

Study on the surface tensions of MDEA-methanol aqueous solutions

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Abstract. The surface tensions (γ) of N-methyldiethanolamine (MDEA)-methanol (MeOH) aqueous solutions were measured by using an automatic surface tension-meter (BZY-1). The temperature ranged from 303.2K to 323.2K. The mass fractions of MeOH and MDEA respectively ranged from 0.05 to 0.15 and 0.2 to 0.4. On the basis of the experimental measurement, the effects of temperature and mass fraction of MDEA and MeOH on surface tensions were analyzed.

1. Introduction

Climate change and environmental problems caused by the emissions of carbon dioxide (CO₂) have attracted increasing attentions worldwide and the reduction of CO₂ has become a global issue[1, 2]. Post combustion CO₂ capture using amine as absorbent is one of the mature technologies for reducing CO₂ emissions from coal-fired power plants[3-8]. Aqueous solutions of MDEA have been widely used for the removal of CO₂ from a variety of gas streams[9, 10].

Besides the amine blends, adding a physical solvent to the aqueous solutions of alkanolamines is considered to be an effective method to lower the regeneration energy cost[11, 12]. For example, *Archane et al.* [11] studied the vapor-liquid equilibria, the concentration of the molecular form of absorbed CO₂, the partial pressure of CO₂ and the liquid phase speciation for CO₂-poly(ethylene oxide)400 (PEG400)-diethanolamine (DEA) aqueous solutions, and demonstrated the influence of PEG400 on the absorption of CO₂. Their results showed that lower energy cost can be achieved in regeneration because at a given CO₂ loading and constant concentration of DEA, the CO₂ molecular concentration increases with the increase of PEG400 concentration, whereas the ion repartition is not significantly influenced by the solvent composition. *Henni and Mather*[13] 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.

A knowledge of surface tension is required when designing or simulating an absorption column for CO₂ capture. In recent years, there are many experimental and theoretical works concerning the surface tensions of aqueous solutions containing MDEA and physical solvent. *Fu et al.* [14] measured the surface tensions of PEG400, MEA-PEG400 and DEA-PEG400 aqueous solutions and satisfactorily modeled by using a thermodynamic equation. On the basis of experiments and calculation, they demonstrated the effects of the temperature, the mass fractions of amines and PEG400 on the surface tension. *Fu et al.* [15] studied the surface tensions of MDEA-piperazine (PZ) aqueous solutions. They proposed a theoretical model to correlate the surface tensions and the calculated results agreed well with



the experiments. However, experimental work concerning the surface tensions of MDEA-MeOH aqueous solutions is relatively rare.

The main purpose of this work is to investigate the surface tension of MDEA-MeOH aqueous solutions, and then demonstrate the effects of temperature and mass fractions of MDEA and MeOH on the surface tension. To this end, the surface tension was measured at the temperatures from 303.2K to 323.2K. The mass fraction of MeOH and MDEA respectively ranged from 0.05 to 0.15 and 0.2 to 0.4.

2. Experimental Section

2.1. Materials

The samples used in this work are detailed in Table 1. Purities are as stated by the supplier, and no further purification was carried out. Aqueous solutions of MDEA-MeOH were prepared by adding doubly distilled water.

2.2. Apparatus and procedure

The surface tension was measured by using the BZY-1 surface tension meter produced by Shanghai Hengping Instrument Factory. The BZY-1 meter employs the Wilhemy plate principle, i.e., the maximum tensile force competing with the surface tension is measured when the bottom edge is parallel to the interface and just touches the liquid. The measurement ranges for temperature and surface tension are respectively (268.15 to 383.15) K and (0.1–400.0) mN·m⁻¹. The uncertainty is ±0.1 mN·m⁻¹. The size-volume of the different samples used in the BZY-1 meter is 20 ml. During the experiments, the copper pan in the host of the BZY-1 meter is connected with the thermostatic bath (CH-1006, uncertainty is ±0.1 K). Via the circulation of the water, the temperature of the water in the copper pan is kept the same as that in the thermostatic bath. The aqueous solution is put into the solution container immersed in the copper pan and its temperature can be measured by a thermocouple. The scale reading of the thermocouple has been well calibrated by a mercury thermometer.

3. Results and discussion

The experimental results for the surface tensions of MDEA-MeOH aqueous solutions are respectively shown in Table 1.

