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RESONANCE SCATTERING OF GAMMA QUANTA BY Mg^{24} *NUCLEI*

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Resonance scattering of 1.38-MeV γ quanta by Mg^{24} nuclei was investigated using a source of radioactive Na^{24} in the form of an aqueous solution of NaOH. The average cross section for resonance scattering was found to be $(3.7 \pm 0.6) \times 10^{-28}$ cm^2. The energy distribution of the emitted γ quanta was calculated for the $\beta-\gamma_2-\gamma_1$ cascade taking account of the slowing down of the recoil nuclei. The lifetime of the 1.38-MeV level in Mg^{24} was determined to be $(1.1 \pm 0.2) \times 10^{-12}$ sec.

RECENT investigations[1-3] have shown that resonance scattering of γ quanta by nuclei can occur when one uses liquid and solid sources, provided the lifetime τ_γ of the initial level is less than 10^{-12} sec. Since the time between collisions of the recoil nuclei with surrounding atoms is of order 10^{-13}—10^{-14} sec, the slowing down of the recoil nuclei results in a change in the energy distribution P(E) of the γ quanta.

To determine τ_γ one must find experimentally the average cross section for resonance scattering and calculate the microspectrum P(E) theoretically. A calculation of the microspectrum, with account of the slowing down of the recoil nuclei, is necessary mainly for two reasons. First, in certain cases, in particular when using very short-lived isotopes, obtaining a source in the gaseous state or the use of the "self-absorption" method for determining τ_γ is a difficult experimental problem. Second, the study of the attenuation of the resonance effect in dense media can give information about the lifetimes of higher-lying levels.

In our work we studied the resonance scattering of 1.38-MeV γ quanta by Mg^{24} nuclei, using the radioactive isotope Na^{24} ($T_{1/2}$ = 14 hr) in the form of an aqueous solution of NaOH. The Na^{24} decay is accompanied by the emission of a β particle with endpoint E_{max} = 1.39 MeV and two γ quanta with energies E_{γ_2} = 2.76 MeV and E_{γ_1} = 1.38 MeV.

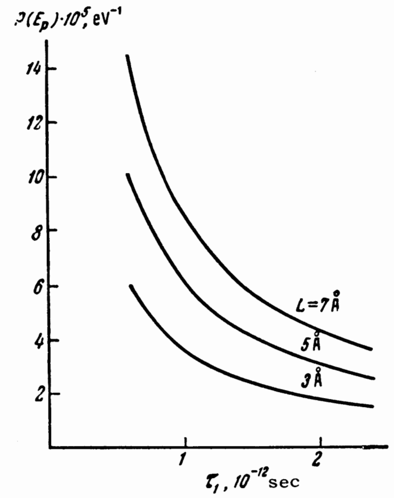
To compute the spectrum P(E), we used a model with continuous slowing down of the recoil nuclei as the result of elastic collisions with the surrounding atoms. The energy of the emitted γ_1 quantum was

$$E_{\gamma 1} = (E_{\gamma 1}{}^0 / Mc) p_{2x} + [E_{\gamma 1}{}^0 - (E_{\gamma 1}{}^0)^2 / 2Mc^2] = ap_{2x} + b,$$

where $E^0_{\gamma_1}$ is the energy of the level, p_{2x} is the projection of the total momentum on the direction of emergence of the γ_1 quantum, and the energy distribution of the γ quanta is given by the density distribution of the momentum projection $\xi(p''_{2x})$:

$$P(E) = \xi(p_{2x}) / a. \quad (1)$$

For the case of a $\beta-\gamma_2-\gamma_1$ cascade, the density distribution of recoil nuclei over momentum pro-



Dependence of $P(E_p)$ on τ_1, computed theoretically for various values of the free path L.

jections, taking account of the slowing down, was found to be

$$\xi(p_{2x}'') = \frac{M^5L^5}{4p_{\gamma_2}\tau_1\tau_2}\int\limits_{|p_{2x}''|}^{p_{max}+p_{\gamma_2}} dp_{2x}''\int\limits_{\lambda_2}^{\lambda_1}\frac{\exp(-t_1/\tau_1)\,dt_1}{(ML-p_2''t)^3}$$

$$\times \int\limits_{\left|\frac{MLp_2''}{ML-p_2''t_1}-p_{\gamma_2}\right|}^{p_{max}} \frac{dp'}{p'}\int\limits_0^{\lambda_0}\exp\left(-\frac{t}{\tau_2}\right) g\left(\frac{MLp'}{ML-p't}\right)$$

$$\times \frac{dt}{(ML-p't)^2},$$

$$\lambda_0 = ML\left(\frac{1}{p'}-\frac{1}{p_{max}}\right), \qquad \lambda_1 = ML\left(\frac{1}{p''}-\frac{1}{p_{\gamma 2}+p_{max}}\right),$$

$$\lambda_2 = ML\left(\frac{1}{p''}-\frac{1}{p_{\gamma 2}-p_{max}}\right)\eta(p_{\gamma 2}-p_{max}-p_2''). \qquad (2)$$

Here $g(p)$ is the momentum distribution of the recoil nuclei, p_{max} is the maximum momentum after the β decay, p_2'' is the total momentum after the β and γ_2 transitions, p_{γ_2} is the momentum of the recoil nucleus from the γ_2 transition, τ_1 and τ_2 are the lifetimes of the first and second excited states, and L is the mean free path.

Theoretical values of $\xi(p_{2x}'')$ were computed on the "Minsk" computer for the cases of the $Na^{24} \to Mg^{24}$ and $Co^{60} \to Ni^{60}$ decays, with different values of τ_1, τ_2, and L. The computations showed that for $Co^{60} \to Ni^{60}$ the value of $P(E_p)$ depends on τ_2, which is easily understood considering that $E_{\gamma_2} < E_{\gamma_1}$. For $Na^{24} \to Mg^{24}$ ($E_{\gamma_2} > E_{\gamma_1}$), the value of $P(E_p)$ depends only on τ_1 and L and is independent of τ_2, which is explained by the position of the resonance line in the microspectrum.

The figure shows the dependence found for $P(E_p)$ on τ_1 for different values of L. Consequently, assigning L, we can determine τ_1 if we know the average cross section $\bar{\sigma}$ for resonance scattering of 1.38-MeV γ quanta by Mg^{24} nuclei. The determination of $\bar{\sigma}$ was done in an apparatus similar to one used earlier.[4] The initial Na^{24} activity was 0.5 Ci. Since the resonance effect also occurs in solid Na^{24},[1,5] to measure the scattering from scatterers of magnesium and aluminium under nonresonant conditions we used the radioactive isotope La^{140} ($T_{1/2}$ = 40 hr) with transition energy 1.59 MeV. The determination of the average cross section for resonance scattering was done by numerical integration over the scatterer surface. We found the value $\bar{\sigma} = (3.7 \pm 0.6) \times 10^{-28}$ cm^2.

Analysis of the data found from resonance scattering of γ quanta emitted after a β transition[4,3] shows that the mean free path of the recoil nuclei in water solution is $(1.5 \pm 0.3) \times 10^{-8}$ cm, which gives $L = (5.0 \pm 1.0) \times 10^{-8}$ cm for the case considered. Using the experimental value of $\bar{\sigma}$ and the theoretical dependence of $P(E_p)$ on τ_1, we find

$$\tau_1 = (1.1 \pm 0.2)\cdot 10^{-12} \text{ sec}.$$

The result is in satisfactory agreement with the data of other work on resonance scattering of 1.38-MeV γ quanta by Mg^{24} nuclei.

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