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Thermodynamic Properties of 1-Alkenes in the Liquid State: 1-Tetradecene[1]

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Thermodynamic properties of liquid 1-tetradecene have been calculated using a grid algorithm based on sound-speed data, obtained in a previous study over a wide range of temperatures and pressures. Since additional information such as densities and isobaric heat capacities at atmospheric pressure are needed for these calculations, the most reliable literature data and those obtained on the basis of structure–property correlations in the homologous series of 1-alkenes were used. Detailed tables, containing values of sound speed, density, isobaric, and isochoric heat capacities, isobaric expansion coefficient, isothermal compressibility, enthalpy, and entropy in the range of temperatures from 303 to 433 K and at pressures from 0.1 to 100 MPa, are given.

KEY WORDS: density; enthalpy; entropy; heat capacity; isobaric expansion coefficient; isothermal compressibility; sound speed; 1-tetradecene.

1. INTRODUCTION

The thermodynamic properties of liquid hydrocarbons of the ethylene series, especially their higher homologs, are of both theoretical and practical interest. To determine these properties at increased pressure with great accuracy, the acoustic method has been applied where the measured sound speed in the liquid state together with literature data for the density and isobaric heat capacities at atmospheric pressure are used to calculate

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such important thermodynamic properties as density, heat capacity, and compressibility. This approach has been used previously [1,2] to investigate the thermodynamic properties of liquid n-alkanes. In the present paper liquid 1-tetradecene (C_{14}), which is representative of the 1-alkene series having the common formula C_nH_{2n}, has been taken as the subject of investigation. It should be noted that information on the thermodynamic properties of liquid 1-alkenes is available for the lower homologs, while the higher ones have been investigated to a less degree. As a result, there is a lack of studies of the thermodynamic properties at high pressures for the alkenes beginning with C_{11} and higher (or at least they are unknown to the authors).

2. INPUT DATA

2.1. Sound-Speed Data

As input data for sound speed, we used the results of our previous study [3] carried out on an ultrasound apparatus using the pulse-echo overlap method. The measurements were made along eight isotherms: 303.15, 313.15, 333.15, 353.15, 373.15, 393.15, 413.15, and 433.15 K both under pressurization from 0.1 to 100.1 MPa and under decompression from 100.1 to 0.1 MPa. In this case, the differences in sound speed on all investigated isotherms did not exceed 0.01%. The reproducibility of the sound-speed data obtained in the course of repeated measurements taken at different temperatures and different pressures (including the starting temperature and atmospheric pressure) is within 0.03%, whereas the maximum uncertainty is estimated as 0.1%.

As a sample for investigation, 1-tetradecene (made by "Fluka" with a mass purity of the main product greater than 97%) has been used. The purity of the sample before and after the measurements was kept under control by gas–liquid chromatography analysis, the results of which showed that the composition of the sample remained unchanged.

Measured experimental values were corrected for diffraction and for waveguide effects. Sound-speed dispersion did not place in the range of investigated parameters. The experimental procedure and features of the apparatus have been described in detail previously [4].

Experimental results for 1-tetradecene (72 sound-speed values) in the investigated range have been obtained for the first time and can be found elsewhere [3].

Thus obtained sound-speed values have been fitted by the equation,

$$\left(\frac{1000}{W}\right)^2 = A + \frac{B}{C + p/100} + \frac{D}{E + p/100}, \quad (1)$$

where W is the sound speed in m·s^{-1}; p is the pressure in MPa; A and B are constants; and C, D, and E are temperature-dependent functions.

The temperature dependences of C, D, and E are represented below:

$$C = c_0 + c_2 \left(T/100\right)^n, \quad (2)$$

$$D = d_0 + d_1 \left(T/100\right), \quad (3)$$

$$E = e_0 + e_1 \left[(T_c - T)/100\right] + e_2 \left[(T_c - T)/100\right]^k, \quad (4)$$

where T and T_c are the temperature and critical temperature, respectively; c_0, c_2, d_0, d_1, e_0, e_1, e_2 are fitting coefficients; and n and k are exponents.