Table 1. Surface tensions (γ) of MDEA-MeOH aqueous solutions under different mass fractions of MDEA (w_{MDEA}) and MeOH (w_{MeOH}). Pressure (p) = 101 kPa.

w_{MDEA}	w_{MeOH}	$\gamma / (\text{mN} \cdot \text{m}^{-1})$		
		303.2K	313.2K	323.2K
0.20	0.00	54.2	53.8	51.7
	0.05	52.6	51.3	49.6
	0.10	48.9	47.6	45.9
	0.15	45.8	44.8	43.6
0.30	0.00	51.2	50.2	48.6
	0.05	49.7	48.6	46.5
	0.10	45.6	44.5	43.2
	0.15	42.8	42.6	42.2

	0.00	49.8	48.8	47.1
0.40	0.05	45.4	44.7	43.4
	0.10	44.2	43.3	42.6
	0.15	42.2	40.7	40.1

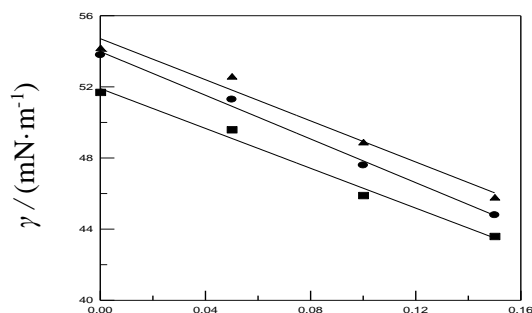


Figure 1. w_{MeOH} dependence of the surface tensions of MDEA-MeOH aqueous solutions at $w_{\text{MDEA}}=0.20$. Symbols: \blacktriangle $T=303.2\text{K}$; \bullet $T=313.2\text{K}$; \blacksquare $T=323.2\text{K}$. Lines: trend lines.

Figure 1. shows the influence of w_{MeOH} on the surface tension of MDEA-MeOH aqueous solutions. From this figure, one may find that at given temperature and given w_{MDEA} , the surface tension decreases with the increase of w_{MeOH} .

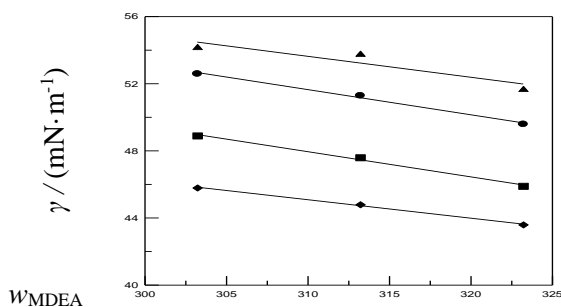


Figure 2. Temperature dependence of the surface tensions of MDEA-MeOH aqueous solutions at $w_{\text{MDEA}}=0.20$. Symbols: \blacktriangle $w_{\text{MeOH}}=0$; \bullet $w_{\text{MeOH}}=0.05$; \blacksquare $w_{\text{MeOH}}=0.10$; \blacklozenge $w_{\text{MeOH}}=0.15$. Lines: trend lines.

Figure 2. shows the temperature dependence of the surface tension of MDEA-MeOH aqueous solutions. One finds that at given w_{MeOH} and w_{MDEA} , the surface tension decreases with the increase of temperature. Figure 3. shows the influence of w_{MDEA} on the surface tension of MDEA-MeOH aqueous solutions. From this figure, one may find that at given temperature and given w_{MeOH} , the surface tension decreases with the increase of w_{MDEA} .

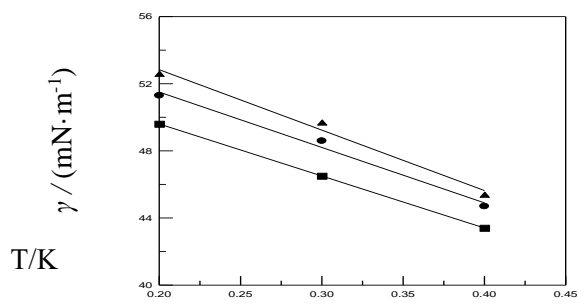


Figure 3. w_{MDEA} dependence of the surface tensions of MDEA-MeOH aqueous solutions at $w_{\text{MeOH}}=0.05$. Symbols: \blacktriangle $T=303.2\text{K}$; \bullet $T=313.2\text{K}$; \blacksquare $T=323.2\text{K}$. Lines: trend lines.

4. Conclusions

In this work, the surface tensions of MDEA-MeOH aqueous solutions were measured by using the BZY-1 surface tension meter. The effects of temperature and mass fractions of MDEA and MeOH on the surface tension were demonstrated. Our results show that:

- (1) The increase of temperature tends to decrease the surface tension of MDEA-MeOH aqueous solution.
- (2) The increase of the mass fraction of MDEA and MeOH tend to decrease the surface tension of MDEA-MeOH aqueous solution.

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