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# Research Trends of Carbon Dioxide Capture using Ionic Liquids and Aqueous Amine-Ionic Liquids Mixtures

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## ABSTRACT

Anthropogenic CO<sub>2</sub> emissions has led to global climate change and widely contributed to global warming since its concentration has been increasing over time. It has attracted vast attention worldwide. Currently, the different CO<sub>2</sub> capture technologies available include absorption, solid adsorption and membrane separation. Chemical absorption technology is regarded as the most mature technology and is commercially used in the industry. However, the key challenge is to find the most efficient solvent in capturing CO<sub>2</sub>. This paper reviews several types of CO<sub>2</sub> capture technologies and the various factors influencing the CO<sub>2</sub> absorption process, resulting in the development of a novel solvent for CO<sub>2</sub> capture.

**Keywords:** *chemical absorption, amine, ionic liquids, CO<sub>2</sub> solubility*

## INTRODUCTION

Generally, major sources of carbon dioxide (CO<sub>2</sub>) emission are from industries such as natural gas treatments, fossil fuel power plant and petroleum industries. Flue gas from coal combustion contains hazardous pollutants such as CO<sub>2</sub>, mercury (Hg) and sulfur dioxide (SO<sub>2</sub>), at different compositions and percentages. Carbon dioxide has been considered a major contributor to greenhouse gases since its concentration in the atmosphere

has been increasing over time. Excessive CO<sub>2</sub> emission has a negative impact that leads to global climate change and disruption of the ecosystem. In order to maintain a safe and secure environment, CO<sub>2</sub> emissions can alternatively be controlled by carbon capture and storage (CCS) [1], whereby CO<sub>2</sub> is separated from flue gas and permanently stored in large subsurface geologic reservoirs.

Various technologies that have been developed for CO<sub>2</sub> capture are gas membrane separation, solid adsorption, and absorption by chemical/physical solvents[1][2][3]. Table 1 shows a comparison of three different CO<sub>2</sub> capture methods. These methods utilize different approaches which can be adapted to the treatment of industrial effluents. In the chemical industry, the use of separation technologies correlate directly with operational confidence [4]. The absorption technology is the most common method for capturing CO<sub>2</sub>, since it is applicable to industry demands and scale. Efficiency of the carbon dioxide absorption technology can be as high as 98%. The source of energy penalty in absorption-based methods is from thermal regeneration, h leads to high-energy consumption. This may be because a large amount of water is vaporized during solvent regeneration. Compared to other CO<sub>2</sub> capture methods, adsorption requires a slightly lower amount of energy for the regeneration process. This is because there is low steam loss during CO<sub>2</sub> desorption [5]. Energy penalty in the adsorption process comes from either thermal or vacuum regenerations. In the membrane separation methods, energy penalty is from feed compression or/and vacuum on the permeate. Membrane separation technology is seldom used as the operating flexibility of the membrane system is strongly affected by flue gas conditions, making it difficult to apply the technology [6].

Absorption processes are commonly employed in chemical industries, where they are significantly utilized for CCS applications, and in the treatment of natural gases. One of the most effective methods for CO<sub>2</sub> capturing is by the use of amine solvents in gas absorption. However, the use of alkanolamines for CO<sub>2</sub> capture has several drawbacks, such as high incidence of corrosion, volatility and proneness to thermal and oxidative degradation [7][8]. These limitations cause extra energy consumption and require more investment on equipment [9]. Therefore, the detriment of using amine solvents for CO<sub>2</sub> capture drives researchers to find alternative solvents with improved absorption performance.

**Table I: Comparison of Post-Combustion CO<sub>2</sub> Capture Methods**

	<b>Absorption</b>	<b>Adsorption</b>	<b>Membrane</b>	<b>Ref</b>
<b>Commercial usage in CPI<sup>a</sup></b>	High	Moderate	Low	[4]
<b>Operational Confidence</b>	High	High but complex	Low to moderate	[4]
<b>Operating Flexibility</b>	Moderate	Moderate	High (CO <sub>2</sub> > 20%) Low (CO <sub>2</sub> < 20%)	[10]
<b>Energy Requirement</b>	4-6 MJ/ kg CO <sub>2</sub>	2-3 MJ/kg CO <sub>2</sub>	0.5-6 MJ/ kg CO <sub>2</sub>	[10]
<b>CO<sub>2</sub> Recovery</b>	90-98%	80-95%	80-90%	[6] [10]
<b>Scale</b>	Industrial	Pilot	Experimental	[11]
<b>Primary source of energy penalty</b>	Solvent Regeneration (Thermal)	Sorbent Regeneration (Thermal/ Vacuum)	Compression on feed and/ or vacuum on permeate	[4]
<b>Development trends</b>	New chemistry, thermal integration	New chemistry, process configuration	New membrane, process configuration	[4]

