

MEASUREMENT OF THE LIFETIME OF THE FIRST EXCITED STATE OF Ne^{21}

A. G. KHABAKHPASHEV and É. M. TSENER

Submitted to JETP editor May 26, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **37**, 991-993 (October, 1959)

The lifetime of the first excited state of Ne^{21} was measured using a 50-channel time analyzer. The measurements gave the value $T_{1/2} = (6.2 \pm 6.2) \times 10^{-11}$ sec. A brief description of the time analyzer is given.

THE lifetime of the first excited state of Ne^{21} , at 0.35 Mev, has been measured with a Po-O^{18} neutron source. The source was a solution of Po^{210} nitrate in water enriched to 24% in O^{18} . The $\text{O}^{18}(\alpha, n)\text{Ne}^{21}$ reaction in the source is accompanied by the 1.38 - 0.35-Mev gamma cascade. The intensity of the direct transition from the second excited state to the ground state is lower by at least a factor of ten than the cascade transition.

The lifetime was measured using a multichannel time analyzer. The use of multichannel analyzers has various advantages over delayed coincidence methods. In multichannel analyzers, the whole time distribution of the pulses is taken simultaneously. This enables one to shorten the measuring time, reduce the effect of instability of the apparatus, and improve the statistical accuracy of the measurement. Green and Bell¹ used a multichannel analyzer successfully to measure the lifetime of positrons in quartz crystals.

Our analyzer was built following the time-to-pulse height conversion scheme proposed by Neilson and James.² A block diagram of the apparatus is shown in Fig. 1. The detectors of the radiation were 40×40 mm crystals of $\text{NaI}(\text{Tl})$ and FEU-1V photomultipliers. The output signals from the anode of each multiplier pass through the broadband amplified UR-3 to a pulse-shaping circuit. The positive rectangular pulses after shaping have an amplitude ~ 1.5 v and a duration of 2×10^{-8} sec. The time-to-pulse-height conversion circuit was built like the one described in the paper of Neilson and James.² The converter element was a 6A3P tube, cut off by a pair of grids. When the positive rectangular pulses are applied to both grids of the tube, a charge is produced in the anode circuit which is proportional to the time of overlap of the input pulses. The output pulses from the converter are amplified and pass through a gating circuit to an AI-50 50-channel pulse analyzer. The gating circuit is opened by pulses from a slow coincidence circuit.

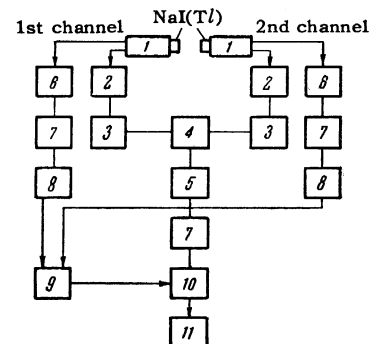


FIG. 1. Block diagram of multichannel time analyzer. 1 - FEU-1V; 2 - 200 Mcs amplifier; 3 - pulse-shaping circuit; 4 - converter circuit; 5 - delay line; 6 - preamplifier; 7 - linear amplifier; 8 - single-channel pulse analyzer; 9 - coincidence circuit with $\tau = 2 \times 10^{-7}$ sec; 10 - gating circuit; 11 - 50-channel pulse analyzer.

Amplitude discrimination on the pulses from each detector is accomplished by using single-channel analyzers in a slow coincidence circuit with a resolving time of 2×10^{-7} sec. The single channel analyzers enable one to select gamma lines of definite energy in each detector, and enable one to improve the resolution of the time analyzer. A calibration curve taken using self-coincidences showed that the analyzer linearity is good in the range from 3×10^{-9} to 18×10^{-9} sec. The width of the analyzer channels was 4.6×10^{-10} sec.

After calibrating the analyzer, we introduced a fixed delay line with a delay of 11×10^{-9} sec into the second channel between the anode of the multiplier and the UR-3 amplifier. In this way the "null" of the time analyzer was shifted to the middle of the linear region of the calibration curve. The single-channel discriminator of the first counter was set to record γ quanta with energy 0.35 Mev, the discriminator of the second counter was set to record γ quanta with energy 1.38 Mev. The channel width of each discriminator was set equal to the width of the photopeak.

