Absorption capacity for CO₂ capture process using DEAE-AMP aqueous solution

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Abstract: The absorption capacity of CO₂ in DEAE –AMP aqueous solution was investigated at temperatures ranging from 303.2K to 323.2K. The mass fraction of DEAE and AMP respectively ranged from 0.3 to 0.4 and 0 to 0.15. On the basis of experimental measurement, the mass fraction and temperature dependences of the absorption capacity are illustrated.

1. Introduction
In the past decades, the level of carbon dioxide in atmosphere has become higher and higher due to the extensive use of fossil fuels. The environmental problems caused by CO₂ have become more and more serious. The reduction of CO₂ has become a hot issue[1,2]. The amine-based chemical absorption technologies are considered to be the most robust and promising methods for post-combustion CO₂ capture[3-5]. Traditional alkanolamines including monoethanolamine(MEA), diethanolamine(DEA), N-methyldiethanolamine(MDEA) and diisopropanolamine(DIPA) have been widely used in CO₂ capture process[6]. However, traditional alkanolamine aqueous solutions have some disadvantages like high corrosion and high energy cost of regeneration[7,8]. Blending amine solvents can preserve the good potentials of individual solvent. They have attracted more and more attention.

DEAE has good potential for the removal of CO₂ from gaseous streams and can be prepared from renewable resources. Many studies have been focused on the absorption capacity of CO₂ in DEAE. Maneenitr K et al. [9] measured the solubility of CO₂ in DEAE aqueous solution and the corresponding physical properties. Their results showed that DEAE provides better performance for CO₂ absorption than MEA. Fu et al. [10] studied the solubility and viscosity of MEA promoted DEAE aqueous solution at temperatures ranging from 303.2 to 323.2K. Adak S et al. [11] investigated the vapor-liquid equilibrium and physicochemical properties of novel aqueous blends of (2-Diethylaminoethanol + Piperazine) (DEAE-PZ) for CO₂ appropriation.

AMP is a space hindrance amine. It takes the advantage of fast kinetics, high mass transfer and low corrosion[12,13]. Dey A et al [14] studied the CO₂ absorption in MEA-AMP blends. Wai S K et al [15] investigated the solubility, absorption and desorption rates of CO₂ in AMP–DETA aqueous solution. AMP-DEAE aqueous solution is expected to be a new solvent for removing CO₂. However, experimental work concerning the solubility of CO₂ in DEAE-AMP aqueous solutions is relatively rare.

The main purpose of this work is to experimentally determine the solubility of CO₂ in DEAE-AMP aqueous solution and demonstrates the effect of temperature and mass fractions on the solubility. This work was studied at the temperatures from 303.2K to 323.2K. The mass fraction of DEAE and AMP respectively ranged from 0.30 to 0.40 and 0.00 to 0.15.
2. Experiment

2.1 Materials
Chemicals used in this work are detailed in Table 1. They were used without further purification. Aqueous solutions of DEAE-AMP were prepared by adding deionized water (Electrical resistivity >15 MΩ·cm at 298 K) obtained from the Heal Force ROE-100 apparatus. An analytical balance (Jingtian FA1604A) with an accuracy of 0.1 mg was used to weigh all required chemicals.

| Chemical name | CAS No. | Purity (mole fraction, as stated by the supplier) | source |
|---------------|---------|--------------------------------------------------|--------|
| DEAE          | 110-37-8| ≥99%                                             | Shanghai Aladdin reagent company |
| AMP           | 124-68-5| ≥95%                                             | Shanghai Aladdin reagent company |

2.2 Apparatus and Procedure
The experiment is carried out in a thermostat water bath. The equipment is composed of one high-pressure CO$_2$ tank, one mass flow controller (MFC), one mass flow meter (MFM), one absorption bottle, one constant temperature water bath, one desiccator and one CO$_2$ analyzer (Advanced Gasmitter by Germany Sensors Europe GmbH, the accuracy is ±2%). The absorption bottle was immersed into the thermostatic bath and the temperature of the solution can be regulated within 0.1 K. The equipment was designed to operate at atmospheric pressure. CO$_2$ was inlet into the MFC to maintain a constant flow rate and then into the absorption bottle and absorbed by the solution. The residual and unabsorbed gas firstly flowed into the CO$_2$ analyzer and then into the mass MFM. The CO$_2$ concentration was measured by the CO$_2$ analyzer, and the flow rate was measured by the MFM. The data was recorded by a computer.

3. Results and discussion
The experimental results for the solubility of CO$_2$ in DEAE-AMP aqueous solutions are shown in Table 2.

| $\omega_{\text{DEAE}}$ | $\omega_{\text{AMP}}$ | m/ (g CO$_2$/100g aqueous solution) |
|------------------------|-----------------------|-------------------------------------|
|                        |                       | 303.2K | 313.2K | 323.2K |
| 0.30                   | 0.00                  | 9.98   | 9.77   | 9.21   |
|                        | 0.05                  | 11.98  | 11.12  | 10.57  |
|                        | 0.10                  | 13.12  | 12.41  | 12.18  |
|                        | 0.15                  | 14.64  | 14.12  | 13.56  |
| 0.40                   | 0.00                  | 12.99  | 12.27  | 12.08  |
|                        | 0.05                  | 14.58  | 14.19  | 12.99  |
|                        | 0.10                  | 15.93  | 15.45  | 14.05  |
|                        | 0.15                  | 17.04  | 16.42  | 15.18  |
Figure 1. Effect of the mass fraction of AMP on the absorption capacity of CO2 in DEAE-AMP aqueous solutions. ωDEAE=0.30, T=313.2K. Symbols: △ωAMP=0; ●ωAMP=0.05; ■ωAMP=0.10; □ωAMP=0.15. Lines: trend lines.

Figure 2. Effect of the temperature on the absorption capacity of CO2 in DEAE-AMP aqueous solutions. ωDEAE=0.30. Symbols: ▲ωAMP=0; ■ωAMP=0.05; ●ωAMP=0.10; ◆ωAMP=0.15. Lines: trend lines.

Figure 1. shows the influence of ωAMP on the absorption capacity of CO2 in DEAE-AMP aqueous solutions. From this figure, one may find that at given temperature and given ωDEAE, the absorption capacity increases with the increase of ωAMP.

Figure 2. shows the influence of temperature on the absorption capacity of CO2 in DEAE-AMP aqueous solutions. From this figure, one may find that at given ωDEAE and given ωAMP, the absorption capacity decreases with the increase of temperature.

4. Conclusions
In this work, the absorption of CO2 in AMP promoted DEAE aqueous solutions was investigated at temperatures ranging from 303.2K to 323.2K. The effects of temperature and mass fractions of AMP on the absorption capacity were demonstrated. Our results show that:

(1) At given temperature and given ωDEAE, the increase of ωAMP tends to increase the absorption capacity of CO2 in DEAE-AMP aqueous solution.

(2) The absorption capacity of CO2 decreases with the increase of temperature at given ωAMP and given ωDEAE in DEAE-AMP aqueous solution.

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