

**VAPOR-LIQUID EQUILIBRIA FOR $\text{CF}_3\text{OCF}_2\text{H}$ /FLUORINATED ETHANE
AND CF_3SF_5 /FLUORINATED ETHANE MIXTURES AS POTENTIAL R-22
ALTERNATIVES**

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Keyword List: vapor-liquid equilibria, vapor pressure, mixture, hydrofluorocarbons(HFC), hydrofluoroethers(HFE), fluorinated hexavalent sulfur derivatives, refrigerant, and R-22.

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Abstract

New vapor pressure data are reported as a function of temperature and concentration for the mixtures; $\text{CF}_3\text{SF}_5/\text{CF}_3\text{CH}_3$, $\text{CF}_3\text{SF}_5/\text{CF}_3\text{CF}_2\text{H}$, $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_3\text{CH}_2\text{F}$, $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_3\text{CF}_2\text{H}$, $\text{CF}_3\text{OCF}_2\text{H}/\text{CF}_3\text{CH}_3$, $\text{CF}_3\text{OCF}_2\text{H}/\text{CF}_3\text{CH}_2\text{F}$, and $\text{CF}_3\text{OCF}_2\text{H}/\text{CF}_3\text{CF}_2\text{H}$. As is expected large positive deviations from the ideal mixing vapor pressure are observed for CF_3SF_5 mixed with ethane derivatives of a low fluorine content and these deviations become small as the fluorine content approaches that of $\text{CF}_3\text{CF}_2\text{H}$. In contrast to this expected vapor pressure behavior, the ether ($\text{CF}_3\text{OCF}_2\text{H}$)/fluorinated ethane mixtures exhibit significantly smaller deviations which may be positive or negative. The mixture, $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_3\text{CH}_2\text{F}$, exhibits sufficiently large negative deviations from ideality to produce an azeotrope at 0.21 mole fraction with boiling point of -33.3°C . The mixtures $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_2\text{CF}_2\text{H}$, $\text{CF}_3\text{OCF}_2\text{H}/\text{CF}_2\text{CH}_3$ and $\text{CF}_3\text{OCF}_2\text{H}/\text{CF}_3\text{CF}_2\text{H}$ are nearly ideal and the mixture $\text{CF}_3\text{OCF}_2\text{H}/\text{CF}_3\text{CH}_2\text{F}$ exhibits positive deviations from ideality. All of the mixtures have boiling points that range from -22°C to -40°C . The mixtures that have boiling points below -30°C have potential as R-22 alternatives.

I. Introduction

Many of the leading R-22 alternatives do not perform as well as R-22 [1,2], because it is difficult to match the low normal boiling point (-40.1°C) and high critical temperature (96°C) of R-22. In order to identify better performing R-22 alternatives, researchers have turned to investigating properties of mixtures [1-3]. In order to expand the array of mixtures that may be investigated the authors have investigated novel fluorinated compounds, like $\text{CF}_3\text{OCF}_2\text{H}$ ($T_b = -34.6^{\circ}\text{C}$, $T_c = 80.7^{\circ}\text{C}$) CF_3SF_5 ($T_b = -20.3^{\circ}\text{C}$, $T_c = 108.1^{\circ}\text{C}$) CF_3SCF_3 ($T_b = -21.9^{\circ}\text{C}$, $T_c = 103.6^{\circ}\text{C}$), CF_3OCH_3 ($T_b = -24.4^{\circ}\text{C}$, $T_c = 105.1^{\circ}\text{C}$), and $\text{CF}_3\text{OCF}_2\text{CF}_3$ ($T_b = -23.7^{\circ}\text{C}$, $T_c = 83.7^{\circ}\text{C}$), as mixture components [4,5].

Primary data needed to screen the mixtures as alternative refrigerants are vapor pressure data. In previous work the authors found that mixtures of perfluorinated ethers and sulfur compounds with hydrofluorocarbons of lower fluorine content exhibit large positive deviations from ideality. However in contrast to this behavior, the authors find that the highly fluorinated ether, $\text{CF}_3\text{OCF}_2\text{H}$, forms nearly ideal mixtures with fluorinated ethane derivatives and these deviations may be either positive or negative.

In this paper we report vapor pressure measurements on mixtures of $\text{CF}_3\text{OCF}_2\text{H}$ with the fluorinated ethanes ($\text{CH}_3\text{CH}_2\text{F}$, $\text{CH}_3\text{CF}_2\text{H}$, CF_3CH_3 , CF_3CFH_2 and $\text{CF}_3\text{CF}_2\text{H}$). The results are compared with the vapor-pressure results of the perfluorinated sulfur compound, CF_3SF_5 , with the fluorinated ethanes.

II. Vapor Pressure Measurements.

The reader is referred to the authors' previous publications for a description of experimental methods [6-8]. The chemicals were purchased from PCR. All the chemicals were 99.5% pure with the exception of $\text{CF}_3\text{OCF}_2\text{H}$ which was found to be 99% pure. The purity of the chemicals was verified by a combination of ^1H and ^{19}F NMR spectroscopy, FT-IR spectroscopy, and GC-MS spectroscopy. The vapor pressures were measured to within ± 0.1 kPa as a function of temperature using an isoteniscope and a capacitance pressure sensor.

