Vapor Pressures of Hydrofluoroethers

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Vapor pressures for 50 hydrofluoroethers have been measured from pressures of less than 30 kPa to 101.3 kPa. Measurements were made by the isoteniscope method. The Antoine constants for each compound were derived using the experimental data.

Introduction

Hydrogen-containing fluorinated ethers have been developed as alternatives to chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).[1] Hydrofluoroethers have almost zero ozone depleting potential (ODP) because of the absence of chlorine atoms in the molecules.[2] Some hydrofluoroethers have low global warming potential and are expected to be environmentally friendly alternatives for use as refrigerants, blowing agents, and cleaning solvents.

Vapor pressure is one of the most important properties in the development of new alternative compounds. The vapor pressures of some hydrofluoroethers whose boiling points are comparatively low have been reported.[3−7] In this paper, the vapor pressures for 50 compounds whose boiling points are higher than 313 K have been measured by the isoteniscope method. The boiling points and vapor pressures at 298.15 K of some of these hydrofluoroethers have been reported previously in the literature.[1]

Experimental Section

Materials. All hydrofluoroether reagents were prepared in this work according to the literatures.[8−14] Gas-chromatographic analysis of most materials indicated that each had a purity of at least 99.5 mol %. The minimum purities and densities of the compounds are listed in Table 1 along with their IUPAC names.

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Vapor Pressures. Vapor pressures were measured directly by means of an isoteniscope and a vacuum system using the standard techniques.[15−16] The pressure was determined using the calibrated Baratron pressure sensor (MKS Instruments, USA) with 690A12TRA in the range less than 13.3 kPa and 690A13TRA in the range from 13.3 kPa to 133 kPa, with an uncertainty of ±0.05%. The temperature was measured with a calibrated platinum resistance thermometer (Pt 100 Ω) with an uncertainty of ±0.03 K. Two baths were used in these experiments. A water bath with a stability of ±0.03 K was used for temperatures less than 368 K. An oil bath with a stability of ±0.1 K was used for temperatures higher than 368 K. The overall temperature uncertainty is ±0.06 K for temperatures less than 368 K, and ±0.13 K for temperatures higher than 368 K. The meniscus was adjusted with 1 mm accuracy.

Densities. Density was measured using a calibrated pycnometer having a bulb volume of 5 cm^3. A water bath was kept at 296.15 K with a stability of ±0.02 K. A Shimazu AEU-210 balance with a precision of ±0.0001 g was used for mass measurements. The density values were reproducible within ±0.0001 $g \cdot cm^{-3}$.

Results and Discussion

Water was chosen for verification of the apparatus and the procedure. The vapor pressure data for water obtained in this work are presented in Table 2 along with the literature values.

