THEORY OF RESONANT INTERACTION OF GAMMA RAYS WITH CRYSTALS

M. V. KAZARNOVSKIĬ

P. N. Lebedev Physics Institute

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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

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

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 **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 $\mu_1 = 1$, $\mu_{n\pm1} = (-1)^l$ 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}

I. P. SELINOV, N. A. VARTANOV, D. E. KHULELIDZE, Yu. A. BLIODZE, N. G. ZAĬTSEVA, and V. A. KHALKIN

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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 ≈ 7 min, changing into the recently discovered isotope Sb^{115} (T

= 32 min).[1] To observe the new isotopes, a tin foil enriched with Sn^{112} (52.3%) was irradiated in a cyclotron by 21-Mev α particles. The foil and the chemically separated tellurium and antimony fractions were investigated with end-window counters and with a one-channel scintillation γ spectrometer. In the tellurium fraction containing elemental tellurium (precipitated by tin chloride) there was observed an activity with T = 6 min belonging to the new isotope Te^{115} formed in the reaction $Sn^{112}(\alpha, n)Te^{115}$.

In order to make a positive identification of this isotope, we carried out a fractional separation (in intervals of 5 min) of the isotope Sb^{115} (T = 32 min) by precipitating the antimony with hydrogen sulfide from the solution containing the tellurium. After the activity of the antimony decreased, it was found that the half-life of Te^{115}, which is the parent of Sb^{115}, is 6.0 ± 0.5 min.

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ON NEW STRANGE PARTICLES

B. PONTECORVO

Joint Institute for Nuclear Research

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THE Gell-Mann systematics of elementary particles[1] provides for the possibility of the existence of as yet unknown baryons and mesons, in particular of particles Z^+ (T = 0, S = +1, baryon number N = 1) and D^+ (T = 0, S = +2, N = 0). At the present time there are strong arguments which indicate that the Z^+ baryon does not exist. In fact, if the mass of the Z^+ baryon is such that it can decay by the scheme $Z^+ \rightarrow \pi + N$, then it would have been found already without difficulty, and if its mass is close to that of the nucleon, it could be formed along with the Λ particle in a reaction of the type $p + n \rightarrow Z^+ + \Lambda^0$, which is excluded by the experiments.[2]

At the conference on high-energy particle physics in Kiev, Wang Kang-Ch'ang and his co-workers[3] reported an interesting event of the interaction of a π meson in a bubble chamber, which can be interpreted by assuming the existence of a new particle — a D particle with mass ~ 750 Mev, which decays by the scheme

$$D^+ \rightarrow K + \pi \begin{cases} K^0 + \pi^+ \\ K^+ + \pi^0. \end{cases}$$

If we identify this particle with the positive meson of strangeness +2 predicted by Gell-Mann, then the lifetime expected for the hypothetical D particle is of the order of 10^{-10} sec. In fact, the isotopic spin of the $(K\pi)$ system can be $1/2$ or $3/2$, so that the selection rule $\Delta T = 1/2$ cannot hinder the decay, as it does in the case of the decay of the K^+ meson.

It is assumed below that the lifetime of the hypothetical D particle does not exceed a few times 10^{-10} sec, so that it is not possible to get collimated beams of these particles by ordinary methods. Therefore it is desirable to look for new methods for detecting these particles. A special property of the new particle, which distinguishes it from all the well known particles, is that it decays with the emission of a K meson. This property can be used in the following way. Let us think of a target bombarded by high-energy particles. In the vacuum near the target K mesons will be produced by the decay of D particles, and these mesons can be registered after they have passed through a collimator that does not point toward the target. This method is reminiscent of that of Garwin, in which strange particles were studied by registering the γ rays from the decay of π^0 mesons emitted "in vacuum" by strange particles (cf. e.g. reference 2).

The ratios of the intensities of K and π mesons from the target and from the "vacuum" near the target are respectively characterized, roughly speaking, by the fractions of interactions in the target that lead to the production of the strange particles and the relative probabilities for production of D particles and ordinary strange particles. It is clear that if the probability of production of D particles is minute, then $(K/\pi)_{vac} \ll (K/\pi)_{targ}$.

If, for example, we assume that the number of D mesons produced is $\sim 10^{-4}$ of the number of interactions produced in the target by protons of energy ~ 10 Bev, and the number of K mesons is $\sim 10^{-2}$ of this number of interactions, then about 1 percent of the total K-meson beam has the D-