Since the tabulations of the measured vapor pressures are extensive, these are reverted to the Appendix. The vapor pressure measurements for the pure components CF_3SF_5 , $\text{CF}_3\text{OCF}_2\text{H}$, CF_3CH_3 , and $\text{CF}_3\text{CF}_2\text{H}$; are tabulated as a function of temperature in Table 1A of the Appendix. Pure component data on other mixture components; $\text{CH}_3\text{CH}_2\text{F}$, $\text{CH}_3\text{CF}_2\text{H}$ and $\text{CF}_3\text{CH}_2\text{F}$ have already been reported in previous publications [4,5,9]. The vapor pressure measurements of the mixtures are presented as function of temperature and mole fraction in Tables 2A to 5A of the Appendix. A more compact parametric representation of the vapor pressure measurements based on Eq. (1),

$$\ln(P) = a + b \ln(T) + \frac{c}{T} \quad , \quad (1)$$

are presented in the body of this paper in Tables 1 and 2 along with the normal boiling point, the heat of vaporization at the boiling point, and the root-mean-square deviation of the experimental data from the least squares calculation.

In order to examine deviations from ideality and construct liquid-vapor phase diagrams for the binary mixtures, the vapor pressure data were fitted to the following van Laar equations [10] by the least squares method,

$$\mathbf{g}_1 = \exp \left[A \left(1 + \frac{AX}{B(1-X)} \right)^{-2} \right], \quad (2)$$

$$\mathbf{g}_2 = \exp \left[B \left(1 + \frac{B(1-X)}{AX} \right)^{-2} \right], \quad (3)$$

$$P = X\mathbf{g}_1P_1^o + (1-X)\mathbf{g}_2P_2^o, \quad (4)$$

$$y = \frac{XP_1^o\mathbf{g}_1}{P} . \quad (5)$$

In the above equations γ_1 and γ_2 are activity coefficients, P_1^o and P_2^o are the vapor pressures of the pure components, X is the mole fraction of component 1 in the liquid phase, and y is the mole fraction of component 1 in the vapor phase. If the vapor

Table 1

Parametric representation of the vapor pressure data using Eq. (1). The X(1) designates mole fraction and in parenthesis are the component number designations of the mixture components. ΔH_{vap} is the heat of vaporization at boiling point

X(1)	Parameters of Eq. (1) (Units of Pressure are kPa)			Temp. Range (°C)	Boiling Pt. (°C)	ΔH_{vap} (kJ/mol)	% RMS Dev.
	a	b	c				
CF ₃ OCF ₂ H(1)/CH ₃ CH ₂ F(2) Mixtures							
0.0	54.6833	-6.1149	-3926.6	-72.6 to -38.3	-37.5	20.67	0.2
0.2	-2.8519	2.8170	-1877.7	-48.7 to -37.0	-36.4	21.16	0.2
0.5	70.7259	-8.5056	-4671.6	-63.3 to -34.4	-33.7	21.91	0.8
0.6	15.3408	0.0000	-2569.0	-49.9 to -34.5	-33.6	21.36	0.3
0.806	112.153	-14.9608	-6128.3	-47.9 to -34.1	-33.3	21.12	0.2
1.0	41.1744	-3.9109	-3614.1	-56.7 to -35.2	-34.5	22.29	0.3
CF ₃ OCF ₂ H(1)/CH ₃ CF ₂ H(2) Mixtures							
0.0	32.1570	-2.5458	-3358.8	-52.0 to -24.5	-24.2	22.66	0.2
0.2	14.4779	0.1797	-2671.6	-42.9 to -27.4	-26.9	22.58	0.2
0.4	-29.6316	6.9821	-1008.3	-46.7 to -29.8	-29.2	22.76	0.3
0.6	71.2384	-8.6151	-4686.1	-50.3 to -31.0	-30.4	21.58	0.4
0.8	49.9020	-5.3052	-3896.0	-60.4 to -36.0	-32.6	21.78	0.4
1.0	41.1744	-3.9109	-3614.1	-56.7 to -35.2	-34.5	22.29	0.3
CF ₃ OCF ₂ H(1)/CF ₃ CH ₂ F(2) Mixtures							
0.0	41.7245	-3.9284	-3825.2	-52.0 to -27.0	-26.5	23.72	0.5
0.2	58.1996	-6.5358	-4315.8	-58.3 to -29.0	-28.4	22.58	0.4
0.4	97.0614	-12.5915	-5651.1	-54.3 to -31.2	-30.7	21.60	0.2
0.6	80.1945	-9.9956	-4994.4	-55.1 to -35.3	-32.8	21.55	0.3
0.85	126.391	-17.1656	-6640.8	-61.6 to -34.2	-33.7	21.04	0.5
1.0	41.1744	-3.9109	-3614.1	-56.7 to -35.2	-34.5	22.29	0.3
CF ₃ OCF ₂ H(1)/CF ₃ CH ₃ (2) Mixtures							
0.0	63.1074	-7.4482	-4096.1	-82.5 to -48.4	-47.0	20.05	0.2
0.2	15.5798	0.0000	-2501.4	-60.5 to -45.6	-45.0	20.80	0.3
0.4	14.2665	0.0000	-2224.2	-64.4 to -43.7	-42.6	18.49	1.0
0.6	-7.8345	3.6123	-1686.2	-56.3 to -40.9	-40.2	21.02	0.3
0.8	47.6342	-4.9501	-3766.0	-64.8 to -38.0	-37.4	21.61	0.3
1.0	41.1744	-3.9109	-3614.1	-56.7 to -35.2	-34.5	22.29	0.3
CF ₃ OCF ₂ H(1)/CF ₃ CF ₂ H(2) Mixtures							
0.0	5.2388	1.7021	-2217.1	-69.8 to -48.5	-47.9	21.62	0.4
0.2	-8.6911	3.8345	-1705.4	-61.4 to -46.3	-45.8	21.43	0.3
0.4	14.5309	0.0000	-2274.0	-61.7 to -44.9	-43.8	18.91	0.9
0.6	15.1109	0.0000	-2437.9	-63.2 to -41.6	-40.8	20.27	0.6
0.8	66.3017	-7.8798	-4389.2	-60.2 to -38.5	-37.8	21.08	0.3
1.0	41.1744	-3.9109	-3614.1	-56.7 to -35.2	-34.5	22.29	0.3

