slowly collecting. Whatever the cause, however, the method advocated eliminates it; while in all other cases this method gives the same result as the regular one.

In the next paper of this series will be considered the standardization of a tip, and the calculation, from the drop weight, of surface tension and the molecular weight; while in the succeeding ones, which will appear in the immediate future, will be presented the results already obtained with the fifty or more liquids examined, using tips of various diameters.

LABORATORY OF PHYSICAL CHEMISTRY.

SOLUBILITY OF OXYGEN IN SEA WATER.

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It is a well recognized fact that oxygen is less soluble in sea water than in fresh water, and that in brackish water the solubility is intermediate, varying with the amount of chlorine present. In studying the pollution of the waters of harbors it is often desirable to express the amount of oxygen present in terms of "per cent. of saturation." Inasmuch as the proportion of sea water varies considerably in different samples it is not easy to determin this percentage on account of the lack of convenient tables showing the amount of oxygen dissolved in saturated waters containing different amounts of chlorine. For this reason the authors have investigated the literature on the subject and have prepared a convenient table for use.

One of the earliest investigations of the solubility of oxygen in sea water was made by Prof. William Ditmar, of Anderson's College, Glasgow, in connection with the Challenger expedition.[1] His method consisted of boiling off the dissolved gases, collecting and analyzing them. His results have been much used. They show the variations in the amount of oxygen in "sea water" dissolved at different temperatures, but do not state fully the corresponding amounts of chlorine in the water used for the experiments.

In connection with the study of the amount of dissolved oxygen in the Thames River, Clowes and Houston carried on some experiments on the solubility of oxygen in distilled water, sea water, and mixtures of the two in different proportions, at temperatures between 13.8° and 16° C.[2]

The data thus secured, taken in connection with the known variations

[1] "Report on Composition of Sea Water," by William Dittmar, *Challenger Report, Physics and Chemistry*, 1, 168. See also page 58 of the Report of Letts and Adeney on the "Pollution of Estuaries and Tidal Waters," Appendix 6 of the "Report of the Royal Commission on Sewage Disposal, 1908."

[2] Report to the London County Council by Dr. F. Clowes and Dr. A. C. Houston on "The Experimental Bacterial Treatment of London Sewage, 1892-1903," page 225.

in the amount of oxygen dissolved in distilled water at different temperatures, have been used as the basis of determining the per cent. of saturation in brackish waters.

Believing that the importance of the subject demanded further investigation, the authors undertook some careful experiments to determin the solubility of dissolved oxygen in sea water of known chlorine content at temperatures of 0°, 10°, 20°, and 30°. Winkler's method was used. Saturation was obtained by forcing a current of air through three liters of water in a bottle so jacketed that a constant temperature was obtained. Determinations were made at intervals and continued until a constant result was reached. This sometimes took several hours.

While these experiments were in progress we received, through the courtesy of Dr. Howard T. Barnes, of McGill University, a paper by Dr. Charles J. J. Fox, on "The Coefficients of Absorption of Nitrogen and Oxygen in Distilled Water and Sea Water and of Atmospheric Carbonic Acid in Sea Water,"[1] which covered the ground so completely that it seemed unnecessary for us to continue our work, especially as the results obtained by Fox agreed with our own, as far as they had been carried.

Fox's results were obtained by exposing the water to an atmosphere of pure dry oxygen and measuring the quantity of gas dissolved. For the practical use of water analysts it is necessary to transform the data thus obtained into the units commonly used, namely, milligrams per liter, or parts per million. Fox himself has given a table in which the results are expressed in terms of cubic centimeters of oxygen absorbed per liter from a dry free atmosphere containing 20.9 per cent. of oxygen at 760 mm. pressure, as follows:

NUMBER OF CC. OF OXYGEN ABSORBED BY 1000 CC. OF SEA WATER FROM A FREE DRY ATMOSPHERE CONTAINING 20.9 PER CENT. OF OXYGEN OF 760 MM. PRESSURE.

$$1{,}000a = 10.291 - 0.2809t + 0.006009t^2 + 0.0000632t^3 - \mathrm{Cl}\,(0.1161 - 0.003922t + 0.0000631t^2).$$

Chlorine, parts per million.	$t = 0°$.	4°.	8°.	12°.	16°.	20°.	24°.	28°.
0	10.29	9.26	8.40	7.68	7.08	6.57	6.14	5.75
4,000	9.83	8.85	8.04	7.36	6.80	6.33	5.91	5.53
8,000	9.36	8.45	7.68	7.04	6.52	6.07	5.67	5.31
12,000	8.90	8.04	7.33	6.74	6.24	5.82	5.44	5.08
16,000	8.43	7.64	6.97	6.43	5.96	5.56	5.20	4.86
20,000	7.97	7.23	6.62	6.11	5.69	5.31	4.95	4.62

For convenient use we have corrected these figures for vapor pressure and have transformed them into parts per million. These results are herewith presented with the hope that they may be of service to sanitary engineers and water analysts.

