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Isochoric Heat Capacity Measurements for Binary Refrigerant Mixtures Containing Difluoromethane (R32), Pentafluoroethane (R125), 1,1,1,2-Tetrafluoroethane (R134a), and Trifluoroethane (R143a) from 200 to 345 K at Pressures to 35 MPa

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Molar heat capacities at constant volume C_v were measured for binary refrigerant mixtures with an adiabatic calorimeter with gravimetric determinations of the amount of substance. Temperatures ranged from 200 to 345 K, while pressures extended up to 35 MPa. Measurements were conducted on liquid samples with equimolar compositions for the following binary systems: R32/R134a, R32/R125, R125/R134a, and R125/R143a. The uncertainty is 0.002 K for the temperature rise and is 0.2% for the change-of-volume work, which is the principal source of uncertainty. The expanded relative uncertainty (with a coverage factor $k = 2$ and thus a two-standard deviation estimate) for C_v is estimated to be 0.7%.

KEY WORDS: binary mixtures; difluoromethane; heat capacity; pentafluoroethane; R32; R125; R134a; R143a; 1,1,1,2-tetrafluoroethane; trifluoroethane.

1. INTRODUCTION

Hydrofluorocarbon (HFC) blends are leading candidates to replace refrigerant 22 (R22), which will be phased out under the terms of the Montreal Protocol. Blends containing HFC substances R32, R125, R134a, and R143a have received a great deal of interest for this purpose. Recently, Lemmon [1] analyzed the available data for binary mixtures of R32, R125, R134a, and R143a and developed a Helmholtz energy model which

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represents the thermodynamic properties for such mixtures. Lemmon noted that published heat capacity data for these mixtures were scarce. The chief goal of this work is to make benchmark measurements of heat capacities at constant volume C_v for binary mixtures, which supplement earlier C_v data reported on the pure components R32 and R125 [2], R134a [3], and R143a [4]. In this paper, new C_v measurements are reported for temperatures ranging from 200 to 345 K and at pressures to 35 MPa.

2. MEASUREMENTS

2.1. Apparatus and Procedures

The adiabatic constant-volume calorimeter used for these measurements has been described in detail by Goodwin [5] and Magee [6]. For the heat-capacity measurement, a precisely determined electrical energy (Q) is applied and the resulting temperature rise $(\Delta T = T_2 - T_1)$ is measured. The heat capacity is obtained from $C_v = (Q - Q_0 - W_{pV})/n\,\Delta T$, where Q_0 is the energy required to heat the empty calorimeter, W_{pV} is the change-of-volume work that results from the slight dilation of the bomb, and n is the number of moles (obtained by weighing) enclosed in the bomb. Further details of this method are available in recently published work [2, 3].

2.2. Gas Mixture Preparation

The gas mixtures were prepared gravimetrically in thoroughly cleaned and dried aluminum cylinders, each with a free volume of about 16 dm^3 and a tare mass of about 14.5 kg. All gases were of high purity and were analyzed before use by gas chromatography/mass spectrometry. Details of the sample purities, materials, and methods are provided in a companion paper [7]. Table I provides the mole fractions and mass fractions for each of the four gas mixtures.

Table I. Compositions of Binary Mixtures Used in this Study

	Mixture			
Designation	Comp. 1	Comp. 2	Mole fraction, Comp. 1	Mass Fraction, Comp. 1
DOE1	R32	R134a	0.4997	0.33744
DOE2	R32	R125	0.4996	0.30208
DOE4	R125	R134a	0.5001	0.54062
ARTI1	R125	R143a	0.5000	0.58812

Table II. Expanded Uncertainties of the Measurements with the Adiabatic Calorimeter

Temperature	0.03 K
Pressure	0.05%
Density	0.15%
Electrical Energy	0.02%
Change-of-Volume Work	0.2%
Moles	0.002%
Temperature Rise	0.002 K
Heat Capacity	0.7%

2.3. Assessment of Uncertainties

A detailed discussion of the uncertainties in measured quantities is available in recent publications [2, 3]. In this work, the expanded uncertainty corresponds to a coverage factor $k=2$ and, thus, a two-standard-deviation estimate. The expanded uncertainties of the original measurements and the resulting combined uncertainties are shown in Table II.