<sup>a</sup> Chemical Process Industry

The use of amines and ionic liquid mixtures as improved solvents has been suggested to overcome these drawbacks[12]. Ionic liquids (ILs) are the organic salts that form stable liquids below 100°C, or even at room temperature. The recent concept of using ILs for CO<sub>2</sub> capture has become attractive when it was discovered that they had CO<sub>2</sub> absorption properties [3][13][14]. The advantages of ILs are that they have low vapor pressure and are thermally stable over a wide range of temperature. However, most ILs are not cost effective compared to commercial amines. Thus, developing economical and energy efficient CO<sub>2</sub> capture technologies is urgently required.

With respect to this, the desirable properties of ILs and alkanolamines may be integrated, so that energy can be saved during the regeneration process. The aim of this short review is to summarize research trends in CO<sub>2</sub> capture, and the factors influencing the CO<sub>2</sub> capture when using ionic liquids and aqueous amine-ionic liquids mixtures.

## RESEARCH PROGRESS ON CO<sub>2</sub> CAPTURE

### Ionic Liquid

In the recent decade, ionic liquids have been considered as good absorbents for CO<sub>2</sub> capture. Zubeir *et al.*, [15] studied the solubility of CO<sub>2</sub> in low viscous ILs; 1-butyl-3-methylimidazolium tricyanomethanide [bmim][tcm] for the first time, using it as a solvent for capturing CO<sub>2</sub>. They performed the experiment at 288.15K to 363.15K with pressure of 0.01 to 10 MPa using two different methods (gravimetric and volumetric). The authors discovered that [bmim][tcm] had good solubility performance compared to other non-fluorinated ionic liquids. This indicated that [bmim][tcm] was a suitable and promising solvent candidate for carbon capture.

In a subsequent research, three ionic liquids; Methyl Trioctyl Ammonium Bis (trifluoromethylsulfonyl)imide [MOA][Tf<sub>2</sub>N], 1-butyl-3-Methylimidazolium Bis (trifluoromethylsulfonyl)imide [bmim][Tf<sub>2</sub>N] and 1-butyl-3-Methylimidazolium Methyl Sulfate [bmim][MeSO<sub>4</sub>] were used by Bahadur *et al.*, [16] to capture CO<sub>2</sub>. They used gravimetric analysis to measure CO<sub>2</sub> solubility and found that absorption increased with pressure and decreased with temperature. [MOA][Tf<sub>2</sub>N] was noted to have the highest CO<sub>2</sub> solubility, followed by [bmim][Tf<sub>2</sub>N] and [bmim][MeSO<sub>4</sub>].

Most CO<sub>2</sub> absorption performance studies were carried out using imidazolium ionic liquids. Pinto *et al.*, [17] investigated CO<sub>2</sub> solubility performance using pyridinium-based ionic liquid, 1-ethylpyridinium ethylsulfate [C2Py][EtSO<sub>4</sub>]. The temperature was set at 298.2 K and pressure up to 1.6 MPa. They compared the CO<sub>2</sub> loading performance between [C2Py][EtSO<sub>4</sub>] and an equivalent imidazolium-based ionic liquids, 1-ethylimidazoliumethylsulfate [C2mim][EtSO<sub>4</sub>] [18]. The authors found that pyridinium ionic liquids exhibited slightly lower CO<sub>2</sub> absorption. This may be due to greater steric effects on [C2mim][EtSO<sub>4</sub>] that led to the generation of more free volume. Pyridinium-based ionic liquids were considered more biodegradable and cheaper compared to imidazolium ionic liquids, and much more promising when used in real scaled-up CO<sub>2</sub> absorption.

