Vapor Pressures of the Ethylamine + Water + Lithium Bromide System and Ethylamine + Water + Lithium Nitrate System

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Vapor pressures of the ethylamine + water + lithium bromide (H_2O:LiBr = 2:1 mass) system and the ethylamine + water + lithium nitrate (H_2O:$LiNO_3$ = 2:1 mass) system were measured by a boiling point method at temperatures from 296.25 K to 318.25 K and at ethylamine concentrations from 4.8 to 59.4 mass %, and at temperatures from 296.35 K to 316.25 K and at ethylamine concentrations from 4.8 to 64.0 mass %, respectively. The experimental vapor pressure data for these ternary systems were fitted to an Antoine-type equation. The calculated values from these equations for vapor pressures of two ternary systems were in good agreement with the experimental vapor pressure data.

Introduction

Two ternary systems of the ethylamine + water + lithium bromide (H_2O:LiBr = 2:1 mass) and the ethylamine + water + lithium nitrate (H_2O:$LiNO_3$ = 2:1 mass) were proposed in order to improve the performance characteristics, to reduce the dangerousness, the toxicity, and the cost of absorption refrigerating machines, absorption heat pumps, and absorption heat transformers, and to lower the pressure of the ammonia + water system. The analyses of absorption refrigeration and heat pump systems need extensive thermodynamic information such as vapor pressures, heat capacities, integral enthalpies of mixing, solubilities, densities, viscosities, and surface tensions for working fluids. Precise vapor pressure data of working fluids are important properties for the research and the reliable design in absorption refrigerating machines, absorption heat pumps, and absorption heat transformers. Vapor pressures of the ethylamine + water + lithium bromide system and the ethylamine + water + lithium nitrate system were measured by a boiling point method at various temperatures and ethylamine concentrations. The experimental vapor pressure data for these ternary systems were fitted to an Antoine-type of equation.

Experimental Section

Materials. The lithium bromide used in this work was from Honjo Chemical Co., Ltd., Japan, analytical reagent grade with a minimum purity of 99.9 mass %. The lithium nitrate used in this work was from Wako Pure Chemical Industries Ltd. (Japan), analytical reagent grade with a minimum purity of 99.8 mass %. The ethylamine used in this work was aqueous solution of 70.0 mass % from Wako Pure Chemical Industries Ltd., Japan, analytical reagent grade. All the reagents were used without further purification. The lithium bromide and lithium nitrate concentrations of solution was determined by Fajans' method (Takagi, 1976) with use of standardized silver nitrate solution and dichlorofluorescein as an adsorption indicator. The ethylamine concentration of solution was determined by a potentiometric titration method with use of potentiometric automatic titrator (Kyoto Electronics Manufacturing

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Table 1. Vapor Pressures of the $C_2H_5NH_2$ + H_2O + LiBr System (H_2O:LiBr = 2:1 mass)

T/K	P/kPa	T/K	P/kPa
	4.8 mass %		
300.45	3.70	306.55	5.38
306.85	5.50	309.25	6.33
310.55	6.83	313.35	8.03
	9.7 mass %		
304.85	6.86	307.05	7.84
310.75	9.75	313.85	11.66
313.95	11.71	316.95	13.86
	14.6 mass %		
300.65	6.97	302.55	7.80
302.65	7.85	308.25	11.02
312.85	14.34	314.15	15.47
	19.6 mass %		
300.55	8.96	305.05	11.75
305.35	11.98	308.05	13.92
315.55	21.17	318.25	24.49
	23.8 mass %		
299.35	10.40	301.55	11.73
307.65	16.54	309.35	18.15
313.65	22.87		
	28.9 mass %		
300.65	14.11	305.35	18.40
307.75	20.84	313.65	28.47
316.95	33.51		
	39.2 mass %		
300.65	22.46	304.15	26.82
305.45	28.84	310.85	37.54
314.35	44.41		
	43.9 mass %		
296.25	21.95	299.05	25.30
305.35	34.48	305.55	34.87
308.85	40.84	311.65	46.40
	48.5 mass %		
299.75	32.28	300.45	33.34
307.95	47.45	308.55	48.81
309.75	51.29	310.65	53.57
	49.2 mass %		
298.05	30.23	301.25	35.10
303.75	39.55	306.25	44.50
309.25	50.94	314.55	64.44
	59.4 mass %		
299.15	49.80	305.35	64.65
306.15	67.06	307.85	71.58
310.25	78.36	311.85	83.59

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Table 2. Vapor Pressures of the $C_2H_5NH_2 + H_2O + LiNO_3$ System (H_2O:$LiNO_3$ = 2:1 mass)

