*	symbols with asterisks refer to isopiestic reference solution
B_i	least-squares coefficients of eq 1
A_i	least-squares coefficients of eq 4 and 5
r_i	powers of eq 4 and 5
A	Debye–Hückel constant for 3–1 electrolytes
M_1	molecular mass of water, g·mol^{-1}
M_2	molecular mass of solute, g·mol^{-1}
$\beta^{(0)}$, $\beta^{(1)}$, C^{ϕ}	parameters for Pitzer's equations
A^{ϕ}	Debye–Hückel constant (1–1 charge type) for Pitzer's Φ equation
σ	standard deviation of fitting equations
$\gamma_{\pm}$	mean molal activity coefficient
a_1	water activity
Φ_f	osmotic coefficient at the freezing temperature of the solution
R	isopiestic molality ratio of $La(NO_3)_3$ to $CaCl_2$

Registry No. $La(NO_3)_3$, 10099-59-9; $Eu(NO_3)_3$, 10138-01-9.

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Viscosities of Gaseous R13B1, R142b, and R152a

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The viscosities of gaseous bromitrifluoromethane (R13B1), 1-chloro-1,1-difluoroethane (R142b), and 1,1-difluoroethane (R152a) were measured with an oscillating disk viscometer of the Maxwell type at 273.15–448.15 K up to 10 MPa for R13B1 and at 298.15–423.15 K up to 5 MPa for R142b and R152a. Two empirical equations were obtained; one is for the viscosity at atmospheric pressure as a function of temperature, and the other is for the viscosity in the whole range of the present measurement as a function of temperature and density. The intermolecular force constants of Stockmayer 12-6-3 potential were determined from the temperature dependence of the viscosity at atmospheric pressure as follows: ϵ/k = 235 K, σ = 0.506 nm, and δ = 0.058 for R13B1; ϵ/k = 362 K, σ = 0.499 nm, and δ = 0.36 for R142b; ϵ/k = 312 K, σ = 0.463 nm, and δ = 0.62 for R152a.

Many halogenated hydrocarbons are commonly used as refrigerants and expected to be used as working fluids of turbines. However, the experimental data of gas viscosity needed for the design of related equipments are scarce and the reliability of the literature data is uncertain because of the large discrepancies among them. Therefore, the measurement of the gas viscosities of halogenated hydrocarbons under pressure is being continued by the present authors, and the viscosity data for chlorodifluoromethane (R22), dichlorodifluoromethane (R12), chlorotrifluoromethane (R13), 1,2,2-trichloro-1,1,2-trifluoroethane (R113), 1,2-dichloro-1,1,2,2-tetrafluoroethane (R114), and chloropentafluoroethane (R115) were reported previously (*1*–*4*). The viscosities of gaseous bromotrifluoromethane (R13B1), 1-chloro-1,1-difluoroethane (R142b), and 1,1-difluoroethane (R152a) are described in the present paper.

Table I. Physical Properties of Refrigerants

	R13B1	R142b	R152a
chem formula	$CBrF_3$	$CClF_2CH_3$	CHF_2CH_3
mol wt[a]	148.910	100.496	66.050
T_b,[a] K	215.4	263.4	248.2
T_c,[a] K	340.2	410.2	386.6
P_c,[b] MPa	3.97	4.12	4.50
ρ_c,[b] kg·m^{-3}	760	435	365
dipole moment,[c] D	0.7	2.1	2.3

[a] T_b, boiling point at atmospheric pressure; T_c, critical temperature; P_c, critical pressure; ρ_c, critical density. [b] Makita, T. *Viscosity and Thermal Conductivity*; Baifukan: Tokyo, 1975; p 224 and 225. [c] Reid, R. C.; Prausnitz, J. M.; Sherwood, T. K. *The Properties of Gases and Liquids*; McGraw Hill: New York, 1977; p 630 and 636.

The viscosity of gaseous R13B1 has been measured by Tsui (*5*), Reed et al. (*6*), Wilbers (*7*), Karbanov et al. (*8*), and Kletskii et al. (*9*). Figure 1 shows the temperatures and pressures at which the literature data were obtained. The present measurement covers the area with oblique lines. The point C.P. denotes the critical point. No experimental data for the viscosities of R142b and R152a could be found in the literature.

