Absorption performance for CO\(_2\) capture process using MDEA-AMP aqueous solution

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Abstract. The absorption capacity and the absorption rate of CO\(_2\) in 2-amino-2-methyl-1-propanol (AMP)-N-methyldiethanolamine (MDEA) aqueous solution were measured. The temperatures ranged from 303.2K to 323.2K. The mass fractions of AMP and MDEA respectively ranged from 0 to 0.03 and 0.2 to 0.3. The influence of temperature and \(w_{\text{AMP}}\) on the absorption capacity and absorption rate of CO\(_2\) was illustrated.

1. Introduction

The concentration of atmospheric carbon dioxide which is considered to be primary greenhouse gas has been increasing at an alarming rate [1, 2]. Large emissions and stability of carbon dioxide lead to the global warming and climatic change [3]. Chemical absorption using amine solvent is the current technology for carbon dioxide capture [4, 5]. Alkanolamines (MEA, DEA, MDEA, PZ, etc.) have been extensively applied to remove CO\(_2\) [6, 7]. However, there are still some drawbacks in their use such as low absorption rate, high energy consumption for CO\(_2\) regeneration [8-10].

In recent decades, interest increased rapidly in the development of new absorbent that gives an optimal trade-off between fast kinetics and low energy requirements. Such new absorbent may be achieved by blended amines [11]. AMP is considered to be an attractive solvent for the removal of CO\(_2\) due to its absorption capacity, absorption rate, selectivity and degradation resistance advantages [12-14]. The blended aqueous solution of AMP and MDEA, preserving the good performances of both AMP and MDEA, is considered to be an attractive solvent for the removal of CO\(_2\). However, studies concerning the absorption capacity of CO\(_2\) in MDEA–AMP aqueous solutions are rarely reported by far. Silkenbäumer et al. [15] measured the solubility of CO\(_2\) in an aqueous solution containing AMP (\(w_{\text{AMP}}=0.11\)) and MDEA (\(w_{\text{MDEA}}=0.15\)) at 313 K. Shokouhi et al. [16] measured solubility of CO\(_2\) in aqueous solution of 40 wt% MDEA +5 wt% AMP, 22.5 wt% MDEA + 22.5 wt% AMP, and 10 wt% MDEA + 35 wt% AMP at (313.15, 333.15, and 353.15) K and pressure from vapor pressure of solutions up to 2.5 Mpa. Their results showed that AMP affects efficiently on solubility of CO\(_2\) in MDEA solution.

The main purpose of this work is to determine an appropriate addition of AMP to MDEA aqueous solution, so that the high absorption rate and large CO\(_2\) loading can be simultaneously achieved. To
this end, we measured the absorption capacity of CO\(_2\) in AMP promoted MDEA aqueous solution at 1atm and series of temperatures, and demonstrated the influence of temperature and the mass fraction of AMP on the absorption capacity and absorption rate.

2. Experimental Section

2.1. Materials
Both MDEA and AMP were purchased from Huaxin chemical Co., with mass purity≥ 99%. They were used without further purification. Aqueous solutions of MDEA-AMP were prepared by adding doubly distilled water. The uncertainty of the electronic balance was ± 0.1mg.

2.2. Apparatus and procedure
The absorption performance of aqueous solutions was measured by the equipment composed of one high-pressure CO\(_2\) tank, two mass flow controllers (MFC), 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 flask was immersed into the thermostatic bath and the temperature of the solution can be regulated within 0.1K. During the experiment, CO\(_2\) from a highpressure tank was inlet into the first 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 desiccator and then into the CO\(_2\) analyzer. The gas concentration was measured by the CO\(_2\) analyzer, and the flow rate was measured by the second MFC. Both the data of gas concentration and flow rate were recorded by the computer. In all the experiments, the rotational speed of the magnetic stirrer is fixed as 1000 rpm. The schematic diagram for the measurements of absorption performance was shown in Fig.1.

![Schematic diagram](image)

3. Results and discussion
The absorption performance of CO\(_2\) in MDEA-AMP aqueous solutions were measured at atmospheric pressure with temperatures ranging from 303.2 K to 323.2 K. The absorption capacity including the mass of the absorbed CO\(_2\) (m) and CO\(_2\) loading (\(\alpha\)) are shown in Table 1. One may find from this table that at given mass fraction of MDEA (\(w_{\text{MDEA}}\)) and AMP (\(w_{\text{AMP}}\)), the absorption capacity decreases with increasing temperature. At given temperature and given \(w_{\text{MDEA}}\), the mass of the absorbed CO\(_2\) and CO\(_2\) loading respectively increase and decrease with the increase of \(w_{\text{AMP}}\).

Table 1. Equilibrium absorption amount (m) of CO\(_2\) in MDEA-AMP aqueous solutions and the corresponding CO\(_2\) loadings (\(\alpha\)) under different \(w_{\text{MDEA}}\) and \(w_{\text{AMP}}\).

| \(w_{\text{MDEA}}\) | \(w_{\text{AMP}}\) | \(\alpha/(\text{molCO}_2/(\text{mol MDEA+mol AMP}))\) | m/(gCO\(_2\)/100g aqueous solution) |
|-------------------|------------------|----------------------------------|-------------------------------------|
|                   |                  | 303.2K                           | 313.2K                              | 323.2K                              |
|                   | 0                | 5.91                             | 5.78                                | 5.38                                |
|                   | 0.2              | 6.64                             | 6.06                                | 5.57                                |
|                   | 0.06             | 7.19                             | 6.97                                | 6.17                                |
Figure 2  $w_{\text{AMP}}$ dependence of the absorption rate of CO$_2$ in MDEA-AMP aqueous solutions. Symbols: ▲ $w_{\text{AMP}}$=0; ● $w_{\text{AMP}}$=0.03; ◆ $w_{\text{AMP}}$=0.06; ■ $w_{\text{AMP}}$=0.09, (a): $w_{\text{MDEA}}$=0.2; $T$=313.2K, (b): $w_{\text{MDEA}}$=0.3; $T$=303.2K.

Figure 2 shows the influence of $w_{\text{AMP}}$ on the absorption rate of CO$_2$ in MDEA-AMP aqueous solutions, the absorption rate increases with the increase of $w_{\text{AMP}}$. Figure 3 shows the influence of the temperature on the absorption rate of CO$_2$ in MDEA-AMP aqueous solutions. The absorption rate slightly increases with increasing temperature when the temperatures ranged from 303.2 K to 313.2 K. However, the absorption rate at 323.2 K seems to be very close to that at 313.2 K, indicating that the temperature has little influence on the absorption rate.

Figure 3 Temperature dependence of the absorption rate of CO$_2$ in MDEA-AMP aqueous solutions. Symbols: ▲ $T$=303.2K; ● $T$=313.2K; ◆ $T$=323.2K, (a) $w_{\text{MDEA}}$=0.2; $w_{\text{AMP}}$=0.06, (b) $w_{\text{MDEA}}$=0.2; $w_{\text{AMP}}$=0.03.

4. Conclusions

In this work, the absorption capacity of CO$_2$ in AMP promoted MDEA aqueous solution was measured at normal pressure with temperatures ranging from 303.2K to 323.2K. The influence of temperature and $w_{\text{AMP}}$ on the absorption capacity and absorption rate of CO$_2$ was illustrated. Our results showed that: AMP promotes the absorption rate of CO$_2$ and affects efficiently on absorption capacity of CO$_2$ in...
MDEA aqueous solution. The temperature has little influence on the absorption rate.

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