3. RESULTS

The experimental mole fraction compositions, temperatures (ITS-90), pressures, densities, and heat capacities at constant volume C_v are presented in Table III. The number of digits presented reflects the empirical resolution of each measurement and is given to avoid round-off errors during a fit to a model. For each binary mixture, the measurements were carried out at eight liquid-phase filling densities. To illustrate the range of measurements for each of the mixtures, the heat capacity data are plotted in Figs. 1 to 4.

Comparisons of the C_v measurements were made with values calculated with the Helmholtz energy formulation developed by Lemmon and Jacobsen [8]. Although no published data were available for comparisons, Fig. 5 shows deviations of the present results from the calculated values for all four mixtures. When developing this model, Lemmon and Jacobsen used the present results for only one binary mixture, R32 + R134a, to determine the adjustable parameters. As expected, all of the data used in the fitting procedure are represented within the claimed uncertainty of 0.7%. On the other hand, the heat capacities for the other three mixtures, each containing R125, are predicted values of the Lemmon and Jacobsen formulation. These calculations are within 1 to 4% of the measured heat capacities, with the R32 + R125 mixture showing the largest deviations.

Table III. Heat Capacity C_v for Binary Refrigerant Mixtures

T (K)	$\rho_{avg}{}^a$ $(mol \cdot L^{-1})$	$p_{avg}{}^a$ (MPa)	C_v $(J \cdot mol^{-1} \cdot K^{-1})$
	0.4997 R32 + 0.5003 R134a		
205.1549	18.356	6.845	65.62
207.0075	18.347	9.649	65.86
209.1393	18.337	12.876	65.80
210.9787	18.328	15.646	65.99
213.0865	18.318	18.792	66.25
214.9223	18.309	21.503	66.22
216.9990	18.300	24.538	66.67
218.8352	18.291	27.198	66.59
220.8813	18.281	30.142	67.09
218.2331	17.895	5.974	66.18
220.0231	17.887	8.430	66.04
222.1939	17.877	11.397	66.25
223.9618	17.869	13.801	66.31
226.1337	17.860	16.737	66.60
227.8752	17.852	19.076	66.62
230.0397	17.843	21.964	66.78
231.7635	17.835	24.248	66.99
233.9400	17.826	27.110	67.01
235.6258	17.837	29.312	67.21
237.8231	17.809	32.162	67.49
237.6503	17.192	5.464	66.69
239.6506	17.184	7.817	67.06
241.6313	17.177	10.140	66.99
243.6361	17.169	12.482	67.29
245.5790	17.162	14.741	67.44
247.5897	17.154	17.068	67.26
249.5286	17.147	19.299	67.77
251.5144	17.139	21.572	67.65
253.4284	17.132	23.750	68.12
255.4037	17.124	25.985	68.14
257.2924	17.117	28.109	68.30
259.2685	17.110	30.319	68.72
261.1411	17.103	32.401	68.74
255.5543	16.515	5.314	67.73
257.2136	16.509	6.998	68.04
259.5791	16.501	9.391	68.14
261.2467	16.495	11.074	68.37
263.5608	16.488	13.399	68.48
265.2552	16.482	15.096	68.43
267.5465	16.474	17.380	68.69
269.2386	16.469	19.059	68.64
271.5212	16.461	21.314	68.99

Table III. *(Continued)*

T (K)	$\rho_{\text{avg}}{}^{a}$ ($\text{mol} \cdot \text{L}^{-1}$)	$p_{\text{avg}}{}^{a}$ (MPa)	C_{v} ($\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$)
273.1974	16.456	22.962	69.31
275.4802	16.448	25.195	69.36
277.1454	16.443	26.817	69.36
281.0600	16.430	30.604	69.90
283.3509	16.422	32.803	70.19
274.9692	15.756	5.779	69.21
276.6332	15.751	7.207	69.35
278.9902	15.745	9.225	69.51
280.6169	15.740	10.615	69.60
283.0052	15.733	12.651	69.66
284.5727	15.729	13.983	70.07
286.9736	15.722	16.017	70.12
290.9336	15.710	19.354	70.36
292.4520	15.706	20.628	70.55
296.3531	15.695	23.883	70.70
298.8279	15.688	25.936	70.83
300.2491	15.684	27.111	71.19
302.7529	15.677	29.172	71.49
304.1469	15.673	30.316	71.71
306.6628	15.666	32.374	71.74
308.0477	15.662	33.503	71.88
291.1686	15.073	6.093	70.41
293.1476	15.068	7.551	70.73
295.2303	15.063	9.084	71.05
297.2023	15.058	10.533	71.07
299.2935	15.053	12.067	71.34
301.2502	15.048	13.499	71.12
303.3305	15.043	15.018	71.52
305.2683	15.038	16.430	71.50
307.3653	15.033	17.954	71.74
309.2597	15.028	19.327	72.29
311.3824	15.023	20.861	71.95
313.2244	15.018	22.189	72.82
315.3864	15.013	23.744	72.22
317.1968	15.008	25.041	72.74
319.3859	15.003	26.606	72.34
321.1541	14.999	27.867	72.92
323.3641	14.991	29.439	72.75
325.1025	14.989	30.671	73.35
327.3453	14.983	32.258	73.53
329.0442	14.979	33.456	73.62
306.7077	14.230	4.722	72.05
307.9167	14.228	5.457	71.97

