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Volumetric Properties of Carbon Dioxide + Sulfur Hexafluoride at High Pressures

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Volumetric properties of binary mixtures of carbon dioxide and sulfur hexafluoride have been determined using a specially designed high-pressure variable-volume view cell. The data are reported for mixtures containing 0, 9, 20.2, 31, 35.6, 50, and 100% by mass sulfur hexafluoride over a temperature range from 296 to 430 K at pressures up to 70 MPa. At these conditions, depending upon the mixture composition, densities are observed to vary in the range from 0.7 to 1.6 g/cm^3.

Introduction

Theoretical and experimental investigation of fluid mixtures at high pressures has been a focus of intense research over the past several years. The documentation of the PVT behavior of fluid mixtures and the effect of temperature and pressure on their densities at high pressures are particularly important for processes at near critical and supercritical conditions (Kiran and Levelt Sengers, 1994). This is particularly because many properties of the supercritical fluids are correlated and scale best with density. From a practical perspective, binary fluid mixtures are of interest to many processes since introduction of the second component to the primary process or processing fluid may permit regulation or improvement of selectivity, solubility, reactivity, recovery, and recycle.

The present paper is concerned with the volumetric properties of sulfur hexafluoride and its binary mixtures with carbon dioxide. Sulfur hexafluoride (SF_6) has been of interest in chromatography (Kiran, 1983; Hellgeth *et al.*, 1988), the electrical power industry (Cole and de Reuck, 1990) and polymer separations (Super *et al.*, 1993). Even though there are extensive data for the density of carbon dioxide (Vargaftik, 1975; Angus *et al.*, 1976; Ely, 1986; Duschek *et al.*, 1990; Kiran *et al.*, 1995), data for SF_6 are more limited (DeZwaan and Jonas, 1975; Cole and de Reuck, 1990; Abbaci and Sengers, 1990; Gilgen *et al.*, 1992; Blanke *et al.*, 1993). As for their binary mixtures, data are scarce and are limited to a few compositions (in the range from 49 to 95% SF_6 by mass) at relatively low temperatures (in the range 294−338 K) and at pressures below 40 MPa (Super *et al.*, 1993). In the present study, data for these mixtures are reported over the full composition range covering a temperature range from 297 to 430 K and pressures up to 70 MPa. This is a part of an ongoing program at the University of Maine on polymer processing with binary fluid mixtures at high pressures (Kiran, 1994; Xiong and Kiran, 1994; Kiran and Gokmenoglu, 1994, 1995). We have already reported the volumetric properties of carbon dioxide + pentane (Kiran *et al.*, 1995) and will be reporting data for other mixtures such as carbon dioxide + toluene (Pöhler and Kiran, 1995) and carbon dioxide + acetone in future papers.

Experimental Section

a. Experimental Apparatus. The experimental system details have been described in our previous publications (Kiran *et al.*, 1995). It consists of a high-pressure variable-volume view cell, a pressure generator (PGN), a solvent delivery manifold, and the associated controls and display modules. The system is operable at pressures up to 70 MPa and temperatures up to 473 K.

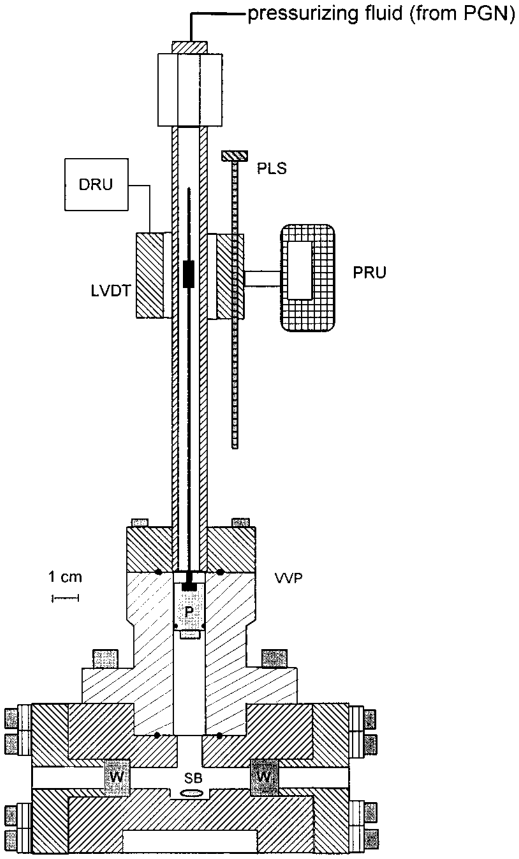

Figure 1. Variable-volume view cell. W = sapphire window, SB = stirring bar, P = piston, DRU = digital read-out unit, LVDT = linear variable differential transformer, PLS = position locator screw, PRU = position read-out unit, PGN = pressure generator, and VVP = variable-volume part.

