ENERGY SHIFTS OF GAMMA TRANSITIONS OBSERVED IN RESONANCE ABSORPTION OF GAMMA QUANTA IN CRYSTALS

V. A. BRYUKHANOV, N. N. DELYAGIN, B. ZVENGLINSKII, and V. S. SHPINEL'

Nuclear Physics Institute, Moscow State University.

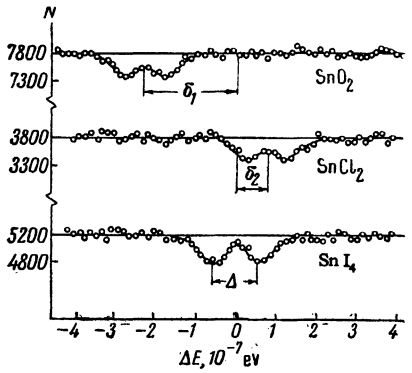
Submitted to JETP editor December 2, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **40**, 713-714 (February, 1961)

IN previous notes[1,2] we have reported an investigation of resonance absorption of gamma quanta in crystals (Mössbauer effect) for the 23.8-kev γ transition in Sn^{119}. In particular, it was shown that in a crystal of white metallic tin (β-tin) the emission and absorption lines are split into two components. According to our latest measurements the separation between these two components is $\Delta = (1.10 \pm 0.15) \times 10^{-7}$ ev.

In the present work, using a source of Sn^{119m} (white metallic tin) at liquid nitrogen temperature, we have obtained absorption spectra for absorbers prepared from different crystalline compounds containing tin (in the normal isotopic mixture): SnI_4 (~ 30 mg/cm^2), $SnCl_2$ (~ 60 mg/cm^2) and SnO_2 (5.3 mg/cm^2). For SnI_4 and $SnCl_2$, the measurements were done with the absorber cooled by liquid nitrogen; for the SnO_2 absorber, the cooling was not done since it did not give any significant increase of the effect. The dependence of the effective cross section for resonance absorption on the velocity of the source relative to the absorber was measured with the apparatus described briefly in an earlier report.[1] The absorption spectra obtained are shown in the figure (where N is the total number of pulses).

The spectra have the doublet structure which we also observed earlier for the $SnNb_3$ crystal.[1] This structure is caused by the splitting of the emission of the source, which we mentioned above. In addition to the doublet structure, for SnO_2 and $SnCl_2$ we also observed an energy shift of the absorption line. For the SnO_2 crystal, the energy shift is negative, $\delta_1 = -(2.4 \pm 0.3) \times 10^{-7}$ ev, while for the $SnCl_2$ crystal it is positive, $\delta_2 = +(0.72 \pm 0.10) \times 10^{-7}$ ev (if we choose as our reference point the energy of the absorption line for SnI_4, which corresponds to zero source velocity in the notation used on the figure). Relative shifts of lines in a source and absorber which are not chemically identical and which are at different temperatures may be due to various causes.[3]



The shifts observed by us can be explained by assuming that the energies of the states between which the transition occurs include an interaction between the nucleus and those electrons which have a nonzero wave function in the region of the nucleus. This interaction depends on the charge distribution in the nucleus, and can differ by an amount ΔE for two different states of the nucleus. Thus the energy of the emitted quantum can be written as $E = E_0 + \Delta E$, and the experimentally observed shifts must be due to the difference in ΔE for the different crystalline compounds. A theoretical computation of such shifts would enable us to obtain additional information concerning the distribution of charge in the nucleus.

[1] Delyagin, Shpinel', Bryukhanov, and Zvenglinskii, JETP **39**, 220 (1960), Soviet Phys. JETP **12**, 159 (1961).

[2] Delyagin, Shpinel', Bryukhanov, and Zvenglinskii, JETP **39**, 894 (1960), Soviet Phys. JETP **12**, 619 (1961).

[3] O. C. Kistner and A. W. Sunyar, Phys. Rev. Letters **4**, 412 (1960).