0021-9568/87/1732-0098$01.50/0

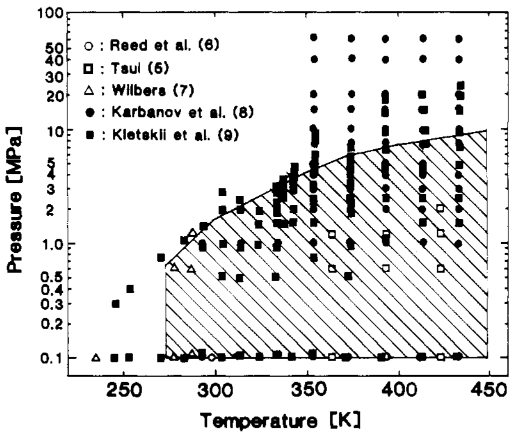

Figure 1. Temperatures and pressures at which the literature data were obtained for R13B1.

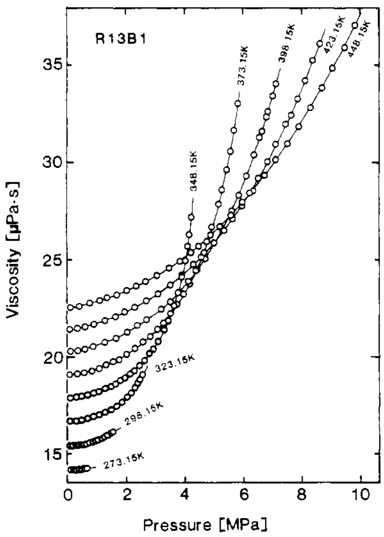

Figure 2. Viscosity vs. pressure plots for gaseous R13B1.

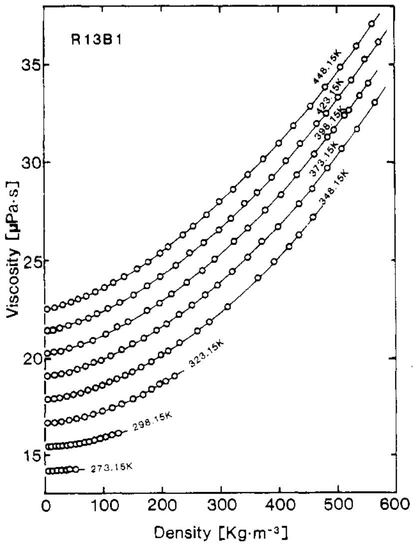

Figure 3. Viscosity vs. density plots for gaseous R13B1.

Table I shows the physical properties of the refrigerants.

Experimental Section

The viscosity measurement was made with an oscillating disk viscometer of the Maxwell type, as described in the previous report (*3*).

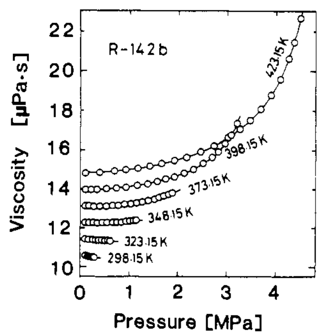

Figure 4. Viscosity vs. pressure plots for gaseous R142b.

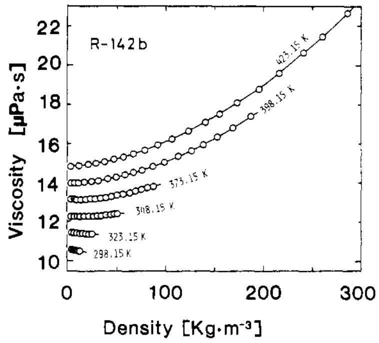

Figure 5. Viscosity vs. density plots for gaseous R142b.

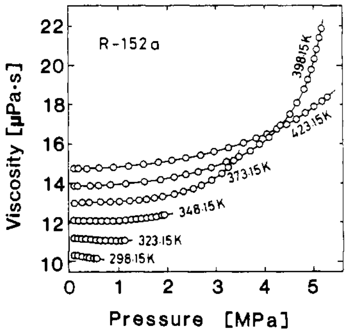

Figure 6. Viscosity vs. pressure plots for gaseous R152a.

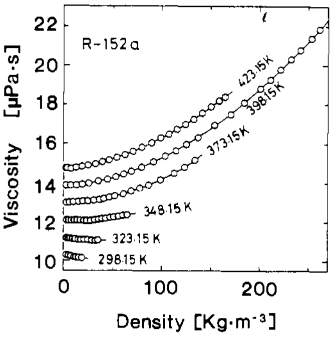

Figure 7. Viscosity vs. density plots for gaseous R152a.

The samples, the purities of which were certified to be above 99.9%, were supplied by the Daikin Kogyo Co. and used without further purification.

