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IDENTIFICATION OF HIGH-SPIN STATES IN ^{235}U

V.E. Makarenko, F.E. Chukreev

(Translation from a Russian original published in Jadernye Konstanty 4/1988)

Translation editor: Dr. A. Lorenz

February 1994

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ABSTRACT

The results of a ^{235}U high spin states study are analyzes. A new way to assign newly observed gamma ray transitions is proposed. Such assignments deals with low spin parts of the level scheme without introducing high spin level states.

Studies of high spin states of heavy atomic nuclei can provide us with information on the characteristics of nuclear material at high excitation energies. Sub-states can arise, for example, during multiple Coulomb excitation of a target nucleus in reactions involving heavy ions. In these experiments the energy of the gamma rays emitted during the decay of the excited state is measured and the results are used to construct a level scheme which corresponds to observed transitions.

The theory put forward in Ref. [1] predicts an exponential rise in the level density as a function of the energy imparted to the nucleon system. As a rule, the number of γ-transitions is even more heavily dependent on the energy of the state. In any case,the amount of gamma spectroscopy data is increasing rapidly as heavy ion accelerator technology develops and coulomb excitation comes into ever wider use in experiments.

Under these circumstances, problems of the uniqueness of the interpretation of experimental results are of prime importance, i.e. the demonstrability of the gamma-ray transition distribution in a proposed level scheme for a particular nucleus.

We present here the results of an analysis of those experimental data given in Ref. [2] in which the rotational band based on the ground state of the ^{235}U nucleus in particular, was studied up to the $J^{\pi} = 57/2^{-}$level.

Experimental results

Figure 1 shows the system of level scheme and γ-transitions presented by the authors of Ref. [2] for the ground state rotational band of ^{235}U . The evidence of the existence of high spin-states is based on the following features of the experiment:

- Use of a series Coulomb excitation mechanism;
- Use of a multiple event filter ($M \geq 3$) and a high energy release filter;
- Use of gamma-ray/particle coincidences;
- Selection of events having the lowest impact parameter values.

In addition, gamma-ray spectra were measured at various colliding particle scattering angles (in the experiment reported in Ref. [2], the ^{235}U target was bombarded with ^{208}Pb ions with an energy of approximately 5 MeV/nucleon).

By combining the above criteria , we can construct a convincing system of arguments in support of the interpretation given in Ref. [2]. However, in our opinion the lack of information on (γ-γ)-coincidences decreases the reliability of the proposed level system (see Fig. 1). If another variant for the γ-transition distribution given in Ref. [2] did exist in the ^{235}U level scheme, then this would cast doubt upon a whole series of high spin states.

Two assignment variations

Within the framework of our analysis of the existing level scheme for ^{235}U [3] we studied the uniqueness of the assignment of the gamma-ray transitions reported in Ref. [2]. We investigated the possibility of reproducing the experimental data given in Ref. [2] by taking into account disintegrations of states having a significantly lower angular momentum than were known before the work described in Ref [20] was performed. We found that it was comparatively easy to distribute the γ-transitions from Ref. [2] in the framework of the familiar ^{235}U level scheme from Ref. [3]. However, imposing the above-mentioned conditions, the number of possible variants is reduced considerably, giving the solution of this problem greater importance.

Figs. 2a to 2d show 14 γ-transitions accompanied by a disintegration cascade initiated by 3 gamma rays. The angular momenta of the states and the energy levels are given in keV. The energies of the γ-transitions which are designated by a thick arrow are taken from Ref. [2] where it is assumed that they are linked to high spin states $J^{\pi} = 57/2^{-} \ldots 27/2^{-}$ (see Fig. 1).

Fig. 2 shows our alternative to the γ-transition distribution given in Ref. [2] which has the following features:

- In arranging the gamma transitions and disintegration cascades we used levels discovered during the studies of the ^{234}U (n,γ) reaction and some levels which were discovered in the course of the investigation of the α-decay processes in ^{239}Pu and the Coulomb excitation of ^{235}U, and the reaction (d,d'). The relevant data are contained in Ref. [3];

- The criteria for the multiplicity of the gamma rays in Ref. [2] and the resulting cascades and the high energy release criteria are satisfied; -The energies of the gamma rays resulting from the disintegration cascades are such that these events could not have been detected in the experiment described in Ref.[2] in which only 300-540 keV gamma rays were being counted;

- The proposed distribution variant involves states in the low-spin portion of the ^{235}U level scheme.

