

**PROTOTROPISM AND AGGREGATION WITHIN DEEP
EUTECTIC SOLVENTS**

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PROTOTROPISM AND AGGREGATION WITHIN DEEP EUTECTIC SOLVENTS

by

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Submitted

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Dedicated to

My Family

CERTIFICATE

This is to certify that the thesis entitled, “**Prototropism and Aggregation within Deep Eutectic Solvents**”, being submitted by **Ms. Vaishali Khokhar** 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 reported in the 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

DESs have been rapidly growing and are becoming solubilizing media of prominence in different aspects of science and technology. They have turned out as notable alternatives for conventional organic solvents and ionic liquids in diverse fields. Their ease of preparation along with the availability of a wide variety of components forming DESs extends their utility in various applications. The type III DESs and the recently emerged lanthanide salt-based DESs investigated in this work offer a water-alike environment. Their unique physicochemical properties stem from the inherent extensive H-bonding network and their tailorability render them impeccably viable solvent systems for both aggregation and proton transfer studies. Therefore, the objectives of the thesis work are designed to advance the understanding of these nascent DESs and help in assessing their untapped potential.

The thesis titled **‘Prototropism and Aggregation within Deep Eutectic Solvents’** is focused towards understanding the influence of novel DESs on prototropism and self-aggregation processes. The thesis includes a spectroscopic investigation of the prototropic behavior of various fluorophores within judiciously selected DESs. A series of prototropes is investigated to comprehend the role of the structure and functional groups of the probe and also the solubilizing media. The thesis also features the preparation of neoteric lanthanide metal salt-based DESs and a detailed characterization of their physical properties. These modern DESs are then employed to investigate the aggregation behavior of polyaromatic hydrocarbon (PAH) and common and popular surfactants.

The thesis has been divided into seven chapters. **Chapter 1 (Background and Introduction)** provides a summarized introduction of different classes of DESs along with their academic and industrial potential. It also includes advances in the field made by the scientific community as well as an overview of the limitations that encouraged our work and potential solutions to circumvent the present problems. The objectives of the research are also discussed in detail. The overall objective of the research work presented in the thesis is to explore DESs and develop a deeper understanding of their key physicochemical properties in turn establishing the groundwork for their application in various relevant fields.

Chapter 2 titled ‘**Materials and Methodologies**’ introduces the specifications of the procurement, preparation, purification and storage of chemicals along with the techniques utilized for the investigations. Particularly, UV-Vis molecular absorbance, steady-state fluorescence and time-resolved fluorescence measurements along with certain non-invasive techniques, such as, dynamic light scattering (DLS), differential scanning calorimetry (DSC), pH-meter, dynamic viscosity, electrical conductivity, density, and surface-tension measurements are exercised to obtain the desired information.

Chapter 3 titled ‘**Prototropic Forms of Hydroxy Derivatives of Naphthoic Acid within Deep Eutectic Solvents**’ explores the sustainability of DESs as a potential solubilizing media for prototropism. Specifically, the prototropic forms of three structurally-distinct hydroxy naphthoic acid derivatives were investigated within two DESs, constituted of H-bond acceptor Choline chloride (ChCl) and different H-bond donors, urea and glycerol (Gly), respectively, in 1:2 mole ratio. Due to the proximity of functional groups, 1,2-HNA and 3,2-HNA exhibit intramolecular H-bonding while no

such H-bonding is feasible in 6,2-HNA. UV-vis molecular absorbance, steady-state fluorescence, and excited-state intensity decay measurements are utilized to distinguish among the different prototropic forms.

The study revealed that in contrast to common polar solvents where both monoanionic and neutral forms of 1,2-HNA are present, only the neutral form was observed within both DESs. However, the addition of aqueous NaOH solution results in the formation of monoanionic 1,2-HNA in ChCl:Urea. However, 3,2-HNA exhibits the presence of both anionic and neutral prototropic forms within ChCl:Gly DES, while only the monoanionic form is observed within ChCl:Urea. Even the addition of high strength of acid to ChCl:Urea does result in the formation of a neutral emitting form. Moreover, addition of aqueous base results in the formation of the dianionic form of 3,2-HNA in ChCl:Urea, whereas in ChCl:Gly, the added base does not form dianionic form as efficiently. As expected, 6,2-HNA exists in its neutral emitting form in ChCl:Urea and in anionic(carboxylate) form in ChCl:Gly owing to the difference in their H-bond donor acidity. It was observed that the addition of acid leads to the formation of a neutral form in ChCl:Urea while no significant changes were observed in ChCl:Gly. The dianionic form is the dominating emitting form in both DESs in the presence of minimal amount of base.