Results and Discussion

The viscosity values obtained in the present measurement are shown in Tables II, III, and IV, and in Figures 2-7. The

Table II. Viscosity of Gaseous Bromotrifluoromethane (R13B1)

P, MPa	ρ, kg·m^{-3}	η, μPa·s	P, MPa	ρ, kg·m^{-3}	η, μPa·s
		273.15 K			
0.1011	6.749	14.16	0.3959	27.94	14.21
0.1021	6.819	14.23	0.4971	35.85	14.19
0.2002	13.60	14.20	0.5796	42.56	14.28
0.2981	20.64	14.21	0.6960	52.91	14.25
		298.15 K			
0.1022	6.227	15.43	0.8671	59.63	15.61
0.1023	6.234	15.44	0.9628	67.34	15.69
0.1834	11.30	15.44	1.061	75.76	15.71
0.2794	17.44	15.49	1.159	84.61	15.78
0.3760	23.82	15.50	1.260	94.04	15.87
0.4746	30.50	15.49	1.356	103.4	15.95
0.5720	37.34	15.50	1.460	115.0	16.06
0.6697	44.43	15.54	1.555	125.6	16.13
0.7865	52.00	15.58			
		323.15 K			
0.1020	5.716	16.70	1.666	115.2	17.47
0.2973	17.01	16.70	1.852	132.5	17.68
0.4919	28.78	16.75	2.025	150.3	17.93
0.6909	41.41	16.83	2.176	167.4	18.15
0.8829	54.24	16.90	2.299	182.5	18.43
1.086	68.53	17.00	2.397	195.8	18.67
1.279	82.79	17.13	2.472	206.8	18.84
1.476	98.62	17.29	2.570	222.8	19.10
		348.15 K			
0.1016	5.273	17.90	2.443	163.4	19.56
0.2983	15.73	17.94	2.635	181.6	19.82
0.4883	26.20	17.98	2.797	198.4	20.18
0.6862	37.47	18.07	2.924	211.7	20.40
0.8814	49.03	18.14	3.083	230.4	20.80
1.076	61.12	18.23	3.314	260.2	21.39
1.272	73.44	18.37	3.451	280.4	21.86
1.469	86.54	18.50	3.648	312.8	22.64
1.644	99.00	18.63	3.899	364.2	24.11
1.800	110.2	18.80	4.010	392.5	24.94
1.967	123.1	18.94	4.095	417.3	25.69
2.142	137.3	19.15	4.147	434.6	26.30
2.282	149.1	19.30	4.216	459.5	27.19
		373.15 K			
0.1024	4.947	19.10	3.519	229.5	22.24
0.1018	4.918	19.09	3.750	252.2	22.72
0.3462	17.00	19.14	3.960	274.4	23.23
0.5861	29.27	19.20	4.164	296.3	23.74
0.8381	42.60	19.27	4.367	320.2	24.43
1.078	56.07	19.41	4.567	346.9	25.16
1.319	69.69	19.60	4.751	371.7	25.95
1.549	83.22	19.79	4.930	399.1	26.69
1.766	96.69	19.85	5.154	344.7	27.87
2.014	112.6	20.14	5.273	455.1	28.61
2.305	132.1	20.44	5.423	483.5	29.67
2.558	150.1	20.77	5.557	509.3	30.67
2.816	169.6	21.03	5.681	535.2	31.66
3.076	190.6	21.43	5.826	565.8	33.04
3.279	207.8	21.77			
		398.15 K			
0.1016	4.595	20.28	4.699	290.3	25.07
0.3445	15.78	20.34	5.066	323.9	25.94
0.6029	28.00	20.39	5.316	347.7	26.61
0.8779	41.40	20.52	5.608	377.3	27.53
1.276	61.52	20.74	5.859	404.0	28.33
1.659	81.91	20.94	6.133	432.0	29.32
2.051	103.7	21.26	6.363	460.5	30.40
2.387	123.4	21.61	6.533	483.4	31.28
2.697	142.5	21.90	6.639	494.6	31.62
3.184	174.2	22.46	6.791	512.8	32.36
3.509	196.4	22.83	6.849	520.3	32.63
3.788	216.9	23.30	7.004	539.2	33.41
4.13	243.3	23.89	7.119	553.6	34.04
4.448	269.1	24.48			
		423.15 K			
0.1013	4.305	21.43	5.009	272.3	25.89
0.3455	14.84	21.47	5.357	297.3	26.52
0.5977	26.00	21.56	5.650	319.0	27.11
0.9122	40.21	21.69	5.951	342.3	27.78
1.280	57.35	21.86	6.218	362.9	28.46
1.642	74.89	22.08	6.525	388.1	29.21
1.944	89.80	22.30	6.819	412.2	30.05
2.302	108.2	22.57	7.112	437.3	30.93
2.685	128.7	22.89	7.442	465.4	31.96
3.093	151.4	23.25	7.633	482.0	32.44
3.507	175.4	23.71	7.860	502.2	33.29
3.871	197.4	24.20	8.112	525.3	34.17
4.283	223.7	24.75	8.373	571.8	36.14
4.661	248.7	25.38			
		448.15 K			
0.1016	4.075	22.55	4.907	236.7	26.29
0.1022	4.099	22.53	5.209	254.3	26.72
0.4157	16.81	22.62	5.595	276.9	27.30
0.7689	31.53	22.77	5.971	299.9	27.97
1.099	45.53	22.90	6.336	322.8	28.58
1.362	57.03	23.04	6.732	348.3	29.36
1.688	71.53	23.20	7.129	374.1	30.15
2.023	86.80	23.42	7.521	400.3	30.95
2.346	101.9	23.64	7.902	426.0	31.84
2.671	117.5	23.88	8.312	454.6	32.83
3.063	136.5	24.19	8.693	480.3	33.84
3.468	157.6	24.58	9.063	506.2	34.84
3.839	177.1	24.92	9.463	534.1	35.96
4.216	197.3	25.35	9.847	561.0	37.09
4.477	211.7	25.69			