The critical temperature of 1-tetradecene $T_c = 692.0$ K has been taken from a review [5]. As a result of analysis, the constant values $A = 0.056365$ and $B = 0.47292$ of Eq. (1) have been calculated along with the values of the exponents $n = -0.63$ and $k = 3.1$ and the coefficients of Eqs. (2–4). The values of these coefficients are given in Table I.

Equation (1) describes the initial values of the sound speed at $T = 303$ to 433 K and $p = 0.1$ to 100 MPa with standard and maximum deviations, respectively, of 0.005 and 0.014%.

2.2. Density and Isobaric Heat Capacity at Atmospheric Pressure

A more detailed list of experimental studies on the thermodynamic properties of alkenes and their analysis is given in a review [5]. The numerical values of a number of properties for different temperatures at atmospheric pressure and on the saturation curve with given uncertainties

Table I. Coefficients c_i, d_i, and e_i of Eqs. (2–4)

I	c_i	d_i	e_i
0	−1.4686	0.022826	−0.0162
1	–	0.060845	0.08209
2	6.7049	–	0.005966

are presented in the review. The given density values for liquid 1-tetradecene cover a range of temperatures from 293 to 360 K, with an uncertainty of 0.5–2 kg·m^{-3}. The heat capacity values in the paper [5] are not represented. A lack of reliable data on the density at temperatures above 360 K and the heat capacity over the complete range of temperatures motivated us to carry out a study to determine these properties on the basis of structure–property correlations in the homologous series of 1-alkenes.

Having analyzed the collection of all the data available for all homologs, it has been estimated that the dependence of the molar volume and the molar heat capacity on the molecular mass in the 1-alkene series from C_6 to C_{16} shows a nearly linear relationship. With the help of analytical graph interpolation and extrapolation, the missing density and isobaric heat capacity values for temperatures from 360 to 433 K and from 303 to 433 K, respectively, were calculated.

Thus obtained, the density values together with the numerical results given in the report [5] were used to determine the temperature dependence of the density ρ_0 (kg·m^{-3}) at atmospheric pressure in the temperature range 293 to 433 K:

$$\rho_0 = 4.52685 \times 10^2 + 9.13779 \times 10^{-1} (T_c - T) - 2.892 \times 10^{-4} (T_c - T)^2, \quad (5)$$

The values of the isobaric heat capacity c_{p0} (kJ·kg^{-1}·K^{-1}) at atmospheric pressure in the temperature range 293–433 K were represented by the following relation:

$$c_{p0} = F + \frac{G}{M_r} + \frac{H}{M_r^2}, \quad (6)$$

where F, G, and H are temperature-dependent parameters; and $M_r =$ 196.3752 kg·kmol^{-1} is the molar mass.

The temperature dependences of F, G, and H have the forms:

$$F = 1.169818 - 0.0695169\,(T/100) + 0.499735\,(T/100)^{0.85};$$
$$G = 2898.516 + 53.49245\,(T/100) - 2916.749\,(T/100)^{0.05};$$
$$H = 13.0689 + 504.2273\,(T/100) + 13.5747\,(T/100)^{-1.2}.$$

It should be noted that during initial data analysis the distinction between density and heat capacity values obtained at atmospheric pressure and those obtained on the saturation curve was not taken into account, as the difference between them according to our estimates is much less than the error in the experimental data.

3. CALCULATION OF THERMODYNAMIC PROPERTIES

To calculate the thermodynamic properties of liquid 1-tetradecene on the basis of sound-speed data, a grid algorithm was used.