In **Chapter 4** titled '**Prototropic Behaviour of Naphthalene Derived Probes in Deep Eutectic Solvents**', the prototropic behaviour of 1-naphthol, 2-naphthol, 1-naphthylamine and 1,8-bis(dimethylamino)naphthalene (DMAN) was examined in type-III ChCl-based DESs. Among the investigated probes, 2-naphthol, 1-naphthol, and 1-naphthylamine behave as strong photoacids, whereas DMAN is a powerful photobase.

The investigated DESs were prepared by mixing urea, tetraethylene glycol (TEG), 1,4-butanediol (BD), ethylene glycol (EG), and Gly as H-bond donors (HBDs) with a common H-bond acceptor (HBA) ChCl. UV-vis molecular absorption is used to study ground-state prototropic behaviour while steady-state fluorescence and time-resolved fluorescence measurements are employed to explore the excited-state prototropism. For 2-naphthol, the neutral form is the only absorbing and emitting form observed in all the investigated DESs indicating absence of excited-state proton transfer (ESPT) in these DESs. 1-Naphthol is predominantly present in its neutral form in the ground-state within all the DESs. However, both neutral and anionic forms of 1-naphthol are supported in the excited-state of ChCl:Urea, whereas the neutral form remains the preferred form in other DESs. Similar to 2-naphthol, the 1-naphthylamine also exhibits only neutral form in ground- and excited-state suggesting the lack of ESPT in the DESs. The cationic form of DMAN remains the dominant prototropic form in ground- and excited-state in all the investigated DESs upholding the high photo-basicity of this probe in DESs as well.

Chapter 5 titled ‘**Effect of Temperature and Composition on Density and Dynamic Viscosity of (Lanthanide Metal Salts + Urea) Deep Eutectic Solvents**’ features the preparation and physical characterization of novel lanthanide salt-based DESs. The type IV DESs prepared in the study are composed of lanthanum nitrate hexahydrate (La), cerium nitrate hexahydrate (Ce), and gadolinium nitrate hexahydrate (Gd) with urea in varying concentrations. The novel Ln : urea mixtures were found to form stable and clear room temperature liquids in a wide composition range. DSC was used to determine the glass transition temperature (T_g) of the newly prepared eutectic systems. The T_g values of all the ten investigated mixtures were well below room

temperature indicating strong interactions between the molecular and ionic components within the eutectic mixture. For effective utilization of these neoteric media, assessment of their physical properties is essential. Thus, the density and dynamic viscosity of different possible eutectic mixtures of La:Urea, Ce:Urea and Gd :Urea are reported in the temperature range 293.15 to 363.15 K. Overall, both density and dynamic viscosity were found to decrease with increasing urea concentration. The density of DESs showed a linear decrease with increasing temperature while dynamic viscosity did not follow simplistic Arrhenius expression, rather the temperature dependence of the dynamic viscosity followed Vogel–Fulcher–Tammann (VFT) expression. While the activation energy of viscous flow ($E_{a,\eta}$) for these (lanthanide salt : urea) DESs is closer to those of (ChCl + H-bond donor) DESs, their viscosity-temperature dependence is more similar to that of common imidazolium ionic liquids.

Chapter 6 titled ‘**Aggregation within (Lanthanide Metal Salts + Urea) Deep Eutectic Solvents**’ first presents intermolecular aggregation of a widely recognized PAH pyrene followed by a detailed study of self-assembly behaviour of common ionic and non-ionic surfactants within lanthanide salt based-DESs. The pyrene self-aggregation is not known to occur at μM concentration in isotropic solvents and common liquids including organic solvents, ionic liquids, or other DESs. However, La:Urea and Gd:Urea DESs of varying compositions support aggregation of pyrene at unprecedented low concentrations manifested by a broad structureless band at ~ 473 nm along with the signature high energy (in the vicinity of 370-420 nm) vibronically-resolved structured emission. This can be attributed to the preferential interaction of the π -cloud of the

pyrene with the polycationic species involving lanthanide results in bringing pyrene molecules together in the vicinity of the urea-water H-bonded nano-domains.

