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THE VISCOSITY OF ISOBUTANE AT HIGH PRESSURES

by

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In literature there is a series of works devoted to the study of the viscosity of liquid and gaseous isobutane. The comparison of experimental findings given in these works showed that they differed from one another substantially, therefore a study was made of the viscosity of liquid and gaseous isobutane (including the line of saturation and the area close to the critical point) in the interval of pressures from 1 to 700 kg/cm(superscipt 2) and temperatures of 0-275 degrees C.

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Block	Italic	Transliteration	Block	Italic	Transliteration
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В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

THE VISCOSITY OF ISOBUTANE AT HIGH PRESSURES

N. A. Agayev and A. D. Yusibova

In literature there is a series of works devoted to the study of the viscosity of liquid and gaseous isobutane [3-7]. The comparison of experimental findings given in these works showed that they differed from one another substantially, therefore a study was made of the viscosity of liquid and gaseous isobutane (including the line of saturation and the area close to the critical point) in the interval of pressures from 1 to 700 kg/cm^2 and temperatures of 0-275°C.

Unlike the procedure applied earlier [1] in this investigation liquid thermostatic control was used [8]. The temperature of the experiment was measured by a model resistance thermometer to within 0.02°C, pressure was measured by manometers of the type MP-60 and PM-600, class 0.05. The timing of escape was conducted automatically with a P-30 electric timer to within 0.1 s.

The main unit of the installation -- a capillary viscometer -- was made from "Supromaks" brand glass and it had the following geometric dimensions: diameter of capillary d_H = 0.008818 cm, length of capillary l_H = 5.170 cm, volume of the measuring balloon V_H = 1.133 cm^3, the drop in the level of mercury in the viscometer ΔH_H = 5.743 cm^3.

Chromatographic analysis of the substance investigated by us showed that it contained 99.87% isobutane, 0.005% propane, and 0.08% n-butane.

Experiments were conducted based on isotherms with the temperature interval after every 10-25°, and in the area close to the critical point after 0.5-2.0°.

The step of pressure measurement in the beginning of every isotherm comprised 5-10 kg/cm^2, at a pressure above 100 kg/cm^2 the step was changed after every 50-100 kg/cm^2. In the area close to the critical point pressure on isotherms was changed with a step of 0.5-1.0 kg/cm^2.

The viscosity of isobutane was measured on the following isotherms: 0, 10, 25, 50, 75, 100, 111.67, 125, 130, 132.6, 134.98, 137, 140, 150, 175, 200, 225, 250, and 275. Here the limit of pressure measurement comprised 1-700 kg/cm^2. For the determination of the viscosity of liquid isobutane on the line of saturation and in the area close to the critical point measurements were made at pressures up to 50 kg/cm^2 on isotherms 131.2, 132.6, 133.3, 134.0, 134.5, and 135.5.

At the assigned temperature and pressure the measurements were made at each point 2-3 times; here the reproducibility of the experiments did not exceed 0.2%. A control measurement was conducted on the isobar 50 kg/cm^2. The isobar data coincided with measurements on the isotherms with an accuracy of 0.2-3%.

The adjusted values of the viscosity coefficients of isobutane are given in Tables 1-3. The possible error of the experimental findings is estimated at ±1%.

The diagram depicts the dependence of the excess viscosity ($\eta_{p,T}-\eta_T$) of isobutane on the density ρ for the limits of temperatures and pressures indicated in Tables 1-3. The values of density have been taken from works [9-10]. Values ($\eta_{p,T}-\eta_T$) at all temperatures and pressures are arranged in one general curve; deviation does not exceed ±1.0%.