A calculation technique for the thermodynamic properties comes from the well known relationships:

$$\left(\frac{\partial \rho}{\partial p}\right)_T = \frac{1}{W^2} + \frac{T\alpha_p^2}{c_p}, \tag{7}$$

$$\left(\frac{\partial c_p}{\partial p}\right)_T = -\frac{T}{\rho}\left[\alpha_p^2 + \left(\frac{\partial \alpha_p}{\partial T}\right)_p\right], \tag{8}$$

$$\alpha_p = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_p, \tag{9}$$

$$\beta_T = \frac{1}{\rho}\left(\frac{1}{W^2} + \frac{T\alpha_p^2}{c_p}\right), \tag{10}$$

$$c_v = \frac{c_p}{\left(1 + \frac{T\alpha_p^2 W^2}{c_p}\right)}, \tag{11}$$

$$h = h_{00} + \int_{T_0}^{T} c_{p0}\,dT + \int_{p_0}^{p} \frac{1}{\rho}\left(1 - T\alpha_p\right) dp, \tag{12}$$

$$s = s_{00} + \int_{T_0}^{T} \frac{c_{p0}}{T}\,dT - \int_{p_0}^{p} \frac{\alpha_p}{\rho}\,dp, \tag{13}$$

where ρ is the density; c_p and c_v are, respectively, the isobaric and isochoric heat capacities; α_p is the thermal expansion coefficient; β_T is the isothermal compressibility; h is the enthalpy; and s is the entropy.

Equations (7) and (8) forming a closed system, were written in a dimensionless form and were solved numerically in the range of 0.1 MPa $\leq p \leq$100 MPa and 303 K $\leq T \leq$433 K with boundary condition $\rho_0(p_0, T)$; $c_{p0}(p_0, T)$ at atmospheric pressure; and a field of sound speeds

Table II. Sound Speed W ($m \cdot s^{-1}$) in 1-Tetradecene

p(MPa)	T(K) 303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	1287.3	1250.6	1214.5	1179.0	1144.1	1109.7	1076.0	1042.7	1010.0	977.7	946.0	914.7	883.9	853.6
2.5	1301.3	1265.1	1229.6	1194.7	1160.4	1126.8	1093.7	1061.2	1029.2	997.8	966.9	936.6	906.8	877.4
5	1315.4	1279.8	1244.9	1210.6	1177.0	1144.0	1111.6	1079.8	1048.6	1017.9	987.9	958.4	929.4	901.0
10	1342.8	1308.2	1274.3	1241.1	1208.6	1176.8	1145.6	1115.0	1085.1	1055.8	1027.2	999.1	971.7	944.9
15	1369.1	1335.3	1302.4	1270.1	1238.6	1207.8	1177.6	1148.1	1119.3	1091.2	1063.7	1036.8	1010.6	985.0
20	1394.2	1361.3	1329.2	1297.8	1267.1	1237.2	1207.9	1179.4	1151.5	1124.3	1097.8	1072.0	1046.8	1022.2
25	1418.4	1386.2	1354.9	1324.2	1294.3	1265.2	1236.8	1209.0	1182.0	1155.6	1130.0	1105.0	1080.6	1056.9
30	1441.8	1410.3	1379.6	1349.6	1320.4	1292.0	1264.3	1237.3	1211.0	1185.3	1160.4	1136.1	1112.5	1089.6
40	1486.1	1455.8	1426.4	1397.6	1369.7	1342.4	1316.0	1290.2	1265.1	1240.7	1217.0	1194.0	1171.6	1149.9
50	1527.9	1498.6	1470.2	1442.5	1415.5	1389.3	1363.9	1339.1	1315.0	1291.7	1268.9	1246.9	1225.5	1204.7
60	1567.3	1539.0	1511.4	1484.6	1458.6	1433.3	1408.7	1384.8	1361.6	1339.0	1317.1	1295.9	1275.3	1255.3
70	1604.8	1577.3	1550.5	1524.5	1499.2	1474.7	1450.9	1427.7	1405.2	1383.4	1362.2	1341.7	1321.7	1302.3
80	1640.5	1613.7	1587.7	1562.4	1537.8	1513.9	1490.8	1468.3	1446.4	1425.2	1404.7	1384.7	1365.3	1346.5
90	1674.7	1648.5	1623.1	1598.5	1574.5	1551.3	1528.7	1506.8	1485.5	1464.9	1444.9	1425.4	1406.6	1388.3
100	1707.5	1681.9	1657.1	1633.0	1609.7	1587.0	1564.9	1543.5	1522.8	1502.6	1483.1	1464.1	1445.7	1427.8