We have also investigated these nascent DESs for their capability in supporting surfactant self-assembly formation. The aggregation behaviour of anionic surfactant SDS, cationic surfactant CTAB, and non-ionic surfactant TX-100 is studied within Ce:Urea and La:Urea. The micelle formation is established by using the fluorescence probe PyCHO which showed a change in fluorescence intensity with varying surfactant concentration. Three different eutectic mixtures of La:Urea are explored to understand the role of urea on the aggregation behaviour of both ionic and non-ionic surfactants. In addition to DES composition, effect of temperature on micellization is also investigated for all three surfactants. The high cohesiveness and hydrophilic nature of these DESs brand them as suitable candidates to support micellization process.

Chapter 7 titled ‘**Conclusions and Future Prospects**’ covers the conclusions drawn from the overall investigation and the future scope of the work. In brief, it is suggested that DESs as solubilizing media have a significant role in controlling the existence of various prototropic forms of the fluorophore. Also, hydrated metal salt-based DES systems may prove to be an efficient solubilizing media for aggregation with potential applications in both academia and industries.

सारांश

डीईएस तेजी से बढ़ रहे हैं और विज्ञान और प्रौद्योगिकी के विभिन्न पहलुओं में प्रमुखता के मीडिया बन रहे हैं। वे विभिन्न क्षेत्रों में पारंपरिक कार्बनिक सॉल्वेंट्स और आयनिक तरल पदार्थ के लिए उल्लेखनीय विकल्प के रूप में सामने आए हैं। डीईएस बनाने वाले घटकों की एक विस्तृत विविधता की उपलब्धता के साथ-साथ तैयारी में आसानी विभिन्न अनुप्रयोगों में उनकी उपयोगिता का विस्तार करती है। टाइप III डीईएस और हाल ही में उभरे लैथेनाइड नमक-आधारित डीईएस इस काम में जांच की गई है जो पानी के समान वातावरण प्रदान करते हैं। उनके अद्वितीय भौतिक रासायनिक गुण अंतर्निहित व्यापक एच-बॉन्डिंग नेटवर्क से उपजी हैं और उनकी अनुकूलता उन्हें एकत्रीकरण और प्रोटॉन हस्तांतरण अध्ययन दोनों के लिए निर्विवाद रूप से व्यवहार्य विलायक प्रणाली प्रदान करती है। इसलिए, थीसिस कार्य के उद्देश्यों को इन नवजात डीईएस की समझ को आगे बढ़ाने और उनकी अप्रयुक्त क्षमता का आकलन करने में मदद करने के लिए डिज़ाइन किया गया है।

'प्रोटोट्रोपिज्म एंड एग्रीगेशन विद डीप यूटेक्टिक सॉल्वेंट' शीर्षक वाली थीसिस प्रोटोट्रोपिज्म और आत्म-एकत्रीकरण प्रक्रियाओं पर उपन्यास डीईएस के प्रभाव को समझने की दिशा में केंद्रित है। थीसिस में विवेकपूर्ण रूप से चयनित डीईएस के भीतर विभिन्न फ्लोरोफोर के प्रोटोट्रोपिक व्यवहार की स्पेक्ट्रोस्कोपिक जांच शामिल है। प्रोटोट्रोप्स की एक श्रृंखला की जांच जांच की संरचना और कार्यात्मक समूहों की भूमिका को समझने के लिए की जाती है और घुलनशील मीडिया भी। थीसिस में नियोटेरिक लैथेनाइड धातु नमक-आधारित डीईएस की तैयारी और उनके भौतिक गुणों का विस्तृत लक्षण वर्णन भी शामिल है। इन आधुनिक डीईएस को तब पॉलीएरोमैटिक हाइड्रोकार्बन (पीएएच) और आम और लोकप्रिय सर्फैक्टेंट्स के एकत्रीकरण व्यवहार की जांच करने के लिए नियोजित किया जाता है।

