International Journal of Thermophysics, Vol. 21, No. 2, 2000

Dielectric Constant of the Nearly Azeotropic Mixture R410A[1]

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The purpose of this paper is to present dielectric constant measurements of R410A, a chlorine-free refrigerant, which is a 50/50 (mass%) mixture of R32/125. The measurements on R410A were performed as a function of pressure and temperature ranging from 2 to 16 MPa and from 217 to 304 K, respectively, by using a direct capacitance method. The values of dielectric constant have an estimated repeatability of ±0.01% and an accuracy of ±0.1%. The data were correlated as a function of density and pressure. The theory developed by Vedam et al., and adapted by Diguet, and the Kirkwood modification of the Onsager equation for the variation of the modified molar polarization with temperature and density were applied to analyze the data and to obtain the dipole moment of R410A in the liquid state. This was found to be 3.31 Debye.

KEY WORDS: azeotropic mixture; density; dielectric constant; Kirkwood equation; pressure; R410A; relative permittivity; Vedam equation.

1. INTRODUCTION

In the post-CFC phase out era, the transition to non-ozone-depleting refrigerants is still underway. New replacement refrigerants are in use in a variety of applications. One of those developments involves evaluating of

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[1] Paper presented at the Fifth Asian Thermophysical Properties Conference, August 30–September 2, 1998, Seoul, Korea.

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air conditioning equipment using R410A,[6] the leading non-ozone-depleting replacement for R22 in new air-conditioning equipment applications.

The refrigerant R410A is a high-pressure, nearly azeotropic mixture of R32 and R125 (50/50 mass%). Although its use requires a complete system redesign for optimum operation [1], it can display a better energy efficiency compared to R22 as a result of the more favorable pressure level, which leads to improved compressor efficiency and reduced energy losses in other system components.

An examination of the properties and performance of R410A reveals that this refrigerant has a higher heating capacity and is more energy efficient than R22, enabling the design of smaller, more compact air conditioning equipment. It has favorable heat-transfer and pressure-drop characteristics. The mixture of these refrigerants contains no chlorine and, therefore, does not deplete the stratospheric ozone layer. Both R32 and R125 have been studied in the Program for Alternative Fluorocarbon Toxicity Testing and found to be of low toxicity. As a result, the industry is beginning to settle on R410A as a standard refrigerant in new residential and light commercial unitary air conditioning equipment, except for centrifugal chillers, where R134a appears to be a more attractive choice.

Measurement of the dielectric constant allows the study of fluid molecular behavior when subjected to an electric field, which is related to chemical structure and molecular interactions. In industry, measuring the dielectric constant gives operational values for design parameters of machinery used in the air conditioning and refrigeration industry. This property also affects the electric properties of compressor lubricants, where the refrigerants are soluble.

In the present work we measured the dielectric constant of R410A in the temperature range from 217 to 304 K and at pressures from close to saturation to 16 MPa. Using a direct capacitance method, measurements were carried out in the liquid phase.

2. EXPERIMENT

Details of the experimental setup can be found in previous publications [2–6]. This is the first application to refrigerant mixtures. In this study, R410A, a binary mixture of R125 and R32, was investigated. The fluid has a purity of 99.5 mass% according to the supplier, Solvay Fluor

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[6] The refrigerant R410A is chlorine-free. The nomenclature HFC410A is not applicable, as it is a mixture, although it is the best way to identify the pure fluids R32 (HFC-32) and R125 (HFC-125). However, to maintain consistency, the ASRAHE designation is used throughout this paper.

Table I. Physical Properties and Purity of R410A

Chemical name	Difluoromethane/pentafluoroethane (50/50 mass%)
Molecular formula	CH_2F_2/CHF_2CF_3 (R32/R125)
Appearance	Colorless
Molar mass	$72.58\ g \cdot mol^{-1}$
Boiling point	$-52.7°C$
Estimated water content	<10 ppm
Purity	$>99.5\%$

und Derivate, Gmbh, Germany. The sample purity and the physical properties of the refrigerant studied are given in Table I. The measurements were made along 10 isotherms separated by about 10 K, in steps of 1 MPa, from 2 to 16 MPa. In the absence of density data at high pressures and low temperatures, the density values were calculated by a correlation scheme for binary and ternary refrigerant mixtures in the liquid state developed by Fialho and Nieto de Castro [7]. Using the hard-sphere DeSantis model (HSDS) and relating it with mixing and combining rules, it is possible to predict the liquid state densities with an uncertainty of 1.5% for reduced temperatures $\leqslant 0.9$.