The variable-volume view cell (Figure 1) is equipped with two sapphire windows for either visual observations or optical detection. The cell content is mixed with a magnetic stirrer and a Teflon-coated stirring bar (SB) inside the cell cavity. The cell pressure and the temperature are monitored with a flush-mount pressure/temperature transducer with an accuracy of ±0.03 MPa and ±0.5 K, respectively. The transducer is in direct contact with the fluid inside the cell. The cell is heated with four cartridge heaters

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Table 1. Density Data for Pure CO_2

ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa
T = 297 K		T = 304 K		T = 314 K		T = 324 K		T = 334 K	
0.7431	6.11	0.7455	9.59	0.7512	13.62	0.7462	17.04	0.7386	20.72
0.7625	6.80	0.7656	10.66	0.7731	15.47	0.7591	18.89	0.7633	23.33
0.7914	7.95	0.7678	11.11	0.7993	17.68	0.7803	20.87	0.7832	25.70
0.8081	9.02	0.7718	11.59	0.8196	19.97	0.7942	22.82	0.8117	29.04
0.8320	10.97	0.7851	12.31	0.8510	23.81	0.8167	25.36	0.8248	31.64
0.8534	13.12	0.7962	12.89	0.8711	27.31	0.8418	28.07	0.8401	34.61
0.8892	17.27	0.8107	14.21	0.8880	30.62	0.8560	31.19	0.8586	38.06
		0.8440	16.70	0.9037	34.12	0.8731	34.18	0.8721	40.81
		0.8622	19.08			0.8958	39.08	0.8889	44.11
		0.8852	23.19			0.9088	41.76	0.9043	48.28
		0.9223	31.11			0.9192	44.87	0.9190	51.93
						0.9353	48.34	0.9303	55.26
T = 347 K		T = 355 K		T = 364 K		T = 381 K		T = 388 K	
0.7388	24.48	0.7395	27.34	0.7398	31.06	0.7423	35.08	0.7388	39.25
0.7679	26.83	0.7732	30.52	0.7693	34.91	0.7722	38.80	0.7553	40.74
0.7918	29.89	0.7954	33.91	0.7862	36.74	0.7866	41.42	0.7622	41.97
0.8139	32.89	0.8144	36.53	0.8113	40.76	0.8056	43.53	0.7738	44.37
0.8354	36.25	0.8285	39.40	0.8257	43.61	0.8198	46.43	0.7914	47.00
0.8539	39.59	0.8423	41.79	0.8471	48.19	0.8304	49.04	0.8087	50.51
0.8706	43.22	0.8573	44.21	0.8664	51.47	0.8404	50.99	0.8204	52.93
0.8866	46.94	0.8695	47.21	0.8844	56.44	0.8545	54.10	0.8359	56.84
0.8927	49.97	0.8842	50.94	0.8897	58.49	0.8624	57.11	0.8406	57.82
0.9108	53.50	0.8889	52.10	0.8992	61.03	0.8713	58.42	0.8467	59.85
0.9268	58.29	0.9021	56.44	0.9182	66.59	0.8798	61.21		
0.9448	62.21	0.9160	60.51			0.8899	63.98		
		0.9299	64.02						
		0.9377	66.57						
T = 398 K		T = 406 K		T = 416 K		T = 425 K			
0.7395	42.76	0.7389	46.18	0.7396	49.12	0.7400	52.74		
0.7638	45.78	0.7593	48.82	0.7513	50.68	0.7572	55.51		
0.7825	49.69	0.7729	51.56	0.7625	52.41	0.7702	57.79		
0.7938	51.85	0.7846	53.78	0.7715	53.81	0.7722	58.22		
0.8118	55.75	0.7934	56.19	0.7808	55.89	0.7782	59.89		
0.8267	59.17	0.8076	58.95	0.7860	57.61	0.7842	61.82		
0.8396	62.55	0.8208	62.58	0.7948	59.74	0.7895	63.64		
0.8522	66.42	0.8295	65.34	0.8029	61.68	0.7984	65.77		
				0.8088	64.47				

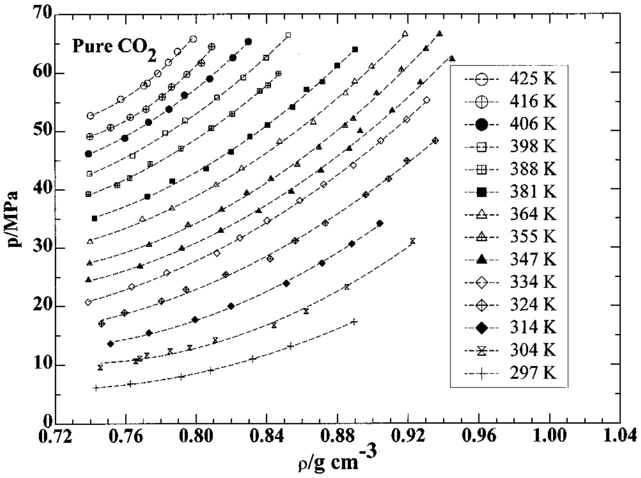

Figure 2. Variation of the density of carbon dioxide with pressure at selected temperatures.

heaters inserted symmetrically into the cell body, and the temperature is controlled with an Omega controller which uses an RTD probe.