थीसिस को सात अध्यायों में विभाजित किया गया है। **अध्याय 1 (पृष्ठभूमि और परिचय)** उनकी शैक्षणिक और औद्योगिक क्षमता के साथ डीईएस के विभिन्न वर्गों का संक्षेप में परिचय प्रदान करता है।

इसमें वैज्ञानिक समुदाय द्वारा किए गए क्षेत्र में प्रगति के साथ-साथ उन सीमाओं का अवलोकन भी शामिल है जो हमारे काम को प्रोत्साहित करते हैं और वर्तमान समस्याओं को दरकिनार करने के लिए संभावित समाधान हैं। अनुसंधान के उद्देश्यों पर भी विस्तार से चर्चा की गई है। थीसिस में प्रस्तुत शोध कार्य का समग्र उद्देश्य डीईएस का पता लगाना और विभिन्न प्रासंगिक क्षेत्रों में उनके आवेदन के लिए आधार स्थापित करने में उनके प्रमुख भौतिक रासायनिक गुणों की गहरी समझ विकसित करना है।

'सामग्री और कार्यप्रणाली' शीर्षक वाले अध्याय 2 में रसायनों की खरीद, तैयारी, शुद्धिकरण और भंडारण के विनिर्देशों के साथ-साथ जांच के लिए उपयोग की जाने वाली तकनीकों का परिचय दिया गया है। विशेष रूप से, यूवी-वी कुछ गैर-इनवेसिव तकनीकों के साथ आणविक अवशोषण, स्थिर-राज्य प्रतिदीप्ति और समय-हल किए गए प्रतिदीप्ति माप हैं, जैसे कि गतिशील प्रकाश प्रकीर्णन (डीएलएस), अंतर स्कैनिंग कैलोरीमेट्री (डीएससी), पीएच-मीटर, गतिशील चिपचिपाहट, विद्युत चालकता, घनत्व और सतह-तनाव माप का प्रयोग किया जाता है। वांछित जानकारी प्राप्त करने के लिए।

अध्याय 3 शीर्षक 'डीप यूटेक्टिक सॉल्वेंट्स के भीतर नाफथोइक एसिड के हाइड्रॉक्सी डेरिवेटिव्स के प्रोटोट्रोपिक रूप' प्रोटोट्रोपिज्म के लिए एक संभावित घुलनशील मीडिया के रूप में डीईएस की स्थिरता की पड़ताल करता है। विशेष रूप से, तीन संरचनात्मक रूप से अलग हाइड्रॉक्सी नेफथोइक एसिड डेरिवेटिव के प्रोटोट्रोपिक रूपों की जांच दो डीईएस के भीतर की गई थी, जो क्रमशः 1: 2 मोल अनुपात में एच-बॉन्ड स्वीकर्ता कोलीन क्लोराइड (सीएचसीएल) और विभिन्न एच-बॉन्ड दाताओं, यूरिया और ग्लिसरॉल (ग्लाइ) से गठित थे। कार्यात्मक समूहों की निकटता के कारण, 1,2-एचएनए और 3,2-एचएनए इंटरमोलेक्यूलर एच-बॉन्डिंग का प्रदर्शन करते हैं, जबकि 6,2-एचएनए में ऐसा कोई एच-बॉन्डिंग संभव नहीं है। विभिन्न प्रोटोट्रोपिक रूपों के बीच अंतर करने के लिए यूवी-विस आणविक अवशोषण, स्थिर-राज्य प्रतिदीप्ति, और उत्तेजित-राज्य तीव्रता क्षय माप का उपयोग किया जाता है।

अध्ययन से पता चला है कि आम ध्रुवीय सॉल्वेंट्स के विपरीत जहां 1,2-एचएनए के मोनोएनियोनिक और तटस्थ दोनों रूप मौजूद हैं, दोनों डीईएस के भीतर केवल तटस्थ रूप देखा गया