density values given in the tables were obtained by the present authors using the experimental method described previously (*10*).

Equation 1 was obtained for the present experimental viscosities at atmospheric pressure as a function of temperature.

$$\eta_1 = a_1T + a_2T^2 \qquad (1)$$

Constants in eq 1 and deviations of the experimental viscosity values from those calculated by eq 1 are shown in Table V. Deviations of the literature values for R13B1 from those calculated by eq 1 are shown in Figure 8.

Force constants of Stockmayer 12-6-3 potential were determined from the temperature dependence of the viscosities at atmospheric pressure by using the collision integral values given by Monchik et al. (*11*). Force constants and deviations of the experimental viscosity values at atmospheric pressure from the theory (*12*) are shown in Table VI.

Equation 2 was obtained for the present experimental viscosities in the whole range of pressure as a function of temperature and density. Constants in eq 2 are given in Table VII,

$$\eta = b_0 + b_1\rho + b_2\rho^2 \qquad (2)$$

$$b_0 = b_{01}T + b_{02}T^2 + b_{03}T^3 \qquad (2.1)$$

$$b_1 = b_{10} + b_{11}T + b_{12}T^2 \qquad (2.2)$$

$$b_2 = b_{20} \qquad (2.3)$$

and deviations of the present experimental viscosity values from those calculated by eq 2 are shown in Table VIII. Deviations of the literature values for R13B1 from those calculated by eq 2 are shown in Figure 9.

Table III. Viscosity of Gaseous 1-Chloro-1,1-difluoroethane (R142b)

P, MPa	ρ, kg·m^{-3}	η, μPa·s	P, MPa	ρ, kg·m^{-3}	η, μPa·s
298.15 K					
0.1027	4.290	10.56	0.2103	9.082	10.49
0.1438	6.082	10.52	0.2488	10.87	10.47
0.1788	7.647	10.51	0.2818	12.44	10.48
323.15 K					
0.1023	3.914	11.42	0.3797	15.66	11.37
0.1025	3.923	11.42	0.4425	18.44	11.35
0.1719	6.686	11.40	0.5100	21.66	11.33
0.2468	9.773	11.39	0.5723	24.76	11.35
0.3202	12.91	11.37	0.6187	27.17	11.31
348.15 K					
0.1019	3.598	12.27	0.7541	30.48	12.28
0.1025	3.619	12.25	0.8414	34.66	12.29
0.1774	6.346	12.26	0.9277	39.05	12.33
0.3537	13.07	12.24	1.014	43.61	12.34
0.4499	16.93	12.27	1.081	47.35	12.38
0.5570	21.38	12.27	1.140	50.58	12.39
0.6649	26.32	12.27			
373.15 K					
0.1019	3.349	13.12	1.027	39.32	13.22
0.1022	3.359	13.10	1.147	44.83	13.27
0.1748	5.811	13.10	1.268	50.62	13.34
0.2762	9.326	13.09	1.387	56.97	13.40
0.4012	13.81	13.10	1.512	63.71	13.47
0.5282	18.55	13.11	1.613	69.60	13.55
0.6601	23.69	13.15	1.703	75.32	13.63
0.7751	28.36	13.15	1.800	81.60	13.71
0.9011	33.80	13.20	1.855	87.82	13.79
398.15 K					
0.1017	3.128	13.95	1.744	66.94	14.51
0.1017	3.128	13.96	1.923	76.02	14.61
0.2134	6.646	13.95	2.122	87.15	14.82
0.3440	10.87	13.96	2.317	99.03	15.02
0.5255	17.01	14.01	2.516	112.9	15.33
0.7310	24.29	14.03	2.690	126.2	15.63
0.9292	31.67	14.08	2.820	138.3	15.92
1.161	40.90	14.18	2.960	152.7	16.34
1.373	49.75	14.26	3.086	168.4	16.80
1.569	58.46	14.39	3.202	187.2	17.38
423.15 K					
0.1019	2.938	14.80	3.691	173.4	18.09
0.1025	2.957	14.80	3.909	195.4	18.79
0.3961	11.77	14.85	4.091	216.0	19.60
0.6898	21.12	14.92	4.272	241.6	20.63
0.9209	28.88	14.99	4.383	260.7	21.46
1.176	37.92	15.06	4.507	286.0	22.67
1.424	47.19	15.19	4.677	333.7	25.18
1.665	56.56	15.31	4.746	358.0	26.73
1.921	67.12	15.47	4.834	396.0	29.18
2.170	78.26	15.64	4.888	421.4	30.96
2.454	91.91	15.92	4.942	447.2	32.93
2.731	106.5	16.22	5.011	480.2	35.63
3.017	123.4	16.64	5.049	495.4	36.97
3.277	140.6	17.09	5.092	511.0	38.45
3.478	155.6	17.52			

