

EXPERIMENTAL INVESTIGATION OF THE SURFACE TENSION OF LIQUID SODIUM

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A number of papers have been published on the measurement of the surface tension of liquid sodium [1-7]. Most were concerned with the interval 100°-150° C from the melting point and only in Taylor's work was the range extended to 470° C.

At higher temperatures the experimental difficulties are much greater, owing to the corrosive nature of sodium and its high volatility. In order to determine the surface tension at higher temperatures, the apparatus shown in Fig. 1 was constructed, where 1) is the balance, 2) FS-K1 photoresistor, 3) SD-60 motor, 4) condenser, 5) plate, 6) crucible, 7) cover, 8) magnet, 9) illumination unit, 10) centering plate, 11) supporting plate, 12) batcher, 13) filter, and 14) oven. The flat plate immersion method is used. Liquid sodium is placed in crucible 6, which is heated externally by electric furnace 14. The crucible temperature is determined by means of three platinum-rhodium thermocouples welded onto the outside of the crucible. The emf's of the thermocouples are measured with a low-resistance potentiometer type R-306.

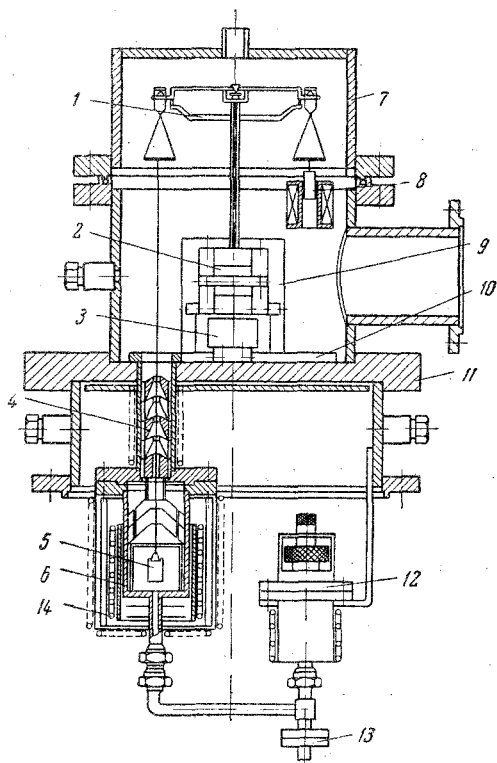


Fig. 1

Temperature equilibration over the height of the crucible is obtained by placing a copper screen inside the oven. Plate 5, measuring 20 × 15 × 1 mm, is suspended on a thin molybdenum filament from one of the

pans of automatic analytical balance 1. Plate condenser 4 is provided to prevent the metal vapor from penetrating into the space where the balance is situated. According to the conditions of the experiment it is necessary to be able periodically to alter the depth of immersion of the plate in the molten metal. This is achieved by varying the amount of metal in the crucible using the slyphon-type batcher 12. The leveling accuracy, verified by careful experiments, is not worse than 0.5 mm, corresponding to an error not greater than 0.1% in surface tension. The apparatus can be evacuated to 10<sup>-5</sup> mm, using a VA-01-1 vacuum unit, or filled with an inert gas. To ensure normal operation of the balance, the apparatus is assembled on a solid supporting plate 11 and placed on an insulated base.

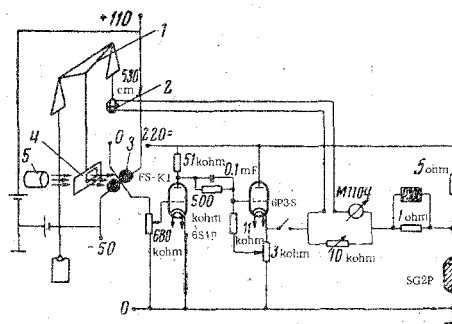


Fig. 2

The circuit diagram of the automatic balance, first used by N. S. Borovik-Romanov for determining the magnetic properties of antiferromagnetic dielectrics, is shown in Fig. 2, in which 1) is the balance, 2) a coil, 3) an FS-K1 photoresistor, 4) a shutter, and 5) a light source. If the balance deviates from the equilibrium position, the photocurrent is redistributed between the two FS-K1 photoresistors. The imbalance signal, after amplification, is supplied to coil 2, whose field, interacting with a permanent magnet suspended from the other arm of the balance beam, again restores the system to equilibrium. The magnitude of the force is estimated from the current in the coil, measured by an R-306 potentiometer or an M1104 milliammeter. A remote stopping device was installed to protect the balance from accidental breakdown. The SD-60 motor, which slowly rotated a cam connected to the arm of the locking device, could switch the balance from the working position to the rest position. In these extreme positions the motor was switched off by limit switches. The balance proved to be very easy to use and the stability was satisfactory. The relationship between current and weight appeared to be linear