Table III. Density ρ ($kg \cdot m^{-3}$) of 1-Tetradecene

p (MPa)	T(K) 303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	764.3	757.4	750.4	743.4	736.3	729.1	721.9	714.6	707.3	699.9	692.5	685.0	677.5	669.8
2.5	766.0	759.2	752.3	745.4	738.4	731.4	724.3	717.2	710.0	702.8	695.6	688.3	680.9	673.5
5	767.7	761.0	754.2	747.4	740.6	733.7	726.7	719.7	712.7	705.7	698.6	691.5	684.4	677.2
10	771.1	764.5	757.9	751.3	744.7	738.0	731.3	724.6	717.9	711.1	704.3	697.5	690.7	683.9
15	774.3	767.9	761.5	755.1	748.6	742.1	735.6	729.1	722.6	716.1	709.6	703.1	696.6	690.1
20	777.4	771.1	764.9	758.6	752.3	746.0	739.7	733.4	727.1	720.8	714.5	708.3	702.0	695.8
25	780.3	774.3	768.1	762.0	755.9	749.8	743.6	737.5	731.4	725.3	719.2	713.1	707.1	701.1
30	783.2	777.3	771.3	765.3	759.3	753.3	747.3	741.4	735.4	729.5	723.5	717.7	711.8	706.0
40	788.7	782.9	777.2	771.5	765.7	760.0	754.3	748.6	742.9	737.3	731.6	726.1	720.5	715.1
50	793.8	788.3	782.7	777.2	771.7	766.2	760.7	755.2	749.8	744.4	739.0	733.7	728.4	723.2
60	798.7	793.3	787.9	782.6	777.3	771.9	766.6	761.4	756.2	751.0	745.8	740.7	735.7	730.7
70	803.3	798.1	792.9	787.7	782.5	777.4	772.2	767.2	762.1	757.1	752.1	747.2	742.3	737.6
80	807.7	802.6	797.6	792.5	787.5	782.5	777.5	772.6	767.7	762.8	758.0	753.3	748.6	744.0
90	811.9	806.9	802.0	797.1	792.2	787.3	782.5	777.7	773.0	768.2	763.6	759.0	754.4	749.9
100	815.9	811.1	806.3	801.5	796.7	792.0	787.3	782.6	778.0	773.4	768.8	764.4	759.9	755.6

Table IV. Isobaric Heat Capacity c_p ($kJ \cdot kg^{-1} \cdot K^{-1}$) of 1-Tetradecene

