Gaseous Viscosity Measurement for Several Refrigerant Mixtures

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An oscillating-disk viscometer was used to measure the gaseous viscosities of several kinds of refrigerant mixtures, which were 1,1-difluoroethane (HFC152a) + chlorodifluoromethane (HCFC22), perfluoropropane (HFC218) + propane (HC290) + chlorodifluoromethane (HCFC22), and 1,1,1,2-tetrafluoroethane (HFC134a) + perfluoropropane (HFC218) + isobutene (HC600a). To check the reliability and uncertainty of the viscometer, the gaseous viscosities of HCFC22 were measured. The deviations between the experimental data and the literature data were less than 3%. The gaseous viscosities of these mixtures were measured at the temperature 297−370 K and at pressures up to 2.14 MPa. The experimental results, the equations, and the curves for the gaseous viscosities of the mixtures are all presented.

Introduction

An oscillating-disk viscometer can be used to measure the viscosities of gases and liquids with high accuracy. By now, there are several sets of equipment of this kind reported, which are respectively at Brown University[1] and Maryland University[2] in the United States, Tuhoko University[3] in Japan, University of Trondheim[4] in Norway, and Xi'an Jiaotong University[5] in China. The two pieces of equipment in the United States and Norway adopt Pt−W alloy as the torsion wire and are used to measure liquid viscosity. The Japanese piece of equipment adopts quartz crystal as the torsion wire and is used to measure the gaseous viscosity. The one at Xi'an Jiaotong University is used to measure the gaseous viscosity and adopts Ti−Ni alloy as the torsion wire.

The oscillating-disk viscometers can have lower uncertainties; at room temperature, they can reached 0.19% for liquid viscosity and 1−2% for gaseous viscosity. The experimental set of this work has the maximum uncertainty of 3% at experimental temperatures and pressures.

The gaseous viscosities of HFC152a + HCFC22 (15 mass % and 25 mass % HCFC22), HFC218 (39 mass %) + HC290 (5 mass %) + HCFC22 (56 mass %), and HFC134a (86 mass %) + HFC218 (9 mass %) + HC600a (5 mass %) were measured with the oscillating-disk viscometer at different temperatures and pressures.

Sample Purity

According to the manufacturer's materials, the purities of the HFC152a and HCFC22 are 99.9%, and the purities of the HFC218, HC290, HFC134a, and HC600a are 99.5%. We did not purify and analyze the samples.

Experimental Apparatus

The structure diagram of the oscillating-disk viscometer is shown in Figure 1, where 1 is the Ti−Ni alloy torsion wire, 2 is the fixed disk, which is used to prevent vertical flow caused by a temperature difference, 3 is the glass, 4 is the mirror, which is used to reflect the laser coming from the outside, 5 is the bearing, and 6 is the oscillating disk.

