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(Vapour + liquid) equilibria of the {pentafluoroethane (HFC-125) + dimethyl ether (DME)} system

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Abstract

Binary (vapour + liquid) equilibrium data were measured for the {pentafluoroethane (HFC-125) + dimethyl ether (DME)} system at temperatures from (313.15 to 363.15) K. These experiments were carried out with a circulating-type apparatus with on-line gas chromatography. The experimental data were correlated well by the Peng–Robinson Stryjek–Vera equation of state using the Wong–Sandler mixing rules.

Keywords: (Vapour + liquid) equilibria; Pentafluoroethane (HFC-125); Dimethyl ether

1. Introduction

As a consequence of the Montreal Protocol in 1987, the production and use of refrigerants with high ozone depletion potentials (ODPs), such as the chlorofluorocarbons (CFCs), became regulated. Hydrofluorocarbons (HFCs) are proposed as promising alternative refrigerants to substitute for CFCs, because of their zero ODPs. With HFCs, dimethyl ether (DME) has been used as an alternative refrigerant of CFCs because of its environmental friendly properties. The DME has zero ODPs and is not toxic. Moreover, DME can be associated with HFCs by hydrogen bonding between the oxygen of DME and the hydrogen of HFCs [1–4]. Thus, mixtures of HFCs and DME have been studied as good candidates of alternative refrigerants.

In this study, isothermal (vapour + liquid) equilibrium data were measured for the (HFC-125 + DME) system as an alternative refrigerant in the temperature range from (313.15 to 363.15) K at 10 K intervals. The experimental data were correlated by the Peng–Robinson Stryjek–Vera (PRSV) equation of state [5,6] with the Wong–Sandler mixing rules [7]. Other experimental (vapour + liquid) equilibrium data for the (HFC-125 + DME) system were presented by Bobbo *et al.* [8]. The temperature range in the literature ranges from (258.15 to 303.15) K.

2. Experimental

2.1. Materials

The DME of mass fraction purity 0.998 was supplied by LG Chem. Ltd. and HFC-125 with purity mass fraction purity 0.998 was obtained from Ulsan Chemical Co. All components were used without further purification in these experiments.

2.2. Experimental apparatus

The measurement of the VLE data was conducted in a circulation type apparatus. Details of this apparatus were

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given in our previous study [9]. The equilibrium cell was made of 316 stainless steel with an inner volume of about 320 cm^3. It was equipped with two windows and two magnetic pumps. Because two magnetic pumps circulated the vapour and liquid phases separately, equilibrium was quickly reached. The temperature in the cell was measured with a 100 Ω platinum resistance thermometer (Hart Scientific Co., model 5627) and a digital indicator (Hart Scientific Co., model 1502A) with an accuracy of 0.05 K. The pressure of the cell was measured with pressure transducer (Sensotec Co., model Super TJE, (0 to 10.3) MPa), calibrated by the national calibration lab 'Korea Testing Laboratory', connected to a digital indicator (Laurel, model L20010WM1). An accuracy of the digital pressure gauge is 0.05%. In order to trap the liquid and vapour samples, we used two sampling valves (Rheodyne Instruments, model 7413 with a $0.5 \cdot 10^{-3}$ cm^3 sampling loop for liquid, model 7010 with a $10 \cdot 10^{-3}$ cm^3 sampling loop for the vapour). A gas chromatograph was connected on-line to the equilibrium apparatus. The gas chromatograph was equipped a thermal conductivity detector (TCD) and a Porapak-Q column(1.83-m long; 3.18-mm diameter; mesh range, 80/100). Helium was used as a carrier gas.

2.3. Experimental procedure

The whole system was evacuated with a vacuum pump to remove all the impurities. Next, a fixed amount of DME was injected into the cell, after which a proper amount of HFC-125 was charged. After the target temperature was reached, two magnetic pumps were started to circulate the vapour and liquid phases. When the equilibrium was reached, the vapour and liquid samples were fed into the gas chromatograph and the compositions were measured. The equilibrium compositions of each phase were measured at least five times in a row to obtain reliable average values. Deviations and the accuracy of the equilibrium composition were less than 0.0005 in the mole fraction.