	T(K)													
p (MPa)	303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	2.168	2.200	2.232	2.266	2.299	2.333	2.368	2.403	2.438	2.474	2.510	2.547	2.583	2.621
2.5	2.166	2.198	2.230	2.263	2.296	2.330	2.365	2.399	2.435	2.470	2.506	2.542	2.579	2.615
5	2.164	2.195	2.228	2.260	2.294	2.327	2.362	2.396	2.431	2.466	2.502	2.538	2.574	2.611
10	2.160	2.191	2.223	2.256	2.289	2.322	2.356	2.391	2.425	2.460	2.495	2.531	2.567	2.603
15	2.157	2.188	2.220	2.252	2.285	2.318	2.352	2.386	2.420	2.455	2.490	2.525	2.560	2.596
20	2.154	2.185	2.217	2.249	2.281	2.314	2.348	2.382	2.416	2.450	2.485	2.520	2.555	2.590
25	2.152	2.183	2.214	2.246	2.279	2.311	2.345	2.378	2.412	2.446	2.481	2.515	2.550	2.586
30	2.150	2.180	2.212	2.244	2.276	2.309	2.342	2.375	2.409	2.443	2.477	2.512	2.547	2.582
40	2.146	2.177	2.208	2.240	2.272	2.304	2.337	2.370	2.404	2.438	2.472	2.506	2.541	2.575
50	2.143	2.174	2.205	2.236	2.268	2.301	2.333	2.366	2.400	2.434	2.467	2.502	2.536	2.571
60	2.141	2.171	2.202	2.234	2.266	2.298	2.331	2.364	2.397	2.430	2.464	2.498	2.533	2.567
70	2.139	2.170	2.200	2.232	2.264	2.296	2.328	2.361	2.394	2.428	2.462	2.496	2.530	2.564
80	2.138	2.168	2.199	2.230	2.262	2.294	2.327	2.359	2.393	2.426	2.460	2.494	2.528	2.562
90	2.136	2.167	2.198	2.229	2.261	2.293	2.325	2.358	2.391	2.425	2.458	2.492	2.526	2.561
100	2.135	2.166	2.197	2.228	2.259	2.292	2.324	2.357	2.390	2.424	2.457	2.491	2.525	2.560

Table V. Isochoric Heat Capacity c_v ($kJ \cdot kg^{-1} \cdot K^{-1}$) of 1-Tetradecene

	T(K)													
p (MPa)	303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	1.824	1.853	1.882	1.913	1.944	1.976	2.009	2.044	2.078	2.114	2.151	2.188	2.227	2.266
2.5	1.824	1.853	1.883	1.914	1.945	1.978	2.011	2.045	2.080	2.115	2.152	2.189	2.227	2.265
5	1.824	1.853	1.883	1.914	1.946	1.979	2.012	2.046	2.081	2.116	2.153	2.189	2.227	2.265
10	1.825	1.855	1.885	1.916	1.948	1.981	2.015	2.049	2.083	2.119	2.154	2.191	2.228	2.265
15	1.826	1.856	1.887	1.918	1.950	1.983	2.017	2.051	2.086	2.121	2.156	2.192	2.229	2.266
20	1.828	1.858	1.889	1.920	1.953	1.985	2.019	2.053	2.088	2.123	2.158	2.194	2.230	2.267
25	1.829	1.860	1.891	1.922	1.955	1.988	2.021	2.055	2.090	2.125	2.160	2.196	2.232	2.268
30	1.831	1.861	1.893	1.924	1.957	1.990	2.023	2.057	2.092	2.127	2.162	2.197	2.233	2.269
40	1.835	1.865	1.897	1.928	1.961	1.994	2.027	2.061	2.095	2.130	2.165	2.201	2.236	2.272
50	1.839	1.869	1.900	1.932	1.965	1.998	2.031	2.065	2.099	2.134	2.169	2.204	2.240	2.276
60	1.843	1.873	1.904	1.936	1.968	2.001	2.035	2.069	2.103	2.137	2.172	2.208	2.243	2.279
70	1.847	1.877	1.908	1.940	1.972	2.005	2.038	2.072	2.106	2.141	2.176	2.211	2.247	2.282
80	1.850	1.881	1.912	1.943	1.976	2.008	2.042	2.075	2.110	2.144	2.179	2.214	2.250	2.286
90	1.854	1.884	1.915	1.947	1.979	2.012	2.045	2.079	2.113	2.147	2.182	2.218	2.253	2.289
100	1.858	1.888	1.919	1.950	1.982	2.015	2.048	2.082	2.116	2.151	2.185	2.221	2.256	2.292

Table VI. Isobaric Expansion Coefficient $\alpha_p \times 10^3$ (K^{-1}) of 1-Tetradecene

