A new experimental limit of the $e^- \to \nu_e + \gamma$ decay

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Preliminary results of an experimental study of the instability of the electron are presented. A lifetime of the electron $\tau_e > 3.5 \times 10^{23}$ yr was obtained for the decay $e^- \to \nu_e + \gamma$.

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Rigorous theoretical constraints were recently imposed on the processes involving nonconservation of electric charge.[1,2] This increased the interest in experiments[3,4] in which attempts were made to set a limit on the rate of the reactions. One such experiment involved verification of the stability of the electron. The highest limit for the lifetime of the electron, regardless of its decay mode ($\tau_e > 5 \times 10^{22}$ yr), was established by Pomansky[5] from the ratio of the number of electrons in the earth to the electric current flowing through the atmosphere.

In this paper we attempt with the help of a NaI(Tl) detector ($l = 400$ mm, $\phi = 70$ mm) to extend the existing lower limits of the process $e^- \to \nu_e + \gamma$ (the energy released in the detector is ~255 keV) and of the electron decay, regardless of its mode. In the second case, the experiment showed that in the decay of the *K*-electron of an iodine atom its binding energy (33.2 keV) is produced in the form of a cascade of photoelectrons and Auger electrons whose energy release in the NaI(Tl) crystal can be recorded.

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The experiment was conducted in an underground, low-background chamber of the Baksansky Neutrino Observatory of the Nuclear Research Institute, USSR Academy of Sciences, at a depth of 660 meters water equivalent [m(w.e.)].[6] By using special low-radiation materials we were able to reduce the radiation background of the detector by a factor of > 5000 compared to that of a standard NaI(Tl) detector in an open-pit mine and to reduce the count to 0.35 pulse/sec in the energy range of 10 to 330 keV [the mass of the NaI(Tl) crystal was ~6 kg]. The spectrum in the indicated energy range was recorded for 515 h (Fig. 1). The drift of all the measuring equipment did not exceed 1% during the measurement time. The energy resolutions (total width at half-height of the peak) in the investigated regions of the spectra (33 and 255 keV) were 48 and 17%, respectively. The statistical accuracy for the 255-keV region of the spectrum was equal to 2.5% per keV and for the 33-keV region it was equal to 1.5% per keV.

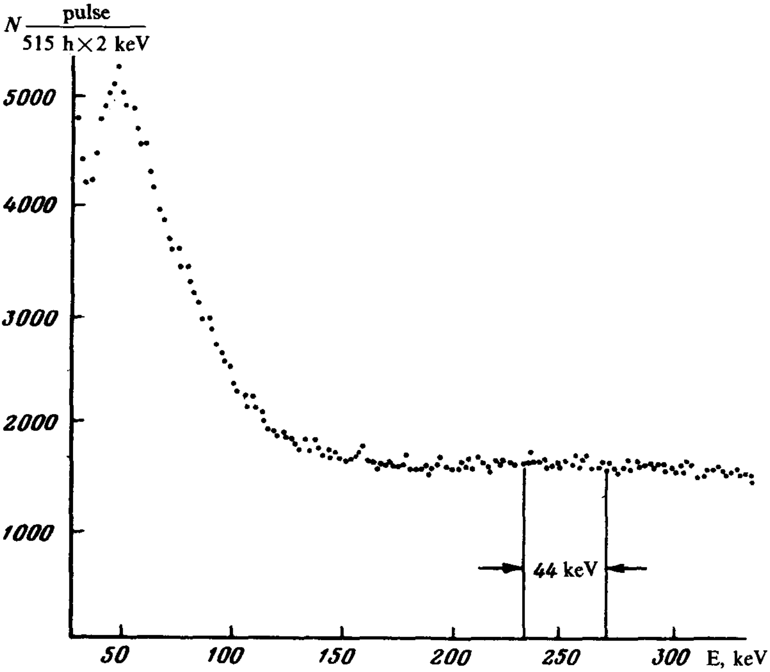

FIG. 1. Pulse spectrum in the NaI(Tl) detector with the dimensions $\phi = 70$ mm and $l = 400$ mm, which was recorded for 515 h in the energy range of 10 to 330 keV.

energy resolution of the detector (44 keV) makes it possible, as in Ref. 3, to assume as the upper limit of the number of pulses from the hypothetic decay $e^- \to \nu_e + \gamma$ the value equal to one standard deviation of the total number of pulses in this range. This can be done because of the absence of a clearly defined structure in the region of the spectrum of interest when each point is statistically well defined. The bulk of the pulses in the examined range is attributed to the radiation background and to the internal β radiation of the NaI(Tl) detector. From the relationship between the single standard deviation of the number of pulses in the investigated interval, the number of electrons in the detector, and the time required to record the spectrum, we found the limit of the lifetime of an electron for the $e \rightarrow \nu_e + \gamma$ decay (with certainty of a single standard deviation) to be $\tau_e \geqslant 3.5 \times 10^{23}$ yr.

