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EXPERIMENTAL INVESTIGATION OF THE P–rho–T DEPENDENCE OF DIHEPTYLMALEINATE WITHIN A WIDE RANGE OF PARAMETERS OF STATE

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Experimental results on the temperature and pressure dependence of the density of diheptylmaleinate are presented. An equation of state for diheptylomaleinate is deduced that fits the experimental data well.

Esters of maleic acid – maleinates – are widely used in various technological processes. For example, they are used as a monomer for copolymerization with acrylates, styrene, and other vinyl monomers as an internal nonmigrating plasticizer in polymer materials [1]. Several homologs of this series with a high boiling temperature (600 K) can be used as heat-transport media and coolants. However, almost no information on their thermophysical properties is available in the literature.

In our preceding works [2-6] we presented results of experimental investigations of the thermal conductivity of maleinates (dipropylmaleinate, diamylmaleinate, dihexylmaleinate, diheptylmaleinate, dioctylmaleinate, and dinonylmaleinate) within the temperature range from room temperature to 570 K and the pressure range 0.1–98.1 MPa.

In the present work we report on results of an investigation of the density of a representative of this series – diheptylmaleinate – within the temperature range 290–600 K and the pressure range 0.1–58.9 MPa. Special attention was paid to the purity of the substance under investigation. Prior to investigation the diheptylmaleinate was dried and purified by vacuum distillation. A chromatographic analysis showed a content of the main product of not less than 99.5%.

Measurements were carried out by hydrostatic weighing with a maximum error of 0.1% within the entire range of parameters of state studied. In order to carry out the investigation we designed and built an experimental setup using elements of earlier experimental installations described in [7, 8]. The setup differs from existing ones by the fact that the coil is withdrawn from the medium under investigation, which made it possible to simplify its use and improve its reliability of operation.

Elements of the supporting structure were calibrated of hydrostatic weighing in (bidistilled) water using a VLA-200 G-M-type analytical balance according to a well-known method [9-11]. The parameters (volumes) of elements of the supporting structure were as follows: the core of hightly polished carbon tool steel 0.4228 cm^3, the thread 0.0043 cm^3, the one-piece quartz float 3.9986 cm^3. The weight of the system in vacuum equals 9.5253 g.

Temperature was measured in the experiments using a PTS-10-type platinum resistance thermometer of the first category and a U-309 potentiometric device.

Pressure in the cell for measurements was created and measured by an MP-600 dead-weight pressure-gauge tester of 0.05 accuracy class. Measurements were carried out along isotherms. We obtained 110 experiemntal density values on 14 isotherms, each of which is an average of three or four results of measurements. The data obtained are presented in Table 1.

The availability of reliable $P-\rho-T$ data makes it possible to deduce an experimentally substantiated equation of state for diheptylmaleinate.

Derivation of an accurate equation of state on the basis of experimental $P-\rho-T$ data that describes the thermodynamic properties of real substances within a wide range of variation of parameters of state is of

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TABLE 1. Density ρ (kg/cm^3) of Diheptylmaleinate as a Function of Temperature and Pressure

Temperature T, K	Pressure P, MPa							
	0.1	5.0	9.9	19.7	29.5	39.3	49.1	58.9
288.98	949.6	951.9	954.5	960.8	965.6	970.6	975.0	980.7
308.33	938.4	941.6	944.8	950.7	956.3	961.5	966.6	971.5
322.11	929.8	933.0	936.1	942.6	948.3	953.7	959.9	964.0
348.30	913.2	917.0	921.0	928.2	934.5	940.5	946.2	951.4
368.29	900.7	904.3	909.3	916.0	923.0	929.8	936.4	941.0
382.76	890.5	895.6	898.8	907.4	915.6	922.0	927.7	933.8
400.72	877.6	882.2	887.0	895.4	904.4	911.4	918.6	923.5
421.34	846.1	852.6	858.2	868.9	877.6	887.0	895.3	902.4
442.17	828.0	836.0	843.0	855.0	865.0	874.0	883.0	890.0
477.77	815.5	824.0	830.3	843.5	855.2	865.5	874.2	881.6
505.32	791.2	800.9	809.1	824.0	836.1	847.2	857.2	865.5
531.76	769.2	779.9	788.6	804.7	817.6	830.3	841.7	850.4
563.23	–	749.8	760.8	780.3	796.0	809.0	820.4	830.9
600.20	–	716.0	730.0	752.0	769.0	784.0	796.4	808.0

TABLE 2. Coefficients of the Polynomials (2)

Coefficients	i			
	0	1	2	3
a	−468.0309	78.68869	907.2474	−584.6542
b	−204.7293	2838.028	−4494.04	2433.416

fundamental importance. Certain advances have been made in this field in recent years. In spite of this, the theory does not provide a satisfactory description of the properties of liquids [12, 13]. Therefore, one should frequently use empirical and semi-empirical equations with coefficients found on the basis of experimental $P-\rho-T$ data [14, 15].

In deriving an equation of state, the emphasis is on the accuracy of the description of the original data and the simplicity and convenience of use of the equation. For this purpose we have chosen from the huge number of empirical equations of state those of greatest interest (the Tate, Bachinskii, Biron–Mamedov, and Planck equations). It is found that none of them can describe the density of diheptylmaleinate within the entire investigated temperature and pressure range with a satisfactory error.

For the liquid under investigation we composed the following equation of state:

$$P = A\left(\frac{T}{T_{\text{boil}}}\right)\rho^2 + B\left(\frac{T}{T_{\text{boil}}}\right)\rho^8. \tag{1}$$

The coefficients A and B are described by polynomials

$$A\,(T/T_{\text{boil}}) = \sum_{i=0}^{3} a_i\,(T/T_{\text{boil}})^i, \quad B\,(T/T_{\text{boil}}) = \sum_{i=0}^{3} b_i\,(T/T_{\text{boil}})^i. \tag{2}$$

The coefficients of the polynomials (2) are presented in Table 2.

Equation (1) describes experimental data with an arithmetic mean error of 0.02%. The maximum deviation at certain points is as large as 0.15%. A check showed that formula (1) is also valid for other homologs of the specified series, and in this case one should vary only the coefficients a_i and b_i.

NOTATION

P, pressure, MPa; T_{boil}, normal boiling temperature, K; ρ, density, kg/m^3.

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