Pa; J°_e, (quasi) equilibrium reversible shear compliance, Pa^{-1}; ω, circular frequency, sec^{-1}; tan δ, mechanical loss tangent; T, temperature, °K; T_g, glass temperature; c, concentration of minor component, mass %; ω_{max}, circular frequency corresponding to maximum in G"(ω).

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DYNAMIC VISCOSITIES OF BENZENE–CHLOROBENZENE SOLUTIONS

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Measurements are reported on the dynamic viscosities of benzene–chlorobenzene solutions.

Sound design of equipment for producing chlorobenzene and improved efficiency in producing it from benzene require reliable data on the thermophysical parameters of benzene–chlorobenzene solutions over wide ranges in temperatures and pressure. The literature carries data only on the densities of these solutions at 298.15-353.15°K and atmospheric pressure [1].

We have measured the dynamic viscosities of benzene–chlorobenzene solutions having molar concentrations of 25-75, 50-50, and 75-25% over the range 290.15-550.15°K at pressures of 1-40 MPa. A Golubev–Petrov capillary viscometer (fifth form) was used [2]. See [2] on the methods of performing the measurements, thermostating the viscometer, and processing the results.

The temperatures were measured to ±0.01-0.02% with a PTS-10 standard resistance thermometer. The pressures were produced and measured by means of MP-60 and MP-600 piston-load gauges of accuracy class 0.05. The flow time was measured with and SDSpr-1 timer having a scale division of ±0.1 sec. The flow time was measured not less than three times for each point.

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TABLE 1. Measured Values of the Dynamic Viscosity $\eta \cdot 10^3$ ($N \cdot sec/m^2$) for Benzene–Chlorobenzene Solutions with Molar Concentrations of 75-25, 50-50, and 25-75%

P, MPa	75—25 %, T, K: 298,15	323,15	348,15	373,15	398,15	423,15	448,15	473,15	498,15
0,1	0,672	0,519	0,409	—	—	—	—	—	—
1	0,676	0,524	0,412	0,328	0,265	0,214	0,174	—	—
2	0,682	0,528	0,415	0,331	0,267	0,217	0,176	0,144	0,115
3	0,689	0,533	0,419	0,334	0,270	0,219	0,179	0,146	0,118
5	0,701	0,542	0,426	0,340	0,275	0,223	0,184	0,151	0,123
10	0,733	0,565	0,443	0,354	0,287	0,235	0,196	0,164	0,137
20	0,794	0,610	0,478	0,382	0,311	0,258	0,218	0,185	0,159
30	0,854	0,656	0,513	0,412	0,335	0,279	0,238	0,203	0,177
40	0,919	0,701	0,548	0,440	0,359	0,301	0,257	0,222	0,194

P, MPa	75—25 %, T, K: 523,15	548,15	50—50 %, T, K: 298,15	323,15	348,15	373,15	398,15	423,15	448,15
0,1	—	—	0,706	0,543	0,430	—	—	—	—
1	—	—	0,712	0,547	0,432	0,347	0,284	0,234	0,194
2	—	—	0,718	0,551	0,436	0,350	0,287	0,236	0,196
3	0,093	—	0,724	0,555	0,439	0,353	0,289	0,239	0,198
5	0,101	0,081	0,736	0,564	0,446	0,359	0,294	0,243	0,203
10	0,116	0,098	0,766	0,587	0,464	0,374	0,306	0,255	0,215
20	0,136	0,118	0,827	0,631	0,498	0,403	0,332	0,278	0,237
30	0,154	0,136	0,885	0,675	0,533	0,434	0,357	0,301	0,257
40	0,170	0,151	0,945	0,719	0,568	0,462	0,382	0,323	0,277

P, MPa	50—50 %, T, K: 473,15	498,15	523,15	548,15	25—75 %, T, K: 298,15	323,15	348,15	373,15
0,1	—	—	—	—	0,725	0,554	0,438	0,355
1	0,160	—	—	—	0,730	0,558	0,441	0,357
2	0,162	0,134	0,109	—	0,736	0,562	0,444	0,360
3	0,165	0,137	0,112	0,090	0,742	0,566	0,448	0,363
5	0,170	0,142	0,118	0,098	0,753	0,575	0,454	0,369
10	0,182	0,154	0,132	0,113	0,782	0,597	0,472	0,384
20	0,203	0,176	0,152	0,134	0,839	0,638	0,506	0,412
30	0,222	0,194	0,171	0,152	0,897	0,682	0,540	0,441
40	0,240	0,211	0,187	0,168	0,954	0,726	0,574	0,470