The results of our analysis show that the arrangement of some gamma-ray transitions in the ^{235}U level scheme is not unique. This not only shows how complex the scheme is (e.g., there are over 100 known levels and over 300 transitions) but it also shows that we must carefully investigate the possibility of distributing transitions without introducing new states into the system. As the experiment in Ref. [4] shows, in the case of level schemes for intermediate and heavy nuclides the experimental results can often be explained without going outside the framework of the known level scheme. In this particular case, the non-uniqueness arose as a result of gaps in the experimental data in Ref. [2]. More specifically, there is a need for measurements of lifetimes of the states which were identified in Ref. [2] as members of the ground state rotational bands as well as of (γ-γ)-coincidences (which may indicate the presence of a cascade).

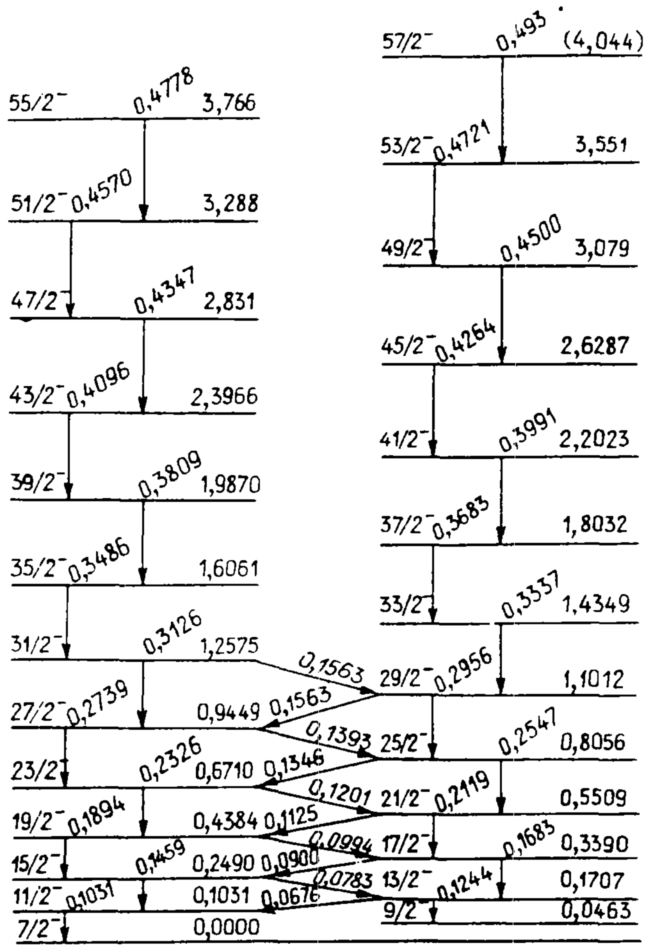
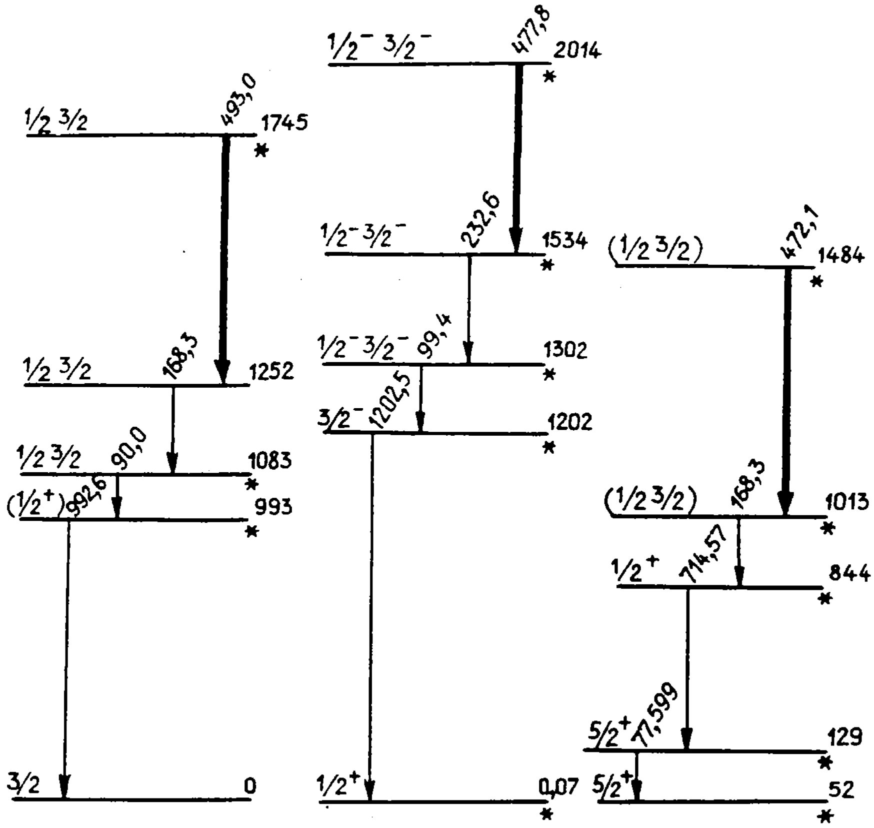
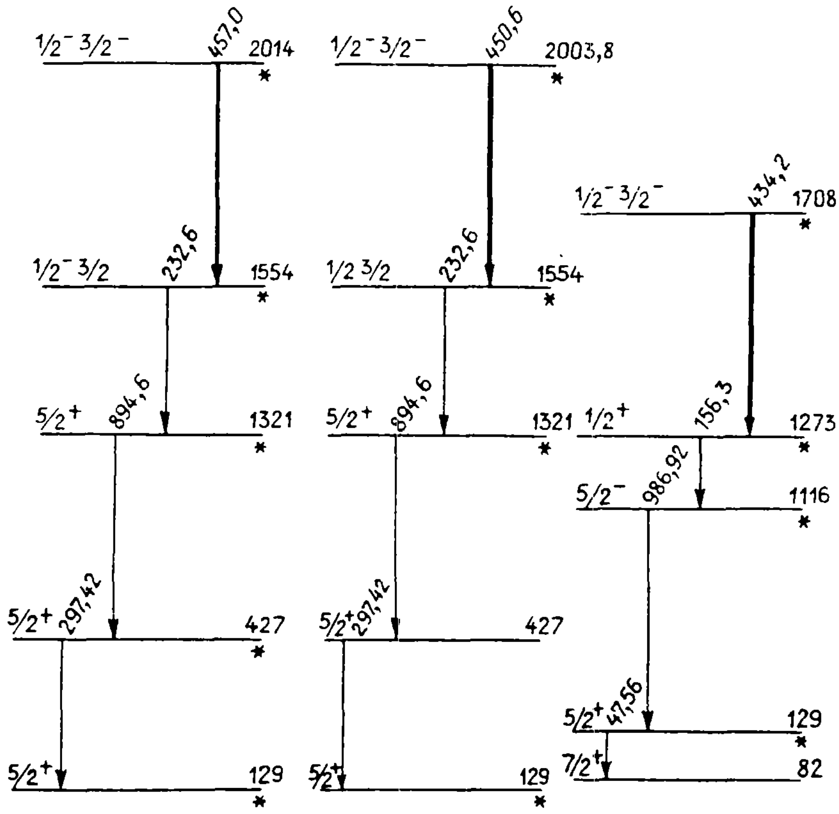


