THE SURFACE TENSIONS OF ETHYL ETHER, ACETONE, TOLUENE AND METHYL ALCOHOL AT LOW TEMPERATURE.

By **Tokuzo TONOMURA** and **Kaoru CHUJO.**

Received June 1st, 1932. Published August 28th, 1932.

The surface tensions of ethyl ether, acetone, toluene and methyl alcohol were measured by means of the capillary rise method. Out of many tubes three capillary tubes, which were considered to have uniform cross sections, were selected, and two marks, say a and b, were etched on them as reference points. The diameters of the capillary tubes were measured with the mercury columns of known weight at point to point, and they were taken against the distances from the reference points a or b as the calibration curves. Each of the capillary tubes, then, was sealed in a tube of about 16 cm. in length and 3 cm. in diameter, as shown in Fig. 1. The tube c was connected to the vacuum loading apparatus which was the same as that in the previous paper.[1]

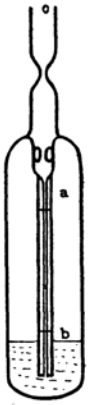


Fig. 1.

(1) Tonomura and Uehara, this bulletin, **6** (1931), 118.

The materials used for the present experiments were obtained from Kahlbaum pure chemicals and were purified by the ordinary ways. Their boiling points were as follows:

Ethyl ether, 34.28—34.30°C./757.2 mm.; Acetone, 55.98°C./753.4 mm.;
Toluene, 109.71—109.80°C./764.9 mm.; Methyl alcohol, 64.89—64.95°C./764.9 mm.

The apparatus sealed off from the loading apparatus was set in the large brass block which was hanged from the ceiling to prevent any disturbances due to the motion of cryostat and others, and to keep vertically. The cryostat and thermometer were the same as those used in the previous experiments.[1]

Table 1.

Surface tensions of ethyl ether.

Temp. °C.	Height. cm.	Radius. cm.	$D^{(2)}-d^{(3)}$	γ (obs.) Dynes/cm.	γ (calc.) Dynes/cm.	Capil.
30.00	1.561	0.02856	0.6982	15.25	15.52	A
,,	2.277	0.01973	,,	15.37	,,	B
25.00	1.609	0.02856	0.7046	15.87	16.11	A
,,	2.359	0.01973	,,	16.07	,,	B
− 1.00	2.694	0.01973	0.7367	19.12	19.24	B
− 18.85	2.926	,,	0.7585	21.46	21.49	B
− 22.48	2.993	,,	0.7616	22.04	21.94	B
− 40.68	2.218	0.02857	0.7821	24.28	24.28	A
− 45.05	3.273	0.01973	0.7869	24.91	24.84	B
− 51.14	3.299	0.02857	0.7936	25.54	25.64	A
− 59.68	2.369	,,	0.8033	26.64	26.78	A
− 63.02	3.501	0.01973	0.8070	27.32	27.23	B
− 70.30	2.454	0.02856	0.8149	27.99	28.21	A
− 72.85	3.612	0.01973	0.8173	28.54	28.54	B
− 80.43	2.552	0.02856	0.8249	29.47	29.56	A
− 85.20	3.744	0.01973	0.8299	30.04	30.14	B
− 93.41	3.852	,,	0.8385	31.23	31.34	B
− 94.75	2.686	0.02856	0.8400	31.58	31.53	A
−108.24	4.026	0.01973	0.8542	33.25	33.42	B

$$\gamma\left(\frac{M}{D}\right)^{\frac{2}{3}} = 2.2261\ (\tau \rightarrow 8.62)$$

(1) Tonomura and Uehara, this bulletin, **6** (1931), 118.
(2) Keyes and Felsing, *J. Am. Chem. Soc.*, **41** (1919), 589.
(3) Curt Ferdinand Mundel, *Z. physik. Chem.*, **85** (1913), 450.

The height of the meniscus in the capillary tube above the liquid surface together with the mark a or b, were observed by a cathetometer through the transparent part of the cryostat. From the distance between the meniscus and the mark, the diameter of the capillary tube at the position of meniscus was determined with the calibration curve which had been obtained previously. The variation of the diameter due to thermal contraction was neglected, as the expansion coefficient of glass was too small to make appreciable errors in the present experiments.(1)

The experimental results were shown in Table 1, 2, 3 and 4, and diagrammatically shown in Fig. 2 and 3. The surface tensions γ of the

Table 2.

Surface tensions of Acetone.

