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THE MEASUREMENT OF THE VISCOSITY COEFFICIENT OF SEA WATER

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In an old study by Ruppin and Krümmel (Krümmel, 1907: 281), the viscosity of sea water was measured by the method of Wil. Ostwald. However, at that time the data for the viscosity of sea water were given relative to that of pure water at 0° C. Since then several precise measurements (Dorsey, 1940: 182) have been made and reliable data obtained, and therefore it is necessary to determine more exact values for the viscosity of sea water.

Method of Measurements. The Ostwald viscometer was used. The size of the capillary was so designed that about 5 cc. of sea water could run through it in five to ten minutes. The temperature variation of a thermostat in which the viscometer was submerged was adjusted to within 0.01° C.

The measurements were made at temperatures near 0°, 5°, 10°, 15°, 20°, 25° and 30° C. Sea water with a chlorinity of 19.39 ‰ was diluted to concentrations which were respectively 2, 4, 6, 8, 10, 12, 14, 16 and 18 ‰; these waters were used as samples.

The coefficients of viscosity can be calculated by the formula

$$\eta = \eta_w \frac{\rho \cdot t}{\rho_w \cdot t_w},$$

where η is the coefficient of viscosity of sea water at any given temperature, η_w the coefficient of pure water at the same temperature, ρ and ρ_w respectively the density of sea and pure water at the given temperature, t and t_w time (sec.) of flow of sea and pure water through the capillary of a viscometer. The time of flow was measured five times for each sample with a stop watch. Since each observed value for the time of flow agreed within 0.2 sec., the possible errors attendant on the determination of t were smaller than 0.1%. The error in the temperature due to the variation of the thermostat was also of the same order. The most important source of error might be due to a delicate change in the condition of the inner wall of the capillary, but it was impossible to estimate its exact magnitude.

The Results of Measurements. In Table I, the results of measurements are shown. Each value in this table was corrected for temperature and chlorinity. We can see that the viscosity of sea water decreases with increasing temperature and increases with chlorinity. O. Krümmel expressed the relation between the viscosity and the temperature of sea water in the following empirical formula:

$$\eta = \frac{\eta_0}{1 + \alpha\theta + \beta\theta^2},$$

Where η_0 is the viscosity of sea water at 0° C., α and β are constants varying with the chlorinity, and θ is the water temperature. We examined the above formula, using our experimental data. Since we found that the formula was sufficient for our purpose, α and β were determined with the above experimental data, where the values of η_0 were those obtained both by experiment and by interpolation.

In Table II, values of α and β for each chlorinity are shown, where values for the odd chlorinity were calculated by interpolation. Using these values of α and β, the viscosity coefficients of sea water for each per mille and each 1° C. were calculated by the above formula. Results are shown in Table III.

Since the mean deviation between calculated and experimental values is smaller than 0.25%, this table will be useful for obtaining viscosity coefficients of sea water of different chlorinity and temperature.

In conclusion, the authors wish to express their thanks to Mr. H. Honda for his earnest assistance throughout this work.

REFERENCES

DORSEY, N. E.

1940. Properties of ordinary water-substance. Amer. Chem. Soc., Monogr. Ser. No. 81. 673 pp.

KRÜMMEL, OTTO

1907. Handbuch der Ozeanographie. Die räumlichen, chemischen und physikalischen Verhältnisse des Meeres. Bd. 1. J. Engelhorn, Stuttgart. 526 pp.

TABLE I—OBSERVED VALUES OF VISCOSITY COEFFICIENT OF SEA WATER (UNIT; MILLI POISE)

Cl	Water Temperature (°C)						
(°/oo)	0	5	10	15	20	25	30
0	17.94	15.19	13.10	11.45	10.09	8.95	8.00
2	18.03	15.26	13.17	11.51	10.15	9.04	8.06
4	18.11	15.32	13.23	11.60	10.22	9.12	8.14
6	18.21	15.41	13.29	11.71	10.29	9.20	8.18
8	18.29	15.52	13.39	11.76	10.39	9.25	8.26
10	18.36	15.61	13.52	11.83	10.44	9.32	8.31
12	18.45	15.71	13.61	11.97	10.50	9.38	8.37
14	18.54	15.80	13.74	12.03	10.58	9.49	8.43
16	18.62	15.91	13.82	12.08	10.67	9.57	8.50
18	18.70	15.97	13.89	12.21	10.71	9.63	8.56
20	18.90	16.12	14.05	12.31	10.87	9.69	8.61

