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REFRACTIVE INDEX AND DISPERSION OF NORMAL AND
HEAVY WATER

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ABSTRACT

Certain provisional values of the refractive index of normal water are given to accompany similar values determined at 25 C by the minimum-deviation method for a sample of heavy water (sp gr = 1.001376 at 25 C) using several wave lengths of the visible spectrum. According to the linear or additive relation for simple mixtures, which was found adequate in Luten's investigation, the differences in index between H_2O and H_2^{18}O are calculated and compared with previously published values.

According to a recent report by Luten¹ the refractive index for mixtures of normal and heavy water may be correctly computed from the mol fractions according to the linear or additive relation for simple mixtures, at least to three significant figures in $(n_1 - n)$ where n_1 and n represent the indices of normal water and of a mixture, respectively. Proceeding in this manner Luten finds good agreement between his sodium *D*-line index for pure H_2^{18}O and a result which he extrapolates from data for $\lambda = 5,876\text{\AA}$ published by Washburn, Smith, and Frandsen² of this Bureau, for a sample of water having a specific gravity of 1.001376 at 25 C. Consequently it is now of interest to publish certain additional index data which at that time (February 1933) were observed for the same sample but not hitherto carefully reduced because sufficiently precise comparison data on normal water were not readily available.

These measurements were made at 25.00 C by the classical method of minimum deviation, using a water-jacketed hollow prism of 72° refracting angle and 10-ml capacity which was mounted in a stirred air bath on the spectrometer table. Temperatures were constant within $\pm 0.01^\circ\text{C}$ during these measurements and were read to thousandths by use of a platinum resistance thermometer with its sensitive element immersed in the sample. Comparatively few observations were made but otherwise all precautions appropriate for precise index determinations³ were taken, just as is done in the absolute measurements on normal distilled water that are in progress in this refractometric laboratory, and all results refer to dry air of 760 mm pressure at the same temperature as that of the sample. Certain of these (provisional) values for the refractive index of normal water are given here (columns 2 and 3 of table 1) because the diversity among such published values precludes their satisfactory use for comparison with measured indices of heavy water.

¹ Daniel B. Luten, Jr., *Phys. Rev.*, **45**, 161-165 (1934).

² Edward W. Washburn, Edgar R. Smith, and Mikkel Frandsen, *J. Chem. Phys.* **1**, 288 (1933); *BS J. Research* **11**, 453-462 (1933); RP601.

³ Many requisites for precision and accuracy in minimum-deviation measurements have previously been discussed. See L. W. Tilton, *BS J. Research* **2**, 909-930 (1929) RP64; **6**, 59-76 (1931) RP262; **11**, 25-57 (1933) RP755.

TABLE 1.—*Refractive index of water*(n₁ for H₂O, n₂ for H₂O, and n for mixture)

λ in angstroms	Pure H ₂ O referred to dry air at t C and p=760 mm Hg		(n ₁ −n) $\times 10^7$ t=25 C		(n ₁ −n ₂) $\times 10^5$					
					t=25 C		t=20 C			
	n ₁ at t=25 C	(n ₂ ²⁰ −n ₂ ²⁵) $\times 10^6$	Observed	Adjusted	Tilton and Taylor (J. K.)	Luten	Tilton and Taylor (J. K.)	Luten	Selwood and Frost corrected by Luten	Taylor (H. S.) and Selwood
(If sp gr H ₂ O at 25 C=1.1056)										
7065.2...	1.329545	475	539	531	403	-----	413	-----	-----	-----
6678.1...	1.330398	478	547	546	415	-----	425	-----	-----	-----
6562.8...	1.330672	479	530	551	418	-----	429	435	429	-----
5892.6...	1.332502	485	586	578	439	445	450	456	473	-----
5875.6...	1.332555	485	590	579	440	-----	451	-----	-----	-----
5800.....	-----	-----	-----	582	442	449	453	-----	-----	-----
5769.6...	1.332894	486	-----	583	443	-----	454	-----	-----	-----
5460.7...	1.333977	489	-----	596	452	461	463	473	-----	-----
5015.7...	1.335860	493	617	614	466	-----	477	-----	-----	-----
4861.3...	1.336628	495	608	620	471	-----	482	491	-----	-----
4713.1...	1.337435	496	-----	626	475	-----	486	-----	-----	-----
4471.5...	1.338924	499	652	636	483	-----	495	-----	-----	-----
4358.3...	1.339709	500	620	641	486	-----	498	516	-----	-----
4046.6...	1.342238	504	662	654	496	-----	508	-----	-----	-----
(If sp gr H ₂ O at 25 C=1.1079)										
6562.8...	-----	-----	-----	-----	427	-----	438	444	438	-----
5892.6...	-----	-----	-----	-----	448	455	459	466	483	462
5800.....	-----	-----	-----	-----	451	459	462	-----	-----	-----
5460.7...	-----	-----	-----	-----	462	471	473	483	-----	-----
4861.3...	-----	-----	-----	-----	481	-----	492	502	-----	-----
4358.3...	-----	-----	-----	-----	497	-----	509	527	-----	-----