3. RESULTS AND DISCUSSION

Each experimental value of the dielectric constant was calculated from the ratio of the capacitances of the cell filled with the fluid and the empty cell. Table II gives the data obtained as a function of pressure and density for each isotherm.

Figures 1 and 2 show the dielectric constant as a function of density and pressure, respectively, for all the isotherms. The behavior found for this mixture is identical to that found for pure fluids, in which $(\partial\varepsilon/\partial P)_T$ is positive and $(\partial\varepsilon/\partial T)_P$ is negative. However, $(\partial\varepsilon/\partial\rho)_T$ is always positive.

The experimental data of the dielectric constant were fitted by the following function in density and temperature (T in K and ρ in $kg \cdot m^{-3}$):

$$\varepsilon(T, \rho) = c_0 + c_1/T + d_0\rho + d_1\rho/T \tag{1}$$

with a mean deviation of 0.17%. The data were fitted by an iterative χ^2 method, implementing a Levenberg–Marquart method. The coefficients of Eq. (1) and their uncertainties are given in Table III.

As in our previous studies, we studied the dependence of dielectric constant on density using the concept of Eulerian deformation, based on

Table II. Experimental Values of the Dielectric Constant of R410A

T (K)	p (MPa)	ρ ($\mathrm{kg \cdot m^{-3}}$)	$\varepsilon(T, p)$	$\rho(T_n, p)$ ($\mathrm{kg \cdot m^{-3}}$)	$\varepsilon(T_n, p)$
		$T_n = 303.65$ K			
303.75	16.00	1138.7	9.6913	1139.0	9.695_4
303.76	15.06	1134.0	9.6379	1134.4	9.642_4
303.76	14.04	1128.8	9.5767	1129.2	9.581_2
303.76	13.09	1123.8	9.5174	1124.2	9.521_9
303.76	12.00	1117.9	9.4475	1118.3	9.452_0
303.77	11.14	1112.9	9.3896	1113.4	9.394_5
303.77	10.03	1106.3	9.3130	1106.8	9.317_9
303.76	8.91	1099.3	9.2312	1099.8	9.235_7
303.77	8.01	1093.4	9.1625	1093.9	9.167_4
303.77	7.10	1087.1	9.0896	1087.6	9.094_5
303.77	6.11	1079.9	9.0045	1080.5	9.009_4
303.78	4.98	1071.2	8.9007	1071.8	8.906_0
303.77	4.03	1063.4	8.8093	1064.0	8.814_2
303.77	3.01	1054.4	8.7012	1055.1	8.706_1
303.76	2.05	1045.5	8.5907	1046.1	8.595_2
		$T_n = 293.15$ K			
293.32	15.99	1172.9	10.5599	1173.4	10.56_7
293.31	15.00	1168.9	10.5076	1169.4	10.51_4
293.31	14.03	1164.8	10.4535	1165.3	10.46_0
293.31	13.05	1160.5	10.3968	1161.1	10.40_3
293.31	12.03	1155.9	10.3370	1156.5	10.344
293.31	11.14	1151.8	10.2829	1152.4	10.29_0
293.31	10.06	1146.6	10.2153	1147.2	10.22_2
293.33	9.02	1141.4	10.1452	1142.0	10.15_3
293.32	8.04	1136.3	10.0795	1137.0	10.08_7
293.31	7.25	1132.1	10.0254	1132.8	10.03_2
293.31	6.11	1125.8	9.9444	1126.5	9.951_0
293.33	4.99	1119.1	9.8569	1119.9	9.864_3
293.32	4.07	1113.5	9.7820	1114.3	9.789_0
293.31	3.04	1107.0	9.6998	1107.7	9.706_4
293.31	1.95	1099.6	9.5963	1100.4	9.602_9
		$T_n = 283.15$ K			
283.26	16.11	1205.5	11.4427	1205.8	11.44_7
283.25	15.02	1201.7	11.3877	1202.0	11.39_2
283.27	14.09	1198.3	11.3407	1198.7	11.34_6
283.25	13.04	1194.6	11.2857	1194.9	11.29_0
283.26	12.06	1190.9	11.2330	1191.2	11.23_8
283.25	11.01	1186.8	11.1746	1187.2	11.17_9
283.25	10.06	1183.1	11.1206	1183.4	11.12_5