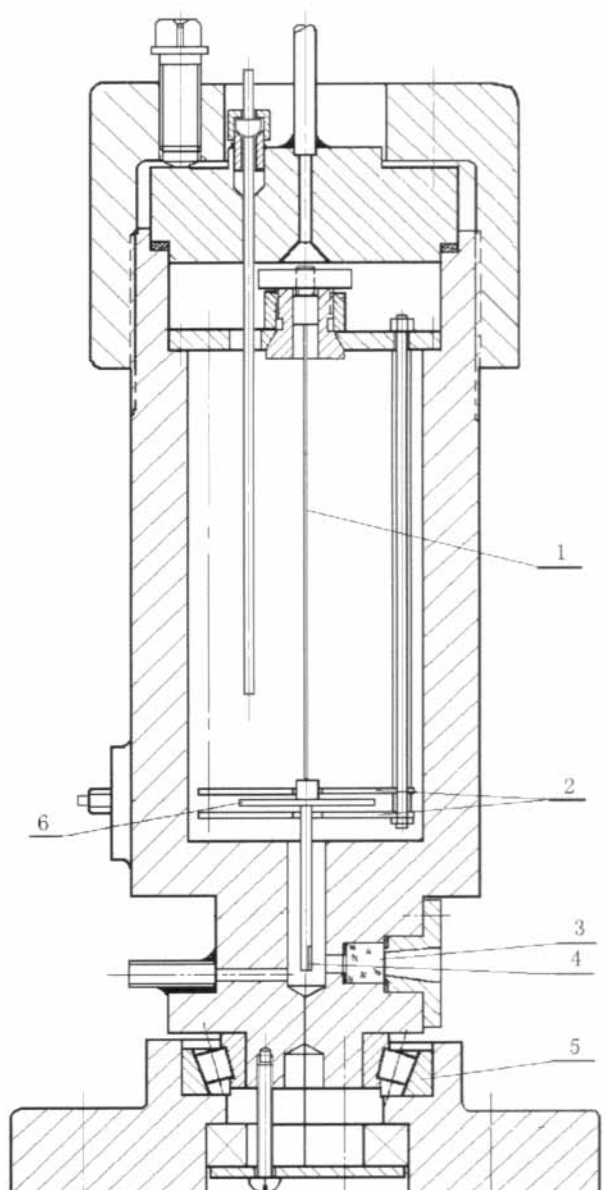

Figure 1. Diagram of the oscillating-disk viscometer.

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Table 1. Comparison for HCFC22 between This Work and Reference Data[9,10]

T	P	ρ	η(this work)	η(ref 10)	η(ref 9)
Kr	MPa	kg·m^{-3}	μPa·S	μPa·S	μPa·S
295.96	0.681	26.79	12.56	12.76	12.82
297.06	0.097	3.43	12.47	12.52	12.66
315.47	1.137	44.25	14.13	13.88	13.95
316.02	0.572	20.29	13.68	13.52	13.59
315.22	0.097	3.24	13.28	13.25	13.27
332.91	1.596	61.37	14.93	15.06	15.35
334.18	1.076	38.02	14.68	14.77	14.99
333.77	0.571	18.96	14.41	14.43	14.78
332.61	0.097	3.05	14.19	14.05	14.19
353.66	2.122	78.82	16.19	16.27	16.43
353.58	1.622	56.36	16.05	15.76	15.90
353.56	1.112	36.42	15.14	15.35	15.50
354.34	0.546	16.85	14.92	15.03	15.19
353.60	0.096	2.86	14.58	14.78	14.98
373.05	2.202	72.80	16.92	17.06	17.25
373.26	1.652	52.00	16.60	16.55	16.72
372.92	1.086	32.58	16.05	16.12	16.33
373.11	0.631	15.25	15.88	15.81	15.92
372.86	0.098	2.75	15.32	15.55	15.76

Table 2. Gaseous Viscosity of HFC152a + HCFC22 (15 mass % HCFC22)

T	P	ρ	η	T	P	ρ	η
K	MPa	kg·m^{-3}	μPa·S	K	MPa	kg·m^{-3}	μPa·S
297.87	0.324	9.517	10.583	345.96	1.274	36.293	12.966
297.89	0.324	9.517	10.535	345.91	1.274	36.293	12.975
297.87	0.324	9.517	10.568	344.80	1.099	30.567	12.769
298.14	0.099	2.771	10.429	344.78	1.099	30.567	12.776
298.11	0.099	2.771	10.338	344.84	0.849	22.694	12.514
308.29	0.583	17.340	11.140	344.88	0.849	22.694	12.580
308.25	0.583	17.340	11.059	345.14	0.599	15.428	12.362