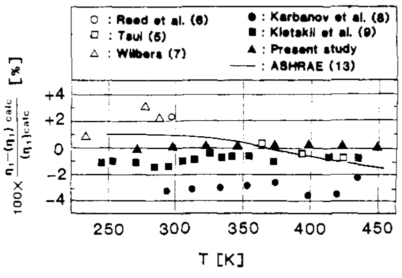

Figure 8. Deviations of the experimental viscosity values of gaseous R13B1 at atmospheric pressure from eq 1.

Table IV. Viscosity of Gaseous 1,1-Difluoroethane (R152a)

P, MPa	ρ, kg·m^{-3}	η, μPa·s	P, MPa	ρ, kg·m^{-3}	η, μPa·s
298.15 K					
0.1029	2.833	10.29	0.3420	10.26	10.19
0.1033	2.843	10.30	0.4203	12.91	10.18
0.1735	4.887	10.28	0.4949	15.65	10.15
0.2658	7.729	10.23	0.5614	18.28	10.15
323.15 K					
0.1011	2.537	11.18	0.6261	17.64	11.09
0.1014	2.545	11.17	0.7302	20.95	11.08
0.1717	4.371	11.16	0.8454	25.01	11.07
0.2477	6.404	11.14	0.9575	29.05	11.05
0.3417	9.013	11.12	1.052	32.68	11.05
0.4394	11.84	11.10	1.123	35.41	11.09
0.5400	14.93	11.09			
348.15 K					
0.1016	2.353	12.09	1.155	31.80	12.10
0.1021	2.365	12.09	1.259	35.46	12.13
0.1957	4.596	12.08	1.363	39.01	12.15
0.2969	7.085	12.07	1.468	42.99	12.18
0.4252	10.35	12.08	1.581	47.41	12.22
0.5390	13.36	12.06	1.681	51.58	12.24
0.6578	16.63	12.07	1.781	55.99	12.28
0.7818	20.18	12.06	1.857	59.67	12.33
0.8930	23.49	12.06	1.876	60.61	12.32
1.022	27.50	12.08	1.951	64.39	12.37
373.15 K					
0.1023	2.205	12.98	1.741	46.52	13.25
0.1027	2.213	12.97	1.902	52.01	13.31
0.2585	5.676	13.01	2.139	60.95	13.42
0.4426	9.941	13.00	2.326	68.59	13.57
0.6379	14.68	13.02	2.526	77.53	13.71
0.8334	19.68	13.04	2.700	86.25	13.87
1.022	24.74	13.06	2.912	98.32	14.14
1.228	30.63	13.10	3.121	112.5	14.49
1.421	36.32	13.12	3.259	123.4	14.80
1.570	40.90	13.18	3.368	134.0	15.14
398.15 K					
0.1018	2.051	13.85	3.475	103.6	15.35
0.1020	2.055	13.86	3.702	114.8	15.62
0.1696	3.389	13.85	3.895	125.4	15.97
0.3314	6.823	13.85	4.088	137.4	16.31
0.5988	12.65	13.87	4.324	154.0	16.93
0.8440	18.27	13.90	4.522	170.4	17.50
1.158	25.87	13.97	4.666	184.5	18.07
1.531	35.60	14.08	4.806	200.8	18.78
1.851	44.44	14.16	4.885	211.0	19.26
2.144	53.13	14.29	4.958	221.7	19.77
2.379	60.70	14.42	5.021	232.2	20.31
2.637	69.43	14.58	5.074	241.8	20.78
2.914	79.64	14.78	5.126	253.3	21.37
3.215	91.89	15.06	5.165	261.5	21.85
423.15 K					
0.1015	1.920	14.73	2.962	70.69	15.59
0.1018	1.925	14.74	3.261	7.99	15.79
0.1961	3.734	14.73	3.564	90.00	16.03
0.3641	7.019	14.70	3.829	99.43	16.28
0.6142	12.06	14.77	4.044	107.5	16.48
0.9108	18.29	14.81	4.252	115.7	16.72
1.211	24.91	14.87	4.452	124.2	16.98
1.520	32.06	14.95	4.644	132.8	17.23
1.819	39.34	15.07	4.832	141.6	17.56
2.085	46.18	15.15	5.012	150.5	17.88
2.387	54.14	15.28	5.175	158.9	18.17
2.686	62.53	15.41	5.282	164.9	18.38

