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Solubility of Ethane in Aqueous Solutions of Triethanolamine

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The solubility of ethane in three triethanolamine solutions (2, 3, and 5 mol dm^{-3}) has been determined at five temperatures between 25 and 125 °C at pressures up to 20 MPa.

Aqueous alkanolamine solutions are commonly used for the removal of H_2S and CO_2 from natural gas streams. The solubility of hydrocarbons in the amine solutions is of interest, since the hydrocarbons which dissolve in the solution represent a loss of valuable products. Kohl and Riesenfeld (1985) presented some data for the solubility of methane in a monoethanolamine solution also containing S and CO_2. Lawson and Garst (1976) reported data for the solubility of methane and ethane in monoethanolamine and diethanolamine solutions at elevated pressures. Sada et al. (1977, 1978) measured the solubility of ethylene and acetylene in aqueous solutions of several amines at 25 °C and atmospheric pressure. Dingman (1986) reported the solubility of hydrogen and methane in aqueous diglycolamine solutions at pressures up to 20.7 MPa. The present work was undertaken to provide data on the effect of pressure, temperature, and concentration of the amine solution of the solubility of ethane in triethanolamine solutions.

Table 1. Solubility of Ethane (2) in 2.0 mol dm^{-3} TEA Solution

P/kPa	S/(mol/ 100 kg)	x_2	P/kPa	S/(mol/ 100 kg)	x_2
		25 °C			
19960	6.71	1.61×10^{-3}	4210	5.58	1.34×10^{-3}
15740	6.37	1.53×10^{-3}	2440	3.98	9.55×10^{-4}
12180	6.04	1.45×10^{-3}	849	1.67	4.02×10^{-4}
8040	5.67	1.36×10^{-3}	96.2[a]	0.197	4.73×10^{-5}
		50 °C			
19600	6.73	1.62×10^{-3}	2390	2.91	6.98×10^{-4}
15110	6.65	1.60×10^{-3}	4300	4.42	1.06×10^{-3}
10640	6.27	1.51×10^{-3}	979	1.40	3.36×10^{-4}
6210	5.50	1.32×10^{-3}	284	0.40	9.64×10^{-5}
		75 °C			
17660	7.10	1.71×10^{-3}	2550	2.83	6.79×10^{-4}
13720	6.98	1.68×10^{-3}	1010	1.33	3.19×10^{-4}
7020	5.63	1.35×10^{-3}	329	0.401	9.65×10^{-5}
4580	4.27	1.02×10^{-3}			
		100 °C			
18290	9.05	2.17×10^{-3}	2690	2.94	7.07×10^{-4}
12710	7.59	1.82×10^{-3}	1290	1.50	3.61×10^{-4}
6730	5.72	1.37×10^{-3}	479	0.515	1.24×10^{-4}
4480	4.35	1.04×10^{-3}			
		125 °C			
17280	10.30	2.47×10^{-3}	4390	4.67	1.13×10^{-3}
13660	9.65	2.32×10^{-3}	2710	3.06	7.35×10^{-4}
10340	8.39	2.01×10^{-3}	1100	1.17	2.82×10^{-4}
6300	6.17	1.48×10^{-3}			

[a] Residual correction.

