GAMMA RAYS FROM INELASTIC SCATTERING OF 2.95-MeV *NEUTRONS ON* Ta^{181}

L. Ya. GRAUDYNYA, O. I. KOSTOCHKIN, K. A. PETRZHAK, and A. V. SOROKINA

Radium Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor July 17, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **42**, 349-352 (February, 1962)

The spectrum of γ rays emitted when 2.95-MeV neutrons are scattered inelastically by Ta^{181} nuclei is obtained.

THE energy levels of Ta^{181}, which are known mainly through the radioactive decay of Hf^{181}, have been studied most thoroughly in [1,2] and are well determined up to 0.619 MeV. Muir and Boehm[2] give the following levels of Ta^{181}: 618.9 ($3/2^+$), 615.0 ($1/2^+$), 482.0 ($5/2^+$), 158.8 ($11/2^-$), 136.25 ($9/2^+$), and 6.25 ($9/2^-$) keV. The literature contains conflicting evidence pertaining to the possible existence of a 958-keV level. Boehm and Marmier[3] detected a very weak 0.476-MeV γ transition accompanying the β decay of Hf^{181}, in addition to the known 0.482-MeV transition. These authors suggested that Ta^{181} has a 0.958-Mev level and attributed the 0.476-MeV quantum to a direct transition from this level to the 0.482-MeV level.

The question of the existence of a 0.958-Mev level has been thoroughly discussed in [1 2]. Berovikov et al[1] used a fast coincidence circuit with 3×10^{-8} sec resolving time and a multichannel amplitude analyzer to measure the γ-ray spectrum coinciding with the 0.482-MeV line. The peaks observed at 0.220, 0.270, and 0.480 MeV were associated with two excited levels, 0.958 and 0.699 MeV, in Ta^{181}. The first two peaks were identified as 0.217- and 0.256-MeV γ lines emitted in cascade from the 0.958-MeV level through a 0.699-MeV level to the 0.482-MeV level. The 0.480-MeV peak was regarded as a direct 0.476-MeV transition.

Muir and Boehm[2] studied γ-γ coincidences between the 0.476- and 0.482-MeV lines. These coincidences were measured by a fast-slow coincidence circuit with the resolving time $2\tau = 4.4 \times 10^{-8}$ sec and two single-channel amplitude analyzers defining the energy range 480 ± 25 kev. The coincidence count was found to be lower than the expected background of random coincidences. This work therefore casts doubt on the existence of a 0.958-MeV level in Ta^{181}. Since it is difficult to decide between these two investigations, which were performed with almost identical experimental techniques, the existence of a 0.958-MeV level is still an open question.

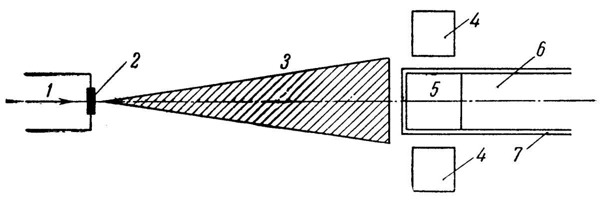

FIG. 1. Experimental arrangement. 1 – deuteron beam, 2 – deuterium target, 3 – lead shielding cone, 4 – Ta scattering ring, 5 – NaI(Tl) crystal, 6 – photomultiplier, 7 – black paper shield

Since the Ta^{181} nucleus is highly deformed we know that it should possess collective excited levels. Experiments on the Coulomb excitation of Ta^{181} have determined[4] the first two rotational levels at 0.131 ($9/2^+$) and 0.303 ($11/2^+$) MeV.

The literature contains very little information about higher excited Ta^{181} levels. One source of information regarding γ transitions associated with high levels is the study of γ rays arising in inelastic neutron scattering. Four investigations[5-8] of γ rays from inelastic neutron scattering on Ta^{181} have been published so far; only two of these[7,8] detected previously unknown γ transitions associated with higher excited levels. However, conflicting results were obtained in these two investigations. It was therefore of interest to make a more thorough study of the γ-ray spectrum arising in the inelastic scattering of neutrons on tantalum.

