

We wish to notice that the difference between S_{exp} and S_{th} at $\phi = 35^\circ$ is somewhat larger than our experimental error which we place at about 0.05 in S_{exp} in this region. We made repeated trials in this region and always found S_{exp} somewhat less than S_{th} . A rather large difference also occurs at $\phi = 10^\circ$ and 15° ; but at these small angles the experimental difficulties increase and the difference is probably not greater than the experimental error. Considering all the values of ϕ , there is a tendency for all the experimental points to fall below the theoretical curve. This is probably due to error in the determination of the numerical factor mentioned at the end of the last section.

4. EFFECT OF CRYSTAL ORIENTATION

In all the work done hitherto in this laboratory x-rays have for convenience been scattered from a crystal with one axis perpendicular to the scattering plane. We have now tried the effect of turning the crystal plate in its own plane upon the S_{exp} values. When the crystal is

oriented so that no principal axis is perpendicular to the scattering plane, Eqs. (6) and (7) for the positions of the Laue spots become more complicated and contain a third integer l . The S_{exp} values for the axis making angles of 0° , 22.5° and 45° with the perpendicular are shown in the second, third and fourth columns of Table II. It is seen that turning the crystal in

TABLE II. *Effect of crystal orientation— S_{exp} values.*

ϕ	0°	22.5°	45°
15°	1.95	1.99	1.93
25°	2.31	2.31	2.29
35°	2.01	2.00	2.01
50°	1.56	1.54	1.54

its own plane has no noticeable effect. The theory of diffuse scattering has been developed on the assumption of spherical symmetry in the atoms.²⁰ Our results are in accord with this assumption in the case of sylvine.

²⁰ G. E. M. Jauncey, Phys. Rev. **37**, 1193 (1931).

The Verdet Constant of Heavy Water

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The Verdet constants of samples of water containing 0, 31.1, and 99.7 percents of heavy hydrogen atoms have been measured for the wave-lengths $\lambda 5893$ and $\lambda 5460.7\text{\AA}$ at 20°C . The results are given in tabular form. From these data the Verdet constant of pure heavy water (H_2^{18}O) is found to be 3.93 percent less than that of ordinary water for both wave-lengths. Non-linearity of the Verdet constant-concentration relation leads to the calculation of an apparent Verdet constant for $\text{H}^1\text{H}^2\text{O}$ which is 0.85 percent less than the Verdet constant of ordinary water. Values of the relative molecular rotatory power and of the magnetic rotatory dispersions are also given.

THE Verdet constants of ordinary and of heavy water have been measured for two wave-lengths of light.

The measurements were made by use of the Schmidt and Haensch Faraday effect apparatus. The optical system of the instrument consists of a triple field polarizer with the Lippich half-shade adjustment and an analyzing Nicol whose position may be read to 0.01° . The magnetic field was produced by the attached electromagnet

with an iron core, drilled parallel to the magnetic field. The mean axial field strength was determined by calibration against a standard solenoid by the ballistic galvanometer deflection method. The test coil used between the magnet pole pieces in calibration was of approximately the same dimensions as the cell used to contain the liquids whose Verdet constants were determined. The current for the electromagnet was supplied from storage batteries, and was determined by

the measurement of the potential drop across a standard resistance by means of a Wolff potentiometer. Current measurements were made before and after each observation and the average of these values used to determine, from the magnet calibration curve, the actual field strength at the time of observation. Two different field strengths were used in each determination. The light sources used were the sodium and mercury arcs with appropriate filters to transmit only the lines $\lambda 5893$ and $\lambda 5460.7\text{\AA}$.

The liquids under observation were sealed in water-jacketed Pyrex cells approximately 5 cm long with thin cover glass ends cemented on with picein. The rotations due to these glass ends were measured and corrected for, the corrections being of the order of one percent of the total rotations. The temperature of each specimen was held constant to within 1.0°C by a constant flow of water through the jacket. The temperature of the liquid is taken as the average of thermometer readings at the inlet and at the outlet from the jacket. These readings differed at most by a few tenths of a degree. The two cells, made by Eck and Krebs of New York, were the same length to within one part in 4000. Measurements of the Verdet constant of ordinary water made in the two different cells agreed within the estimated precision.

Samples of heavy water of two different concentrations and one sample of ordinary water were kindly loaned by Dr. H. C. Urey and his assistants. These samples were freshly distilled and were sealed in the cells before delivery. The concentrations of these samples were also determined by Dr. Urey's staff.

The results of the measurements are given in Table I. Column 1 gives the concentration of the solutions in mol fractions of H_2O . Column 2 gives the specific gravity as computed from the known concentrations by the equation of Luten,¹ and using the value $D^{25}_{25} = 1.1079$ given by Taylor and Selwood² for 100 percent H_2O . The indices of refraction in column 3 are taken from the data of Luten¹ by interpolation from his tables. Columns 4, 5 and 6, respectively, give the wavelength, temperature and field strength at which the measurements were taken. Each value in columns 5, 6 and 7 is the average of at least two independent sets of observations. Columns 7 and 8 give the Verdet constants as measured. The values in column 8 are to be taken as the final values and are the weighted means of the values shown in column 7, corrected³ to 20°C . By extrapolation the values 0.012554 ± 0.000030

¹ D. B. Luten, Jr., *Phys. Rev.* **45**, 161 (1934).