Table III. *(Continued)*

T (K)	$\rho_{\text{avg}}{}^{a}$ $(\text{mol} \cdot \text{L}^{-1})$	$p_{\text{avg}}{}^{a}$ (MPa)	C_{v} $(\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})$
309.1318	14.225	6.196	72.09
309.9226	14.224	6.677	72.01
312.1744	14.219	8.047	72.32
313.3226	14.217	8.745	72.49
314.1685	14.215	9.260	72.31
315.0976	14.213	9.824	72.91
316.4162	14.210	10.626	72.61
317.5167	14.208	11.294	72.82
318.3977	14.206	11.829	72.68
319.2768	14.204	12.363	73.05
320.6436	14.201	13.192	73.13
321.6988	14.199	13.832	72.80
322.6053	14.197	14.381	73.43
323.4352	14.195	14.884	73.20
324.8639	14.192	15.748	73.76
325.8751	14.190	16.359	73.54
326.8115	14.188	16.925	73.87
327.5760	14.187	17.386	73.89
329.0725	14.183	18.289	74.23
330.0489	14.181	18.877	73.78
331.0292	14.179	19.467	73.60
331.7528	14.178	19.902	74.14
333.2913	14.175	20.827	74.10
334.2186	14.173	21.383	74.13
335.2387	14.170	21.995	74.10
335.9211	14.169	22.404	74.41
337.5019	14.166	23.350	74.51
338.3842	14.164	23.877	74.65
340.0833	14.160	24.891	74.85
341.7293	14.157	25.872	74.75
342.5627	14.155	26.368	74.96
322.9165	13.260	4.317	74.06
324.1539	13.258	4.918	73.92
326.2003	13.254	5.914	74.22
327.2656	13.253	6.432	74.70
328.5386	13.250	7.053	74.68
329.6079	13.249	7.574	74.68
331.6416	13.245	8.567	74.78
332.9257	13.243	9.193	74.75
333.9739	13.241	9.705	74.73
334.9911	13.239	10.202	74.83
336.0112	13.238	10.700	75.02
337.3025	13.235	11.331	75.02

Table III. *(Continued)*

T (K)	$\rho_{\mathrm{avg}}{}^{a}$ ($\mathrm{mol \cdot L^{-1}}$)	$p_{\mathrm{avg}}{}^{a}$ (MPa)	C_{v} ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)
339.4039	13.232	12.358	74.91
340.3908	13.230	12.840	75.06
341.7117	13.228	13.486	75.05
	0.4996 R32 + 0.5004 R125		
207.5681	17.130	6.089	69.29
211.4449	17.114	11.336	69.59
215.2969	17.098	16.500	69.90
219.1178	17.082	21.564	70.28
222.9146	17.067	26.530	70.53
226.6845	17.051	31.394	70.83
207.6108	17.130	6.147	69.52
211.4883	17.114	11.395	69.47
215.3374	17.098	16.554	69.69
219.1598	17.082	21.619	70.17
222.9591	17.066	26.588	70.32
226.7248	17.051	31.446	70.68
223.0991	16.572	5.880	70.06
226.9671	16.558	10.487	70.04
230.8115	16.543	15.031	70.37
234.6350	16.529	19.508	70.73
238.4368	16.515	23.915	71.06
242.2184	16.502	28.252	71.32
245.9754	16.488	32.516	71.57
243.7595	15.785	5.575	71.25
247.6649	15.773	9.454	71.24
251.5447	15.760	13.286	71.36
255.4094	15.748	17.080	71.62
259.2331	15.736	20.805	72.01
263.0342	15.725	24.479	72.46
266.8376	15.713	28.125	72.91
270.5992	15.701	31.701	73.22
263.7140	14.958	5.247	72.72
267.6546	14.947	8.474	72.77
271.5631	14.937	11.666	73.15
275.4679	14.926	14.840	73.47
279.3497	14.916	17.980	73.54
283.2104	14.906	21.086	74.06
287.0686	14.896	24.171	74.01
290.8917	14.886	27.209	74.47
294.7144	14.876	30.227	74.98
298.5029	14.866	33.200	75.31
283.1125	14.059	4.991	74.54
287.0962	14.050	7.629	74.59

