Study on apparent absorption rate of CO_2 in DEAE-AMP aqueous solutions

Y X Chu[1], C Li, L M Wang, X Feng and D Fu

School of Environmental Science and Engineering, North China Electric Power University, Baoding 071003, People's Republic of China

E-mail addresses: 1378925636@qq.com

Abstract: Apparent absorption rates of CO_2 in DEAE-AMP aqueous solutions were measured at temperatures ranging from 303.2K to 323.2 K. 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 measurements, the effects of temperature, mass fraction of AMP on apparent absorption rate were demonstrated.

1. Introduction

Currently, a series of eco-environmental problems caused by the CO_2 emissions have received increasing attention, CO_2 emission reduction has become a global issue [1,2]. The chemical absorption method using Alkanolamines as the absorbent is the most mature and the most widely applied technology. Alkanolamines, such as monoethanolamine (MEA), diethanolamine(DEA) and N-methyldiethanolamine (MDEA), have been widely applied to remove the acid gases in industrial processes [3-5]. However, traditional alkanolamine aqueous solutions have some disadvantages like high corrosivity and high energy cost of regeneration [6-8]. In general, new absorbent may be achieved by blended amines like primary-tertiary amines (e.g. MEA-MDEA) or secondary-tertiary amines (e.g., DEA-MDEA) [9].

DEAE is a good alternative to traditional tertiary alkanolamine like MDEA, because it has good potential for the removal of CO_2 from gaseous streams, and can be prepared from renewable resources [10,11]. Chowdhury et al. [12] investigated the absorption characteristics of 24 kinds of tertiary amine absorbents and compared their performances with those of MDEA. Comparison shows DEAE has better chemical stability, higher CO_2 loading capacity, higher cyclic capacity yet lower heat of reaction.

The sterically hindered amine 2-amino-2-methyl-1-propanol (AMP) has similar advantageous qualities as tertiary amines while exhibiting relatively much higher CO_2 absorption rates [13]. Wai et al. [14] found the initial absorption rates of most AMP–DETA blends were higher than DEAE. The blended aqueous solution of AMP and DEAE, preserving the good performances of both AMP and DEAE, is considered to be an attractive solvent for the removal of CO_2. However, the effects of temperature, mass fraction on CO_2 absorption rate in this blend are still unknown.

The main purposes of this work are to experimentally determine the apparent absorption rate of DEAE-AMP aqueous solution and demonstrate the effects of temperature and mass fractions on the absorption rate.

2. Experimental Section

2.1. Materials

The DEAE was manufactured by Shanghai Aladdin Reagents, with a mass purity ≥ 99%. The AMP was purchased from Shanghai Aladdin Reagents, with mass purity≥ 95%.They were used without further purification. Aqueous solutions of DEAE–AMP were prepared by adding the high purity water.

2.2. Apparatus and procedure

The apparent absorption rate was measured by the equipment 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%).

During the experiment, CO_2 and N_2 from high-pressure tanks were respectively inlet into the mass flow controllers to maintain constant flow rates v_{CO2} and v_{N2}, and then into the gas mixer. The gas mixture with certain volume fraction of CO_2 flowed into the absorption bottle and then was absorbed by the solution. The residual and unabsorbed gas firstly flowed into the desiccator, and then into the CO_2 analyser and finally into the mass MFM. The volume concentration of CO_2 (C_i) was measured by the CO_2 analyser, and the flow rate (v_i) was measured by the MFM. We defined the absorption rate (R/g CO_2 100g aqueous solution min^{-1}) as 0.5m/t 0.5 ($t_{0.5}$ is the absorption time at which 50% of the absorption capacity is achieved).

3. Result and discussion

The experimental results for the absorption rate of DEAE-AMP aqueous solutions are shown in Table 1.

Table 1. Absorption rate (R) of CO_2 in DEAE-AMP aqueous solutions. Pressure (p) = 101 kPa

w_{DEAE}	w_{AMP}	*R*/ (g CO_2/100g aqueous solution/min)		
		303.2K	313.2K	323.2K
0.30	0.00	0.3477	0.5048	0.6279
	0.05	0.6061	0.7669	0.7748
	0.10	0.7454	0.7740	0.7875
	0.15	0.7585	0.7830	0.7914
0.40	0.00	0.3066	0.4451	0.5813
	0.05	0.7647	0.7740	0.7902
	0.10	0.7860	0.7923	0.8106
	0.15	0.7963	0.8075	0.8147

Table 1 shows that the absorption rate of CO_2 absorbed by DEAE solution increases significantly when AMP is added.