Experimental Section

Amine solutions were prepared from distilled water and triethanolamine having a purity of 99.4% obtained from Fisher Scientific. Ethane (c.p. grade, 99.0% minimum, liquid phase) was obtained from Matheson. The equipment used to determine the solubility data was that previously used in our laboratory (Jou et al., 1985). The apparatus consisted of a Jerguson liquid level gauge with a 50 cm^3 tubular gas reservoir mounted on the top. A magnetically driven piston pump was used to circulate the gas phase and bubble it through the liquid solution. The total volume of the apparatus including the cell, gas reservoir, tubing, and the pump is 250 cm^3. The apparatus is mounted in an air bath of dimensions 0.61 × 0.91 × 1.22 m. The air bath is equipped with a 3000 W heater and a refrigeration unit and fan; it can be controlled to within ±0.5 deg. The temperature inside the cell was measured with an iron−constantan thermocouple with an accuracy of ±0.1 deg. The pressure in the cell was measured with two calibrated digital Heise gauges (0−10 MPa and 0−35 MPa). The Heise gauges have an accuracy of 0.1% of full scale according to a calibration against a dead-weight gauge. The TEA solution of the desired concentration was charged to the evacuated cell, and ethane was then added in an amount determined by observation of the pressure. Analysis of the vapor phase with the gas chromatograph showed that the vapor was greater than 99.9% ethane. To ensure that equilibrium was reached, the vapor was bubbled through the liquid for at least 4 h prior to sampling of the liquid phase. The liquid sample from the cell was passed into a 40 mL weighed and evacuated sample bomb which contained a stirring bar. The bomb was then attached to a mercury-filled buret and the pressure brought to atmospheric with nitrogen gas while agitation with the stirring magnet took place. The amount of ethane evolved from the liquid sample upon expansion into the evacuated bomb was so small that the pressure was subatmospheric. Hence the introduction of nitrogen. The vapor phase in the sample bomb was analyzed by taking a 0.5 mL sample through a rubber septum and injecting it into a chromatograph equipped with a 1.82 m long, 3.175 mm o.d. column packed with Poropak QS. The sample bomb was reweighed to determine the mass of solution from which the ethane evolved. To determine the residual ethane content of the liquid at the local atmospheric pressure, a 4 μL sample of the liquid was injected into the chromatograph. A 100 μL sample of ethane gas was injected to quantify the residual amount of ethane in the solution. From the $P-V-T$ data and the mole fraction of ethane in the vapor phase of the sample bomb, and by allowing for the water vapor by use of Raoult's law, the amount of ethane evolved was calculated. This quantity added to the the residual gives the solubility of ethane in the triethanolamine solution at the

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Table 2. Solubility of Ethane (2) in 3.0 mol dm^{-3} TEA Solution

P/kPa	S/(mol/ 100 kg)	x_2	P/kPa	S/(mol/ 100 kg)	x_2
25 °C					
19450	6.79	1.93×10^{-3}	4230	5.63	1.63×10^{-3}
14370	6.25	1.78×10^{-3}	3150	4.68	1.33×10^{-3}
9790	6.31	1.80×10^{-3}	2050	3.54	1.01×10^{-3}
6560	5.88	1.68×10^{-3}	422	0.85	2.42×10^{-4}
50 °C					
18990	8.34	2.37×10^{-3}	5340	6.16	1.75×10^{-3}
14490	7.49	2.13×10^{-3}	3250	4.75	1.35×10^{-3}
12470	8.36	2.38×10^{-3}	872	1.55	4.42×10^{-4}
10340	7.78	2.20×10^{-3}	280	0.53	1.51×10^{-4}
7390	7.17	2.04×10^{-3}			
75 °C					
18610	9.39	2.67×10^{-3}	5910	6.63	1.89×10^{-3}
14330	9.24	2.63×10^{-3}	3650	4.86	1.38×10^{-3}
13160	9.36	2.66×10^{-3}	989	1.63	4.66×10^{-4}
10590	8.79	2.50×10^{-3}	264	0.46	1.30×10^{-4}
100 °C					
17010	10.65	3.03×10^{-3}	3110	4.16	1.19×10^{-3}
13150	9.97	2.83×10^{-3}	891	1.37	3.90×10^{-4}
11130	9.55	2.72×10^{-3}	261	0.39	1.12×10^{-4}
6530	7.16	2.04×10^{-3}			
125 °C					
16970	13.5	3.84×10^{-3}	2930	4.46	1.27×10^{-3}
12700	12.77	3.63×10^{-3}	1020	1.71	4.88×10^{-4}
9390	10.51	2.99×10^{-3}	274	0.49	1.41×10^{-4}
6250	8.46	2.41×10^{-3}			

