RESONANCE SCATTERING OF GAMMA QUANTA BY Sr^{88} *NUCLEI*

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THE method of resonance scattering has been applied successfully to determine short lifetimes for excited states.

Resonance scattering will occur only when the energy of the γ quantum is matched to the resonance. To compensate for the energy loss to recoil, one uses different methods depending on the properties of the particular isotope, but all of them are based on the use of the Doppler broadening of the line. In the case of $Rb^{88} \rightarrow Sr^{88}$, the energy required for compensating the energy loss to recoil in the emission and absorption can be obtained from the Doppler broadening due to recoil in the 13% β-transition (3.60 MeV) to the first excited state, and also from the total recoil in the preceding β and γ transitions.

In this work, in order to determine the true lifetime τ_γ of the excited state we used the self-absorption method.[1]

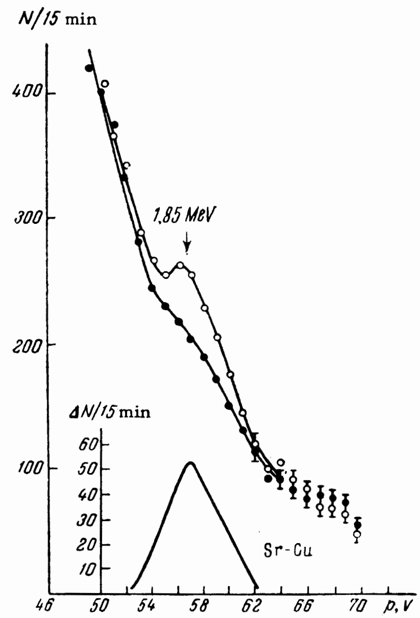
A solid source of $RbNO_3$ was irradiated for one hour in a neutron flux of 1.8×10^{13} neuts/cm^2-sec at the VVR-S reactor of the Nuclear Physics Institute of the Academy of Sciences, Uzbek SSR. The studies were made using the plane geometry described earlier.[2]

The resonance effect was determined by analysis of the spectrum of the scattered radiation, using a 100-channel pulse analyzer.

The figure shows the results of one series of measurements (each curve is the average of the measurements with two sources having identical activities), and a total of 30 such series were run. The peak near 57 V, obtained with a strontium scatterer, is caused by the resonance effect. The effect amounted to about 16% of the total counting rate.

During the measurements we compared the efficiency of the two absorbers, the strontium resonance absorber and the copper nonresonant absorber, in attenuating the primary beam, and also measured the attenuation of the resonance effect by a strontium absorber compared to a copper absorber.

For each absorber we determined the ratio



Resonance scattering of γ quanta by Sr^{88}: o — spectrum of radiation scattered from Sr scatterer, • — spectrum of radiation scattered from Cu scatterer, solid curve is the difference $N_{Sr} - N_{Cu}$.

$(N_{Sr} - N_{Cu})/N$; the determination of the effectiveness of the resonance absorber in attenuating the resonance effect was made by comparing the ratios $[(N_{Sr} - N_{Cu})/N]_{Sr}$ and $[(N_{Sr} - N_{Cu})/N]_{Cu}$, where N_{Sr} and N_{Cu} are the counting rates with strontium and copper absorbers. Each such series consisted of measurements on four identical 1-Curie sources, and a total of 20 such series were run.

The results of measurements of Γ_γ for the 1.85 MeV level in Sr^{88} by the self-absorption method are the following: a 9.4 g/cm^2 strontium absorber decreased the resonance effect by (6.9 ± 1.4)% more than did a copper absorber chosen so that under nonresonant conditions their absorptions of the direct beam were the same to within (99.9 ± 0.1)%.

The effective temperature of scatterer and absorber was found to be 300°K (assuming a Debye temperature of 140°K for strontium), which gives

Values of vibrational parameters for Sr^{88} and Mo^{96}

Nucleus	E_1, MeV	E_2/E_1	$\frac{B(E2.2\to 0)}{e^2\,b^2}$	$\frac{B(E2.2\to 0)}{B(E2)\ s.p}$	C_2, MeV	$\frac{B_2}{B_2\text{hydro}}$	$\sqrt{\langle\beta^2\rangle}$
Sr^{88}	1.850	1.49	0.034	7.3	364	14.8	0.249
Mo^{96}	0.78	—	—	21	62	12.5	—

$\Delta = 1.46$ eV. Taking $\lambda^2 = 4.5 \times 10^{-21}$ cm^2, $n = 5.3 \times 10^{22}$ cm^{-2}, $g_2/g_1 = 5$, we find $\Gamma_\gamma = (6.0 \pm 1.2) \times 10^{-3}$ eV, which corresponds to a lifetime $\tau_\gamma = (1.10 \pm 0.22) \times 10^{-13}$ sec for the 1.85 MeV level of Sr^{88}.

The Weisskopf-Moszkowski one-particle estimate gives $\tau_\gamma = 8 \times 10^{-13}$ sec. Thus the E2 transition with $E_\gamma = 1.85$ MeV is enhanced, with an enhancement factor $\tau_{\gamma\,s.p.}/\tau_{\gamma\,exp} = 7.3$.

The lifetime of the first excited state of Sr^{88} is known from the work of Helm ($\tau_\gamma = 1.4 \times 10^{-13}$ sec),[3] who studied inelastic scattering of electrons, the work of Ofer [$\tau_\gamma = (2.24 \pm 0.58) \times 10^{-13}$ sec][4] from measurements of resonance scattering, and the work of Lemberg et al. ($\tau_\gamma = 1.2 \times 10^{-13}$ sec)[5] on Coulomb excitation of this level by nitrogen ions accelerated in a cyclotron to E = 44.5 MeV, where, because of the poor statistics, the error was ±35%.

On the unified model this result permits an interpretation of the first excited state of the even-even Sr^{88} nucleus as the result of quadrupole vibrations of the nuclear surface around its equilibrium spherical shape.

The table gives our calculated values of the vibrational parameters C_2, B_2 and $\sqrt{\langle\beta^2\rangle}$ for Sr^{88} and Mo^{96}. From the table it follows that for the Sr^{88} nucleus, with a closed neutron shell, the elastic coefficient C_2 is very large. Such a behavior of C_2 is explained[6] in terms of its dependence on the number of particles in the shell. Far enough away from the closed shell, the spherical shape becomes unstable and the nucleus becomes deformed. Near the deformation region, C_2 should be very small.

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108