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Abstract

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On the Dependence of the Surface Tension of Cesium on Temperature

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An experimental study of the surface tension σ of alkali metals is of fundamental importance for the development of the theory of surface phenomena in metals. Indeed, alkali metals are the best object for testing the correctness of theories of surface tension, since in them the number of free electrons is equal to the number of atoms, and the ions have the structure of atoms of elements of the zero group. Discrepancies between theoretically calculated data on surface tension and experimental data in the case of alkali metals indicate fundamental shortcomings of the theory, since only for this group of metals are the simplifications introduced into the theory in order to obtain practical conclusions of a sufficiently rigorous character (1). However, owing to methodological difficulties arising from the high chemical activity of alkali metals, until recently there were no reliable experimental data in the literature on their surface tension (1). Only recently have the results of experimental investigations of the temperature dependence of the surface tension of lithium, sodium, and potassium (2, 3) been published; as for rubidium and cesium, such data were absent from the literature.

In this connection we carried out measurements of the surface tension of molten cesium at various temperatures. To measure σ of cesium we used the maximum-pressure method, which is well substantiated theoretically (4). In view of the chemical activity of cesium and the high elasticity of its vapor, it was decided to investigate the surface tension in a sealed glass apparatus. Since, both in vacuum and in an atmosphere of inert gas, cesium wets glass well, it proved impossible to measure σ by the maximum-pressure method in a drop. To resolve this difficulty, we designed and constructed an apparatus for measuring σ by the maximum-pressure method in a bubble under conditions of phase equilibrium (5–8).

After thorough thermovacuum treatment of the apparatus (Fig. 1), mounted on a rotating frame, the required amount (~ 40 g) of cesium was distilled in vacuum through tube 3 into vessels 1 and 2; the apparatus was then filled to a pressure of 480 mm Hg with argon previously purified by bubbling through molten lithium at 300°, sealed off from the setup along line 44′, and placed in a thermostat

Fig. 1 and Fig. 2

Figure 1: Fig. 1 and Fig. 2

with observation windows. To measure σ, the apparatus had to be rotated in the plane of the drawing clockwise so that the molten cesium filled manometer 5 and the lower part of reservoir 6, while the end of capillary 7 was beneath the layer of metal. After the apparatus was returned to its initial position, the metal remaining in vessel 2, by rotating the apparatus about the axis xx away from oneself through an angle somewhat greater than 90°, flowed through tubes 8 and 9 into vessel 1, and the apparatus was returned to the position shown in the drawing. The plane of manometer 5 made a certain angle with the plane of the drawing and therefore the cesium did not flow out of manometer 5 and reservoir 6. Under the action of gravity, cesium flowed through the narrow-

10 into vessel 2 and closed the opening of tube 8 (see Fig. 1). A closed volume of gas was created in the apparatus, bounded by the surface of the cesium in vessel 2, capillary 7, and the left limb of manometer 5. As the metal flowed into vessel 2, the pressure in the indicated volume and, consequently, in the gas bubble forming at the cut end of capillary 7 increased, while above the surface of the metal in reservoir 6 and in the space connected with it it decreased. The increase in the pressure difference in the bubble and above the surface of the metal in vessel 6 led to gas bubbles beginning to detach from the tip of capillary 7 (⌒9). This maximum pressure difference could be determined from the difference in the levels (h) of cesium in the left limb of manometer 5 and in reservoir 6, which was a continuation of the right limb of manometer 5. When the

Fig. 1 **Fig. 2**

apparatus was turned about the axis xx_1 away from the observer through an angle slightly greater than 90°, the pressure in all its parts equalized, and the cesium flowed from vessel 2 into vessel 1. On returning the apparatus to its initial position, the measurement could be repeated, and this procedure could be carried out many times. The advantage of the indicated operating mode of the apparatus was that it eliminated the need to measure the immersion depth of the capillary (h_1).

Indeed (see Fig. 1), the value of the maximum pressure entering Cantor’ s calculation formula (⌒4) is equal to the difference $\rho gh - \rho gh_1$, where ρ is the density of cesium. But, as is seen from Fig. 1, the quantity $h - h_1$ is the vertical distance from the cut end of capillary 7 to the level of the metal in the left limb of manometer 5; consequently, to determine σ of cesium it was necessary each time to determine the level of the cut end of the capillary (which was easily done by means of a mark on the capillary) and the level of the metal in the left limb of manometer 5.

The values of the density of molten cesium needed for calculating σ by Cantor’ s formula were taken by us from works (⌒10, ⌒11). The thermal dependence of

σ of cesium in the investigated temperature interval from 62 to 280° proved to be linear and can be represented by the formula

$$\sigma = 68.4 - 0.046\,(t - 28). \qquad (4)$$

The constants of equation (1) were calculated by the method of least squares; moreover, the largest deviation of the experimental points from the straight line expressed by equation (1) is less than 1.0 dyn/cm.

As is seen from Fig. 2, which presents the results of our investigations, as well as the temperature dependences of the surface tension of Li,

For Na and K, according to data in (2), and for Rb (12), the surface tension of the alkali metals decreases with increasing atomic weight. The results we obtained are in good agreement with data on the surface tension of cesium calculated theoretically in the works of S. N. Zadumkin (13), V. N. Eremenko (14), and Taylor (15).

For example, according to S. N. Zadumkin' s data, σ for cesium near the melting point is equal to 60.2 dyn/cm; 88 dyn/cm, and the temperature coefficient of surface tension $\partial\sigma/\partial t$ is -0.049 dyn/cm • deg; our corresponding values are 68.4 dyn/cm and -0.046 dyn/cm • deg.

Comparison of our data with the results of theoretical studies (16–18) confirms the conclusion drawn by V. K. Semenchenko (1) that the theories of the surface tension of metals proposed in these works require improvement or reconsideration of certain fundamental premises.

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Note: Figure translations are in progress. See original paper for figures.