ions whose energy does not exceed 10 ev is of the same order as for slow positive ions.

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Some Cases of Very Small Life Times of Low Nuclear Levels

E. E. BERLOVICH AND G. V. DUBINKIN
Leningrad Physico-Technical Institute,
Academy of Sciecnes, USSR

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The life times of short-lived excited states of nuclei were studied by the delayed coincidence method. The life times of the lower levels of the Ti^{46} and Mo^{95} nuclei were found to be less than 10^{-10} sec.

The experimental half-life of the excited state of the Tl^{203} nucleus was found to be $(2.9 \pm 0.3) \cdot 10^{-10}$ sec., a result which does not agree with that of de-Waard. The method applied by de-Waard is discussed. The partial half-times for magnetic dipole and electric quadrupole transitions are compared with the values predicted by the formulas of the single-particle model.

BERLOVICH[1] has demonstrated the influence of the particle energy and of the pulse front shape associated with it on the results of measuring the lifetime of excited states by the method of delayed coicidences. This effect which is particularly important in the case of short-lived states (10^{-10} – 10^{-9} sec) was eliminated by introduction into both side channels of triple coincidence circuit amplitude analyzers by means of which it was possible to select the coincidences of only those pulses which lie in equivalent amplitude intervals.

In this article we present the results of investigating short-lived states of Ti^{46}, Mo^{95} and Tl^{203} nuclei. Before the measurements were made, the following control experiment was carried out: by means of investigating the curves of $\gamma\beta$—$\gamma\beta$—coincidences for the Co^{60} → Ni^{60} decay for which the limiting values of the energies of the β—spectrum and of the Compton distribution differ by a factor of more than 3½, we satisfied ourselves that when coincidences of pulses in energy—equivalent intervals were recorded no mutual displacement of the centers of gravity of the two curves occurred. This agrees with the results of Bay[2] according to which the life times for both excited states of the Ni^{60} nucleus are less than 10^{-11} sec.

Figure 1 shows the experimental results for the Sc^{46} → Ti^{46} decay. The maximum energy of the β-spectrum is 0.340 mev, the energies of the two γ-rays in cascade accompanying the β-decay are 0.880 and 1.120 mev. According to the data of Nag, Sen, and Chatterjee[3] the mean life of these levels is $\tau = 1.3 \times 10^{-5}$ sec. However, it follows from the measurements of Koicki, Ballini, and Chaminade[4] that this life-time must be less than 2×10^{-6} sec.

From the measurement of conversion coefficients,[5] and also from experiments on angular $\gamma\gamma$—correlation[6] and on angular correlation of the directions of polarization[7], it follows that both γ-transitions are of the E2 type. The life times of nuclear states for electric quadrupole transitions with energies of about one mev must (in accordance with the single particle formulas of Weisskopf[8] and of Moszkowsky[9] be smaller than the values given above by six or seven orders of magnitude.

It may be seen from Fig. 1 that the experimental curves for the $\beta\gamma$– and $\gamma\beta$–coincidences show no mutual displacment. When the experimental accuracy of our measurements istaken into account this means that for each of the two lowest excited states of the Ti^{46} nucleus $\tau < 10^{-10}$ sec.

Similar measurements for the $Nb^{95} \rightarrow Mo^{95}$ transition have shown that for the level of the Mo^{95} nucleus of 0.764 mev energy, which decays by a mixture of Ml and E2 transitions,[10], the life time is also less than 10^{-10} sec.

Finally, Fig. 2 illustrates the experimental results on the lifetime of the level of the Tl^{203} nucleus of energy 0.279 mev. In an earlier paper,[11] we have obtained from the mutual displacement of the centers of gravity of the $\beta\gamma$– and $\gamma\beta$-coincidence curves (the method of "self–comparison") the value of 4×10^{-10} sec for the half life of this level which, however, we found useful to regard as the upper limit for the half life. The introduction of the amplitude analyzers, which for all practical purposes has eliminated the influence of the difference of the spectra of the two kinds of coincident particles (Compton electrons and β-particles), has enabled us to obtain a more definite result for the life time of the Ti^{203} level.

Curves similar to those shown in Fig. 2 were taken repeatedly with the amplitude intervals in the channels being varied and with both energy-equivalent and arbitrary intervals (within the limits of both spectra) being taken. In all cases, a displacement of the two curves ($\beta\gamma$– and $\gamma\beta$–coincidences) was observed in the same direction. The mean value for the half life obtained from measurements carried out with equivalent amplitude intervals turned out to be equal to

$$T = (2.9 \pm 0.3) \cdot 10^{-10} \text{ sec.}$$

In all the measurcments, the possible coincidences of conversion electrons with x-rays were eliminated either by absorbing the latter by a lead filter or by choosing the amplitude intervals outside the region within which x-ray pulses could lie.