The density values used in eq 2 are calculated conveniently by use of the following equation of state (*14*), the constants in which were determined by the present authors using the density data are given in Table II and III for R13B1 and R142b.

$$P = RT\rho + (B_0RT - A_0 - C_0/T^2 + D_0/T^3 - E_0/T^4)\rho^2 + (bRT - a - d/T - e/T^4 - f/T^{23})\rho^3 + \alpha(a - d/T + e/T^4 + f/T^{23})\rho^6 + (c/T^2 + g/T^8 + h/T^{17})\rho^3(1 + \gamma\rho^2)\exp(-\gamma\rho^2) \quad (3)$$

Table V. Constants in Eq 1 and Deviations of the Experimental Viscosity Values at Atmospheric Pressure from Those Calculated by Eq 1

	R13B1	R142b	R152a
a_1	5.47521×10^{-2}	3.63417×10^{-2}	3.38791×10^{-2}
a_2	-9.74815×10^{-6}	-3.22163×10^{-6}	2.32458×10^{-6}
T range, K	273.15–423.15	298.15–423.15	298.15–423.15
n^a	8	6	6
devn^b			
av	0.12	0.04	0.11
bias	+0.03	+0.03	−0.03
max	0.20	0.11	0.19

$^a n$ = number of data. ^{b}Deviation, av = $100\sum\{|\eta_{\text{exptl}} - \eta_{\text{calcd}}|/\eta_{\text{calcd}}\}/n$. Deviation, bias = $100\sum\{(\eta_{\text{exptl}} - \eta_{\text{calcd}})/\eta_{\text{calcd}}\}/n$. Deviation, max = maximum of $100|\eta_{\text{expt6}} - \eta_{\text{calcd}}|/\eta_{\text{calcd}}$.

Table VI. Force constants of Stockmayer 12-6-3 Potential and Deviations of the Experimental Viscosity Values at Atmospheric Pressure from the Theory (*12*)

	R13B1	R142b	R152a
ϵ/k, K	235	362	312
σ, nm	0.506	0.499	0.463
δ	0.058	0.36	0.62
n^a	8	6	6
devn,^{b} %			
av	0.12	0.33	0.44
bias	−0.02	+0.01	+0.02
max	0.24	0.73	0.77

$^a n$ = number of data. ^{b}Definition of deviations is the same as in Table V.

Table VII. Constants in Eq 2

	R13B1	R142b	R152a
b_{01}	5.50785×10^{-2}	4.20227×10^{-2}	3.46108×10^{-2}
b_{02}	-1.11377×10^{-5}	-3.33786×10^{-5}	3.25497×10^{-7}
b_{03}	0	3.93484×10^{-8}	0
b_{10}	-3.49981×10^{-2}	-7.50116×10^{-2}	-2.47301×10^{-1}
b_{11}	1.74849×10^{-4}	3.16220×10^{-4}	1.19717×10^{-3}
b_{12}	-1.74610×10^{-7}	-3.00990×10^{-7}	-1.41875×10^{-6}
b_{20}	3.52934×10^{-5}	7.99536×10^{-5}	1.01762×10^{-4}