10.1021/je010322y CCC: $22.00
Published on Web 05/04/2002

Table 1. Formulas, IUPAC Names, Minimum Purities, and Densities, ρ, of Compounds

no.	formula	IUPAC name	CAS registry number[a]	minimum purity / mol %	ρ^b / g·cm^{-3}
1	$CF_3CF_2CF_2CF_2OCH_2CH_2CH_3$	1,1,1,2,2,3,3,4,4-nonafluoro-4-propoxybutane	72372-80-6	99.7	1.3664
2	$CF_3CF_2CF_2CF_2CF_2OCH_3$	1,1,1,2,2,3,3,4,4,5,5-undecafluoro-5-methoxypentane	181214-74-4	99.9	1.5753
3	$CF_3CF_2CF_2CF_2CF_2OCH_2CH_3$	1-ethoxy-1,1,2,2,3,3,4,4,5,5,5-undecafluoropentane	181214-75-5	99.7	1.4903
4	$CF_3CF(OCF_3)CH_2CH_3$	1,1,1,2-tetrafluoro-2-trifluoromethoxybutane	200501-98-0	99.8	1.3469
5	$(CF_3)_3COCH_3$	1,1,1,3,3,3-hexafluoro-2-methoxy-2-trifluoromethylpropane	66670-22-2	99.9	1.5585
6	$(CF_3)_2CFCF_2CF_2OCH_3$	1,1,1,2,3,3,4,4-octafluoro-4-methoxy-2-trifluoromethylbutane	203783-56-6	99.6	1.6081
7	$(CF_3)_2CFCF_2CF_2OCH_2CH_3$	1-ethoxy-1,1,2,2,3,4,4,4-octafluoro-3-trifluoromethylbutane	203783-57-7	99.9	1.5194
8	$CF_3CF(OCF_3)CH_2CHF_2$	1,1,1,2,4,4-hexafluoro-2-trifluoromethoxybutane		99.5	1.5403
9	$(CF_3)_3COCH_2CH_3$	2-ethoxy-1,1,1,3,3,3-hexafluoro-2-trifluoromethylpropane	186493-82-3	99.9	1.4504
10	$CF_3CF(OCF_3)CH_2CF_3$	1,1,1,2,4,4,4-heptafluoro-2-trifluoromethoxybutane	347148-74-7	99.8	1.5647
11	$CF_3CHFCF_2OCH_2CF_3$	1,1,1,2,3,3-hexafluoro-3-(2,2,2-trifluoroethoxy)propane	993-95-3	99.9	1.5319
12	$CF_3CHFCF_2OCH_2CF_2CHF_2$	1,1,1,2,3,3-hexafluoro-3-(2,2,3,3-tetrafluoropropoxy)propane	65064-78-0	99.9	1.5739
13	$CF_3CHFCF_2OCH_2CF_2CF_3$	1,1,1,2,3,3-hexafluoro-3-(2,2,3,3,3-pentafluoropropoxy)propane	290-28-8	99.9	1.5749
14	$CHF_2CF_2CH_2OCF_2CHF_2$	1,1,2,2-tetrafluoro-3-(1,1,2,2-tetrafluoroethoxy)propane	16627-68-2	99.9	1.5323
15	$CHF_2CF_2CF_2CF_2CH_2OCH_3$	1,1,2,2,3,3,4,4-octafluoro-5-methoxypentane	77527-96-9	99.5	1.4850
16	$CH_2FCF_2OCH_3$	1,1,2-trifluoro-1-methoxyethane	428-66-0	99.9	1.2031
17	$CF_3CF_2CH_2OCH_3$	1,1,1,2,2-pentafluoro-3-methoxypropane	378-16-5	99.5	1.2816
18	$CHF_2CF_2CH_2OCHF_2$	3-difluoromethoxy-1,1,2,2-tetrafluoropropane	35042-99-0	99.5	1.4749
19	$CF_3CF_2CH_2OCHF_2$	3-difluoromethoxy-1,1,1,2,2-pentafluoropropane	56860-81-2	99.9	1.4688
20	$(CF_3)_2CHOCH_3$	1,1,1,3,3,3-hexafluoro-2-methoxypropane	13171-18-1	99.6	1.3802
21	$CHF_2CF_2OCH_2CH_3$	1-ethoxy-1,1,2,2-tetrafluoroethane	512-51-6	99.9	1.2022
22	$CF_3CH_2OCF_2CH_2F$	1,1,1-trifluoro-2-(1,1,2-trifluoroethoxy)ethane	25449-61-0	99.9	1.4239
23	$CHF_2CF_2OCH_2CF_3$	1,1,2,2-tetrafluoro-1-(2,2,2-trifluoroethoxy)ethane	406-78-0	99.9	1.4789
24	$CF_3CH_2OCH_2CF_3$	1,1,1-trifluoro-2-(2,2,2-trifluoroethoxy)ethane	333-36-8	99.9	1.4045
25	$CHF_2CF_2OCH_2CHF_2$	1-(1,1-difluoroethoxy)-1,1,2,2-tetrafluoroethane	50807-77-7	99.4	1.4659
26	$CH_2FCF_2OCHF_2$	1-difluoromethoxy-1,1,2-trifluoroethane	69948-24-9	99.9	1.4262
27	$CF_3CHFCF_2OCH_3$	1,1,1,2,3,3-hexafluoro-3-methoxypropane	382-34-3	99.8	1.3979
28	$CHF_2CH_2OCHF_2$	2-difluoromethoxy-1,1-difluoroethane	32778-16-8	99.9	1.3705
29	$CHF_2CF_2CF_2OCH_3$	1,1,2,2,3,3-hexafluoro-1-methoxypropane	160620-20-2	99.9	1.4157
30	$(CF_3)_2CHOCHF_2$	2-difluoromethoxy-1,1,1,3,3,3-hexafluoropropane	26103-08-2	99.6	1.5481
31	$CF_3CF_2CH_2OCF_2CHF_2$	1,1,1,2,2-pentafluoro-3-(1,1,2,2-tetrafluoroethoxy)propane	50807-74-4	99.0	1.5299
32	$CHF_2CF_2CH_2OCF_3$	1,1,2,2-tetrafluoro-3-trifluoromethoxypropane	1683-81-4	99.8	1.4697
33	$(CF_3)_2CHOCH_2F$	1,1,1,3,3,3-hexafluoro-2-fluoromethoxypropane	28523-86-6	99.9	1.5111
34	$CF_3CF_2OCH_2CHF_2$	1-(2,2-difluoroethoxy)-1,1,2,2,2-pentafluoroethane	171182-95-9	99.9	1.4439
35	$(CF_3)_2CHCF_2OCH_3$	1,1,1,3,3-pentafluoro-3-methoxy-2-trifluoromethylpropane	382-26-3	99.8	1.4965
36	$CF_3CHFCF_2CH_2OCF_3$	1,1,1,2,3,3-hexafluoro-4-trifluoromethoxybutane	69948-43-2	96.3	1.5299
37	$CF_3CF_2CF_2OCH_2CH_3$	1-ethoxy-1,1,2,2,3,3,3-heptafluoropropane	22052-86-4	99.9	1.3222
38	$CF_3CF_2CF_2OCH_2CF_3$	1,1,1,2,2,3,3-heptafluoro-3-(2,2,2-trifluoroethoxy)propane	142469-08-7	99.9	1.5261
39	$CF_3CF_2CF_2OCH_2CF_2CHF_2$	1,1,1,2,2,3,3-heptafluoro-3-(2,2,3,3-tetrafluoropropoxy)propane	176310-29-5	99.7	1.5672
40	$CF_3CF_2CH_2OCF_2CF_3$	1,1,1,2,2-pentafluoro-3-pentafluoroethoxypropane	155653-44-4	97.8	1.5075
41	$CHF_2CF_2CH_2OCF_2CF_3$	1,1,2,2-tetrafluoro-3-pentafluoroethoxypropane	176310-27-3	99.9	1.5086
42	$CF_3CF_2CF_2OCH_2CHF_2$	1-(2,2-difluoroethoxy)-1,1,2,2,3,3,3-heptafluoropropane	176310-28-4	99.9	1.5195
43	$CF_3CF_2CF_2OCH_2CF_2CF_3$	1,1,1,2,2,3,3-heptafluoro-3-(2,2,3,3,3-pentafluoropropoxy)propane	176310-30-8	99.7	1.5741
44	$CHF_2CH_2OCH_3$	1,1-difluoro-2-methoxyethane	461-57-4	99.9	1.0735
45	$CHF_2CF_2CH_2OCH_3$	1,1,2,2-tetrafluoro-3-methoxypropane	60598-17-6	99.9	1.2518
46	$CF_3CF_2CF_2CH_2OCH_3$	1,1,1,2,2,3,3-heptafluoro-4-methoxybutane	376-98-7	99.9	1.3945
47	$CF_3CHFCF_2CH_2OCH_3$	1,1,1,2,3,3-hexafluoro-4-methoxybutane	58705-93-4	99.9	1.3526
48	$CHF_2CF_2OCH_2F$	1,1,2,2-tetrafluoro-1-fluoromethoxyethane	37031-31-5	99.3	1.4545
49	$CF_3CF_2CF_2OCH_2F$	1,1,1,2,2,3,3-heptafluoro-3-fluoromethoxypropane	184899-81-8	99.5	1.5233
50	$CF_3CF_2CF_2CF_2OCH_2CH_3$	1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluorobutane	163702-05-4	99.0	1.4168

