Chemistry. — *"Investigations on the Temperature-Coëfficients of the Free Molecular Surface-Energy of Liquids from —80° C. to 1650° C."* **XIV.** *Measurements of a Series of Aromatic and Heterocyclic Substances.* By Prof. Dr. F. M. JAEGER and Dr. JUL. KAHN.

(Communicated in the meeting of September 25, 1915).

§ 1. In the present paper the results are published, obtained with the measurements of the surface-energy of the following 28 compounds; these measurements may be considered as a supplement of the formerly published researches with aromatic and cyclic derivatives:

1-2-4-*Chlorodinitrobenzene*; *para-Dibromobenzene*; *Iodobenzene*; *ortho-Bromotoluene*; *Phenol*; 1-2-4-*Dinitrophenol*; 2-4-6-*Trichlorophenol*; *para-Nitrophenetol*; 2-*Nitro-resorcine*; *Veratrol*; 4-5-*Dinitro-veratrol*; *Ethyl-Cinnamylate*; *Anisaldehyde*; *Benzophenone*; 3-4-3'-4'-*Tetra-chloro-benzophenone*; 2-4-2'-4'-*Tetrachlorobenzophenonebichloride*; *Monomethylaniline*; *Nitrosomethylaniline*; *Diisobutylaniline*; *Diphenylamine*; *Dibenzylamine*; *Azoxybenzene*; *α-Dihydrocampholenic Acid*; *Ethyl-α-Dihydro-campholenate*; *α-Furfurol*; *Thiophene*; and *Piperidine*.

The specific gravities were determined in the way previously described, either by means of a dilatometer, or by the aid of the pycnometer, or finally in some cases by a hydrostatical method. Of some substances only such small quantities were available, that it appeared impossible to determine these specific weights with sufficient exactitude; or there were other causes, which prohibited these determinations in some cases. It is more especially the very rapid evaporation of many of the higher melting substances, which causes the formation of a crystalline layer round the fine platinum suspension-wire of the immersion-conus, and which of course must appear a serious obstacle for the exact determinations of the density required.

§ 2.

I.

1-2-4-Chlorodinitrobenzene: $C_6H_3Cl_{(1)}(NO_2)_{2(2,4)}$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm²
	in mm. mercury of 0° C.	in Dynes			
60.4°	1.517	2021.3	45.5	1.515	1189.5
76.2	1.428	1954.8	43.9	1.497	1156.8
95	1.416	1884.4	42.2	1.477	1122.1
114	1.343	1791.0	40.4	1.455	1085.0
136	1.278	1703.8	38.3	1.432	1039.6
155.1	1.219	1623.9	36.4	1.412	997.3
175.5	1.158	1544.0	34.5	1.391	954.7
190	1.101	1467.8	32.9	1.378	916.2
204.2	1.057	1408.0	31.5	1.365	882.8

Molecular weight: **202.50.** Radius of the Capillary tube: 0.04595 cm. Depth: 0.1 mm.

The substance melts at 51° C.

The specific gravity at 75° C. was: 1.4982; at 100° C.: 1.4706; at 125 C.: 1.4439. At t C. · $d_{4°} = 1.5267 - 0.001158\,(t-50°) + 0.0000007\,(t-50°)^2$.

The temperature coefficient of μ is fairly constant; its mean value is **2.23** Erg. pro degree.

II.

para-Dibromobenzene: 1-4-$C_6H_4Br_2$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
94.8°	1.069	1424.9	32.0	1.840	813.4
115	1.008	1345.6	30.3	1.807	779 5
130.1	0.967	1289.2	28.8	1.782	747.8
144.5	0.923	1229.4	27.4	1.756	718.5
168.5	0.850	1133.0	25.2	1.715	671.3
180	0.810	1078.8	23.8	1.694	639.2
194.5	0.757	1009 2	22.3	1.668	605.1
209	0.701	926.6	20.4	1.643	559.2

Molecular weight: **235.79.** Radius of the Capillary tube: 0.04660 cm. Depth: 0.1 mm.

Under atmospheric pressure the boiling point is 216° C. The substance melts at 89° C. It sublimes already notoriously at rather low temperature (130°).

The density at 100° C. was: 1.8322; at 120° C.: 1.8000; at 140° C.: 1.7683. At t° C. it is calculated from: $d_{4°} = 1.8649 - 0.0016475\,(t-80°) - 0.000000625\,(t-80°)^2$.

The somewhat oscillating temperature-coefficient of μ has below 195°C. a mean value of about: **2.15** Erg pro degree.

III

Iodobenzene: C_6H_5J.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
— 21°	1.375	1833.1	41.0	1.892	928.7
0	1.314	1751.6	39.1	1.861	895.5
25.4	1.233	1644.5	37.1	1.823	861.4
40.4	1.188	1584.5	35.7	1.801	835.7
54.1	1.144	1524.6	34.4	1.781	811.3
76.1	1.076	1434.7	32.3	1.747	771.6
95.1	1.015	1353.3	30.4	1.716	734.9
117.2	0.944	1260.5	28.2	1.683	690.6
135.1	0.857	1143.4	25.5	1.659	630.5
150.5	0.803	1070.6	23.9	1.637	596.2
176	0.704	938.6	20.7	1.598	524.7

Molecular weight: **203.96.**

Radius of the Capillary tube: 0.04670cm.
Depth: 0.1 mm.

Under a pressure of 13 mm. the liquid boils constantly at 79° C. under 760 mm. at 188°.5 C.; on heating it becomes slightly coloured. In solid carbondioxide and alcohol it solidifies into a hard crystalline mass, which melts at —26° C.; according to TIMMERMANS at —31°.3 C. The specific gravity at 25° C. was: 1.8230; at 50° C.: 1.7852; at 100° C : 1.7090. At $t°$ it can be calculated from: $d_{4°} = 1\,8606 - 0.0015\,t - 0.00000016\,t^2$.

The temperature-coefficient of μ increases regularly with rising temperature: between —21° C. and 76° C. its mean value is: **1.65**; between 76° C. and 150° C : **2.46**; and above 150° C.: **2.80** Erg. The μ-t-curve therefore is concave towards the t-axis.

