Articles

Densities and Viscosities of the Water + Lithium Bromide + Ethanolamine System

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Densities and viscosities of the water + lithium bromide + ethanolamine system ($LiBr/H_2N(CH_2)_2OH$ mass ratio = 3.5/1), a possible new working fluid for absorption heat pump, were measured in the temperature range of (283.15 to 343.15) K and in the concentration range of (30.2 to 75.0) mass %. The measurements were carried out using a set of hydrometers and Ubbelohde-type capillary viscometers. Each data set was correlated with the appropriate regression equation as a function of concentration and temperature. The average absolute deviations between the experimental and calculated values were found to be 0.07% and 0.72% for the densities and the viscosities, respectively.

Introduction

In the optimum design of an absorption heat pump several physical and transport properties of the working fluid such as density, viscosity, surface tension, and thermal conductivity are required. Because the development of new working fluids for absorption heat pumps is mainly focused on the suppression of crystallization of the solution (Iizuka et al., 1989, 1990; Inoue, 1993), the new absorbent fluid may not be satisfactory due to physical properties. Thus the accurate measurements of several important properties of the working fluid are essential (Iyoki et al., 1993; Wimby and Berntsson, 1994). In our previous work (Kim et al., 1996) we suggested the water lithium bromide + ethanolamine system ($LiBr/H_2N(CH_2)_2OH$ mass ratio 3.5/1) as a possible new working fluid for absorption heat pumps and reported vapor pressure and solubility data. In this work we report the densities and viscosities at various concentration and temperature ranges along with correlating equations.

Experimental Section

Materials. The lithium bromide (99+%) and ethanolamine (99+%) were supplied by Aldrich Chemical Co. and were used without further purification. All solutions were prepared with deionized water.

Apparatus and Procedure. The temperature of the sample solution was measured with a thermistor thermometer (Cole Parmer, 08502-16), the accuracy of which is ±0.2 K, capable of reading to 0.01 K, and was controlled within ±0.05 K with a constant temperature bath connected to a refrigeration bath circulator. All the sample solutions were initially prepared at desired concentrations with a fixed $LiBr/H_2N(CH_2)_2OH$ mass ratio by weighing each component with a precision balance (Mettler, PM2000). The density measurements were carried out by using a set of hydrometers (Alla). Each hydrometer was capable of reading to 0.001, and the possible measuring interval of one hydrometer was 0.1 in specific gravity. The sample solution was first placed in the cylinder-type vessel fixed in the constant temperature bath. A suitable hydrometer was then selected and immersed in the sample solution. After the solution temperature reached a desired point, the specific gravity value was read from the meniscus of the solution with the hydrometer. The measured specific gravity values were simply converted to the density values with the density data of water (CRC, 1994). The viscosities were measured by using five well-calibrated Ubbelohde-type viscometers (Witeg, Capillary No. 0C, 0B, 1, 1C, and 2) which have different capillary diameters. A suitable viscometer was clamped in the constant temperature bath, and the temperature was adjusted at a desired point. The efflux time of a sample solution through the capillary of the viscometer was accurately measured by a stopwatch. The reproducibility of efflux time measurement was within ±0.1% of each value. The viscosity values were calculated by the following equation.

$$\eta = tK\rho \quad (1)$$

where η is the absolute viscosity, t is the efflux time, K is the given constant of each viscometer for the calculation

Table 1. Densities and Viscosities of the H_2O (1) + LiBr (2) + $H_2N(CH_2)_2OH$ (3) System ($LiBr/H_2N(CH_2)_2OH$ Mass Ratio 3.5/1) at Various Mass Fractions of Absorbent w_{2+3}

	T/K						
$100w_{2+3}$	283.15	293.15	303.15	313.15	323.15	333.15	343.15
			ρ/kg m^{-3}				
30.2	1200	1196	1193	1189	1185	1180	1175
40.2	1284	1281	1277	1272	1268	1263	1258
50.1	1380	1376	1371	1366	1361	1357	1352
59.9	1485	1480	1475	1470	1765	1460	1455
69.2	1607	1603	1597	1593	1587	1581	1576
75.0			1676	1672	1666	1661	1655
			η/mPa s				
30.2	2.58	1.98	1.57	1.29	1.06	0.898	0.779
40.2	3.74	2.84	2.25	1.81	1.51	1.27	1.10
50.1	6.56	4.87	3.76	3.05	2.53	2.08	1.83
59.9	17.8	12.4	9.09	6.90	5.38	4.36	3.63
69.2	89.0	53.9	34.6	23.9	17.2	12.9	9.93
75.0			104	65.2	43.4	29.9	21.6

