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DISCONTINUITY OF THE THERMAL EXPANSION COEFFICIENT OF Nb_3Sn AT THE SUPERCONDUCTING TRANSITION

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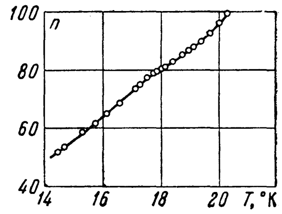
To study the jump in the expansion coefficient of tin and lead during transition through the superconducting transition temperature (T_K) and the volume change during the transition in a magnetic field, a sensitive method was developed which allowed measurements of these quantities to be made with sufficient accuracy (for example, volume changes $\Delta V/V \leq 10^{-8}$ were measured[1,2]).

1. This method allowed us to measure the discontinuity in the thermal expansion coefficient of Nb_3Sn at the transition. It was important to obtain this data in connection with a number of peculiarities in the properties of superconductors of this type, for example, the large magnetic field destroying superconductivity and the small field at which field penetration into the volume of the superconductor starts.

As in the previous measurements, the sensitive element of the apparatus was a long bimetallic strip, twisted into a spiral, one end of which was fixed, whilst the other could rotate when there were volume changes of one metal with respect to the other. This rotation is the measured quantity. In the present case one of the metals was niobium (99.5% purity) on which a layer of Nb_3Sn was deposited (from the outer side of the spiral) by the method of diffusive growth.[3] The dimensions of the spiral (length of strip 55 cm, niobium thickness ~ 0.26 mm, thickness of Nb_3Sn layer ~ 0.05 mm) ensured adequate sensitivity to changes of length of one component of the strip relative to the other (7×10^{-8} deg^{-1} for one division of the scale when reading with a mirror system).

The curve shown in the figure gives the rotation of the spiral (in scale divisions) as a function of



temperature in the neighborhood of the superconducting transition of Nb_3Sn. It is seen that, superposed on a monotonic behavior due to the difference in the coefficients of expansion of the components of the spiral, there is a singularity at the superconducting transition temperature, i.e., 18°K. In fact, the slope of the curve (i.e., the difference in expansion coefficients) above T_K (range 19–20°K) is greater than the slope of the curve below this temperature (17–14°K). The jump in the expansion coefficient of Nb_3Sn measured thus is 1.5 $\times 10^{-7}$ ($\pm 10\%$) deg^{-1}. It is interesting that this value of the jump in expansion for Nb_3Sn is close to the values of this quantity during the superconducting transitions in tin (1×10^{-7})[2] and lead (4×10^{-7}).[2] The value is three orders smaller than that ($\sim 5 \times 10^{-4}$ deg^{-1}) calculated using well-known thermodynamic formulae and the values of the quantities $\partial T_K/\partial p$ and $\partial H_K/\partial T$ for Nb_3Sn.[3] This means that in this superconductor probably only an insignificant part of the volume has the property that high field values are needed to destroy superconductivity,—a deduction which agrees with measurements of other properties of Nb_3Sn.[4,5] Otherwise one has to assume that in Nb_3Sn (and similar superconductors) the penetration depth of the magnetic field is extremely large.

2. Apart from measurements in the neighborhood of T_K, measurements were made in the same apparatus of the behavior of the differences in expansion coefficients and in compressibilities of Nb_3Sn and Nb in the temperature range 300–2°K.

It appeared that in this entire range the expansion coefficient of Nb_3Sn was slightly greater than that of niobium—the difference in the coefficients decreases from 3×10^{-6} at 300°K to 2×10^{-7} at 2.4°K (being 1.8×10^{-6} at 70° and 6×10^{-7} at 16°K). This indicates that the thermal properties of Nb_3Sn and Nb are very similar, i.e., the Debye temperatures are also close. The closeness of the elastic constants of these substances agrees with this also.

As has been made clear earlier,[2] a bimetallic spiral is also very sensitive to volume changes in its components under hydrostatic compression. For example, even 0.1 atm sufficed to rotate a copper-tin spiral enough to enable the difference in the compressibility coefficients of these metals to be determined at this pressure. The spiral of Nb_3Sn–Nb showed that the compressibilities were equal throughout the entire temperature range, within the accuracy of the experiment (± 5%).

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INTRAMOLECULAR ENERGY TRANSFER AND QUANTUM GENERATORS

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THE most efficient among the many quantum generators (lasers) developed so far to operate in the visible and in the infrared regions is the ruby laser. Its high efficiency is due for the most part to the location of the energy levels of the chromium ion. The energy spectrum of the Cr^{+++} ion, which isomorphically replaces the Al^{+++} ion in the corundum lattice, comprises a system of broad and narrow excited levels, of which the most important to laser operation is ^2E, the transition from which to the unexcited state $^4A_2$ is accompanied by luminescence, and the broad level $^4F_2$ which lies somewhat above it. The transition from the unexcited state $^4A_2$ to the $^4F_2$ level ensures absorption of the pumping light in a broad spectral interval (5300—6000 Å). On the other hand, because of the small width of the ^2E level, the emission is in a narrow spectral line, so that the oscillation conditions are easier to satisfy [1]. The closeness of the levels $^4F_2$ and ^2E results in high luminescence yield, so that high laser efficiency is feasible in principle.

In most other luminescent substances, the levels are not so located. As a rule, in substances with narrow luminescence lines the broad absorption band lies too high. It is known, for example, that the ions of rare-earth elements exhibit photoluminescence, with narrow luminescence lines. The luminescence of these ions is due to transition between the excited levels of the inner 4f shell of the ion. All these levels are very narrow, since the 4f shell is well screened against external perturbations by the 5s and 5p shells. The broad levels connected with the excited 6s and 6p states lie very high. Thus, in the trivalent europium ion the luminescence levels lie not higher than 20,000 cm^{-1} whereas the broad absorption level is at 40,000 cm^{-1}.

We wish to call attention to one yet-unused possibility. As was shown by Weissman[2] and confirmed by Sevchenko and Trofimov [3], in molecules of some complex compounds energy transfer is observed from some atoms of the molecule to others. These investigations pertained to europium and samarium compounds of the type EuR_3 and SmR_3, where R is an organic radical. In some cases these states lie near 25,000 cm^{-1}, which is sufficiently close to the luminescence levels of the rare-earth ions.

The luminescence of the investigated compounds is determined by the 4f shell of the rare-earth ions. This shows that the energy absorbed by the organic radical can be transferred to the rare-earth ion.

The level system of such a compound (see the figure) is thus similar to that of the chromium ion in ruby and is more suitable for use in lasers than the level system of the rare-earth ion proper. Another advantage of these compounds is that the screening action of the surrounding radicals causes a strong change in the probability of the nonradiative transitions in the 4f shell of the rare-earth ion, and consequently the quantum lumines-