Excitation of high-spin metastable states following capture of negative pions by nuclei

V. S. Buttsev, Yu. K. Gavrilov, Zh. Ganzorig, S. M. Polikanov, and D. Chultém

Joint Institute for Nuclear Research
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Formation of metastable states with high spin was observed following the capture of stopped negative pions by nuclei.

Using the slow-pion beam of the synchrocyclotron of the Nuclear Problems Laboratory of our Institute, [1] experiments were performed on the activation of heavy nuclei by pions. The identification of the produced isotopes was based on the γ rays emitted in the decay, using a high-resolution Ge(Li) detector.

In the reaction ^{181}Ta (π^- $4n$) we observed the isomer ^{177m_2}Hf, with $I^\pi = 37/2^-$. This isomer was observed earlier by Y. Chu *et al.* [2] in the reaction ^{176}Yb (α, $3n$) ^{177m_2}Hf. Figure 1 shows a section of the spectrum of the γ rays from the decay of the Hf isotopes produced in the reaction ^{181}Ta (π^-, xn). All the γ rays connected with the decay of ^{177m_2}Hf (51.4 min) and of the isomer ^{177m_1}Hf (1.1 sec), which is in equilibrium with it, have been identified. The half-life determined by measuring the 214-keV γ line is 51.6 min, in accord with the known data.

The formation of metastable states with high spin is observed also following the capture of pions by other nuclei. Thus, e.g., bombardment of lead by negative

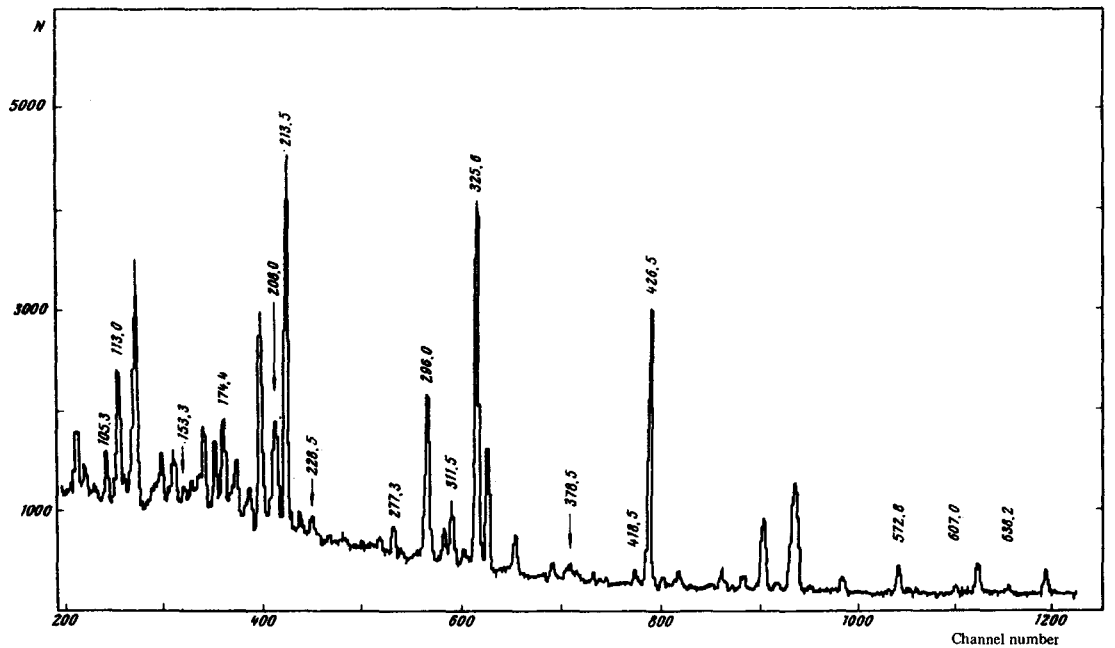

FIG. 1. Section of γ-ray spectrum of the Hf isotopes obtained by bombarding a Ta target with negative pions. The numbers designate the energies of the γ rays of the ^{177}Hf isomers (in keV).

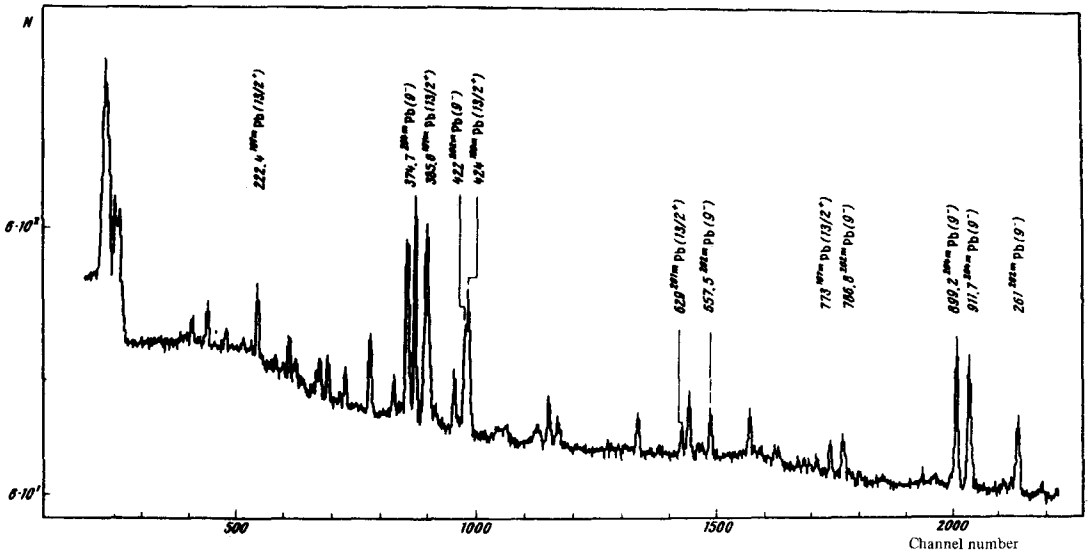

FIG. 2. Section of the spectrum of the γ rays of Pb isotopes obtained in the reaction Bi(π^-, xn).

pions excites the isomers ^{196m}Tl(7$^+$) and ^{198m}Tl(7$^+$) with the unusually high isomer ratio[3] $\xi = \sigma m/\sigma g = 5.0$.

When pions are captured by bismuth nuclei, the metastable states ^{197m}Pb(13/2$^+$), ^{199m}Pb(13/2$^+$), ^{201m}Pb(13/2$^+$), ^{202m}Pb(9$^-$), and ^{204m}Pb(9$^-$) are produced[4] (Fig. 2).

High-spin states were also obtained in the reactions Pt(π^-, xn) ^{190m}Ir(11$^-$) and Hg(π^-, xn) ^{196m}Au(12$^-$).

The very fact of excitation of high-spin metastable states following capture of negative pions is surprising.

As is well known, the capture of a pion by a heavy nucleus occurs principally at the instant when the negative pion is on the orbit 4f of the pionic atom. The pion having zero spin can impart to the nucleus in this case only its orbital angular momentum, which is equal to $3\hbar$. It might seem that the probability of excitation of high-spin states of the nucleus should be low. At present there are no theoretical studies to indicate the mechanism whereby such states are excited when pions are captured by nuclei.

In our opinion, the observed effect may be due to the fact that the pion is captured predominantly by nucleons that are in states with large orbital angular momenta.

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