At a given temperature, the cell volume (and hence the pressure in the cell) can be changed by moving a piston (P) inside the variable-volume part (VVP) of the cell. The position of the piston is detected by a linear variable differential transformer (LVDT) and a digital read-out unit (DRU) which responds to the location of a ferromagnetic slug connected to the piston with a rigid stainless-steel rod. When the internal volume of the cell is at its maximum (i.e., piston is all the way up), the LVDT coil is moved using the position locator screw (PLS) until the digital readout unit indicates zero which corresponds to the ferromagnetic slug being at the exact center of the LVDT coil. At this point, the reading of the position readout unit (PRU) is set to zero. When the piston moves downward to a new position (i.e., smaller cell volume), the LVDT coil is moved (with PLS) to locate its new position which is again identified, with the signal from the DRU becoming zero. The distance traveled from the initial zero reference point is directly read from the PRU with an accuracy of ±0.013 mm.

b. Operational Procedure. Density determinations are based on the measurement of the cell volume at any given temperature and pressure. The fluid to be tested is charged to the cell at room temperature from a fluid transfer vessel which has been previously filled with the fluid (about 50−100 g) of interest. The amount charged during pumping is monitored from the decrease in the weight of the transfer vessel. The weight is recorded with a Mettler balance (model 6100) with an accuracy of ±0.01 g.

In loading the cell with two fluids, SF_6 which has a lower vapor pressure than CO_2 is charged first. After charging the cell with SF_6, the cell is removed and weighed on a Sartorius balance (16 kg capacity with 0.1 g accuracy) for further verification of the exact amount loaded. The cell is then connected to the system. A new transfer vessel filled with carbon dioxide is connected to the solvent charge line. The line is purged with carbon dioxide before the valve to the cell is opened and carbon dioxide is pumped into the cell. The amount charged is again monitored from the weight change of the transfer vessel. The cell, now loaded with both fluids, is once again removed and weighed for accurate determination of the exact amounts loaded. Typically, about 18 g of fluid mixture is loaded into the cell.

After loading, the cell content is stirred and heated to the desired temperature. While the piston is at the top of the variable-volume cell (which is assured by not applying pressure on the pressure generation line behind the piston), the zero reference point of the position readout unit (PRU),

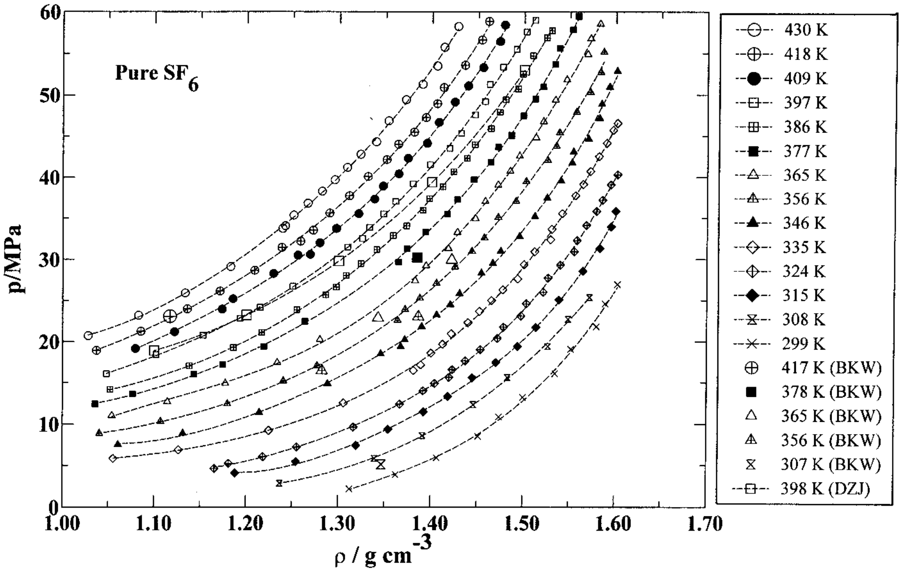

Figure 3. Variation of the density of sulfur hexafluoride with pressure at selected temperatures. BKW = data from Blanke *et al.* (1993), and DZJ = data from DeZwann and Jonas (1975).

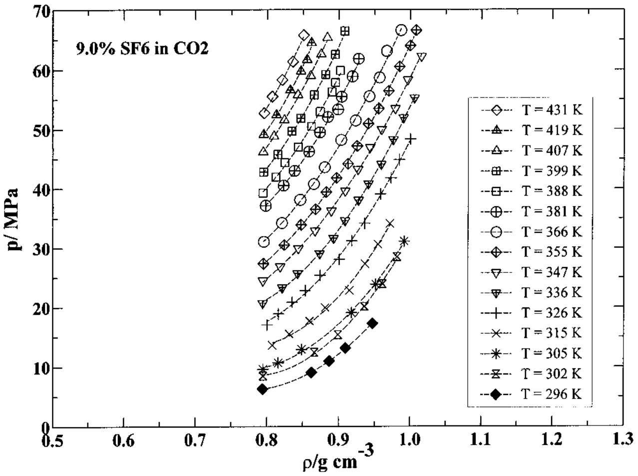

Figure 4. Variation of the density of the carbon dioxide + sulfur hexafluoride mixture (9.0% by mass SF_6) with pressure at selected temperatures.

