RELATION BETWEEN TRANSPORT PROPERTIES AND DENSITIES OF LIQUIDS

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Using water and toluene as examples, it was established that the ratio between the coefficients of thermal conductivity and dynamic viscosity at high state parameters was proportional to the density to the power $\varkappa$.

A qualitative relation between transport properties and sound velocity was established in the formula of Shirokov [1]:

$$\frac{\eta}{\lambda} = \frac{T}{u^2}. \qquad (1)$$

Our calculations for water and toluene showed that if Eq. (1) was represented in the form

$$\frac{\lambda}{\eta} = \frac{u^{m(T)}}{A(T)} \qquad (2)$$

through the introduction of supplementary quantities, it then provides a quantitative relation between λ and η within experimental accuracy even at high state parameters.

By using the Rao rule and Eq. (2), an attempt was made to establish a relation between transport properties and density that was valid at high temperatures and pressures.

Considering that $u \approx c\rho^3$ according to the Rao rule, Eq. (2) can be represented in the form

$$\frac{\lambda}{\eta} = \frac{\rho^{\varkappa(T)}}{C(T)}. \qquad (3)$$

Taking the logarithm of the last equation and using the data from [2-4], we constructed a series of isotherms for water and toluene in the log λ/η — log ρ coordinate system, which were obtained in the form of straight lines as can be seen in Figs. 1 and 2.

Using the linearity of the isotherms plotted, values of the exponent $\varkappa$ of the density and of log C were calculated from two points; they were approximated by polynomials of the form $\Sigma a_i t^i$ with the coefficients given in Table 1 for water in the temperature range 50 to 300°C and for toluene in the temperature range 50 to 250°C.

TABLE 1. Coefficients of the Polynomials $\varkappa = \Sigma a_i t^i$ and Log $C = \Sigma a_i t^i$ for Water and Toluene

Coefficient	Water		Toluene	
	$\varkappa$	log C	$\varkappa$	log C
a_0	$32328000 \cdot 10^{-7}$	$72008100 \cdot 10^{-7}$	$-7172870 \cdot 10^{-6}$	$-23407450 \cdot 10^{-6}$
a_1	$-48001567 \cdot 10^{-10}$	$-29999520 \cdot 10^{-9}$	$6422412 \cdot 10^{-8}$	$18786147 \cdot 10^{-8}$
a_2	$-49468550 \cdot 10^{-11}$	$-13918493 \cdot 10^{-10}$	$-2923938 \cdot 10^{-10}$	$-87242167 \cdot 10^{-11}$
a_3	$39521767 \cdot 10^{-13}$	$11529920 \cdot 10^{-12}$	$5094733 \cdot 10^{-13}$	$15842933 \cdot 10^{-13}$
a_4	$-11914600 \cdot 10^{-15}$	$-35057067 \cdot 10^{-15}$	$-1416667 \cdot 10^{-10}$	$-57373333 \cdot 10^{-17}$
a_5	$13106400 \cdot 10^{-18}$	$38675200 \cdot 10^{-18}$	—	—

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TABLE 2. Comparison of Calculated and Experimental Values for Coefficients of Thermal Conductivity of Water and Toluene