[a] Provided by the authors. [b] At 296.15 K.

Table 2. Vapor Pressure, *P*, of Water

T / K	P_{expt} / kPa	$P_{lit.}$[17] / kPa	δP^a / kPa	T / K	P_{expt} / kPa	$P_{lit.}$[17] / kPa	δP^a / kPa
293.15	2.34	2.34	0.00	333.15	19.97	19.95	0.02
303.15	4.25	4.25	0.00	343.15	31.21	31.20	0.01
313.15	7.39	7.39	0.00	353.15	47.41	47.41	0.00
323.15	12.36	12.35	0.01				

[a] $\delta P = P_{expt} - P_{lit.}$.

The vapor pressures for the 50 compounds are reported in Table 3 along with values calculated with the Antoine equation,

$$\log(P/\mathrm{kPa}) = A - \frac{B}{(T/\mathrm{K}) + C}$$

where P is the vapor pressure, T is the absolute temperature, and A, B, and C are adjustable constants. The Antoine constants, which were reported in Table 3, were determined on the basis of the experimental data. The fit was made by weighting all data equally. The average absolute deviations (AADs) between calculated and experi-

Table 3. Experimental Vapor Pressures, *P*, of 50 Hydrofluoroethers

(1) $CF_3CF_2CF_2CF_2OCH_2CH_2CH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
288.15	3.52	3.52	0.00
298.15	6.05	6.04	−0.01
303.15	7.77	7.78	−0.01
313.15	12.50	12.52	−0.02
323.15	19.45	19.43	0.02
333.15	29.17	29.16	0.01
343.15	42.54	42.52	0.02
353.15	60.41	60.39	0.02
363.15	83.77	83.78	−0.01
369.30	101.325	101.37	−0.05

