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DETERMINATION OF THE SPINS OF Pt^{196} *NUCLEAR LEVELS ON THE BASIS OF GAMMA RAYS EMITTED IN THE CAPTURE OF RESONANCE NEUTRONS*

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Gamma rays produced in the capture of resonance neutrons are investigated. The spin of the compound-nucleus levels is determined from the presence of the ground transition in the γ-ray spectrum. It is found that the spin of the Pt^{196} nucleons is 1 for levels with neutron energies of 11.9 and 68.2 ev and 0 for a level energy of 19.6 ev.

MEASUREMENT of the total neutron cross section yields all the parameters of the excited level of the nucleus, with the exception of the spin. To determine the spin it is necessary to measure, in addition to the total cross section, one of the partial cross sections, for example the radiative-capture cross section or the scattering cross section. Another method of determining the spin is also possible, based on the study of the spectrum of γ rays emitted in the capture of neutrons at different levels. The use of the method is particularly simple in those cases when the radiative transition from the excited state into the ground state is possible only for one value of the excited-state spin. This is the situation in the case of even-odd nuclei with spin $\frac{1}{2}$. In this case one obtains upon capture of a neutron an even-even compound nucleus, in which the spin of the ground state is 0 and the spin of the excited state may be either 0 or 1. Since the $0 \rightarrow 0$ transition is forbidden, the presence in this case of γ rays of energy corresponding to the ground-state transition will determine uniquely that the spin of the excited state is 1, while the absence of γ rays of the ground-state transition will correspond to a spin of 0.

Using such measurements, the spins were determined[1-4] for a series of levels of Hg^{199} and W^{183}. In the present investigation, this method was used to determine the values of the spin for several levels of platinum. The nucleus of Pt^{195} is even-odd and has a spin $\frac{1}{2}$, i.e., it is included among the nuclei whose spin levels are completely determined by the γ rays of the ground-state transition.

The arrangement of the apparatus is shown in Fig. 1. The neutron source was a cyclotron with a "pulsed" beam. The duration of the neutron pulse was 2 to 3 microseconds. The energy of the neutrons was determined by means of a time analyzer[5] from the time required to cover the 10-cm base. The width of the electronic channel was 2 microseconds. The γ rays produced by neutron capture in the sample were detected with two NaI(Tl) crystals and FÉU-24 photomultipliers. The crystal dimensions were 8 cm high and 10 and 7 cm in diameter. The γ-ray detectors were placed in a shield made of lead and boron carbide. The crystals were protected by filters made of boron carbide, 2 cm thick, against neutrons scattered by the sample.

The pulses from the photomultipliers were fed to cathode followers, linear amplifiers, and an amplitude discriminator, with which the necessary γ-ray energy interval E_γ was selected. The pulses were then analyzed by a time analyzer. The amplitudes of the pulses in the crystal were calibrated by measuring the energies of the γ rays from Co^{60} (1.17 and 1.33 Mev) and from Po + Be (4.45 Mev). The measurements were made

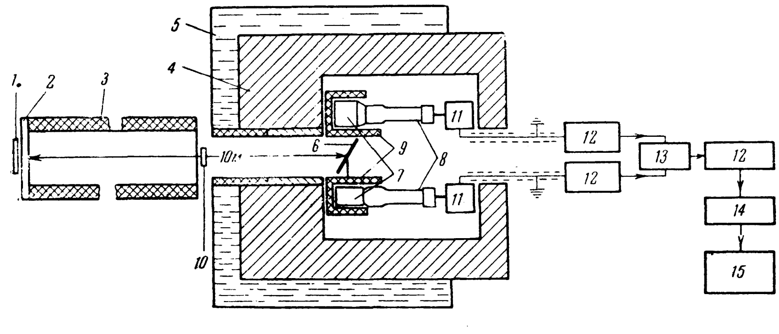

FIG. 1. Diagram of the setup: 1 – cyclotron target, 2 – paraffin moderator, 3 – boron-carbide neutron collimator, 4 – lead shield, 5 – boric-acid shield, 6 – specimen, 7 – NaI(Tl) crystals, 8 – FEU-24 photomultipliers, 9 – boron-carbide filter, 10 – monitoring neutron counter with BF_3, 11 – cathode followers, 12 – amplifiers, 13 – adder, 14 – discriminator, 15 – time analyzer.

with a multi-channel amplitude analyzer.

It must be noted that the crystals did not have sufficiently good resolution. The forms of the spectra of the γ rays from the Co^{60} and Po + Be are shown in Fig. 2. As can be seen from the figure, the distribution of the amplitudes for monochromatic 4.45-Mev γ rays is rather complicated. In addition to the maximum corresponding to total absorption of the energy, two other maxima are observed, corresponding to one of the two annihilation quanta going outside the crystal. In addition, relatively many low-amplitude pulses are abserved. Such a pulse distribution is probably due both to insufficient crystal size (for total absorption of the γ rays) and to rather poor quality of the crystal, with respect to uniformity of the light yield and the gathering of the light over the volume of the crystal. Under such conditions only the lower limit of the registered energy can be established more or less accurately, and the efficiency of registration of γ rays of high energies is substantially reduced.

