DETERMINATION OF THE FIRST IONIZATION POTENTIALS OF NEODYMIUM AND PRASEODYMIUM BY THE SURFACE IONIZATION METHOD

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THE ionization potentials V of the majority of rare earth elements have not yet been determined spectroscopically. This is primarily due to the extreme complexity of the optical spectra of these elements. An attempt made to determine these values from the electrical conductivity of flames[1] did not produce the anticipated results. A surface-ionization method described earlier[2] has been used in the present work to determine the ionization potentials of neodymium and praseodymium atoms.

As is shown in the theory of surface ionization of atoms on composite surfaces,[2,3] if V significantly exceeds the maximum value of the localized work function of the surface, then the logarithm of the ion current from the surface must be a linear function of the surface inverse temperature 1/T. Furthermore if atoms of two different elements are simultaneously ionized on the surface (occurring in numbers n_1 and n_2 per second), the relation of their ion currents J_1/J_2 with the surface is determined by the equation:

$$\log(J_1/J_2) = \log(n_1A_1/n_2A_2) + 5040\,(V_1 - V_2)/T.$$

($A = Q_+/Q_0$ is the ratio of the statistical sum of the states of the positive ion Q_+ and of the atom Q_0).

Therefore the slopes of the plots of the $\log J_1/J_2 = f(1/T)$ can be used to find the ionization potential difference $(V_1 - V_2)$ for atoms of the two elements being compared.

For our comparison element we selected indium, whose value V = 5.79 ev has been determined reliably by spectroscopic means. In order to obtain and measure the currents J_1 and J_2, atomic fluxes produced by vaporizing metallic In, Nd and Pr in a special evaporator were directed onto a heated tungsten filament 0.005 cm in diameter. The filament temperature was measured with an optical pyrometer. The steadiness of the atomic flux density arriving at the filament (i.e., the values n_1 and n_2) was monitored by observing the stability of the ion current during the course of the measurements with the filament at T_0 = 2700° K.

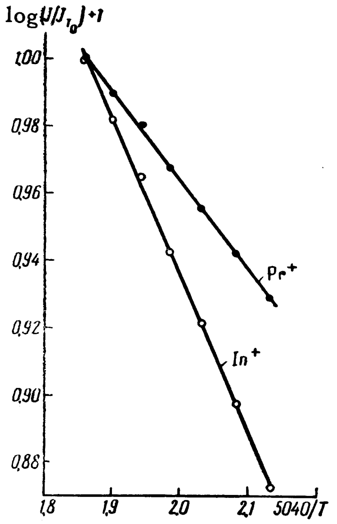

FIG. 1

Figure 1 shows plots of $\log(J/J_{T_0})$ versus 1/T for surface ionization of atoms of In and Pr, from which it can be seen that within the temperature interval 2300 to 2700° K this relation can be satisfactorily approximated by straight lines. Analogous results were obtained for the ionization of Neodymium atoms.

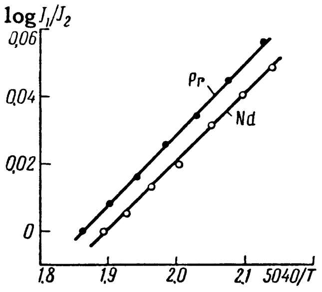

FIG. 2

Figure 2 shows plots of $\log(J_1/J_2)$ versus 1/T for the ratio of Nd and Pr ion currents to the indium ion current in the tungsten filament temperature interval 2300 to 2700° K. The average values of $V_1 - V_2$, found from eight independent determinations of the slope for the pair Pr-In and from ten determinations for the pair Nd-In, turned out to be respectively (0.22 ± 0.01) and (0.19 ± 0.02) ev. It is necessary to introduce a correction into the differences $V_1 - V_2$ determined by slope of the plots in Fig. 2, because of the temperature dependence of the ratio of the statistical sums A of the ionized elements. This correction amounts to 0.09 ev for indium in the filament temperature interval from 2300 to 2700° K. Unfortunately it is not presently possible to evaluate the magnitude of the correction for the case of Nd and Pr, since the energy level diagrams of the atoms and positive ions of these elements are not known.

The corrections may amount to several hundredths ev. In the case of lanthanum, for example, where the atomic and ionic energy level diagrams are known, the correction for the above temperature interval amounts to 0.04 ev. Thus our values of the ionization potentials for atoms of neodymium and praseodymium, not taking into account the possibility of excited atomic and ionic states near the ground state, turned out to be:

$$V_{\mathrm{Pr}} = 5.79 - 0.09 - 0.22 = (5.48 \pm 0.01) \text{ ev},$$

$$V_{\mathrm{Nd}} = 5.79 - 0.09 - 0.19 = (5.51 \pm 0.02) \text{ ev}.$$

We would like to remark in conclusion that our results might be viewed as experimental confirmation of the validity of the theoretical equations[3] for the surface ionization of indium, neodymium and praseodymium atoms on incandescent tungsten.