(2) $CF_3CF_2CF_2CF_2CF_2OCH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
288.15	5.55	5.55	0.00
298.15	9.33	9.34	−0.01
313.15	18.88	18.88	0.00
333.15	42.74	42.72	0.02
353.15	86.43	86.43	0.00
358.08	101.325	101.34	−0.02

(3) $CF_3CF_2CF_2CF_2CF_2OCH_2CH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
288.15	2.85	2.85	0.00
298.15	4.97	4.97	0.00
308.15	8.27	8.29	−0.02
323.15	16.59	16.56	0.03
343.15	37.08	37.05	0.03
363.15	74.35	74.36	−0.01
373.00	−101.325	101.35	−0.02

(4) $CF_3CF(OCF_3)CH_2CH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	23.85	23.85	0.00
288.15	29.94	29.95	−0.01
298.15	45.92	45.92	0.00
303.15	56.16	56.14	0.02
313.15	82.01	82.00	0.01
319.09	101.325	101.33	0.00

(5) $(CF_3)_3COCH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
288.15	21.75	21.75	0.00
298.15	33.96	33.96	0.00
303.15	41.87	41.86	0.01
313.15	62.05	62.07	−0.02
323.15	89.36	89.34	0.02
326.79	101.325	101.32	0.01

(6) $(CF_3)_2CFCF_2CF_2OCH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
288.15	5.83	5.83	0.00
298.15	9.72	9.72	0.00
313.15	19.41	19.42	−0.01
323.15	29.49	29.49	0.00
333.15	43.45	43.44	0.01
343.15	62.26	62.26	0.00
353.15	87.06	87.08	−0.02
357.90	101.325	101.32	0.01

(7) $(CF_3)_2CFCF_2CF_2OCH_2CH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
288.15	2.97	2.98	−0.01
298.15	5.15	5.13	0.02
313.15	10.72	10.72	0.00
328.15	20.60	20.61	−0.01
343.15	36.96	36.96	0.00
358.15	62.48	62.45	0.03
369.14	88.79	88.79	0.00
373.48	101.325	101.33	0.00

(8) $CF_3CF(OCF_3)CH_2CHF_2$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	12.65	12.65	0.00
293.15	20.84	20.84	0.00
298.15	26.33	26.33	0.00
303.15	32.97	32.95	0.02
313.15	50.21	50.23	−0.02
323.15	74.11	74.12	−0.01
331.78	101.325	101.31	0.02

(9) $(CF_3)_3COCH_2CH_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
288.15	12.50	12.51	−0.01
298.15	20.06	20.05	0.01
313.15	37.96	37.98	−0.02
328.15	66.99	66.97	0.02
340.27	101.325	101.33	0.00

(10) $CF_3CF(OCF_3)CH_2CF_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
288.15	23.75	23.74	0.01
298.15	37.27	37.31	−0.04
303.15	46.17	46.14	0.03
313.15	68.81	68.80	0.01
323.64	101.325	101.32	0.01

(11) $CF_3CHFCF_2OCH_2CF_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
293.15	11.02	11.02	0.00
298.15	14.21	14.21	0.00
313.15	28.64	28.63	0.01
328.15	53.17	53.18	−0.01
345.87	101.325	101.32	0.01

(12) $CF_3CHFCF_2OCH_2CF_2CHF_2$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
293.15	2.33	2.33	0.00
298.15	3.14	3.14	0.00
313.15	7.16	7.15	0.01
328.15	14.75	14.75	0.00
348.15	34.21	34.24	−0.03
379.07	101.325	101.30	0.03

(13) $CF_3CHFCF_2OCH_2CF_2CF_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
293.15	5.71	5.71	0.00
298.15	7.49	7.49	0.00
318.15	19.85	19.87	−0.02
338.15	45.64	45.61	0.03
360.64	101.325	101.34	−0.02

(14) $CHF_2CF_2CH_2OCF_2CHF_2$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
293.15	4.15	4.15	0.00
298.15	5.51	5.52	−0.01
303.15	7.23	7.24	−0.01
313.15	12.05	12.05	0.00
323.15	19.24	19.26	−0.02
333.15	29.68	29.70	−0.02
343.15	44.37	44.38	−0.01
353.15	64.42	64.45	−0.03
363.15	91.18	91.24	−0.06
366.32	101.325	101.37	−0.05

(15) $CHF_2CF_2CF_2CF_2CH_2OCH_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
293.15	1.09	1.08	0.01
298.15	1.48	1.49	−0.01
303.15	2.01	2.01	0.00
323.15	5.97	5.98	−0.01
343.15	15.15	15.16	−0.01
363.15	33.92	33.82	0.10
395.83	101.325	101.43	−0.11

