Liquid Densities and Vapor Pressures of 1-Chloro-1,1-difluoroethane (HCFC 142b)

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Thirty-six saturated liquid densities of HCFC 142b (1-chloro-1,1-difluoroethane) were measured in a range of temperatures from 210 to 400 K. Twelve vapor pressures, from 320 to 400 K, and six compressed liquid *PVT* properties, from 320 to 360 K and of pressures up to 2 MPa, were also measured. All measurements were made by a magnetic densimeter coupled with a variable volume cell. The experimental uncertainties in temperature, pressure, and density were estimated to be not greater than ±15 mK, ±10 kPa, and ±0.2%, respectively. The purity of the sample used was 99.8 wt % or better. The simple correlation for the saturated liquid density of HCFC 142b was developed.

Introduction

Hydrochlorofluorocarbon 142b (HCFC 142b, 1-chloro-1,1-difluoroethane) has not been applied into an engineering practice due to its flammability but now attracts the public attention because of its low ozone depletion potential. HCFC 142b is expected to be a substitutive working fluid for vapor-compression refrigeration systems, especially as a component of a binary mixture of HCFC 22 + HCFC 142b for replacing pure CFC 12. General features of HCFC 142b are listed in Table I.

Concerning the saturated liquid density of HCFC 142b, four publications are available up to the present. These are listed in Table II. The purity of the sample used by Mears et al. (*3*) was not described in their paper, but they used the sample that they had purified. Unfortunately, however, these saturated liquid density values are not consistent with each other.

This paper reports the saturated liquid densities, the vapor pressures, and the *PVT* properties of the compressed liquid HCFC 142b.

Experimental Section

A magnetic densimeter coupled with a variable volume cell accompanying a metallic bellows was applied for the measurements in the present study. The apparatus and procedure used here were reported in detail in our previous publication (*6*).

The sample temperature, which was determined to be in equilibrium with the thermostated bath fluid temperature, was measured by a 25-Ω standard platinum resistance thermometer. The sample pressure was measured by a precision digital pressure gauge (Heise Model 901B) and a differential pressure gauge. The Validyne Model DP15-42 was used as a differential pressure gauge in our previous work (*6*), but in the present study, a small metallic bellows cell associated with a linear variable differential transformer was used. The density of the sample was measured by the magnetic densimeter.

The experimental uncertainty of the temperature was estimated to be within ±15 mK as the sum of 2 mK, the precision of the thermometer, 1 mK, the precision of the thermometer bridge, and 12 mK, the possible temperature fluctuation of the thermostated liquid in the bath. The uncertainty of the pressure was estimated to be within ±10 kPa as the sum of 5 kPa, the precision of the pressure gauge, and 5 kPa, the reproducibility of the differential pressure gauge. The uncertainty of the density was estimated to be within ±0.2% as the reproducibility of the magnetic densimeter.

The purities of the samples used were 99.8 and 99.9 wt %.

Table I. General Features of HCFC 142b

chemical formula	CH_3CClF_2
molecular weight	100.496 g/mol
normal boiling point (*1*)	263.45 K
normal freezing point (*1*)	142.15 K
critical temperature (*7*)	410.29 K
critical pressure (*8*)	4.041 MPa
critical density (*7*)	446 kg/m³
flammable limit (*1*)	7.8–16.8 vol % in air
ozone depletion potential (*1*)	(<0.05)
global warming potential (*1*)	(≤0.2)
toxicity (*1*)	5A

Table II. Available Saturated Liquid Density Measurements of HCFC 142b

temp range/K	no. of data	accuracy %	purity (wt %)	ref
193–303	7	0.2	98	2
232–400	14	0.2		3
213–366	15	0.1	97	4
298–373	4	0.1	98.8	5
210–400	36	0.2	>99.8	this work

Table III. Experimental Saturated Liquid Densities and Vapor Pressures

no.	T/K	ρ/(kg/m³)	no.	T/K	P/MPa	ρ/(kg/m³)
1	210.002	1304.1	19	309.999		1078.6
2	219.999	1283.1	20	320.000		1052.1
3	220.009	1282.4	21	329.999		1023.4
4	220.009	1286.5	22	340.002		993.2
5	229.991	1261.1	23	349.997		961.2
6	230.001	1263.3	24	359.960		923.6
7	239.996	1240.6	25	319.994	0.632	1051.4
8	239.996	1241.7	26	330.005	0.815	1021.2
9	249.993	1218.5	27	339.998	1.030	995.5
10	250.003	1221.1	28	349.996	1.274	959.5
11	260.001	1198.2	29	350.003	1.277	956.9
12	260.012	1198.3	30	359.996	1.587	924.5
13	270.010	1174.6	31	370.006	1.939	881.9
14	270.010	1175.7	32	370.008	1.943	882.5
15	270.031	1175.4	33	380.001	2.349	837.1
16	279.999	1152.7	34	390.001	2.838	779.9
17	289.968	1127.7	35	400.003	3.381	705.4
18	300.049	1104.1	36	400.005	3.388	703.5