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THE LINE SHAPE OF THE NUCLEAR ACOUSTIC RESONANCE

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RECENTLY there appeared in the literature a number of articles on nuclear acoustic resonance in which the line shape A (ω) of the nuclear acoustic resonance absorption and the relaxation process in acoustically-excited spin systems is interpreted on the basis of the existing theory of nuclear magnetic resonance (cf. references 1 and 2).

Our investigation of the character of the interaction of the ultrasonic field with the nuclear spin system in cubic crystals, based on the quantum theory of irreversible processes,[3] shows that the above-mentioned method of interpretation of acoustic magnetic resonance data is unfounded and leads to erroneous conclusions. While the line shape of ordinary paramagnetic resonance is determined by the Fourier transform of the auto-correlation function $G_M(t)$ of the magnetic moment M of the spin system,[3] the line shape of the acoustic nuclear resonance is analogously determined by means of the auto-correlation function $G_K(t)$ of the nuclear quadrupole moment K_0 of the spin system. Since M and K_0 are described by a linear and bilinear function of the spin variables, respectively, the character of the time variation of M and K_0 differs for dipole-dipole ($\mathcal{H}_d$), exchange ($\mathcal{H}_{ex}$), and other inner interactions, and the functions $G_M(t)$ and $G_K(t)$ do not coincide.

In particular, in the case when the longitudinal sound wave propagates along the [110] axis and a strong static magnetic field H parallel to the z axis forms an angle θ with the [110] axis, we obtained

$$A(\omega) = \sum_a \omega^2 \frac{\langle |K(\omega_a)|^2 \rangle}{VkT} \left(1 - \sum_{\omega_\gamma \neq 0} \frac{\Delta^2_{a\gamma}}{\omega^2_\gamma}\right) (2\pi\Delta^2_{a0})^{-1/2} \times \exp\left\{-\frac{1}{2\Delta^2_{a0}} \left(\omega - \omega_a + \sum_\gamma \frac{\Delta^2_{a\gamma}}{\omega_\gamma}\right)^2\right\}, \tag{1}$$

where the coefficients for the transition a = ξ, in the course of which the magnetic quantum number m of nuclei with spin I changes by ± 2, are calculated according to the formula

$$K(\omega_\xi) = \frac{K_0}{4I(2I-1)} \left[\frac{3}{4} + \frac{S_{44}}{S_{11}} + \left(\frac{S_{44}}{S_{11}} - \frac{3}{4}\right)\sin^2\theta\right] S_{11}\varepsilon_1 \sum_j [I_x^{j2} - I_y^{j2}],$$

$$\Delta^2_{\xi 0} = \frac{1}{6} I(I+1) \sum_{k(\neq j)} \{(P^{jk}_{xx} + P^{jk}_{yy})^2 + 8P^{jk^2}_{zz}\},$$

$$\mathcal{H}_d + \mathcal{H}_{ex} = \sum_{j>k} \sum_{\alpha,\beta} P^{jk}_{\alpha\beta} I^j_\alpha I^k_\beta,$$

$$\Delta^2_{\xi 1} = \frac{5}{3} I(I+1) \sum_{k(\neq j)} (P^{jk2}_{xz} + P^{jk2}_{yz}),$$

$$\Delta^2_{\xi 2} = \frac{1}{6} I(I+1) \sum_{k(\neq j)} \{(P^{jk}_{xx} - P^{jk}_{yy})^2 + 4P^{jk2}_{xy}\}.$$

Here ϵ_1 is the mean value of the time-dependent component of the deformation tensor ϵ; $S_{\eta\eta}$ are the components of the fourth-rank tensor relating ϵ with the tensor of the electric field gradient on the nucleus [see (1), (2), and (14) in reference 4]; $\Delta^2_{\xi 0}$ is the adiabatic second moment of the resonance line, $\Delta^2_{\xi 1}$ and $\Delta^2_{\xi 2}$ are the nonadiabatic second moments for transitions with m changing by ± 1 and ± 2, respectively (cf. reference 5), and ω_1 and ω_2 are the corresponding transition frequencies; V is the volume of the crystal, k the Boltzmann constant, and T the temperature. The form of the components of the