IV

ortho-Bromotoluene: $CH_{3(1)}\ C_6H_4Br_{(2)}$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
— 20°	1.236	1647.8	38.4	1.471	914.6
0	1.177	1569.3	36.5	1.447	878.9
25.8	1.102	1469.2	34.1	1.416	833.1
40	1.052	1402.3	32.5	1.399	800.4
55.5	1.002	1335.5	31.1	1.386	770.7
80	0.923	1231.2	28.6	1.352	720.6
92	0.886	1181.2	27.4	1.338	695 2
115.5	0.814	1085.1	25.1	1.310	645.8
*133.5	0.784	1045.0	23.6	1.288	614.1
*149.5	0.725	966.6	21.8	1.269	573.0
*175	0.634	845 2	18.9	1.239	504.7

Molecular weight: **170.98**

Radius of the Capillary tube: 0.04792 cm.; with the determinations indicated by *, it was: 0.04670 cm.
Depth: 0.1 mm.

Under a pressure of 755 mm. the liquid boils at 179° C. At —20° it becomes turbid, and solidifies at a somewhat lower temperature into a white crystalline mass, whose meltingpoint is: —27° C. The specific weight at 25° C. is: 1.4173; at 50° C.: 1.3876; at 75° C.: 1.3578; at $t°$: in general it is: $d_{4°} = 1.4470 - 0.00119\,t$. The temperature-coefficient of μ oscillates round a mean value of **2.09** Erg pro degree.

V.

Phenol: C_6H_5OH.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
41°2	1.207	1609.4	37.0	1.063	734.6
60.1	1.156	1538.9	35.2	1.043	707.8
82.1	1.090	1453.2	33 3	1.021	679.2
95.1	1.052	1400.8	32.0	1.019	653.5
115	0.980	1306.5	29 9	0 990	622.5
130.5	0.936	1245.6	28.3	0.979	593.6
144.5	0.868	1160.0	26.7	0.964	565.9
166	0.793	1057.2	24.1	0.951	515.4
180.5	0.719	958.6	21.8	0.940	469.8

Molecular weight: **94.05.** Radius of the Capillary tube: 0.04660 cm. Depth: 0.1 mm.

The compound boils at 180°.5 C. under a pressure of 758 mm. The melting-point is 41° C. The specific gravity was determined by means of the hydrostatic method; at 50° C. it was: 1.0529; at 75° C.: 1.0272; at 100° C.: 1.0033. At $t°$ C.: $d_{4°} = 1\ 1097 - 0.001208\,t + 0.00000144\,t^2$.

The temperature-coefficient of μ is between 41° and 82° C.: **1.36**; between 82° and 166° C.: **1.94** Erg.; above 166° C it increases very rapidly.

VI.

1-2-4-Dinitrophenol: $C_6H_3(OH)_{(1)}(NO_2)_2$

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
125°.4	1.361	1813.3	41.1	1.426	1049.6
140	1.318	1757.1	39.9	1.411	1026.2
155.1	1.279	1705.5	38.7	1.396	1002 4
170	1.235	1645.9	37.3	1.380	973.7
185.8	1.177	1570.3	35.6	1.363	937.0
200.1	1.142	1511.6	34.2	1.348	906.8
215	1.091	1455.7	32.9	1.333	878.9

Molecular weight: **184,07.** Radius of the Capillary tube: 0.04644 cm. Depth: 0.1 mm.

The beautifully crystallised compound melts at 114° C. The specific gravity at 120° C. was: 1.4309; at 140° C.: 1.4106; at 160° C.: 1.3898. At $t°$ C. $d_{4°} = 1.4507 - 0\,000962\,(t - 100°) - 0.00000062\,(t - 100°)^2$.

The temperature-coefficient of μ has a mean value of about: **1.90** Erg per degree.

VII.

2-4-6-Trichlorophenol: $C_6H_2(OH).Cl_3$.

Temperature in ° C.	Maximum Pressure H in mm. mercury of 0° C.	Maximum Pressure H in Dynes	Surface-tension γ in Erg pro cm².	Specific gravity d_{4^0}	Molecular Surface-energy μ in Erg pro cm².
70°.2	1.202	1600.8	36.3	1.495	941 3
90	1.134	1522.4	34.7	1.466	911.6
109	1.095	1459.3	33.1	1.438	880.8
124.9	1.040	1387.7	31.6	1.414	850.4
140.2	0.998	1328.7	30.0	1.386	818.2
156	0.941	1256.2	28.6	1 360	789.9
170	0 897	1195.9	27.1	1.333	758.5
185.5	0.846	1127.9	25.5	1.308	722.8
196.5	0.803	1070.5	24.1	1.290	689.8

Molecular weight: **197.40.** Radius of the Capillary tube: 0 04644 cm. Depth: 0.1 mm.

Under a pressure of 760 mm. the substance boils at 246° C. It melts at 69°5 C. and evaporates rapidly on heating above the meltingpoint. Above 196° the liquid gets darker by a gradual decomposition. At 75° C the density was: 1.4901; at 100° C.: 1.4587; at 125° C.: 1.4294. At $t°$ C.: $d_{4^0} = 1.5236 - -0.001382\,(t-50°) - 0.00000168\,(t-50)^2$.

The temperature-coefficient of μ increases gradually with rise of temperature; between 70° and 109° C. it is about **1.57** Erg; between 109° and 185° C.: **2.07** Erg; and between 185° and 196°.5 C.: **3.02** Erg pro degree Celsius.

VIII.

para-Nitrophenetol: $C_6H_4(NO_2)_{(1)} \cdot OC_2H_{5(4)}$.

Temperature in ° C.	Maximum Pressure H in mm. mercury of 0° C.	Maximum Pressure H in Dynes	Surface-tension γ in Erg pro cm².	Specific gravity d_{4^0}	Molecular Surface-energy μ in Erg pro cm².
70°.2	1 164	1549.0	35.3	1.171	963.9
90	1.096	1461.7	33.6	1.152	927.6
107.5	1.051	1401.7	32.2	1.111	910.6
124.5	1 004	1338.9	30 7	1.094	877 2
140	0.964	1284.1	29.3	1.079	844.9
157	0 914	1218.7	27.9	1.063	812.6
170	0.871	1162.9	26.7	1.051	784.0
185.6	0.840	1119.9	25.4	1.036	752 6
201	0.785	1048.8	24.1	1.020	721.5
220	0.747	994 2	22.6	1.002	684.6

Molecular weight: **167.08.** Radius of the Capillary tube: 0.04644 cm. Depth: 0.1 mm.