Table VIII. Deviations of the Experimental Viscosity Values from Those Calculated by Eq 2

temp, K	P range, MPa	ρ range, kg·m^{-3}	n^a	devn,^{b} % av	bias	max
		R13B1				
273.15	0.7	53	8	0.22	−0.16	0.38
298.15	1.55	126	17	0.17	−0.15	0.29
323.15	2.57	223	16	0.10	+0.02	0.21
348.15	4.22	460	26	0.09	+0.05	0.27
373.15	5.83	566	29	0.18	+0.08	0.36
398.15	7.12	554	27	0.12	+0.06	0.41
423.15	8.62	572	28	0.13	−0.03	0.39
448.15	9.85	561	29	0.11	+0.03	0.31
		R142b				
298.15	0.28	12	6	0.41	−0.41	0.60
323.15	0.62	27	10	0.16	−0.10	0.49
348.15	1.14	51	13	0.10	+0.10	0.24
373.15	1.89	88	18	0.09	+0.00	0.29
398.15	3.20	187	20	0.15	−0.04	0.39
423.15	5.09	511	29	0.17	−0.07	0.62
		R152a				
298.15	0.56	18	8	0.20	+0.16	0.68
323.15	1.12	35	13	0.17	−0.10	0.43
348.15	1.95	64	20	0.09	+0.00	0.23
373.15	3.37	134	20	0.17	+0.03	0.67
398.15	5.17	262	28	0.28	−0.26	0.34
423.15	5.28	165	24	0.19	−0.09	0.42

$^a n$ = number of data. ^{b}Definition of deviations is the same as in Table V.

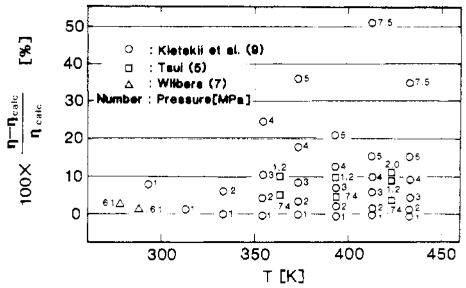

Figure 9. Deviations of the literature viscosity values of R13B1 from eq 2.

Table IX. Constants in Eq 3

	R13B1	R142b
A_0	2.2767733	5.1911889
B_0	3.6079451×10^{-2}	1.0857300×10^{-1}
C_0	1.0169748×10^{6}	1.8166956×10^{6}
D_0	1.4895405×10^{8}	1.7744227×10^{8}
E_0	8.6656266×10^{9}	5.9726111×10^{9}
a	1.4029387	2.3033661
b	2.9431270×10^{-2}	3.2457400×10^{-2}
c	9.5090836×10^{4}	2.7865687×10^{5}
d	-1.3073586×10^{2}	-2.4298043×10^{2}
e	2.8918960×10^{8}	3.8007168×10^{8}
f	1.0115291×10^{38}	$-4.5621683 \times 10^{48}$
g	$-3.3200057 \times 10^{14}$	$-6.8531196 \times 10^{16}$
h	$-2.3494151 \times 10^{31}$	$-7.6400906 \times 10^{33}$
α	4.5958429×10^{-4}	7.4438000×10^{-4}
γ	2.1169121×10^{-2}	2.5041108×10^{-2}

Table X. Deviations of the Experimental Density Values from Those Calculated by Eq 3

temp, K	P range, MPa	ρ range, kg·m^{-3}	n^a	devn,^{b} % av	bias	max
		R13B1				
273.15	0.7	53	8	0.56	−0.56	1.12
298.15	1.55	126	17	0.57	−0.57	1.41
323.15	2.57	223	16	0.55	−0.55	1.01
348.15	4.22	460	26	0.59	−0.56	2.00
373.15	5.83	566	29	0.30	−0.18	0.88
398.15	7.12	554	27	0.16	−0.11	0.46
423.15	8.62	572	28	0.22	+0.22	0.42
448.15	9.85	561	29	0.25	+0.20	0.57
		R142b				
298.15	0.28	12	6	0.13	−0.13	0.37
323.15	0.62	27	10	0.17	+0.17	0.81
348.15	1.14	51	13	0.38	+0.30	1.45
373.15	1.89	88	18	0.75	+0.75	1.56
398.15	3.20	187	20	0.94	+0.80	1.72
423.15	5.09	511	29	1.85	+1.38	5.51

$^a n$ = number of data. ^{b}Deviation, av = $100\sum\{|\rho_{\text{exptl}} - \rho_{\text{calcd}}|/\eta_{\text{calcd}}\}/n$. Deviation, bias = $100\sum\{(\eta_{\text{exptl}} - \eta_{\text{calcd}})/\eta_{\text{calcd}}\}/n$. Deviation, max = maximum of $100|\eta_{\text{exptl}} - \eta_{\text{calcd}}|/\eta_{\text{calcd}}$.

