SURFACE TENSION OF DEUTEROHYDROGEN

V. N. GRIGOR'EV

Physico-technical Institute, Academy of Sciences, Ukr.S.S.R.

The surface tension coefficient of liquid HD is measured between 16.7 and 20.5°K, and is found to depend linearly on the temperature in this interval.

PUBLISHED data are available on the surface tension of the two hydrogen isotopes H_2[1] and D_2[2]. The present paper is devoted to a study of surface tension of the third isotopic modification of hydrogen, namely deuterohydrogen HD.

The measurements were carried out by the method of capillary rise in the instrument shown in Fig. 1. The surface tension was determined from the difference in the height of the capillary rise (Δh) in two capillaries 1, immersed in a vessel 2 with liquid deuterohydrogen. The instrument was placed in a metallic Dewar 3, with flat glass windows 4 to eliminate optical distortion. The difference in the heights of the menisci was measured with a KN-6 cathetometer. The measurements were made in the temperature interval 16.7—20.4°K. The required temperature was maintained by pumping out liquid-hydrogen vapor and was measured by determining the saturated vapor tension of the hydrogen contained in vessel 6. A ground joint 5 made it possible to

FIG. 1. Diagram of the instrument.

raise or lower the capillaries, so that the constancy of the radius in height could be verified.

Preliminary experiments with ordinary hydrogen yielded values which were in good agreement with the data of Kammerlingh-Onnes[1] as reduced by Voerschaveldt[3]. The discrepancy did not exceed 0.5%. The deuterohydrogen was obtained by rectifying the mixture of isotopes, produced by electrolysis of 50% solution of ordinary and heavy water, in a metal column analogous to that described earlier[4]. Repeated distillation of the employed deuterohydrogen has shown that it contained $(0.4 \pm 0.2)\%$ H_2 and not more than 0.5% D_2. No corrections are introduced for the hydrogen and deuterium contents, since they are comparable with the measurement accuracy and cancel each other at least in part.

The surface tension was calculated from the formula

$$\sigma = \frac{gR_1R_2(\rho^V - \rho^l)}{2\Delta R}\left(\Delta h - \frac{\Delta R}{3}\right),\qquad(1)$$

where g is the acceleration due to gravity, and R_1 and R_2 are the radii of the capillaries [R_1 = $(5.43 \pm 0.01) \times 10^{-2}$ cm and R_2 = $(1.776 \pm 0.05) \times 10^{-2}$ cm]. The density ρ^l of the liquid was taken from [5], while the density ρ^V was calculated from the laws for perfect gases. A check with the aid of Sugden's tables[6] has shown that formula (1) has in this case an accuracy not worse than 0.1%.

The table lists the data from three series of measurements with deuterohydrogen, obtained as the result of different distillations. The temperature dependence of the surface tension of deuterohydrogen is shown in Fig. 2. As in the case of hydrogen and deuterium, it is linear in this temperature interval, within the measurement accuracy limits, and described by the formula

$$\sigma \text{ dyne/cm} = 6.53_7 - 0.188_3 T.\qquad(2)$$

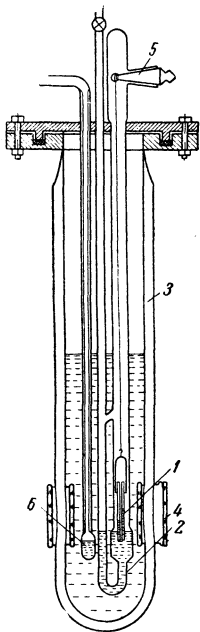The last column of the table gives the values of the difference $\delta\sigma$ between the experimental values of

| $T,°K$	Δh, cm	σ, dyne/cm	$10^3 \delta\sigma$, dyne/cm	$T°K$	Δh, cm	σ, dyne/cm	$10^3 \delta\sigma$, dyne/cm
20.45	1.793	2.683	—4	18.72	1.962	3.018	+4
20.44	1.795	2.686	—3	18.36	1.995	3.087	+6
20.44	1.789	2.677	—12	18.16	2.007	3.114	—5
20.42	1.797	2.692	—1	17.92	2.050	3.189	+24
20.41	1.801	2.699	+4	17.56	2.072	3.239	+7
20.41	1.802	2.700	+6	17.48	2.079	3.255	+8
20.12	1.827	2.748	—2	17.43	2.079	3.258	+2
19.65	1.871	2.837	—1	16.80	2.135	3.374	—1
19.58	1.875	2.845	—6	16.76	2.137	3.377	—6
19.12	1.922	2.942	+4	16.71	2.143	3.389	—3
18.84	1.875	2.993	+3				
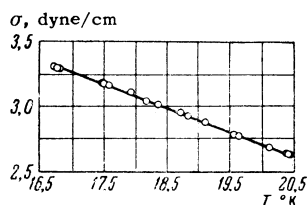
FIG. 2. Temperature dependence of the surface tension of deuterohydrogen.

σ and those calculated by (2). We see that the deviations from linearity lie as a rule within the limits of the measurement accuracy, which amounts to approximately 0.5%.

In accordance with the quantum theorem on corresponding states[7], the surface tension of simple liquids should obey in the reduced coordinates the relation $\sigma^* = f(\lambda^2)$ for $T^* = $ const, where $f(\lambda^2)$ is a function which is the same for all elements and depends only on the quantum parameter $\lambda = h/r\sqrt{m\epsilon}$ (m —isotope mass, r and ϵ —parameters characterizing the potential of intermolecular interaction), and the reduced values of the surface tension and of the temperature are defined as $\sigma^* = \sigma r^2/\epsilon$ and $T^* = kT/\epsilon$. Knowledge of the form of the function $f(\lambda^2)$, and particularly its curvature, is very essential for the calculation of the properties of solutions of isotopes[8]. The data obtained make it possible to estimate the curvature in the region of values of λ correspond-ing to the hydrogen isotopes. It has been found that $\partial^2\sigma^*/\partial(\lambda^2)^2 > 0$ and consequently[8] the surface tension of solutions of hydrogen isotopes should be smaller than the additive values.

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[1] H. Kamerlingh Onnes and H. A. Kuypers, Commun. Labor. Univ. of Leiden, No. 142d.

[2] A. Van Itterbeek and O. Van Paemel, Physica 7, 325 (1940).

[3] Landolt-Bornstein, Phys. Chem. Tabellen, 5th ed., Berlin, 1931, p. 166.

[4] Bulatova, Girgor'ev, and Kogan, Atomnaya énergiya 12, 428 (1962).

[5] Wooley, Scott, and Brickwedde, J. Res. NBS 41, 379 (1948).

[6] N. K. Adam, Physics and Chemistry of Surfaces, Gostekhizdat, 1947.

[7] J. de Boer, Physica 14, 139 (1948).

[8] A. Englerl-Chwoles and I. Prigogine, Nuovo cimento Suppl. 9, 347 (1958).

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