The beautifully crystallised compound melts at 60° C.; under atmospheric pressure it boils at 283° C. The specific gravity at 75° C is: 1.1416; at 100° C.: 1.1176; at 125° C.: 1.0937. At $t°$ C.: $d_{4^0} = 1.1656 - 0.00096\,(t-50)$.

The temperature-coefficient of μ is fairly constant; its mean value is: **2.0** Erg pro degree.

IX

2-Nitroresorcinol: $C_6H_3(OH)_2(NO_2)$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes	
90.7°	1.276	1701.1	39.5
109.5	1.208	1610.6	37.4
125	1.150	1533.2	35.6
140	1.101	1466.6	34.0
156.2	1.037	1382.5	32.1
169.2	0.988	1317.8	30.6
185.5	0.940	1253.2	29.1

Molecular weight: **139.05.** Radius of the Capillary tube: 0.04644 cm.
Depth: 0.1 mm.

The substance crystallises in bloodred crystals, and melts at 85° C. At higher temperatures it is very volatile. Above 180° C. the liquid becomes gradually darker by oxydation and decomposition; thus the determinations were no longer continued. (Added in the English translation.)

X

Veratrol: $C_6H_4(OCH_3)_{2\,(1,2)}$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity d_{4°	Molecular Surface-energy μ in Erg pro cm².
	in mm mercury of 0° C.	in Dynes			
* 0°	1.345	1793.7	42.5	1.105	1062.4
29 9	1.209	1611.8	37.7	1.077	958.6
47.3	1.143	1524.0	35.6	1.059	915.4
64.5	1.083	1444.2	33.7	1.044	874.9
81.2	1.026	1367.9	31.9	1.029	836.2
104 5	0.945	1260.2	29.3	1.009	778.2
124.8	0.879	1172.3	27.2	0.989	732.1
151.5	0.795	1058.2	24.4	0.967	666.6
178	0.719	958.8	22.1	0.943	614.0
196	0.678	904.3	20.8	0.928	584.1

Molecular weight: **138.1** Radius of the Capillary tube: 0.04777 cm.; with the measurements indicated by * it was: 0.04839 cm.
Depth: 0.1 mm.

Under a pressure of 759 mm. the boilingpoint is 206° C. In a refrigerant mixture it solidifies rapidly, and melts then again at +22° C. At the boiling point χ will have about the value: 19.9 Erg pro cm². The specific gravity at 25° C. was: 1.0812; at 50° C. 1.0570; at 75° C.: 1.0325; at $t°$: $d_{4^\circ} = 1.1051 - 0.00095\,t - 0.00000024\,t^2$.

The temperature-coefficient of μ is between 0° and 30° C. very great: **3.47** Erg; between 30° and 150° it remains fairly constant, or only slowly decreasing from **2.42** to **2.36** Erg. Between 150° and 176° it decreases: **1.98** Erg, and between 176° and 196° C.: **1.66** Erg. The curve thus is slightly concave.

XI

4-5-Dinitro-Veratrol: $CH_3O.C_6H_2(NO_2)_2.OCH_3$.

Temperature in 0° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
130°.8	1.349	1798.3	41.0	1.326	1268.0
144.5	1.307	1742.5	39.7	1.312	1236.5
167.2	1.236	1648.0	37.5	1.287	1183.1
182	1.178	1570.8	35.7	1.270	1136.3
194.5	1.125	1499 3	34.0	1.251	1093.1
208	1.042	1389.2	31.5	1.241	1018.2

Molecular weight: **228.06.** Radius of the Capillary tube: 0.04660 cm. Depth: 0.1 mm.

The compound was recrystallised from chloroform or ethylacetate; the long, yellow needles melt sharply at 130°.5 C. On heating above ca. 160° C., the liquid becomes gradually brownish. The specific gravity is at 140° C.: 1.3164; at 160° C.: 1.2948; and at 180° C.: 1.2726. At $t°$ C: $d_{4°} = 1.3374 - 0.001035\,(t - 120°) - 0.00000075\,(t - 120°)^2$. The temperature-coefficient of μ increases rapidly with the temperature: between 130° and 167° C. it is: **2.32** Erg; between 167° and 182° C.: **3.17** Erg; between 182° and 194° C.: **3.45** Erg. Above 198° C. the increase grows rapidly, to about **5.5** Erg at 208° C., indicating a decomposition setting in.

XII.

Ethyl-Cinnamylate: $C_6H_5 . CH : CH . COO\,(C_2H_5)$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
25°.7	1.164	1552.6	36.5	1.045	1113.6
40.5	1.111	1481.5	34.8	1.032	1070.7
55.8	1.064	1418.5	33.3	1.018	1033.8
80	0.994	1325.2	31.0	0.997	975.9
92	0.956	1274.5	29.8	0.987	944.4
116.5	0.883	1176.9	27.5	0.966	884.1
*136	0.854	1139 2	26.0	0.953	843.5
*149.5	0.819	1092.1	24.9	0.941	814.6
*176	0.732	976.4	22.2	0.922	736.3
*194.8	0.694	925.0	21.0	0.909	703.1

Molecular weight: **176.1.** Radius of the Capillary tube: 0.04792 cm.; in the measurements indicated by*, it was: 0.04670 cm. Depth: 0.1 mm.

Under a pressure of 755 mm. the liquid boils at 269° C.; at 158° C. under a pressure of 21 mm. On cooling it solidifies soon and melts again at + 6° 5 C. The rapid decrease of the χ-t-curve above 194° C. indicates doubtless a beginning decomposition. The specific weight at 25° C. is: 1.0457; at 50° C.: 1.0234; at 75° C.: 1.0018. At $t°$ it is calculated from: $d_{4°} = 1.0687 - 0.000934\,t + 0.00000056\,t^2$.

The temperature-coefficient of μ oscillates in a somewhat irregular way round a rather considerable value of: **2.41** Erg pro degree.

XIII.

Anisaldehyde: $CH_3O_{(1)} . C_6H_4 . COH_{(4)}$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Mol Sur energ Erg p
	in mm. mercury of 0° C.	in Dynes			
0°	1.489	1984.7	44.9	1.142	108
24.5	1.386	1847.8	41.8	1.120	102
31.5	1.364	1818.9	40.9	1.114	100
46.5	1.299	1741.1	39.5	1.101	98
61	1.268	1682.9	38.0	1.088	95
74.2	1.205	1609.3	36.5	1 077	91
90.3	1.159	1545 8	34.8	1.063	88
101	1.132	1506.8	33 7	1.054	86
124	1.052	1400.8	31.3	1.030	81
140.2	0.996	1327.8	29.8	1.022	77
154.2	0.946	1262.3	28.4	1.009	74
175	0.882	1177.6	26.5	0.993	70
194.1	0.822	1095.7	24.5	0.977	65
210	0.770	1027.2	22.9	0.963	62

Molecular weight: **136.07.** Radius of the Capillary tube: 0 0459
Depth: 0.1 mm.