The CO<sub>2</sub> solubility performance using six hydroxyl ammonium ionic liquids; 2-hydroxyethanaminium acetate [hea], bis (2-hydroxyethyl) ammonium acetate [bheaa], 2-hydroxy-N-(2-hydroxyethyl)-N-methylethanaminium acetate [hhemea], 2-hydroxyethanaminium lactate [hel], bis (2-hydroxyethyl) ammonium lactate [bheal] and 2-hydroxy-N-(2-hydroxyethyl)-N-methylethanaminium lactate [hhemel] were studied by Kurnia *et al.*, [19]. They observed the CO<sub>2</sub> solubility results in the sequences of [hea] > [bheaa]  $\approx$  [hel] > [bheal] > [hhemel] > [hhemea]. Enthalphy and entropy from estimated Henry's constant showed that solubility increased with pressure and decreased with temperature.

## AQUEOUS AMINE-IONIC LIQUID MIXTURES

Recently, Lv *et al.*, [20] forwarded the idea of mixing Monoethanolamine (MEA) and hydrophilic amino acid ionic liquid [C<sub>2</sub>OHmim][Gly] in order to study CO<sub>2</sub> capture performance. They found that the CO<sub>2</sub> absorption capacity of the mixed solution was higher compared to the total absorption of MEA single solution. The MEA/[C<sub>2</sub>OHmim] system tend reacts with CO<sub>2</sub> as zwitterions They act as a base to participate in the carbamate formation.

This is in agreement with the findings of Taib and Murugesan [21] which compared the CO<sub>2</sub> absorption performance of ionic liquids [bmim][BF<sub>4</sub>] and [bheaa], to MEA solution. Both amine ionic liquid mixtures were found to have higher CO<sub>2</sub> loading compared with single amines or ionic liquid solutions. In subsequent research, Feng *et al.*, [22] found that the addition of ionic liquids ([N<sub>111</sub>][Gly]), ([N<sub>222</sub>][Gly]), ([N<sub>111</sub>][Lys]) and ([N<sub>222</sub>][Lys]) to amine mixtures greatly reinforced CO<sub>2</sub> absorption. .

In contrast, Fu and Zhang [23] found that CO<sub>2</sub> loading decreased significantly when 1-butyl-3-methylimidazolium glycinate [bmim][Gly] was added to the methyldiethanolamine MDEA aqueous solution. However, the absorption rate increased with the addition of ILs into MDEA aqueous solution. Results from the study of Xu *et al.*, [24] supported the findings, where the addition of ionic liquids in amine solution was shown to decrease CO<sub>2</sub> absorption efficiency. They conducted the experiment using two low viscous ionic liquids; [C<sub>2</sub>OHmim][DCA] and [bmim][DCA], mixed with an aqueous MEA solution. The authors reported that both [C<sub>2</sub>OHmim]

[DCA] and [bmim][DCA] gave slightly reduced solubility, due to salting out effects that inhibited CO<sub>2</sub> absorption.

Ahmady *et al.*, [25] also found that the amount of CO<sub>2</sub> loading declined with the addition of [bmim][DCA], [bmim][BF<sub>4</sub>] and [bmim][Ac], into MDEA solution. Similarly, results from Sairi *et al.*, [26] demonstrated that the use of MDEA and [gua]<sup>+</sup>[OTf]<sup>-</sup> mixtures resulted in less CO<sub>2</sub> absorption, as [gua]<sup>+</sup>[OTf]<sup>-</sup> hindered the tertiary amine of MDEA.

Table 2 shows summarizes recent research findings in CO<sub>2</sub> capture using amine and ionic liquid mixtures.

**Table 2: Summary of the Effects of Various Aqueous Amine-Ionic Liquid Mixtures on CO<sub>2</sub> Loading**

Amine	Ionic Liquids	CO <sub>2</sub> Loading	Ref
MEA	• hydrophilic amino acid ionic liquid [C <sub>2</sub> OHmim][Gly]	Increase	[20]
MEA	• bis(2 hydroxyethyl)ammonium acetate (bheea) • 1-butyl-3-methylimidazolium tetrafluoroborate [bmim][BF <sub>4</sub> ]	Increase	[21]
MDEA	• tetramethylammonium glycinate [N <sub>1111</sub> ][Gly] • tetraethylammonium glycinate [N <sub>2222</sub> ][Gly] • tetramethylammonium lysinate [N <sub>1111</sub> ][Lys] • tetraethylammonium lysinate [N <sub>2222</sub> ][Lys]	Enhance	[22]
MDEA	• 1-butyl-3-methylimidazolium glycinate [bmim][Gly]	Decrease	[23]
MEA	• 1-(2-hydroxyethyl)-3-methyl-imidazolium dicyanamide [C <sub>2</sub> OHmim][DCA] • 1-butyl-3-methylimidazolium [Bmim][DCA]	Decrease	[24]
MDEA	• 1-butyl-3-methyl-imidazolium tetrafluoroborate [bmim][BF <sub>4</sub> ] • 1-butyl-3-methyl-imidazolium acetate [bmim][Ac] • 1-butyl-3-methyl-imidazolium dicyanamide [bmim][DCA]	Decrease	[25]