Table III. *(Continued)*

T (K)	ρ_{avg} [a] ($\mathrm{mol \cdot L^{-1}}$)	p_{avg} [a] (MPa)	C_{v} ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)
291.0614	14.041	10.253	74.83
295.0151	14.033	12.864	75.21
298.9676	14.024	15.467	75.13
302.8951	14.016	18.045	75.42
306.8199	14.007	20.612	76.14
310.7310	13.999	23.160	76.54
314.6419	13.990	25.696	76.65
318.5307	13.982	28.208	77.15
322.4259	13.973	30.713	77.21
326.3047	13.965	33.196	77.64
283.1551	14.059	5.020	74.39
287.1584	14.050	7.671	74.64
291.1401	14.041	10.305	74.91
295.1132	14.033	12.929	75.17
299.0713	14.024	15.535	75.28
303.0137	14.015	18.123	75.69
306.9539	14.007	20.700	76.28
310.8763	13.998	23.254	76.47
314.7948	13.990	25.795	76.76
318.7005	13.981	28.318	77.20
322.5990	13.973	30.824	77.72
326.4981	13.964	33.319	77.97
302.3245	12.993	4.602	76.68
306.4171	12.985	6.696	77.02
310.5053	12.978	8.793	76.81
314.5841	12.971	10.887	77.06
318.6559	12.964	12.978	77.60
322.7312	12.957	15.071	77.85
326.7973	12.950	17.157	77.74
330.8663	12.943	19.241	77.78
334.9246	12.936	21.316	78.27
338.9947	12.929	23.391	78.62
343.0640	12.922	25.461	78.99
302.2438	12.993	4.561	76.56
306.3592	12.986	6.667	77.30
310.4742	12.978	8.777	77.42
314.5874	12.971	10.889	77.59
318.7016	12.964	13.002	77.43
322.8087	12.957	15.111	77.26
326.9122	12.950	17.216	77.54
331.0152	12.943	19.317	77.86
335.1060	12.936	21.408	78.44
339.2040	12.928	23.498	79.20
343.3113	12.921	25.587	79.25

Table III. *(Continued)*

T (K)	ρ_{avg} [a] $(mol \cdot L^{-1})$	p_{avg} [a] (MPa)	C_v $(J \cdot mol^{-1} \cdot K^{-1})$
312.4133	12.333	4.549	77.91
316.6267	12.327	6.381	77.75
320.8375	12.320	8.221	77.81
325.0490	12.314	10.067	77.95
329.2616	12.308	11.918	78.34
333.4787	12.301	13.774	78.57
337.6884	12.295	15.627	78.82
341.9099	12.289	17.485	78.84
312.4758	12.333	4.576	77.98
316.7044	12.327	6.415	77.97
320.9317	12.320	8.262	78.22
325.1673	12.314	10.119	77.97
329.3755	12.308	11.968	77.85
333.5811	12.301	13.819	78.15
337.8165	12.295	15.683	78.41
342.0485	12.288	17.546	78.68
322.7756	11.467	4.342	79.77
327.1288	11.462	5.864	79.79
331.4877	11.456	7.400	79.70
335.8493	11.451	8.949	79.92
340.2248	11.445	10.510	80.09
344.6004	11.440	12.077	79.86
322.6849	11.467	4.311	79.63
327.0381	11.462	5.832	79.32
331.3906	11.456	7.366	79.64
335.7649	11.451	8.919	79.82
340.1399	11.445	10.479	79.98
344.5284	11.440	12.051	79.49
	0.5001 R125 + 0.4999 R134a		
206.3050	14.006	5.923	85.12
210.1978	13.993	11.098	85.72
214.0630	13.980	16.174	86.26
217.8882	13.968	21.129	87.07
221.6929	13.955	25.987	87.57
225.4579	13.943	30.726	88.37
224.9002	13.500	5.434	86.79
228.7491	13.489	9.836	87.36
232.5719	13.477	14.170	87.88
236.3734	13.466	18.437	88.92
240.1418	13.456	22.622	89.51
243.8842	13.445	26.731	90.01
247.6172	13.434	30.783	90.54
242.9952	12.983	5.016	88.84