The aldehyde boils under a pressure of 751 mm. at 246° C. At — solidifies and melts again at +2°.5 C.; according to WALDEN, the me point is —2° C. The density at 25° C. is: 1.1199; at 50° C.: 1.0980; at 7 1.0764. In general at $t°$: $d_{4°} = 1.1421 - 0.000894\,t + 0.00000024\,t^2$.

The temperature-coefficient of μ oscillates round a mean value of **2.0** pro degree.

XIV.

Benzophenone: $C_6H_5 . CO . C_6H_5$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Mole Sur energ Erg p
	in mm. mercury of 0° C.	in Dynes			
50°.3	1.397	1862.5	40.0	1.087	121
65	1.341	1787.9	38.4	1.075	117
75	1.317	1755.9	37.7	1 067	116
91	1.255	1673.5	35.9	1.055	111
104.1	1.214	1618.6	34 7	1.039	108
121	1.165	1558.7	33.2	1.028	104
130.5	1.138	1518.0	32.5	1.021	102
151	1.076	1435.7	30.7	1.003	98
171 8	1.015	1349.9	28.9	0.985	93
184.3	0.977	1303.1	27.8	0.973	90
200	0.925	1234.5	26.3	0.960	86

Molecular weight: **182.08.** Radius of the Capillary tube: 0.0437
Depth: 0.1 mm.

The compound was purified by repeated crystallisation from alcoh melts at 48°.5 C.; its metastable form at 26° 5 C. Under atmospheric pre the boilingpoint is 305° C. The specific gravity at 50° C. is: 1.0869; at 7 1.0669; at 100° C.: 1.0464. At $t°$ C.: $d_{4°} = 1.1064 - 0.00077(t-25°) - 0.00($ $(t-25°)^2$.

The temperature-coefficient of μ has a mean value of **2.27** Erg per de

XV.

3-4-3′-4′-Tetrachlorobenzophenone: $C_6H_3Cl_2 . CO . C_6H_3Cl_2$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes	
154°	1.134	1511.7	35.1
170	1.090	1453.1	33.7
186.5	1.037	1382.4	32.1
201.8	0.993	1323.6	30.7
220	0.948	1263 7	29.3

Molecular weight: **319.88.** Radius of the Capillary tube: 0.04644 cm. Depth: 0.1 mm.

The colourless, beautifully crystallised substance melts at 142° C.

The quantity available did not allow the determination of the specific weight of the liquid.

XVI.

2-4-2′-4′-Tetrachlorobenzophenone-Dichloride: $C_6H_3Cl_2 . CCl_2 . C_6H_3Cl_2$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
156°	1.037	1382.5	31.2	1.442	1270.7
170	1.002	1358.7	30.6	1.429	1253 8
185.5	0.994	1325.2	29.9	1.415	1233.2
199 2	0.969	1291.9	29.1	1.401	1208.2
218	0.943	1253.2	27.9	1.390	1164 5

Molecular weight: **374.80.** Radius of the Capillary tube: 0.04644 cm. Depth: 0.1 mm.

The compound, which crystallises in beautiful, colourless crystals, melts at 140° C At 145° C. the specific weight was: 1.4523; at 165° C.: 1.4336; at 185° C.: 1.4146. At t° C.: $d_{4°} = 1.4570 - 0.0009425\,(t - 140°)$. The temperature-coefficient of μ increases rather rapidly with rise of temperature: between 156° and 170° C it is: **1.21** Erg; between 170° and 185° C. **1.33** Erg; between 185° and 199° C.: **1.82** Erg; and between 199° and 218° C.: **2.32** Erg per degree.

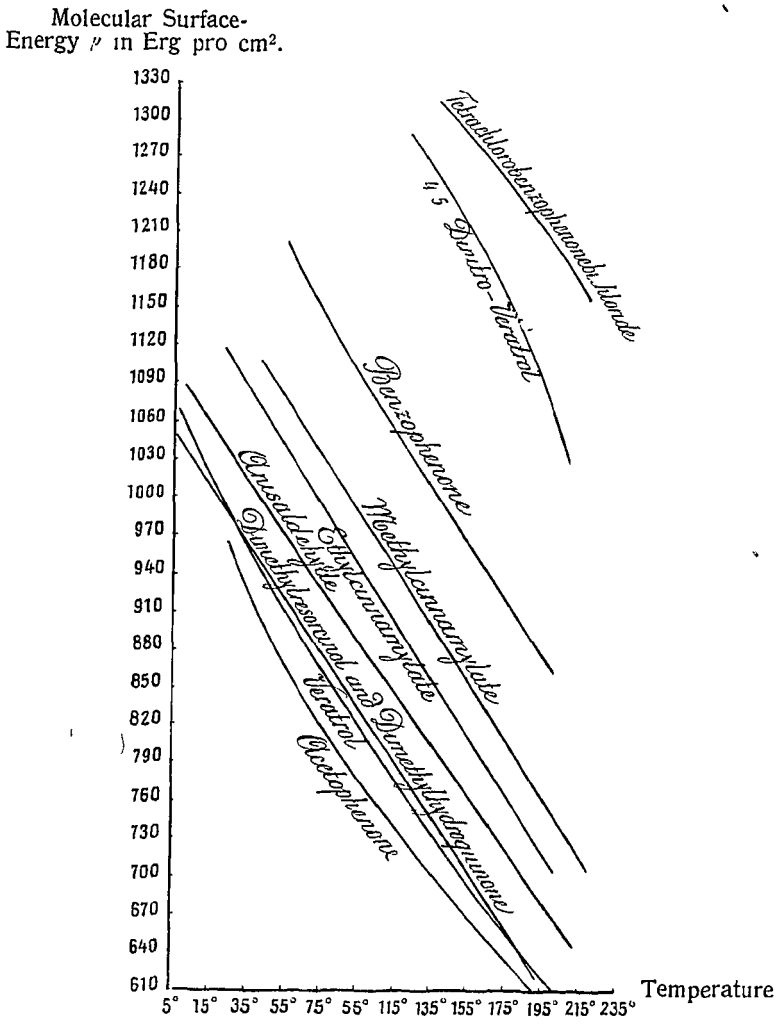
Molecular Surface-
Energy p in Erg pro cm².
1330
1300
1270
1240
1210
1180
1150
1120
1090
1060
1030
1000
970
940
910
880
850
820
790
760
730
700
670
640
610
5° 15° 35° 55° 75° 95° 115° 135° 155° 175° 195° 215° 235°
Temperature
Tetrachlorbenzophenonchlorid
1, 5 Dinitro-Veratrol
Benzophenone
Methylzimmtsäureäthyl
Äthylcinnamylate
Cuminaldehyde
Dimethylresorcinäthyl and Dimethylhydrochinone
Veratrol
Acetophenone

Fig. 1.