Table 2

Parametric representation of the vapor pressure data using Eq. (1). The X(1) designates mole fraction and in parenthesis are the component number designations of the mixture components. ΔH_{vap} is the heat of vaporization at boiling point

X(1)	Parameters of Eq. (1) (Units of Pressure are kPa)			Temp. Range (°C)	Boiling Pt. (°C)	ΔH_{vap} (kJ/mol)	% RMS Dev.
	a	b	c				
CF ₃ SF ₅ (1)/CF ₃ CH ₃ (2) Mixtures							
0.0	63.1074	-7.4482	-4096.1	-82.5 to -48.4	-47.0	20.05	0.2
0.1	51.7835	-5.6743	-3717.2	-79.0 to -47.3	-46.3	20.20	0.4
0.2	32.6930	-2.6819	-3071.5	-74.1 to -46.5	-46.0	20.47	0.2
0.4	34.3943	-3.0541	-3018.4	-70.6 to -44.9	-44.2	19.28	0.6
0.6	13.8856	0.0000	-2155.2	-60.4 to -41.6	-40.6	17.92	0.9
0.8	142.150	-20.0446	-6612.4	-56.5 to -37.9	-37.0	15.61	0.3
1.0	158.745	-22.1236	-8021.2	-49.8 to -21.5	-20.3	20.18	0.5
CF ₃ SF ₅ (1)/CF ₃ CF ₂ H(2) Mixtures							
0.0	5.2388	1.7021	-2217.1	-69.8 to -48.5	-47.9	21.62	0.4
0.2	15.2358	0.0000	-2418.8	-64.8 to -46.2	-45.3	20.11	0.7
0.4	14.7205	0.0000	-2324.5	-59.7 to -43.9	-43.1	19.33	0.3
0.6	88.9742	-11.6458	-4866.1	-60.9 to -40.8	-39.9	17.87	0.3
0.8	13.8890	0.0000	-2247.1	-53.8 to -31.7	-30.8	18.68	0.8
1.0	158.745	-22.1236	-8021.2	-49.8 to -21.5	-20.3	20.18	0.5

pressure exhibits a maximum or a minimum, the mixtures have an azeotropic concentration, which may be calculated from Equations (2) to (4) and the condition,

$$g_1 P_1^o = g_2 P_2^o \quad (6)$$

The deviations from ideality can be conveniently expressed in terms of the van Laar parameters, A and B by expanding the excess free energy, DG^e , about its symmetric approximation in powers of $(A-B)/(A+B)$ according to the relation,

$$\Delta G^e = X(1-X)w \left[1 + \sum_{n=1}^{\infty} (1-2X)^n \left(\frac{A-B}{A+B} \right)^n \right], \quad (7)$$

$$w = 2RT \frac{AB}{A+B} \quad (8)$$

The free energy parameter, ω , is an expression of the deviation from ideality within the symmetric mixture approximation.

