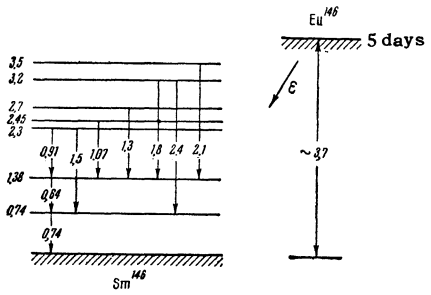

FIG. 2

We found coincidences of 0.74-Mev quanta (Fig. 1a) with quanta of 0.64, 0.91, 1.07, 1.3, 1.5, 1.8, 2.1, and 2.4 Mev. We also observed coincidences of 0.64-Mev quanta (Fig. 1b) with all the quanta enumerated above, except for 1.5 and 2.4 Mev; we also found self coincidences of the 6.4-Mev quanta, which compells us to assume that there is still one more quantum with energy close to 0.64 Mev. Moreover, we investigated coincidences with various parts of the hard region of the spectrum in the range of 2.4, 2.1, 1.8, 1.5, 1.3, 1.1, and 0.9 Mev.

In the spectrum of coincidences with 0.24-Mev quanta the peak at 0.74 Mev is plainly visible, while the 0.64-Mev peak is absent, which is in agreement with the data of the spectrum of 0.64-Mev coincidences. In the case of the coincidences with 2.1-Mev quanta, both peaks are absent. Coincidences with parts of the spectrum in the regions of 0.9, 1.1, and 1.3 Mev give peaks at 0.64 and 0.74 Mev of approximately the same intensity. However, while investigating the coincidences with the part in the region of 1.5 Mev, we observed a sharp increase in the intensity of the 0.74-Mev peak, which is in agreement with the results of experiments on coincidences with 0.64-Mev quanta and gives a basis to assume that the 1.5- and 0.64-Mev transitions are not in cascade. It thus follows that the 0.74-Mev transition is the lower one in the 0.64-0.74 Mev cascade, since the 1.5- and 2.4-Mev transitions proceed directly to the 0.74 level. As regards the remaining transitions, it can be said that they go to the 1.38-Mev level.

In neither the singles spectrum nor in the coincidence spectrum was there observed a direct transition from the 1.38-Mev level of intensity greater than 5% of the 0.74-Mev lines.

In conclusion, we propose a variant of the decay scheme of the Eu^{146} nucleus which is in agreement with the results of the present work (Fig. 2). The energy of the Eu^{148} decay into Sm^{146} is 3350 kev according to Cameron's formula and 3700 kev according to Levi's formula,[4] which allows the existence of the levels introduced by us up to 3.5 Mev.

Some of the transitions occurring in coincidence are probably individual components of the groups shown in the table (for example, the 1.07-Mev line from the group of 1.1-Mev lines.

We noted a γ line of energy 280 kev which was in coincidence with quanta of 115 — 120 kev; they are apparently associated with the decay of Gd^{146} or Eu^{147}.

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ON THE THEORY OF PARAMAGNETIC RESONANCE OF Ti *AND* Co *IONS IN CORUNDUM*

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As a result of recent experimental investigations of paramagnetic resonance in Al_2O_3 crystals containing different paramagnetic impurities it has been found that the magnetic properties of Ti ions[1] and of Co ions[2,3] differ appreciably from the properties of these ions in other crystals studied previously. If we make certain natural assumptions then, as our calculations have shown, the whole set of experimental facts relating to the paramagnetic resonance spectra and the spin-lattice relaxation times can be simply explained.