XVII.

Monomethylaniline: $C_6H_5 . NH(CH_3)$.

Temperature in ° C.	Maximum Pressure H in mm. mercury of 0° C.	Maximum Pressure H in Dynes	Surface-tension γ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
*—18°	1.332	1775.8	42.2	1.033	931.2
* 0	1.268	1690.5	40.1	1 015	895.3
29.8	1.174	1565.8	36.7	0.985	835.9
49.3	1.106	1474.5	34.6	0.965	799.0
65	1.058	1410.9	33.0	0.952	768.9
80 9	1.005	1339.8	31.3	0.936	737.6
104.5	0.934	1245.2	29.0	0.915	693 8
122	0 879	1172.3	27.3	0.899	660 9
152	0.791	1055.0	24.5	0.872	605.3
178.8	0.713	950 4	22.0	0.850	552.9
195	0.672	895.9	20.7	0.837	525.6

Molecular weight **107 08** Radius of the Capillary tube 0.04777 cm.; with the observations indicated by *, it was· 0.04839 cm. Depth· 0.1 mm.

The substance boils constantly at 195°.5 C under a pressure of 759 mm. After strongly undercooling it solidifies and melts afterwards at —57° C. The specific weight at 25° C is 0.9898; at 50° C. 0 9656; at 75° C.· 0 9420; at t° C.: $d_{4°} = 1\,0146 - 0.001004\,t + 0.00000048\,t^2$.

The temperature coefficient of μ is fairly constant; its mean value is: **1.90** Erg pro degree.

XVIII

para-Nitro-Monomethylaniline: $C_6H_4 . (NHCH_3)(1) . NO_2(4)$.

Temperature in ° C.	Maximum Pressure H in mm. mercury of 0° C.	Maximum Pressure H in Dynes	Surface-tension γ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
155°.2	1 525	2032.7	46.3	1.201	1167.5
170	1.469	1958.2	45.2	1.189	1147.5
186	1.440	1919.7	43.7	1.175	1117.5
199	1.373	1830.3	41.5	1.165	1070.5
210	1.324	1765.7	40.1	1 156	1037.2

Molecular weight: **152.08.** Radius of the Capillary tube: 0.04644 cm. Depth: 0.1 mm.

The yellow crystals, which possess a beautiful pink lustre, melt at 152° C. Above 190° the liquid becomes gradually darker tinged; therefore the measurements were no longer continued. The specific gravity at 160° C. was: 1.1968; at 180° C.: 1.1807; at 200° C.: 1 1643. At t C.· $d_{4°} = 1.2049 - 0\,0008125\,(t - 150°)$. The temperature-coefficient of μ increases very rapidly with rise of temperature from **1.3** Erg at 155° C. to **3.3** Erg at 210° C. Evidently the above mentioned decomposition must be considered the cause of this phenomenon.

XIX.

Nitrosomethylaniline: $C_6H_5.N(NO)CH_3$.

Temperature in 0° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm^2.	Specific gravity d_{4^0}	Mol Su ener Erg
	in mm mercury of 0° C.	in Dynes			
* 0°	1.439	1919.1	45.7	1.143	11
* 30.4	1.356	1808.1	43.0	1.117	10
46.9	1.314	1752.4	41.4	1.099	10
58.6	1.280	1707.0	40.3	1.092	10
85.9	1.190	1587.1	37.5	1.068	9
103.3	1.132	1508.6	35.6	1 054	9
117.6	1.079	1438.3	33.9	1.041	8
127.4	1.048	1397.0	32.9	1.033	8

Molecular weight: **136.08.** Radius of the Capillary tube: 0.04839 c
the observations indicated by *, it was: 0.048
Depth: 0.1 mm.

The substance boils constantly at 128° C. under a pressure of 760 n a mixture of ice and salt it solidifies, and melts afterwards at + Above 125° C. the liquid becomes gradually brownish by slow decompo The specific gravity at 25° C was: 1.1213; at 50° C.: 1.0995; at 75° C.: At t^0 C.: $d_{4^0} = 1.1430 - 0.000868\,t$.

Originally the temperature-coefficient of μ increases with rise of ter ture from **1.63** Erg at 0° C. to **1.99** Erg at 30° C. Then it remains constant at **2.27** Erg pro degree.

XX.

Diïsobutylaniline: $C_6H_5 . N[CH_2 . CH(CH_3)_2]_2$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm^2.	Specific gravity d_{4^0}	Mol Su ener Erg
	in mm. mercury of 0° C.	in Dynes			
—18°	(1.118)	(1490.0)	(37.0)	0.949	(13
0	1.049	1398.1	32.8	0.932	11
26	0.959	1278.5	29.9	0.909	11
40.7	0.908	1210.3	28.3	0.899	10
55.7	0.864	1151.9	26.9	0.885	10
80.2	0.800	1066.6	24.8	0.866	9
92.5	0.700	1026.7	23.9	0.860	9
115.5	0.711	947.4	22.1	0.847	8
*135.3	0.678	903.6	20.5	0.836	8
*149.2	0.642	856.6	19.4	0.832	7
*175.9	0.577	769.2	17.4	0.823	6
*195.8	0.530	706.6	15.9	0.818	6

Molecular weight: **205.11.** Radius of the Capillary tube: 0.0479
in the measurements indicated by
radius was: 0.04670 cm.
Depth: 0.1 mm.