With this setup, we used a Co^{60} source to measure the resolution of the time analyzer. The first

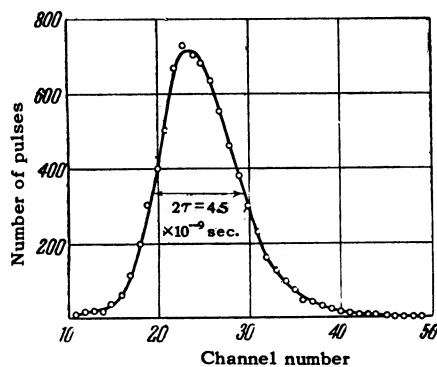


FIG. 2. Resolution curve of time analyzer.

counter recorded part of the Compton distribution from the 1.17-Mev line, the second counter recorded the photopeak of the 1.33-Mev line. Since the lifetime of the first excited state of Ni^{60} is³ 1.1×10^{-12} sec, we could assume for our measurements that the 1.17- and 1.38-Mev quanta are emitted simultaneously. The resolving time was $2\tau = 4.5 \times 10^{-9}$ sec (see Fig. 2). The asymmetry of the distribution curve is due to the difference of excitation energy in the first and second crystal.

The operation of the analyzer was checked on a source with an artificial "lifetime." For this purpose the Co^{60} source was placed between the detectors, and the time distribution curve of artificially delayed pulses was measured. This curve was determined from the sum of ten measurements, made with different delay times of $t_1 = \Delta t/2$, $t_2 = t_1 + \Delta t$, etc. A step delay line with $\Delta t = 4 \times 10^{-10}$ sec was introduced into the first channel of the analyzer. The time of the measurement for each delay t_n was determined from the expression $T_n = \text{const} \cdot \exp(-t_n/\Theta)$, where Θ is the "lifetime." The distribution curve of the delayed pulses was compared with the prompt curve of the distribution (Fig. 2), using Bay's⁴ method. For a source

with an artificial "lifetime" $\Theta = 1 \times 10^{-9}$ sec, we found experimentally a value $(1.1 \pm 0.1) \times 10^{-9}$ sec.

The lifetime of Ne^{21} was measured by comparing the distributions from the Po-O^{18} and Co^{60} sources. The data were treated by Bay's method⁴ and Newton's method.⁵ The half-life, found from an average of nine measurements, is $T_{1/2} = (6.2 \pm 6.2) \times 10^{-11}$ sec (where we give the mean square error of the average). A correction for internal conversion is not necessary in this case, since it is 8×10^{-5} .

Thus the upper limit on the half-life of the first excited state of Ne^{21} is 1×10^{-10} sec.

Middleton and Tai⁶ have shown that the spins and parity of the ground and first excited states of Ne^{21} are $3/2^+$ and $5/2^+$. From measurements of γ - γ angular correlation⁷ for Ne^{21} it follows that the 0.35-Mev transition is dipole. The single particle model⁸ gives a half life for a magnetic dipole transition of $T_{1/2} = 6 \times 10^{-13}$ sec.

¹R. Green and R. Bell, Nucl. Instr. **3**, 127 (1958).

²G. Neilson and D. James, Rev. Sci. Instr. **26**, 1018 (1955).

³F. Metzger, Phys. Rev. **103**, 983 (1956).

⁴Z. Bay, Phys. Rev. **77**, 419 (1950).

⁵T. Newton, Phys. Rev. **78**, 490 (1950).

⁶R. Middleton and C. Tai, Proc. Phys. Soc. (London) **A65**, 752 (1952).

⁷A. G. Khabakhpashev and É. M. Tsenter, Izv. Akad. Nauk SSSR, Ser. Fiz. **23**, 883 (1959), Columbia Tech. Transl., in press.

⁸S. A. Moszkowsky, Theory of Multipole Radiation, in Beta and Gamma Spectroscopy, (ed. Siegbahn), North-Holland, Amsterdam 1955.

Translated by M. Hamermesh