[1] *Trans. Faraday Soc.*, Sept., 1909, p. 68.

DISSOLVED OXYGEN IN DISTILLED WATER AND IN SEA WATER OF DIFFERENT DEGREES
ATMOSPHERE CONTAINING

(Calculated by G. C. Whipple and M. C.

Temperature centigrade.	Distilled water.[1]	Chlorine in Sea Water (parts per million). 0.	1000.	2000.	3000.	4000.	5000.	6000.	7000.	8000.	9000.
0	14.70	14.62	14.45	14.29	14.12	13.96	13.79	13.63	13.46	13.30	13.13
1	14.28	14.23	14.06	13.90	13.73	13.57	13.41	13.25	13.09	12.93	12.77
2	13.88	13.84	13.68	13.52	13.36	13.20	13.05	12.90	12.74	12.59	12.43
3	13.50	13.48	13.32	13.17	13.02	12.87	12.72	12.58	12.43	12.28	12.13
4	13.14	13.13	12.99	12.84	12.70	12.55	12.41	12.26	12.12	11.98	11.84
5	12.80	12.80	12.65	12.51	12.37	12.23	12.09	11.95	11.81	11.67	11.53
6	12.47	12.48	12.34	12.20	12.06	11.93	11.79	11.66	11.52	11.39	11.25
7	12.16	12.17	12.03	11.90	11.77	11.64	11.51	11.37	11.24	11.11	10.98
8	11.86	11.87	11.74	11.62	11.49	11.37	11.24	11.12	10.99	10.86	10.73
9	11.58	11.59	11.46	11.34	11.22	11.09	10.97	10.85	10.73	10.60	10.48
10	11.31	11.33	11.20	11.08	10.97	10.85	10.73	10.60	10.48	10.37	10.25
11	11.05	11.08	10.96	10.84	10.73	10.61	10.49	10.38	10.26	10.15	10.03
12	10.80	10.83	10.72	10.61	10.50	10.39	10.28	10.17	10.06	9.94	9.83
13	10.57	10.60	10.49	10.38	10.27	10.16	10.05	9.95	9.84	9.73	9.63
14	10.35	10.37	10.27	10.16	10.06	9.95	9.85	9.74	9.63	9.53	9.42
15	10.14	10.15	10.05	9.95	9.85	9.75	9.65	9.55	9.45	9.35	9.25
16	9.94	9.95	9.85	9.75	9.65	9.56	9.46	9.36	9.26	9.16	9.06
17	9.75	9.74	9.64	9.55	9.45	9.36	9.26	9.16	9.07	8.97	8.88
18	9.56	9.54	9.44	9.35	9.25	9.16	9.07	8.99	8.90	8.80	8.71
19	9.37	9.35	9.26	9.17	9.08	8.99	8.89	8.80	8.71	8.63	8.54
20	9.19	9.17	9.08	9.00	8.91	8.82	8.73	8.65	8.56	8.47	8.38
21	9.01	8.99	8.91	8.83	8.74	8.65	8.57	8.48	8.40	8.31	8.23
22	8.84	8.83	8.75	8.67	8.59	8.50	8.42	8.33	8.25	8.16	8.08
23	8.67	8.68	8.60	8.52	8.44	8.35	8.27	8.18	8.10	8.02	7.93
24	8.51	8.53	8.45	8.37	8.29	8.20	8.12	8.04	7.96	7.87	7.79
25	8.35	8.38	8.29	8.21	8.12	8.04	7.96	7.88	7.80	7.72	7.64
26	8.19	8.22	8.14	8.06	7.98	7.90	7.81	7.73	7.65	7.57	7.50
27	8.03	8.07	7.99	7.91	7.83	7.75	7.67	7.60	7.52	7.44	7.36
28	7.86	7.92	7.84	7.76	7.68	7.61	7.53	7.45	7.37	7.30	7.[illegible]2
29	7.74	7.77	7.69	7.62	7.54	7.47	7.39	7.31	7.23	7.15	7.07
30	7.60	7.63	7.55	7.48	7.40	7.33	7.25	7.17	7.09	7.01	6.93

[1] The figures in this column are those of the Committee on Standard Methods

OF SALINITY WHEN SATURATED AT DIFFERENT TEMPERATURES AND EXPOSED TO AN 20.9 PER CENT. OXYGEN.