307.70	0.348	9.903	10.801	345.98	0.348	8.649	12.279
307.77	0.348	9.903	10.880	346.02	0.348	8.649	12.216
307.16	0.098	2.656	10.774	345.65	0.098	2.364	12.198
307.19	0.098	2.656	10.646	345.62	0.098	2.364	12.133
314.82	0.822	25.004	11.3287	356.54	1.648	47.490	13.562
314.94	0.597	17.325	11.278	356.55	1.648	47.490	13.546
314.97	0.597	17.325	11.233	356.56	1.648	47.490	13.516
315.18	0.347	9.614	11.177	356.70	1.349	36.941	13.268
315.16	0.347	9.614	11.107	356.71	1.348	36.941	13.167
315.12	0.097	2.588	11.078	357.83	1.098	28.852	13.107
315.14	0.097	2.588	11.099	357.80	1.098	28.852	13.139
327.20	0.923	27.004	11.891	357.82	0.848	21.551	12.851
327.18	0.923	27.004	11.803	355.97	0.598	14.816	12.689
327.25	0.597	16.464	11.666	356.03	0.598	14.816	12.746
327.28	0.597	16.464	11.749	358.38	0.348	8.307	12.494
327.47	0.347	9.189	11.663	358.36	0.348	8.307	12.559
327.50	0.347	9.189	11.633	358.78	0.098	2.271	12.377
327.34	0.097	2.479	11.483	358.83	0.098	2.271	12.304
327.40	0.097	2.479	11.569	363.66	1.698	47.505	13.798
337.96	1.148	33.294	12.427	364.43	1.348	35.762	13.328
337.98	1.148	33.294	12.491	365.34	1.098	27.991	13.287
338.01	0.848	23.333	12.322	365.30	1.098	27.991	13.264
338.09	0.848	23.333	12.334	365.54	0.848	20.955	12.991
338.14	0.598	15.824	12.154	365.66	0.598	14.345	12.873
338.22	0.598	15.824	12.188	365.62	0.598	14.345	12.882
338.92	0.349	8.873	12.089	366.86	0.347	8.072	12.763
338.72	0.099	2.430	11.891	366.05	0.097	2.203	12.499
338.71	0.099	2.430	12.049	365.99	0.097	2.203	12.553