Table III. *(Continued)*

T (K)	$\rho_{\text{avg}}{}^{a}$ (mol · L^{-1})	$p_{\text{avg}}{}^{a}$ (MPa)	C_{v} (J · mol^{-1} · K^{-1})
246.8336	12.974	8.775	89.42
250.6500	12.964	12.487	90.15
254.4400	12.954	16.146	90.78
258.2105	12.945	19.756	91.34
261.9512	12.935	23.306	91.79
265.6850	12.926	26.818	92.48
269.3892	12.917	30.271	93.05
262.9326	12.376	4.642	92.09
266.7925	12.368	7.787	92.52
270.6235	12.360	10.895	92.95
274.4367	12.351	13.972	93.20
278.2184	12.343	17.006	93.68
281.9764	12.335	20.001	94.52
285.7239	12.327	22.968	95.02
289.4375	12.319	25.888	95.71
293.1478	12.311	28.786	96.24
296.8334	12.303	31.644	97.00
283.5002	11.688	4.309	94.75
287.3842	11.681	6.872	95.11
291.2489	11.674	9.418	95.49
295.0934	11.668	11.942	95.87
298.9253	11.661	14.450	96.32
302.7404	11.654	16.937	97.17
306.5420	11.647	19.405	97.83
310.3297	11.640	21.852	98.49
314.1102	11.634	24.282	98.63
317.8726	11.627	26.688	99.13
321.6281	11.620	29.078	100.10
325.3846	11.613	31.456	100.47
303.0084	10.945	4.055	97.59
306.9638	10.939	6.126	97.92
310.9107	10.933	8.193	98.27
314.8452	10.927	10.254	98.80
318.7708	10.922	12.307	99.38
322.6907	10.916	14.354	99.68
326.5975	10.910	16.390	100.34
330.5068	10.904	18.423	100.58
334.4139	10.898	20.448	101.03
338.3199	10.893	22.466	101.30
342.2265	10.887	24.477	101.77
303.0288	10.945	4.066	97.77
307.0137	10.939	6.152	97.72
310.9857	10.933	8.232	97.93
314.9509	10.927	10.309	98.32

Table III. *(Continued)*

T (K)	$\rho_{\text{avg}}{}^{a}$ $(\text{mol} \cdot \text{L}^{-1})$	$p_{\text{avg}}{}^{a}$ (MPa)	C_{v} $(\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})$
318.9077	10.921	12.378	98.83
322.8511	10.916	14.438	99.42
326.7959	10.910	16.494	99.85
330.7294	10.904	18.538	100.33
334.6617	10.898	20.576	100.49
338.5849	10.892	22.602	101.05
342.5174	10.886	24.627	101.73
312.5371	10.529	3.933	98.96
316.5839	10.524	5.791	99.19
320.6195	10.518	7.647	100.05
324.6656	10.513	9.511	100.04
328.6995	10.508	11.370	100.63
332.7353	10.502	13.229	101.14
336.7704	10.497	15.086	101.44
340.8018	10.492	16.939	101.66
344.8334	10.486	18.788	102.25
312.5419	10.529	3.936	98.95
316.6044	10.524	5.800	99.01
320.6516	10.518	7.662	99.62
324.7083	10.513	9.531	100.43
328.7666	10.508	11.401	100.59
332.8155	10.502	13.266	100.95
336.8623	10.497	15.128	101.24
340.9166	10.492	16.992	101.58
322.6964	10.028	3.836	100.64
326.8262	10.023	5.451	100.96
330.9654	10.018	7.077	101.32
335.1012	10.014	8.706	101.91
339.2465	10.009	10.343	102.49
343.3936	10.004	11.983	102.42
322.6830	10.028	3.831	101.01
326.8250	10.023	5.451	100.99
330.9602	10.018	7.075	101.35
335.1115	10.014	8.710	101.69
339.2524	10.009	10.346	102.41
343.4070	10.004	11.989	102.43
	0.5000 R125 + 0.5000 R143a		
205.3442	13.956	5.993	79.81
209.3956	13.943	10.830	80.55
213.4088	13.931	15.576	80.99
213.4710	13.931	15.649	80.93
217.4707	13.919	20.343	81.62
221.4378	13.907	24.962	82.28