	T(K)													
p (MPa)	303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	0.901	0.917	0.933	0.950	0.967	0.984	1.002	1.021	1.039	1.059	1.078	1.099	1.119	1.141
2.5	0.889	0.903	0.917	0.932	0.947	0.963	0.979	0.995	1.012	1.029	1.046	1.064	1.083	1.101
5	0.876	0.889	0.902	0.915	0.928	0.942	0.956	0.971	0.985	1.001	1.016	1.032	1.048	1.065
10	0.852	0.862	0.872	0.883	0.894	0.905	0.916	0.927	0.939	0.951	0.963	0.976	0.988	1.001
15	0.829	0.837	0.846	0.854	0.863	0.872	0.881	0.890	0.899	0.909	0.918	0.928	0.938	0.949
20	0.808	0.815	0.821	0.828	0.835	0.842	0.850	0.857	0.864	0.872	0.880	0.888	0.896	0.904
25	0.788	0.794	0.799	0.805	0.810	0.816	0.822	0.828	0.834	0.840	0.846	0.852	0.859	0.865
30	0.770	0.774	0.779	0.783	0.788	0.792	0.797	0.802	0.806	0.811	0.816	0.821	0.826	0.831
40	0.737	0.740	0.742	0.745	0.748	0.751	0.754	0.757	0.759	0.762	0.765	0.768	0.771	0.774
50	0.708	0.709	0.711	0.713	0.714	0.716	0.717	0.719	0.720	0.722	0.723	0.725	0.726	0.728
60	0.682	0.683	0.683	0.684	0.685	0.685	0.686	0.686	0.687	0.688	0.688	0.688	0.689	0.689
70	0.659	0.659	0.659	0.659	0.659	0.659	0.658	0.658	0.658	0.658	0.658	0.657	0.657	0.657
80	0.638	0.637	0.637	0.636	0.636	0.635	0.634	0.634	0.633	0.632	0.631	0.630	0.629	0.628
90	0.619	0.618	0.617	0.616	0.615	0.614	0.613	0.612	0.610	0.609	0.608	0.607	0.605	0.604
100	0.601	0.600	0.599	0.597	0.596	0.595	0.593	0.592	0.590	0.589	0.587	0.585	0.584	0.582

Table VII. Isothermal Compressibility $\beta_T \times 10^3$ (MPa^{-1}) of 1-Tetradecene

	T(K)													
p (MPa)	303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	0.938	1.002	1.072	1.146	1.227	1.315	1.410	1.513	1.626	1.749	1.883	2.031	2.192	2.370
2.5	0.915	0.976	1.041	1.112	1.187	1.269	1.357	1.453	1.556	1.669	1.791	1.924	2.069	2.227
5	0.893	0.950	1.012	1.078	1.149	1.225	1.307	1.396	1.491	1.594	1.705	1.825	1.955	2.097
10	0.851	0.903	0.958	1.017	1.080	1.147	1.219	1.295	1.377	1.465	1.559	1.659	1.767	1.882
15	0.814	0.861	0.911	0.964	1.020	1.080	1.143	1.210	1.282	1.358	1.438	1.524	1.615	1.711
20	0.780	0.823	0.869	0.917	0.967	1.021	1.077	1.137	1.200	1.267	1.337	1.411	1.489	1.572
25	0.749	0.789	0.831	0.874	0.920	0.969	1.020	1.073	1.130	1.189	1.251	1.316	1.384	1.456
30	0.721	0.758	0.796	0.836	0.879	0.923	0.969	1.017	1.068	1.121	1.176	1.234	1.294	1.357
40	0.671	0.703	0.736	0.771	0.807	0.844	0.883	0.923	0.965	1.008	1.053	1.100	1.149	1.199
50	0.629	0.657	0.686	0.716	0.747	0.779	0.812	0.846	0.882	0.918	0.956	0.995	1.035	1.076
60	0.592	0.617	0.643	0.669	0.696	0.724	0.753	0.783	0.813	0.845	0.877	0.910	0.944	0.978
70	0.560	0.582	0.605	0.628	0.653	0.677	0.703	0.729	0.755	0.783	0.811	0.839	0.868	0.898
80	0.531	0.552	0.572	0.593	0.615	0.637	0.659	0.683	0.706	0.730	0.755	0.780	0.805	0.831
90	0.506	0.524	0.543	0.562	0.582	0.601	0.622	0.642	0.663	0.685	0.707	0.729	0.751	0.774
100	0.483	0.500	0.517	0.534	0.552	0.570	0.589	0.607	0.626	0.645	0.665	0.685	0.705	0.725