TABLE II—VALUES OF α AND β

$$\left(\eta = \frac{\eta_0}{1 + \alpha\theta + \beta\theta^2}\right)$$

Cl (°/oo)	α	β
1	0.03481	0.0002110
2	0.03489	0.0002024
3	0.03490	0.0001945
4	0.03490	0.0001891
5	0.03494	0.0001840
6	0.03496	0.0001825
7	0.03478	0.0001855
8	0.03447	0.0001897
9	0.03422	0.0001915
10	0.03397	0.0001923
11	0.03363	0.0002005
12	0.03325	0.0002219
13	0.03297	0.0002290
14	0.03279	0.0002314
15	0.03274	0.0002270
16	0.03272	0.0002219
17	0.03253	0.0002265
18	0.03225	0.0002360
19	0.03222	0.0002370
20	0.03239	0.0002357

TABLE III—VISCOSITY COEFFICIENTS OF SEA WATER, CALCULATED BY THE FORMULA, $\eta = \frac{\eta_0}{1 + \alpha\theta + \beta\theta^2}$, USING THE VALUES OF α AND β IN TABLE II. Cl, CHLORINITY IN PRO MILLE; θ, WATER TEMPERATURE; UNIT, MILLI POISE

	Cl (°/oo)																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
0	17.94	17.98	18.03	18.07	18.11	18.16	18.21	18.25	18.29	18.33	18.36	18.40	18.45	18.49	18.54	18.58	18.62	18.66	18.70	18.80	18.90	0
1	17.34	17.37	17.42	17.46	17.50	17.54	17.59	17.63	17.68	17.72	17.75	17.80	17.85	17.90	17.95	17.99	18.03	18.07	18.11	18.21	18.30	1
2	16.76	16.80	16.84	16.88	16.92	16.96	17.01	17.05	17.10	17.14	17.18	17.23	17.29	17.33	17.38	17.42	17.46	17.51	17.55	17.65	17.74	2
3	16.22	16.25	16.30	16.33	16.37	16.41	16.46	16.50	16.55	16.60	16.64	16.69	16.75	16.80	16.85	16.89	16.93	16.97	17.02	17.11	17.19	3
4	15.71	15.74	15.78	15.81	15.85	15.89	15.94	15.98	16.03	16.08	16.12	16.17	16.23	16.28	16.34	16.38	16.41	16.46	16.51	16.60	16.68	4
5	15.22	15.25	15.29	15.32	15.36	15.40	15.44	15.49	15.54	15.59	15.63	15.68	15.75	15.80	15.85	15.89	15.93	15.97	16.02	16.11	16.18	5
6	14.75	14.78	14.82	14.85	14.89	14.93	14.97	15.02	15.07	15.12	15.17	15.22	15.28	15.33	15.39	15.42	15.46	15.51	15.56	15.64	15.71	6
7	14.31	14.34	14.38	14.41	14.45	14.49	14.53	14.57	14.63	14.68	14.72	14.78	14.84	14.89	14.94	14.98	15.02	15.06	15.11	15.20	15.26	7
8	13.81	13.92	13.96	13.99	14.03	14.06	14.10	14.15	14.20	14.25	14.30	14.35	14.41	14.46	14.52	14.56	14.59	14.64	14.69	14.77	14.83	8
9	13.49	13.52	13.55	13.59	13.62	13.66	13.70	13.74	13.80	13.85	13.90	13.95	14.01	14.06	14.11	14.15	14.19	14.23	14.28	14.36	14.42	9
10	13.10	13.13	13.17	13.21	13.24	13.28	13.31	13.36	13.41	13.47	13.51	13.57	13.62	13.67	13.72	13.76	13.80	13.84	13.89	13.97	14.03	10
11	12.74	12.77	12.80	12.84	12.87	12.91	12.95	12.99	13.05	13.10	13.14	13.20	13.25	13.30	13.35	13.39	13.43	13.47	13.52	13.59	13.65	11
