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Note

Saturated Liquid Viscosities and Densities of Environmentally Acceptable Hydrochlorofluorocarbons (HCFCs)

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Measurements of saturated liquid viscosities and densities were performed on environmentally acceptable hydrochlorofluorocarbons (HCFCs), CH_3CCl_2F (HCFC-141b), CH_3CClF_2 (HCFC-142b; only for viscosity), $CF_3CF_2CHCl_2$ (HCFC-225ca), and $CClF_2CF_2CHClF$ (HCFC-225cb), using a capillary viscometer and a glass pycnometer in the temperature range from 273 to 353 K. The uncertainty in the measurement of viscosity is estimated to be 5% based on the comparison of the present data with those in the literature for HCFC-141b. An equation is given to represent our saturated liquid viscosity data as a function of temperature.

KEY WORDS: density; HCFC; HCFC-141b; HCFC-142b; HCFC-225ca; HCFC-225cb; hydrochlorofluorocarbon; viscosity.

1. INTRODUCTION

Reliable information on thermophysical properties of hydrochlorofluorocarbons (HCFCs) is needed for their application as refrigerants, blowing agents, and cleaning agents. In an earlier paper [1], we have presented measurements of the viscosity of 11 kinds of saturated liquid HCFCs, HFCs, and CFCs using an improved capillary viscometer.

This paper extends the measurements to environmentally acceptable HCFCs: HCFC-141b, HCFC-142b, HCFC-225ca and HCFC-225cb.

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Table I. Density (in $kg \cdot m^{-3}$) and Viscosity (in $mPa \cdot s$) of HCFC-141b, HCFC-142b, HCFC-225ca, and HCFC-225cb

	HCFC-141b		HCFC-142b		HCFC-225ca		HCFC-225cb	
T(K)	ρ	η	ρ[5]	η	ρ	η	ρ	η
273.15	1281.2	0.5467	1172.0	0.2984	1609.2	0.8124	1613.2	0.8388
283.15	1262.5	0.4827	1147.6	0.2670	1585.5	0.7045	1590.1	0.7288
293.15	1243.0	0.4299	1122.8	0.2402	1561.5	0.6172	1566.9	0.6392
303.15	1223.2	0.3853	1097.0	0.2170	1537.3	0.5448	1543.5	0.5653
313.15	1203.7	0.3472	1069.8	0.1964	1512.4	0.4842	1519.8	0.5030
323.15	1183.7	0.3145	1040.7	0.1781	1487.0	0.4329	1495.4	0.4503
333.15	1162.4	0.2859	1009.3	0.1618	1461.1	0.3887	1470.6	0.4051
343.15	1141.4	0.2610	975.1	0.1470	1434.7	0.3501	1445.1	0.3658
353.15	1118.8	0.2385	937.7	0.1334	1407.5	0.3164	1418.8	0.3310

2. EXPERIMENTS

The viscosity was measured using a capillary viscometer described in detail previously [1]. The viscosity η is derived from the measurement of the efflux time t using the following equation:

$$\eta = C\rho t \qquad (1)$$

where ρ is the density of the liquid, and C the viscometer constant, respectively. The value of C was determined with a repeatability of 0.3%, by calibration using chloroform as the reference material instead of water, since it was difficult for water to pass through the capillary (I.D., 0.25 mm) of the viscometer. The viscosity of chloroform has been measured in the previous work [1], which agreed, within 0.6%, with the literature data [2]. Except for HCFC-142b, the value ρ used in Eq. (1) was measured,

Table II. Comparison of Density (in $kg \cdot m^{-3}$) Obtained in the Present Measurement with Literature Values at 298 K

HCFC-141b		HCFC-225ca		HCFC-225cb	
Present work	Lit. [4]	Present work	Lit. [6]	Present work	Lit. [6]
1.2332	1.232	1.5494	1.55	1.5552	1.56

with an accuracy of 0.03%, using a glass pycnometer which has been described in detail elsewhere [3]. The viscometer and the pycnometer were thermostatically controlled to within 30 mK. The repeatability of the efflux time for five readings at the same temperature is ±0.1%. The repeatability of viscosity measurements was less than 0.5%. The purities of HCFC-141b, HCFC-142b, HCFC-225ca, and HCFC-225cb were 99.9, 99.8, 99.9, and 99.9%, respectively, based on the analysis by gas chromatography.