Table IV. Experimental Compressed Liquid *PVT* Properties

no.	T/K	P/MPa	ρ/(kg/m³)
1	319.998	0.996	1053.2
2	320.003	1.501	1055.7
3	319.992	1.997	1057.8
4	339.996	1.503	1000.9
5	339.996	2.000	1004.5
6	359.992	1.995	929.8

Results

The saturated liquid densities of HCFC 142b were measured at temperatures from 210 to 400 K. The vapor pressures were

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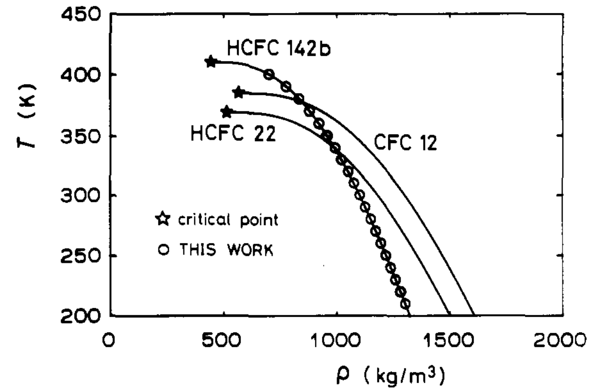

Figure 1. Saturated liquid densities of HCFC 142b, HCFC 22, and CFC 12. Solid lines were calculated by eq 1 for HCFC 142b and by Okada's correlations (*10*) for HCFC 22 and CFC 12.

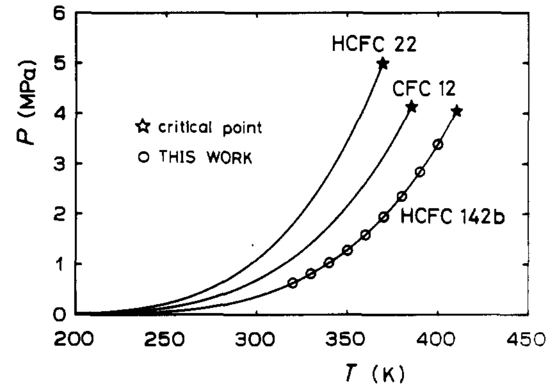

Figure 2. Vapor pressures of HCFC 142b, HCFC 22, and CFC 12. Solid lines were calculated by K. Kumagai's correlation (*8*) for HCFC 142b and by correlations reported in JAR tables (*11*, *12*) for HCFC 22 and CFC 12, respectively.

measured at temperatures from 320 to 400 K, while the compressed liquid densities were measured from 320 to 360 K and pressures up to 2 MPa. Some experimental series of measurements were carried out without using the differential pressure gauge due to its (Validyne DP15-42) difficulty in operation. All experimental results are listed in Tables III and IV.

Figure 1 shows the temperature dependences of the saturated liquid densities of HCFC 142b, HCFC 22, and CFC 12. The saturated liquid density curve of HCFC 142b intersects with that of CFC 12 at a temperature of about 380 K and with that of HCFC 22 at about 340 K. HCFC 142b has the smallest density at temperatures below these temperatures.

Figure 2 shows the temperature dependences of the vapor pressures of HCFC 142b, HCFC 22, and CFC 12. The vapor pressure curve of CFC 12 is always between those of HCFC 142b and HCFC 22.

Figure 3 shows the saturated and compressed liquid densities on a pressure–density diagram.

Discussion

The present saturated liquid densities were correlated as a simple function of temperature as follows:

$$\rho'_r = 1 + A(1 - T_r)^a + B(1 - T_r)^b \qquad (1)$$

$$\rho'_r = \rho'/\rho_c, \quad T_r = T/T_c$$

$$T_c = 410.29 \text{ K}, \quad \rho_c = 446 \text{ kg/m}^3$$

$$A = 2.349, \quad a = 0.38, \quad B = 0.4544, \quad b = 1.7$$

where ρ' and T denote the saturated liquid density and temperature, respectively, and ρ_c and T_c are the critical density and the critical temperature, respectively. A, a, B, and b are adjustable parameters. A set of the two exponents, a and b, was determined by trial and error, while the two coefficients, A and B, were determined by the least-squares fitting. The critical parameters used here were the measured values by Tanikawa et al. (*7*). The input data to develop eq 1 were 36 points of the present results. The standard deviations of parameters A and B are ±0.002 and ±0.0077, respectively.

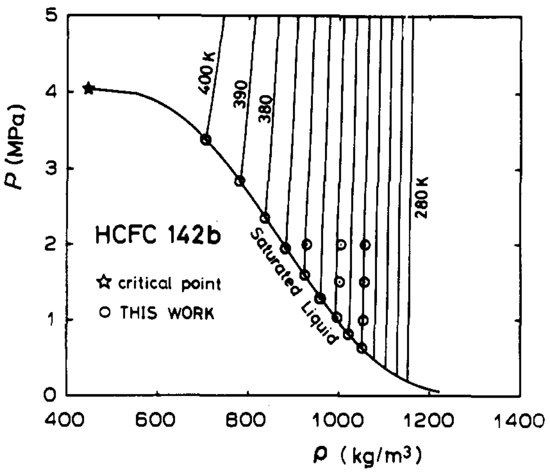

Figure 3. Saturated and compressed liquid densities of HCFC 142b. The saturated liquid curve was calculated by eq 1 and K. Kumagai's vapor pressure correlation (*8*). The compressed liquid isotherms were calculated by A. Kumagai's Tait equation (*9*).