Amine	Ionic Liquids	CO <sub>2</sub> Loading	Ref
MDEA	• Guanidium trifluoromethanesulfonate [gua] <sup>+</sup> [OTf] <sup>-</sup>	Decrease	[26]
MDEA	• Guanidium tris(pentafluoroethyl) trifluorophosphate [gua] <sup>+</sup> [FAP] <sup>-</sup>	Decrease	[27]the solubility of CO <sub>2</sub> in aqueous blends of N-methyldiethanolamine (MDEA
AMP	• N-butyl-3-methylpyridinium tetrafluoroborate, [B <sub>3</sub> MPYR][BF <sub>4</sub> ]	Decrease	[28]

## FACTORS AFFECTING ABSORPTION PERFORMANCE

In recent years, several experimental works have been carried out to investigate the efficiency of CO<sub>2</sub> capture. Details on the effect of temperature, pressure, absorbent/solvent concentration, anion types, and alkyl chain length in cations, on the performance of CO<sub>2</sub> capture is further discussed in following subsections.

### Effects of Temperature and Pressure

Gas absorption theories by chemical reaction have assumed in isothermal conditions to facilitate the experimental procedure. Generally, liquid phase temperature can increase due to the heat given off by the solution, or even by the reaction itself. In CO<sub>2</sub> removal with alkanolamine solution, high thermal effects have been recorded.

The study of CO<sub>2</sub> solubility using aqueous mixtures of MEA + Ionic liquids; bis (2-hydroxyethyl) ammonium acetate [bheaa] and 1-butyl-3-methylimidazolium tetrafluoroborate [bmim] [BF<sub>4</sub>] was conducted by Taib and Murugesan [21]. They discovered that the solubility of CO<sub>2</sub> increased linearly with pressure, for both aqueous bheaa and in addition of MEA solution. A similar trend was also reported when they used aqueous [bmim] [BF<sub>4</sub>]. The addition of ionic liquid was expected predominated the process by physical solubility of CO<sub>2</sub>. In terms of temperature effects, they found that there was not much change in CO<sub>2</sub> absorption when temperature was increased in the range of 298.15K-313.15K.

This CO<sub>2</sub> solubility pattern is in agreement with findings of other researchers. Feng *et al.*, [22] used four amino acid based ILs: tetramethylammonium glycinate [N<sub>1111</sub>][Gly], tetraethylammonium glycinate [N<sub>2222</sub>][Gly], tetramethylammonium lysinate [N<sub>1111</sub>][Lys], and tetraethylammonium lysinate [N<sub>2222</sub>][Lys] to investigate the effect of temperature ranging 298K to 318K towards the absorption of CO<sub>2</sub> in ILs + MDEA aqueous solutions. They found that raising the temperature increased the absorption rate only during the first 20 minutes. This is due to the larger reaction rate and might be attributed to the solution becoming less viscous at higher temperatures, which led to higher diffusibility. However, a further increase of temperature resulted in less CO<sub>2</sub> amount being absorbed.

This similar trend was also seen by Xu *et al.*, [24] in their work where CO<sub>2</sub> solubility decreased with an increase in temperature. The authors used two low viscous ionic liquids; [C<sub>2</sub>OHmim][DCA] and [Bmim][DCA] mixed with aqueous 30 wt% MEA. In terms of pressure effects toward CO<sub>2</sub> absorption, results showed that CO<sub>2</sub> solubility was directly proportional to the increase in CO<sub>2</sub> partial pressure.