The value of 4×10^{-10} sec adopted in our earlier paper[11] for the upper limit on the half life turned out to be larger than in the present experiments apparently due to the difference in the upper limits of the β-spectrum ($E_{\beta \max} = 0.215$ mev) and of the Compton distribution for γ-rays of energy 0.279 mev ($E_{\text{Compt max}} = 0.148$ mev) which should increase the mutual displacement of the $\beta\gamma$- and $\gamma\beta$-coincidence curves.

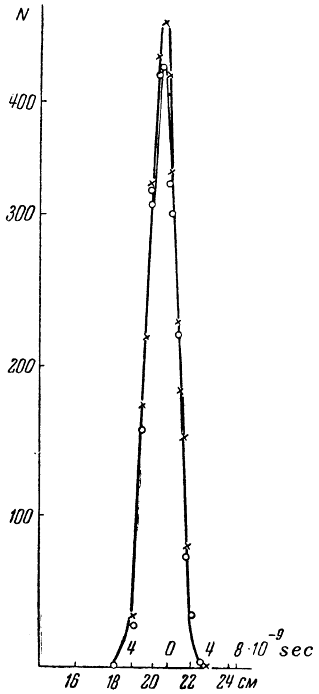

FIG. 1. Coincidence curves for the transition $Sc^{46} \rightarrow Ti^{46}$. O–$\beta\gamma$-coincidences, x–$\gamma\beta$-coincidences. The number of coincidences is plotted along the vertical axis while the horizontal axis gives the readings of the variable delay line scale in units of time and in centimeters.

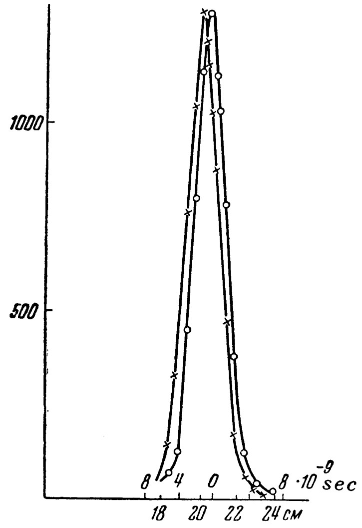

FIG. 2. Coincidence curves for the transition $Hg^{203} \rightarrow Tl^{203}$. O–$\beta\gamma$-coincidences, x–$\gamma\beta$-coincidences. The number of coincidences is plotted along the vertical axis while the horizontal axis gives the readings of the variable delay line scale in units of time and in centimeters.

Recently, de-Waard[12] obtained (by the method of delayed coincidences) the value $T = (1.2 \pm 0.3) \times 10^{-10}$ sec for the level in question. The measurement was made by means of comparing the displacement of the curves for the $\beta\gamma$- and $\gamma\beta$-coincidences for the transition $Hg^{203} \rightarrow Ti^{203}$ with the displacement of similar curves for the transition ThB →ThC to the level with 0.238 mev excitation energy. In the second case the displacement could have been due only to instrumental effects since, according to the data of Graham and Bell,[13] the lifetime of the ThC level is less than 2×10^{-11} sec. The author assumes that the displacement due to instrumental causes is the same in both cases since the energies of the radiation are nearly the same (in thecase of Hg^{203} : $E_{\beta\max} = 0.215$ mev, $E_\gamma = 0.279$ mev; in the case of Thb: $E_{\beta\max} = 0.340$ mev, $E_\gamma = 0.238$ mev). The coincidences were registered only between β-particles and recoil electrons having an energy within the range from 75 to 150 kev.

It appears to us that the "instrumental" displacement of the $\beta\gamma$- and $\gamma\beta$-coincidence curves due to the influence of the difference in the pulse front shape must be larger in the case of ThB than in the case of Hg^{203} when measurements are made in the energy range 75–150 kev, since in the first case the average energy of the β-particles in this interval, which contains the neighborhood of the maximum of the β-spectrum (with the maximum value of 340 kev), is greater than in the second case of the softer β-spectrum (with a maximum energy of 215 kev) when the neighborhood of the maximum is strongly displaced and only the decreasing part of the spectrum falls within the working interval. Conversely, the average energy of the recoil electrons for the γ-rays of ThC ($E_\gamma = 0.239$ mev) whose maximum is near the limiting energy $E_{\text{Compt max}} = 0.115$ mev turns out to be lower over the working interval than in the case of the γ-rays from Tl^{203} ($E_\gamma = 0.279$ mev) for which the limit of the recoil electron distribution lies at $E_{\text{Compt max}} = 0.147$ mev. In the light of the detailed analysis of the effect of the steepness of the pulse fronts (which depends, in particular, on the energy of the particles) which was carried out in our earlier work,[1] it appears to us to be probable that the mutual displacements of the $\beta\gamma$- and $\gamma\beta$-coincidence curves brought about by instrumental causes must be different in the two cases under consideration and that the subtraction made by Zarubin[10] of the displacement of the curves for the ThB →ThC transition from the displacement of the curves for the $Hg^{203} \rightarrow Tl^{203}$ transition must lead to an underestimate of the lifetime of the Tl^{203} level. In order that the difference in the form of the spectra of β-particles and of recoil electrons should not lead to a displacement of the $\beta\gamma$- and $\gamma\beta$-coincidence curves, it is necessary to choose a considerably more narrow energy interval than was done in the work under consideration. This would have eliminated the necessity to subtract the displacements of the curves observed in the two transitions. Measurements made on a level with a negligibly small lifetime would then serve only to verify the absence of an "instrumental" displacement.