था। हालांकि, जलीय एनएओएच समाधान के अतिरिक्त सीएचसीएल: यू री में मोनोएनियोनिक 1,2-एचएनए का गठन होता है। हालांकि, 3,2-एचएनए सीएचसीएल: जी ली डीईएस के भीतर आयनिक और तटस्थ प्रोटोट्रोपिक दोनों रूपों की उपस्थिति को प्रदर्शित करता है, जबकि केवल मोनोएनियोनिक रूप सीएचसीएल: यूरिया के भीतर देखा जाता है। यहां तक कि सीएचसीएल: यू री में एसिड की उच्च शक्ति के अलावा एक तटस्थ उत्सर्जक रूप का गठन होता है। इसके अलावा, जलीय आधार को जोड़ने से सीएचसीएल: यू री में 3,2-एचएनए के डायनियोनिक रूप का निर्माण होता है, जबकि सीएचसीएल: जीली में, जोड़ा गया आधार उतनी कुशलता से डायनियोनिक रूप नहीं बनाता है। जैसा कि अपेक्षित था, 6,2-एचएनए अपने तटस्थ उत्सर्जक रूप में सीएचसीएल: यूरी में और सीएचसीएल: जीएल वार्ड में आयनिक (कार्बोक्सिलेट) रूप में मौजूद है, क्योंकि उनके एच-बॉन्ड दाता अम्लता में अंतर है। यह देखा गया कि एसिड के अतिरिक्त सीएचसीएल: यू री में एक तटस्थ रूप का गठन होता है, जबकि सीएचसीएल: जी एलवार्ड में कोई महत्वपूर्ण परिवर्तन नहीं देखा गया था। डायनोनिक रूप आधार की न्यूनतम मात्रा की उपस्थिति में दोनों डीईएस में हावी उत्सर्जक रूप है।

अध्याय 4 में 'डीप यूटेक्टिक सॉल्वैंट्स में नेफ्थलीन व्युत्पन्न जांच का प्रोटोट्रोपिक व्यवहार' शीर्षक से, टाइप-III सीएचसीएल-आधारित डीईएस में 1-नाफ्थोल, 2-नैफ्थिलामाइन और 1,8-बिस (डिमेथिलमिनो) नेफ्थलीन (डीएमएएन) के प्रोटोट्रोपिक व्यवहार की जांच की गई थी। जांच की गई जांच में, 2-नाफ्थोल, 1-नाफ्थोल और 1-नेफ्थिलामाइन मजबूत फोटोसिड के रूप में व्यवहार करते हैं, जबकि डीएमएएन एक शक्तिशाली फोटोबेस है। जांच किए गए डीईएस को यूरिया, टेट्राइथिलीन ग्लाइकोल (टीईजी), 1,4-ब्यूटेनडियोल (बीडी), एथिलीन ग्लाइकोल (ईजी), और ग्लाइ को एच-बॉन्ड दाताओं (एचबीडी) के रूप में एक सामान्य एच-बॉन्ड स्वीकर्ता (एचबीए) सीएचसीएल के साथ मिलाकर तैयार किया गया था। उत्तेजित-राज्य प्रोटोट्रोपिज्म का पता लगाने के लिए 2-नाफ्थोल के लिए, तटस्थ रूप सभी जांच किए गए डीईएस में देखा गया एकमात्र अवशोषित और उत्सर्जक रूप है जो इन डीईएस में उत्तेजित-राज्य प्रोटॉन ट्रांसफर (ईएसपीटी) की अनुपस्थिति को दर्शाता है। 1-नाफ्थोल मुख्य रूप से सभी

डीईएस के भीतर जमीनी-राज्य में अपने तटस्थ रूप में मौजूद है। हालांकि, 1-नाफथोल के तटस्थ और आयनिक दोनों रूपों को सीएचसीएल: यूरे के उत्तेजित-अवस्था में समर्थित किया जाता है, जबकि तटस्थ रूप अन्य डीईएस में पसंदीदा रूप बना हुआ है। 2-नाफथोल के समान, 1-नेफ्थिलामाइन भी जमीन और उत्तेजित अवस्था में केवल तटस्थ रूप प्रदर्शित करता है जो डीईएस में ईएसपीटी की कमी का सुझाव देता है। डीएमएएन का धनिक रूप सभी जांच किए गए डीईएस में जमीनी और उत्साहित-अवस्था में प्रमुख प्रोटोट्रोपिक रूप बना हुआ है, जो डीईएस में भी इस जांच की उच्च फोटो-बेसिकता को बरकरार रखता है।