In this equipment, the Ti–Ni alloy torsion wire and oscillating disk are key elements.

The reflected laser is received by two fixed photodetectors and is converted to digital signals by a set of instruments. From the signals, the period and logarithm decrement (that is attenuation rate) can be obtained. The viscosities can be derived from the period and attenuation rate.

The measurement theory is illustrated in several papers.[1,5–7] The relative measurement method is used in this work; the imaginary part of the governing equation is used to determine the viscosity on condition that the density of the fluid had been known.[8]

Table 3. Gaseous Viscosity of HFC152a + HCFC22 (25 mass % HCFC22)

T	P	ρ	η	T	P	ρ	η
K	MPa	kg·m^{-3}	μPa·S	K	MPa	kg·m^{-3}	μPa·S
300.81	0.447	13.665	11.019	347.63	0.598	15.627	12.612
301.22	0.097	2.777	10.845	347.66	0.598	15.627	12.623
312.13	0.598	17.957	11.428	347.65	0.348	8.812	12.568
312.14	0.598	17.957	11.418	347.74	0.348	8.812	12.625
312.14	0.598	17.957	11.365	347.78	0.348	8.812	12.538
312.05	0.348	9.980	11.284	347.81	0.348	8.812	12.551
312.09	0.348	9.980	11.317	348.63	0.098	2.403	12.471
312.19	0.348	9.980	11.348	348.73	0.098	2.403	12.437
312.60	0.098	2.696	11.292	348.88	0.098	2.403	12.547
312.66	0.098	2.696	11.171	355.06	1.598	46.928	13.592
320.46	0.884	27.053	11.864	355.14	1.598	46.928	13.533
320.48	0.884	27.053	11.844	358.38	1.374	38.290	13.433
320.77	0.599	17.334	11.766	358.31	1.374	38.290	13.490
321.16	0.349	9.666	11.690	358.17	1.099	29.477	13.321
321.29	0.099	2.636	11.600	358.23	1.099	29.477	13.368
321.28	0.099	2.636	11.541	358.32	1.099	29.477	13.227
321.27	0.099	2.636	11.629	358.41	0.849	22.016	13.064
331.55	1.174	36.047	12.429	358.53	0.849	22.016	13.142
331.53	1.174	36.047	12.334	356.32	0.599	15.183	12.874
331.59	0.849	24.516	12.260	356.31	0.599	15.183	12.975
331.62	0.849	24.516	12.279	356.29	0.349	8.595	12.797
331.66	0.849	24.516	12.296	356.48	0.099	2.372	12.685
333.97	0.599	16.443	12.203	363.63	1.924	56.948	14.297
334.00	0.599	16.443	12.181	363.55	1.924	56.948	14.183
333.99	0.349	9.231	12.028	363.53	1.924	56.948	14.188
334.02	0.349	9.231	12.069	363.51	1.599	44.961	13.850
334.06	0.349	9.231	12.078	363.68	1.599	44.961	13.862
334.09	0.349	9.231	12.040	367.82	1.323	35.128	13.681
333.99	0.099	2.524	11.825	367.85	1.323	35.128	13.709
334.11	0.099	2.524	11.907	367.80	1.098	28.349	13.523
334.16	0.099	2.524	11.950	367.82	1.098	28.349	13.612
334.18	0.099	2.524	11.921	369.23	0.824	20.486	13.525
345.97	1.374	40.676	13.327	369.34	0.824	20.486	13.616
345.94	1.374	40.676	13.314	369.44	0.599	14.522	13.499
345.74	1.073	30.235	12.912	369.48	0.599	14.522	13.384
347.91	0.848	22.903	12.836	369.53	0.599	14.522	13.438
347.94	0.848	22.903	12.814	369.58	0.349	8.241	13.312
347.87	0.848	22.903	12.742	369.66	0.349	8.241	13.353
347.77	0.848	22.903	12.748	369.75	0.349	8.241	13.292
347.61	0.598	15.627	12.625	369.64	0.099	2.278	13.244
347.62	0.598	15.627	12.640	369.72	0.099	2.278	13.275