Table 1. Viscosity of isobutane (adjusted values), 10^{-5} N·s/m^2.

p, кГ/см² (2)	Температура, °С (1)																	
	0	10	25	50	75	100	110	125	130	134,98	137	140	150	175	200	225	250	275
1	0,69	0,72	0,75	0,81	0,86	0,924	0,947	0,980	0,991	1,002	1,007	1,013	1,036	1,092	1,148	1,205	1,262	1,319
5	19,82	17,80	15,20	0,83	0,88	0,944	0,966	1,000	1,012	1,023	1,027	1,033	1,056	1,112	1,168	1,224	1,280	1,336
10	19,95	17,93	15,33	11,78	0,90	0,964	0,986	1,020	1,031	1,043	1,048	1,054	1,077	1,113	1,189	1,245	1,301	1,356
15	20,08	18,05	15,46	11,91	9,09	0,992	1,015	1,048	1,059	1,070	1,075	1,082	1,104	1,158	1,213	1,267	1,322	1,375
20	20,22	18,19	15,58	12,04	9,27	6,725	1,054	1,084	1,095	1,104	1,109	1,114	1,135	1,187	1,239	1,291	1,343	1,395
25	20,35	18,32	15,71	12,16	9,42	6,951	5,922	1,145	1,152	1,159	1,162	1,166	1,181	1,226	1,271	1,320	1,367	1,414
30	20,50	18,46	15,82	12,29	9,58	7,149	6,160	1,273	1,264	1,257	1,255	1,252	1,248	1,272	1,308	1,345	1,388	1,434
35	20,62	18,57	15,94	12,38	9,71	7,320	6,383	4,841	4,137	1,514	1,462	1,419	1,363	1,334	1,351	1,376	1,410	1,453
36,5	20,65	18,63	15,98	12,43	9,76	7,390	6,455	4,950	4,361	2,360	1,651	1,537	1,421	1,360	1,366	1,386	1,416	1,458
40	20,74	18,70	16,06	12,50	9,85	7,496	6,583	5,200	4,690	3,984	3,660	2,754	1,590	1,422	1,402	1,416	1,440	1,470
50	21,01	18,97	16,31	12,76	10,11	7,810	6,947	5,605	5,299	4,875	4,689	4,429	3,227	1,735	1,575	1,558	1,564	1,575
60	21,27	19,23	16,56	12,99	10,33	8,100	7,252	6,110	5,730	5,362	5,233	5,041	4,199	2,365	1,850	1,770	1,710	1,720
70	21,52	19,46	16,81	13,20	10,57	8,350	7,533	6,444	6,102	5,771	5,644	5,488	4,793	3,107	2,216	2,030	1,890	1,870
80	21,78	19,73	17,04	13,44	10,78	8,594	7,801	6,740	6,410	6,136	5,969	5,815	5,193	3,675	2,591	2,270	2,100	2,010
100	22,32	20,23	17,53	13,89	11,20	9,053	8,322	7,260	6,983	6,675	6,560	6,397	5,823	4,508	3,435	2,780	2,470	2,310
120	22,82	20,70	17,98	14,31	11,60	9,470	8,773	7,750	7,470	7,180	7,005	6,890	6,321	5,075	4,075	3,270	2,910	2,650
150	23,59	21,45	18,64	14,94	12,20	10,050	9,400	8,410	8,150	7,850	7,730	7,580	7,030	5,846	4,882	3,980	3,500	3,160
200	24,88	22,68	19,76	15,98	13,13	10,970	10,270	9,374	9,091	8,827	8,710	8,555	8,032	6,822	5,858	5,020	4,400	3,950
250	26,20	23,85	20,84	16,95	14,03	11,840	—	10,220	9,900	9,653	9,524	9,376	8,878	7,651	6,675	5,900	5,170	4,650
300	27,48	25,03	21,93	17,92	14,92	12,700	—	10,990	10,690	10,420	10,300	10,120	9,603	8,415	7,413	6,600	5,880	5,295
400	30,06	27,42	24,10	19,80	16,63	14,320	—	12,450	12,150	11,910	11,750	11,580	11,040	9,781	8,689	7,750	7,005	6,450
500	32,66	29,71	26,26	21,63	18,25	15,760	—	13,800	13,480	13,180	13,040	12,880	12,320	10,990	9,820	8,880	8,150	7,520
600	35,32	32,06	28,40	23,45	19,80	17,050	—	15,050	14,700	14,380	14,250	14,080	13,490	12,120	10,910	9,870	9,150	8,550
700	37,95	34,35	30,52	25,32	21,31	18,370	—	16,200	15,820	15,480	15,350	15,150	14,550	13,150	11,850	10,820	10,070	9,520

KEY: (1) Temperature, °C; p, kg/cm^2.

