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Experimental Study of Coulomb Excitation of Nuclei by Nitrogen Ions

D. G. ALKHAZOV, D. S. ANDREEV, A. P. GRINBERG AND I. KH. LEMBERG
Leningrad Physico-Technical Institute, Academy of Sciences, USSR

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THEORETICAL estimates[1] indicate some advantage can be gained if heavy ions are used as bombarding particles in the study of Coulomb excitation of nuclei. We have carried out an experimental investigation of Coulomb excitation of the nuclei of 21 elements by nitrogen ions. The purpose of the measurements was the determination of the lowest excited levels of the nuclei under investigation and the value of the reduced probabilities $B_e(2)$ for the corresponding transitions.

A beam of triply ionized nitrogen ions, accelerated in a cyclotron to 15.6 mev, was brought into a vacuum tube by means of the usual deflector and passed through a system of two magnetic quadrupole lenses, which focussed the beam on the target. To rid the beam of singly charged ions, the beam was passed through a plane condenser with horizontal plates, located at the exit of the deflector unit. A constant voltage of ~ 14 kv was applied across the plates.

The target was pressed into the bottom of an isolated metallic vessel which served as a Faraday cylinder. The beam spot on the target had a height of ~ 5, and a depth of ~ 14 mm. Use of the magnetic lenses permitted an increase in the intensity of the ion beam falling on the target (by a factor of about 5) and also separated the deflecting arrangement by 1.8 m. The quantity of electricity in the incident beam was measured by integration of the current.

The γ-radiation of the target was investigated with the help of a scintillator γ-spectrometer. The latter consisted of a crystal of NaJ(Tl), a photomultiplier, a linear amplifier and a 50 channel pulse-amplitude analyzer*.

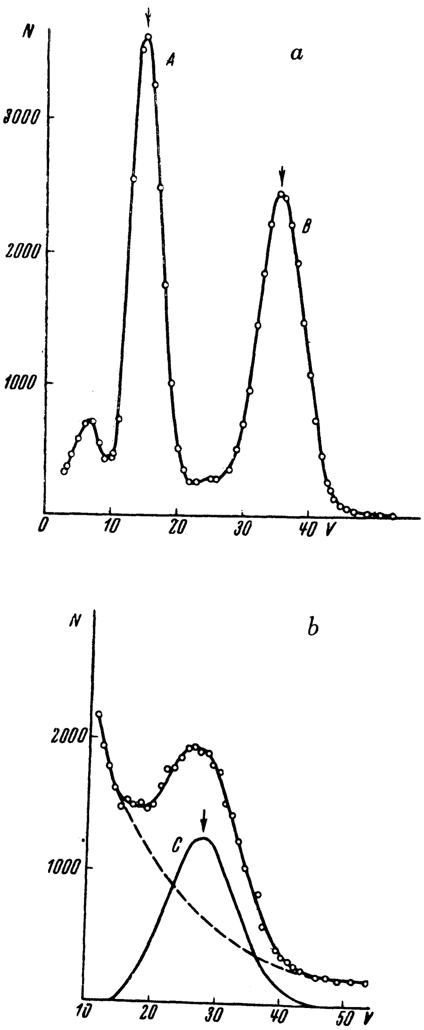

FIG. 1. Amplitude spectrum of pulses in the Coulomb excitation of Ta ^{181}: a = x-ray K-line of Ta; $B = \gamma$-line corresponding to the decay of the second excited level of Ta ^{181} with $E = 301$ kev (the curve was obtained after subtraction of the noise, indicated by the broken curve).

The form of the spectrum of Coulomb excitation obtained for radiation of tantalum foil (of 100 μ thickness) by nitrogen ions is shown in Fig. 1. The peak A corresponds to the x-ray K-radiation of the atoms Ta with $E = 57.2$ kev. According to the data of Huus and Zupancic[2] the ratio $(I_K/I_\gamma)_p$, the number of K-quanta which are produced by the ionization of the atoms of Ta by protons with energy 2.1 mev, to the number of γ-photons with energy 137 kev, is equal to 12.4. Therefore, in accord with Ref. 1, we should expect in our case that $(I_K/I_\gamma)_T = 12.4/15 \approx 0.83$; experiment gives $(I_K/I_\gamma)_T \approx 0.65$ (this figure was obtained after subtraction from the total number of K-quanta of that part which is connected with the process of internal conversion for the transition, with $\Delta E = 137$ kev). The result confirms the theory of Henneberg on which the calculation in Ref. 1 is based.