(16) $CH_2FCF_2OCH_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
276.15	17.91	17.89	0.02
283.15	25.17	25.18	−0.01
293.15	39.58	39.63	−0.05
298.15	49.02	49.02	0.00
308.15	73.30	73.17	0.13
316.93	101.325	101.42	−0.09

(17) $CF_3CF_2CH_2OCH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	20.52	20.52	0.00
293.15	32.67	32.67	0.00
298.15	40.65	40.64	0.01
303.15	50.12	50.11	0.01
313.15	74.36	74.38	−0.02
321.55	101.325	101.31	0.02

(18) $CHF_2CF_2CH_2OCHF_2$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	6.12	6.12	0.00
293.15	10.39	10.38	0.01
298.15	13.29	13.30	−0.01
308.15	21.20	21.21	−0.01
323.15	40.05	40.01	0.04
340.15	75.87	75.83	0.04
348.60	101.325	101.38	−0.05

(19) $CF_3CF_2CH_2OCHF_2$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	22.84	22.84	0.00
293.15	36.17	36.17	0.00
298.15	44.88	44.88	0.00
308.15	67.37	67.35	0.02
319.09	101.325	101.33	0.00

(20) $(CF_3)_2CHOCH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	17.81	17.81	0.00
293.15	28.81	28.79	0.02
298.15	36.05	36.06	−0.01
308.15	55.08	55.07	0.01
324.10	101.325	101.32	0.01

(21) $CHF_2CF_2OCH_2CH_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	14.23	14.23	0.00
293.15	23.13	23.13	0.00
298.15	29.05	29.05	0.00
313.15	54.57	54.57	0.00
329.80	101.325	101.32	0.01

(22) $CF_3CH_2OCF_2CH_2F$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	9.12	9.11	0.01
298.15	19.60	19.62	−0.02
308.15	31.08	31.07	0.01
323.15	58.06	58.01	0.05
338.18	101.325	101.37	−0.05

(23) $CHF_2CF_2OCH_2CF_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	13.61	13.61	0.00
293.15	22.44	22.45	−0.01
298.15	28.39	28.39	0.00
313.15	54.41	54.38	0.03
329.37	101.325	101.35	−0.02

(24) $CF_3CH_2OCH_2CF_3$

T/K	P_{expt}/kPa	$P_{ca/c}$/kPa	δP^a/kPa
283.15	9.77	9.77	0.00
298.15	20.80	20.82	−0.02
308.15	32.81	32.81	0.00
323.15	60.94	60.89	0.05
336.91	101.325	101.37	−0.05

(25) $CHF_2CF_2OCH_2CHF_2$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
288.15	6.01	6.00	0.01
298.15	10.29	10.31	−0.02
313.15	21.47	21.47	0.00
333.15	50.40	50.32	0.08
352.13	101.325	101.39	−0.06

(26) $CH_2FCF_2OCHF_2$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
283.15	24.87	24.86	0.01
288.15	31.55	31.56	−0.01
293.15	39.69	39.66	0.03
298.15	49.30	49.36	−0.06
308.15	74.53	74.49	0.04
313.15	90.46	90.41	0.05
316.20	101.325	101.38	−0.05

(27) $CF_3CHFCF_2OCH_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
288.15	20.12	20.11	0.01
298.15	31.86	31.88	−0.02
303.15	39.58	39.58	0.00
313.15	59.54	59.52	0.02
323.15	86.83	86.82	0.01
327.47	101.325	101.34	−0.02

(28) $CHF_2CH_2OCHF_2$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
288.15	18.96	18.95	0.01
293.15	24.07	24.07	0.00
298.15	30.28	30.27	0.01
303.15	37.70	37.71	−0.01
313.15	57.04	57.03	0.01
323.15	83.62	83.59	0.03
328.49	101.325	101.35	−0.02

(29) $CHF_2CF_2CF_2OCH_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
288.15	11.23	11.21	0.02
293.15	14.39	14.40	−0.01
298.15	18.29	18.30	−0.01
303.15	23.04	23.04	0.00
313.15	35.54	35.54	0.00
323.15	53.09	53.07	0.02
333.15	77.04	77.01	0.03
341.02	101.325	101.36	−0.03

(30) $(CF_3)_2CHOCHF_2$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
283.15	26.31	26.30	0.01
288.15	33.25	33.24	0.01
293.15	41.59	41.60	−0.01
298.15	51.61	51.60	0.01
303.15	63.45	63.44	0.01
313.15	93.67	93.66	0.01
315.27	101.325	101.34	−0.02