Table III. *(Continued)*

T (K)	$\rho_{\text{avg}}{}^{a}$ ($\text{mol} \cdot \text{L}^{-1}$)	$p_{\text{avg}}{}^{a}$ (MPa)	C_{v} ($\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$)
225.3683	13.895	29.491	82.82
224.5914	13.415	5.976	81.79
228.6246	13.404	10.114	82.40
232.6279	13.393	14.190	83.25
236.6019	13.382	18.201	83.77
240.5417	13.372	22.140	84.51
244.4562	13.362	26.014	84.77
248.3278	13.351	29.806	85.63
242.6010	12.865	5.503	84.18
246.6193	12.856	9.011	84.61
250.6128	12.846	12.477	85.13
254.5767	12.837	15.894	85.69
258.5177	12.828	19.266	86.52
262.4375	12.819	22.594	87.08
266.3291	12.810	25.871	87.44
270.2001	12.801	29.101	88.31
274.0492	12.792	32.282	89.06
263.3117	12.193	5.209	86.95
267.3382	12.185	8.087	87.34
271.3373	12.178	10.935	88.18
275.3215	12.170	13.761	88.73
279.2795	12.162	16.553	89.13
283.2210	12.154	19.319	89.51
287.1405	12.147	22.052	90.20
291.0479	12.139	24.760	90.72
294.9334	12.132	27.436	91.20
298.8059	12.124	30.085	92.21
302.6743	12.117	32.714	92.44
283.5412	11.464	4.960	89.92
287.5984	11.457	7.288	90.26
291.6370	11.450	9.602	90.58
295.6608	11.444	11.904	91.21
299.6777	11.437	14.195	91.91
303.6804	11.431	16.470	91.96
307.6683	11.424	18.728	92.79
311.6472	11.418	20.970	93.39
315.6131	11.412	23.195	94.11
319.5732	11.405	25.407	94.59
323.5289	11.399	27.606	95.08
327.4714	11.392	29.788	95.67
331.4134	11.386	31.962	96.12
283.6015	11.464	4.994	89.70
287.6628	11.457	7.325	90.62
291.7217	11.450	9.651	90.84

Table III. *(Continued)*

T (K)	ρ_{avg} [a] $(\mathrm{mol \cdot L^{-1}})$	p_{avg} [a] (MPa)	C_v $(\mathrm{J \cdot mol^{-1} \cdot K^{-1}})$
295.7518	11.444	11.956	91.29
299.7756	11.437	14.251	91.87
303.7828	11.431	16.528	92.42
307.7834	11.424	18.793	92.95
311.7712	11.418	21.040	93.41
315.7551	11.411	23.275	93.97
319.7167	11.405	25.487	94.50
323.6656	11.399	27.682	94.61
327.6183	11.392	29.870	95.42
331.5744	11.386	32.051	96.49
295.5765	10.970	4.730	91.61
299.6429	10.964	6.738	92.44
303.6945	10.958	8.738	92.87
307.7327	10.952	10.732	92.90
311.7539	10.947	12.715	93.44
315.7665	10.941	14.690	93.84
319.7630	10.935	16.652	94.34
323.7571	10.930	18.609	94.60
327.7142	10.924	20.541	95.46
295.6016	10.970	4.743	91.48
299.7237	10.964	6.777	92.12
303.8377	10.958	8.809	92.73
307.9438	10.952	10.836	92.88
312.0154	10.946	12.844	93.36
316.0789	10.940	14.843	94.16
320.1594	10.935	16.847	94.42
324.2270	10.929	18.838	94.66
328.2898	10.923	20.822	95.21
332.3282	10.917	22.786	95.58
336.3500	10.912	24.736	95.94
340.3831	10.906	26.684	96.34
310.2678	10.484	6.361	93.49
314.4480	10.478	8.144	93.99
318.6274	10.473	9.929	94.40
322.7973	10.468	11.710	94.77
326.9703	10.463	13.493	95.24
331.1318	10.458	15.269	95.79
335.2972	10.452	17.045	96.41
339.4644	10.447	18.818	96.88
343.6301	10.442	20.587	96.90
314.5369	10.478	8.182	93.94
318.7221	10.473	9.969	94.31
322.8991	10.468	11.754	94.97
327.0726	10.463	13.536	95.51