The results for the van Laar parameters, A and B , and the free energy parameter, ω , calculation are presented in Table 3. Within the framework of lattice theory of mixtures the

Table 3

Results of the van Laar Analysis of the Vapor Pressure Data for the Binary Mixtures. The Highest Temperature Value Designated with an Asterisk is the Normal Boiling Point of the 0.5 Mole Fraction Mixture

Temp. °C	Van Laar Parameters		ω kJ	% RMS Dev.
	A	B		
CF ₃ OCF ₂ H(2)/CH ₃ CH ₂ F(1) Mixtures				
-50.0	-0.4782	-0.4177	-0.83	3.0
-40.0	-0.5050	-0.3783	-0.84	1.9
-35.0	-0.7615	-0.2295	-0.70	0.6
-33.3*	-0.7323	-0.2862	-0.74	1.6
CF ₃ OCF ₂ H(2)/CH ₃ CF ₂ H(1) Mixtures				
-50.0	0.0718	0.0718	0.13	1.5
-40.0	0.009	0.009	0.02	0.9
-35.0	-0.0142	-0.0142	-0.03	1.0
-29.8	-0.0329	-0.0329	-0.07	1.2
CF ₃ OCF ₂ H(1)/CF ₃ CH ₃ (2) Mixtures				
-60.0	0.1797	0.1797	0.32	3.7
-50.0	0.0528	0.0528	0.10	1.4
-45.0	0.0129	0.0129	0.02	0.5
-41.4*	-0.0053	-0.0053	-0.01	0.6
CF ₃ OCF ₂ H(2)/CF ₃ CH ₂ F(1) Mixtures				
-50.0	0.5114	0.2356	0.60	0.8
-45.0	0.5048	0.2242	0.59	0.7
-40.0	0.4415	0.2121	0.56	0.7
-31.8*	0.2693	0.1916	0.53	0.8
CF ₃ OCF ₂ H(1)/CF ₃ CF ₂ H(2) Mixtures				
-60.0	0.5362	0.1904	0.50	3.0
-50.0	0.1718	0.0878	0.22	1.3
-45.0	0.0331	0.0331	0.01	0.6
-42.3*	-0.1205	-0.0134	-0.05	0.2
CF ₃ SF ₅ (1)/CF ₃ CH ₃ (2) Mixtures				
-60.0	1.3201	1.7495	2.76	1.0
-50.0	1.0258	1.6741	2.36	1.4
-45.0	0.9333	1.4990	2.18	1.9
-42.4*	0.8817	1.2249	2.09	2.4
CF ₃ SF ₅ (1)/CF ₃ CF ₂ H(2) Mixtures				
-60.0	1.2510	0.7950	1.72	1.6
-50.0	0.8445	0.6150	1.32	2.4
-45.0	0.6500	0.5175	1.09	2.6
-41.5*	0.5197	0.4461	0.9	2.6

free energy parameter, ω , is independent of temperature and represents the difference between the interaction energy of the unlike components and the average interaction energy of the like components. We note that from Table 3 this parameter does have a small temperature dependence. In order to make comparisons of this parameter for the different mixtures under the same vapor pressure conditions, we have included its value at the normal boiling point of each mixture at a mole fraction of 0.5.

Figure 1 is an exemplary phase diagram for the $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_3\text{CH}_2\text{F}$ mixtures showing the bubble line and dew line calculated from the van Laar parameters and compares the bubble line with the experimental measurements. The Figure shows that these mixtures, $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_3\text{CH}_2\text{F}$, form an maximum boiling azeotrope. The azeotropic boiling point is -33.3°C and its $\text{CF}_3\text{OCF}_2\text{H}$ mole fraction is 0.21. The $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_3\text{CH}_2\text{F}$ mixtures were the only mixtures in this investigation that formed an azeotrope.