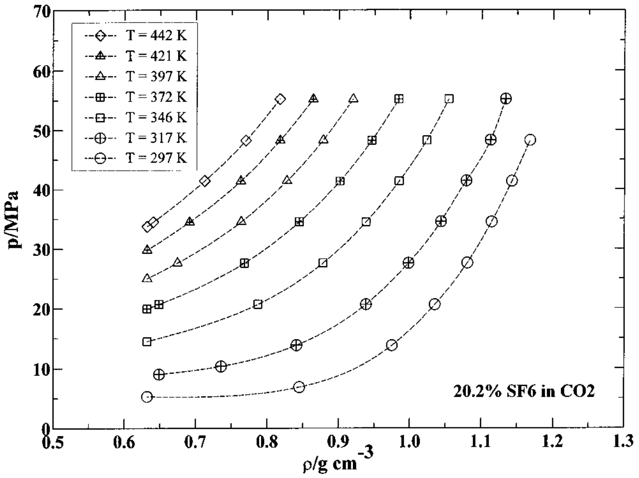

Figure 5. Variation of the density of the carbon dioxide + sulfur hexafluoride mixture (20.2% by mass SF_6) with pressure at selected temperatures.

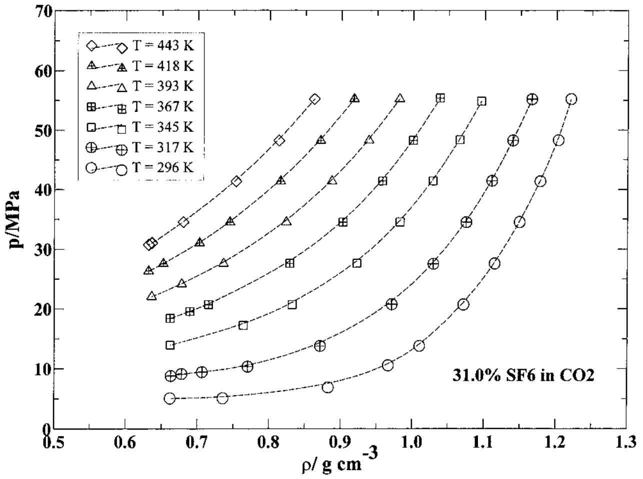

Figure 6. Variation of the density of the carbon dioxide + sulfur hexafluoride mixture (31.0% by mass SF_6) with pressure at selected temperatures.

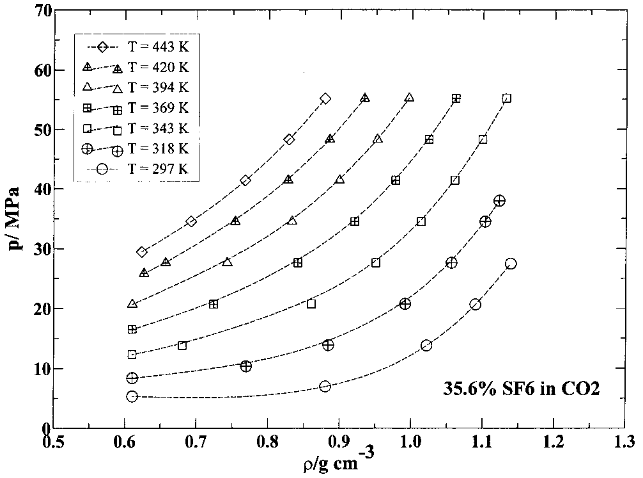

Figure 7. Variation of the density of the carbon dioxide + sulfur hexafluoride mixture (35.6% by mass SF_6) with pressure at selected temperatures.

corresponding to the maximum internal volume of the cell (which is 22.43 ± 0.05 cm^3), is established. After thermal equilibration is achieved, the piston is moved by applying pressure from the pressure generator to bring the system to a new pressure. [Here, *n*-pentane is used as the pressurizing fluid behind the piston.] The new position of the piston, and thus the internal volume of the cell corresponding to the prevailing pressure, is determined by moving the LVDT with the aid of the position locator screw. All accessible pressures up to 70 MPa at a given temperature are mapped in a similar fashion. From the total amount of the fluid that has been charged, and the