12	12.39	12.42	12.45	12.49	12.52	12.56	12.60	12.64	12.69	12.75	12.79	12.85	12.89	12.94	12.99	13.03	13.07	13.11	13.16	13.23	13.29	12
13	12.06	12.08	12.12	12.16	12.19	12.23	12.26	12.30	12.36	12.41	12.46	12.51	12.55	12.60	12.65	12.69	12.73	12.77	12.82	12.89	12.94	13
14	11.73	11.76	11.80	11.84	11.87	11.91	11.94	11.98	12.04	12.09	12.13	12.19	12.23	12.27	12.32	12.36	12.40	12.44	12.49	12.55	12.60	14
15	11.43	11.46	11.49	11.53	11.56	11.60	11.63	11.67	11.73	11.78	11.82	11.87	11.91	11.96	12.01	12.05	12.09	12.13	12.17	12.34	12.28	15
16	11.13	11.22	11.20	11.24	11.27	11.31	11.34	11.38	11.43	11.48	11.53	11.58	11.61	11.66	11.71	11.75	11.79	11.82	11.86	11.93	11.97	16
17	10.89	10.88	10.92	10.96	10.99	11.03	11.06	11.10	11.15	11.20	11.24	11.29	11.32	11.37	11.41	11.45	11.49	11.53	11.57	11.63	11.68	17
18	10.58	10.61	10.65	10.69	10.72	10.76	10.79	10.82	10.88	10.92	10.97	11.02	11.05	11.09	11.13	11.17	11.21	11.25	11.29	11.35	11.39	18
19	10.32	10.35	10.39	10.43	10.46	10.50	10.53	10.56	10.61	10.66	10.71	10.75	10.78	10.82	10.86	10.90	10.94	10.98	11.01	11.07	11.11	19
20	10.07	10.10	10.14	10.18	10.21	10.25	10.28	10.31	10.36	10.41	10.45	10.50	10.52	10.56	10.60	10.64	10.68	10.72	10.75	10.81	10.85	20
21	9.83	9.86	9.90	9.94	9.97	10.06	10.04	10.07	10.12	10.17	10.21	10.25	10.27	10.31	10.35	10.39	10.43	10.47	10.50	10.56	10.59	21
22	9.60	9.63	9.67	9.71	9.74	9.83	9.80	9.84	9.89	9.93	9.98	10.02	10.03	10.07	10.11	10.15	10.19	10.22	10.25	10.31	10.35	22
23	9.37	9.40	9.44	9.48	9.52	9.60	9.58	9.62	9.66	9.71	9.75	9.79	9.80	9.84	9.88	9.92	9.96	9.98	10.02	10.07	10.11	23
24	9.16	9.19	9.23	9.27	9.30	9.39	9.37	9.40	9.45	9.49	9.53	9.57	9.58	9.61	9.66	9.70	9.73	9.76	9.79	9.84	9.88	24
25	8.95	8.98	9.02	9.06	9.10	9.18	9.16	9.19	9.24	9.28	9.32	9.36	9.37	9.40	9.44	9.48	9.52	9.55	9.57	9.62	9.66	25
26	8.75	8.78	8.82	8.86	8.90	8.98	8.96	8.99	9.04	9.08	9.12	9.15	9.16	9.19	9.23	9.27	9.31	9.34	9.36	9.41	9.44	26
27	8.56	8.59	8.63	8.67	8.71	8.78	8.77	8.80	8.84	8.88	8.92	8.95	8.96	8.99	9.03	9.07	9.10	9.13	9.15	9.20	9.24	27
28	8.37	8.40	8.44	8.49	8.52	8.60	8.58	8.61	8.65	8.69	8.74	8.76	8.77	8.79	8.83	8.87	8.91	8.94	8.96	9.00	9.04	28
29	8.19	8.22	8.26	8.31	8.34	8.42	8.40	8.43	8.47	8.51	8.55	8.57	8.58	8.61	8.64	8.68	8.72	8.75	8.76	8.81	8.84	29
30	8.02	8.05	8.09	8.13	8.17	8.20	8.23	8.26	8.30	8.34	8.38	8.39	8.40	8.42	8.46	8.56	8.54	8.56	8.58	8.62	8.66	30