Whipple from measurements of C. J. J. Fox.)

10000.	11000.	12000.	13000.	14000.	15000.	16000.	17000.	18000.	19000.	20000.	Difference per 100 parts per million of chlorine.
12.97	12.80	12.64	12.47	12.31	12.14	11.98	11.81	11.65	11.48	11.32	0.0165
12.61	12.46	12.30	12.14	11.98	11.82	11.67	11.51	11.35	11.19	11.03	0.0160
12.28	12.13	11.98	11.83	11.67	11.52	11.37	11.22	11.06	10.91	10.76	0.0154
11.98	11.83	11.68	11.54	11.39	11.24	11.09	10.95	10.80	10.65	10.50	0.0149
11.69	11.55	11.40	11.26	11.11	10.97	10.83	10.69	10.54	10.40	10.25	0.0144
11.39	11.26	11.12	10.98	10.84	10.70	10.57	10.43	10.29	10.15	10.01	0.0140
11.12	10.99	10.85	10.72	10.58	10.45	10.32	10.18	10.05	9.91	9.78	0.0135
10.85	10.73	10.60	10.47	10.34	10.21	10.09	9.96	9.83	9.70	9.57	0.0130
10.61	10.48	10.36	10.23	10.11	9.98	9.86	9.73	9.61	9.48	9.36	0.0125
10.36	10.24	10.12	10.00	9.88	9.76	9.64	9.52	9.40	9.28	9.17	0.0121
10.13	10.02	9.90	9.78	9.66	9.55	9.44	9.33	9.21	9.09	8.98	0.0118
9.92	9.81	9.69	9.58	9.46	9.35	9.24	9.13	9.02	8.91	8.80	0.0114
9.72	9.61	9.50	9.39	9.28	9.17	9.06	8.95	8.84	8.73	8.62	0.0110
9.52	9.41	9.30	9.19	9.09	8.98	8.87	8.76	8.66	8.56	8.46	0.0107
9.32	9.22	9.11	9.01	8.90	8.80	8.70	8.60	8.50	8.40	8.30	0.0104
9.14	9.03	8.93	8.83	8.73	8.63	8.53	8.43	8.33	8.23	8.14	0.0100
8.96	8.86	8.77	8.67	8.57	8.47	8.38	8.28	8.18	8.08	7.99	0.0096
8.78	8.68	8.59	8.49	8.40	8.30	8.20	8.11	8.02	7.93	7.84	0.0095
8.62	8.52	8.43	8.33	8.24	8.15	8.07	7.98	7.88	7.79	7.70	0.0092
8.45	8.36	8.27	8.18	8.09	8.00	7.91	7.82	7.74	7.65	7.56	0.0089
8.30	8.21	8.12	8.03	7.95	7.86	7.77	7.68	7.60	7.51	7.42	0.0086
8.14	8.05	7.97	7.88	7.80	7.71	7.62	7.54	7.45	7.37	7.28	0.0086
7.99	7.91	7.83	7.74	7.66	7.57	7.48	7.40	7.31	7.23	7.14	0.0085
7.85	7.76	7.68	7.60	7.51	7.43	7.34	7.25	7.17	7.08	7.00	0.0083
7.71	7.63	7.54	7.46	7.38	7.30	7.21	7.13	7.05	6.96	6.87	0.0083
7.56	7.48	7.40	7.31	7.23	7.15	7.07	6.99	6.90	6.82	6.74	0.0082
7.42	7.34	7.26	7.18	7.10	7.02	6.94	6.86	6.78	6.70	6.61	0.0080
7.28	7.20	7.12	7.04	6.96	6.88	6.81	6.73	6.65	6.57	6.49	0.0079
7.14	7.06	6.99	6.91	6.83	6.75	6.68	6.60	6.52	6.44	6.37	0.0078
7.00	6.92	6.83	6.77	6.70	6.62	6.55	6.47	6.40	6.32	6.25	0.0076
6.86	6.79	6.72	6.64	6.56	6.49	6.43	6.35	6.28	6.20	6.13	0.0075

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