3. Correlations

Experimental data were correlated with Peng–Robinson Stryjek–Vera equation of state (PRSV EoS) [5,6], which was our objective function, using the Wong–Sandler mixing rules [7]. The PRSV EoS and the Wong–Sandler mixing rules are expressed as follows:

TABLE 1
Pure component parameters

	HFC-125	DME
T_c/K	339.16	400.1
P_c/kPa	3666.1	5439.8
ω	0.3053	0.2002
κ_1	−0.0216	−0.0447

TABLE 2
(Vapour − liquid) equilibrium measurements for the {xHFC-125 + (1 − x)DME} system

P_{exp}/kPa	x_{exp}	y_{exp}	P_{cal}/kPa	y_{cal}	ΔP^a/kPa	$\Delta y_1{}^b$
			313.15 K			
887	0.0000	0.0000	889	0.0000	2	0.0000
924	0.0831	0.1080	915	0.1072	−9	−0.0008
968	0.1790	0.2130	960	0.2372	−8	0.0242
1000	0.2430	0.2933	998	0.3234	−2	0.0301
1070	0.3558	0.4355	1082	0.4680	12	0.0325
1182	0.4807	0.5890	1201	0.6117	19	0.0227
1406	0.6569	0.7723	1416	0.7808	10	0.0085
1523	0.7298	0.8352	1523	0.8394	0	0.0042
1651	0.8050	0.8903	1645	0.8927	−6	0.0024
1795	0.8849	0.9393	1787	0.9421	−8	0.0028
1894	0.9391	0.9689	1891	0.9713	−3	0.0024
2009	1.0000	1.0000	2013	1.0000	4	0.0000
			323.15 K			
1147	0.0000	0.0000	1145	0.0000	−2	0.0000
1196	0.0869	0.1131	1186	0.1137	−10	0.0006
1238	0.1560	0.1951	1228	0.2057	−10	0.0106
1277	0.2146	0.2679	1271	0.2825	−6	0.0146
1326	0.2797	0.3469	1326	0.3653	0	0.0184
1364	0.3261	0.4036	1370	0.4222	6	0.0186
1446	0.4079	0.5046	1457	0.5173	11	0.0127
1558	0.5040	0.6048	1575	0.6201	17	0.0153
1688	0.5920	0.6968	1700	0.7055	12	0.0087
1869	0.6944	0.7956	1869	0.7947	0	−0.0009
2020	0.7688	0.8554	2008	0.8530	−12	−0.0024
2275	0.8863	0.9347	2261	0.9340	−14	−0.0007
2537	1.0000	1.0000	2547	1.0000	10	0.0000
			333.15 K			
1451	0.0000	0.0000	1452	0.0000	1	0.0000
1490	0.0432	0.0580	1481	0.0578	−9	−0.0002
1533	0.0960	0.1262	1522	0.1278	−11	0.0016
1566	0.1374	0.1748	1556	0.1818	−10	0.0070
1626	0.2116	0.2616	1626	0.2762	0	0.0146
1693	0.2808	0.3408	1700	0.3608	7	0.0200
1766	0.3501	0.4244	1783	0.4416	17	0.0172
1999	0.5153	0.6089	2021	0.6169	22	0.0080
2129	0.5882	0.6816	2147	0.6863	18	0.0047
2289	0.6624	0.7508	2289	0.7519	0	0.0011
2491	0.7507	0.8271	2479	0.8238	−12	−0.0033
2674	0.8241	0.8796	2658	0.8789	−16	−0.0007
2849	0.8871	0.9255	2827	0.9235	−22	−0.0020
3170	1.0000	1.0000	3183	1.0000	13	0.0000
			343.15 K			
1817	0.0000	0.0000	1817	0.0000	0	0.0000
1850	0.0304	0.0423	1841	0.0395	−9	0.0028
1948	0.1222	0.1565	1928	0.1595	−20	−0.0030
2004	0.1753	0.2193	1989	0.2277	−15	0.0084
2070	0.2373	0.2934	2068	0.3050	−2	0.0116
2155	0.2986	0.3702	2155	0.3788	0	0.0086
2275	0.3882	0.4611	2299	0.4789	24	0.0178
2437	0.4790	0.5655	2464	0.5725	27	0.0070
2557	0.5411	0.6224	2589	0.6317	32	0.0093
2669	0.5977	0.6729	2711	0.6826	42	−0.0097
2904	0.6889	0.7537	2927	0.7588	23	−0.0051
3144	0.7680	0.8220	3134	0.8200	−10	0.0020
3344	0.8378	0.8701	3336	0.8713	−8	−0.0012
3594	0.9119	0.9218	3575	0.9242	−19	−0.0024
3630	0.9224	0.9285	3611	0.9316	−19	−0.0031
3640	0.9274	0.9296	3628	0.9350	−12	−0.0054

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