने के लिए नियोजित किया जाता है। आईएल के एंटिक भाग में अम्लीय प्रोटोन की उपलब्धता के आधार पर विवेकपूर्ण तरीके से चुने गए जांच के लिए नौ आईएलएस का उपयोग किया जाता है। प्रायोगिक परिणामों ने आईएलएस के धनआयन और एनियन दोनों के संरचनात्मक घटक पर एनओर्मकी निर्भरता को दर्शाया है। आईएल के दौरान प्रदान की गई अम्लता की भूमिका आईएलएस में जांच नोरहारमेन के प्रोटोट्रोपिक व्यवहार को तय करने में महत्वपूर्ण भूमिका निभाती है। इसके अलावा, समान अम्लता वाले आईएलएस के लिए, आईएल के एनियोनिक समकक्ष की लुईस बुनियादीता (जैसे, पानी-मिसेबिलिटी) विभिन्न प्रोटोट्रोपिक रूपों की सापेक्ष उपस्थिति को नियंत्रित करती है। एक सोल्यूट के प्रोटोट्रोपिक रूपों को नियंत्रित करने के लिए डिजाइनर सॉल्वेंट्स के रूप में आईएलएस स्पष्ट रूप से स्थापित है।

अध्याय 7 शीर्षक से निष्कर्ष और भविष्य की संभावनाएं समग्र जांच का सारांश प्रस्तुत करती हैं और किए गए कार्य का दायरा भी। संक्षेप में, यह निष्कर्ष निकाला गया है कि डीएसएस, सर्फेक्टेंट और तरल पॉलिमर के लिए सुपरबेस के अलावा उनके SiO_2 तेज दक्षता में काफी वृद्धि हो सकती है। इसके अलावा, डीएसएस और आईएलएस के रूप में सुस्त मीडिया की जांच के विभिन्न प्रोटोट्रोपिक रूपों के अस्तित्व को नियंत्रित करने में महत्वपूर्ण भूमिका है, जमीनी और उत्साहित दोनों राज्यों में नोरहारमेन। इस कार्य के समग्र परिणामों से शिक्षा और उद्योग दोनों में संभावित अनुप्रयोगों के साथ पर्यावरण की दृष्टि से सौम्य घुलनशील मीडिया के रूप में कोलीन क्लोराइड आधारित डीएसएस, आईएलएस और तरल पॉलिमर/सर्फेक्टेंट स्थापित करने में मदद मिल सकती है।

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LIST OF ABBREVIATIONS

Abbreviation	Full form
IL	Ionic Liquid
CIL	Chiral ionic liquid
SPIL	Switchable polarity ionic liquid
BIL	Bio ionic liquid
DES	Deep Eutectic Solvent
ChCl	Choline chloride
[omim][PF ₆]	1-octyl-3-methylimidazolium hexafluorophosphate
[omim][BF ₄]	1-octyl-3-methylimidazolium tetrafluoroborate
[bmim][NO ₃]	1-butyl-3-methylimidazolium nitrate
[emim][EtSO ₄]	1-ethyl-3-methylimidazolium ethylsulfate
[hmim][Tf ₂ N]	1-hexyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide
[hmmim][Tf ₂ N]	2, 3-dimethyl-1-hexyl-imidazolium bis(trifluoromethylsulfonyl)imide
[bmpyrr][OTf]	1-butyl-1-methyl pyrrolidinium triflate
[bmpyrr][Tf ₂ N]	1-butyl-1-methyl pyrrolidinium bis(trifluoromethylsulfonyl)imide
[bmim][OTf]	1-butyl-3-methylimidazolium triflate
[dmpim][Tf ₂ N]	1,2-dimethyl-3-propylimidazolium bis(trifluoromethylsulfonyl)imide

[emim][Tf ₂ N]	1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide
[bmim][Tf ₂ N]	1-butyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide
[emim][BF ₄]	1-ethyl-3-methylimidazolium tetrafluoroborate
[(OH) ₂ Im][Tf ₂ N]	1,3-dihydroxyimidazolium bis(trifluoromethylsulfonyl)imide
[choline][Tf ₂ N]	choline bis(trifluoromethylsulfonyl)imide
PEG	Polyethyleneglycol
PEI	Polyethyleneimine
PDI	Polydispersity index
CO ₂	Carbon dioxide
CCS	Carbon dioxide capture and sequestration
TBD	1,5,7-triazabicyclo[4.4.0]dec-5-ene
DBU	1,8-diazabicyclo [5.4.0]undec-7-ene
DBN	1,5-diazabicyclo[4.3.0]non-5-ene
R6G	Rhodamine 6G
BPP	1,3-bis(1-pyrenyl)propane
BPD	1,10-bis(1-pyrenyl)decane
TFE	2,2,2-Trifluoroethanol
$E_T(30)$	Energy transfer corresponding to betaine dye 30
$E_T(33)$	Energy transfer corresponding to betaine dye 33
E_T^N	Normalized E_T values

DENA	<i>N, N</i> -diethyl-4-nitroaniline
NA	4-Nitroaniline
LED	Light emitting diode
IRF	Instrument response function
ATR-FTIR	Attenuated total reflectance fourier transform infra-red
NMR	Nuclear magnetic resonanace
uv	Ultraviolet
vis	Visible