Novel Green Solvents for CO_2 Capture

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Abstract--- Novel amine based deep eutectic solvents (DESs) were prepared. The solubility of carbon dioxide in these DESs, (Choline chloride + Monoethanolamine), (Choline chloride + Diethanolamine) and (Choline chloride + Methyldiethanolamine), was measured. The solubility experiments were performed based on the conditions of the absorber in the post-combustion capture process (P_{CO2} = 15 kPa and T = 40°C). Results showed that amine-based DESs have absorption capacity that is comparable to aqueous amine solutions. The solubility of CO_2 was found to increase as the molar ratio of the amine in the DES increased.

Keywords---CO_2; Deep Eutectic Solvent; Absorption; Environment; Power Plants.

I. Introduction

Green Engineering focuses on the design of materials, processes, systems, and devices with the objective of minimizing overall environmental impact, including energy utilization and waste production, throughout the entire life cycle of a product or process.

Many scientists believe that the major cause of global warming is the emission of greenhouse gases, such as carbon dioxide (CO_2). It has been estimated that CO_2 is contributing to about 60% of the global warming effects [Yamasaki, 2003]. The CO_2 capture and sequestration from fossil-fuelled power plants is drawing increasing attention as a potential method for controlling greenhouse gas emissions. However, several technological, economic and environmental issues as well as safety problems remain to be solved, such as (i) increasing the CO_2 capture efficiency, (ii) reducing process costs, and (iii) verifying environmental sustainability of CO_2 storage [Pires et al., 2011]. The most mature technology for the CO_2 post-combustion is the amine-based absorption due to its high affinity to CO_2 [Abu-Zahra et al., 2007]. However, this process demands intensive energy use to break the chemical bonds between the absorbents and the absorbed CO_2 in the solvent regeneration step. Therefore, it is of benefit to find alternative solvents that compromise the high affinity for CO_2 with the ease of solvent regeneration and reuse. Recently, a new group of solvents called deep eutectic solvents (DESs) has attracted intensive interest in the research world. DESs are composed of a mixture of a salt and a hydrogen bond donor (HBD), which results in a liquid medium with a freezing point lower than the freezing points of the constituting compounds [Zhang et al. 2013]. DESs are advantageous in comparison to ionic liquids (ILs) because they are easily synthesized and their component salts are much cheaper than those of ILs. In addition, their components can be selected to be biodegradable and nontoxic.(Hayyan et al. 2013) DESs have found applications in various fields as reported by many research groups [Zhang et al. 2013].

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II. Description Of The Work

In this study, choline chloride (ChCl) and different amines as HBDs, namely: monoethanolamine (MEA), Diethanolamine (DEA), and methyldiethanolamine (MDEA) were used for the preparation of the DESs. A jacketed vessel with a mechanical stirrer was used to mix each salt with different HBDs in different molar ratios at 80 ºC until a homogenous liquid was observed. Table 1 shows the compositions and abbreviations of the DESs used in this study.

Solubility measurements were performed in a variable volume high-pressure equilibrium cell. This cell was equipped with a stirrer for optimal mixing of the phases, three sapphire windows and a heating jacket, which allowed operation at a constant temperature. A motorized volume variation - piston actuation with a nitrogen pressure for the precise measurement of the equilibrium at a constant pressure was connected to the cell.

III. Results & Discussion

The measured solubility of CO_2 in ChCl:MEA DESs at room temperature and atmospheric pressure are using two different methods is shown in Fig. 1. It is obvious from Fig. 1, Fig. 2 and Fig. 3 that the type of salt, HBD, and the mole ratio of salt:HBD affected the solubility of CO_2 in the tested DESs.

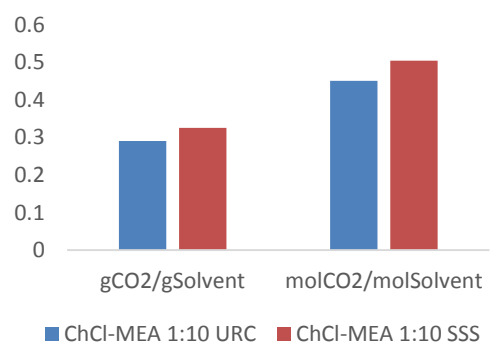

Fig. 1 Solubility of CO_2 in ChCl:MEA DES

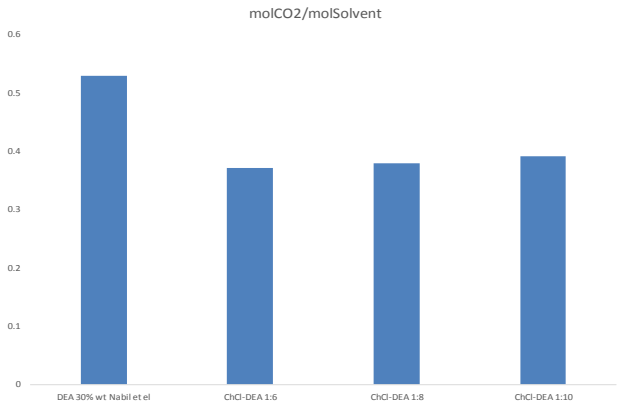

Fig. 2 Solubility of CO_2 in ChCl:DEA DES

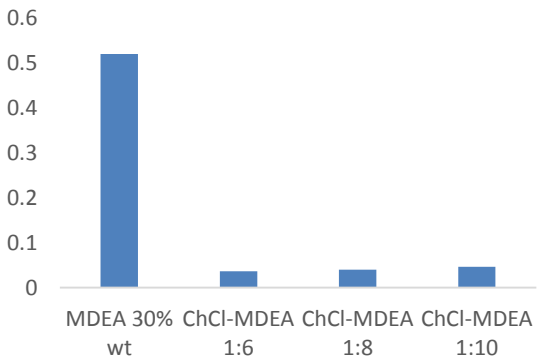

Fig. 3 Solubility of CO_2 in ChCl:MDEA DES

When compared to the work reported by Sarwono et al., it is clear that solubility of CO_2 in anine based DESs have higher values than those in ethylene glycol or glycerol based DESs.

IV. Conclusions

In this study, we measured the solubility of carbon dioxide in three DESs and for three different choline chloride:amine molar ratios. The solubility experiments were performed based on the conditions of the absorber in the post-combustion capture process (P_{CO2} = 15kPa and T = 40°C). Results revealed that amine-based DESs have absorption capacity that is comparable to pure amines. The solubility of CO_2 was found to increase as the molar ratio of the amine in the DES increased.

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