Using the value[14] $\alpha = 0.27$ for the total conversion coefficient, we obtain from the experimental value of the half-life the following value for the half life for radiative decay

$$T_\gamma = T(1' + \alpha) = (3.7 \pm 0.4) \cdot 10^{-10} \text{ sec.}$$

This value agrees well with the result of Barloutand, Grjebine and Rion,[15] who obtained $T_\gamma = (3.8 \pm 1.2) \times 10^{-10}$ sec from measurements of the cross section for Coulomb excitation.

The contradiction noted by de-Waard[12] with the result of Metzger's measurements[16] who obtained from experiments on the resonance scattering of γ-rays the value $T_\gamma = (6.9 \pm 2.8) \times 10^{-10}$ sec is considerably reduced since within experimental error this result almost overlaps with the two results given above. Nevertheless, taking into account the fact that Metzger's result has been obtained from three different ypes of experiment on the resonance scattering of γ-rays, one should suppose that the above difference is not accidental.

It is well established [14] that the transition in question is a mixture of 30% Ml and 70% E2 transitions. A calculation of the partial half lives for both types of transitions gives:

$$T_\gamma(M1) = 1.23 \cdot 10^{-9} \text{ sec.}$$

$$\text{and } T_\gamma(E2) = 5.3 \cdot 10^{-10} \text{ sec.}$$

The second value is by a factor 9 less than the value calculated from Weisskopf's single particle formula (4.7×10^{-9} sec). This may be explained by the effect of the polarization of the nuclear core by the last odd proton. On the other hand a calculation using Weiskopf's formula for the Ml transition gives a value (1×10^{-12} sec) which is

1200 times less than the experimental value. Delayed magnetic dipole transitions have been studied by Graham and Bell,[13] who explained the reduction in the transition probability as being due to a forbidden change in orbital angular momentum: $\Delta l = 2$. The transition under consideration may be identified as the transition $d_{3/2} \to s_{1/2}$. A partial relaxation of the rule forbidding the transition in this case is apparently related to the meson exchange currents between nucleons.

Note added in proof. After the present article had been submitted for publication, the authors learned of the paper by Azuma[17] in which the estimate $\tau < 5 \times 10^{-11}$ sec is given for the upper limit on the lifetimes of both excited states of the Ti^{46} nucleus.

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Two Limiting Momenta in Scalar Electrodynamics

L. P. GOR'KOV
Institute for Physical Problems, Academy of Sciences, USSR

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A study is made of the possibility of introducing two limiting momenta in scalar electrodynamics. It is shown that the difficulties connected with the vanishing of the renormalized charge in the limit of a point interaction appear also in the theory considered here.

KHALATNIKOV and the writer[1] have written integral equations for the Green's functions and vertex parts in the electrodynamics of charged mesons with spin zero [Eqs. (2), (4) and (7) in Ref. 1]. The last of these equations is valid only if in the photon function

$$D_{\mu\nu}(k) = \left(\delta_{\mu\nu} - \frac{k_\mu k_\nu}{k^2}\right)\frac{d_t(k^2)}{k^2} + \frac{k_\mu k_\nu}{k^2}\frac{d_l(k^2)}{k^2}$$

one chooses $d_l = d_t$, and was introduced in the approximation $e_1^2 \ll 1$. The solution of these equations was carried through in accordance with the general scheme of Landau, Abrikosov and Khalatnikov[2] for a smeared out interaction, in which the interaction factor β_σ is replaced by

$$\beta_\sigma \to \beta_\sigma \delta_{\Lambda_p}(p)\,\delta_{\Lambda_p}(p-l)\,\delta_{\Lambda_k}(l),$$

$$\delta_\Lambda(p) = \begin{cases} 1; & -p^2 \ll \Lambda^2 \\ 0; & -p^2 \gg \Lambda^2. \end{cases}$$

In Refs. 1 and 3, it was assumed that $\Lambda_p \sim \Lambda_k$; the changes appearing in the case in which there is a decided inequality between the two limiting values have been investigated by Abrikosov and Khalatnikov[4] in the ordinary electrodynamics and the pseudoscalar meson theory. In connection with a conclusion stated by Pomeranchuk[5] about the vanishing of the charge on the passage to a point interaction, the two-limit scheme takes on particular interest. We consider this question in the