Table 2. Viscosity of isobutane (adjusted values) 10^{-5} N·s/m^2.

(2) p, кГ/см²	(1) Температура, °С					
	131,2	132,0	133,0	134,0	134,5	135,5
35	3,935	3,785	3,530	—	—	—
36	4,100	3,965	3,770	3,450	—	—
36,2	4,130	3,995	3,815	3,525	3,330	—
37	4,225	4,105	3,910	3,725	3,585	3,900
37,5	4,282	4,180	4,015	3,815	3,700	3,350
38	4,345	4,230	4,080	3,900	3,790	3,560
39	4,450	4,340	4,200	4,030	3,940	3,730
40	4,545	4,435	4,300	4,145	4,070	3,900
45	4,915	4,830	4,725	4,615	4,570	4,455
50	5,200	5,130	5,040	4,955	4,910	4,825

KEY: (1) Temperature, °C;
(2) p, kg/cm^2.

Table 3. Viscosity of isobutane on the line of saturation (adjusted values) 10^{-5} N·s/m^3.

t_s, °C	p_s (3)	η_s' (1) (жидкость)	η_s'' (2) (газ)
0	1,585	19,700	0,699
10	2,223	17,720	0,725
20	3,039	16,000	0,751
30	4,073	14,400	0,778
40	5,356	12,980	0,806
50	6,927	11,700	0,836
60	8,809	10,580	0,866
70	11,06	9,520	0,900
80	13,71	8,530	0,937
90	16,79	7,593	0,979
100	20,33	6,721	1,030
110	24,38	5,860	1,100
120	28,97	4,952	1,216
125	31,38	4,375	1,312
130	34,13	3,830	1,485
132	35,25	3,575	1,615
135	37,22	2,360	2,360

KEY: (1) (liquid); (2) (gas); (3) p, kg/cm^2.

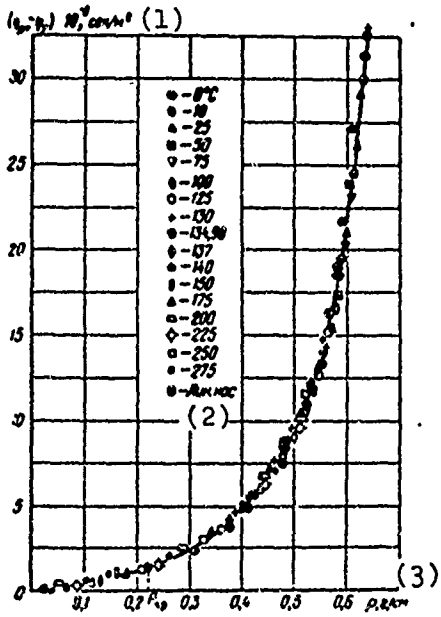

Figure: Dependence of $(\eta_{p,T}-\eta_T)$ on density for isobutane.
KEY: (1) s/m^2; (2) saturation line; (3) g/cm.

Data found in the literature for the gaseous state at atmospheric pressure [4] and data given in work [3] for liquid isobutane on the saturation line are respectively 2 and 9% higher than that obtained by us. It should be noted that the comparative analysis of the data on the viscosity of liquid saturated hydrocarbons of a normal series and their isomers at atmospheric pressure showed that the viscosity of isomers as a rule is less. And only the data given in work [3]

are an exception. The latter gives grounds to doubt their reliability.

The comparison of data on the viscosity of isobutane at increased temperatures and pressures shows that the data of the authors of work [6] are 8% lower than ours. The divergences of our data and data of work [7] on all isotherms do not exceed 2.5%.

The sufficiently satisfactory coincidence of our data with the data of work [7], obtained by the capillary method, and the large divergence with the data obtained by the method of the rolled ball [6], again confirms the inadequacy of the method of the rolled ball, which was already indicated earlier [1, 11].

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