Table 2. Density Data for Pure Sulfur Hexafluoride

ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa
T = 299 K		T = 308 K		T = 315 K		T = 324 K			
1.3127	2.18	1.2370	2.84	1.1882	4.08	1.1655	4.62	1.4784	21.78
1.3622	3.90	1.3392	5.86	1.2545	5.45	1.1812	5.23	1.4973	23.13
1.4063	5.93	1.3909	8.63	1.3194	7.44	1.2185	6.06	1.5033	24.60
1.4513	8.54	1.4460	12.34	1.3540	9.38	1.2554	7.23	1.5218	26.02
1.4738	10.87	1.4828	15.63	1.3920	11.46	1.3165	9.63	1.5269	27.72
1.4998	13.22	1.5269	19.45	1.4185	13.34	1.3665	12.40	1.5402	29.31
1.5347	16.12	1.5489	22.72	1.4448	15.61	1.3916	14.02	1.5553	30.94
1.5521	19.09	1.5721	25.37	1.4705	17.48	1.4039	14.93	1.5583	32.31
1.5798	21.82			1.4938	19.44	1.4196	15.64	1.5685	34.12
1.5892	24.59			1.5138	21.73	1.4232	16.58	1.5792	35.83
1.6025	26.95			1.5389	25.06	1.4370	17.68	1.5859	37.21
				1.5647	28.58	1.4534	19.04	1.5949	39.08
				1.5831	31.35	1.4719	20.42	1.6022	40.34
				1.5954	33.95				
				1.6002	35.85				
T = 335 K		T = 346 K		T = 356 K		T = 365 K		T = 377 K	
1.0554	5.86	1.0608	7.53	1.0404	8.877	1.0539	11.03	1.0357	12.41
1.1268	6.90	1.1314	8.90	1.1072	10.32	1.1144	12.69	1.0767	13.62
1.2247	9.25	1.2144	11.38	1.1796	12.42	1.1773	14.91	1.1430	16.02
1.3057	12.53	1.2883	14.88	1.2404	15.21	1.2336	17.44	1.1742	17.23
1.3812	16.49	1.3458	18.52	1.2769	17.08	1.2799	20.25	1.2191	19.38
1.3888	17.17	1.3672	19.43	1.3636	22.58	1.3824	27.40	1.2636	22.43
1.4000	18.62	1.3715	20.25	1.3717	23.91	1.3942	29.25	1.3643	29.68
1.4125	19.70	1.3899	21.83	1.3877	25.28	1.4183	31.31	1.3736	31.32
1.4218	20.98	1.4059	23.25	1.4057	27.10	1.4279	33.29	1.3933	33.31
1.4400	22.31	1.4207	24.49	1.4256	29.11	1.4474	34.97	1.4169	35.51
1.4525	23.69	1.4306	25.85	1.4439	30.98	1.4581	37.07	1.4277	37.29
1.4654	25.02	1.4541	28.36	1.4572	32.63	1.4719	39.07	1.4455	39.76
1.4777	26.32	1.4666	29.55	1.4721	35.13	1.4847	40.79	1.4640	41.88
1.4936	27.64	1.4750	31.00	1.4913	37.10	1.4950	42.63	1.4717	43.74
1.5005	29.38	1.4953	32.80	1.5023	39.51	1.5128	44.86	1.4859	45.13
1.5121	30.95	1.5121	35.23	1.5256	42.13	1.5210	46.80	1.4990	47.51
1.5292	32.41	1.5254	37.51	1.5352	43.85	1.5339	49.41	1.5123	49.53
1.5308	33.67	1.5404	39.60	1.5386	45.44	1.5463	51.89	1.5207	51.02
1.5420	35.57	1.5524	41.80	1.5569	47.95	1.5688	54.89	1.5336	53.71
1.5564	37.78	1.5540	43.14	1.5718	50.34	1.5721	56.80	1.5383	55.64
1.5647	39.14	1.5702	44.69	1.5834	52.72	1.5823	58.57	1.5526	57.91
1.5724	40.74	1.5820	47.17	1.5865	55.18			1.5588	59.46
1.5817	42.56	1.5842	48.91						
1.5901	44.19	1.5929	50.98						
1.5971	45.74	1.6011	52.89						
1.6017	46.56								
T = 386 K		T = 397 K		T = 409 K		T = 418 K		T = 430 K	
1.0521	14.17	1.0480	16.06	1.0794	19.16	1.0368	18.93	1.0279	20.72
1.1381	17.04	1.1022	18.40	1.1220	21.21	1.0853	21.25	1.0827	23.18
1.1861	19.29	1.1530	20.76	1.1735	23.93	1.1357	23.95	1.1334	25.91
1.2168	21.11	1.1932	22.79	1.1853	25.20	1.1712	26.14	1.1826	29.11
1.2547	23.85	1.2148	24.12	1.2292	28.27	1.2087	28.66	1.2389	33.76
1.2860	25.66	1.2502	26.70	1.2556	30.50	1.2382	31.44	1.2417	34.06
1.2972	26.63	1.3093	31.46	1.2690	30.61	1.2585	32.19	1.2509	35.36
1.3077	28.02	1.3254	32.54	1.2792	32.02	1.2720	33.53	1.2661	36.82
1.3239	29.48	1.3328	33.86	1.2970	33.74	1.2896	35.63	1.2814	38.29
1.3410	31.19	1.3480	35.51	1.3210	35.56	1.3108	37.76	1.2950	39.70
1.3583	32.89	1.3608	37.04	1.3380	37.33	1.3309	40.12	1.3083	41.22
1.3728	34.07	1.3795	39.18	1.3474	38.95	1.3510	42.19	1.3229	42.82
1.3905	35.97	1.3978	41.55	1.3641	40.44	1.3632	44.04	1.3396	44.35
1.3974	37.40	1.4189	43.57	1.3738	42.35	1.3805	45.51	1.3528	46.85
1.4118	38.85	1.4315	45.35	1.3944	44.17	1.3931	47.26	1.3715	49.42
1.4234	40.70	1.4464	47.58	1.4072	46.70	1.4052	48.94	1.3895	51.29
1.4379	42.35	1.4572	49.21	1.4243	49.14	1.4125	50.89	1.4052	53.50
1.4464	44.00	1.4624	51.30	1.4388	51.12	1.4354	53.59	1.4129	55.75
1.4640	45.93	1.4767	53.37	1.4551	53.33	1.4536	56.64	1.4277	58.26
1.4733	47.92	1.4913	55.48	1.4733	56.46	1.4612	58.89		
1.4796	49.44	1.5023	57.58	1.4784	58.43				
1.4931	50.74	1.5116	59.02						
1.4980	52.53								
1.5093	54.72								
1.5243	56.90								
1.5297	57.75								

information on volume at different T and P, densities of the mixture are calculated. After the mapping of volumes is completed at a given temperature, the cell is heated to a new temperature and the procedure is repeated. When tests are completed, the pressure in the pressure generation line is released, and the fluid in the cell is discharged after cooling.