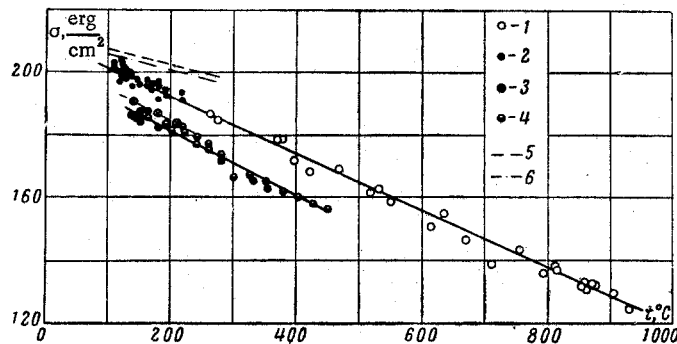


Fig. 3

throughout the whole range necessary for the measurements (0–1000 mg). Deviations of the calibration points from a straight line did not exceed 0.1 mg over the whole range.

The surface tensions of water, ethyl alcohol, and toluene were measured before carrying out experiments with sodium; the values obtained agreed with tabulated data within 1%.

"Pure" grade sodium was used. Before entering the batcher it passed through a stainless-steel porous filter. The system was carefully outgassed and filled with pure helium before charging with sodium. In this series of experiments the plate was fabricated from 1Kh18N9T stainless steel. The sodium was slowly extruded from the batcher into the crucible, which was preheated to 400°–500° C. In this case the plate was immediately and thoroughly wetted. The measurements were carried out in the following order. When the temperature was constant the level in the crucible was lowered until the plate was just out of the liquid and then slowly raised until the plate was immersed to a depth of 10–12 mm. The level was then lowered to 4–6 mm and the current in the coil of the balance and the emf's of the thermocouples were measured. No fewer than three measurements were taken at each temperature.

$t, ^\circ\text{C}$	$\sigma, \text{erg/cm}^2$	$t, ^\circ\text{C}$	$\sigma, \text{erg/cm}^2$
194	192.3	673	147.21
265	186.33	714	139.34
275	184.48	757	143.73
371	178.31	797	136.35
377	178.82	816	137.73
398	171.42	816	138.14
422	168.48	855	132.35
470	169.42	856	133.55
521	162.9	865	131.38
534	163.57	875	133.33
554	159.34	878	133
616	151.47	905	130.01
637	155.11	932	124.55

In this method of measurement we are concerned with the so-called "drip angle" and can assume that the contact angle is almost zero. Altogether 26 experimental points were plotted from 100°–937° C. During these measurements, metal twice got right into the batcher and solidified there. It was found that immediately after fusion the surface tension was lower by approximately 5–8%, compared with values obtained after 1–1.5 hours. This may be connected with the concentration of impurities on the surface of the liquid metal.

Only the steady values of the surface tension are cited below.

The surface tension was calculated from the formula

$$\sigma = \frac{g(txdl + F)}{2(t+x)}$$

Here  $t$  and  $x$  are the width and thickness of the plate,  $l$  is the depth of immersion,  $d$  is the metal density, and  $F$  is the force in grams measured by the balance.

The results of the calculations are shown in the table and in Fig. 3, in which the points designated 1 are the authors' data, 2 and 3 are Addison's data from [6] and [7], respectively, 4 are Taylor's data [5], curve 5 is from [2] and curve 6 from [4]. Our results agree best with those of [7] in the low-temperature region. The interpolated straight line obtained from our data is described by the equation

$$\sigma = 202 - 0.091(t - 98)$$

The standard deviation from this straight line is 1.47%.

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