DENSITY OF HEAVY WATER

By PROF. TSING-LIEN CHANG

AND
LÜ-HO TUNGChemistry Department, National Tsing Hua University,
Peiping

THE density of heavy water was accurately determined by Stokland, Ronaess and Tronstad¹ in the temperature range 10–27°. Measurements were extended to 50° by Chang and Chien², and later by Wirtz³. Recently, we have further extended the measurement up to the boiling point of heavy water.

A 16-ml. quartz pycnometer consisting of a bulb with a short stem of 0.5-mm. calibre and a ground-joint cap was used. A thermostat kept the temperature constant within 0.01°. Special precautions were taken regarding the pycnometry, thermometry, purification of water, avoidance of contact with atmospheric moisture, reduction of the weighings to vacuum, and volume correction for the thermal expansion of vitreous quartz. In order to make sure of the accuracy of our measurements, we have determined the density of ordinary water between 50° and 100° and found that the results agree with Thiessen's data⁴ within three units in the fifth decimal place.

Two ampoules of heavy water of different concentrations supplied by Norsk Hydro-Elektrisk Kvaestof A/S were distilled under vacuum direct into the pycnometer. The mole percentage of D₂O was calculated⁵ from its density ratio $d_{H_2O}^{D_2O}$ in comparison with ordinary water at 25°. The Norwegian heavy water is known⁶ to contain 0.32 weight per cent D₂O¹⁸. Three series of measurements were carried out on samples containing 99.71–99.77 mol. per cent D₂O at intervals of 5° between 25° and 100° with special attention to the temperature range above 50°. The density ratio $d_{H_2O}^{D_2O}$ of the sample was determined before and after each series of measurements.

From the density values so obtained are subtracted those of ordinary water at the corresponding temperatures. The difference of density between heavy water and ordinary water is obtained by linear extrapolation. In the extrapolation to 100 per cent D₂O with normal isotopic composition of oxygen, the excess of the oxygen-18 water is included in the D₂O content. The possible error so introduced will not affect the fifth decimal place of the density value.

The density differences at various temperatures were smoothed by the graphical method. The mean deviation of the measured values from those of the smoothed curve is 0.000 02 gm./ml. Using Swift's value⁵ for 5° and Tronstad's values¹ between 10° and 25°, we have prepared the accompanying table for the density of heavy water (d_{D_2O}) in the liquid state, covering the complete temperature range between its freezing and boiling point. Considering the errors from different sources, we believe that our density values are accurate to 0.000 05 gm./ml. The density of ordinary water (d_{H_2O}) is also given for comparison, together with the density ratio of heavy and ordinary water. This ratio has also a tendency to pass over a maximum as predicted by Chang and Chien. The temperature for such a maximum seems to lie not far above the boiling point.

The density values in the temperature range between 30° and 50° formerly determined in this

Temperature °C.	d_{H_2O} gm./ml.	d_{D_2O} gm./ml.	$d_{D_2O} - d_{H_2O}$ gm./ml.	$\frac{d_{D_2O}}{d_{H_2O}}$
3.8	1.00000	1.10538	0.10538	1.10538
5	0.99999	1.0555	556	556
10	9973	10595	622	625
11.2	9961	10596	635	639
15	9913	10583	670	678
20	9823	10530	707	726
25	9707	10440	733	764
30	9568	10319	751	798
35	9406	10169	763	827
40	9225	99992	767	851
45	9024	9790	766	871
50	8807	9565	758	888
55	8573	9319	746	902
60	8324	9054	730	913
65	8059	8771	712	924
70	7781	8471	690	933
75	7489	8154	665	940
80	7183	7821	638	946
85	6865	7472	607	950
90	6534	7109	575	954
95	6192	6732	540	957
100	5838	6342	504	960
101.4	5736	6229	493	960

laboratory² are slightly too high, and those of Wirtz too low, while Bridgman's approximate values⁷ for 60° and 80°, which represent the only known data above 50° up to the present, are much too high.

Experimental details will appear elsewhere.

¹ Stokland, K., Ronaess, E., and Tronstad, L., *Trans. Farad. Soc.*, **35**, 312 (1939).

² Chang, T. L., and Chien, J. Y., *J. Amer. Chem. Soc.*, **63**, 1709 (1941).

³ Wirtz, K., *Naturwiss.*, **30**, 330 (1942); *Physik. Z.*, **43**, 465 (1942).

⁴ "International Critical Tables", **3**, 24 (1928). Stähler, "Handbuch der Arbeitsmethoden in der anorganischen Chemie", **3/1**, 51 (1913).

⁵ Swift, E., Jr., *J. Amer. Chem. Soc.*, **61**, 198 (1939).

⁶ Tronstad, L., and Brun, J., *Trans. Farad. Soc.*, **34**, 766 (1938).

⁷ Bridgman, P. W., *J. Chem. Phys.*, **3**, 597 (1935).

MATHEMATICAL ASSOCIATION

ANNUAL MEETING

FOR the first time, the annual meeting of the Mathematical Association was held outside London; at the invitation of the Association's Midland Branch, and with the generous co-operation of the University of Birmingham, which provided lecture theatres and hostel accommodation, the Association met at Birmingham during April 20–23.

Duties abroad prevented the president, Sir Harold Spencer Jones, Astronomer Royal, from attending the meetings. In his absence, Mr. A. W. Siddons presided over the business meeting on April 21, at which Mr. A. Robson, until recently senior mathematical master at Marlborough College, was elected president for the forthcoming year. Sir Harold Spencer Jones will give his presidential address next year, Mr. Robson having agreed to give his address this year to fill the gap. Under the title, "How they Learnt, 1600–1850", Mr. Robson traced the development in content and treatment of the mathematical curriculum in English schools during this period, based on a study of text-books and school records, particularly those relating to Christ's Hospital. Mr. Robson's investigations show that the common view that mathematics was taught entirely as an academic subject, with little relation to practical applications, is not wholly correct. Prof. S. Brodetsky, formerly of the University of Leeds, then gave a lecture on nomography, showing how the solution of equations and the performance of various types of calculation can be carried out rapidly and with reasonable