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Density and Viscosity of Aqueous Blends of *N*-Methyldiethanolamine and 2-Amino-2-methyl-1-propanol

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The density and kinematic viscosity of aqueous blends of *N*-methyldiethanolamine and 2-amino-2-methyl-1-propanol were determined from experiments within the temperature range 10–60 °C. The composition of the alkanolamines in water ranged from 5% to 50% by mass.

Introduction

Aqueous solutions of alkanolamines such as *N*-methyldiethanolamine (MDEA) and 2-amino-2-methyl-1-propanol (AMP) have application in acid gas treatment for the removal of acid gases such as carbon dioxide and hydrogen sulfide. More recently, attention is drawn to blended solutions of primary or secondary and tertiary amines for the simultaneous removal of CO_2 in the presence of H_2S (Versteeg et al., 1990). One such system that has not been thoroughly investigated is the combination of AMP, a secondary amine, and MDEA, a tertiary amine. In this work, two physical properties, density and viscosity, of aqueous blends of MDEA and AMP were determined over the temperature range of 10–60 °C. The properties of the single amine solutions of AMP in water and MDEA in water have been reported previously in the literature (Al-Ghawas et al., 1989; Xu et al., 1991). These properties are important for the design of gas treating operations and are useful in determining other physicochemical properties of this system such as acid gas solubility and reaction kinetics.

Experimental Procedure

All solutions were prepared from deionized, distilled water and 99+% (mass) pure MDEA and AMP supplied by Janssen Chimica. Prepared solutions were titrated with 1 N HCl to an equivalence point of pH 4.5 with a Mettler DL12 autotitrator (Al-Ghawas et al., 1989). All reported compositions are accurate to within ±0.05% by mass.

The temperature of each experiment was controlled by immersing the density and viscosity measuring devices in a constant temperature bath, maintained to within ±0.05 °C of the set point. The temperature of the bath was measured with a Fisher Scientific calibrated mercury-filled glass thermometer. Experiments were repeated a minimum of three times at each temperature for all amine compositions.

Viscosity. The viscosity of the amine solutions was found using Cannon-Fenske type capillary tube viscometers following the ASTM D 445 standard test method. The viscometers, sizes 50, 100, 150, and 200, were purchased calibrated from Ace Glass, Inc. Initially, a viscometer was charged with an aqueous amine solution and allowed to equilibrate to the set point temperature in a constant temperature bath for at least 15 min. The efflux time was measured with a hand-held digital stopwatch. The kinematic viscosity was calculated from the product of the viscometer constant and the efflux time. The efflux time was measured at least three times for each temperature. The viscometer constant was a linear function of temperature.

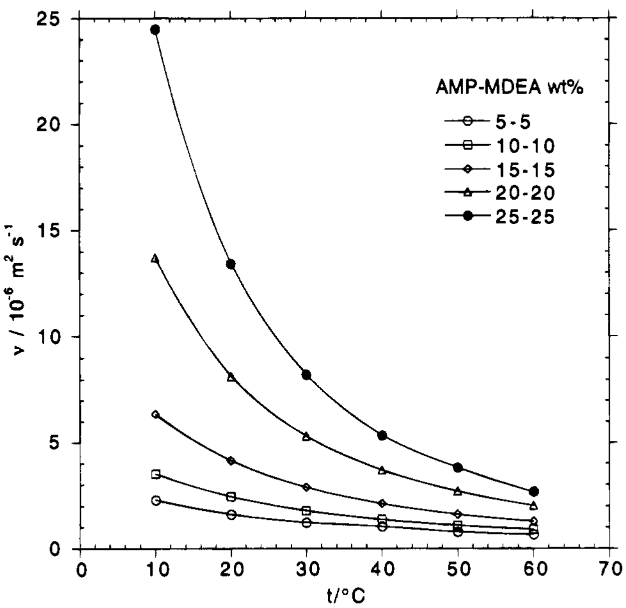

Figure 1. Kinematic viscosity of aqueous blends of AMP and MDEA for 0–50 wt % amine.