T/K	*P*/kPa	*T*/K	*P*/kPa
	4.8 mass %		
304.65	5.07	305.75	5.37
307.95	6.08	310.75	7.06
311.65	7.42	312.65	7.82
	9.6 mass %		
298.35	4.67	302.45	5.98
307.55	8.04	307.65	8.08
309.55	9.02	314.55	11.82
	19.5 mass %		
297.45	6.80	305.95	11.19
308.85	13.13	313.45	16.77
313.85	17.19	316.25	19.48
	23.6 mass %		
305.05	12.48	305.75	12.95
307.35	14.06	308.15	14.69
309.95	16.28	310.95	17.14
	28.9 mass %		
300.25	11.75	303.75	14.28
309.55	19.44	310.65	20.53
313.45	23.68	314.05	24.43
	33.8 mass %		
301.35	15.32	302.65	16.44
306.15	19.75	307.35	20.89
307.55	21.06	310.85	25.05
	38.6 mass %		
298.15	15.97	300.25	17.84
302.15	19.69	304.15	21.95
309.95	29.27	312.05	32.35
	44.2 mass %		
296.35	18.53	298.65	20.76
304.95	28.69	305.75	29.70
308.05	33.49	309.15	34.97
	50.5 mass %		
298.35	27.25	303.65	35.58
303.75	35.89	304.55	37.27
304.85	37.76	307.45	42.91
	59.0 mass %		
299.55	43.02	301.35	46.62
303.75	51.67	305.15	55.05
306.45	58.12	309.95	67.16
	64.0 mass %		
300.45	56.12	302.05	59.80
302.85	61.63	304.25	65.08
310.05	80.71	310.75	82.73

Co., Ltd., Japan, model AT-400). The lithium bromide of solution was titrated by using a microburet of 10 mL total delivery, with divisions of 0.02 mL. All weighings were made on a direct-reading balance (mass capacity 200 g, reciprocal sensibility 1 mg). Double-distilled and degassed water was used in this work.

Apparatus and Procedure. The experimental apparatus used for vapor pressure measurements has been reported in our previous papers (Iyoki and Uemura, 1989, 1990; Iyoki et al., 1990, 1993). It consists primarily of a sample vessel with a volume of about 500 cm^3, a constant temperature bath, a heater, a temperature controller, and a U-tube manometer. The equilibrium still was made of Pyrex glass. The temperature inside the sample vessel was measured by using a standard thermometer. The measurements of pressure were carried out with a mercury U-tube manometer. The constant temperature bath was maintained to within ±0.01 K. The heights of the meniscuses in the manometer limbs were read to ±0.05 mm with a cathetometer.

A sample solution (250 cm^3) at various ethylamine concentrations was placed in the sample vessel, and it was stirred well with a magnetic stirrer to prevent superheating. After thermal equilibrium was reached, the temperature of the sample solution and the pressure in the apparatus were measured. The vapor pressure measurements at various temperatures were also made on pure water to examine the accuracy of the experimental apparatus and procedure. The results agreed well with literature value (Steam Tables, 1980), with a maximum deviation of less than 0.3%.

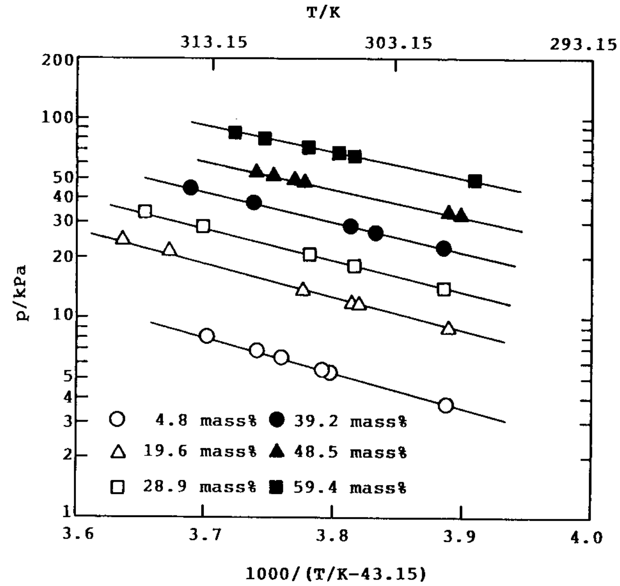

Figure 1. Vapor pressures of the $C_2H_5NH_2 + H_2O$ + LiBr (H_2O:LiBr = 2:1 mass) system.