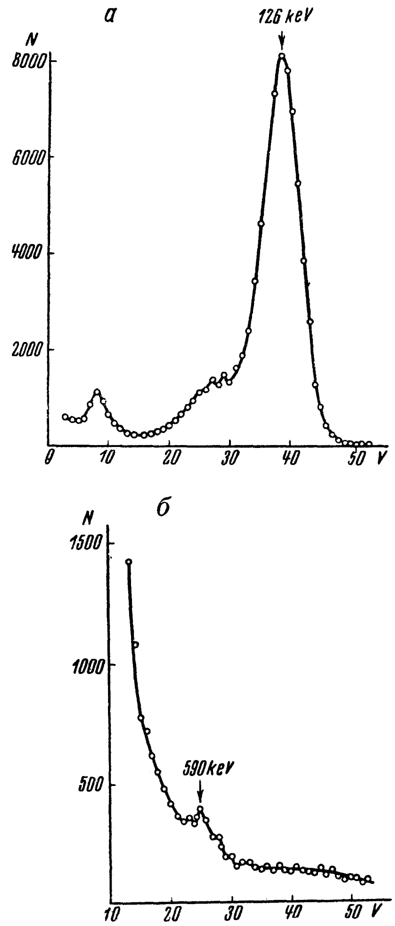

FIG. 2. Amplitude spectrum of pulses for Coulomb excitation of Mn^{55} ; $a = \gamma$-line corresponding to the decay of the first excited level of Mn^{55} with $E = 126$ kev; b = energy region from 300 to 1200 kev.

The peak B corresponds to Coulomb excitation of the first excited level of Ta^{181} with $\Delta E = 137$ kev. The energy of the corresponding γ-rays is 138 ± 2 kev according to our measurements.

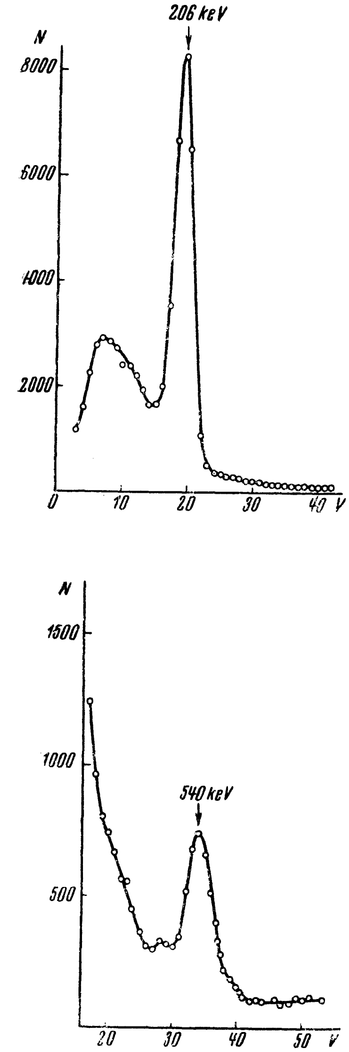

FIG. 3. Amplitude spectrum of pulse for Coulomb excitation of molybdenum; γ-line with energy 206 kev refers to Mo^{95}, γ - line with energy 540 kev, probably to Mo^{100}.

The probability of excitation of the second excited level of Ta^{181} with $\Delta E = 303$ kev is much less than the probability of excitation of its first level. In Fig. 1b we have plotted the γ-spectrum which corresponds to the Coulomb excitation of the second excited level of Ta^{181}. The spectrum was taken with a separation which prevents the charging and blocking of the analyzer with a large number of small pulses. In this case, one can obtain the necessary readings which correspond to γ-photons with $E = 303$ kev after a very short time. According to our data, the energy of the second excited level is equal to 301 ± 9 kev.

Irradiated nuclei and the energy of γ-photons in kev.

F^{19}_{9}	125	205	
Na^{23}_{11}	435		
V^{51}_{23}	320		
Mn^{55}_{25}	126	590	
Ge^{73}_{32}	72		
Se^{77}_{34}	238	452	
Mo_{42}	206	540	
Rh^{103}_{45}	295	358	
Ag_{47}	310	409	
Cd_{48}	297	325	543
In^{115}_{49}	562		
J^{127}_{53}	60	205	
Ta^{181}_{73}	138	301	
W_{74}	112		
Au^{197}_{79}	286	580	
Pb^{207}_{82}	580		

Figure 2 shows the amplitude spectrum obtained in the irradiation of manganese by nitrogen ions. We have plotted in Fig. 2*b* the spectrum in the energy region from 300 to 1200 kev. As is evident from the drawing, only one line is observed in this region, with energy ~ 590 kev. In Ref. 3, in which protons are used for the Coulomb excitation of Mn, a number of lines are observed in the given energy region. From comparision of the data of Ref. 3 with ours, it follows that these lines are connected with nuclear reactions, and not with Coulomb excitation. The spectra of Coulomb excitation of molybdenum are plotted in Fig. 3.

In bombardment of K, Ni, Cu, Sn, Bi Coulomb excitations was not observed.

Data are given in the Table of the energy of the excited levels of the nuclei under investigation.

At present, calculations are being carried out on the value of $B_e(2)$ and on treatment of the data on the bremmstrahlung of nitrogen ions.

* The amplitude analyzer was constructed by L. N. Gal'perin.

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One-Meson and Zero-Meson Annihilation of Antinucleons

B. M. PONTECORVO

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IN connection with the extremely interesting communication that appeared recently[1] on the creation of antinucleons in the collisions of protons of high energy with nuclei, certain processes of "extraordinary" annihilation of antinucleons are considered in the present note.

In the collision of antinucleons with free nucleons, the annihilation is evidently connected with the release of not less than two π-mesons (or K-mesons). This process ("extraordinary" annihilation), in which, in all probability, several mesons are emitted, also takes place in the collision of