Table III. *(Continued)*

T (K)	$\rho_{\mathrm{avg}}{}^{a}$ ($\mathrm{mol \cdot L^{-1}}$)	$p_{\mathrm{avg}}{}^{a}$ (MPa)	C_{v} ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)
331.2440	10.457	15.317	95.82
339.5707	10.447	18.863	96.52
343.7424	10.442	20.634	97.07
317.0797	9.920	4.514	95.46
321.3172	9.915	6.025	95.94
325.5444	9.910	7.539	96.00
329.7626	9.906	9.053	96.35
333.9680	9.901	10.566	96.72
342.3767	9.892	13.596	97.38
321.3054	9.915	6.021	95.82
325.5366	9.910	7.536	96.21
329.7554	9.906	9.051	96.46
333.9834	9.901	10.572	96.77
338.2052	9.897	12.092	97.13
342.4115	9.892	13.609	97.47

[a] Subscript avg denotes a condition evaluated at the average of the initial and final temperatures.

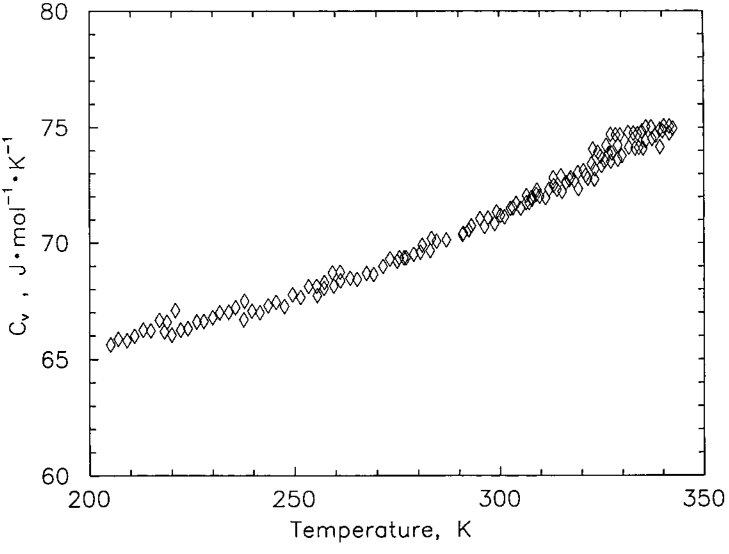

Fig. 1. Range of C_{v}–T measurements for 0.4997 R32 + 0.5003 R134a (designated DOE1).

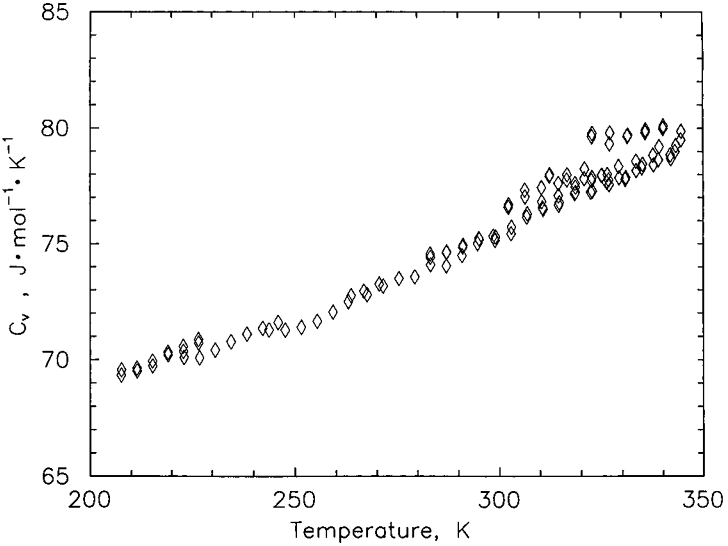

Fig. 2. Range of C_v–T measurements for 0.4996 R32 + 0.5004 R125 (designated DOE2).