Using this system, volume changes are determined with an accuracy of ± 0.0025 cm^3. From comparisons with density data for carbon dioxide and pentane, density measurements have been on the average shown to be accurate to ±1.2% (Kiran *et al.*, 1995).

c. Materials. Sulfur hexafluoride was instrument grade (Scott Specialty Gases) with a purity of 99.99%. Carbon dioxide was bone-dry grade with an eductor tube (Airco) with a purity of 99.8%. They were used without further purification.

Results and Discussions

a. Densities of the Pure Fluids. The results of density measurements for pure carbon dioxide and sulfur hexafluoride are shown in Figures 2 and 3. Numerical data are given in Tables 1 and 2. For carbon dioxide, data have been collected up to 65 MPa in the temperature range from

Table 3. Density Data for Sulfur Hexafluoride + Carbon Dioxide [9.0% by Mass SF_6]

ρ(g/cm^3)	p/MPa	ρ(g/cm^3)	p/MPa	ρ(g/cm^3)	p/MPa	ρ(g/cm^3)	p/MPa	ρ(g/cm^3)	p/MPa
$T = 296$ K		$T = 302$ K		$T = 305$ K		$T = 315$ K		$T = 326$ K	
0.7941	6.26	0.7947	8.448	0.7947	9.59	0.8003	17.04	0.8075	13.62
0.8621	9.021	0.8657	12.40	0.8159	10.66	0.8158	18.89	0.8311	15.47
0.8868	10.97	0.8989	15.36	0.8483	12.89	0.8352	20.87	0.8592	17.68
0.9095	13.12	0.9359	20.13	0.9178	19.08	0.8532	22.82	0.8811	19.97
0.9473	17.27	0.9613	23.95	0.9518	23.87	0.8740	25.36	0.9149	22.85
		0.9817	28.49	0.9917	31.11	0.9007	28.07	0.9364	27.31
						0.9181	31.19	0.9547	30.62
						0.9361	34.18	0.9717	34.12
						0.9582	39.08		
						0.9731	41.76		
						0.9848	44.87		
						1.0002	48.34		
$T = 336$ K		$T = 347$ K		$T = 355$ K		$T = 366$ K		$T = 381$ K	
0.7941	20.72	0.7943	24.48	0.7950	27.34	0.7954	31.06	0.7981	37.12
0.8213	23.33	0.8184	26.83	0.8240	30.52	0.8206	34.23	0.8230	40.53
0.8426	25.70	0.8436	29.89	0.8474	33.91	0.8461	38.10	0.8381	43.00
0.8733	29.04	0.8669	32.89	0.8675	36.53	0.8650	40.76	0.8582	46.25
0.8927	31.64	0.8896	36.25	0.8824	39.40	0.8802	43.61	0.8732	49.48
0.9089	34.61	0.9091	39.59	0.8969	41.79	0.9029	48.19	0.8844	52.08
0.9277	38.06	0.9268	43.22	0.9127	44.21	0.9232	51.47	0.8986	53.34
0.9413	40.81	0.9436	46.94	0.9256	47.21	0.9423	55.54	0.9036	55.48
0.9594	44.11	0.9598	49.97	0.9410	50.94	0.9565	58.67	0.9187	58.87
0.9763	48.28	0.9792	53.50	0.9557	53.50	0.9667	63.11	0.9272	61.82
0.9906	51.93	0.9964	58.29	0.9698	56.44	0.9872	66.59		
1.0060	55.26	1.0158	62.21	0.9849	60.51				
				0.9998	64.02				
				1.0081	66.57				
$T = 388$ K		$T = 399$ K		$T = 407$ K		$T = 419$ K		$T = 431$ K	
0.7943	39.25	0.7950	42.76	0.7944	46.18	0.7952	49.12	0.7956	52.74
0.8124	41.97	0.8148	45.78	0.8093	48.82	0.8127	52.41	0.8070	55.51
0.8246	44.37	0.8345	49.69	0.8238	51.56	0.8320	56.57	0.8209	58.31
0.8432	47.00	0.8465	51.85	0.8426	55.78	0.8467	59.74	0.8356	61.36
0.8614	50.51	0.8656	55.75	0.8603	58.95	0.8553	61.68	0.8506	65.77
0.8738	52.93	0.8813	59.17	0.8751	62.58	0.8616	64.47		
0.8901	56.25	0.8949	62.55	0.8836	65.34				
0.8951	57.82	0.9082	66.42						
0.9015	59.85								

Table 4. Density Data for Sulfur Hexafluoride + Carbon Dioxide [20.2% by Mass SF_6]

ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa
$T = 297$ K		$T = 317$ K		$T = 346$ K		$T = 372$ K	
0.6319	5.27	0.6488	9.01	0.6319	14.48	0.6319	19.93
0.8447	6.83	0.7354	10.34	0.7866	20.67	0.6485	20.70
0.9748	13.78	0.8407	13.83	0.8781	27.60	0.7676	27.58
1.0348	20.62	0.9383	20.66	0.9383	34.44	0.8444	34.47
1.0802	27.60	0.9978	27.57	0.9846	41.32	0.9013	41.34
1.1140	34.47	1.0432	34.52	1.0230	48.24	0.9461	48.24
1.1424	41.36	1.0786	41.40	1.0540	55.15	0.9841	55.15
1.1675	48.26	1.1123	48.29				
		1.1333	55.18				
$T = 397$ K		$T = 421$ K		$T = 442$ K			
0.6319	24.99	0.6319	29.78	0.6319	33.72		
0.6742	27.62	0.6911	34.45	0.6403	34.47		
0.7630	34.49	0.7624	41.38	0.7121	41.42		
0.8270	41.38	0.8174	48.26	0.7695	48.26		
0.8778	48.30	0.8638	55.15	0.8172	55.19		
0.9196	55.15						

Table 5. Density Data for Sulfur Hexafluoride + Carbon Dioxide [31.0% by Mass SF_6]

ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa
$T = 296$ K		$T = 317$ K		$T = 345$ K		$T = 367$ K	
0.6618	5.06	0.6628	8.78	0.6618	13.92	0.6618	18.40
0.7355	5.08	0.6777	9.10	0.7640	17.23	0.6892	19.54
0.8825	6.87	0.7062	9.41	0.8323	20.68	0.7153	20.68
0.9662	10.54	0.7701	10.34	0.9222	27.61	0.8287	27.59
1.0102	13.78	0.8711	13.78	0.9824	34.50	0.9024	34.47
1.0716	20.71	0.9712	20.75	1.0285	41.42	0.9578	41.42
1.1148	27.59	1.0294	27.53	1.0656	48.35	1.0006	48.26
1.1491	34.50	1.0749	34.47	1.0952	54.81	1.0381	55.35
1.1778	41.36	1.1106	41.45				
1.2029	48.31	1.1394	48.26				
1.2200	55.17	1.1655	55.15				
$T = 393$ K		$T = 418$ K		$T = 443$ K			
0.6362	22.00	0.6319	26.32	0.6319	30.72		
0.6779	24.13	0.6522	27.55	0.6363	31.02		
0.7358	27.57	0.7024	31.03	0.6800	34.47		
0.8235	34.48	0.7446	34.48	0.7532	41.36		
0.8868	41.36	0.8153	41.36	0.8130	48.26		
0.9385	48.26	0.8709	48.24	0.8621	55.21		
0.9812	55.22	0.9176	55.21				

Table 6. Density Data for Sulfur Hexafluoride + Carbon Dioxide [35.6% by Mass SF_6]

ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa
$T = 297$ K		$T = 318$ K		$T = 343$ K		$T = 369$ K	
0.6105	5.31	0.6105	8.35	0.6105	12.30	0.6105	16.48
0.8801	6.93	0.7692	10.34	0.6805	13.78	0.7238	20.68
1.0214	13.74	0.8838	13.83	0.8604	20.71	0.8408	27.57
1.0899	20.65	0.9913	20.72	0.9501	27.57	0.9203	34.49
1.1392	27.44	1.0561	27.57	1.0135	34.46	0.9775	41.36
		1.1033	34.47	1.0606	41.39	1.0239	48.26
		1.1230	37.95	1.0992	48.26	1.0614	55.15
				1.1322	55.15		
$T = 394$ K		$T = 420$ K		$T = 443$ K			
0.6105	20.68	0.6268	25.80	0.6234	29.44		
0.7423	27.57	0.6570	27.57	0.6920	34.52		
0.8326	34.47	0.7534	34.47	0.7671	41.36		
0.8988	41.36	0.8266	41.36	0.8277	48.26		
0.9514	48.24	0.8849	48.26	0.8785	55.13		
0.9958	55.15	0.9333	55.12				

297 to 425 K. Densities cover a range from about 0.74 to 0.94 g/cm^3. Results of independent measurements using the same experimental system and detailed comparisons with the literature have been provided in our earlier publications (Kiran *et al.*, 1995). Carbon dioxide densities are within 1.3% of the literature values at low temperatures, and within 2.5% at higher temperatures.

For SF_6, densities have been determined at pressures up to 60 MPa in the temperature interval from 299 to 430 K. A density range from about 1.05 to 1.60 has been covered. In the figure, limited literature data (Blanke *et al.*, 1993; DeZwaan and Jonas, 1975) at comparable temperatures are also included and are shown with the larger symbols. The average deviation at these limited comparison points is ±1.3%. It should be noted that the recent SF_6 data of high accuracy (Blanke *et al.*, 1993) are limited to pressures of less than 30 MPa.

b. Densities of the Binary Mixtures. The densities have been determined for mixtures containing 9, 20.2, 31, 35.6, and 50% by mass sulfur hexafluoride. The results are shown in Figures 4−8 over a wide range of temperatures from 296 to 430 K. Numerical data are given in Tables 3−7. As would be expected, densities of these fluids increase with pressure at a given temperature, but decrease with increasing temperature at a fixed pressure.