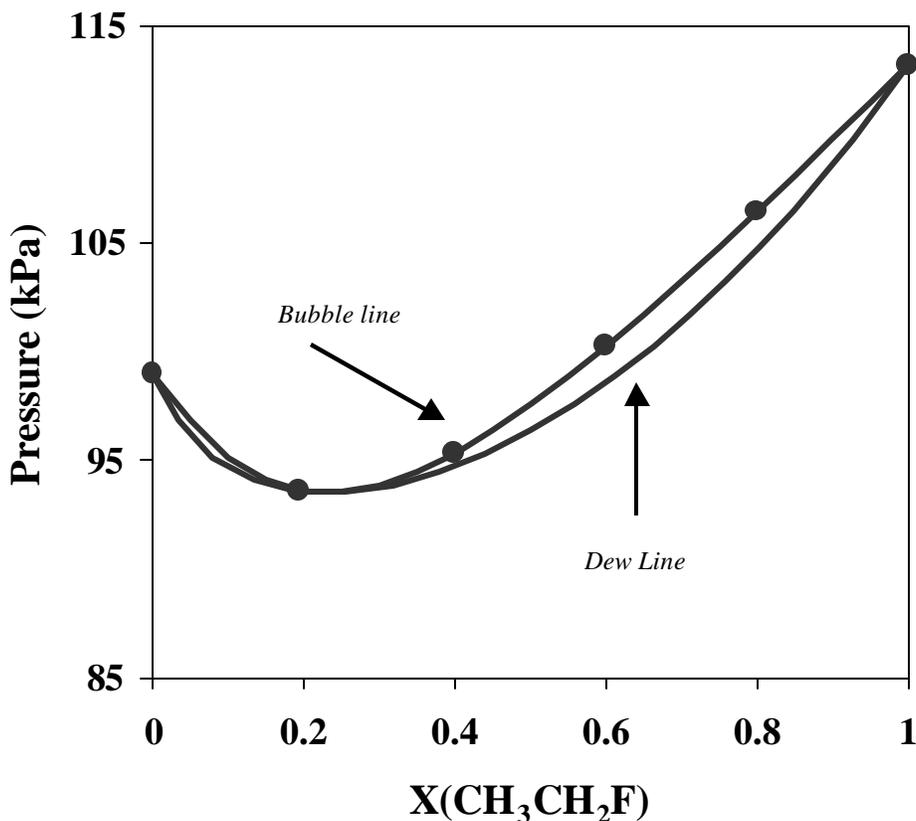


Figure 1. Vapor pressure of $\text{CF}_3\text{OCF}_2\text{H}/\text{CH}_3\text{CH}_2\text{F}$ mixtures at -35°C . The solid lines represent the least squares results for Equations 2 and 3.

Discussion and Conclusions

The CF_3SF_5 /fluorinated ethane mixtures all exhibit positive deviations from the ideal vapor pressure which is generally what is observed for HFC (hydrofluorocarbon) mixtures [3] and for mixtures involving the perfluorinated ether, $\text{CF}_3\text{OCF}_2\text{CF}_3$ [5]. The CF_3SF_5 mixture data may be interpreted in terms of steric considerations and the larger molecular volume of the perfluorinated species, CF_3SF_5 , which does not permit as close approach of unlike species as for like molecules of the ethane derivative which has a lower fluorine content. This weakens the attractive interaction between the unlike molecule interactions compared with the like molecules of the ethane derivative. This interpretation is consistent with the decrease of ω with the number of fluorine atoms (See Figure 2). It is notable from the Figure 3 that the decrease in ω is nearly linear with the number of fluorine atoms, N , for the CF_3SF_5 mixtures.

In contrast with the behavior of CF_3SF_5 mixtures and previous observations on perfluorinated ether mixtures, the highly fluorinated ether ($\text{CF}_3\text{OCF}_2\text{H}$)/fluoroethane ($\text{CH}_3\text{CH}_2\text{F}$) mixtures exhibit negative deviations from ideality of sufficient magnitude to produce an azeotrope. The more highly fluorinated $\text{CF}_3\text{CH}_2\text{F}$ (R-134a) when combined with $\text{CF}_3\text{OCF}_2\text{H}$ forms mixtures exhibiting positive deviations from ideality which is opposite to the trends observed for CF_3SF_5 mixtures with increasing fluorine content of the ethane derivative (See Figure 2).

The binary mixtures $\text{CF}_3\text{OCF}_2\text{H}$ with $\text{CH}_3\text{CF}_2\text{H}$, CF_3CH_3 , or $\text{CF}_3\text{CF}_2\text{H}$ are nearly ideal. The interesting aspect of the latter nearly ideal mixtures is that the free energy parameter, ω , changes sign as temperatures increase towards boiling point of the 50:50 mixture (See Table 3) indicating that deviations from ideal mixing change from positive to negative as temperatures increase.

The $\text{CF}_3\text{OCF}_2\text{H}$ mixture behavior can likely be interpreted as hydrogen bonding interactions being the dominant consideration rather than increasing molecular volume