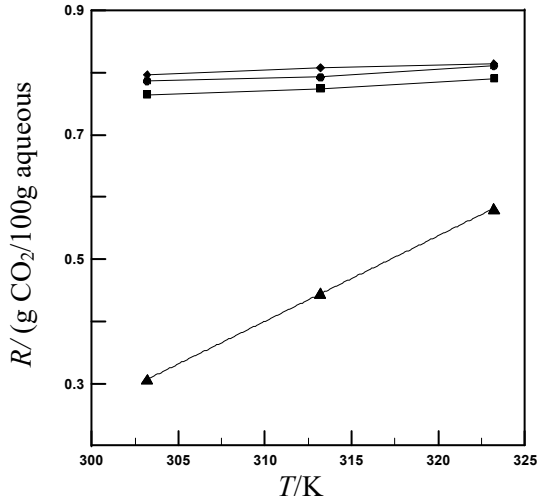

Figure 1. The effect of different temperatures on the apparent rate of CO2 in 40%DEAE aqueous solution. Symbols: experimental data; ▲$_{wAMP}$=0.00; ■$_{wAMP}$ =0.05; ●$_{wAMP}$ =0.10; ◆$_{wAMP}$ =0.15. Lines: for guiding the eyes.

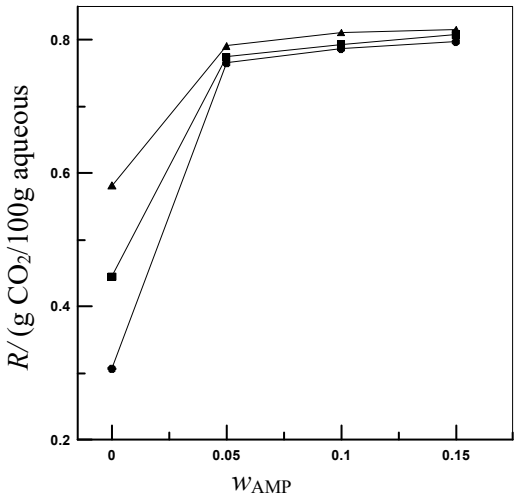

Figure 2. The effect of the mass fraction of AMP on the absorption rate of CO2 in 40%DEAE aqueous solution. Symbols: experimental data; ●T=303.2K; ■T=313.2K; ▲T=323.2. Lines: for guiding the eyes.

Figure 1 shows that under certain w_{DEAE} and w_{AMP} , the apparent absorption rate of CO_2 in the mixed solution of DEAE-AMP becomes larger with the increase of temperature for the mixed absorption solution. However, when AMP was not added, the apparent absorption rate of CO_2 was greatly affected by temperature, and the mixed aqueous solution after AMP addition was significantly affected by temperature.

Figure 2 shows that under certain conditions of temperature and w_{DEAE}, the apparent absorption rate of CO_2 in the mixed solution of DEAE-AMP has a significant increase, and it becomes larger with the increase of w_{AMP}.

4. Conclusions

In this work, apparent absorption rate of CO_2 in DEAE-AMP aqueous solution was measured. The effects of temperature and mass fractions of AMP on the absorption rate were demonstrated. Our results show that:

(1) For DEAE-AMP aqueous solution, the absorption rate increases with the increase of the w_{AMP} at given temperature and w_{DEAE}.

(2) The absorption rate increases with the increase of the temperature at given w_{DEAE} and w_{AMP}. The apparent absorption rate of CO_2 in DEAE aqueous solution is greatly affected by temperature, and the addition of small amount of AMP.

References

[1] Kohl A L and Nielsen R B 1997 *Gas Purification* (Amsterdam: Elsevier) 40-186
[2] Steeneveldt R,Berger B and Torp T A 2006 *Chem. Eng. Res. Des*. 84739–763
[3] Rochelle G T 2009 Amine scrubbing for CO_2 capture *Science* **325** 1652-1654..
[4] Maham Y,ather A E and Mathonat C 2000 *J.Chem.Thermodyn* **32** 229-236.
[5] Yang Z Y,Soriano A N,Caparanga A and Li M H 2010 *J.Chem.Thermodyn* **42** 659-65.
[6] Idem R,Wilson M,Tontiwachwuthikul P,Chakma A,Veawab A and Aroonwilas A 2006 *Ind.Eng.Chem.Res.* **45** 2414-20.
[7] Fu D, Zhang P,Du L X and Dai J 2014 *J. Chem. Thermodyn* **78** 109–113.

[8] Fu D, Du L X,Wang H M and Chem J 2014 *Thermodyn* **69** 132–136.
[9] Haghtalab A and Ghahremani E 2015 *Fluid Phase Equilibr* **400** 62–75.
[10] Vaidya P D and Kenig E Y 2009 *Chem. Eng. Technol.* **32** 556–63.
[11] Vaidya P D and Kenig E Y 2007 *Chem. Eng. Sci.* **62** 7344–50.
[12] Chowdhury F A., Yamada H, Higashii T, Goto K and Onoda M 2013 *Ind. Eng. Chem.Res.* **52** 8323–31.
[13] Lepaumier H, Picq D and. Carrette P L 2009 *Ind. Eng. Chem. Res.* **48** 9061–7.
[14] Wai S K, Nwaoha C, Saiwan C,Idem R and Supap T 2018 *Sep.Purif.Technol*. **194** 89-95