The units of P, T, and ρ in eq 3 are atm, K, and mol·L^{-1}, respectively. Constants in eq 3 are given in Table IX, and deviations of the experimental density values from those calculated by eq 3 are shown in Table X. The equation of state for R152a has not been obtained. Therefore, the density of R152a should be interpolated by using the density data given in Table IV.

Glossary

A_0, B_0, C_0, D_0, E_0	constants in eq 3
P	pressure, MPa or atm
R	gas constant (=0.0820568 L·atm·K^{-1}·mol^{-1})
T	temperature, K
a	constant in eq 3
a_i	constant in eq 1 (i = 1, 2)
b	constant in eq 3

b_i	constants in eq 2 (i = 0, 1, 2)
b_{0i}	constants in eq 2.1 (i = 1, 2, 3)
b_{1i}	constants in eq 2.2 (i = 0, 1, 2)
b_{20}	constant in eq 2.3
c, d, e, f, g, h	constants in eq 3
k	Boltzmann constant (=1.380622 × 10^{-23} J·K^{-1})
α, γ	constants in eq 3
δ	force constant of Stockmayer 12-6-3 potential
ϵ	force constant of Stockmayer 12-6-3 potential, J
η	viscosity, μPa·s
η_1	viscosity at atmospheric pressure, μPa·s
ρ	density, kg·m^{-3}
σ	force constant of Stockmayer 12-6-3 potential, nm

Registry No. R13B1, 75-63-8; R142B, 75-68-3; R152A, 75-37-6.

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Infinite-Dilution Activity Coefficients for Alkanals, Alkanoates, Alkanes, and Alkanones in 4-Methyl-2-pentanone

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Infinite-dilution activity coefficients are determined in a gas–liquid partition chromatograph for three alkanals, two alkanoates, four alkanes, and three alkanones in 4-methyl-2-pentanone (MIBK) as the stationary phase. The three temperatures observed are 55, 75, and 115 °C with column operating pressures up to 7.0 atm. The measured values are compared to those from two group contribution methods.

Activity coefficients are a fundamental thermodynamic property of liquid mixtures. They provide a measure of the deviation from ideality of a component's behavior in a mixture. Activity coefficients at infinite dilution (γ_A^∞) are important because solution effects are usually at a maximum at infinite dilution. Data are reported in this work for 12 solutes in the stationary phase 4-methyl-2-pentanone (MIBK) at 55, 75, and 115 °C, with the column pressures from 4.5 to 7.0 atm. The solutes are alkanals, alkanoates, alkanes, and alkanones. Additionally benzene is studied for comparison with literature values.

The experimental apparatus, procedure, and data reduction have been described (*1–3*). The chemicals used are presented in Table I. To check our experiment at the two higher temperatures of interest, we determined data in the solvent of this work for comparison with data in the literature. Table II shows that the present result is practically identical with the literature value for the first and last points. The divergence of the second point seems not excessive in view of the extrapolation that has to be made on the literature data.

Table I. Chemicals Used in Experimental Work

compound	source	purity
helium	Airco (purified, Grade 4.5)	99.995
argon	Airco (prepurified, Grade 4.8)	99.998
n-propanal	Fluka AG, Buchs SG	>99%
n-butanal	Eastman	research grade
n-pentanal	Aldrich	99%
ethyl ethanoate	Fluka AG, Buchs SG	spectrophotometric grade
ethyl propanoate	Fluka AG, Buchs SG	>99%
n-hexane	Aldrich	spectrophotometric grade
n-heptane	Aldrich	99+%
2,2,4-trimethylpentane	Fluka AG, Buchs SG	spectrophotometric grade
n-octane	Phillips	99.5% by GC
2-propanone	Fisher	99.5%
2-butanone	Baker	99.8%
2-pentanone	Aldrich	97%
4-methyl-2-pentanone (MIBK)	Aldrich	99.5%
benzene	Mallinckrodt	spectrophotometric grade

Each of Tables III, IV, and V presents the new results at one temperature of this work. For each solute we show V_g^∞, K_A^∞, P_A^0, ϕ_A^0, Poynting term, ϕ_A, and finally γ_A^∞. The specific retention volume, V_g, is defined as the volume of gas, measured at the column temperature and pressure, needed to elute one-half of the solute from a GLPC column containing 1 g of the liquid stationary phase. This definition assumes that the peaks are symmetrical. The K value is $K_A = y_A/x_A$, where y_A and x_A are the mole fractions of the solute A in the vapor and

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