² H. S. Taylor, and P. W. Selwood, *J. Am. Chem. Soc.* **56**, 998 (1934); H. S. Taylor, *J. Frank. Inst.* **218**, 1 (1934).

³ *Int. Crit. Tab.* **6**, 425 (1929).

TABLE I. *The Verdet constants of solutions of H_2^{18}O in H_2^{16}O .*

Concentration mol fraction (H_2^{18}O)	Specific gravity (D^{25}_{25})	Refractive index (20°C)	Wave- length (\AA)	Temp. of liquid ($^\circ\text{C}$)	Field strength (gauss)	Verdet constant (min./g-cm)	Verdet constant (20°C)
0.000	1.0000	1.33449	5460.7	20.89	2205	0.015426	0.015397
.000	1.0000	1.33449	5460.7	20.40	1953	.015333	± 0.000030
.000	1.0000	1.33300	5893	19.80	2207	.013069	.013067
.000	1.0000	1.33300	5893	19.80	1954	.013065	± 0.000030
.311	1.0333	1.33302	5460.7	20.00	2202	.015293	.015274
.311	1.0333	1.33302	5460.7	20.00	1945	.015256	± 0.000030
.311	1.0333	1.33158	5893	20.00	2206	.012979	.012963
.311	1.0333	1.33158	5893	20.00	1952	.012948	± 0.000030
.997	1.1076	1.32977	5460.7	20.23	2196	.014798	.014793
.997	1.1076	1.32977	5460.7	19.90	1960	.014782	± 0.000030
.997	1.1076	1.32845	5893	19.90	2191	.012583	.012556
.997	1.1076	1.32845	5893	19.90	1960	.012530	± 0.000030
1.000	1.1079	1.32976	5460.7	20.00			.014791*
1.000	1.1079	1.32844	5893	20.00			.012554*

* These values obtained by extrapolation.

and 0.014791 ± 0.000030 min./gauss-cm are obtained for the Verdet constants of 100 percent H_2O at 20°C for the wave-lengths $\lambda 5893$ and $\lambda 5460.7$ respectively.

DISCUSSION OF RESULTS

These measurements show the Verdet constant of heavy water (H_2^{18}O) to be 3.93 percent less than that for ordinary water (H_2^{16}O) at each of the two wave-lengths investigated. Thus the rotatory power relative to H_2^{16}O is independent of wave-length in this region. The indices of refraction for the two waters at $\lambda 5893$ differ by approximately 0.34 percent and the dispersions ($dn/d\lambda$) between the wave-lengths $\lambda 5893$ and $\lambda 5461$ differ by more than 11 percent.¹ The failure of the linear relations between Verdet constant and concentration and between magnetic rotatory dispersion and concentration is striking. This does not necessarily indicate a violation of the Schönrock rule of mixtures, however, for we must recall the possibility of $\text{H}^1\text{H}^2\text{O}$ molecules in the solution. Assuming the equilibrium constant $K = (\text{H}^1\text{H}^2\text{O})^2 / (\text{H}_2^{18}\text{O})(\text{H}_2^{16}\text{O}) = 3.27$ as found by Topley and Eyring⁴ we may compute from the known ratio of the number of heavy to light hydrogen atoms the percent of each type of molecule in a solution. This calculation results in the following concentrations for the 0.311 solution: 10.61 percent H_2^{18}O ; 48.38 percent H_2^{16}O ; 40.98 percent $\text{H}^1\text{H}^2\text{O}$. Assuming the linear relation between Verdet constant and concentration we may then calculate the apparent Verdet constant of a liquid consisting only of the $\text{H}^1\text{H}^2\text{O}$ molecules. The values so obtained are 0.012955 and 0.015266 min./gauss-

cm for the wave-lengths $\lambda 5893$ and $\lambda 5460.7$, respectively. These values are both 0.85 percent less than the corresponding values for ordinary water, indicating approximate independence of wave-length for the relative rotatory power as was seen above in the case of H_2^{18}O . The assumption of any other equilibrium constant ($K=4$, for example) does not lead to this result. This thus indicates a means of checking the equilibrium constant of such solutions by measurement of the Verdet constant at different wave-lengths. Further checks by measurements on several different concentrations are suggested.

The relative molecular rotatory power (Ω) of H_2^{18}O with respect to H_2^{16}O at 20°C for $\lambda 5893$ and for $\lambda 5460.7$ is 0.9640 assuming molecular weights of 20.027 and 18.014 for the respective molecules. Lack of data on the density of $\text{H}^1\text{H}^2\text{O}$ prevents calculation of its molecular rotatory power.

The magnetic rotatory dispersion in the wave-length region used may also be obtained from the data. Expressed in min./g-cm per A the values for H_2^{16}O , H_2^{18}O , and $\text{H}^1\text{H}^2\text{O}$ are, respectively, 5.39×10^{-6} ; 5.18×10^{-6} ; 5.35×10^{-6} .

Although the value measured for the Verdet constant of ordinary water ($\lambda 5893$) agrees within the precision of measurements stated in the table with the value given in the *International Critical Tables*, this precision is stated for comparative purposes only and not for the absolute values.

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⁴ B. Topley, and H. Eyring, J. Chem. Phys. 2, 217 (1934); A. Farkas, and L. Farkas, J. Chem. Phys. 2, 468 (1934).