Table 7. Density Data for Sulfur Hexafluoride + Carbon Dioxide [50.0% by Mass SF_6]

ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa	ρ/(g/cm^3)	p/MPa
T = 296 K		T = 323 K		T = 348 K		T = 398 K		T = 423 K	
0.8133	6.08	0.8022	11.39	0.7922	17.18	0.7781	27.88	0.7721	33.10
1.0112	9.02	0.9512	15.98	0.8611	19.76	0.8292	31.15	0.8053	35.60
1.0781	12.49	1.0120	19.14	0.9263	23.19	0.8732	34.52	0.8411	38.68
1.1224	15.82	1.0610	22.83	0.9822	26.95	0.9171	38.36	0.8772	42.12
1.1463	18.02	1.0842	25.04	1.0271	30.70	0.9542	42.11	0.9123	45.77
		1.1033	26.95	1.0632	34.47	0.9883	46.06	0.9454	49.73
		1.1234	29.10	1.0962	38.51	1.0171	49.75	0.9752	53.68
		1.1471	32.04	1.1231	42.31	1.0441	53.56	1.0021	57.40
						1.0692	57.39	1.0260	61.19
						1.0912	60.93	1.0473	64.64
						1.1100	64.65		

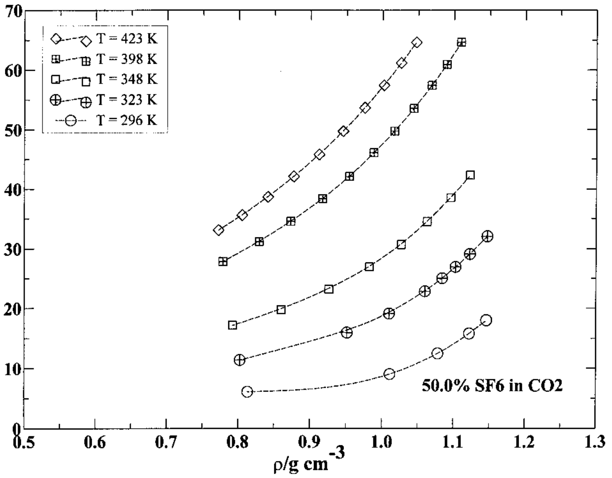

Figure 8. Variation of the density of the carbon dioxide + hexafluoride mixture (50.0% by mass SF_6) with pressure at selected temperatures.

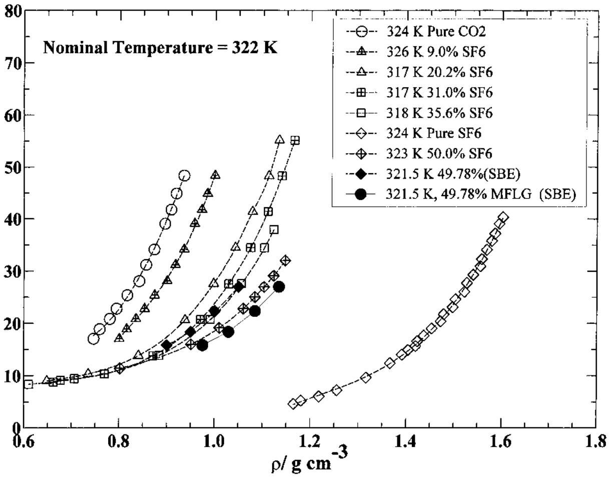

Figure 9. Variation of the density of the carbon dioxide + hexafluoride mixture with composition and pressure at a fixed temperature. SBE = data from Super *et al.* (1993).

Figure 9 shows a comparative plot of pressure versus density for different mixtures at comparable temperatures. The densities increase with increasing SF_6 content of the mixture. Since at the conditions investigated, SF_6 densities are higher than the highest density for carbon dioxide, the mixtures do not show the density crossovers that were encountered in the carbon dioxide + pentane system (Kiran *et al.*, 1995).

Density information on SF_6 + CO_2 mixtures have been reported at low temperatures (in the range from 295 to 336 K) for selected compositions (23 mol % or 49.78% by mass and higher SF_6 contents) (Super *et al.*, 1993). The measurements were conducted by a flotation technique in which the density of the mixture is assigned by determining the flotation point of small metal balls of known density. The same authors have also reported predictions by the mean-field lattice-gas theory (MFLG). The present data cover mixtures with 50% or lower SF_6 content. Their experimental data for 49.78% SF_6 and their prediction for the same mixture by mean-field lattice gas theory are also included in Figure 9. The data differ by about 6% from the present measurements. Their MFLG predictions compare better with the present data. Even though not shown in the figure, comparisons of the density data for this mixture at 295 K display similar differences.

Conclusions

Densities of carbon dioxide + sulfur hexafluoride mixtures over the entire composition range have been determined at temperatures in the range from 296 to 430 K and at pressures up to 70 MPa. It is shown that, at these conditions, depending upon the mixture composition, densities change from 0.7 to 1.6 g/cm^3. The density increases with increasing sulfur hexafluoride content of the mixture.

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