अध्याय 5 शीर्षक 'घनत्व और गतिशील चिपचिपाहट पर तापमान और संरचना का प्रभाव (लैथेनाइड धातु लवण + यूरिया) डीप यूटेक्टिक सॉल्वैंट्स' में नए लैथेनाइड नमक-आधारित डीईएस की तैयारी और भौतिक लक्षण वर्णन शामिल है। अध्ययन में तैयार किए गए प्रकार IV डीईएस अलग-अलग सांद्रता में यूरिया के साथ लैथेनम नाइट्रेट हेक्साहाइड्रेट (एलए), सेरियम नाइट्रेट हेक्साहाइड्रेट (सीई), और गैडोलीनियम नाइट्रेट हेक्साहाइड्रेट (जीडी) से बने होते हैं। यूरिया मिश्रण को एक विस्तृत संरचना सीमा में स्थिर और स्पष्ट कमरे के तापमान तरल पदार्थ बनाने के लिए पाया गया था। डीएससी का उपयोग नए तैयार यूटेक्टिक सिस्टम के ग्लास संक्रमण तापमान (टी जी) को निर्धारित करने के लिए किया गया था। सभी दस जांच किए गए मिश्रणों के टी जी मान कमरे के तापमान से काफी नीचे थे जो यूटेक्टिक मिश्रण के भीतर आणविक और आयनिक घटकों के बीच मजबूत बातचीत का संकेत देते हैं। इन नियोटेरिक मीडिया के प्रभावी उपयोग के लिए, उनके भौतिक गुणों का आकलन आवश्यक है। इस प्रकार, ला: यूरिया, सीई: यू रिया और जीडी: यू रिया के विभिन्न संभावित यूटेक्टिक मिश्रणों का घनत्व और गतिशील चिपचिपाहट तापमान सीमा 293.15 से 363.15 K में रिपोर्ट की गई है। कुल मिलाकर, घनत्व और गतिशील चिपचिपाहट दोनों यूरिया एकाग्रता में वृद्धि के साथ कम होते पाए गए। डीईएस के घनत्व ने बढ़ते तापमान के साथ एक रैखिक कमी दिखाई, जबकि गतिशील चिपचिपाहट ने सरलीकृत अरहेनियस अभिव्यक्ति का पालन नहीं किया, बल्कि गतिशील चिपचिपाहट की तापमान निर्भरता वोगेल-

फुलचर-टैमन (वीएफटी) अभिव्यक्ति के बाद हुई। जबकि इन (लैथेनाइड नमक: यूरिया) डीईएस के लिए चिपचिपा प्रवाह (ई ए, η) की सक्रियण ऊर्जा (सीएचसीएल + एच-बॉन्ड दाता) डीईएस के करीब है, उनकी चिपचिपाहट-तापमान निर्भरता आम इमिडाज़ोलियम आयनिक तरल पदार्थ के समान है।

अध्याय 6 जिसका शीर्षक है '(लैथेनाइड धातु लवण + यूरिया) के भीतर एकत्रीकरण डीप यूटेक्टिक सॉल्वैंट्स' पहले एक व्यापक रूप से मान्यता प्राप्त पीएएच पाइरीन के अंतर-आणविक एकत्रीकरण को प्रस्तुत करता है, जिसके बाद लैथेनाइड नमक आधारित-डीईएस के भीतर सामान्य आयनिक और गैर-आयनिक सर्फेक्टेंट के स्व-असेंबली व्यवहार का विस्तृत अध्ययन किया जाता है। पाइरीन स्व-एकत्रीकरण आइसोट्रोपिक सॉल्वैंट्स और कार्बनिक सॉल्वैंट्स, आयनिक तरल पदार्थ, या अन्य डीईएस सहित सामान्य तरल पदार्थों में μM एकाग्रता पर होने के लिए नहीं जाना जाता है। हालांकि, अलग-अलग रचनाओं के ला: यूरी और जीडी: यू री डीईएस अभूतपूर्व कम सांद्रता पर पाइरीन के एकत्रीकरण का समर्थन करते हैं जो ~ 473 एनएम पर एक व्यापक संरचनाहीन बैंड द्वारा प्रकट होता है, साथ ही हस्ताक्षर उच्च ऊर्जा (370-420 एनएम के आसपास के क्षेत्र में) विब्रोनिक रूप से हल किए गए संरचित उत्सर्जन के साथ। इसे पाइरीन के π -क्लाउड की पॉलीकेनिक प्रजातियों के साथ अधिमन्य बातचीत के लिए जिम्मेदार ठहराया जा सकता है, जिसमें लैथेनाइड शामिल है, जिसके परिणामस्वरूप यूरिया-पानी एच-बॉन्डेड नैनो-डोमेन के आसपास के क्षेत्र में पाइरीन अणुओं को एक साथ लाया जाता है।