The substance boils under a pressure of 21 mm. at 146° C. It rema liquid condition down to — 20° C., but is then very viscous; at — 79° becomes glassy, but does not crystallise. Under atmospheric pressu liquid boils at 250° C. The specific gravity at 25° C. is: 0.90 50° C.: 0.8901; at 75° C.: 0.8725. At t^0 in general: $d_{4^0} = 0.9319 - 0.0009 + 0.00000176\,t^2$.

The temperature-coefficient of μ is in the beginning (below 41° C.) 3.43 Erg, afterwards very constant: **2.73** Erg pro degree. It is therefore great, also at higher temperatures.

XXI.

Diphenylamine: $(C_6H_5)_2NH$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
60.5°	1.284	1710.7	38.6	1.054	1143.3
76.8	1.230	1639.5	37.0	1.039	1106.4
95	1.171	1570.4	35.2	1.025	1062.1
114.2	1.103	1472.8	33.4	1.010	1017.8
136	1.041	1389.4	31.4	0.993	967.7
155	0.991	1321.2	29.7	0.980	923.4

Molecular weight: **169.89.** Radius of the capillary tube: 0.04595 cm. Depth: 0.1 mm.

The substance boils at 179° C.; under a pressure of 12 mm The melting-point is 54° C. Above 150° C. the liquid is soon coloured darkly; the measurements therefore were no longer continued. The density at 75° C. was: 1.0412; at 100° C.: 1.0210; at 125° C.: 1.0022. In general at $t°$ C.: $d_{4°} = 1.0628 - 0.000892\,(t-50°) + 0.00000112\,(t-50°)^2$.

The temperature-coefficient of μ is constant, and **2.31** Erg pro degree.

XXII.

Dibenzylamine: $(C_6H_5CH_2)_2NH$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
−18.5°	1.413	1883.6	43.3	1.060	1410.6
0	1.340	1787.8	41.1	1.045	1351.7
25.1	1.254	1683.5	38.5	1.024	1283.5
41.5	1.204	1603.9	36.7	1.011	1234.0
56	1.158	1543.7	35.4	0.999	1199.6
71	1.117	1489.2	34.1	0.988	1164.3
84.8	1.071	1437.3	33.1	0.977	1138.4
100	1.039	1385.1	31.7	0.963	1101.0
*116	1.026	1367.9	30.3	0.950	1061.9
*130.5	0.977	1305.1	28.9	0.938	1021.5
*146	0.931	1242.6	27.5	0.925	981.1
*162.5	0.900	1200.9	26.2	0.912	943.6
*176	0.853	1135.9	24.9	0.901	904.0
*196.8	0.803	1069.2	23.4	0.884	860.4
*209.5	0.772	1024.6	22.4	0.873	830.6
*228	0.713	949.4	20.7	0.858	776.4

Molecular weight: **197.10.** Radius of the Capillary tube: 0.04676 cm.; in the measurements indicated by *, the radius was 0.04529 cm. Depth: 0.1 mm.

Under a pressure of 19 mm. the amine boils constantly at 186° C. At −70° it becomes a transparent glassy mass, but does not crystallise. The specific gravity was volumetrically determined: at 0° C. it was 1.045; at 25° C.: 1.024; at 50° C.: 1.004. Generally: $t°$ C.: $d_{4°} = 1.045 - 0.00082\,t$.

The temperature-coefficient of μ is oscillating round a mean value of: **2.53** Erg pro degree Celsius.

XXIII.

Azoxybenzene: $C_6H_5 . N_2O . C_6H_5$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity d_{4°	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
55.8°	1.296	1725.4	39.3	1.133	1228.8
70.6	1.257	1676.0	38.3	1.121	1206.1
85	1.219	1625.2	37.1	1.110	1176.0
100	1.181	1579.9	35.9	1.098	1146.3
*115	1.180	1572.0	34.7	1.087	1115.4
*130.5	1.139	1519.0	33.5	1.074	1085.5
*145.5	1.085	1448.8	32.1	1.063	1047.3
*162	1.050	1400.0	30.8	1.050	1013.2
*176	1.017	1355.4	29.7	1.039	983.9
*196.9	0.950	1265.5	27.7	1.022	927.7
*211	0.906	1210.1	26.6	1.011	897.3
*226	0.833	1110.5	24.2	1.000	822.4

Molecular weight: **198.1.** Radius of the Capillary tube: 0.04676 cm.; in the measurements indicated by *, this radius was: 0.04529 cm.
Depth: 0.1 mm.

At 36° C. the substance melts; the liquid is of a clear yellow colour. The specific gravity at 50° C. was 1.1373; at 75° C : 1.1177; at 100° C.: 1.0982. In general at t° C.: $d_{4^\circ} = 1.1764 - 0.000782\,t$.

The temperature-coefficient of μ increases gradually with rise of temperature: between 56° and 71° it is: C. **1.53** Erg; between 71° and 100° C : **1.96** Erg; between 100° C. and 162° C : **2.16** Erg; between 162° and 211° C.: **2.31** Erg and above 211° C. increasing very rapidly, up to about **4.98** Erg per degree at 226° C., decomposition evidently setting in.

XXIV

ν-Dihydrocampholenic Acid: $C_5H_6(CH_3)_3.CH_2.COOH$

Temperature in ° C.	Maximum Pressure H		Surface-tension ζ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes	
— 21°	(1.752)	(2335.8)	(54.4)
0	1.102	1468.9	34.3
25	1.008	1344.7	31.4
40.3	0.960	1280.5	29.9
54.1	0.915	1220.5	28.5
75.5	0.861	1147.5	26.8
95	0.813	1083.8	25.3
115	0.758	1010.7	23.6
134.3	0.723	963.6	22.5
150.5	0.684	912.2	21.3
175.5	0·636	847.9	19.8
195.3	0.607	809.4	18.9

Molecular weight: **170.14.** Radius of the Capillary tube: 0.04670 cm.
Depth: 0.1 mm

At — 79° the liquid becomes a glassy mass, but does not crystallise. At — 20° and 0° C. also it is already very viscous.

The quantity of the liquid was too small to permit the determination of its specific gravity.

XXV.

Aethyl-γ-Dihydrocampholenate: $C_5H_6(CH_3)_3 . CH_2 . COOC_2H_5$.