Table II. *(Continued)*

T (K)	p (MPa)	ρ ($\mathrm{kg \cdot m^{-3}}$)	$\varepsilon(T, p)$	$\rho(T_n, p)$ ($\mathrm{kg \cdot m^{-3}}$)	$\varepsilon(T_n, p)$
283.25	9.01	1178.8	11.0592	1179.1	11.06_4
283.26	7.98	1174.4	10.9958	1174.8	11.00_1
283.26	6.95	1169.9	10.9299	1170.3	10.93_5
283.25	6.07	1166.0	10.8755	1166.4	10.88_0
283.26	5.00	1161.0	10.8014	1161.5	10.80_1
283.25	3.72	1154.9	10.7165	1155.3	10.72_1
283.25	3.05	1151.5	10.6661	1151.9	10.67_0
283.26	2.00	1146.0	10.5869	1146.5	10.59_2
$T_n = 273.15$ K					
273.07	15.87	1236.4	12.3707	1236.1	12.36_7
273.06	14.96	1233.7	12.3290	1233.4	12.32_5
273.06	14.07	1231.0	12.2868	1230.7	12.28_3
273.07	13.06	1227.9	12.2382	1227.6	12.23_5
273.07	12.04	1224.6	12.1874	1224.4	12.18_4
273.06	11.03	1221.4	12.1372	1221.1	12.13_3
273.06	10.06	1218.2	12.0867	1217.9	12.08_3
273.05	9.05	1214.8	12.0343	1214.5	12.03_0
273.06	8.02	1211.2	11.9778	1210.9	11.97_4
273.07	7.10	1207.9	11.9256	1207.6	11.92_2
273.05	5.93	1203.7	11.8580	1203.3	11.85_3
273.05	5.12	1200.6	11.8101	1200.3	11.80_5
273.05	3.84	1195.7	11.7331	1195.3	11.72_8
273.06	3.11	1192.7	11.6860	1192.4	11.68_2
273.06	2.11	1188.7	11.6536	1188.3	11.64_9
$T_n = 263.15$ K					
263.23	15.89	1266.3	13.3407	1266.6	13.34_5
263.23	14.94	1263.9	13.3201	1264.1	13.32_4
263.23	13.93	1261.3	13.2547	1261.5	13.25_9
263.24	13.03	1258.8	13.2149	1259.1	13.22_0
263.23	11.77	1255.4	13.1571	1255.7	13.16_1
263.23	11.02	1253.4	13.1216	1253.6	13.12_6
263.22	10.05	1250.7	13.0758	1250.9	13.07_9
263.22	9.06	1247.8	13.0292	1248.1	13.03_3
263.23	7.99	1244.7	12.9742	1244.9	12.97_8
263.24	7.02	1241.7	12.9250	1242.0	12.93_0
263.23	6.03	1238.7	12.8735	1239.0	12.87_8
263.23	5.11	1235.9	12.8235	1236.1	12.82_8
263.23	4.02	1232.4	12.7671	1232.7	12.77_1
263.23	3.17	1229.6	12.7164	1229.9	12.72_1
263.23	2.05	1225.8	12.6509	1226.1	12.65_5