Temp. °C.	Height. cm.	Radius. cm.	$D^{(2)}-d^{(2)}$	γ (obs.) Dynes/cm.	γ (calc.) Dynes/cm.	Capil.
30.00	1.954	0.02856	0.7797	21.32	21.72	A
,,	2.856	0.01973	,,	21.53	,,	B
20.00	2.045	0.02856	0.7911	22.64	22.98	A
,,	2.979	0.01973	,,	22.79	,,	B
− 1.44	3.288	,,	0.8153	25.92	25.75	B
−14.86	3.431	,,	0.8302	27.54	27.52	B
−18.14	3.495	,,	0.8338	28.17	27.96	B
−25.25	3.551	,,	0.8416	28.89	28.92	B
−35.16	3.690	,,	0.8523	30.41	30.26	B
−36.87	2.567	0.02586	0.8542	30.68	30.50	A
−44.15	3.792	0.01973	0.8620	31.60	31.50	B
−44.88	2.625	0.02586	0.8628	31.69	31.60	A
−57.32	2.716	,,	0.8761	33.30	33.33	A
−66.88	2.798	,,	0.8863	34.71	34.68	A
−75.72	4.150	0.01973	0.8957	35.93	36.07	B
−81.65	2.916	0.02856	0.9019	36.81	36.79	A
−86.41	4.255	0.01973	0.9069	37.30	37.47	B
−91.09	2.989	0.02856	0.9118	38.14	38.15	A

$$\gamma\left(\frac{M}{D}\right)^2 = 1.8516\ (\tau+1.808)$$

(1) The apparatus was constructed by ordinary soda glass, whose expansion coefficient is the order of 10^{-5}.

(2) Felsing and Durban, *J. Am. Chem. Soc.*, **48** (1926), 2885.

liquid in the fifth columns of the tables were calculated with the following formula:

$$\gamma = \frac{1}{2} g\, r \left(h + \frac{r}{3}\right)(D-d)$$

where r is the diameter of the capillary tube, and g the acceleration due to gravity, that is 980.1 cm./sec.^{2} at Sendai. D and d are the

Table 3.

Surace tensions of toluene.

Temp. °C.	Height. cm.	Radius. cm.	$D^{(1)} - d$.	γ (obs.) Dynes/cm.	γ (calc.) Dynes/cm.	Capil.
20.00	3.362	0.01973	0.8659	28.14	28.12	B
,,	2.681	0.02466	,,	28.05	,,	C
10.50	3.473	0.01973	0.8755	29.40	29.36	B
,,	2.774	0.02466	,,	29.35	,,	C
− 0.00	2.876	0.02466	0.8842	30.72	30.70	C
− 6.33	3.669	0.01973	0.8904	31.59	31.53	B
−10.00	2.967	0.02466	0.8940	32.06	32.02	C
−15.46	3.771	0.01973	0.8994	32.79	32.75	B
− 20.13	3.056	0.02466	0.9039	33.39	33.37	C
−25.73	3.886	0.01973	0.9093	34.16	34.13	B
−30.05	3.136	0.02466	0.9135	34.63	34.71	C
−35.52	4.003	0.01973	0.9187	35.55	35.46	B
−41.07	3.230	0.02466	0.9241	36.08	36.21	C
−44.74	4.103	0.01973	0.9273	36.78	36.71	B
−50.67	3.315	0.02466	0.9332	37.39	37.54	C
−55.10	4.214	0.01973	0.9373	38.18	38.15	B
−60.25	3.398	0.02466	0.9421	38.69	38.86	C
−66.20	4.325	0.01973	0.9476	39.62	39.69	B
−70.30	3.484	0.02466	0.9514	40.06	40.27	C
−76.10	4.451	0.01973	0.9568	41.16	41.09	B
−81.30	3.596	0.02466	0.9615	41.79	41.82	C
−85.85	4.558	0.01973	0.9657	42.54	42.47	B
−92.25	3.704	0.02466	0.9714	43.49	43.38	C
−96.50	4.677	0.01972	0.9753	44.08	43.99	B

$$\gamma\left(\frac{M}{D}\right)^{\frac{2}{3}} = 2.4109\ (\tau - 39.05)$$

(1) Tonomura and Uehara, this bulletin, **6** (1931), 255.

densities of liquid and vapour respectively. The values of D and d used were found in the literatures given in the foot note of the tables. When the values of d were not found in the literatures, they were calculated from the vapour pressure, assuming that the vapour obeys the ideal gas law. The letters in the last columns of the tables represent the capillary tubes used in the measurements.