Table 3. Solubility of Ethane (2) in 5.0 mol dm^{-3} TEA Solution

/kPa	S/(mol/ 100 kg)	x_2	P/kPa	S/(mol/ 100 kg)	x_2
25 °C					
19890	9.28	4.10×10^{-3}	2240	5.56	2.46×10^{-3}
14050	9.18	4.06×10^{-3}	793	2.25	1.00×10^{-3}
10010	8.73	3.86×10^{-3}	282	0.845	3.75×10^{-4}
6100	8.26	3.65×10^{-3}			
50 °C					
18470	11.2	4.98×10^{-3}	4130	7.76	3.46×10^{-3}
14770	11.2	4.93×10^{-3}	2510	5.47	2.44×10^{-3}
12170	10.4	4.57×10^{-3}	843	1.93	8.68×10^{-4}
10560	11.1	4.89×10^{-3}	278	0.779	3.45×10^{-4}
6390	9.85	4.37×10^{-3}			
75 °C					
13710	13.4	5.90×10^{-3}	2490	5.30	2.37×10^{-3}
11030	13.1	5.78×10^{-3}	963	2.19	9.78×10^{-4}
6840	10.7	4.75×10^{-3}	328	0.783	3.47×10^{-4}
4490	8.34	3.73×10^{-3}			
100 °C					
17890	16.9	7.43×10^{-3}	4470	8.66	3.86×10^{-3}
13650	16.3	7.16×10^{-3}	2830	6.00	2.67×10^{-3}
10840	14.5	6.38×10^{-3}	1070	2.33	1.04×10^{-3}
6600	11.5	5.11×10^{-3}	364	0.799	3.54×10^{-4}
125 °C					
16800	20.4	8.94×10^{-3}	4910	9.82	4.36×10^{-3}
12850	18.7	8.24×10^{-3}	3130	6.79	3.02×10^{-3}
9940	16.3	7.16×10^{-3}	1110	2.37	1.06×10^{-3}
6430	12.6	5.59×10^{-3}			

conditions of the experiment. Replicate measurements indicated that the uncertainty in the solubility is less than 5%.

Results

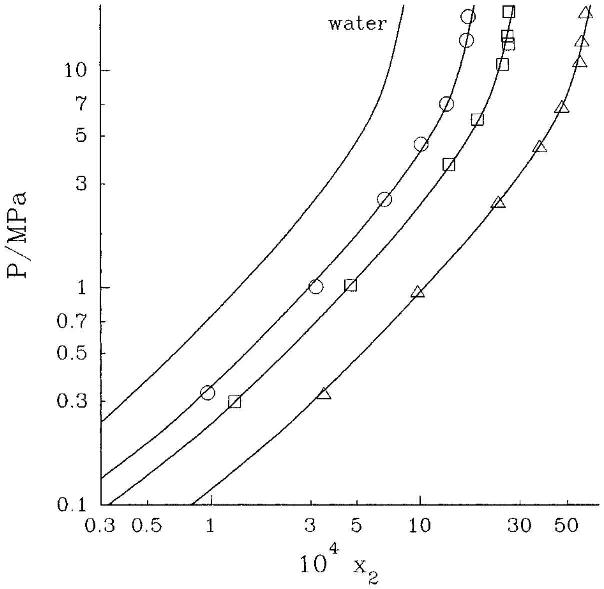

Figure 1. Effect of pressure on the solubilty of ethane (2) in triethanolamine solutions at 75 °C: (○) 2 mol dm^{-3}; (□) 3 mol dm^{-3}; (△) 5 mol dm^{-3}.

The solubility of ethane in (2.0, 3.0, and 5.0) mol dm^{-3} triethanolamine solutions has been measured at (25, 50, 75, 100, and 125) °C at pressures up to 20 MPa. The results are presented in Tables 1−3. At 25 °C ethane liquefies at 4250 kPa, and hence data at pressures greater than this value are for liquid−liquid equilibrium. The solubility is reported in two units, S, the moles of ethane per 100 kg of solution, and x_2, the mole fraction of ethane in the liquid phase. Typical results are shown in Figure 1 for 75 °C. It can be seen that the solubility of ethane is greater in the triethanolamine solutions than in water. The curve for water was obtained by interpolation of the measurements of Culberson and McKetta (1950).

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