(31) $CF_3CF_2CH_2OCF_2CHF_2$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
293.15	12.33	12.32	0.01
325.86	101.325	101.35	−0.02
298.15	15.80	15.82	−0.02
303.15	20.09	20.10	−0.01
313.15	31.56	31.55	0.01
323.15	47.82	47.82	0.00
333.15	70.30	70.28	0.02
343.40	101.325	101.36	−0.03

(32) $CHF_2CF_2CH_2OCF_3$

T/K	P_{expt}/kPa	P_{calc}/kPa	δP^a/kPa
288.15	28.41	28.41	0.00
298.15	44.28	44.30	−0.02
303.15	54.61	54.59	0.02
313.15	80.98	80.96	0.02
319.21	101.325	101.34	−0.02

Table 3 (Continued)

T	P_{expt}	$P_{ca/c}$	δP^a	T	P_{expt}	P_{calc}	δP^a	T	P_{expt}	$P_{ca/c}$	δP^a	T	P_{expt}	P_{calc}	δP^a
K	kPa	kPa	kPa	K	kPa	kPa	kPa	K	kPa	kPa	kPa	K	kPa	kPa	kPa
(33) $(CF_3)_2CHOCH_2F$				(38) $CF_3CF_2CF_2OCH_2CF_3$				(43) $CF_3CF_2CF_2OCH_2CF_2CF_3$				(47) $CF_3CHFCF_2CH_2OCH_3$			
288.15	15.89	15.89	0.00	288.15	22.53	22.54	−0.01	288.15	9.96	9.96	0.00	293.15	6.28	6.27	0.01
298.15	25.77	25.78	−0.01	293.15	28.41	28.39	0.02	293.15	12.84	12.84	0.00	298.15	8.13	8.14	−0.01
308.15	40.28	40.27	0.01	298.15	35.37	35.38	−0.01	298.15	16.37	16.36	0.01	303.15	10.43	10.44	−0.01
323.15	73.83	73.81	0.02	303.15	43.69	43.69	0.00	303.15	20.64	20.65	−0.01	313.15	16.69	16.69	0.00
331.73	101.325	101.34	−0.02	323.15	93.34	93.42	−0.08	313.15	31.98	31.99	−0.01	333.15	38.52	38.49	0.03
				325.47	101.325	101.25	0.08	323.15	47.93	47.92	0.01	353.15	79.25	79.24	0.01
								333.15	69.70	69.68	0.02	360.65	101.325	101.35	−0.02
								343.95	101.325	101.34	−0.02				
(34) $CF_3CF_2OCH_2CHF_2$				(39) $CF_3CF_2CF_2OCH_2CF_2CHF_2$				(44) $CHF_2CH_2OCH_3$				(48) $CHF_2CF_2OCH_2F$			
288.15	28.89	28.89	0.00	288.15	5.48	5.47	0.01	288.15	25.49	25.48	0.01	288.15	19.63	19.62	0.01
298.15	45.20	45.21	−0.01	293.15	7.17	7.17	0.00	293.15	32.08	32.10	−0.02	298.15	31.54	31.55	−0.01
303.15	55.80	55.79	0.01	298.15	9.28	9.30	−0.02	298.15	40.08	40.06	0.02	303.15	39.45	39.45	0.00
313.15	82.91	82.91	0.00	303.15	11.91	11.92	−0.01	303.15	49.54	49.54	0.00	313.15	60.10	60.09	0.01
318.53	101.325	101.33	0.00	313.15	19.00	19.02	−0.02	308.15	60.74	60.74	0.00	323.15	88.77	88.73	0.04
				323.15	29.32	29.28	0.04	313.15	73.89	73.89	0.00	326.74	101.325	101.36	−0.03
				333.15	43.72	43.66	0.06	318.15	89.21	89.20	0.01				
				343.15	63.29	63.28	0.01	321.65	101.325	101.34	−0.02				
				353.15	89.37	89.39	−0.02								
				356.97	101.325	101.37	−0.05								
(35) $(CF_3)_2CHCF_2OCH_3$				(40) $CF_3CF_2CH_2OCF_2CF_3$				(45) $CHF_2CF_2CH_2OCH_3$				(49) $CF_3CF_2CF_2OCH_2F$			
288.15	10.47	10.46	0.01	288.15	27.77	27.77	0.00	293.15	10.95	10.95	0.00	283.15	25.37	25.37	0.00
298.15	17.05	17.08	−0.03	293.15	34.84	34.83	0.01	298.15	14.03	14.01	0.02	288.15	32.04	32.04	0.00
313.15	33.18	33.17	0.01	298.15	43.29	43.28	0.01	303.15	17.75	17.75	0.00	293.15	40.06	40.07	−0.01
333.15	71.91	71.88	0.03	303.15	53.28	53.30	−0.02	313.15	27.71	27.71	0.00	298.15	49.65	49.65	0.00
343.07	101.325	101.36	−0.03	308.15	65.09	65.08	0.01	323.15	41.84	41.83	0.01	303.15	60.99	60.99	0.00
				313.15	78.87	78.86	0.01	333.15	61.29	61.30	−0.01	308.15	74.33	74.32	0.01
				318.15	94.85	94.84	0.01	343.15	87.49	87.47	0.02	313.15	89.86	89.86	0.00
				319.99	101.325	101.33	0.00	347.50	101.325	101.33	0.00	316.42	101.325	101.34	−0.02
(36) $CF_3CHFCF_2CH_2OCF_3$				(41) $CHF_2CF_2CH_2OCF_2CF_3$				(46) $CF_3CF_2CF_2CH_2OCH_3$				(50) $CF_3CF_2CF_2CF_2OCH_2CH_3$			
288.15	13.03	13.02	0.01	288.15	13.69	13.69	0.00	293.15	12.69	12.68	0.01	293.15	10.69	10.69	0.00
298.15	21.09	21.11	−0.02	293.15	17.52	17.53	−0.01	298.15	16.16	16.18	−0.02	298.15	13.58	13.58	0.00
313.15	40.58	40.58	0.00	298.15	22.21	22.21	0.00	303.15	20.43	20.43	0.00	303.15	17.09	17.10	−0.01
323.15	60.24	60.21	0.03	303.15	27.87	27.87	0.00	313.15	31.68	31.68	0.00	313.15	26.36	26.37	−0.01
333.15	86.85	86.81	0.04	313.15	42.73	42.72	0.01	323.15	47.52	47.52	0.00	323.15	39.41	39.39	0.02
337.62	101.325	101.37	−0.05	323.15	63.37	63.36	0.01	333.15	69.22	69.18	0.04	333.15	57.19	57.18	0.01
				333.15	91.30	91.31	−0.01	344.13	101.325	101.36	−0.03	343.15	80.88	80.89	−0.01
				336.14	101.325	101.32	0.01					350.04	101.325	101.34	−0.02
(37) $CF_3CF_2CF_2OCH_2CH_3$				(42) $CF_3CF_2CF_2OCH_2CHF_2$											
288.15	22.84	22.84	0.00	288.15	11.28	11.28	0.00								
293.15	28.60	28.58	0.02	293.15	14.53	14.52	0.01								
298.15	35.42	35.44	−0.02	298.15	18.48	18.50	−0.02								
303.15	43.57	43.58	−0.01	303.15	23.33	23.34	−0.01								
313.15	64.37	64.34	0.03	313.15	36.14	36.13	0.01								
323.15	92.33	92.32	0.01	323.15	54.12	54.10	0.02								
				333.15	78.67	78.64	0.03								
				340.38	101.325	101.37	−0.05								