The study of the effects of temperature and pressure on CO<sub>2</sub> absorption in aqueous N-methyldiethanolamine (MDEA) and guanidinium trifluoromethanesulfonate, [gua]<sup>+</sup> [OTf]<sup>-</sup> ionic liquid system at elevated pressures and various temperatures were conducted by Sairi *et al.*, [26]. Their finding is in agreement with the expected general trend. Equilibrium loading was found to decrease with temperature and increase with pressure. This indicated that more gas was present in the solution with a lower temperature, compared to a solution of higher temperature. This trend can be explained by the fact that vapor pressure increases with temperature. Based on Henry's law, the solubility of a gas in a liquid is proportional to the partial pressure of the gas above the surface of the liquid [29]. The same phenomenon was also reported by Anthony *et al.*, [30] and Husson-Borg *et al.*, [31].

In 2012, Aziz *et al.*, [27] demonstrated the effects of temperature and pressure on absorption by conducting an experiment, using aqueous mixtures of MDEA and [gua]<sup>+</sup>[FAP]<sup>-</sup>. They concluded that the solubility of carbon dioxide was inversely proportional to an increase in temperature and pressure.

## Effects of Anions and Cations of Ionic Liquids

Anions and cations also provide significant impact on absorption systems and CO<sub>2</sub> solubility.

With respect to the influence of anion and cation, the effect of length of the alkyl chain was evaluated by Gonzalez-Miquel *et al.*, [32]. They compared three different imidazolium based ionic liquids; 1-hexyl-3-methylimidazolium bis (trifluoromethylsulfonyl) imide [hxmim][Tf<sub>2</sub>N], 1-octyl-3-methylimidazolium bis (trifluoromethylsulfonyl) imide [omim][Tf<sub>2</sub>N] and 1-decyl-3-methylimidazolium bis (trifluoromethylsulfonyl) imide [dcmim][Tf<sub>2</sub>N] in CO<sub>2</sub> capture. They found that CO<sub>2</sub> absorption in ILs slightly increased with increasing length of cation alkyl chain. This solubility pattern was supported by evaluating the Henry's law constant ( $K_H$ ) of CO<sub>2</sub>, where  $K_H$  values decreased with increasing length of the alkyl chain, indicating higher CO<sub>2</sub> solubility.

Yunus *et al.*, [33] investigated the effect of alkyl chain length in four of pyridinium based ionic liquids toward CO<sub>2</sub> capture where the CO<sub>2</sub> solubility in [C4py][Tf<sub>2</sub>N], [C8py][Tf<sub>2</sub>N], [C10py][Tf<sub>2</sub>N], and [C12py][Tf<sub>2</sub>N] were measured at 3 different temperatures of 298.15 K, 313.15 K and 333.15 K. They found that [C12py][Tf<sub>2</sub>N] had the greatest total of CO<sub>2</sub> absorbed compared to others, since the absorption performance depends on the length of chain. Aki *et al.*, [34] reported that increasing the cation alkyl chain length of the ionic liquid will decrease the density of the ionic liquid and subsequently increase free volume. Space filling allows for greater absorption of CO<sub>2</sub>. Thus, it was concluded that an increase in the cation alkyl chain length, slightly increases the CO<sub>2</sub> solubility in the ionic liquid [35].

Most studies have proved that the solubility of CO<sub>2</sub> was far more influenced by the nature of anions, compared to cations of the ILs [36] [37][38]. Bahadur *et al.*, studied the effect of anions and cations of ionic liquids on CO<sub>2</sub> solubility. They used Methyl Trioctyl Ammonium Bis (trifluoromethylsulfonyl) imide [MOA][Tf<sub>2</sub>N], 1-butyl-3-Methylimidazolium Bis (trifluoromethylsulfonyl) imide [bmim][Tf<sub>2</sub>N] and 1-butyl-3-Methylimidazolium Methyl Sulfate [bmim][MeSO<sub>4</sub>] as the solvent to absorb CO<sub>2</sub>. The authors reported that CO<sub>2</sub> solubility is in the sequence of [MOA]

$[\text{Tf}_2\text{N}] > [\text{bmim}][\text{Tf}_2\text{N}] > [\text{bmim}][\text{MeSO}_4]$ . The increasing fluorination of the ionic liquids resulted in higher absorption. Solubility was influenced by the strong interaction between anion gas and the molar volume of the ionic liquid. When the molar volume of the ILs increases, the void space eventually increases, allowing for more gas to be dissolved.

