ON THE 892.4-kev GAMMA TRANSITION IN W^{182}

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Results of measurements of the relative intensities of γ transitions from the 1221.8-kev level in W^{182} to the levels of the ground rotational band are presented. The intensity of the 892.4-kev transition is found to be smaller than that computed according to the theory for axial nuclei as well as that computed according to the theory for nonaxial nuclei.

1. In the decay of Ta^{182} to W^{182}, the transitions shown in Fig. 1 occur. The 1221.8-kev excited state of W^{182} is formed in most of the decays. It is a 2^+ level as shown by the following experimental data:

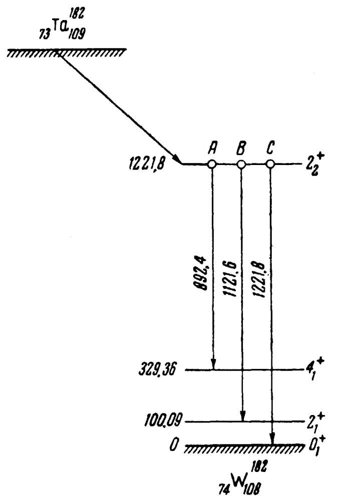

FIG. 1. Decay scheme.

a) On the basis of internal conversion coefficient measurements,[1] the transition from the 1221.8-kev level to the ground state of W^{182} is an E2 transition.

b) Investigation[2] of the $\gamma\gamma$ angular correlation in the 67.74 — 1221.8 and 67.74 — 1121.6 kev cascades shows that the spin of the 1221.8-kev level is 2.

c) The 1221.8-kev level is produced by Coulomb excitation.[3]

The 1221.8-kev state can decay to levels of the lowest rotational band — transitions A, B, and C in Fig. 1. The transitions C and B to the ground state and 100.09-kev level are well known; they are the most intense of the high-energy γ transitions. In this work we are concerned with the competing 892.4-kev transition A.

An 892-kev line was observed in 1950 by O'Meara[4] in the photoelectron spectrum. In 1955, the information[5] appeared that Fowler had also observed this line in the photoelectron spectrum. However, in the article itself to which reference had been made[6] there was no such indication. In 1959 in a study of the γ spectrum of Ta^{182} on an elotron,[7] an upper limit of 0.017 was established for the ratio of the intensities of the 892.4- and 1221.8-kev γ rays.

In the conversion spectrum of Ta^{182}, the line corresponding to this transition has never been observed. Gvozdev, Rusinov, and Khazov[8] made a special search for this line in the conversion spectrum and did not find it. From their work it follows that $K_{892.4}/K_{1221.8} \leq 0.02$.

In 1959 Gallagher, Newton, and Shirley[9] found a K-conversion line in the spectrum of Re^{182}, which also decays to W^{182} with a 13-hour half-life; this line was from a transition with nearly the same energy, $h\nu = 894.7 \pm 0.8$ kev, and had a large intensity, $K_{894.7}/K_{1221.8} = 2/3$. Such an intense line could not have escaped notice in the work of Gvozdev, Rusinov, and Khazov.[8]

On the other hand, Gallagher, Newton, and Shirley's experiments[9] show that the relative intensity of the corresponding γ transition is 0.35 if the 894.7-kev γ is an E2 transition or 0.16 if it is M1. Such an intense line could not have remained undetected in the work of Voinova, Dzhelepov, and Zhukovskii.[7] We therefore conclude that the 894.7-kev transition found by Gallagher is not connected with the 1221.8-kev level in W^{182}.

The question of the intensity of the 892.4-kev transition in the Ta^{182} decay remains unanswered. Meanwhile, knowledge of the intensities of the competing transitions A, B, and C is important both as a check on current theories and for discovering the nature of the 1221.8-kev state.