Table VIII. Enthalpy h ($kJ \cdot kg^{-1}$) of 1-Tetradecene

	T(K)													
p (MPa)	303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	0.0	21.8	44.0	66.5	89.3	112.5	136.0	159.8	184.0	208.6	233.5	258.8	284.5	310.5
2.5	2.3	24.1	46.2	68.7	91.5	114.6	138.1	161.9	186.1	210.6	235.5	260.7	286.3	312.3
5	4.7	26.5	48.6	71.0	93.8	116.9	140.3	164.1	188.3	212.8	237.6	262.8	288.4	314.3
10	9.5	31.2	53.3	75.7	98.4	121.5	144.9	168.6	192.7	217.1	241.9	267.0	292.5	318.3
15	14.3	36.0	58.1	80.4	103.1	126.1	149.5	173.2	197.2	221.6	246.3	271.3	296.8	322.5
20	19.1	40.8	62.8	85.2	107.8	130.8	154.1	177.8	201.7	226.1	250.8	275.8	301.1	326.9
25	24.0	45.7	67.7	90.0	112.6	135.5	158.8	182.4	206.4	230.7	255.3	280.3	305.6	331.3
30	28.9	50.5	72.5	94.8	117.4	140.3	163.5	187.1	211.0	235.3	259.9	284.9	310.1	335.8
40	38.7	60.3	82.2	104.5	127.0	149.9	173.1	196.7	220.5	244.7	269.3	294.2	319.4	345.0
50	48.6	70.2	92.0	114.3	136.8	159.6	182.8	206.3	230.1	254.3	278.8	303.6	328.8	354.4
60	58.5	80.0	101.9	124.1	146.6	169.4	192.6	216.0	239.8	264.0	288.4	313.2	338.4	363.9
70	68.4	90.0	111.8	134.0	156.5	179.3	202.4	225.8	249.6	273.7	298.2	322.9	348.1	373.5
80	78.4	99.9	121.8	143.9	166.4	189.1	212.3	235.7	259.4	283.5	308.0	332.7	357.8	383.3
90	88.4	109.9	131.7	153.9	176.3	199.1	222.2	245.6	269.3	293.4	317.8	342.6	367.7	393.1
100	98.4	119.9	141.7	163.8	186.3	209.0	232.1	255.5	279.3	303.3	327.7	352.5	377.6	403.0