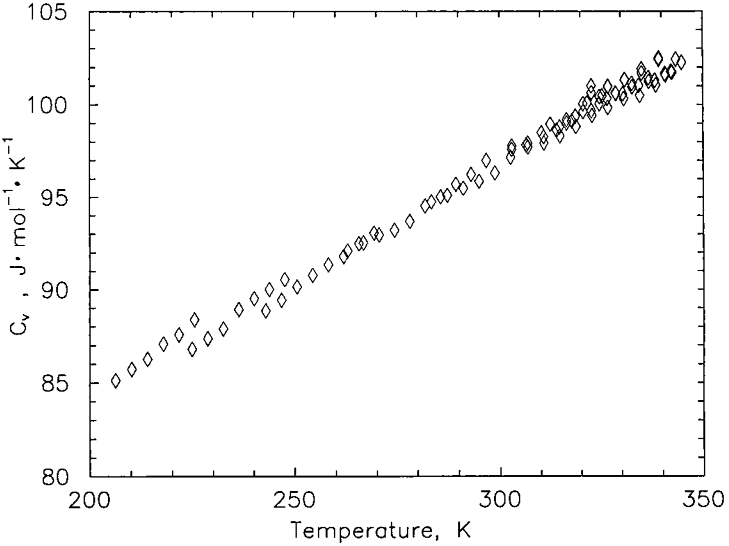

Fig. 3. Range of C_v–T measurements for 0.5001 R125 + 0.4999 R134a (designated DOE4).

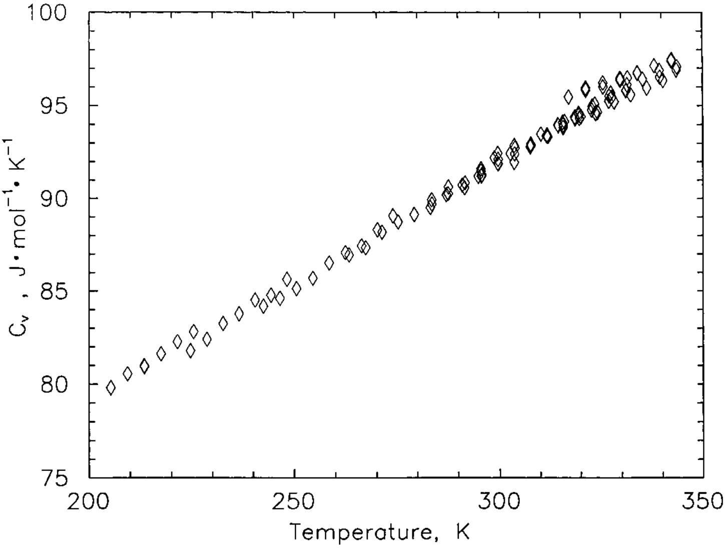

Fig. 4. Range of C_v–T measurements for 0.5000 R125 + 0.5000 R143a (designated ARTI1).

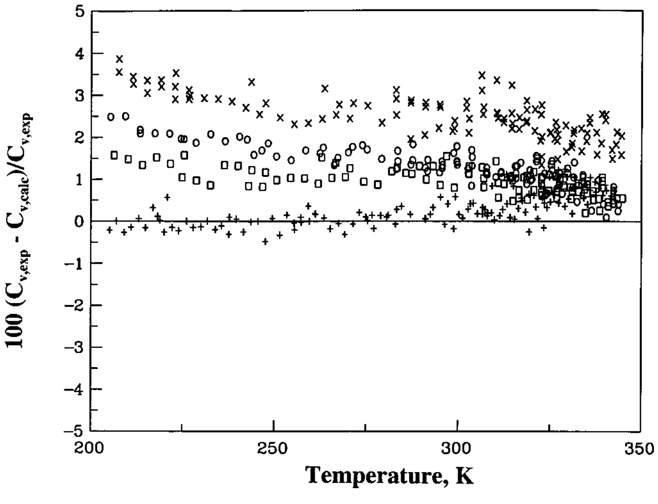

Fig. 5. Percentage deviations of the experimental liquid heat capacities for 0.4997 R32 + 0.5003 R134a (DOE1) (+), 0.4996 R32 + 0.5004 R125 (DOE2) (×), 0.5001 R125 + 0.4999 R134a (DOE4) (□), and 0.5000 R125 + 0.5000 R143a (ARTI1) (○) obtained in this work from the values calculated with the Helmholtz energy model of Lemmon and Jacobsen [8].

Further p–ρ–T and C_v studies on pure R125 and its mixtures with R32, especially in the supercritical gas region, should lead to a better understanding of their behavior and, ultimately, lead to improved predictions of their thermodynamic properties.

4. CONCLUSIONS

For four binary mixtures, a total of 445 C_v measurements has been reported. For C_v, the uncertainty of pressure is 0.05%, that of density is 0.15%, that of temperature is 0.03 K, that of the temperature rise is 0.002 K, and that of heat capacity is 0.7%. No published heat capacities at constant volume were available for comparison.

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