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EXPERIMENTAL DETERMINATION OF THE SURFACE TENSION OF MOLTEN NEODYMIUM

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The study of the surface tension σ of molten rare-earth metals is of considerable interest in connection with their extensive use in metallurgy for modifying alloys ([1]). Recently, values of the free surface energy of the lanthanides have been determined by theoretical calculations ([2,3]); however, the literature contained no experimental data that would make it possible to confirm the validity of the conclusions of the theory. In this connection we undertook a study of the surface tension of molten neodymium. Industrially produced neodymium, relatively pure with respect to impurities of other elements, contains a certain amount of neodymium oxide. In view of this, the metal used in the experiments was preliminarily filtered twice to remove oxides in a vacuum of $\sim 1 \cdot 10^{-5}$ mm Hg, using special funnels made of beryllium oxide and tantalum (Fig. 1).

To determine σ of molten neodymium, the method of maximum pressure in a gas bubble was used, the most rigorously substantiated theoretically ([4,5]). The measurements were carried out with two capillaries of different diameter, mounted so that their cuts lay in one horizontal plane; this made it possible practically to eliminate the need to take into account the depth of immersion of the capillaries in the melt ([6,7]). The wall thickness of the working capillaries at the cut was about 1% of the magnitude of their radii, although in the present case this was of no special significance, since in the experiments it turned out that molten neodymium wets the material of the capillaries ([4,8]). The high chemical activity of neodymium at temperatures above its melting point imposed strict limitations on the choice of materials for crucibles, working capillaries, and heater. In the present work, capillaries and crucibles made of beryllium oxide were used; a cylinder of tantalum sheet served as the heater. Neodymium was melted in vacuum at a pressure of $1 \cdot 10^{-5}$ mm Hg; as the working gas for forcing through gas bubbles, argon was used, previously purified by bubbling through molten lithium at $t \sim 300°$. The maximum pressures were read from a U-shaped manometer by means of a KM-10 cathetometer. As the working liquid of the manometer, polyphenylmethylsiloxane vacuum oil was used, possessing comparatively low–

Fig. 1

Figure 1: Fig. 1

Fig. 2. Dependence of the surface tension of neodymium on temperature

Figure 2: Fig. 2. Dependence of the surface tension of neodymium on temperature

Fig. 1. Designations: 1—neodymium, 2—beryllium oxide funnel, 3—tantalum funnel, 4—tantalum cylinder, 5—beryllium oxide crucible, 6—tantalum heater.

low viscosity and low elasticity of the vapors (10^{-8} mm Hg). Since the capillaries used had diameters up to 5 mm, in calculating σ for neodymium the effective capillary radii were used, computed by the method of successive approximations with the aid of Sugden' s table ([6]). The accuracy in determining the surface tension was $\sim 1\%$, i.e., less than 7.0 dyn/cm.

Table 1

Dependence of the surface tension of neodymium on temperature

No.	t, °C	σ, dyn/cm	No.	t, °C	σ, dyn/cm
1	1030	688	5	1110	682
2	1054	685	6	1154	680
3	1072	684	7	1167	681
4	1094	681	8	1186	674

The results of measurements of σ for neodymium are presented in Fig. 2 and in Table 1. The value of the surface tension of neodymium obtained by us is in satisfactory agreement with the value calculated in ([2]) by a theoretical method and equal to 600 dyn/cm. The discrepancy between the theoretical and experimental data, less than 12%, apparently confirms the correctness of the theoretical estimates of the specific free surface energy values for lanthanides made in ([2,3]). In this connection it is of interest, using the data of ([2,9]), to compare the dependences of the surface tension and a number of other physical properties of the lanthanides on atomic number, analogous to what was done earlier for other groups of elements ([10–12]). As is seen from Fig. 3, in the lanthanide family the curves graphically depicting the dependence of surface tension, density (ρ), and the quantity reciprocal to the isothermal compressibility ($1/\beta$) on atomic number have a similar character, which illustrates the existence of a deep connection between the bulk and surface properties of substances.

Fig. 2. Dependence of the surface tension of neodymium on temperature

Fig. 3

Fig. 3

Figure 3: Fig. 3

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