हमने सर्फेक्टेंट सेल्फ-असेंबली गठन का समर्थन करने में उनकी क्षमता के लिए इन नवजात डीईएस की भी जांच की है। आयनिक सर्फेक्टेंट एसडीएस, कैनिक सर्फेक्टेंट सीटीएबी और गैर-आयनिक सर्फेक्टेंट टीएक्स -100 के एकत्रीकरण व्यवहार का अध्ययन सीई: यूरिया और ला: यू रे के भीतर किया जाता है। मिसेल गठन फ्लोरेसेंस प्रोब पाइचो का उपयोग करके स्थापित किया गया है जिसने अलग-अलग सर्फेक्टेंट एकाग्रता के साथ प्रतिदीप्ति तीव्रता में बदलाव दिखाया। आयनिक और गैर-आयनिक सर्फेक्टेंट दोनों के एकत्रीकरण व्यवहार पर यूरिया की भूमिका को समझने के लिए ला: यू री के तीन अलग-अलग यूटेक्टिक मिश्रणों का पता लगाया गया है। डीईएस संरचना के अलावा, सभी तीन सर्फेक्टेंट के लिए

मिसेलाइजेशन पर तापमान के प्रभाव की भी जांच की जाती है। इन डीईएस की उच्च सामंजस्य और हाइड्रोफिलिक प्रकृति उन्हें माइसेलाइजेशन प्रक्रिया का समर्थन करने के लिए उपयुक्त उम्मीदवारों के रूप में ब्रांड करती है।

'निष्कर्ष और भविष्य की संभावनाएं' शीर्षक वाले अध्याय 7 में समग्र जांच और काम के भविष्य के दायरे से निकाले गए निष्कर्षों को शामिल किया गया है। संक्षेप में, यह सुझाव दिया जाता है कि घुलनशील मीडिया के रूप में डीईएस की फ्लोरोफोरे के विभिन्न प्रोटोट्रॉपिक रूपों के अस्तित्व को नियंत्रित करने में महत्वपूर्ण भूमिका है। इसके अलावा, हाइड्रेटेड धातु नमक-आधारित डीईएस सिस्टम अकादमिक और उद्योगों दोनों में संभावित अनुप्रयोगों के साथ एकत्रीकरण के लिए एक कुशल घुलनशील मीडिया साबित हो सकता है।

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LIST OF ABBREVIATIONS

Abbreviation	Full form
1,2-HNA	1-Hydroxy-2-naphthoic acid
3,2-HNA	3-Hydroxy-2-naphthoic acid
6,2-HNA	6-Hydroxy-2-naphthoic acid
ATC	Automatic temperature compensation
BD	1,4-Butanediaol
CAC	Critical aggregation concentration
CCD	Charge coupled device
CMC	Critical micelle concentration
CTAB	Cetyltrimethylammonium bromide
ChCl	Choline Chloride
DES	Deep Eutectic Solvent
DLS	Dynamic light scattering
DLS	Dynamic light scattering
DMAN	(Bis-1,8-dimethylamino)naphthalene
EC	Electrolyte conductivity
EG	Ethylene glycol
ESIPT	Excited-state intramolecular proton transfer
ESPT	Excited-state proton transfer
Gly	Glycerol
HBA	Hydrogen Bond Acceptor

HBD	Hydrogen bond donors
IL	Ionic liquid
Py	Pyrene
PyCHO	Pyrene-1-carboxyaldehyde
SDS	Sodiumdodecyl sulfate
TCSPC	Time-correlated single photon counting
TEG	Tetraethyleneglycol
TX-100	Triton X-100
UV	Ultraviolet
Vis	Visible
VOC	Volatile organic compound