Temperature in ° C.	Maximum Pressure H in mm. mercury of 0° C.	Maximum Pressure H in Dynes	Surface-tension χ in Erg pro cm².	Specific gravity $d_{4°}$	Molecular Surface-energy μ in Erg pro cm².
— 21°	1.020	1359.9	31.0	0.961	1082.0
0	0.964	1284.8	29.3	0.945	1034.2
25.3	0.893	1190.6	27.1	0.924	971.0
40.4	0.859	1145.2	26.0	0.912	939.8
54.1	0.822	1095.9	24.9	0.901	907.3
75.5	0.768	1023.9	23.2	0.884	856.2
95.5	0.714	951.9	21.5	0.869	802.5
115.2	0.673	896.2	20.2	0.852	764.0
134.8	0.620	826.5	18.6	0.837	711.9
153	0.577	769.2	17.3	0.822	670.2
176.1	0.517	689.5	15.4	0.804	605.4
194	0.456	607.9	13.5	0.789	537.4

Molecular weight: **198.18.** Radius of the Capillary tube: 0.04670 cm. Depth: 0.1 mm.

Under a pressure of 20 mm. the colourless liquid boils at 147° C. At – 79° C. it gets turbid and very viscous, but does not crystallise. The specific gravity at 0° C. is: 0.9445; at 25° C.: 0.9250; at 50° C.: 0.9045. At t° C.: $d_{4°} = 0.9445 - 0.0008\,t$.

Below 176° C. the temperature-coefficient of μ is relatively constant, with a mean value of: **2.46** Erg pro degree.

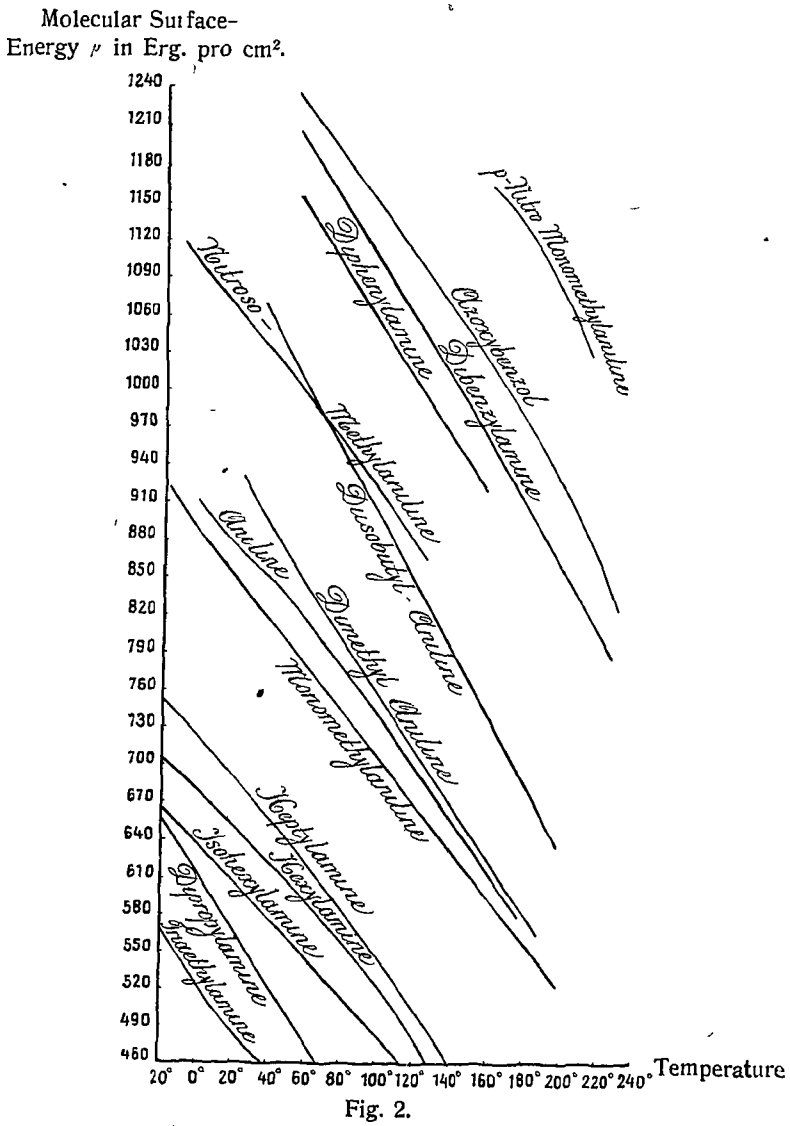
Molecular Surface-
Energy μ in Erg. pro cm².
1240
1210
1180
1150
1120
1090
1060
1030
1000
970
940
910
880
850
820
790
760
730
700
670
640
610
580
550
520
490
460
20° 0° 20° 40° 60° 80° 100° 120° 140° 160° 180° 200° 220° 240°
Temperature
p-Nitro Monomethylaniline
Brombenzol
Dibenzylamine
Diphenylamine
Nitroso-
Methylaniline
Diisobutyl-Aniline
Aniline
Dimethyl Aniline
Monomethylaniline
Hexylamine
Hexylamine
Isohexylamine
Dipropylamine
Triaethylamine

Fig. 2.

XXVI.

Furfurol: ν-$C_4H_3O.\ C\overset{H}{\underset{O}{}}$.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity d_{4^0}	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
*—22°	1.437	1915.8	45.7	1 211	921.8
* 0	1.368	1824.5	43.5	1.185	869.8
29.9	1.289	1719.3	40.7	1.151	806.3
46.8	1.214	1618.5	38.3	1.133	745.2
58.3	1.171	1561.2	37.0	1.119	713.9
86.5	1.072	1429.0	33.8	1 089	645.4
102.3	1.017	1355.5	32.0	1 074	599.3
117.7	0.961	1281 2	30.2	1.060	557.4

Molecular weight: **96.03.** Radius of the Capillary tube: 0.04839 cm.; in the observations indicated by *, it was: 0.04867 cm. Depth: 0.1 mm.

The liquid boils at 162° and 761 mm. mercury. The substace crystallises in a bath of solid carbondioxide and alcohol, and melts then again at —31° C.; according to WALDEN at —36° C Above 100° C. the liquid is rapidly oxydized, and gets a brownish colour. At the boilingpoint, the value of χ can only differ slightly from: 25.4 Erg pro cm². The specific gravity at 25° C. was: 1.1563; at 50° C.: 1.1287; at 75° C.: 1.1023; at $t°$: d_{4^0}=1 1851—0.001176 t+0.00000096 t^2.

The temperature-coefficient μ is almost constant, and has the mean value: **2.70** Erg pro degree; it is rather high.