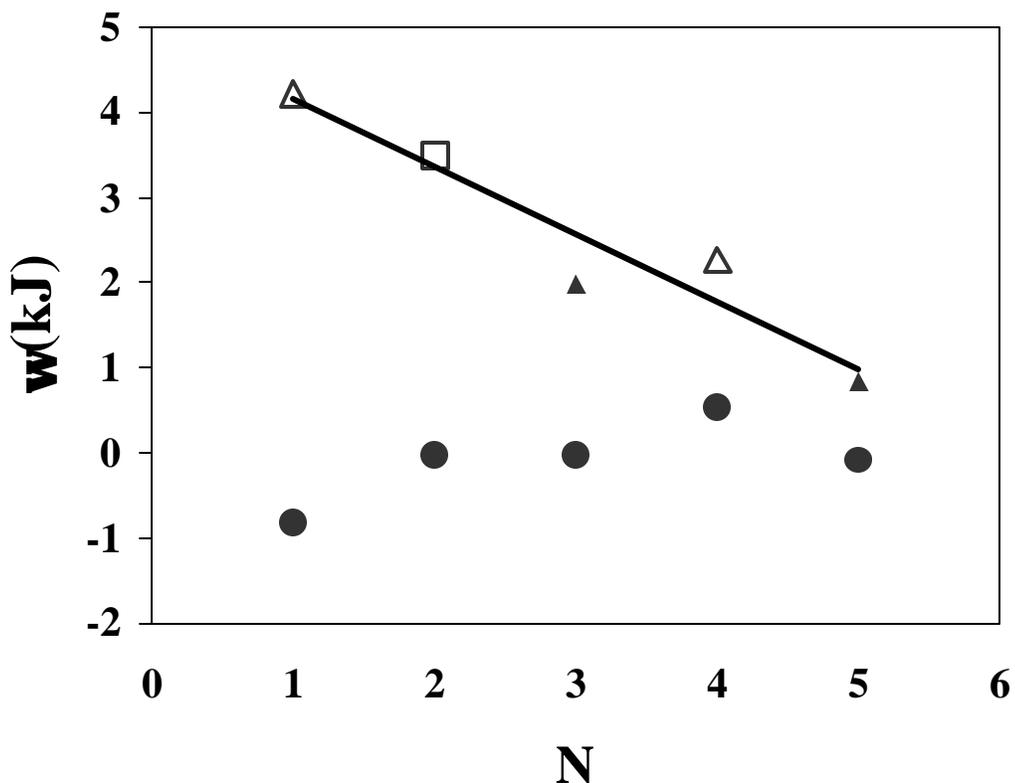


Figure 2. The free energy parameter ω calculated for the boiling point of the 50:50 mixture versus the number of fluorine atoms in the ethane derivative. The smooth line is the linear least squares result for the CF_3SF_5 mixture data. \blacktriangle calculated from CF_3SF_5 mixtures data obtained in this work. \triangle calculated from CF_3SF_5 mixture data of Ref. 4. \bullet calculated from CF_3SF_5 /ethane mixture data of Ref. 9. \bullet calculated from $\text{CF}_3\text{OCF}_2\text{H}$ /fluorinated ethane mixtures investigated in this work.

and steric interactions as in the case of the CF_3SF_5 mixtures. Hydrogen bonding with fluorine atoms plays a role in both HFC and ether/HFC mixtures. Since the negative deviations from ideality are different in general from what has been observed with binary HFC mixtures, one would anticipate that hydrogen bonding with the oxygen atom in the ether must play the role that differentiates $\text{CF}_3\text{OCF}_2\text{H}$ mixtures from binary HFC mixtures.

List of Symbols

Roman

ΔH_{vap} = Heat of Vaporization

P = Vapor Pressure

T = Kelvin Temperature

T_b = Normal Boiling Point

T_c = Critical Temperature

X = liquid phase mole fraction

y = vapor phase mole fraction

(a, b, c) are parameters of the vapor pressure Eq. (1)

(A, B) are parameters of the van Laar Eqs. (7) and (8).

Greek

γ = activity coefficient of component I.

Acknowledgements

The authors gratefully acknowledge the Electric Power Research Institute in Palo Alto, California for supporting this research.

Appendix

Tabulations of Measured Vapor Pressure Data In Tables 1A to 5A

Table 1A
Vapor Pressure of Pure Chemicals Below the Boiling Point

CF ₃ OCF ₂ H		CF ₃ SF ₅				CF ₃ CH ₃		CF ₃ CF ₂ H	
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)
-56.7	31.5	-49.8	23.6	-30.7	65.6	-82.5	12.4	-69.8	29.3
-54.4	35.9	-47.4	27.6	-29.9	68.0	-76.9	18.4	-67.5	34.0
-52.6	39.9	-45.3	31.3	-29.4	69.7	-73.6	22.9	-65.2	39.1
-51.0	43.7	-43.5	34.8	-28.9	71.3	-70.6	28	-63.6	42.8
-48.9	48.8	-41.9	38.3	-27.9	74.1	-68.0	32.8	-62.2	46.5
-47.2	53.5	-40.1	41.7	-27.1	76.7	-65.8	37.3	-61.1	50.0
-45.6	58.0	-38.9	44.7	-26.4	79.5	-63.8	42.1	-59.6	53.9
-44.3	62.5	-37.5	47.6	-25.5	82.1	-61.9	46.9	-58.4	57.5
-43.0	66.9	-36.2	50.5	-24.8	84.8	-60.1	51.9	-57.3	61.1
-41.8	71.3	-35.2	53.1	-24.0	87.2	-58.3	57.1	-56.1	65.3
-40.6	75.7	-34.2	55.7	-23.2	90.8	-56.7	62.4	-54.8	70.1
-39.4	80.0	-33.2	58.4	-22.2	94.4	-55.1	67.6	-53.7	74.4
-38.3	84.3	-32.1	61.3	-21.5	97.5	-53.7	73.1	-52.6	79.3
-37.3	88.7					-52.2	78.4	-51.7	83.2
-35.2	98.0					-50.9	83.5	-50.8	87.3
						-49.7	89.1	-49.6	92.4
						-48.4	95.1	-48.5	98.5

Table 2A
 Vapor Pressure of CF₃SF₅(1)/CF₃CH₃(2) and CF₃SF₅(1)/CF₃CF₂H(2) Mixtures Below the Boiling Point

