Carbon Dioxide Capture with Choline-Based DESs Solvents

Gabriela Ciriaco Villegas*, Alain Ledoux, Lionel Estel, Arnaud Delanney

INSA Rouen Normandie, Univ. Rouen Normandie, Normandie Université, LSPC, UR4704, F 76000 Rouen, France

**Corresponding author: gabriela.ciriaco_villegas@insa-rouen.fr*

Highlights

- New solvents for carbon dioxide capture.
- Reduced energy requirement for desorption.
- Very high stability of solvents.
- Low environmental impact.

1. Introduction

Humanity is becoming aware of global warming, as according to IPCC reports, this trend is largely linked to greenhouse gases emissions[1]. Global carbon emissions from fossil fuels have risen again in 2023. The impacts of climate change are evident all around us, and carbon dioxide remains the most human emitted greenhouse gases in the world[2]. In the context of increasing energy demand, carbon dioxide capture and storage continue to receive much attention to further reduce these emissions. Amine absorption is currently the most mature technology for carbon dioxide capture. Despite their high absorption capacity, these absorbents carry a drawback such as solvent loss due to the heating required for regeneration and corrosiveness[3]. Deep eutectic solvents (DESs) have been considered as a new type of ionic liquids with improved synthesis and lower environmental impact. Choline-based eutectic solvents represent a promising category of solvents for carbon dioxide separation. The main concern for the application of DESs is their high viscosity. High viscosity inhibits mass transfer between gas and DES[4], one method to address this problem is to form aqueous deep eutectic solvents.

2. Methods

In this work, Choline-Based DES have been prepared with different amounts of water. The Henry constants and mass transfer kinetics were determined experimentally for CO_2 capture by different mixtures. On this purpose, two devices have been instrumented and optimized. As shown in Figure 1(a), a stirred tank reactor with a volume of 0.305 L (±0.020 L), handled with Labview software was operated to determine Henry's constants. A heat transfer fluid circulating through the envelope controls the temperature. The reactor and buffer tank are fitted with temperature and pressure sensors.

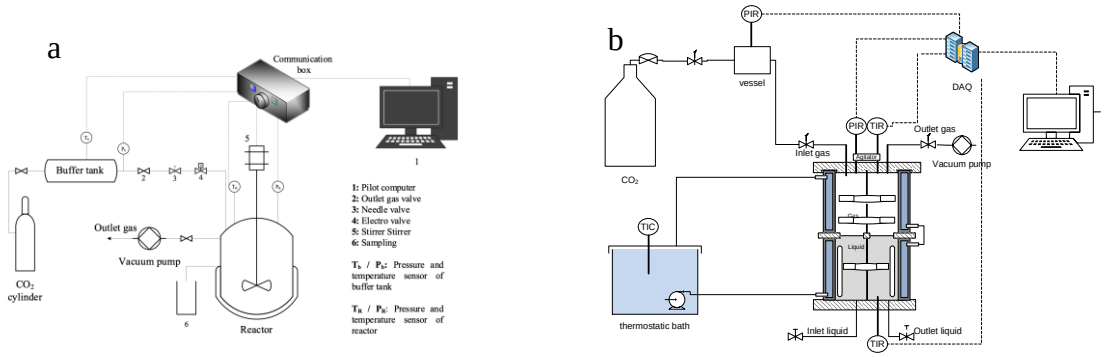

Figure 1. experimental setup **(a)** autoclave reactor **(b)** Lewis' Cell

To calculate the amount of CO_2 soluble in aqueous choline chloride, two methods were used: the calculation of Z experimentally and mathematically with the Peng-Robinson equation. On the other hand, the study of the absorption kinetics has been performed in a stirred reactor (Lewis's cell). As shown in Figure 1(b), the Lewis cell allows mixing the different parts independently and at different speeds. It should be noted that two temperature sensors are used, one for the liquid phase and one for the gas phase, and it is also equipped with a pressure sensor. The main advantages of this experimental setup are automated gas micro-injections and the simplicity of the analysis, by recording the pressure and temperature.

3. Results and discussion

To validate our measurements of CO_2 solubility in aqueous choline chloride, we applied the methodology previously established in our laboratory for determining CO_2 solubility in alcohols. This approach allowed us to accurately determine the solubility of CO_2 and the corresponding Henry's Law constant for the system[5]. An efficient absorption of CO_2 is observed depending on the composition of the solvent. According to the literature, the absorption of CO_2 in DESs made of choline chloride and glycerol (ChCl:Gly) is only due to physisorption[6]. As expected from the experimental results presented in Figure 2, they are quite consistent with the behavior of the other DESs in the literature[7]. The value of Henry's constant $H_{CO_2}(T)$ increased with increasing temperature for all ChCl:Gly compositions and the value of $H_{CO_2}(T)$ decreased with increasing water content, reflecting an increase in CO_2 absorption. One trend observed in the experiments was the effect of temperature on the decrease in CO_2 absorption kinetic as temperature increases. This behavior agrees with the results reported in the literature for other DESs [8]. In Figure 2(b) the initial CO_2 absorption rate is found by linear regression of the first 30 pressure time data points, as observed the absorption rate decreases as the CO_2 load increases. This is due to the saturation of the solution.

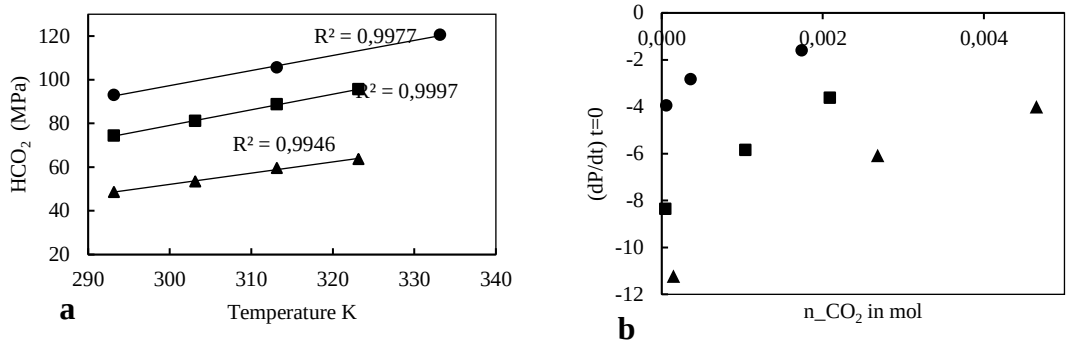

Figure 2. **(a)** Henry's constant of {CO_2} in {ChCl/Gly 1:3} at different wt% of water**.**
(b) Absorption Rate of {ChCl-Gly 1:3} for different concentration at 40 °C. Symbols: ●, 30 wt%; ■, 40 wt%; ▲, 50 wt%.

4. Conclusions

Our work focuses on investigating the effect of the decent of viscosity with the solubility of CO_2 and the kinetic of absorption by varying the water content in the synthesized DESs with the aim of finding optimal operating conditions that lead to greater capture of CO_2 in the selected deep eutectic solvents. Considering the measurements of the ChCl:Gly experiment, it was found that the conditions for which the greatest solubility were obtained at 293.15 K with a water content of 50 wt%. The solvents remain very stable for loop use and the desorption heats are much lower than those necessary for amine carbamates.

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Keywords
CO_2 capture; Deep eutectic solvent; Henry's law equation; Absorption.