Table II. *(Continued)*

T (K)	p (MPa)	ρ (kg · m^{-3})	$\varepsilon(T, p)$	$\rho(T_n, p)$ (kg · m^{-3})	$\varepsilon(T_n, p)$
$T_n = 253.15$ K					
253.23	16.00	1296.3	14.4232	1296.5	14.42_8
253.22	15.00	1294.1	14.3817	1294.3	14.38_6
253.22	14.00	1291.8	14.3395	1292.0	14.34_4
253.22	13.00	1289.5	14.2968	1289.7	14.30_1
253.22	12.00	1287.2	14.2535	1287.4	14.25_8
253.23	11.00	1284.8	14.2083	1285.0	14.21_3
253.23	10.00	1282.4	14.1633	1282.6	14.16_8
253.23	9.00	1279.9	14.1174	1280.2	14.12_2
253.22	8.00	1277.4	14.0723	1277.7	14.07_6
253.22	7.01	1274.9	14.0253	1275.2	14.02_9
253.22	6.00	1272.3	13.9761	1272.5	13.98_0
253.21	5.00	1269.7	13.9269	1269.9	13.93_0
253.22	4.00	1267.0	13.8757	1267.2	13.88_0
253.21	3.02	1264.3	13.8261	1264.5	13.83_0
253.21	2.02	1261.5	13.7731	1261.8	13.77_7
$T_n = 243.65$ K					
243.49	15.82	1324.3	15.5603	1323.8	15.55_0
243.49	15.02	1322.7	15.5441	1322.3	15.53_3
243.49	14.06	1320.8	15.4889	1320.3	15.47_8
243.50	13.00	1318.6	15.4449	1318.2	15.43_5
243.50	12.10	1316.8	15.4077	1316.4	15.39_8
243.50	11.06	1314.7	15.3654	1314.2	15.35_5
243.51	10.05	1312.5	15.3192	1312.1	15.31_0
243.50	9.03	1310.4	15.2751	1309.9	15.26_5
243.52	8.02	1308.1	15.2284	1307.7	15.22_0
243.52	7.04	1306.0	15.1848	1305.6	15.17_6
243.51	5.99	1303.7	15.1381	1303.2	15.12_9
243.52	4.97	1301.3	15.0881	1300.9	15.07_9
243.53	4.06	1299.2	15.0389	1298.8	15.03_1
243.52	3.57	1298.1	15.0221	1297.7	15.01_3
243.52	3.06	1296.9	14.9973	1296.5	14.98_9
$T_n = 233.65$ K					
233.78	15.98	1352.4	16.8357	1352.8	16.84_6
233.78	14.98	1350.7	16.7978	1351.1	16.80_8
233.77	13.98	1349.0	16.7586	1349.3	16.76_8
233.77	13.00	1347.2	16.7206	1347.6	16.73_0
233.78	12.00	1345.4	16.6804	1345.8	16.69_1
233.77	11.02	1343.6	16.6414	1344.0	16.65_1
233.77	10.00	1341.8	16.5996	1342.1	16.60_9

Table II. *(Continued)*

T (K)	p (MPa)	ρ (kg · m^{-3})	$\varepsilon(T, p)$	$\rho(T_n, p)$ (kg · m^{-3})	$\varepsilon(T_n, p)$
233.77	9.00	1339.9	16.5574	1340.2	16.56_7
233.77	8.00	1338.0	16.5176	1338.4	16.52_7
233.77	7.00	1336.1	16.4769	1336.5	16.48_6
233.77	6.02	1334.2	16.4293	1334.6	16.43_8
233.77	5.02	1332.2	16.3873	1332.6	16.39_6
233.77	4.02	1330.2	16.3404	1330.6	16.35_0
233.77	3.01	1328.2	16.2962	1328.6	16.30_5
233.77	2.02	1326.2	16.2492	1326.6	16.25_8
		$T_n = 224.65$ K			
224.45	15.94	1378.7	18.1796	1378.2	18.16_2
224.44	15.00	1377.3	18.1451	1376.7	18.12_7
224.44	13.99	1375.7	18.1078	1375.1	18.09_0
224.44	13.01	1374.2	18.0704	1373.6	18.05_2
224.44	12.02	1372.6	18.0331	1372.0	18.01_5
224.44	10.96	1370.9	17.9887	1370.3	17.97_1
224.43	9.98	1369.3	17.9513	1368.7	17.93_2
224.43	9.01	1367.7	17.9106	1367.1	17.89_2
224.44	8.01	1366.0	17.8696	1365.4	17.85_1
224.44	6.91	1364.1	17.8257	1363.5	17.80_8
224.44	5.93	1362.5	17.7842	1361.8	17.76_6
224.43	4.90	1360.7	17.7416	1360.0	17.72_3
224.43	3.94	1359.0	17.6997	1358.4	17.68_1
224.43	2.97	1357.3	17.6600	1356.6	17.64_1
224.42	2.01	1355.6	17.6306	1354.9	17.61_1
		$T_n = 217.15$ K			
217.23	16.00	1399.1	19.3381	1399.3	19.34_6
217.23	15.00	1397.7	19.3011	1397.9	19.30_9
217.22	14.00	1396.3	19.2656	1396.5	19.27_2
217.27	13.00	1394.7	19.2213	1395.0	19.23_3
217.29	11.99	1393.1	19.1785	1393.5	19.19_2
217.28	10.99	1391.7	19.1409	1392.0	19.15_3
217.19	10.00	1390.4	19.1145	1390.6	19.11_8
217.17	8.99	1389.0	19.0803	1389.0	19.08_2
217.16	7.98	1387.5	19.0416	1387.5	19.04_3
217.23	7.00	1385.7	18.9955	1386.0	19.00_3
217.26	6.02	1384.1	18.9474	1384.4	18.95_8
217.24	5.01	1382.6	18.9065	1382.9	18.91_5
217.21	4.01	1381.1	18.8691	1381.3	18.87_5
217.19	3.00	1379.5	18.8301	1379.6	18.83_4
217.18	2.01	1377.9	18.7909	1378.0	18.79_4