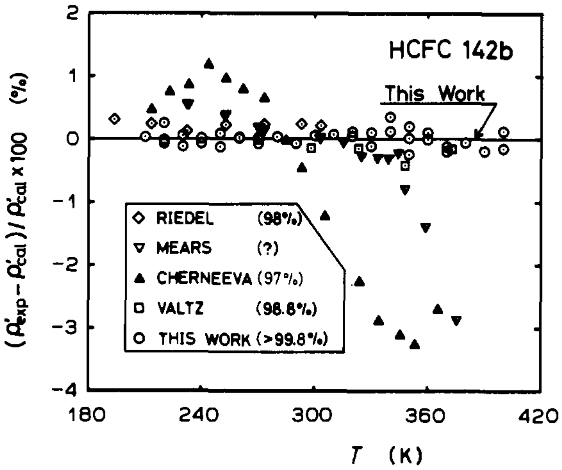

Figure 4. Saturated liquid density deviations from eq 1.

Figure 4 shows the saturated liquid density deviations from eq 1. Equation 1 reproduces the present saturated liquid density measurements with the standard and maximum deviations of 0.10% and 0.35%, respectively. The present results are systematically smaller than those of Riedel (*2*) by about 0.2%, while systematically larger than those of Valtz et al. (*5*) by 0.1–0.2%. The data measured by Mears et al. (*3*) and by Cherneeva (*4*) show large systematic deviations from other data, including the present results. Cherneeva described in his paper that the sample used was "Freon 142". This expression was sometimes used for HCFC 142b in the earlier period. The sample used by Cherneeva might be HCFC 142b because the normal boiling point and the critical point are close to those of HCFC 142b. The difference in saturated liquid densities may be considered due to the different sample purities and/or isomer compositions.

Figure 5 shows the vapor pressure deviations from K. Kumagai's correlation (*8*). The present vapor pressure measurements and those of K. Kumagai et al. (*8*) are in good agreement, but they show systematic deviations from those of Valtz et al. (*5*) and of Cherneeva (*4*) at higher temperatures. The maximum and standard deviations of our results from K.

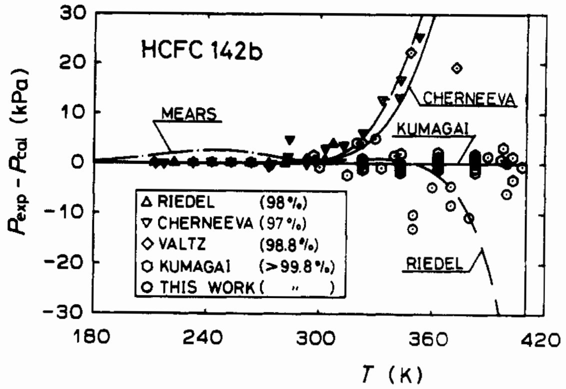

Figure 5. Vapor pressure deviations from K. Kumagai's correlation (*8*).

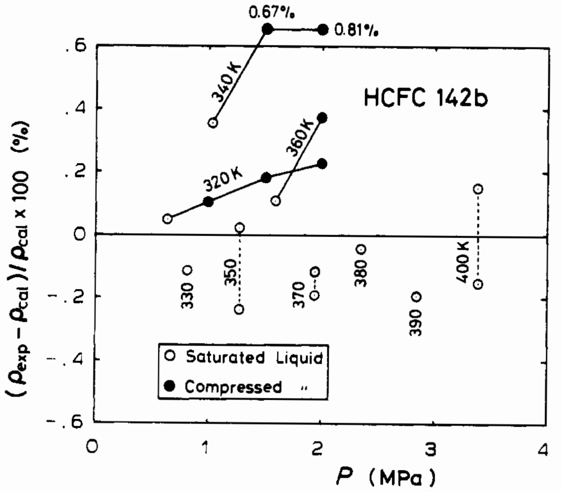

Figure 6. Density deviations from K. Kumagai's vapor pressure correlation (*8*) and eq 1 for the saturated liquid data as well as those from A. Kumagai's Tait equation (*9*) for the compressed liquid data.

Kumagai's correlation are −13 and 5.8 kPa, respectively, whereas the reproducibility of the present measurements was 6 kPa.

Figure 6 shows the density deviations from K. Kumagai's vapor pressure correlation (*8*) and eq 1 for the saturated liquid data as well as those from A. Kumagai's Tait equation (*9*) for the compressed liquid data. The density deviations of our compressed liquid densities increase with increasing pressure and with increasing temperature.

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