Translated by M. Hamermesh
112

ON THE ENERGY DEPENDENCE OF THE SCATTERING CROSS SECTION AT SMALL ENERGIES

S. M. BILEN'KII

Joint Institute for Nuclear Research

Submitted to JETP editor December 26, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **40**, 714-715 (February, 1961)

F. L. Shapiro[1] has shown that the first two terms in the expansion of the total inelastic cross section

σ_r in powers of k (relative momentum of the particles in the initial state) are determined by the value of $(\sigma_r k)$ at k = 0, and that for small k the cross section can be written as

$$\sigma_r = (\sigma_r k)_0 \frac{1}{k}\left(1 - \frac{1}{2\pi} k\,(\sigma_r k)_0 + \ldots\right), \qquad (1)$$

where the subscript 0 indicates that the value at k = 0 has to be taken. This equation follows from the circumstance that for forces of finite range the expansion of k cot δ (δ is the complex s-wave phase shift) in powers of k has the form[1,2]

$$k \operatorname{ctg} \delta = b(k^2) = b(0) + k^2 b'(0) + \ldots. \qquad (2)^*$$

We now show that (2), together with unitarity, leads also to a similar form of the expansion of the elastic cross sections in powers of k. Here the first two terms of the series have the form

$$\sigma = \sigma_0\left(1 - \frac{1}{2\pi} k\,(\sigma_r k)_0 + \ldots\right), \qquad (3)$$

which means that up to terms linear in k the elastic scattering cross section is determined by the quantity $(\sigma_r k)_0$ and by the value of the scattering cross section at k = 0.

Since the lowest power with which the partial waves contribute to the power series expansion is k^{4l}, only s waves have to be considered. From (2) we have

$$\sigma = \frac{4\pi}{|b(k^2)|^2 + k^2 - 2k \operatorname{Im} b(k^2)} = \frac{4\pi}{|b(0)|^2}\left(1 + 2k\frac{\operatorname{Im} b(0)}{|b(0)|^2} + \ldots\right). \qquad (4)$$

It is easy to see, for example from the optical theorem, that

$$|b(0)|^{-2} \cdot \operatorname{Im} b(0) = -(\sigma_r k)_0/4\pi. \qquad (5)$$

From this we obtain Eq. (3).

In the case where only elastic scattering occurs, i.e., when $b(k^2)$ is real, the cross section has thus for small k the form

$$\sigma = \sigma_0 + k^2\sigma_1 + \ldots. \qquad (6)$$

If, on the other hand, inelastic processes also occur at k = 0 then a term linear in k appears in the power series expansion, and owing to unitarity its coefficient is determined by the total inelastic cross section. The expressions (1) and (3) are applicable for those cases where one can limit oneself to the first term in the expansion (2). We note that when (3) holds the cross section decreases with increasing k. We also note that (3) is correct even if only one of the initial particles has zero spin. Formula (3) can be used in the extrapolation of π^-p and $\bar{K}$p scattering to zero energy.

In conclusion, I express my deep gratefulness to Professor Ya. A. Smorodinskii for interesting discussions.

*ctg = cot

[1] F. L. Shapiro, JETP **34**, 1648 (1958), Soviet Phys. JETP **7**, 1132 (1958).

[2] H. A. Bethe, Phys. Rev. **76**, 38 (1949).

Translated by M. Danos
113

BEHAVIOR OF THE CROSS SECTION OF ELECTROMAGNETIC PRODUCTION OF PARTICLES AT THE THRESHOLD

V. N. BAĬER and S. A. KHEĬFETS

Submitted to JETP editor December 1, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **40**, 715-717 (February, 1961)

As was shown previously,[1] the total cross section of high energy inelastic and elastic scattering of electrons at large angles in the center-of-mass system (c.m.s.), calculated in a doubly logarithmic approximation, can be represented in the form

$$d\sigma = d\sigma_0 \exp\left\{-\frac{8e^2}{\pi} \ln\frac{E}{m} \ln\frac{E}{\Delta E}\right\}. \qquad (1)$$

Here $d\sigma_0$ is the scattering cross section computed in the low-order perturbation theory, E the electron energy, m the electron mass, and ΔE the maximum achievable energy of the quanta radiated in the collision process, which defines the threshold sensitivity of the detector of electrons.

If ΔE = E (i.e., the detector records all electrons, independently of their energy), then the total cross section coincides with the cross section computed in the low-order perturbation theory approximation ($d\sigma = d\sigma_0$). As is known,[2] this is connected with the fact that in this approximation, the decrease of the cross section of the fundamental process, without emission of additional quanta, due to taking the radiation corrections into account, is entirely compensated by the increase of the cross section of processes with multiple additional radiation of hard photons in the case of an arbitrary radiation (ΔE = E).

The same formula also holds for the scattering of electrons on positrons.

In principle, another situation arises in the conversion of an electron-positron pair into a pair of