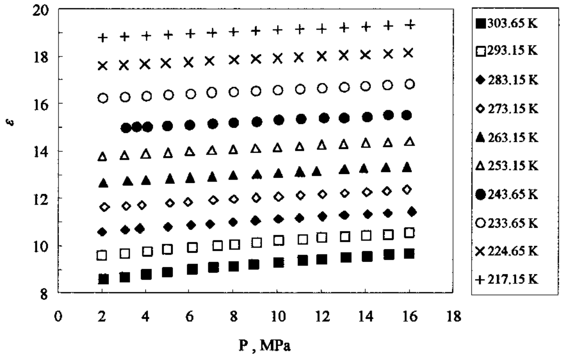

Fig. 1. Graphical representation of the dielectric constant as a function of density, along isotherms.

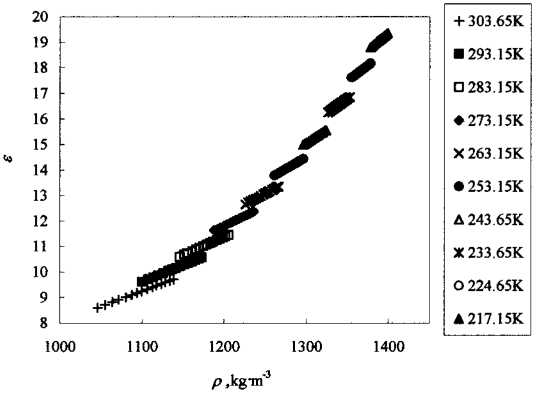

Fig. 2. Graphical representation of the dielectric constant as a function of pressure, along isotherms.

Table III. Coefficients of Eq. (1)

c_0	c_1 (K)	$10^{-2}d_0$ ($\mathrm{kg^{-1} \cdot m^3}$)	d_1 ($\mathrm{K \cdot m^3 \cdot kg^{-1}}$)
12.012 ± 0.426	5159 ± 152	-1.0188 ± 0.0275	7.027 ± 0.097

the work of Vedam et al. [8, 9] and Diguet [10]. According to this theory, the variation of the dielectric constant with pressure is a function of the volume deformation, showing a nonlinear behavior in the case of liquids. This nonlinearity can be reduced when the variation of ε and $\Delta\varepsilon$ is analyzed as a function of the Eulerian deformation Σ, also called the Eulerian strain. We can verify that Σ provides a linear relation for Δ independent of the type of molecules that compose the fluid. The Vedam relation was extended to the dielectric constant data from previous analysis of the refractive index versus density results at a given temperature. We used the relation between $\varepsilon^{1/2}$ and the Eulerian strain Σ, which is defined according to the Vedam relation as

$$\Delta = \varepsilon^{1/2}(\rho) - \varepsilon^{1/2}(\rho_0) \qquad (2)$$

$$\Sigma = \frac{1}{2}\left[\left(1 - \frac{\rho}{\rho_0}\right)^{2/3}\right] \qquad (3)$$

