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AN EXPERIMENTAL STUDY OF THE THERMOPHYSICAL PROPERTIES OF CYCLOHEXANE

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Measurements of thermal conductivity and specific heat of cyclohexane are presented for the temperature range 293-623°K for pressures of 2-30 MPa.

A knowledge of the thermophysical properties of liquids, foremost, specific heat and thermal conductivity, is necessary for study of the character of thermal molecular motion and transfer processes with the liquids [1, 2]. In recent years studies have demonstrated that in liquids which are semitransparent in infrared regions of the spectrum there exists together with a molecular heat-transfer mechanism a photon mechanism which has a marked effect even at room temperatures [3]. A consequence of this fact is that data on thermal conductivity of organic liquids are distorted in the majority of cases by a radiant component, the magnitude of which is difficult to estimate [3]. Under such conditions it is of interest to study the purely molecular thermal conductivity of liquids over a wide range of states and at high pressure singularities.

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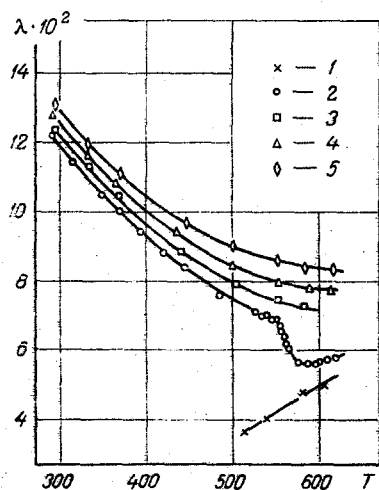


Fig. 1

Fig. 1. Thermal conductivity λ of cyclohexane at pressures: 1) 2 MPa; 2) 4.8; 3) 10; 4) 20; 5) 30 MPa.

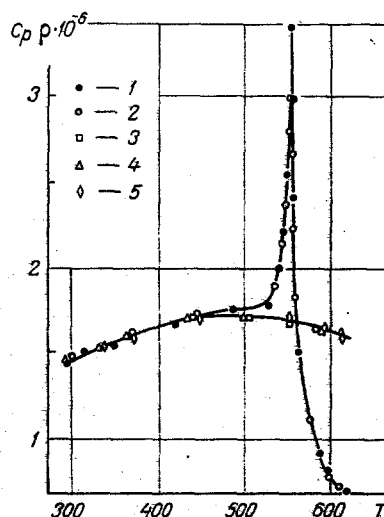


Fig. 2

Fig. 2. Volume isobaric heat capacity of cyclohexane $c_{p\rho}$ at isobars: 1, 2) 4.8 MPa (1, temperature increasing; 2, temperature decreasing); 3) 10; 4) 20; 5) 30 MPa.

The present study will offer the results of an experimental investigation of the thermophysical properties of cyclohexane by a new stationary heated filament method. In the apparatus constructed, a thin (ϕ 2-5 μm) platinum filament located in the liquid under study is heated by an audio frequency (60-600 Hz) current, and radio methods are used to record the amplitude and phase of the filament temperature oscillations [1, 4]. The phase and amplitude measurements are used to determine the thermophysical properties [1, 5]. One of the most important features of this method is that heat transfer by radiation and convection has practically no effect on the measurement results over a wide range of temperature and pressure. This is true because temperature waves of relative high frequency (~ 100 Hz) are damped quite strongly in liquids, while the measurements were performed in liquid layers hundredths of a millimeter in thickness.

The study was conducted over the temperature range 293-623°K at pressures from 2 to 30 MPa. Actual temperature was determined to an accuracy of $\pm(0.1-0.3)^\circ\text{K}$ from the resistance of the filament-probe, which was calibrated with a reference platinum resistance thermometer, type PTS, constructed at VNIIFTRI. Experimental pressure was monitored by a class 0.35 reference manometer. The uncertainty in the values of thermal conductivity, specific heat c_p , thermal diffusivity, and thermal activity of cyclohexane in the region of states studied, excluding the critical point, comprises 1-1.5, 1.5-2, 2, and 1-1.5%, respectively.

Experimental data on thermal conductivity λ and volume isobaric thermal capacity $c_{p\rho}$ of cyclohexane for several isobars are shown in Figs. 1, 2. As is evident from Fig. 1, the temperature dependence of thermal conductivity is linear in the vapor phase and nonlinear in the liquid. For the isobars close to critical this dependence is not monotonic, and the curve has a minimum in the postcritical state region. In Fig. 2 the sharp peak in thermal capacity for the 4.8-MPa isobar is of interest. This is characteristic of the critical point vicinity; in the peak region the data obtained for both increasing and decreasing temperature paths are reproducible. With the exception of the critical point, the isobars in the variables $c_{p\rho}$ -T practically coincide over a wide state range. This fact has also been observed for a number of other organic liquids.

Consideration of the excess thermal conductivity $\Delta\lambda = \lambda(p, T) - \lambda(0, T)$ and specific heat c_p of cyclohexane reveals that the dependence of $\Delta\lambda$ and c_p on the two thermodynamic variables, temperature T and pressure p, over a quite wide range of T and p reduces to a dependence on the one variable, density ρ (ρ values are taken from [6]). This fact is confirmation of the concept of the role of specific volume as a geometric factor in the physics of fluids [1, 7].

The experimental data on specific heat c_p and thermal conductivity λ of liquid cyclohexane at $\rho > 450 \text{ kg/m}^3$ can be described by the following expressions:

$$\begin{aligned}c_p &= 6.4 - 5.8 \cdot 10^{-3} \rho, \\ \lambda &= -33.3 + 0.13757T + 0.325\rho - 1.37 \cdot 10^{-3} \rho^2 + 2.1 \cdot 10^{-6} \rho^3 - 8.1 \cdot 10^{-10} \rho^4.\end{aligned}\quad (1)$$

The results of the c_p measurements on the saturation line and under pressure agree with data from [8] and [9] in the temperature range studied to an accuracy of 1-2%. The thermal conductivity data for the vapor agree with the results of [3] within 1-2%. The results for thermal conductivity at supercritical pressure lie below the data recommended in [3] by 2.5-4% at 293°K, and by 15-20% at 573°K. We explain this systematic divergence of data as a result of the fact that the data in the literature on cyclohexane thermal conductivity contain a radiant component, while our results describe molecular thermal conductivity alone. According to our data, such fractions of radiant transfer are also characteristic of toluol, N-heptane, and carbon tetrachloride.

NOTATION

c_p , specific heat at constant pressure, kJ/kg·deg K; λ , thermal conductivity, W/m·deg K; ρ , density, kg/m³; $\Delta\lambda$, excess thermal conductivity; T, temperature, °K; p, pressure, MPa.

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