[a] $\delta P = P_{expt} - P_{calc}$.

Table 4. Antoine Constants and AAD between Calculated and Experimental Pressures

		Antoine const.			
no.	compd	A	B	C	AAD (%)
1	$CF_3CF_2CF_2CF_2OCH_2CH_2CH_3$	6.017 08	1219.964	−65.16	0.085
2	$CF_3CF_2CF_2CF_2CF_2OCH_3$	6.085 51	1207.929	−62.00	0.035
3	$CF_3CF_2CF_2CF_2CF_2OCH_2CH_3$	6.048 56	1237.128	−66.99	0.096
4	$CF_3CF(OCF_3)CH_2CH_3$	6.039 71	1075.895	−52.38	0.011
5	$(CF_3)_3COCH_3$	5.991 31	1072.474	−57.70	0.015
6	$(CF_3)_2CFCF_2CF_2OH_3$	6.078 56	1216.898	−59.12	0.023
7	$(CF_3)_2CFCF_2CF_2OCH_2CH_3$	6.068 21	1265.873	−61.88	0.087
8	$CF_3CF(OCF_3)CH_2CHF_2$	6.101 88	1102.070	−62.73	0.024
9	$(CF_3)_3COCH_2CH_3$	5.994 40	1120.491	−59.35	0.031
10	$CF_3CF(OCF_3)CH_2CF_3$	6.111 62	1095.140	−56.92	0.047
11	$CF_3CHFCF_2OCH_2CF_3$	6.087 27	1126.735	−69.82	0.014
12	$CF_3CHFCF_2OCH_2CF_2CHF_2$	6.180 21	1272.909	−74.15	0.088
13	$CF_3CHFCF_2OCH_2CF_2CF_3$	6.159 83	1212.610	−68.73	0.046
14	$CHF_2CF_2CH_2OCF_2CHF_2$	6.225 87	1247.989	−70.59	0.070
15	$CHF_2CF_2CF_2CF_2CH_2OCH_3$	6.269 41	1384.446	−71.09	0.253
16	$CH_2FCF_2OCH_3$	6.113 16	1080.517	−53.84	0.088
17	$CF_3CF_2CH_2OCH_3$	6.157 20	1113.777	−53.27	0.017
18	$CHF_2CF_2CH_2OCHF_2$	6.287 18	1264.351	−53.28	0.064