Results and Discussion

Before measurements, the instrumental constants, the period, and the logarithm decrement in a vacuum state were measured. The corrections of working equations were derived by measuring the gaseous viscosity of nitrogen (purity 99.999%) and comparing with the reference data.[9] Then the viscosities of HCFC22 were measured at the temperature 296–373 K (ITS-90) and at pressures up to 2.2 MPa. The results are compared with the reference data of Vargaftik[9] and Hongo et al.[10] to check the reliability and uncertainty of the equipment; the deviations are 3%. The detailed comparison is shown in Table 1.

The gaseous viscosities of the mixtures are measured. Those of HFC152a + HCFC22 are measured at the temperature 297–370 K and at pressures up to 1.9 MPa; those of HFC218 + HC290 + HCFC22 are measured at the temperature 303–363 K and at pressures up to 2.14 MPa; and those of HFC134a + HFC218 + HC600a are measured at the temperature 305–363 K and at pressures up to 1.82 MPa.

All the experimental results are listed in Tables 2–5, where the densities are calculated with the P–R equation.

On the basis of the experimental results, the equations of gaseous viscosity of the mixtures are correlated in the

Table 4. Gaseous Viscosity of HFC218 + HC290 + HCFC22

T/K	P/MPa	ρ/kg·m^{-3}	η/μPa·S	T/K	P/MPa	ρ/kg·m^{-3}	η/μPa·S
303.88	1.131	57.118	13.3619	342.56	1.921	90.235	15.6005
303.84	1.131	57.118	13.3274	344.74	1.321	55.628	15.1175
303.74	1.126	56.844	13.3165	344.50	1.321	55.628	15.1022
303.41	0.821	38.769	13.0751	344.24	1.071	43.713	14.6685
303.40	0.821	38.769	12.9542	344.16	1.071	43.713	14.6440
303.38	0.821	38.769	12.9827	343.96	1.071	43.713	14.6325
302.85	0.631	28.765	12.8568	343.55	0.821	32.550	14.5327
302.78	0.631	28.765	12.8585	343.51	0.821	32.550	14.4297
306.84	0.321	13.646	12.6825	342.58	0.571	22.053	14.3244
302.31	0.096	4.011	12.3721	342.53	0.571	22.053	14.3663
302.33	0.096	4.011	12.3787	342.49	0.571	22.053	14.3472
302.35	0.096	4.011	12.3053	341.37	0.321	12.060	14.2930
311.70	1.346	68.203	13.7903	340.71	0.321	12.060	14.2386
311.69	1.346	68.203	13.7865	344.84	0.096	3.497	14.1977
311.71	1.346	68.203	13.7585	354.99	2.141	96.464	16.3447
311.44	1.071	51.082	13.5838	354.84	2.131	95.948	16.3435
311.56	1.071	51.082	13.6331	354.73	2.131	95.948	16.3034
311.67	1.071	51.082	13.6170	354.58	2.126	95.801	16.3257
311.72	1.071	51.082	13.5950	354.06	1.846	79.986	16.2164
313.20	0.821	36.966	13.3621	354.00	1.846	79.986	16.2123
313.25	0.821	36.966	13.3971	353.94	1.846	79.986	16.2086
314.24	0.571	24.516	13.2952	353.86	1.846	79.986	16.2318
314.13	0.571	24.516	13.2372	352.78	1.596	67.218	15.9835
314.03	0.571	24.516	13.3254	352.82	1.596	67.218	15.9857
313.53	0.321	13.301	13.0950	352.73	1.596	67.218	15.9500
313.56	0.321	13.301	13.0071	352.54	1.346	54.910	15.5993
314.53	0.096	3.839	12.9438	352.50	1.346	54.910	15.5867
314.41	0.096	3.839	12.9283	352.53	1.346	54.910	15.5875
323.94	1.571	77.439	14.4747	352.44	1.096	43.374	15.1884
323.90	1.571	77.439	14.4434	352.46	1.096	43.374	15.1781
323.65	1.321	61.950	14.2074	352.53	1.096	43.374	15.1921
323.64	1.321	61.950	14.3333	352.99	0.846	32.471	15.0391
323.45	1.071	48.033	14.0530	352.82	0.846	32.471	14.8923
323.46	1.071	48.033	13.9989	352.66	0.846	32.471	14.9572
323.11	0.821	35.370	13.7392	352.60	0.846	32.471	14.9798
323.77	0.571	23.634	13.6548	352.42	0.596	22.307	14.7390
323.82	0.571	23.634	13.6278	352.50	0.596	22.307	14.7303
323.22	0.321	12.862	13.4961	352.54	0.596	22.307	14.7483
323.18	0.321	12.862	13.3709	353.58	0.096	3.400	14.4990
322.88	0.096	3.746	13.3003	353.60	0.096	3.400	14.4303
322.91	0.096	3.746	13.3215	362.90	2.126	91.301	16.8339
333.86	1.696	80.555	15.0258	363.18	1.846	76.346	16.4314
333.87	1.691	80.233	15.0147	362.99	1.846	76.346	16.4698
333.84	1.691	80.233	15.0339	363.40	1.596	63.874	16.0311
333.49	1.321	58.794	14.7895	363.18	1.596	63.874	16.0047
333.51	1.321	58.794	14.7767	363.17	1.596	63.874	16.0474
333.46	1.321	58.794	14.7450	363.19	1.346	52.483	15.6497
333.45	1.321	58.794	14.7659	363.31	1.346	52.483	15.6688
335.64	1.071	45.371	14.2681	363.33	1.346	52.483	15.6519
335.51	1.071	45.371	14.3051	363.32	1.346	52.483	15.6681
335.34	1.071	45.371	14.2523	363.19	1.096	41.598	15.4680
334.97	0.821	33.667	14.2340	363.24	1.096	41.598	15.4649
334.35	0.571	22.699	14.0381	363.21	1.096	41.598	15.4319
334.36	0.571	22.699	14.0501	363.16	1.096	41.598	15.4601
334.33	0.571	22.699	14.0649	362.76	0.846	31.347	15.0832
334.30	0.571	22.699	14.0874	362.80	0.596	21.538	15.0436
334.07	0.321	12.382	13.8305	362.82	0.596	21.538	15.0269
334.10	0.321	12.382	13.7806	362.77	0.596	21.538	15.0343
334.09	0.321	12.382	13.7905	362.61	0.346	12.219	14.8192
334.06	0.321	12.382	13.7733	362.69	0.346	12.219	14.8616
335.48	0.096	3.585	13.6455	362.74	0.346	12.219	14.8408
342.34	1.921	90.235	15.6044	362.76	0.346	12.219	14.8369
342.40	1.921	90.235	15.5929	362.76	0.096	3.311	14.5869
342.46	1.921	90.235	15.6241	362.83	0.096	3.311	14.6040

following form. The parameters are listed in Table 6.