In the case of Ti in corumdum an anisotropy of the g-factor has been experimentally obtained which is unusually large for ions of the iron group with an odd number of electrons: $g_{\parallel} = 1.067$, $g_{\perp} < 0.1$. As the temperature was lowered from 9 to 1.55° K the spin-lattice relaxation time increased from $T_1 = 5 \times 10^{-8}$ to $T_1 = 0.1$ sec. We assume that the trigonal component of the crystalline field is much stronger than the spin-orbit interaction and, therefore, the effects of the cubic and the trigonal components must be taken into account simultaneously. Moreover, we shall assume that the constant of the trigonal field is negative, as the result of which the lowest energy level turns out to be an orbital doublet. The assumptions made by us find confirmation in the structure of the corundum crystalline unit cell. The spin-orbit interaction splits the ground orbital level into two Kramers spin doublets separated by a gap of $\delta = 70$ cm^{-1}. The character of the symmetry of the wavefunctions of the lowest doublet is such that even when higher order approximations are taken into account we have $g_{\perp} = 0$. For a definite ratio of the constants of the cubic and the trigonal fields we can easily obtain $g_{\parallel} = 1.07$. It is well known that in corundum the covalent bonds between the metal ion and the oxygen atoms surrounding it play an appreciable role. Taking this bonding into account for the titanium ion will lead to $g_{\perp}$ somewhat different from zero. The relatively small value of the gap δ leads to a very strong spin-lattice interaction. Even at helium temperatures two-phonon processes play the predominant role, as a result of which $T_1 \sim T^{-7}$.

If we assume that the Co^{2+} ions in corundum are situated in a crystalline field of the same character and magnitude as the Ti^{3+} ions, then the lowest orbital level will be a singlet separated from the nearest orbital level by a gap of 1300 cm^{-1}. Taking into account the spin-orbit coupling in second-order perturbation theory, and also the effect of the external magnetic field and of the hyperfine interactions leads to the following spin-Hamiltonian:

$$\mathcal{H} = D\left[S_z^2 - \tfrac{1}{3}S(S+1)\right] + g_{\parallel}\beta H_z S_z + g_{\perp}\beta(H_x S_x + H_y S_y) + AI_z S_z + B(I_x S_x + I_y S_y),$$

where $S = 3/2$. Agreement with experimental values of $g_{\parallel}$, $g_{\perp}$, A and B is obtained if we alter somewhat the constant of the trigonal field, in such a way that the initial splitting of the spin quadruplet is equal to $2D = 24$ cm^{-1}. In this case the coefficient describing the contribution to the hyperfine structure of higher electronic configurations containing S states has been taken equal to $K = 0.25$; in order of magnitude the coefficient K agrees with values obtained in the study of paramagnetic resonance spectra in other crystals.[4]

Measurements of the spin-lattice relaxation of Co^{2+} ions have shown that while at 25° K the spin-lattice coupling of the Co^{2+} ions is much stronger than of Cr^{3+} ions, on the other hand at helium temperatures the relaxation time T_1 for the Cr^{3+} ions is much shorter than for the Co^{2+} ions. This fact may be explained as follows.

As a result of the fact that the gap between the lowest orbital energy levels of the Co^{2+} ions is relatively small, the spin-lattice coupling is strong, and at temperatures above helium temperatures is determined by two-phonon processes. In this case the principal role is played by the relaxation transitions between spin levels belonging to different Kramers doublets. The probabilities of these transitions are higher by several orders of magnitude than the probabilities of transitions within Kramers doublets. The exceptionally strong increase of the relaxation time T_1 as the temperature is lowered from 30° to 6° K is related to the fact that this is accompanied by a very rapid diminution in the population of the upper Kramers doublet. Calculations show that for $\Theta < T < 6°$ K (Θ is the Debye temperature)

$$1/T_1 \sim e^{\epsilon/T}\,(120T^7 + 60\epsilon T^6 + 12\epsilon^2 T^5 + \epsilon^3 T^4),$$

where $\epsilon = 2Dk/\hbar = 35°$. At temperatures below helium temperatures $T_1 \sim 1/T$, since the relaxation is determined by the single phonon processes associated with the transitions between the spin levels of the lowest Kramers doublet. Calculations show that in this case $T_1(Co^{2+})/T_1(Cr^{3+}) = 560$ if the magnetic field is equal to 3000 oe.

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