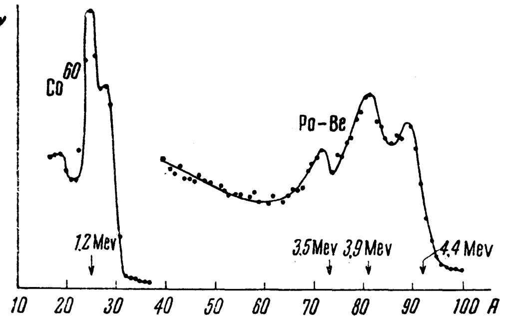

FIG. 2. Calibration curves for NaI(Tl) crystals. A – pulse amplitude in relative units, N_γ – number of pulses in relative units.

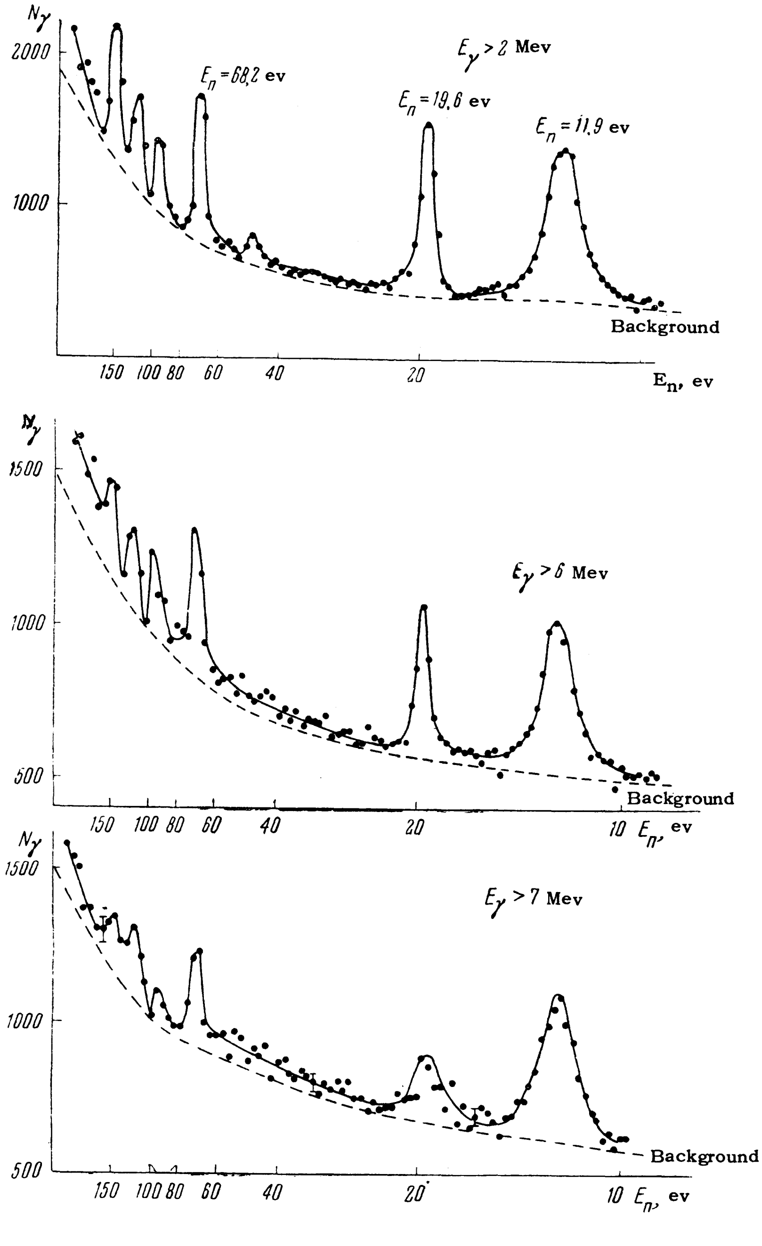

FIG. 3. Intensity of resonances of Pt^{195} at different energies of registered capture γ rays, N_γ – number of pulses.

The measured dependence of the intensity of the γ rays due to neutron capture on the neutron energy E_n, for a sample of platinum, are shown in Figs. 3 and the table.

Comparison of the intensities of the neutron resonances for different energies of registered capture γ rays

Resonance energy, ev	11.9	19.6	68.2	95
$N(E_\gamma > 6\text{Mev})/N(E_\gamma > 2\text{Mev})$	1	0.9	1.1	1.0
$N(E_\gamma > 7\text{Mev})/N(E_\gamma > 2\text{Mev})$	1	0.56	0.9	0.36

The counting rate of the capture γ rays at $E_\gamma > 2$ Mev is sufficiently large under our conditions, and within two or three hours one can obtain a curve with a statistical accuracy of nearly 3% (Fig. 3). However, when changing to energies $E_\gamma > 6$ or 7 Mev, the counting rate decreases sharply, and a time 10 or 15 times longer is necessary to obtain the same accuracy.