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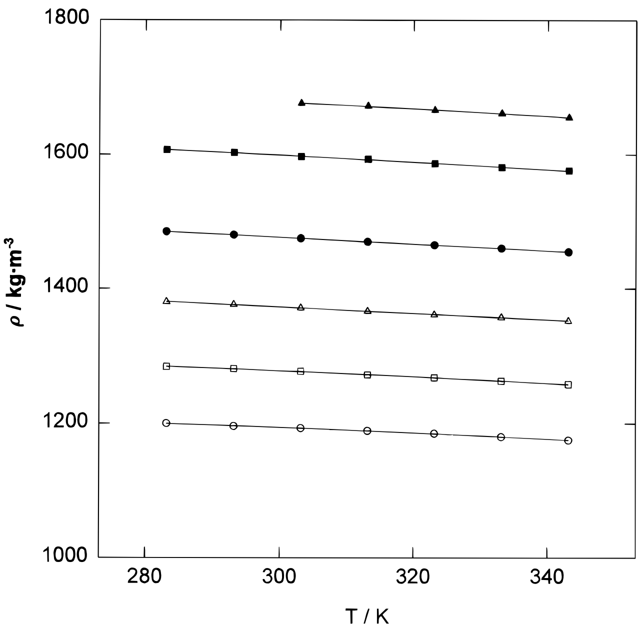

Figure 1. Densities of the H_2O (1) + LiBr (2) + $H_2N(CH_2)_2OH$ (3) system (LiBr/ $H_2N(CH_2)_2OH$ mass ratio = 3.5/1) at various mass fractions: (○) w_{2+3} = 0.302; (□) w_{2+3} = 0.402; (△) w_{2+3} = 0.501; (●) w_{2+3} = 0.599; (■) w_{2+3} = 0.692; (▲) w_{2+3} = 0.750; (—) calculated.

of kinematic viscosity (tK), and ρ is the density value at the same condition. The experimental apparatus and procedure were checked by the lithium bromide + water solution (Uemura and Hasaba, 1964) for the density measurement and by three pure components (CRC, 1994), water, 1-propanol, and ethylene glycol, for the viscosity measurement at various temperatures. The relative errors between the measured and the literature values were less than 0.1% for the density measurement and were less than 1% for the viscosity measurement.

Results and Discussion

Densities and viscosities of the water + lithium bromide ethanolamine (LiBr/$H_2N(CH_2)_2OH$ mass ratio = 3.5/1) were measured in the temperature range of (283.15 to 343.15) K and in the concentration range of (30.2 to 75.0) mass %. The measured density values were listed in Table 1 and were regressed by the following equation

$$\rho/\text{kg m}^{-3} = \sum_{i=0}^{3}[(a_i + b_iT + c_iT^2)(100w)^i] \qquad (2)$$

where ρ is the density of the solution, T is the absolute temperature in K, a_i, b_i, and c_i are the regression coefficients, and w is the absorbent (LiBr + $H_2N(CH_2)_2OH$) concentration in mass fraction. The regression coefficients were determined by a least-squares method and the results were listed in Table 2. The average absolute deviation between the experimental and the calculated values was 0.07%. Figure 1 shows the experimental and the calculated results of the density measurement. The measured viscosities were also listed in Table 1, and all the values were regressed by the following equation.

$$\log(\eta/\text{mPa s}) = \sum_{i=0}^{4}[(a_i + b_i/T + c_i/T^2)(100w)^i] \qquad (3)$$

where η is the viscosity of the solution, T is the absolute temperature in K, a_i, b_i, and c_i is the regression coefficients, and w is the absorbent (LiBr + $H_2N(CH_2)_2OH$) concentration in mass fraction. The regression coefficients were determined by a least-squares method and listed in Table 2. The average absolute deviation between the experimental and calculated values was found to be 0.72%. The experimental and calculated viscosity values were plotted in Figure 2 as a function of temperature at a fixed concentration. The new solution proposed shows slightly higher viscosity values over the entire experimental range compared with the existing working fluids. This is mainly due to the viscous ethanolamine used to suppress the crystallization of the solution.