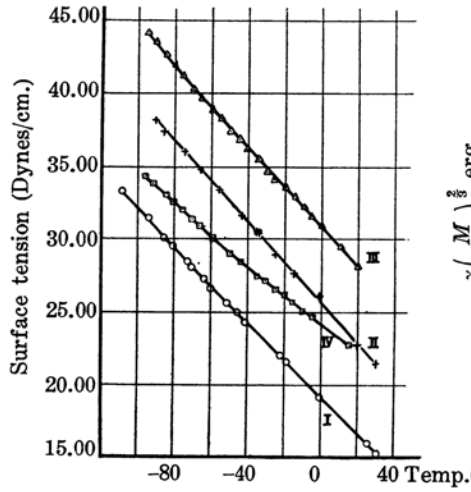
Table 4.

Surface tensions of methyl alcohol.

Temp. °C	Height. cm.	Radius. cm.	$D-d$[1]	γ (obs.) Dynes/cm.	γ (calc.) Dynes/cm.	Capil.
25.00	2.861	0.01973	0.7882	21.80	21.75	B
,,	2.288	0.02466	,,	21.80	,,	C
15.00	2.945	0.01973	0.7970	22.69	22.70	B
,,	2.354	0.02466	,,	22.67	,,	C
− 0.36	2.456	0.02466	0.8106	24.06	24.04	C
− 5.63	3.131	0.01973	0.8154	24.69	24.57	B
−10.91	2.528	0.02466	0.8205	25.07	25.10	C
−16.54	3.226	0.01973	0.8255	25.75	25.67	B
−20.60	2.600	0.02466	0.8293	26.05	26.09	C
−25.11	3.298	0.01973	0.8334	26.58	26.58	B
−31.78	2.685	0.02466	0.8397	27.24	27.25	C
−34.67	3.383	0.01973	0.8424	27.56	27.56	B
−40.24	2.743	0.02466	0.8476	28.10	28.15	C
−44.00	3.466	0.01973	0.8512	28.53	28.56	B
−49.83	2.811	0.02466	0.8569	29.11	29.19	C
−55.13	3.565	0.01973	0.8619	29.71	29.77	B
−59.42	2.875	0.02466	0.8662	30.10	30.25	C
−66.12	3.671	0.01973	0.8729	30.98	31.00	B
−70.26	2.958	0.02466	0.8770	31.36	31.47	C
−74.66	3.758	0.01973	0.8813	32.02	31.97	B
−80.72	3.038	0.02466	0.8873	32.54	32.67	C
−84.43	3.854	0.01973	0.8911	33.20	33.10	B
−91.27	3.124	0.02466	0.8981	33.91	33.91	C
−94.75	3.970	0.01973	0.9017	34.61	34.32	B

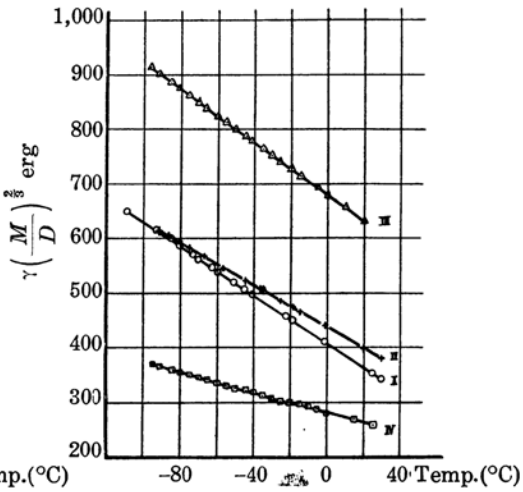
$$\gamma\left(\frac{M}{D}\right)^{\frac{2}{3}} = 560.89 - 1.12481T + 0.000333186T^2$$

(1) Körber, Ann. Physik., (4), **37** (1912), 1012.



I. Ethyl ether II. Acetone
III. Toluene IV. Methyl alcohol

Fig. 2.



I. Ethyl ether II. Acetone
III. Toluene IV. Methyl alcohol

Fig. 3.

The values of γ in the sixth columns of the tables were calculated from the empirical formula of the Eötvös type given at the end of the tables. They were obtained from the experimental values of γ with the method of the least square. M in those formulae is the molecular weight of the substances and τ is the temperature measured from the critical temperature, which is 194.5°C. for ethyl ether, 235.6°C. for acetone and 320.8°C. for toluene. In the case of methyl alcohol whose molecules were considered to be much associated, the constants suitable for the Eötvös formula were not found and a quadratic formula, therefore, was used, where T is the absolute temperature.

In conclusion, the present authors thank to Prof. S. Mitsukuri for his helpful guidance during their experiments.

The Laboratory of Theoretical Chemistry, Faculty of Science,
Tohoku Imperial University, Sendai.

May, 1932.