Referring to table 1, the observed values of $(n_1 - n) \times 10^7$ for the Washburn, Smith, and Frandsen mixture were used in determining, by the method of least squares, constants in the equation

$$(n_1 - n) \times 10^7 = 818.2 - 407.0\lambda$$

which (with λ in microns) yields the corresponding adjusted values as tabulated for various wave lengths. Values of $(n_1 - n_2)_{25} \times 10^5$, n_2 being the index for H₂O, were then computed from $(n_1 - n) \times 10^7$ by the additive relation for mixtures after using Luten's nonlinear relation between specific gravity and composition to determine a value $N_2 = 0.01318$ for the mol fraction of H₂O in this particular sample of heavy water. Luten's temperature coefficients of index of H₂O were used in deriving $(n_1 - n_2)_{20} \times 10^5$. Table 1 also includes values of $(n_1 - n_2) \times 10^5$ as reported by Luten and by other observers.⁴

Since Taylor and Selwood⁵ have announced a value of 1.1079, instead of 1.1056 as previously used, for the specific gravity of H₂O at 25 C and also a refractive index determined for such water, all of these previously considered results have been revised and are recompared in the lower portion of table 1. The new value for the mol fraction of the Washburn, Smith, and Frandsen sample of heavy water becomes 0.01290.

⁴ P. W. Selwood and A. A. Frost, J. Am. Chem. Soc., 55, 4335(1933).

⁵ Hugh S. Taylor and P. W. Selwood, J. Am. Chem. Soc., 56, 998(1934).

In general, the various values of $(n_1 - n_2)$ show good agreement. It should be noticed that the extrapolation from the sample of specific gravity 1.001376 would propagate an error of 1 in the sixth decimal place of n or n_1 to 8 in the fifth decimal of n_2 . As compared with Luten's results, the slightly higher index and higher dispersion for the sample measured in this laboratory may, therefore, be the result of very slight systematic errors in measurement but it should be remembered, also, that Washburn, Smith, and Frandsen gave some results which indicate that some O^{18} should be present in this sample. According to the provisional data given by Lewis and Luten,⁶ an excess atom fraction of 0.001 for O^{18} would account for the difference in these values of $(n_1 - n_2)$ as tabulated for wave length 5800 Å.

TABLE 2.—Dispersion of water for specified intervals of wave length
 $\Delta n_1 \times 10^5$ for normal water

Observer	Temperature	4047 to 4358 Å	4358 to 4861 Å	4861 to 5461 Å	5461 to 5893 Å	5893 to 6563 Å	6563 to 7065 Å	4358 to 6563 Å
	° C							
Tilton and Taylor (J. K.)-----	25	252.8	308.1	265.1	147.5	183.1	112.7	903.8
Do-----	20	253.2	308.7	265.6	147.9	183.6	113.2	905.8

$\Delta n_2 \times 10^5$ for pure H₂O

Tilton and Taylor (J. K.)-----	25	243	292	247	134	162	97	835
Luten-----	20	-----	288	245	132	161	-----	826
Selwood and Frost-----	20	-----	-----	-----	-----	160	-----	-----

The apparent lower dispersion that might be inferred for n_2 from the Selwood and Frost values of $(n_1 - n_2)$ is a result of the unusually high dispersion of the values which they tabulate for "ordinary water", namely, $(n_D - n_C) \times 10^5 = 199$ at 20 C. Their tabulated indices for all three solutions of heavy water yield reasonable values of dispersion and, as shown in table 2, their computed results for H₂O yield a difference, $n_D - n_C$, that is in good agreement with Luten's value and with the data of this paper.

WASHINGTON, May 28, 1934.

⁶ G. N. Lewis and D. B. Luten, Jr., J. Am. Chem. Soc., 55, 5062(1933).