3. EXPERIMENTAL RESULTS AND CORRELATION

Viscosity and density measurements for saturated liquids were performed at temperatures from 273 to 353 K in steps of 10 K. Table I presents the experimental viscosity data together with density. The efflux time ranging from 390 to 1440 s corresponds to Reynolds numbers from 270 to 20. Table II shows the comparison of density obtained in the present work with the literature values. The present results for the density of HCFC-141b, HCFC-225ca, and HCFC-225cb agree with those in the literature [4, 6] to within 0.3%. As shown in Fig. 1, the present data for the viscosity of HCFC-142b deviate considerably from the literature data [7, 8], however, the values for HCFC-141b agree, within 5%, with those reported by Sukornick [4], Shankland [9], and Diller et al. [10] in their overlap region from 280 to 320 K. It is believed that the significant differ-

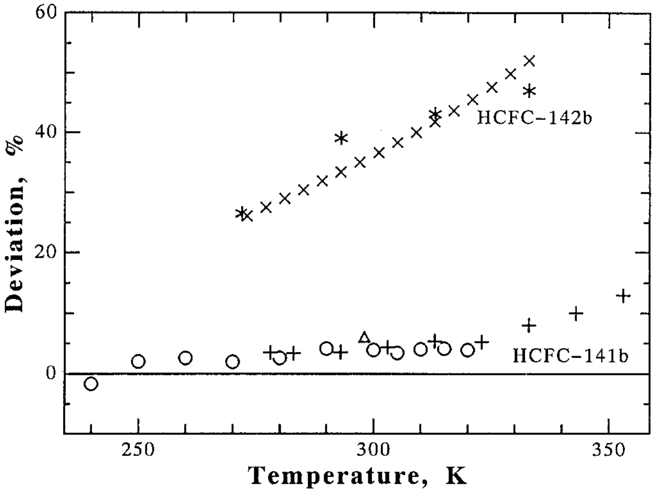

Fig. 1. Deviations of viscosities for HCFC-141b and HCFC-142b between the literature data and the present work. (*) Mears et al. [7]; (×) Geller et al. [8]; (△) Sukornick [4]; (+) Schankland [9]; (○) Diller et al. [10]. Deviation = $100[(\eta_{\rm exp} - \eta_{\rm Eq.(2)})/\eta_{\rm Eq.(2)}]$.

Table III. Constants in the Viscosity Equation, Eq. (2), with η (in mPa · s) and T (in K)

HCFC	Temp. range (K)	a	$10^{-3}b$	$10^{2}c$	$10^{5}d$	Av. dev. (%)[a]	Max. dev. (%)[b]
HCFC-141b	273–353	−9.460	1.4503	1.9418	−2.3553	0.01	0.03
HCFC-142b	273–353	−11.779	1.4728	2.9591	−3.8938	0.02	0.05
HCFC-225ca	273–353	−12.095	1.8447	2.7663	−3.2461	0.01	0.03
HCFC-225cb	273–353	−11.193	1.7536	2.4777	−2.9094	0.02	0.03

[a] Av. dev. $= 100(\sum |\eta_{\mathrm{exp}} - \eta_{\mathrm{calc}}|/\eta_{\mathrm{calc}})/n$.

[b] Max. dev. = maximum of $100(|\eta_{\mathrm{exp}} - \eta_{\mathrm{calc}}|/\eta_{\mathrm{calc}})$.

ence in the reported data on HCFC-142b was caused by the large Reynolds numbers in the previous measurement. The uncertainty in the viscosity of this work was estimated to be 5% by comparing the present data for HCFC-141b with those in the literature which were recently obtained by different techniques.

The experimental viscosity values are presented as a function of temperature by the following equation:

$$\ln \eta = A + B/T + CT + DT^{2} \tag{2}$$

where η is in mPa · s, T is in K, and A, B, C, and D are constants. Table III gives the constants and shows that Eq. (2) reproduces the present results within the repeatability of the measurements.

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