XXVII.

Thiophene: C_4H_4S.

Temperature in ° C.	Maximum Pressure H		Surface-tension χ in Erg pro cm².	Specific gravity d_0	Molecular Surface-energy μ in Erg pro cm².
	in mm. mercury of 0° C.	in Dynes			
*—19°	1.134	1512.3	36.0	1.110	644.6
* 0	1.057	1409.5	33.5	1.087	608.3
29.9	0.939	1252.3	29.5	1.051	547 8
47.3	0.874	1165.5	27.4	1.032	515.1
58.7	0.834	1111.8	26.1	1.006	499.0
87	0.732	975.4	22.8	0.987	441.5

Molecular weight: **84.10.** Radius of the Capillary tube: 0.04839 cm.; in the measurements indicated by *, this radius was: 0.04867 cm. Depth: 0.1 mm.

The liquid boils constantly at 87° C. under a pressure of 770 mm. In a bath of solid carbondioxide and alcohol, the substance crystallises, and melts at —29°.8 C.; according to TSAKALOTOS the meltingpoint is —37°.1 C. At the boilingpoint χ has the value: **22.8** Erg pro cm².

At 0° C. the specific gravity is: 1.0873; at 25° C.: 1.0573; at 50° C.: 1.0285. At $t°$ C.: d_{4^0} = 1.0873—0.001224 t + 0.00000096 t^2.

The temperature-coefficient of μ is fairly constant, with a mean value of: **1.90** Erg pro degree.

XXVIII

Piperidine: $C_5H_{10} > NH$.

Temperature in ° C.	Maximum Pressure H		Surface-tension $\varkappa$ in Erg pro cm².	Specific gravity $d_{4°}$	Mol Sur ener Erg p
	in mm. mercury of 0° C.	in Dynes			
* —19°	1.041	1388 6	32.8	0 900	6
* 0	0.973	1297 7	30.6	0.882	6
29.4	0.876	1168.0	27.1	0.855	5
48	0.813	1084.3	25.1	0.838	5
64.5	0.753	1004.8	23.2	0.823	5
80.9	0.703	937.8	21.6	0.808	4
104.5	0.628	837.4	19.2	0.786	4

Molecular weight: **85.10** Radius of the Capillary tube: 0.04777 cm.; observations indicated by *, it was: 0.048
Depth: 0.1 mm.

Under a pressure of 760 mm. the base boils at 108° C. On cooling i
tallises, and melts afterwards at — 9° C.; according to MASCARELLI thi
perature would be — 13° C.; at the boiling point $\varkappa$ is about: 19.7 Erg pr
The specific gravity at 0° C. is: 0.8820; at 25° C.: 0.8586; at 50°C.: (
At t° C.: $d_{4°} = 0.8821 - 0.00092\ t$. The temperature-coefficient of ρ is
constant: its mean value can be fixed upon **1.98** Erg pro degree.

Molecular Surface-Energy α in Erg pro c.m².

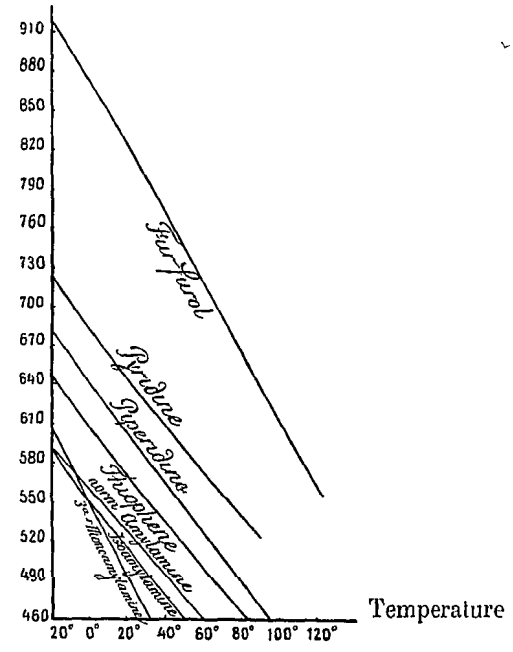

Fig. 3.

§ 3. In connection with these data we can make the following remarks.

The substitution of the bromine in *bromobenzene* by iodine, makes the value of u at the same temperatures increase, just as we formerly observed with the substitution of chlorine by bromine in the *chlorobenzene*. This behaviour is evidently opposite to what was formerly stated in the case of the molten halogenides of the alcali-metals. In agreement with our previous experiences, the substitution of H in the benzene-nucleus by CH_3, makes the value of μ increase (*bromobenzene* and *o-bromotoluene*); and the same holds good for the substitution of H by a NO_2-group, by *halogenides*, or by the *azoxy*-radical; in general by substitution of H by radicals built up from strongly electronegative atoms. This seems to be a general rule. An analogous phenomenon is observed, if aromatic hydrocarbon-radicals substitute the H-atoms: a comparison of the *hexyl-*, or *heptylamines* with *diphenyl-*, and *dibenzylamine* makes this very evident, and just in the same way a comparison of *acetophenone* and *benzophenone*. The μ-t-curve for *ethylcinnamylate* lies beneath that for *methylcinnamylate*, and the same is the case with *monomethylaniline* in comparison with *aniline* itself. On the contrary, the value of μ for *aniline* is very much increased by substitution of the H of the amino-group by two *isobutyl*-radicals.

The addition of hydrogen in *pyridine*, this thus being transformed into *piperidine*, makes the μ-t-curve of the former compound fall; for *thiophene* it lies beneath that for *piperidine*.

Some curves for *amylamines* are reproduced here also for the purpose of comparison. This is connected on the one hand with the substitution of the atom $\backslash S /$ in *thiophene* by the combination: $-N = \overset{/}{C}H-$, and perhaps on the other hand with the presence of the unsaturated C-atoms in *pyridine*, in comparison with those in *piperidine*. However it must be remarked here at once, that evidently this last may not be considered a general rule, as for instance the curve of *benzene* lies lower than that for *cyclohexane*. Certainly a number of constitutive influences are superposed one upon the other, thus prohibiting the statement of the precise connection between the value of μ and the degree of saturation of the C-atoms in this case, to a more or less degree.

We intend to finish here untill a later date the investigation of organic compounds with the series here described.

University Laboratory for Inorganic

Groningen, August 1915. *and Physical Chemistry.*