The spectrum was studied with a scintillation γ spectrometer using annular geometry in an arrangement shown in Fig. 1. The energy resolution of the spectrometer for the 0.66-MeV γ line of Cs^{137} was 10%. A metallic tantalum ring weighing 286 g was the scatterer for measurements of the spectrum up to 1 MeV. For measurements of the harder portion of the spectrum the scatterer was an annular clear plastic container filled with 818 g

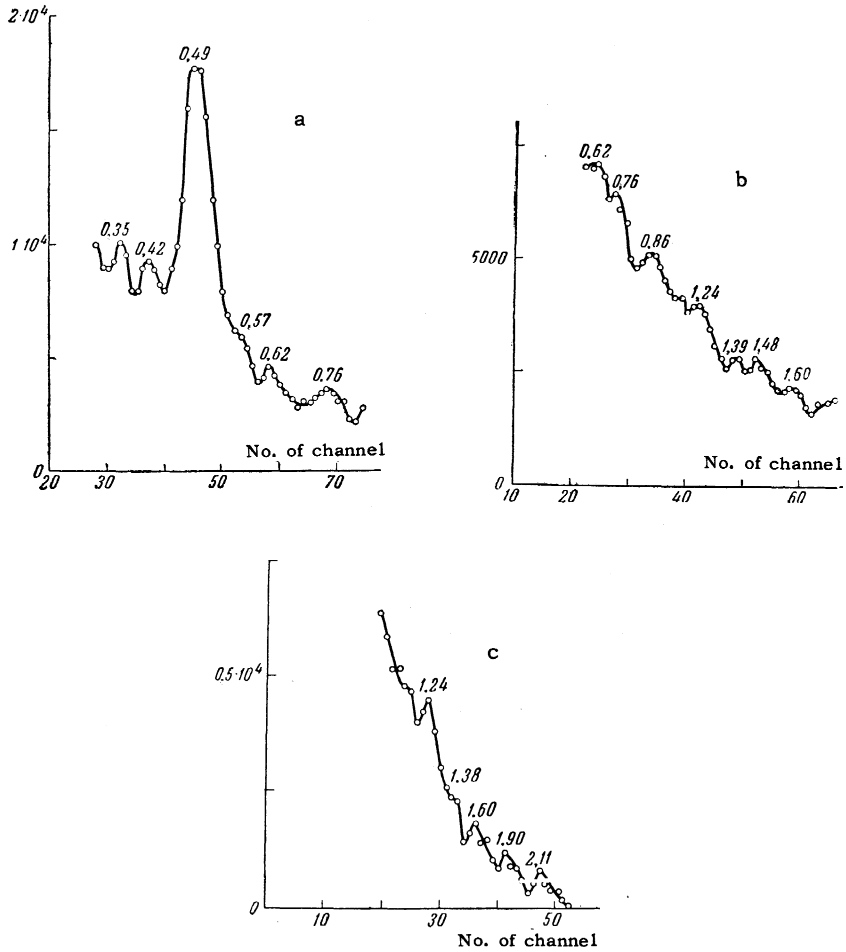

FIG. 2. Spectra of γ-ray pulses from the inelastic scattering of 2.95-MeV neutrons on Ta^{181}. The ordinates are the numbers of pulses.

of metallic tantalum powder. The background of neutrons scattered into the crystal by the scattering ring and surrounding objects, together with the γ-ray background from various nuclear reactions between neutrons and nuclei of the environment was determined by measuring the γ-ray spectrum from the plastic scattering ring. The tantalum and plastic scattering rings contained the same number of scattering atoms.

In the present work the spectrum from 0.35 to 3 MeV was investigated. Figure 2 shows the pulse-height spectra of γ rays from the inelastic scattering of 2.95-MeV neutrons on Ta^{181}. Each region of the spectrum shown in the figure was measured eight to ten times; the indicated γ-ray energies are average values. In our opinion, the pulse-height peaks at 1.39 and 1.60 MeV resulted from pair production in the NaI(Tl) crystal by 1.90- and 2.11-MeV quanta followed by the emission of one annihilation quantum from the crystal. The broadening in the higher amplitude direction of the peak corresponding to a 0.62-MeV quantum (Fig. 2a) indicates a possible γ transition of about 0.7 MeV.

γ-ray energy, MeV		
Present work	$E_n = 3$ MeV[7]	$E_n = 3$ MeV [8]
0,35**		
0,42*		
0.49**	0.46	0.46
0,57*		
0,62**		
0,76*		
0,86		
1.24		0.87
1.47	1,44	1,18
1.90		1.82
2,11*		

Our present results are compared with [7,8] in the table. The γ transitions from inelastic neutron scattering that were here observed for the first time are denoted by single asterisks, while those known from the radioactive decay of Hf^{181} are denoted by double asterisks.

All the observed γ transitions can be accounted for if we assume that, in addition to the known excited levels up to 0.619 MeV, Ta^{181} possesses the following higher levels: 0.7, 1.24, 1.47, 1.90, and 2.11 MeV. The table shows that no 0.958-MeV γ rays were detected, and all the observed γ transitions can be obtained without introducing a 0.958-MeV level.

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Translated by I. Emin
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