$$\eta = A_0 + A_1\rho + A_2\rho^2 + A_3\rho^3 \quad (1)$$

$$A_0 = A_{00} + A_{01}T + A_{02}T^2 + A_{03}T^3 \quad (1a)$$

$$A_1 = A_{10} + A_{11}T + A_{12}T^2 + A_{13}T^3 \quad (1b)$$

$$A_2 = A_{20} + A_{21}T + A_{22}T^2 + A_{23}T^3 \quad (1c)$$

$$A_3 = A_{30} + A_{31}T \quad (1d)$$

Table 5. Gaseous Viscosity of HFC134a + HFC218 + HC600a

T/K	P/MPa	ρ/kg·m^{-3}	η/μPa·S	T/K	P/MPa	ρ/kg·m^{-3}	η/μPa·S
305.59	0.691	32.077	12.6396	343.41	1.347	59.239	14.6618
305.45	0.686	31.828	12.5374	343.31	1.347	59.239	14.6046
305.40	0.686	31.828	12.4290	343.27	1.347	59.239	14.6522
304.87	0.346	14.924	12.3445	343.02	1.097	46.162	14.2739
304.84	0.346	14.924	12.3373	343.04	1.097	46.162	14.3066
304.81	0.346	14.924	12.3203	343.08	0.847	34.259	14.1260
303.83	0.096	3.958	12.0164	343.13	0.847	34.259	14.1724
303.79	0.096	3.958	12.0142	344.66	0.597	23.058	14.0581
303.75	0.096	3.958	12.0077	344.54	0.597	23.058	14.0359
315.33	0.926	43.296	12.9823	342.85	0.347	13.031	13.7737
314.63	0.596	25.977	12.7175	342.76	0.347	13.031	13.7469
314.58	0.596	25.977	12.6136	342.77	0.347	13.031	13.7341
314.26	0.346	14.391	12.5407	342.72	0.097	3.527	13.6998
314.20	0.346	14.391	12.5564	342.65	0.097	3.527	13.6799
313.98	0.096	3.832	12.4020	351.88	1.642	72.878	15.3348
314.03	0.096	3.832	12.4205	351.98	1.642	72.878	15.3427
314.04	0.096	3.832	12.4267	352.02	1.642	72.878	15.3484
325.07	1.092	50.328	13.5976	352.38	1.347	56.594	15.0801
324.98	1.087	50.064	13.5820	352.48	1.347	56.594	15.1112
324.85	1.087	50.064	13.4940	352.65	1.097	44.207	14.7200
324.44	0.847	37.137	13.3587	352.69	1.097	44.207	14.8322
324.36	0.847	37.137	13.2688	352.80	1.097	44.207	14.7190
324.01	0.597	24.982	13.1824	353.80	0.847	32.733	14.4568
324.09	0.597	24.982	13.1598	353.42	0.847	32.733	14.4725
324.07	0.597	24.982	13.1510	353.77	0.597	22.300	14.3419
323.82	0.347	13.911	12.9586	353.63	0.597	22.300	14.3800
323.90	0.347	13.911	12.9733	353.35	0.347	12.572	14.0786
323.66	0.097	3.732	12.9156	353.13	0.347	12.572	14.0610
323.71	0.096	3.732	12.9150	355.56	0.097	3.388	14.0204
334.97	1.312	60.061	14.2834	355.44	0.097	3.388	14.0116
334.66	1.312	60.061	14.2591	355.29	0.097	3.388	14.0232
335.02	1.097	47.985	14.0402	362.94	1.822	78.306	15.8518
334.96	1.097	47.985	13.9738	362.83	1.822	78.306	15.7824
334.93	1.097	47.985	14.0163	362.82	1.822	78.306	15.9038
334.59	0.827	34.473	13.7033	362.70	1.597	66.264	15.5351
334.56	0.827	34.473	13.6847	362.73	1.597	66.264	15.4808
334.54	0.827	34.473	13.6888	363.57	1.347	53.592	15.3477
335.17	0.597	23.890	13.6520	363.30	1.347	53.592	15.2977
334.73	0.347	13.400	13.4116	362.48	1.097	42.379	14.9486
334.66	0.347	13.400	13.4282	362.57	1.097	42.379	14.8953
334.60	0.347	13.400	13.4043	364.28	0.847	31.460	14.8698
333.85	0.097	3.617	13.3362	363.51	0.847	31.460	14.7974
333.86	0.097	3.617	13.3129	363.28	0.347	12.189	14.4263
333.83	0.097	3.617	13.3568	363.29	0.347	12.189	14.4166
343.70	1.562	71.689	14.8240	363.10	0.347	12.189	14.3996
343.63	1.562	71.689	14.8042	363.09	0.347	12.189	14.3994
343.57	1.562	71.689	14.8479	363.14	0.097	3.311	14.2569
343.54	1.562	71.689	14.8157	363.42	0.097	3.311	14.3377

The correlation deviations are within 2%. The curves of viscosities versus pressure and temperature are shown in Figures 2−5, respectively.

Nagaoka et al.[11] measured the gaseous viscosity of HFC152a + HCFC22 at 298−323 K and 0.1 MPa with the rolling-ball viscometer. The data calculated with eq 1 at 0.1 MPa are compared with the experimental results of Nagaoka et al.;[11] the detailed results are shown in Table 7. From the table it can be seen that the results are in good agreement.