CF ₃ SF ₅ (1)/ CF ₃ CH ₃ (2)									
X(1)		X(1)		X(1)		X(1)		X(1)	
0.1		0.2		0.4		0.6		0.8	
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)
-79.0	15.5	-74.1	21.5	-70.6	26.1	-60.4	43.46	-56.5	45.7
-74.2	21.5	-71.2	25.7	-68.1	30.5	-58.3	47.60	-54.3	50.8
-70.5	27.3	-67.7	31.9	-65.3	36.0	-56.3	51.60	-52.5	55.5
-67.4	33.1	-65.6	36.1	-63.0	40.5	-54.4	56.00	-50.5	60.1
-64.7	38.5	-63.7	40.3	-61.2	44.8	-52.5	60.79	-48.8	65.1
-60.3	49.6	-61.7	44.9	-58.2	52.0	-50.4	66.39	-46.9	69.9
-58.6	54.4	-57.8	56.0	-54.9	60.8	-48.8	71.99	-44.9	75.9
-56.5	60.5	-56.3	60.4	-53.6	65.2	-47.0	77.59	-42.6	82.8
-54.6	66.8	-54.6	66.0	-52.1	70.1	-45.3	84.13	-40.8	88.8
-53.3	71.9	-53.4	70.3	-50.4	75.9	-43.9	89.33	-37.9	98.1
-51.7	77.9	-52.1	75.5	-48.8	82.0	-42.5	94.26		
-49.7	86.1	-50.7	80.9	-47.1	88.8	-41.6	98.13		
-48.2	92.7	-49.2	87.2	-45.6	95.1				
-47.3	97.3	-47.7	93.3	-44.9	98.9				
		-46.5	98.9						
CF ₃ SF ₅ (1)/ CF ₃ CF ₂ H (2)									
X(1)		X(1)		X(1)		X(1)			
0.2		0.4		0.6		0.8			
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)		
-64.8	38.0	-59.7	46.4	-60.9	38.7	-53.8	38.9		
-62.6	42.8	-56.5	54.0	-58.4	43.9	-50.6	44.4		
-60.4	47.6	-54.8	58.7	-56.3	48.8	-48.2	48.9		
-58.5	52.3	-52.8	64.8	-54.0	54.7	-46.4	53.2		
-56.7	57.6	-50.7	71.3	-51.7	61.2	-44.2	58.1		
-54.1	66.0	-49.0	77.5	-49.6	67.3	-40.8	67.9		
-52.4	71.9	-47.5	82.9	-47.7	73.3	-38.9	73.2		
-50.0	81.2	-46.2	88.3	-45.6	79.9	-37.3	78.5		
-49.1	85.3	-44.9	93.5	-43.8	86.4	-35.5	84.4		
-47.7	90.8	-43.9	98.0	-42.1	92.4	-33.7	90.4		
-46.2	98.1			-40.8	98.1	-31.7	98.8		

Table 3A
 Vapor Pressure of CF₃OCF₂H(1)/CH₃CF₂H(2) and CF₃OCF₂H(1)/CH₃CH₂F(2) Mixtures
 Below the Boiling Point

CF₃OCF₂H(1)/CH₃CH₂F(2)							
X(1)		X(1)		X(1)		X(1)	
0.2		0.5		0.6		0.806	
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)
-48.7	56.4	-63.3	20.0	-49.9	46.4	-47.9	49.6
-47.4	60.1	-59.9	24.7	-47.9	51.2	-46.3	53.7
-46.1	64.4	-56.7	30.1	-46.2	55.9	-44.8	58.3
-45.0	67.5	-54.2	34.9	-43.3	64.0	-43.4	62.9
-43.8	71.7	-51.6	40.4	-41.8	69.1	-41.6	68.5
-42.5	76.3	-49.6	45.5	-40.4	74.1	-40.2	73.6
-41.4	80.3	-47.0	52.8	-38.8	79.7	-39.0	77.9
-40.4	84.4	-45.2	57.6	-37.0	86.3	-37.9	82.1
-39.3	88.5	-43.5	63.2	-35.5	92.9	-36.7	87.1
-38.2	93.3	-41.1	70.7	-34.5	97.7	-35.1	93.3
-37.0	98.5	-39.4	77.2			-34.1	97.7
		-38.3	83.9				
		-36.9	86.7				
		-35.4	93.2				
		-34.4	98.1				
CF₃OCF₂H(1)/CH₃CF₂H(2)							
X(1)		X(1)		X(1)		X(1)	
0.2		0.4		0.6		0.80	
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)
-42.9	47.2	-46.7	43.7	-50.3	37.7	-60.4	23.5
-41.4	50.8	-44.6	48.4	-47.5	44.0	-57.2	28.4
-39.6	55.6	-42.4	54.3	-44.7	51.7	-53.9	34.3
-37.2	62.3	-40.3	59.7	-42.5	57.5	-51.2	39.7
-36.2	66.0	-39.0	64.3	-40.4	63.3	-48.5	46.5
-34.8	70.5	-37.2	69.6	-38.5	69.5	-46.1	52.7
-33.6	74.4	-35.7	74.9	-36.7	76.1	-44.0	58.8
-32.1	79.9	-33.9	81.1	-35.1	81.9	-42.5	63.5
-30.8	84.8	-32.6	86.4	-33.8	87.2	-40.5	69.3
-29.5	90.3	-31.1	92.5	-32.4	92.8	-38.0	78.7
-28.7	93.5	-29.8	98.7	-31.0	99.2	-36.0	86.6
-27.4	98.9						