At γ-ray energies above 2 Mev (see Fig. 3), all the neutron resonances, which are well known[6] for this energy range in platinum, appear. It is known that three levels corresponding to the neutron energies (E_n) 11.9, 19.6 and 68.2 ev belong to the isotrope $_{78}Pt^{195}$, while the 95-ev level belongs to $_{78}Pt^{198}$. At higher neutron energies, the individual resonances cannot be resolved by our system.

On going to γ-ray energies greater than 6 Mev (Fig. 3), the same resonances are observed, but, as can be seen from the table, the ratio of the intensities remains the same as for the lower γ-ray energies. Upon further increase of the lower threshold of registered γ rays, to 7 Mev, a noticeable change is observed in the relative intensities of the maxima.

From the form of the γ-ray spectrum upon capture of thermal neutrons, and from the binding energies of the isotopes of platinum,[7] one would expect the neutron-energy maximum at 95 ev to disappear for γ rays with $E_\gamma > 7$ Mev, since the binding energy of the neutron in the compound nucleus Pt^{199} amounts to 6.5 Mev. Experimentally, however, a noticeable reduction in this maximum is observed. The fact that it does not vanish completely is apparently explained by the inaccuracy in calibration of the apparatus in γ-ray energies, due to the poor resolution of the crystals, and also by a certain instability of the threshold of registration of γ rays in prolonged measurements.

Next, when the γ-ray lower energy threshold is approximately 7 Mev, transitions should be registered for the isotope Pt^{195}, both to the ground state, with energy 7.9 Mev, and to the lower levels, with energies 7.6 and 7.26 Mev. Both lower levels have spin 2. Therefore all three transitions should take place from excited levels with spin 1 and should be forbidden (or have very low probability) for excited levels with spin 0.

In our experiment (see Fig. 3), as can be judged from the incomplete vanishing of the maximum with neutron-resonance energy 95 ev, the true threshold of the registered γ-ray energy is found to be not 7 Mev, but approximately 6 Mev. Therefore, even in the absence of the ground-state and the two neighboring transitions, one could hardly achieve total vanishing of the resonance, because of the partial registration of transitions with lower energy.

Thus, the observed resonance-intensity ratio can be explained in the following manner. For levels corresponding to neutron energies 11.9 and 68.2 ev, a ground-state transition is observed, and therefore the spins of these levels should be 1. For the level corresponding to $E_n = 19.6$ ev, the reduction in the intensity corresponds apparently to the absence of a ground-state transition, and corresponds therefore to spin 0.

Unfortunately, our apparatus cannot as yet operate at high γ-ray energies, owing to the poor resolution of the crystals and the low intensity, and we cannot establish precisely the absence of a ground-state transition for the 19.6-ev level. Nor can we deny, until such an experiment is carried out, the other possible explanation of the observed effect, namely that the intensity change obtained may be due to fluctuations of the partial radiation widths of the levels under consideration. In this case the deduced value of the spin of the 19.6-ev level may be incorrect.

We have also attempted to detect the presence of a ground-state transition by direct observation of the spectrum of the γ rays emitted upon capture of 11.9- and 19.6-ev neutrons. For this purpose we chose the necessary neutron-energy interval in the maximum region and analyzed the γ-ray spectrum with a multi-channel amplitude analyzer.

Figure 4 shows an overall view of the spectra obtained. As can be seen, the intensity of the γ rays diminishes sharply at high energies for both levels, and it becomes very difficult to compare the spectra in our region, owing both to the low intensity and to the fact that the effect little exceeds the background. In addition, the spectra are not measured simultaneously for the two levels, and

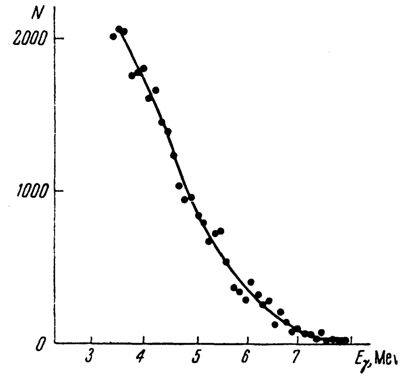

FIG. 4. Form of γ-ray spectrum.

therefore more stringent requirements are imposed on the stabilities of the amplitudes.

Nevertheless, our comparison of the two spectra, shown in Fig. 5, confirms qualitatively the result

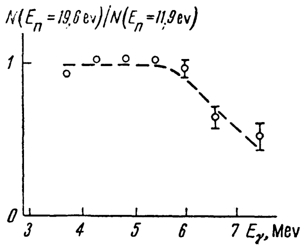

FIG. 5. Comparison of intensity of γ-ray spectra for the 19.6- and 11.9-ev resonances.

previously obtained, that in the γ-ray energy region 6.5 — 7 Mev the intensity of the spectrum for the 19.6-ev resonance drops approximately to half the intensity of the γ rays for the 11.9-ev resonance.

To confirm the final conclusions regarding the spins of the levels under consideration, it would be desirable to perform further measurements with better resolution for γ rays of higher energy.

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