Results and Discussion

The vapor pressures of the ethylamine + water + lithium bromide system were measured in the range of temperatures from 296.25 K to 318.25 K and in the range of ethylamine concentrations from 4.8 to 59.4 mass %. The experimental results of 63 measurements for this ternary system at various temperatures and ethylamine concentrations are shown in Table 1. The vapor pressures of the ethylamine + water + lithium nitrate system were measured in the range of temperatures from 296.35 K to 316.25 K and in the range of ethylamine concentrations from 4.8 to 64.0 mass %. The experimental results of 66 measurements for this ternary system at various temperatures and ethylamine concentrations are shown in Table 2. These experimental results were used to determine the constants for an empirical formula with a least-squares method. A part of the experimental results for the ethylamine + water + lithium bromide system and the ethylamine + water + lithium nitrate system are plotted in the form of log P/kPa vs 1000/(T/K − 43.15) in Figures 1 and 2, respectively. In these figures, the log P/kPa vs 1000/(T/K − 43.15) relationships for the ethylamine concentration over the temperature and pressure measured were linear. The experimental data were correlated by means of the Antoine-type equation, which expresses vapor pressure as a function of temperature and ethylamine concentration

$$\log p/\mathrm{Pa} = \sum_{n=0}^{6}\{A_n + [10^3 B_n/(T/\mathrm{K} - 43.15)]\}w^n \qquad (1)$$

where P is the vapor pressure, n is the integer exponent, T is the absolute temperature, and w is the ethylamine concentration in mass % of solution. Values of the constants A_n and B_n in eq 1 are shown in Table 3 for the ethylamine + water + lithium bromide system. Values of

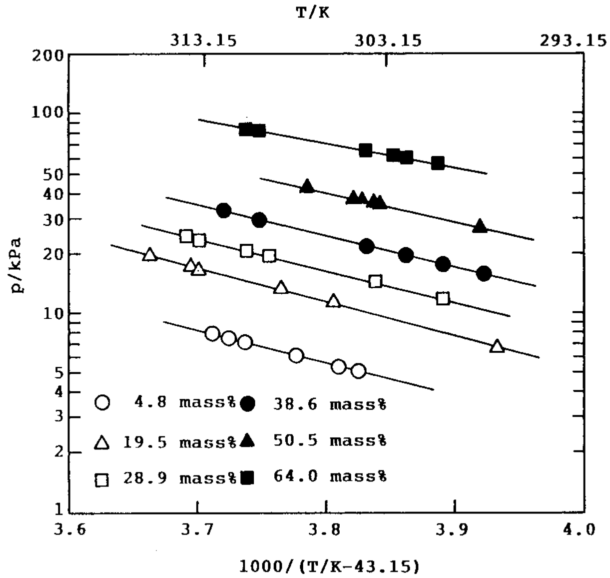

Figure 2. Vapor pressures of the $C_2H_5NH_2 + H_2O + LiNO_3$ (H_2O:$LiNO_3$ = 2:1 mass) system.

Table 3. Values of Coefficients A_n and B_n in Eq 1 for the $C_2H_5NH_2 + H_2O + LiBr$ System (H_2O:LiBr = 2:1 mass)

n	A_n	B_n
0	9.989 90	−1.702 89
1	$1.684\ 80 \times 10^{-1}$	$-3.057\ 95 \times 10^{-2}$
2	$-1.192\ 21 \times 10^{-2}$	$2.512\ 14 \times 10^{-3}$
3	$3.395\ 05 \times 10^{-4}$	$-6.358\ 34 \times 10^{-5}$
4	$-4.156\ 31 \times 10^{-6}$	$4.863\ 50 \times 10^{-7}$
5	$9.471\ 39 \times 10^{-9}$	$4.947\ 37 \times 10^{-9}$
6	$1.163\ 11 \times 10^{-10}$	$-6.715\ 66 \times 10^{-11}$

the constants A_n and B_n in eq 1 are shown in Table 4 for the ethylamine + water + lithium nitrate system. The percent deviation at a given temperature and ethylamine concentration is defined as $100(P_{exp} - P_{cal})/P_{exp}$. The percent average absolute deviation is defined as $100[\Sigma\{(P_{exp} - P_{cal})/P_{exp}\}/N]$. N is the number of experimental data. Maximum and average absolute deviations between the experimental data and the calculated values from eq 1 were 0.92% and 0.27% for the ethylamine + water + lithium bromide system, respectively. Maximum and average absolute

Table 4. Values of Coefficients A_n and B_n in Eq 1 for the $C_2H_5NH_2 + H_2O + LiNO_3$ System (H_2O:$LiNO_3$ = 2:1 mass)

n	A_n	B_n
0	9.160 38	−1.480 05
1	$2.641\ 78 \times 10^{-1}$	$-5.501\ 96 \times 10^{-2}$
2	$-1.911\ 45 \times 10^{-2}$	$4.253\ 20 \times 10^{-3}$
3	$6.633\ 09 \times 10^{-4}$	$-1.445\ 54 \times 10^{-4}$
4	$-1.292\ 34 \times 10^{-5}$	$2.778\ 80 \times 10^{-6}$
5	$1.401\ 56 \times 10^{-7}$	$-3.017\ 89 \times 10^{-8}$
6	$-6.723\ 56 \times 10^{-10}$	$1.474\ 32 \times 10^{-10}$

deviations between the experimental data and the calculated values from eq 1 were 0.98% and 0.28% for the ethylamine + water + lithium nitrate system, respectively.

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