Similar solubility trends was also reported by Ramdin *et al.*, [39] using inexpensive solvents; tributylmethylammonium methylsulfate [TBMN][ $\text{MeSO}_4$ ] and tributylmethylphosphonium methylsulfate [TBMP][ $\text{MeSO}_4$ ] for capturing  $\text{CO}_2$ . The authors compared the solvents with commonly used industrial ILs. Their findings revealed that both [TBMN][ $\text{MeSO}_4$ ] and [TBMP][ $\text{MeSO}_4$ ], had slightly higher solubility compared to 1-butyl-3-methylimidazolium methylsulfate [bmim][ $\text{MeSO}_4$ ] [40]. However, by comparing with 1-butyl-3-methylimidazolium bis(trifluoromethylsulfonyl) imide [bmim][ $\text{Tf}_2\text{N}$ ] [41], obviously fluorinated anion has a much larger effect on solubility. This explanation was strongly supported by the sequences of  $\text{CO}_2$  solubility reported by Sharma *et al.*, [42] where;  $\text{BF}_4^- < \text{DCA}^- < \text{PF}_6^- < \text{TfO}^- < \text{Tf}_2\text{N}^-$ . The anion effect on  $\text{CO}_2$  solubility was attributed to the presence of the fluoroalkyl group, which led to highest  $\text{CO}_2$  solubility [43][44][45][46], and due to the weaker ILs cation-anion interactions. Table 3 lists anion classification and  $\text{CO}_2$  solubility.

**Table 3: Influence of Anions in Different Ionic Liquids**

Anion	Nomenclature	Classification	$\text{CO}_2$ solubility
Tetrafluoroborate	$\text{BF}_4$	Fluorinated	High
Hexafluorophosphate	$\text{PF}_6$		
Trifluoromethanesulfonate	TfO		
Bis (trifluoromethylsulfonyl) imide	$\text{Tf}_2\text{N}$		
Tris (trifluoromethylsulfonyl) methide	methide	Non fluorinated	Low
Dicyanamide	DCA		
Nitrate	$\text{NO}_3$		

## Effects of Ionic Liquids / Amines Concentrations

Recently, Lv *et al.*, [7] compared the CO<sub>2</sub> capture into different mole ratios of MEA / [C<sub>2</sub>OHmim] [Gly] mixtures. They found that the absorption capacity of aqueous MEA solution was lower than pure ionic liquid. The absorption capacity increased with increasing [C<sub>2</sub>OHmim] [Gly] concentration for mixed solutions of MEA and [C<sub>2</sub>OHmim] [Gly].

Nordin *et al.*, [28] evaluated the interaction of 2- amino-2-methyl-1 propanol (AMP) with N-butyl-3-methylpyridinium tetrafluoroborate, [B<sub>3</sub>MPYR][BF<sub>4</sub>]. The amount of CO<sub>2</sub> absorbed was found to decrease with increasing of [B<sub>3</sub>MPYR][BF<sub>4</sub>] concentrations. The acidity of the ionic liquid reduced the alkalinity of aqueous AMP in the mixtures, causing the driving force for the mass transfer to decrease and inhibit CO<sub>2</sub> absorption [27]. Blends of methyldietanolamine (MDEA) with three different types of ionic liquids, 1-butyl-3-methyl-imidazolium tetrafluoroborate [bmim][BF<sub>4</sub>], 1-butyl-3-methyl-imidazolium acetate [bmim][Ac] and 1-butyl-3-methyl-imidazolium dicyanamide [bmim][DCA] have been extensively studied by Ahmady *et al.*, [25] who observed similar trends.

## CONCLUSION

Generally, the addition of ionic liquids into aqueous amine solution enhanced CO<sub>2</sub> absorption and CO<sub>2</sub> loading performance. However, in some cases there is still contrasting trends found by researchers. Absorption was seen to decrease with increasing temperatures, and linearly increased with increasing pressure. Carbon dioxide solubility was found to decrease with increased concentrations of amine or ionic liquids, due to the increase in viscosity and decreased presence of water molecules in the solution. Anions and cations significantly affects CO<sub>2</sub> absorption. Solubility is more affected by the nature of anions, compared to cations. Ionic liquids with fluoroalkyl groups absorb a high amount of CO<sub>2</sub> compared to non-fluorinated ionic liquids. Cation alkyl chains impart a slight effect on CO<sub>2</sub> solubility. Increasing the chain length will slightly increase CO<sub>2</sub> solubility. Selecting the right combination of amine-ionic liquid mixtures can improve the performance of CO<sub>2</sub> absorption.

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