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Abstract

Full Text

PHYSICAL CHEMISTRY

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VISCOSITY OF *n*-HEXANE IN THE LIQUID AND GASEOUS STATES AT HIGH PRESSURES AND VARIOUS TEMPERATURES

(Presented by Academician V. A. Kirillin on 20 III 1963)

In the previous article (1) the layout of the apparatus, the construction of the instrument—the viscosimeter—and the experimental procedure were described. The results of measurements of the viscosity of *n*-pentane at high pressures and various temperatures were also given there.

In the present article we give the results of measurements of the viscosity of *n*-hexane over the temperature range from 15 to 275° and pressures from 1 to 500 atm, which were carried out on the same apparatus; however, the glass viscosimeter had somewhat different geometrical dimensions, namely: capillary radius 0.005312 cm; volume of the measuring bulb 0.5775 cm^3; volume of the preliminary bulb 0.6711 cm^3; capillary length 5.44 cm; difference of mercury levels at the beginning of outflow 7.48 cm, at the end of outflow 5.09 cm; mean height of the mercury column in the viscosimeter during outflow 10.31 cm.

Fig. 1. Viscosity of liquid (*a*) and gaseous (*b*) *n*-hexane at atmospheric pressure and various temperatures according to data of various investigators. The numbers in the figure correspond to the numbers of the cited literature. 1 —data of the authors

There is a very limited number of works in the literature on the viscosity of *n*-hexane, both for the liquid and for the gaseous state, especially at high pressures. The viscosity of gaseous *n*-hexane at atmospheric pressure was determined by the capillary method by Titani (2) over the temperature range from 120.7 to

Fig. 2. Viscosity of n-hexane as a function of temperature at constant pressures

Figure 2: Fig. 2. Viscosity of n-hexane as a function of temperature at constant pressures

306.6° and by Graven and Lambert ([3]) by the oscillating-pendulum method over the temperature range 35–77.8°.

The viscosity of liquid *n*-hexane at atmospheric pressure was measured by the capillary method by Shepard, Henne, and Midgley ([4]) at 25°, by Gartenmeister ([5]) at 20°, by Geist and Cannon ([6]) at 0, 20, and 40°, and by Gillam and Drickamer ([7]) over the range from −98.5 to +20°. It may also be noted

and the earlier work of Thorpe and Rodger ([8]), carried out by the capillary method in the range from 0.8 to 63.6°.

A comparison of the data on the viscosity of *n*-hexane by the investigators listed with the data obtained in the present work is presented in Fig. 1, from which good agreement is seen for the liquid and gaseous states. At high pressures the viscosity of *n*-hexane was measured by Bridgman ([9]) by the falling-weight method at 30 and 75° and pressures from 1 to 12,000 kg/cm^2. Khalilov ([10]), using the capillary method, measured the viscosity of *n*-hexane on the saturation line from 20 to 220°.

For our investigation we used *n*-hexane from the Novocherkassk Synthetic Products Plant, which had the following characteristics: specific gravity $d^{20} = 0.6595$ g/cm^3, refractive index $n_D^{20} = 1.3752$, and boiling temperature $t_{760} = 69.00$. This technical *n*-hexane was subjected to additional purification. First it was treated with sulfuric acid to remove impurities of unsaturated hydrocarbons, a small content of which was detected by chromatographic analysis.

Further, the *n*-hexane was distilled on a rectification column, with the middle fraction being collected. After purification the *n*-hexane had the following characteristics: specific gravity $d^{20} = 0.6592$ g/cm^3, refractive index $n_D^{20} = 1.3749$, and boiling temperature $t_{760} = 68.88°$. According to the most reliable literature data ([11,12]), for pure *n*-hexane $d^{20} = 0.66937$ g/cm^3, $n_D^{20} = 1.37486$, $t_{760} = 68.7°$. As can be seen, there is good agreement. Chromatographic analysis of the product showed a content of *n*-hexane of 99.8% by weight.

Fig. 2. Viscosity of *n*-hexane as a function of temperature at constant pressures

The results of our measurements of the viscosity of *n*-hexane are collected in Table 1. The experimental data were graphically smoothed, as a result of which Table 2 was compiled for the coefficients of dynamic viscosity at constant values of temperature and pressure, and also Table 3 for values on the saturation line. For greater clarity, the general picture of the dependence of viscosity

Table 2

Graph of $(\eta_{pT} - \eta_T)$ versus density for n-hexane. The ordinate is labeled $(\eta_{p,T} - \eta_T)$ in 10^{-7} g/(cm · s), and the abscissa is density ρ in g/cm^3. The legend identifies temperatures 25°C, 50, 75, 100, 125, 150, 175, 200, 225, 234.8, 250, 275, and "Schinnos."

Figure 3: Graph of $(\eta_{pT} - \eta_T)$ versus density for n-hexane. The ordinate is labeled $(\eta_{p,T} - \eta_T)$ in 10^{-7} g/(cm · s), and the abscissa is density ρ in g/cm^3. The legend identifies temperatures 25°C, 50, 75, 100, 125, 150, 175, 200, 225, 234.8, 250, 275, and "Schinnos."