Table 4A
 Vapor Pressure of CF₃OCF₂H(1)/CF₃CH₂F(2) and CF₃OCF₂H(1)/CF₃CH₃(2) Mixtures
 Below the Boiling Point

CF₃OCF₂H(1)/CF₃CH₃(2)							
X(1)		X(1)		X(1)		X(1)	
0.2		0.4		0.6		0.8	
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)
-60.5	45.6	-64.4	37.9	-56.3	45.7	-64.8	22.9
-58.7	50.4	-61.3	43.3	-54.3	50.8	-62.0	27.2
-57.0	54.9	-58.7	48.8	-52.6	55.1	-59.6	31.5
-55.4	59.7	-55.4	56.8	-50.9	60.1	-57.0	36.4
-54.0	64.3	-53.7	61.6	-48.6	68.0	-55.0	40.8
-52.5	69.7	-52.2	66.1	-47.0	73.1	-53.2	45.3
-50.0	78.9	-49.5	75.2	-45.7	78.1	-51.4	50.0
-48.8	83.7	-48.0	80.1	-44.2	83.7	-47.9	60.5
-47.7	89.1	-46.6	85.6	-42.8	89.9	-46.5	65.2
-46.8	93.3	-45.6	90.1	-41.7	94.1	-44.6	71.5
-45.6	98.0	-44.5	94.4	-40.9	98.0	-42.8	78.5
		-43.7	97.9			-40.7	86.5
						-39.4	92.3
						-38.0	98.0
CF₃OCF₂H(1)/CF₃CH₂F(2)							
X(1)		X(1)		X(1)		X(1)	
0.2		0.4		0.6		0.85	
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)
-58.3	20.4	-54.3	29.7	-55.1	32.0	-61.6	22.0
-55.5	24.3	-51.5	35.1	-52.7	36.8	-58.4	27.2
-52.5	29.1	-49.4	39.7	-51.1	40.4	-55.3	32.7
-50.1	33.3	-47.3	44.5	-49.2	44.9	-52.6	38.3
-47.8	38.0	-45.5	49.1	-47.4	49.3	-50.7	42.9
-45.9	42.7	-43.7	54.0	-46.0	53.5	-48.5	49.1
-44.1	46.8	-41.9	59.1	-44.3	58.1	-46.9	53.3
-42.2	51.7	-40.4	64.1	-43.0	62.4	-45.0	58.9
-40.8	55.7	-38.8	69.3	-41.4	67.6	-42.4	67.6
-39.0	60.8	-37.5	74.1	-39.9	72.4	-40.0	75.6
-37.3	65.9	-35.8	80.0	-37.4	81.7	-38.9	80.0
-35.8	71.1	-34.4	85.5	-36.3	86.1	-37.7	84.9
-34.1	77.3	-33.2	90.4	-35.3	90.4	-35.6	93.6
-32.8	82.5	-32.4	93.6			-34.2	98.1
-31.5	88.1	-31.2	98.9				
-30.2	93.3						
-29.0	98.9						

Table 5A
Vapor Pressure of CF₃OCF₂H(1)/CF₃CF₂H(2) Mixtures Below the Boiling Point

CF ₃ OCF ₂ H(1)/CF ₃ CF ₂ H(2)							
X(1)		X(1)		X(1)		X(1)	
0.2		0.4		0.6		0.8	
Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)	Temp. (°C)	Press. (kPa)
-61.4	44.3	-61.7	44.3	-63.2	33.5	-60.2	31.3
-59.5	49.3	-59.4	49.2	-60.5	38.4	-57.9	36.1
-58.0	53.6	-54.9	60.7	-58.2	43.3	-55.2	41.7
-56.3	58.3	-52.7	66.7	-55.9	48.4	-53.1	47.3
-54.6	64.4	-51.3	71.9	-53.7	54.5	-50.9	53.1
-53.1	69.3	-49.8	77.1	-51.5	60.8	-49.4	57.6
-52.0	74.0	-48.4	82.3	-49.9	66.1	-47.7	62.5
-50.7	79.1	-46.9	88.3	-48.6	70.8	-45.7	69.5
-49.3	84.4	-45.7	93.7	-46.4	77.6	-43.8	76.4
-48.1	90.1	-44.9	98.0	-45.0	83.9	-41.5	85.6
-47.2	94.1			-43.4	90.7	-40.2	91.1
-46.3	98.7			-41.6	98.1	-38.5	98.0

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