Study on viscosity of MDEA- MeOH aqueous solutions

F Wang¹, L M Wang, S Q Wang and D Fu

¹ Corresponding author. Address: School of Environmental Science and Engineering, North China Electric Power University, Baoding, 071003, People's Republic of China. Tel.: +86-312-1593575212; E-mail addresses:464750393@qq.com

Abstract. The viscosities of the N-methyldiethanolamine (MDEA)-methanol (MeOH) aqueous solutions were measured at temperatures ranging from (303.2 to 323.2) K. The mass fraction of MDEA and MeOH respectively ranged from 0.2 to 0.4 and 0 to 0.15. On the basis of experimental measurement, the effects of temperature, mass fraction of MDEA and MeOH on viscosities were demonstrated.

1. Introduction

In recent decades, atmospheric levels of CO₂ have increased rapidly due to the utilization of grand amount of fossil fuel. The reduction of CO₂ emission became a global issue [1, 2]. Currently, aqueous solutions of alkanol amines are popularly used for the removal of CO₂ from a variety of gas streams [3-5]. MDEA takes the advantages of high resistance to thermal and chemical degradation, low solution vapor pressure, and low enthalpy of absorption [6, 7]. However, the absorption of CO₂ in MDEA aqueous solution is quite slow, in industrial applications this shortcoming can be overcome by adding activators, including MEA, piperazine (PZ), or DEA in MDEA aqueous solution [8-9]. Besides, adding a physical solvent in MDEA aqueous solution is considered to be an effective method to lower the regeneration energy cost [10, 11].

The use of methanol as physical solvent in these kinds of chemical absorption processes could be interesting. Henni and Mather [12] studied the solubility of CO₂ in a mixed nonaqueous solvent of MDEA and MeOH. The results showed that at low acid gas partial pressures the solubility of CO₂ is higher in the mixed solvent than in pure MeOH.

The viscosities of alkanol amine aqueous solutions are required when designing or simulating an absorption column for CO₂ absorption. In particular, solution viscosity is important in the mass transfer rate modeling of absorbers and regenerators because these properties affect the liquid film coefficient for mass transfer. By far, there are some experiments concerning the viscosities of aqueous solutions containing MDEA and its blends [13-16]. However, the experiments for the viscosities of MDEA-MeOH aqueous solutions are rare.

The main purposes of this work are to experimentally determine the viscosities of MDEA-MeOH aqueous solution and demonstrate the effects of temperature and mass fractions on the viscosity.

2. Experimental Section

2.1. Materials

The MDEA and MeOH were purchased from HuaXin Chemical Co, with mass purity≥ 99.5%. They were used without further purification. Aqueous solutions of MDEA-MeOH were prepared by adding doubly distilled water.
2.2. Apparatus and procedure
The viscosities of the MDEA-MeOH aqueous solutions were measured at temperatures from 303.2 K to 323.2 K by using the NDJ-5S digital rotational viscometer produced by the Shanghai Changji Geological Instrument factory. The measurement range and measurement error for viscosity are respectively (0.1 to 105) mPa·s and ±1% (for a Newtonian fluid). The instrument was designed and manufactured with 5 cylindrical rotors (0#, 1#, 2#, 3# and 4#) and 4 different velocities (6 rpm, 12 rpm, 30 rpm and 60 rpm). In our experiments, the combination (0-60) rpm correspond to the upper limits of 10 mPa s. The uncertainty of the temperature is ±0.1 K.

3. Results and discussion
The experimental results for the viscosities of MDEA-MeOH aqueous solutions are shown in Table 1.