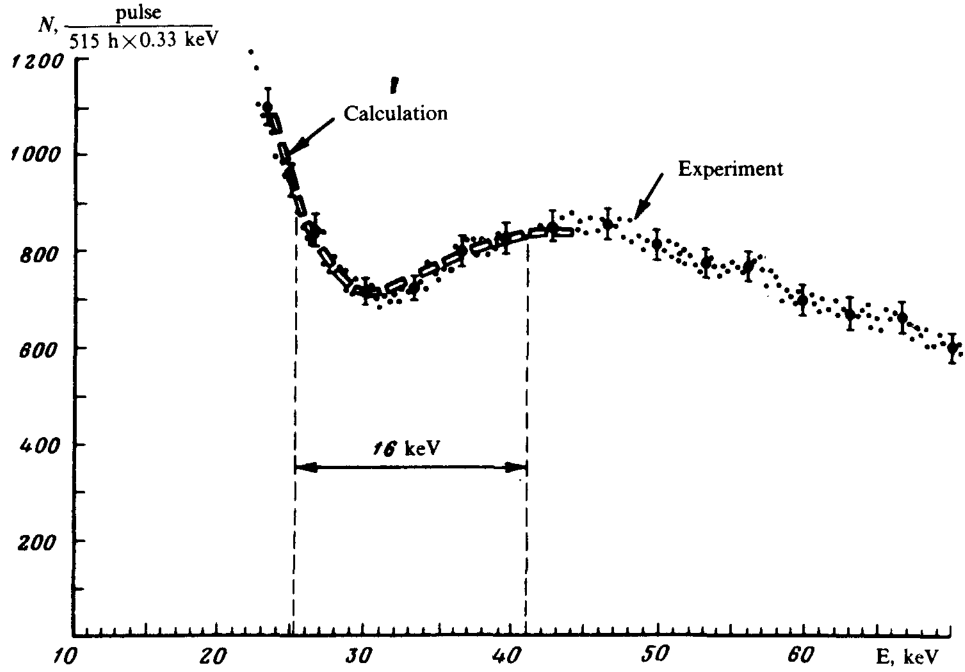

FIG. 2. Pulse spectrum in the NaI(Tl) detector in the energy range close to the binding energy of the K electron of an iodine atom. The broken curve denotes the distribution calculated by taking into account the theoretical cross section for absorption of γ rays and the energy resolution of the detector.

The 33-keV region of the background spectrum, shown in Fig. 2, was also investigated. If all the pulses in the 16-keV-wide energy interval, which corresponds to a 48% energy resolution, are treated as a hypothetic electron decay, then the limit of the electron lifetime will be too low, because this part of the experimental spectrum parallels very closely the behavior of the theoretical curve (Fig. 2) calculated by a computer, taking into account the energy resolution of the detector and the cross section for interaction of γ radiation with the NaI(Tl) crystal in the investigated energy interval and assuming that the distribution of the γ radiation background is uniform. This indicates that the main contribution to the experimental spectrum comes from the background γ rays which are not connected with the decay of electrons, since their pulses have a Gaussian distribution with a half-width equal to the resolution of the detector. As seen in Fig. 2, the calculated curve, which was normalized to the area under the experimental curve, coincides with the latter curve within the limits of statistical errors, which indicates that the correlation between the single standard deviation of the total number of pulses in this energy range and the maximum contribution from the hypothetic decay of electrons to the observed spectrum is correct. Hence, the lower limit of the lifetime of an electron for all its decay modes is

$\tau_e > 2\times 10^{22}$ yr, which is slightly lower than the value obtained by Pomansky[5] using an indirect method, but much higher than the limits obtained earlier by direct measurements.[3,4]

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