Table 4 (Continued)

no.	compd	Antoine const. A	B	C	AAD (%)
19	$CF_3CF_2CH_2OCHF_2$	6.091 68	1074.018	−56.23	0.016
20	$(CF_3)_2CHOCH_3$	6.171 38	1111.854	−57.19	0.027
21	$CHF_2CF_2OCH_2CH_3$	6.147 22	1131.658	−56.55	0.007
22	$CF_3CH_2OCF_2CH_2F$	6.260 36	1186.247	−59.36	0.063
23	$CHF_2CF_2OCH_2CF_3$	6.301 52	1176.625	−55.46	0.029
24	$CF_3CH_2OCH_2CF_3$	6.324 09	1218.754	−54.67	0.047
25	$CHF_2CF_2OCH_2CHF_2$	6.379 56	1276.387	−60.29	0.123
26	$CH_2FCF_2OCHF_2$	6.167 41	1075.139	−57.84	0.061
27	$CF_3CHFCF_2OCH_3$	6.195 29	1147.412	−53.59	0.027
28	$CHF_2CH_2OCHF_2$	6.152 27	1119.817	−58.42	0.025
29	$CHF_2CF_2CF_2OCH_3$	6.221 92	1205.827	−55.01	0.050
30	$(CF_3)_2CHOCHF_2$	6.212 43	1105.488	−52.48	0.020
31	$CF_3CF_2CH_2OCF_2CHF_2$	6.193 73	1173.291	−63.24	0.056
32	$CHF_2CF_2CH_2OCF_3$	6.230 55	1134.867	−50.59	0.024
33	$(CF_3)_2CHOCH_2F$	6.286 49	1178.914	−56.33	0.028
34	$CF_3CF_2OCH_2CHF_2$	6.181 17	1098.671	−55.40	0.010
35	$(CF_3)_2CHCF_2OCH_3$	6.177 43	1197.966	−55.90	0.075
36	$CF_3CHFCF_2CH_2OCF_3$	6.143 83	1155.013	−58.49	0.050
37	$CF_3CF_2CF_2OCH_2CH_3$	6.074 46	1118.112	−51.05	0.033
38	$CF_3CF_2CF_2OCH_2CF_3$	5.808 63	969.407	−70.58	0.057
39	$CF_3CF_2CF_2OCH_2CF_2CHF_2$	6.158 85	1221.906	−62.74	0.090
40	$CF_3CF_2CH_2OCF_2CF_3$	6.052 23	1056.314	−58.95	0.014
41	$CHF_2CF_2CH_2OCF_2CF_3$	6.112 27	1127.942	−61.47	0.015
42	$CF_3CF_2CF_2OCH_2CHF_2$	6.162 39	1163.214	−60.53	0.049
43	$CF_3CF_2CF_2OCH_2CF_2CF_3$	6.090 73	1152.169	−61.90	0.028
44	$CHF_2CH_2OCH_3$	6.118 20	1082.746	−58.36	0.024
45	$CHF_2CF_2CH_2OCH_3$	6.215 07	1225.419	−56.38	0.026
46	$CF_3CF_2CF_2CH_2OCH_3$	6.121 81	1166.591	−60.70	0.040
47	$CF_3CHFCF_2CH_2OCH_3$	6.195 13	1263.163	−59.13	0.053
48	$CHF_2CF_2OCH_2F$	6.356 11	1191.990	−52.74	0.029
49	$CF_3CF_2CF_2OCH_2F$	6.113 98	1070.233	−55.91	0.009
50	$CF_3CF_2CF_2CF_2OCH_2CH_3$	6.122 41	1221.188	−53.39	0.026

mental values are shown in Table 4. The uncertainties of the calculated values of the 48 hydrofluoroethers were less than 0.1% except for those of $CHF_2CF_2CF_2CF_2CH_2OCH_3$ and $CHF_2CF_2OCH_2CHF_2$, where the AAD was 0.253% and 0.123%, respectively.

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Received for review December 7, 2001. Accepted March 14, 2002. The authors acknowledge the financial support of the New Energy and Industrial Technology Development Organization (NEDO).

JE010322Y