Table IX. Entropy s ($kJ \cdot kg^{-1} \cdot K^{-1}$) of 1-Tetradecene

	T(K)													
p (MPa)	303.15	313.15	323.15	333.15	343.15	353.15	363.15	373.15	383.15	393.15	403.15	413.15	423.15	433.15
0.1	0.0	0.0709	0.1405	0.2091	0.2766	0.3431	0.4087	0.4735	0.5375	0.6008	0.6634	0.7254	0.7867	0.8475
2.5	–0.0028	0.0680	0.1376	0.2060	0.2735	0.3399	0.4055	0.4702	0.5341	0.5973	0.6597	0.7216	0.7828	0.8435
5	–0.0057	0.0650	0.1346	0.2029	0.2703	0.3367	0.4021	0.4667	0.5306	0.5937	0.6561	0.7178	0.7789	0.8395
10	–0.0113	0.0593	0.1287	0.1970	0.2642	0.3304	0.3957	0.4602	0.5238	0.5868	0.6490	0.7106	0.7715	0.8319
15	–0.0167	0.0538	0.1230	0.1912	0.2583	0.3244	0.3896	0.4539	0.5175	0.5803	0.6424	0.7038	0.7646	0.8248
20	–0.0220	0.0484	0.1176	0.1856	0.2526	0.3186	0.3837	0.4480	0.5114	0.5741	0.6360	0.6974	0.7580	0.8181
25	–0.0271	0.0432	0.1123	0.1803	0.2472	0.3131	0.3781	0.4422	0.5056	0.5682	0.6300	0.6912	0.7518	0.8118
30	–0.0321	0.0381	0.1072	0.1751	0.2419	0.3077	0.3727	0.4367	0.5000	0.5625	0.6243	0.6854	0.7459	0.8058
40	–0.0417	0.0285	0.0974	0.1651	0.2318	0.2976	0.3623	0.4263	0.4894	0.5518	0.6134	0.6744	0.7347	0.7945
50	–0.0508	0.0192	0.0881	0.1557	0.2223	0.2880	0.3526	0.4165	0.4795	0.5418	0.6033	0.6642	0.7244	0.7841
60	–0.0595	0.0104	0.0792	0.1468	0.2133	0.2788	0.3435	0.4072	0.4702	0.5323	0.5938	0.6546	0.7148	0.7743
70	–0.0679	0.0020	0.0707	0.1382	0.2047	0.2702	0.3347	0.3984	0.4613	0.5234	0.5848	0.6456	0.7057	0.7652
80	–0.0760	–0.0061	0.0626	0.1300	0.1965	0.2619	0.3264	0.3900	0.4529	0.5149	0.5763	0.6370	0.6970	0.7565
90	–0.0837	–0.0139	0.0547	0.1222	0.1885	0.2539	0.3184	0.3820	0.4448	0.5068	0.5682	0.6288	0.6888	0.7483
100	–0.0912	–0.0214	0.0472	0.1146	0.1809	0.2463	0.3107	0.3743	0.4371	0.4991	0.5604	0.6210	0.6810	0.7404

$W(p, T)$ over the whole range. The boundary conditions were specified by analytical relations Eqs. (5) and (6), and the field of sound speeds was defined by Eq. (1). As a result of the calculation, the obtained sets of data $\rho(p, T)$, $\alpha_p(p, T)$, and $c_p(p, T)$ were used in Eqs. (10–13) to obtain values of β_T, c_υ, h, and s. This calculation technique is given in detail in Refs. 1 and 6. While carrying out enthalpy and entropy calculations, a thermodynamic state at a minimum temperature $T_0 = 303.15$ K and pressure $p_0 = 0.1$ MPa was taken as a reference point, where $h_{00} = 0$ and $s_{00} = 0$.

The values of W, ρ, α_p, c_p, c_υ, β_T, h, and s obtained in the range of temperatures from 303 to 433 K and at pressures from 0.1 to 100 MPa are given in Tables II–IX.

According to our estimations, the uncertainties of table values at atmospheric pressure are as follows: for the density, $\delta\rho = 0.1$–0.2%; for the isobaric heat capacity, $\delta c_p = 0.2$–2.7%; for the isochoric heat capacity, $\delta c_\upsilon = 0.6$–3.7%; for the isothermal expansion coefficient, $\delta\alpha_p = 1.1$–2.3%; and for the isothermal compressibility, $\delta\beta_T = 0.7$–1.5%. The uncertainties can reach $\delta\rho = 0.2$–0.5%, $\delta c_p = 0.6$–3.8%, $\delta c_\upsilon = 1.2$–5.2%, $\delta\alpha_p = 2.0$–5.1%, and $\delta\beta_T = 0.9$– 2.1% at a pressure of 100 MPa. Large errors of the calculated values are caused mainly by a low accuracy of the initial values of density and heat capacity at atmospheric pressure and can be reduced in further calculations by having more precise initial data.

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