Fig. 1. Level scheme of the rotational band of the ^{235}U ground state (as given in Ref. [2])



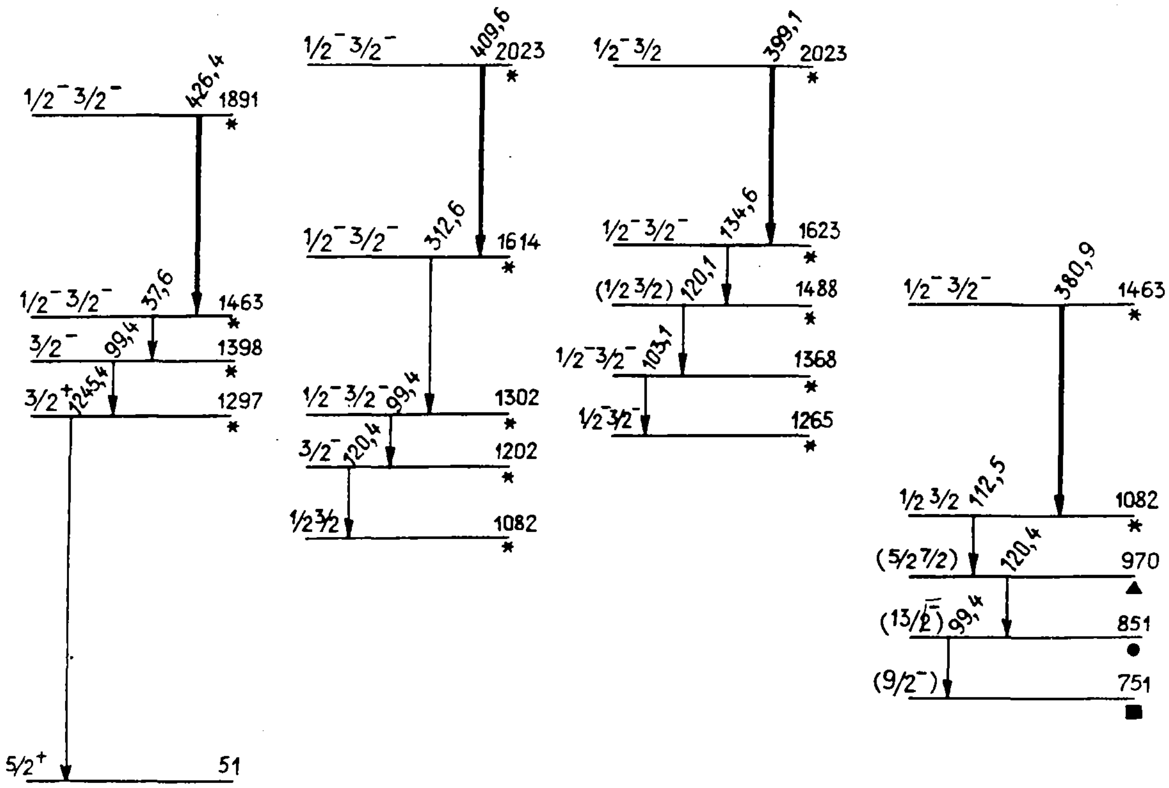
a

Fig. 2. Four alternatives (a,b,c and d) for the gamma-ray transition distribution [2] in the low spin part of the ^{235}U level scheme: ★ - $^{234}U(n,\gamma)$ reaction, ▲ - ^{239}Pu α decay, ■ - (d,d') reaction, ● - ^{235}U Coulomb excitation.



b

Fig. 2. (continued)



c

Fig. 2. (continued)

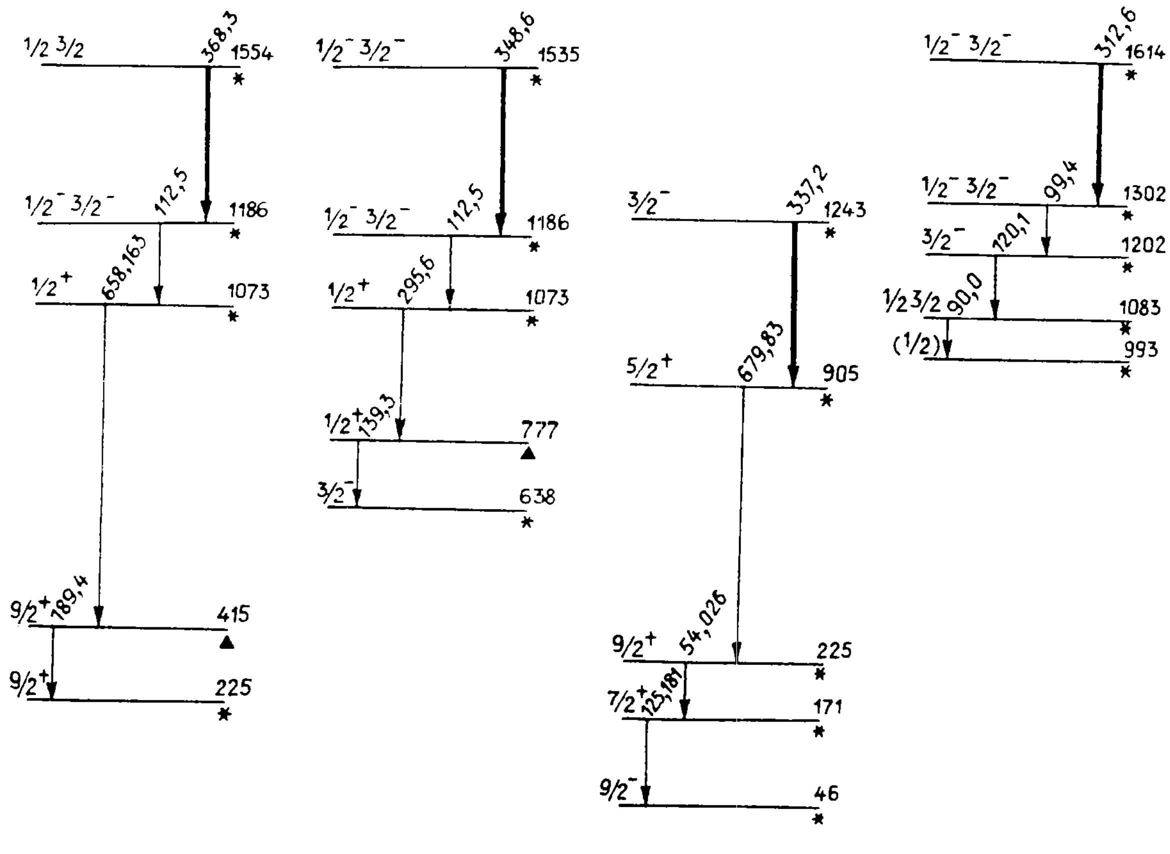


Fig. 2. (concluded)

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