Here ρ_0 is the reference density, taken as the saturated liquid density value for each isotherm. No experimental data exist for temperatures below −30°C. The saturation density data of R410A were calculated by correlating the experimental values measured by Widiatmo et al. [11] for the interval 280 to 310 K with an estimated uncertainty of $\pm 0.2\%$ and by extrapolating to lower temperatures. We also compared these data with the values reported by Piao et al. [12], measured in the temperature range of −30 to 60°C. No reference is made to the uncertainty of these data. A comparison between these experimental data sets show deviations from the extrapolated data of 6% at low temperature. All of these data sets (experimental and extrapolated) are shown in Fig. 3. The extrapolation is in agreement to within 2.5% with the REFPROP database [13], the same

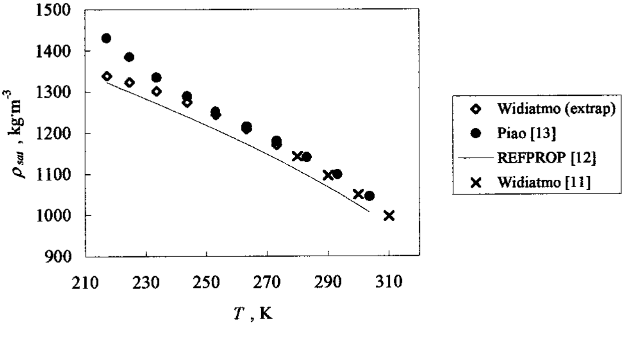

Fig. 3. The saturation density of R410A as a function of temperature.

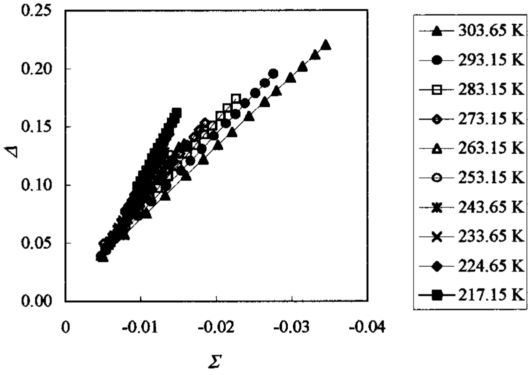

Fig. 4. Variation of Δ with the Eulerian strain Σ, Eq. (3).

deviation as found between REFPROP and the Widiatmo et al. [11] experimental data.

From the data obtained it is possible to conclude that the function Δ indeed represents a linear variation with the Eulerian strain Σ, as can be seen in Fig. 4. Some noise in the behavior of the Eulerian function at low temperatures can be attributed to the low accuracy in the saturation density values used, as compared to the accuracy achieved in earlier studies for pure refrigerants.

As observed in previous studies, it was found that the slope of the linear variation of Δ with Σ is negative for all temperatures and the *y*-crossing values are close to zero for all isotherms, $B \cong 0$. Table IV presents the

Table IV. Values of the Constants A and B of the Vedam Equation, Eq. (2)

T (K)	ρ_{sat} $(\mathrm{kg \cdot m^{-3}})^a$	$\varepsilon(\rho_{\mathrm{sat}})$	A	B
217.15	1339.3	17.949	−12.094	−0.01762
224.65	1323.3	16.958	−11.431	−0.01329
233.65	1301.4	15.813	−10.829	−0.01359
243.65	1273.6	14.595	−10.233	−0.00993
253.15	1243.9	13.489	−9.3755	−0.00548
263.15	1209.0	12.375	−8.7161	−0.00114
273.15	1170.5	11.312	−7.9091	0.00660
283.15	1128.4	10.299	−7.4565	0.00568
293.15	1082.6	9.334	−6.8307	0.00716
303.65	1030.6	8.372	−6.1474	0.00900

[a] The values of the saturation density were obtained according to the procedure described in the text, based on the experimental data of Widiatmo et al. [11].

values of the coefficients A and B of the Vedam equation for each isotherm. As a consequence, using the concept of Eulerian strain seems to be completely appropriate for the interpretation of the density dependence of dielectric constant data.

The Vedam relation can be used to estimate the dielectric constant assuming that $B=0$ in Eq. (2). In this work the experimental data were recalculated by fitting the data as a function of Σ, in this case with a constraint that "the constant" B is equal to zero. The Vedam equation takes the following form:

$$\Delta = A'\Sigma \tag{4}$$

The new values of the slope A' according to Eq. (4) are presented in Table V. We can estimate the dielectric constant as a function of density for each isotherm, using Eq. (4), where $\varepsilon^{1/2}(\rho_0)$ is constant at a given temperature, to within 0.3%.