Table 2. Values of a_i, b_i, and c_i for Least-Squares Representation by Equations 2 and 3

eq 2	eq 3
$a_0 = -1.97805 \times 10^3$	$a_0 = 2.10282 \times 10^3$
$a_1 = 1.92298 \times 10^2$	$a_1 = -1.95812$
$a_2 = -3.74217$	$a_2 = 6.32437 \times 10^{-2}$
$a_3 = 2.53180 \times 10^{-2}$	$a_3 = -8.55411 \times 10^{-4}$
$b_0 = 1.86551 \times 10$	$a_4 = 4.22498 \times 10^{-6}$
$b_1 = -1.14529$	$b_0 = -1.25024 \times 10^4$
$b_2 = 2.30560 \times 10^{-2}$	$b_1 = 1.09462 \times 10^3$
$b_3 = -1.52694 \times 10^{-4}$	$b_2 = -3.55379 \times 10$
$c_0 = -2.94943 \times 10^{-2}$	$b_3 = 4.87940 \times 10^{-1}$
$c_1 = 1.76887 \times 10^{-3}$	$b_4 = -2.46546 \times 10^{-3}$
$c_2 = -3.56152 \times 10^{-5}$	$c_0 = 1.72976 \times 10^6$
$c_3 = 2.35479 \times 10^{-7}$	$c_1 = -1.40951 \times 10^5$
	$c_2 = 4.65569 \times 10^3$
	$c_3 = -6.55108 \times 10^1$
	$c_4 = 3.46838 \times 10^{-1}$

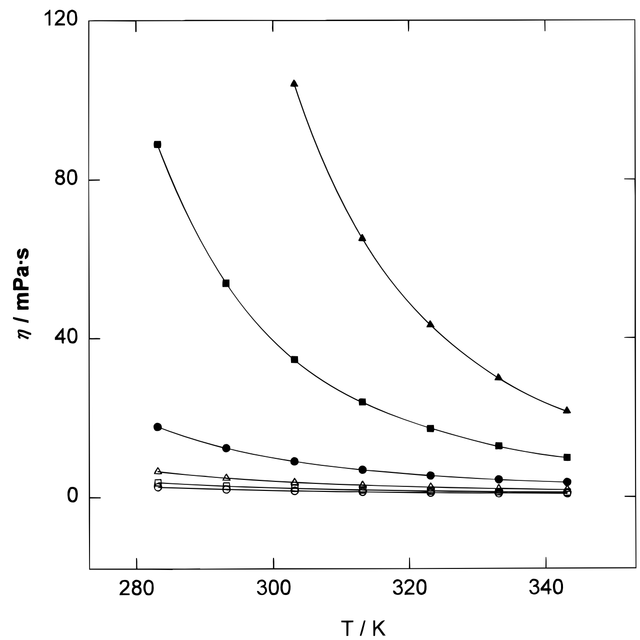

Figure 2. Viscosities of the H_2O (1) + LiBr (2) + $H_2N(CH_2)_2OH$ (3) system (LiBr/ $H_2N(CH_2)_2OH$ mass ratio = 3.5/1) at various mass fractions: (○) w_{2+3} = 0.302; (□) w_{2+3} = 0.402; (△) w_{2+3} = 0.501; (●) w_{2+3} = 0.599; (■) w_{2+3} = 0.692; (▲) w_{2+3} = 0.750; (—) calculated.

Conclusions

Densities and viscosities of the water + lithium bromide + ethanolamine system (LiBr/$H_2N(CH_2)_2OH$ mass ratio = 3.5/1) were measured at various temperatures and concentrations. All the experimental data sets were correlated with simple regression equations, and the results showed good agreements with the experimental values. The viscosity values of the new solution proposed in this study appeared to be a little higher than those of the existing working fluids. The density and viscosity measurements together with the solubility and vapor pressure data of the new working fluid are essential for the optimum design of an absorption heat pump.

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