Viscosity (10^{-7} g · cm^{-1} · s^{-1}) of n-hexane (smoothed values)

p, atm	25°	50°	75°	100°	125°	150°	175°	200°	225°	234.8°	250°	275°
1	24300	23300	735	796	850	907	965	1014	1072	1090	1124	1177
5	29410	23440	19400	15980	13100	931	983	1038	1105	1111	1144	1198
10	29600	23600	19520	16050	13230	10840	1065	1096	1150	1157	1186	1235
15	29760	23730	19670	16190	13360	10940	8610	1211	1230	1240	1253	1285
20	29920	23880	19820	16300	13480	11110	8770	6655	1281	1360	1354	1355
25	30100	24040	19980	16430	13600	11240	8920	6875	1647	1550	1470	1452
28	30200	24130	20000	16500	13700	11280	9010	7008	4800	1755	1610	1570
29.62	30250	24190	20070	16560	13700	11330	9050	7111	5075	2720	1730	1600
36	30430	24330	20200	16680	13830	11460	9220	7299	5480	4600	2590	1900
40	30600	24500	20330	16800	13950	11600	9360	74800	5780	5052	3480	2380
50	30910	24770	20580	17040	14200	11830	9600	7750	6220	5638	4480	3200
60	31250	25070	20340	17300	14420	12400	9880	8091	6580	6043	5070	3840
80	31960	25700	21340	17840	14910	12580	10380	8651	7170	6687	5830	4860
100	32640	26310	21850	18320	15330	12920	10840	9180	7680	7216	6430	5250
150	34320	27750	23080	19470	16470	14030	11980	10260	8816	8349	7584	6506
200	35980	29180	24350	20610	17600	15100	12960	11240	9758	9245	8520	7465
250	37610	30650	25560	21730	18680	16170	13950	12180	10670	10200	9472	8350
300	39350	32100	26800	22890	19780	17240	14950	13070	11500	11050	10290	9232
400	42700	35080	29860	25140	21900	19250	16840	14780	13130	12590	11810	10680
500	46130	38140	31990	27440	24000	21200	18640	16400	14630	14040	13190	11950

Fig. 3. Dependence of $(\eta_{pT} - \eta_T)$ on density for n-hexane.

Table 3

Viscosity of *n*-hexane on the saturation line (10^{-7} g · cm^{-1} · sec^{-1})

t_s, °C	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	225	230	233	234.8
p_s, atm	1.03	1.40	1.85	2.42	3.10	3.98	4.89	6.06	7.38	8.94	10.09	12.61	14.91	17.52	20.42	23.81	26.02	27.52	28.82	29.52

t_s, °C	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	225	230	233	234.8
η_s (liquid)	20,01[illegible]	18,35[illegible]	17,03[illegible]	15,87[illegible]	14,79[illegible]	13,58[illegible]	12,51[illegible]	11,53[illegible]	10,59[illegible]	9,72[illegible]	8,88[illegible]	8,41[illegible]	7,31[illegible]	6,55[illegible]	5,89[illegible]	5,12[illegible]	4,86[illegible]	4,23[illegible]	3,77[illegible]	2,720
η_s (vapor)	730	754	778	802	830	861	895	932	974	1,02[illegible]	1,07[illegible]	1,13[illegible]	1,21[illegible]	1,30[illegible]	1,42[illegible]	1,58[illegible]	1,72[illegible]	1,88[illegible]	2,10[illegible]	2,720

The dependence of the viscosity of *n*-hexane on temperature at constant pressures is shown in Fig. 2.

The error of the experimental data, determined by us on the basis of the general theory of errors, is estimated as ±1.0% for the liquid state, ±2.0% for the gaseous state, and ±3.0% near the critical point.

Figure 3 presents the dependence of the viscosity of *n*-hexane on density in the coordinates $(\eta_{p,T} - \eta_T)$–ρ, where $\eta_{p,T}$ is the viscosity at the given pressure and temperature, and η_T is the viscosity at the same temperature and atmospheric pressure.

The density values were taken from works [13–16]. As is seen from Fig. 3, all the experimental data on the viscosity of *n*-hexane as a function of density for the temperature range from 25 to 275° and pressures from 1 to 500 atm are well arranged on a single common curve.

Khalilov' s data over the entire temperature interval investigated by him agree satisfactorily with our data; the maximum discrepancy at $t = 170°$ is 3%. Bridgman' s data agree well with ours at temperatures of 30 and 75° and pressures up to 500 kg/cm^2. The discrepancy between these data does not exceed 1%.

By the capillary method, the viscosity of *n*-hexane was measured in the liquid and gaseous states at temperatures from 15 to 275° and pressures from 1 to 500 atm. Values of the experimental and smoothed coefficients of dynamic viscosity are given, as well as graphs of the dependence of viscosity on temperature, pressure, and density.

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Note: Figure translations are in progress. See original paper for figures.