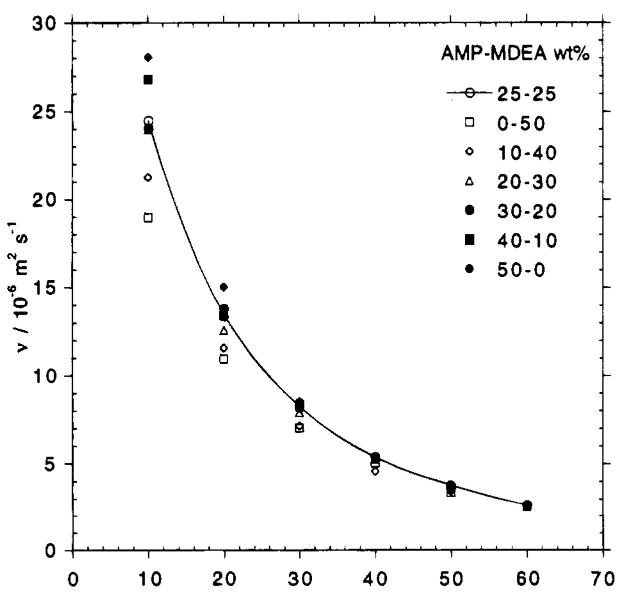

Figure 2. Kinematic viscosity of aqueous blends of AMP and MDEA at 50 wt % total amine.

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Table 1. Kinematic Viscosity of Aqueous Blends of AMP and MDEA

[AMP]/ (mass %)	[MDEA]/ (mass %)	t/°C	ν/ (10^{-6} m^2·s^{-1})	σ/ (10^{-6} m^2·s^{-1})
5	5	10	2.284	0.009
5	5	20	1.600	0.006
5	5	30	1.228	0.006
5	5	40	1.031	0.004
5	5	50	0.783	0.003
5	5	60	0.657	0.002
10	10	10	3.506	0.016
10	10	20	2.440	0.007
10	10	30	1.774	0.007
10	10	40	1.360	0.005
10	10	50	1.083	0.005
10	10	60	0.895	0.003
15	15	10	6.372	0.032
15	15	20	4.136	0.016
15	15	30	2.867	0.012
15	15	40	2.097	0.008
15	15	50	1.598	0.007
15	15	60	1.271	0.003
20	20	10	13.70	0.06
20	20	20	8.142	0.023
20	20	30	5.304	0.019
20	20	40	3.682	0.012
20	20	50	2.680	0.007
20	20	60	2.009	0.008
25	25	10	24.49	0.07
25	25	20	13.40	0.06
25	25	30	8.226	0.033
25	25	40	5.347	0.017
25	25	50	3.794	0.017
25	25	60	2.659	0.008
0	50	10	18.99	0.07
0	50	20	10.94	0.04
0	50	30	7.041	0.020
0	50	40	5.033	0.015
0	50	50	3.387	0.009
0	50	60	2.545	0.007
10	40	10	21.25	0.08
10	40	20	11.58	0.05
10	40	30	7.148	0.032
10	40	40	4.592	0.012
10	40	50	3.605	0.009
10	40	60	2.522	0.011
20	30	10	24.01	0.11
20	30	20	12.58	0.05
20	30	30	7.909	0.037
20	30	40	5.269	0.014
20	30	50	3.689	0.011
30	20	10	24.07	0.06
30	20	20	13.82	0.06
30	20	30	8.469	0.037
30	20	40	5.383	0.022
30	20	50	3.696	0.011
30	20	60	2.617	0.013
40	10	10	26.81	0.08
40	10	20	13.42	0.04
40	10	30	8.283	0.026
40	10	40	5.309	0.025
40	10	50	3.653	0.010
40	10	60	2.525	0.009
50	0	10	28.06	0.12
50	0	20	15.02	0.04
50	0	30	8.526	0.041
50	0	40	5.339	0.026
50	0	50	3.448	0.009
50	0	60	2.508	0.007

Density. Experiments to determine density were performed with a 25 cm^3 Gay-Lussac type pycnometer from Ace Glass Inc. The clean, dry pycnometer was weighed before each experiment on a Sartorius analytical balance, accurate to ±0.0002 g. The temperature was controlled by immersing the amine solution-charged pycnometer in a constant temperature bath for at least 30 min. The density was found by dividing the difference in the mass of the charged and empty pycnometer by the calibrated pycnometer volume.