p, bar	$10^7\eta$, N·sec/m² [2, 4]	ρ, kg/m³ [2, 3]	$10^3\lambda$, W/m·deg [2, 5]	$10^3\lambda$, W/m·deg (3)	$10^7\eta$ [2, 4]	ρ [2, 3]	$10^3\lambda$ [2, 5]	$10^3\rho$ (3)
				Water				
		$t = 50$ °C				$t = 100$ °C		
p_s	5440	988,04	643	643	2790	958,31	680	680
100	5451	992,36	651	650	2809	962,83	688	687
200	5461	996,71	659	658	2828	967,49	694	694
300	5471	1000,80	666	665	2848	971,91	701	701
400	5481	1004,92	672	672	2867	976,18	707	708
500	5491	1008,88	678	679	2887	980,39	713	715
		$t = 150$ °C				$t = 200$ °C		
p_s	1810	916,93	686	685	1338	864,68	664	667
100	1832	922,00	693	692	1358	870,85	672	673
200	1854	927,47	700	699	1381	877,89	681	680
300	1876	932,75	706	706	1404	884,64	689	688
400	1898	937,73	713	714	1427	890,95	697	695
500	1920	942,60	720	721	1450	897,02	704	703
		$t = 250$ °C				$t = 300$ °C		
p_s	1070	799,23	617	629	901	712,45	540	568
100	1084	805,87	625	632	904	715,81	545	568
200	1108	816,26	639	639	929	735,29	571	573
300	1132	825,70	651	646	954	751,31	592	580
400	1156	834,45	662	654	978	764,53	609	588
500	1180	842,60	671	662	1004	776,40	622	597
				Toluene				
		$t = 50$ °C				$t = 100$ °C		
p_s	4206	839,21	1224	1224	2718	789,64	1094	1101
50	4374	844,02	1244	1240	2839	797,32	1114	1115
100	4550	848,10	1262	1261	2962	803,21	1136	1136
150	4721	852,30	1280	1279	3080	808,73	1158	1156
200	4895	856,09	1300	1299	3204	813,93	1180	1178
250	5072	859,99	1318	1318	3324	818,00	1202	1199
		$t = 150$ °C				$t = 200$ °C		
p_s	1880	737,03	980	980	1335	676,31	884	884
50	1987	745,49	1001	1008	1430	689,18	910	909
100	2095	753,92	1026	1033	1530	702,30	936	933
150	2203	761,73	1052	1060	1635	713,22	962	964
200	2296	768,82	1076	1079	1731	722,28	988	993
250	2390	775,13	1101	1101	1816	731,47	1014	1014
		$t = 225$ °C				$t = 250$ °C		
p_s	1110	638,28	844	845	930	599,99	808	814
50	1213	657,50	872	868	960	621,61	836	836
100	1322	674,31	902	898	1139	643,58	872	868
150	1427	687,52	930	930	1249	660,81	906	903
200	1528	699,01	956	962	1345	674,49	934	934
250	1612	709,22	984	985	1432	686,01	961	961

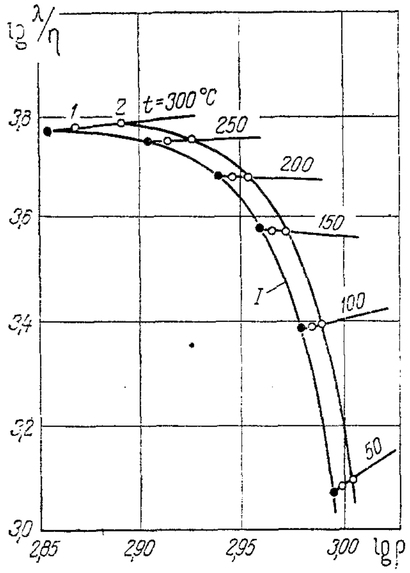

Fig. 1

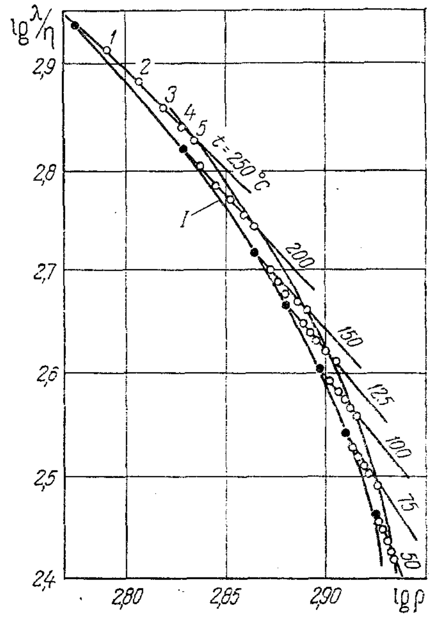

Fig. 2

Fig. 1. Isotherms of liquid water in the log λ/η — log ρ coordinate system: 1) 200 bar; 2) 500 bar; I) line of saturated liquid; solid points are liquid in saturated state.

Fig. 2. Isotherms of liquid toluene in the log λ/η — log ρ coordinate system: 1) 50 bar; 2) 100 bar; 3) 150 bar; 4) 200 bar; 5) 250 bar; I) line of saturated liquid; solid points are liquid in saturated state.

As is clear from Table 2, Eq. (3) yields rather good values of λ for given values of η, ρ, ϰ, and log C within the specified limits of the state parameters for both water and toluene.

Because of the absence of the necessary experimental data, we were limited in this work to consideration of two liquids of different classes — water and toluene — and we assume that Eq. (3) will also be valid for other pure liquids.

NOTATION

λ, coefficient of thermal conductivity; η, coefficient of dynamic viscosity; T, absolute temperature; u, velocity of sound; ρ, density; ϰ, C, coefficients depending on temperature and type of liquid.

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