In the present work we correlate the dielectric constant data with the apparent dipole moment μ^* using the equation developed by Kirkwood [14] for the liquid state:

$$\frac{(\varepsilon-1)(2\varepsilon+1)}{9\varepsilon}\frac{M}{\rho}=\frac{4\pi N_0}{3}\left(\alpha+\frac{g\mu^2}{3k_\mathrm{B}T}\right) \tag{5}$$

The value of μ^* was obtained from the slope of the line, representing the left side of the equation (Kirkwood function) as a function of $1/T$. In this equation M is the molar mass of the fluid, N_0 is Avogadro's number, α is the molecular polarizability of the molecule, ε_0 is the electric permittivity in vacuum, T is the temperature, and k_B is the Boltzmann constant.

Table V. Values of the Constant A' in Eq. (4)

T (K)	A'
217.15	−10.6842
224.65	−10.2449
233.65	−9.50539
243.65	−9.23844
253.15	−8.84878
263.15	−8.61770
273.15	−8.39324
283.15	−7.80106
293.15	−7.18496
303.65	−6.50565

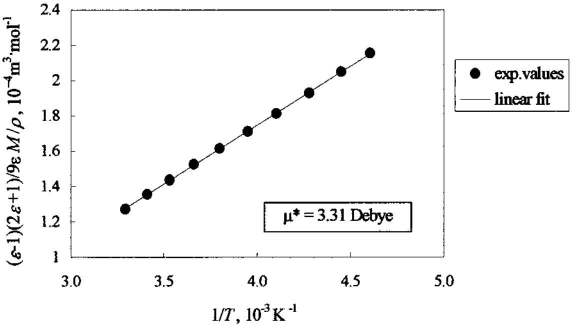

Fig. 5. Kirkwood function versus $1/T$ for R410A.

Figure 5 shows the plot of the Kirkwood function versus $1/T$ for all isotherms studied and the value of the apparent dipole moment μ^*, which was found to be equal to 3.31 Debye.

The relation between the dipole moment of a binary mixture in the liquid state and the dipole moments of its components is not well understood, except for dilute solutions of polar components in nonpolar solvents. In this case we have a 50/50 mass% mixture of R32 and R125, which corresponds to a mole fraction composition of $x_{32} = 0.6976$. As it has been shown that the volumetric properties of these refrigerant mixtures are nearly ideal, we can assume an ideal combining law for the dipole moment of the binary mixture,

$$\mu^*_{\mathrm{mix}} = x_1\mu^*_1 + x_2\mu^*_2 \tag{6}$$

The values of the dipole moments in the liquid phase have been calculated by the authors and found to be 3.60 Debye for R32 and 2.48 Debye for R125 [6, 15]. The value calculated from Eq. (6) is 3.26 Debye, a value which is in excellent agreement with the value found experimentally. This result seems to support the use of a law of the type of Eq. (6) to estimate the dipole moments of these types of binary mixtures in the liquid state. However, we need further mixture data to validate this statement, and experimental results for other binary and ternary mixtures of refrigerants will be published in the future.

4. CONCLUSION

This work presents experimental dielectric constant data of a single refrigerant blend, R410A, a nearly azeotropic mixture of R32 and R125, as a function of pressure and temperature. The data for R410A cover 10 isotherms from 217 to 304 K at pressures up to 16 MPa.

These data were analyzed using the concept of Eulerian strain and the Kirkwood function. We can conclude that the Eulerian function seems to be successful in representing the density dependence of the dielectric constant. It is possible to estimate the dielectric constant data at any given temperature, assuming that $B = 0$ in Eq. (2). As shown, the Vedam relation can be used as a predictive tool for the dielectric constant of refrigerants.

Also presented was the value of the apparent dipole moment in the liquid phase μ^* for R410A, which was found to be equal to 3.31 Debye. A mole fraction average model was successfully applied to the estimation of the dipole moment of the binary mixture from the values of the dipole moments of the pure components.

ACKNOWLEDGMENTS

The authors would like to thank Solvay Fluor und Derivate for supplying the refrigerant blend R410A. A.N.G. gratefully acknowledges FCT (PRAXIS XXI) for a postdoctoral research grant.

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