P, MPa	25—75 %, T, K: 398,15	423,15	448,15	473,15	498,15	523,15	548,15
0,1	—	—	—	—	—	—	—
1	0,294	0,246	0,207	0,174	—	—	—
2	0,296	0,249	0,209	0,176	0,148	0,123	—
3	0,299	0,251	0,212	0,179	0,150	0,126	0,103
5	0,303	0,256	0,216	0,183	0,155	0,132	0,111
10	0,316	0,268	0,227	0,194	0,166	0,144	0,124
20	0,342	0,289	0,247	0,215	0,188	0,164	0,144
30	0,368	0,312	0,268	0,234	0,205	0,182	0,162
40	0,393	0,334	0,288	0,252	0,222	0,198	0,178

The maximum relative error in determining the viscosity was ±1.2%.

The solutions were prepared with a molar accuracy of ±0.01% by weighing with an AVD-200 analytical balance. The solutions were made up from benzene of cryoscopically pure grade and chlorobenzene of pure grade, which were repeatedly carefully purified in a rectification column. After redistillation, each of the components was dried with metallic Na. The purity was checked with various chromatographs having flame-ionization detectors, the values being 99.98% for benzene and 99.90% for chlorobenzene.

We also measured the density and refractive index at 293.15°K and atmospheric pressure, the values found being: for benzene ρ_{20} = 0.87901 kg/m³, n^{20}_D = 1.50112 and for chlorobenzene ρ_{20} = 1.1066 kg/m³, n^{20}_D = 1.5248.

The viscosities were measured along isotherms with a temperature step of 25°K. The measurements were made on 11 isotherms in the range 298-548°K at pressures of 0.1-40 MPa. All

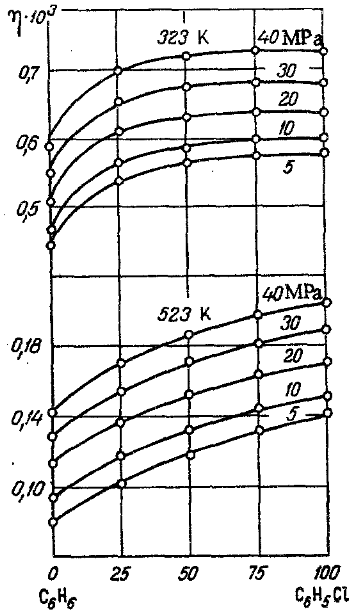

Fig. 1. Effects of molar composition on dynamic viscosity for benzene-chlorobenzene solutions, compositions in %, $\eta \cdot 10^3$ $N \cdot sec/m^2$.

the measurements were made with a single viscometer, in which the Reynolds number did not exceed 1200 throughout the parameter range.

The Hagen–Puaseil equation was used with the corrections required in the capillary method in calculating the dynamic viscosity. The internal consistency in the data was checked by constructing η–P, η–T, and P–T sections. The spread in the experimental points around the smoothed curves was not more than ±0.5-0.8%.

Table 1 gives the measured viscosities together with the concentrations.

It was found that the values for the 50-50% benzene–chlorobenzene solution at 293.15-373.15°K [3] were too high and did not lie on the same curves as those for the other molar concentrations, so we repeated the measurements with the 50-50% benzene–chlorobenzene solution. We consider that the discrepancy between the two series of experiments was due to low purity in the components used in the first series.

Graphical processing showed that the dynamic viscosity did not follow additivity throughout the temperature and pressure ranges. At 298°K, the deviation from additivity was on average 5-6%, although the deviation fell to 4.7% as the pressure increased. The deviation increased with temperature on average to about 8-9%, or to a maximum of 13% at 423°K. Above 423°K, the deviation decreased slightly as the temperature rose and was on average about 7.3% (Fig. 1).

NOTATION

ρ_{20}, density at 293.15°K; n^{20}_D, refractive index at 293.15°K for sodium yellow line; η, dynamic viscosity; P, pressure; T, absolute temperature.

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