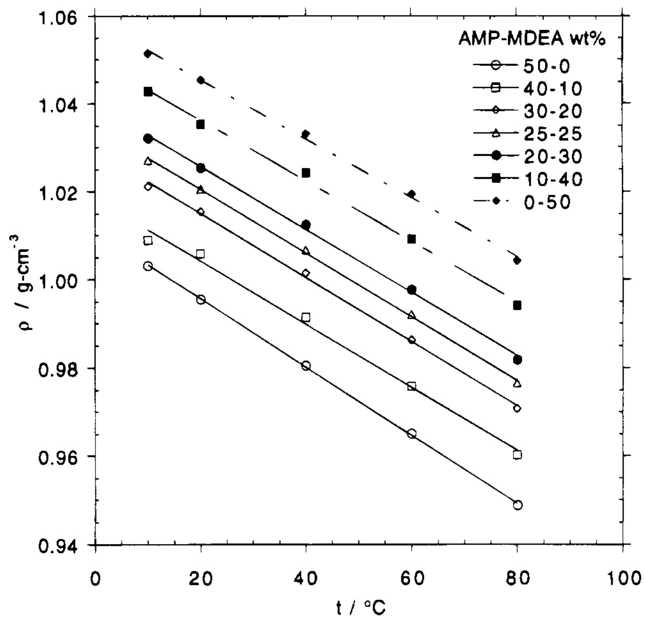

Figure 3. Density of aqueous blends of AMP and MDEA.

Table 2. Density of Aqueous Blends of AMP and MDEA

[AMP]/ (mass %)	[MDEA]/ (mass %)	t/°C	ϱ/ (g·cm^{-3})	σ/ (g·cm^{-3})
50	0	10	1.0032	0.0026
50	0	20	0.9955	0.0016
50	0	40	0.9806	0.004
50	0	60	0.9651	0.0020
50	0	80	0.9489	0.0014
40	10	10	1.0090	0.0015
40	10	20	1.0059	0.0026
40	10	40	0.9914	0.0021
40	10	60	0.9759	0.0009
40	10	80	0.9602	0.0014
30	20	10	1.0212	0.0007
30	20	20	1.0154	0.0022
30	20	40	1.0015	0.0008
30	20	60	0.9863	0.0006
30	20	80	0.9708	0.0027
25	25	10	1.0272	0.0024
25	25	20	1.0206	0.0029
25	25	40	1.0067	0.0013
25	25	60	0.9921	0.0020
25	25	80	0.9766	0.0014
20	30	10	1.0322	0.0001
20	30	20	1.0254	0.0010
20	30	40	1.0125	0.0008
20	30	60	0.9977	0.0005
20	30	80	0.9819	0.0003
10	40	10	1.0429	0.0028
10	40	20	1.0353	0.0017
10	40	40	1.0242	0.0029
10	40	60	1.0091	0.0003
10	40	80	0.9941	0.0028
0	50	10	1.0514	0.0012
0	50	20	1.0454	0.0022
0	50	40	1.0331	0.0024
0	50	60	1.0194	0.0026
0	50	80	1.0042	0.0019

Results and Discussion

The kinematic viscosity was determined for AMP/MDEA compositions ranging from 5% to 50% by mass in water. The temperature was varied from 10 to 60 °C in 10 °C increments. The average experimental results and standard deviations for the kinematic viscosity are reported in Table 1. As shown in Figures 1 and 2, the viscosity of each solution varies exponentially with temperature. The kinematic viscosities of aqueous solutions with a total AMP/MDEA composition of 50% by mass were nearly equal at temperatures from 40 to 60 °C. Density experiments were performed for 50% total amine by mass at each of the temperatures 10, 20, 40, 60, and 80 °C. The average experimental results for density along with the standard deviations are listed in Table 2. The density results are plotted as a function of temperature in Figure 3. In all cases of viscosity and density measurements, the standard deviation from the mean was less than ±0.5%.

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