Table 1. Viscosities (η) of MDEA-MeOH aqueous solutions under different wMDEA and wMeOH.
Pressure (p) = 101 kPa.

| wMDEA | wMeOH | η/ (mPa·s) |
|-------|-------|------------|
|       | 303.2K| 313.2K     | 323.2K     |
| 0.00  | 1.72  | 1.36       | 1.14       |
| 0.05  | 1.93  | 1.56       | 1.28       |
| 0.10  | 2.18  | 1.71       | 1.38       |
| 0.15  | 2.10  | 1.57       | 1.30       |
| 0.00  | 2.81  | 2.02       | 1.71       |
| 0.05  | 2.96  | 2.20       | 1.80       |
| 0.10  | 3.24  | 2.44       | 2.00       |
| 0.15  | 3.02  | 2.32       | 1.88       |
| 0.00  | 4.24  | 3.13       | 2.31       |
| 0.05  | 4.77  | 3.48       | 2.64       |
| 0.10  | 5.18  | 3.69       | 2.78       |
| 0.15  | 5.02  | 3.53       | 2.67       |
Figure 1 shows the influence of $w_{\text{MDEA}}$ on the viscosities of MDEA-MeOH aqueous solutions. One may find that at given temperature and $w_{\text{MeOH}}$, the viscosity increases with the increasing of $w_{\text{MDEA}}$.

Figure 2 shows the temperature dependence of the viscosities of MDEA-MeOH aqueous solutions. One may find that at given $w_{\text{MDEA}}$ and $w_{\text{MeOH}}$, the viscosity decreases with the increase of temperature. Figure 3 shows the influence of $w_{\text{MeOH}}$ on the viscosities of MDEA-MeOH aqueous solutions. One may find that at given temperature and given $w_{\text{MDEA}}$, the viscosity firstly increase and then decrease, one maximum was observed at $w_{\text{MeOH}}=0.10$.

4. Conclusions
In this work, the viscosities of MDEA-MeOH aqueous solutions were measured. The effects of temperature and mass fractions of MDEA and MeOH on the viscosities were demonstrated. Our results show that:
(1) The solution viscosity increases with the increase of $w_{\text{MDEA}}$ at given temperature and given $w_{\text{MeOH}}$, and decreases with the increase of temperature at given solution composition;
(2) At given temperature and given $w_{\text{MDEA}}$, the viscosity firstly increase and then decrease, one maximum was observed at $w_{\text{MeOH}}=0.10$. 
Acknowledgments
The authors appreciate the financial support from the National Natural Science Foundation of China (No. 21276072) and the Fundamental Research Funds for the Central Universities (No.13ZD16 and No.2016XS108).

References
[1] Nahicenovic N and John A 1991 Energy 16 1347–1377
[2] Steeneveldt R, Berger B and Torp TA 2006 Chem. Eng. Res. Des. 84 739–763
[3] Knudsen JN, Jensen JN and Vilhelmsen PJ 2009 Energy Proc. 1 783–790
[4] Raynal L, Bouillon P and Gomez A 2011 Chem. Eng. J. 171 742–752
[5] Chakravarty T, Phukan UK and Weilund RH 1985 Chem. Eng. Prog. 81 32–36
[6] Pant KK and Srivastava VK 2007 Chem. Eng. J. 133 229-237
[7] Navaza JM, Gómez-Díaz D and Rubia MDL 2009 Chem. Eng. J. 146 184-188
[8] Kadiwala S, Rayer AV and Henri A 2010 Fluid Phase Equilib. 292 20–28
[9] Derks PWJ, Hogendoorn JA and Versteeg GF 2010 J. Chem. Thermodyn. 42 151–163
[10] Fu D, Chen LH and Qin LG 2012 Fluid Phase Equilibria 319 42-47
[11] Fu D, Xu Y and Hua X 2012 Fluid Phase Equilibria 314 121–127
[12] Henri A and Mather AE 1995 J. Chem. Eng. Data 40 493-495
[13] Muhammad A, Mutalib MIA and Wilfred CD 2008 Journal of Chem. & Eng. Data 53 2226-2229
[14] Fu D, Chen LH and Qin LG 2012 Fluid Phase Equilibria 319 42-47
[15] Fu D, Hao H and Qin L 2013 Journal of Molecular Liquids 181 105-109
[16] Fu D, Qin L and Hao H 2013 Journal of Molecular Liquids 186 81-84