Conclusion

An oscillating-disk viscometer was built and was used to measure the gaseous viscosity. The instrumental constants of the equipment and the correction of the working equations were derived. The measurement deviations were 3%, which were derived by measuring the gaseous viscosity of HCFC22. The gaseous viscosities of HFC152a + HCFC22 were measured from 297 to 370 K and up to 1.9 MPa. The

Table 6. Parameters of Eq 1 for 85 mass % HFC152a + 15 mass % HCFC22, 75 mass % HFC152a + 25 mass % HCFC22, HFC218 + HC290 + HCFC22, and HFC134a + HFC218 + HC600a

	85 mass % HFC152a + 15 mass % HCFC22	75 mass % HFC152a + 25 mass % HCFC22	HFC218 + HC290 + HCFC22	HFC134a + HFC218 + HC600a
A_{00}	5.350 705 96	$-0.105\,411\,065 \times 10^{3}$	$-0.524\,020\,723 \times 10^{2}$	$+0.314\,993\,599 \times 10^{2}$
A_{01}	$-0.119\,231\,056$	0.966 952 790	+0.445 129 074	$-0.321\,482\,297$
A_{02}	$0.793\,884\,783 \times 10^{-3}$	$-0.273\,410\,408 \times 10^{-2}$	$-0.100\,187\,128 \times 10^{-2}$	$+0.131\,796\,069 \times 10^{-2}$
A_{03}	$-0.113\,528\,447 \times 10^{-5}$	$0.266\,802\,679 \times 10^{-5}$	$+0.785\,322\,104 \times 10^{-6}$	$-0.155\,239\,813 \times 10^{-5}$
A_{10}	$0.210\,027\,431 \times 10^{2}$	$0.144\,456\,878 \times 10^{2}$	+8.119 519 94	$+0.188\,265\,578 \times 10^{2}$
A_{11}	$-0.180\,610\,339$	$-0.120\,702\,416$	$-0.071\,231\,915\,5$	$-0.164\,268\,590$
A_{12}	$0.513\,599\,277 \times 10^{-3}$	$0.334\,417\,792 \times 10^{-3}$	$+0.208\,273\,377 \times 10^{-3}$	$+0.476\,418\,260 \times 10^{-3}$
A_{13}	$-0.482\,485\,658 \times 10^{-6}$	$-0.306\,894\,655 \times 10^{-6}$	$-0.202\,909\,530 \times 10^{-6}$	$-0.459\,127\,077 \times 10^{-6}$
A_{20}	$-0.397\,768\,873$	$-0.873\,395\,104$	$-0.043\,536\,769\,7$	$-0.275\,117\,343$
A_{21}	$0.337\,490\,912 \times 10^{-2}$	$0.736\,365\,280 \times 10^{-2}$	$+0.376\,660\,288 \times 10^{-3}$	$+0.238\,859\,372 \times 10^{-2}$
A_{22}	$-0.932\,922\,458 \times 10^{-5}$	$-0.205\,516\,523 \times 10^{-4}$	$-0.108\,403\,062 \times 10^{-5}$	$-0.687\,505\,838 \times 10^{-5}$
A_{23}	$0.839\,118\,128 \times 10^{-8}$	$0.189\,902\,200 \times 10^{-7}$	$+0.104\,922\,237 \times 10^{-8}$	$+0.656\,780\,159 \times 10^{-8}$
A_{30}	$-0.407\,827\,088 \times 10^{-3}$	$-0.234\,663\,744 \times 10^{-3}$	$-0.179\,656\,896 \times 10^{-5}$	$-0.339\,418\,992 \times 10^{-4}$
A_{31}	$0.114\,611\,419 \times 10^{-5}$	$0.656\,299\,579 \times 10^{-6}$	$-0.420\,166\,896 \times 10^{-8}$	$+0.908\,065\,276 \times 10^{-7}$

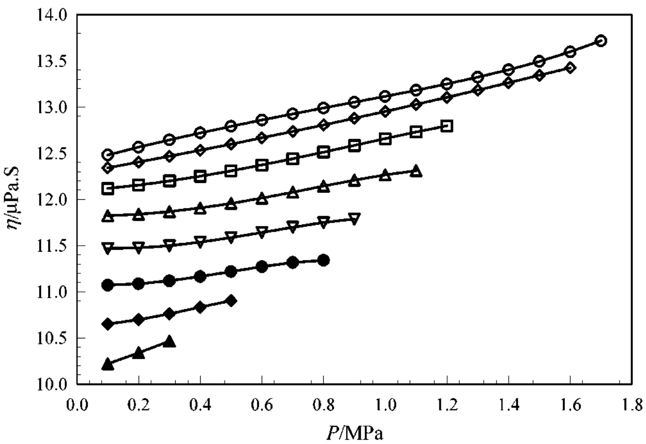

Figure 2. Viscosity of HFC152a + HCFC22 (15 mass % HCFC22): ○, 365 K; ◇, 355 K; □, 345 K; △, 335 K; ▽, 325 K; ●, 315 K; ◆, 305 K; ▲, 295 K.

