Experimental Evidence on the Ground State Energy of ^{229}Pa ◇

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A spin $5/2^+$ was assigned to the ground state of ^{229}Pa in [1]. Suggestion of a level at 0.2 keV with spin $5/2^-$ as the parity doublet for the $5/2^+$ ground state was dependent from the energy of the $3/2^-$ head of the $K^\pi = 1/2^-$ band [1]. Our study [2,3] of the ^{231}Pa(p,t)^{229}Pa reaction shows that a different assignment is necessary. The energy of the $3/2^-$ state was estimated as 19±9 keV from Q-values measured for the $3/2^-$ state and evaluated for the ground state. Nevertheless, using the (p,t) data of [2] and reversing the order of the transitions observed in the decay experiment [1], a new level scheme was proposed in which the parity doublet at the ground state was retained [4] and the $3/2^-$ state was placed at 31 keV.

A decisive argument in this discussion would be the observation of the $3/2^- \to$ g.s. transition. A transition with such a small energy can be observed only if it is of E1-multipolarity. Therefore such an observation would support the assignment of spin $5/2^+$ to the ground state.

The ^{231}Pa(p,t) reaction was used to populate the $3/2^-$ state. A radioactive ^{231}Pa target was bombarded by 24 MeV protons. The coincidences between γ-rays and tritons were used to select the (p,tγ) channel. The results of the 20 hour exposure are shown in Fig. 1. Inelastic scattering of protons, the (p,d) and (p,t) reactions lead to the excitation of different isotopes of Pa. Therefore the Pa X-rays are produced and indeed observed in coincidence with protons, deuterons and tritons. An additional line at 11.6±0.3 keV appears only in coincidence with tritons. Its origin has to be nuclear excitation. Its multipolarity must be E1 or it would be unobservable because of internal conversion.

The $3/2^- \to 5/2^+$ transition energy of 11.6 keV leads to a value of the (p,t)-reaction energy $Q_{g.s.}$=-4133(2) keV and to the corrected mass defect of ^{229}Pa 29 894(3) keV (the old value was 29 887(9) keV).

The ^{229}Pa and ^{231}Pa nuclei show striking similarity of their the 1/2[530] and 1/2[660] bands [3]. In a recent study of Coulomb excitation of ^{231}Pa we have observed a strong population of the 3/2[651] band from the 1/2[530] band. There are indications on a similar population also in ^{229}Pa [3]. The present result confirms such a population. Taking into account these facts and the results of calculations in the framework of the quasiparticle-plus-phonon model (to be published) the main configuration of the ground state with spin $5/2^+$ must be 3/2[651]. The $3/2^-$ level at 11.6 keV and the $1/2^+$ level at 251.9 keV (all energies are relative to the ground state, in [3] they are given relative to the $3/2^-$ state) have predominately the 1/2[530] and 1/2[660] configurations, correspondingly. The configuration 5/2[532] is suggested for the $(5/2^-)$ level at 134.1 keV. Then two levels at 223.6 and 253.3 keV [3] have to belong to the 5/2[642] configuration. Assignment of spin $5/2^+$ is preferable for the 223.6 keV level(instead of $3/2^+$ in [3]).

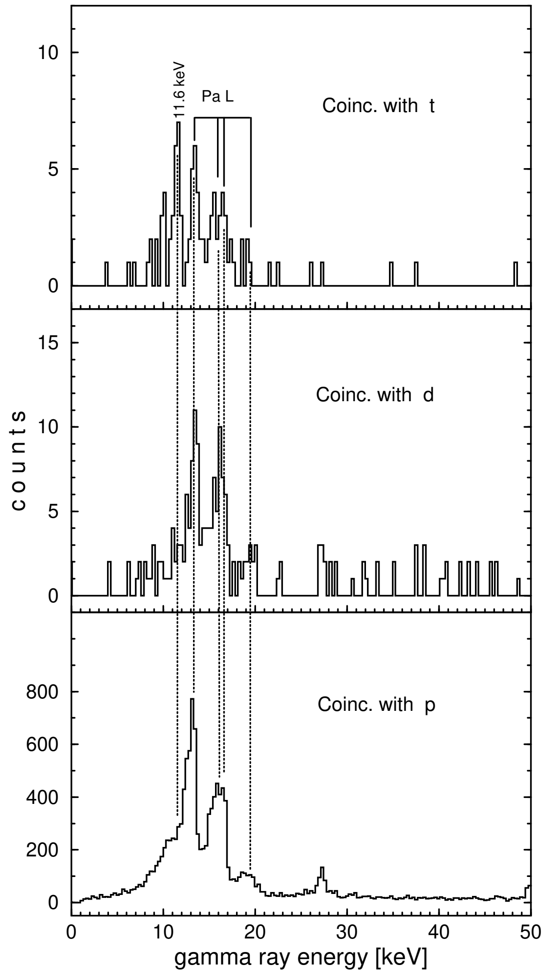

Fig. 1: Gamma-rays from the ^{231}Pa(p,tγ) reaction in coincidence with protons, deuterons and tritons

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