THEORY OF RESONANT INTERACTION OF GAMMA RAYS WITH CRYSTALS

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As Mössbauer has shown, the probability of elastic resonant interaction (without change of the quantum state of the crystal lattice) of gamma rays with nuclei in crystals contains the factor

$$f = \exp\left[g_\infty(T)\right],$$

where

$$g_\infty(T) = -2\sum_s \frac{(\mathbf{p}\mathbf{e}_s)^2}{2m\hbar\omega_s N}\left[\alpha\left(\frac{\hbar\omega_s}{kT}\right)+\frac{1}{2}\right], \quad \alpha(x) = \frac{1}{e^x - 1}. \tag{1}$$

Here $\mathbf{p}$ is the momentum of the photon, T is the temperature of the crystal, m is the mass of the atoms in the crystal, N is their density, and $\mathbf{e}_s$ and ω_s are the polarization and frequency, respectively, of the s-th phonon in the crystal.

Since f depends on $g_\infty(T)$ exponentially, an evaluation of the latter in the Debye approximation[1] is not always satisfactory. If, however, no correlation exists between the direction of the vector $\mathbf{e}_s$ and the frequency ω_s (as in crystals of cubic symmetry), then $g_\infty(T)$ can be more exactly calculated directly from the experimental data on the heat capacity at constant volume* (referred to a single atom)

$$C_v(T) = 3\frac{d}{dT}\int_0^\infty \nu(\omega)\hbar\omega\alpha\left(\frac{\hbar\omega}{kT}\right)d\omega, \tag{2}$$

where $\nu(\omega)$ is the spectrum of frequencies of the lattice vibrations. It is easy to verify that in this case

$$g_\infty(T) = -(E^2/2mc^2)\left[G_0 + G_1(T)\right], \quad E = pc,$$

$$G_0 = \int_0^\infty \frac{d\omega}{\hbar\omega}\nu(\omega), \qquad G_1(T) = 2\int_0^\infty \frac{d\omega}{\hbar\omega}\nu(\omega)\,\alpha\left(\frac{\hbar\omega}{kT}\right). \tag{3}$$

By direct substitution one obtains

$$G_0 = (\pi k)^{-2}\int_0^\infty C_v(T)\,dT/T^2. \tag{4}$$

By a method similar to that described in reference 3, one can show that

$$G_1(T) = \frac{2}{3}k^{-2}\sum_{n=1}^\infty \int_0^{T/n} \frac{dT'}{T'^2}\left(\frac{1}{T'} - \frac{n}{T}\right)\phi(T'),$$

$$\phi(T) = \sum_{n=1}^\infty \mu_n \int_0^{T/n} C_v(T')\,dT', \tag{5}$$

where $\mu_1 = 1$, $\mu_{n\pm 1} = (-1)^l$ if n is the product of l different prime numbers, and $\mu_n = 0$ in all remaining cases.

The values of $g_\infty(0)$ computed from the specific data[2,4] for Ir^{191} (E = 129 kev) and Zn^{67} (E = 93 kev)† are −2.75 and −5.6, respectively. From the experiments[5] on the resonant interaction of gamma rays in Ir^{141} one obtains $g_\infty(0) = -3.0 \pm 0.3$.

In conclusion the author expresses his gratitude to A. V. Stepanov and F. L. Shapiro for helpful discussions.

*Strictly speaking, formula (2) gives only that part of C_v which arises from the lattice vibrations. Therefore one should subtract the electronic heat capacity from the experimental values of C_v before substitution into formulas (4) and (5). As is shown by the numerical calculation of $g_\infty(0)$ for Ir^{191}, however, the pertinent correction amounts to 3% in all, as the Debye temperature (in particular its dependence on T) varies considerably[2] in the calculation of this correction.

†As is known, Zn^{67} can be used for measuring the red shift in the laboratory.

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NEW ISOTOPE Te^{115}

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On the basis of the systematics of radioisotope half-lives, it was hypothesized that the unknown Te^{115} isotope decays with $T \approx 7$ min, changing into the recently discovered isotope Sb^{115} (T