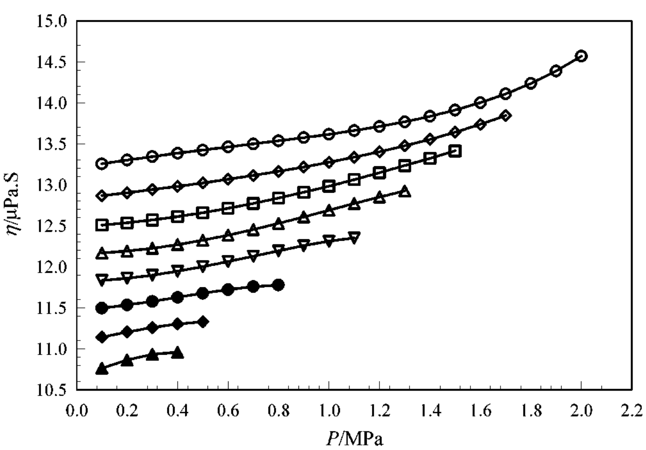

Figure 3. Viscosity of HFC152a + HCFC22 (25 mass % HCFC22): ○, 370 K; ◇, 360 K; □, 350 K; △, 340 K; ▽, 330 K; ●, 320 K; ◆, 310 K; ▲, 300 K.

Table 7. Comparison for HFC152a + HCFC22 between This Work and Ref 11

	15 mass % HCFC22		25 mass % HCFC22	
T/K	η(this work)	η(ref 11)	η(this work)	η(ref 11)
298.15	10.4575	10.0890	10.7932	10.4255
323.15	11.4981	11.1320	11.7045	11.3152

gaseous viscosities of HFC218 + HC290 + HCFC22 were measured at 303−363 K and up to 2.14 MPa. The gaseous viscosities of HFC134a + HFC218 + R600a were measured at 305−363 K and up to 1.82 MPa.

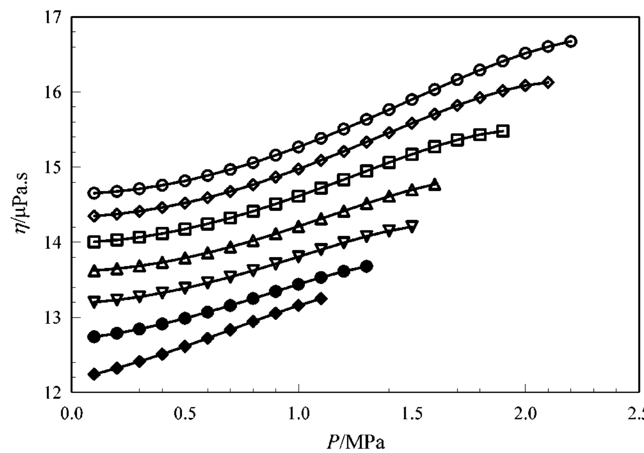

Figure 4. Viscosity of HFC218 + HC290 + HCFC22: ○, 360 K; ◇, 350 K; □, 340 K; △, 330 K; ▽, 320 K; ●, 310 K; ◆, 300 K.

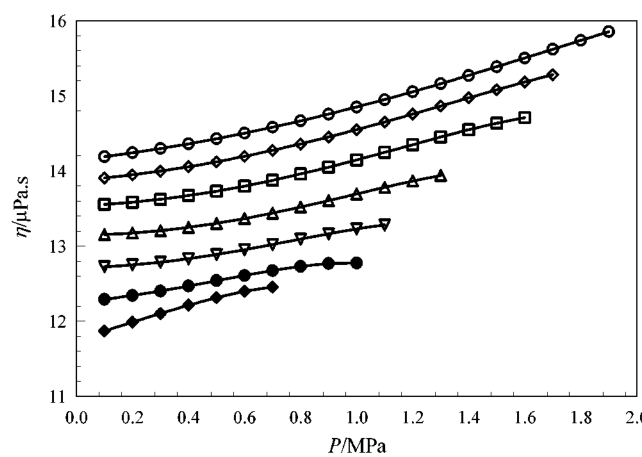

Figure 5. Viscosity of HFC134a + HFC218 + HC600a: ○, 360 K; ◇, 350 K; □, 340 K; △, 330 K; ▽, 320 K; ●, 310 K; ◆, 300 K.

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