2. With the new magnetic spectrometer of the elotron type, constructed at the Metrology Institute,

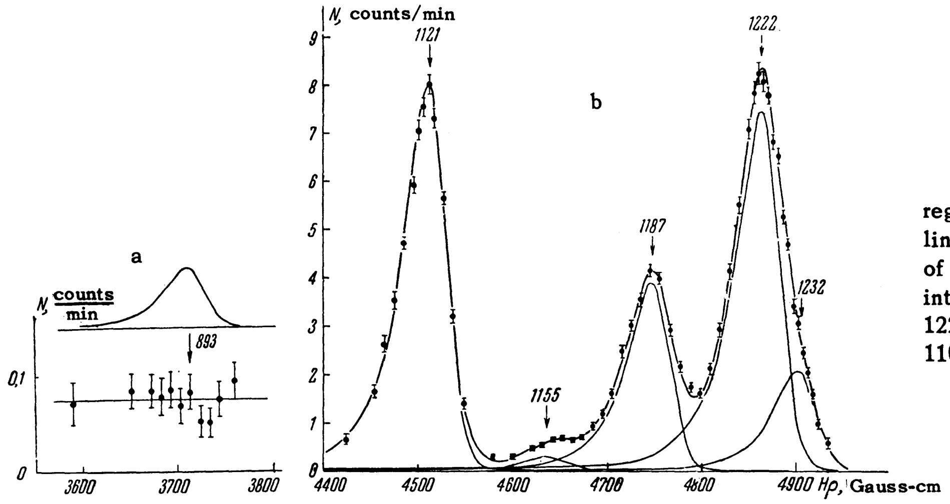

FIG. 2. Electron spectrum: a – the region which should contain the 892.4-kev line; the upper curve is the expected form of this line under the assumption that its intensity is 1% of the intensity of the 1221.8-kev line; b – the spectrum in the 1100–1250 kev region.

we have reinvestigated the portions of the γ spectrum in the energy ranges 850 — 910 kev and 1100 — 1250 kev. The higher resolution (1.2% at 1 Mev) of this spectrometer, as compared to the previous one,[7] and the lower background allowed us to lower the upper limit on the ratio of the intensities of the 892.4-kev and 1221.8-kev γ rays.

Figure 2 shows the electron spectrum in the regions studied. The background, which in the energy range 850 — 910 kev is practically constant at 0.04 count/min, has been subtracted from the experimental points. The signal that remains after subtraction of background can be attributed to the tails of the hard lines, which in this region contribute about 0.1 count/min. From our results it follows that the intensities of the γ rays satisfy

$$I(\gamma_{892.4})/I(\gamma_{1221.8}) \leqslant 0.006.$$

3. In the theory of nonaxial nuclei developed by Davydov et al.,[10,11] the intensity ratios of the transitions A, B, and C are determined uniquely.

The energy ratio of the two spin-2 rotational levels gives γ, the parameter characterizing the nonaxial nucleus, according to the formula[10]

$$E(2_2^+)/E(2_1^+) = [1+\sqrt{9-8\sin^2(3\gamma)}]/[1-\sqrt{9-8\sin^2(3\gamma)}].$$

(2_1^+ is the first 2^+ level, counting from the ground state). Setting $E(2_1^+) = 100.092$ kev[12] and $E(2_2^+) = 1221.8$ kev,[13] we find that $\gamma = 11.40°$.

Using the formula for the reduced transition probability from Davydov's review,[10] we calculated the relative intensities of the 1221.8-kev and 1121.6-kev transitions (see the table).

The formula for the reduced transition probability for the $2_2^+ \to 4_1^+$ transition is not given in the papers of Davydov et al.; only an approximate value for the reduced probability for the $4_1^+ \to 2_2^+$ transition is given.[11] However, according to a private communication from Davydov, for $\gamma = 11.4°$ the exact value is 15 per cent higher. The $2_2^+ \to 4_1^+$ transition probability is higher by a factor $(2I_f+1)/(2I_i+1) = 9/5$ (I_f and I_i are the spins of the final and initial states in the transition). The relative intensities calculated in this way are given in the table. They differ appreciably from the experimental result.

Recently Davydov and Chaban,[14] in order to obtain better agreement of theory with experiment, have proposed a "nonadiabatic" correction, i.e., one that accounts for the change of shape of the nucleus caused by its rotation. In this theory, besides the parameters β and γ, characterizing the nuclear shape, there appears a new parameter, μ, characterizing the "stiffness" of the nucleus. To determine γ' (the new "nonadiabatic" γ) and μ, one must know the energy ratios for three levels, for example, 2_1^+, 2_2^+, and 4_1^+, or 2_1^+, 2_2^+ and 6_1^+. The corrections to the reduced transition probability can be made after γ' and μ have been computed; for small μ this amounts to replacing the old "adiabatic" γ by γ'. Using the above energy values for the 2_1^+ and 2_2^+ levels and 329.36 kev for the 4_1^+ level, we found $\gamma' = 11.19°$ and $\mu = 0.186$. Using the same values for the 2_1^+ and 2_2^+ levels and 680.38 kev for the 6_1^+ level, we found $\gamma' = 11.21$ and $\mu = 0.181$. Thus the values derived from the positions of the 4_1^+ and 6_1^+ levels are in excellent agreement. For $\gamma' = 11.20°$, the relative intensities of the competing transitions are almost the same as for $\gamma = 11.40°$ (see table). The disagreement with the experiments on the 892.4-kev line is essentially unchanged.

4. In the theory of axial nuclei developed by Alaga, Alder, Bohr, and Mottelson,[15] the relative intensities of the transitions A, B, and C depend

Relative intensities of transitions from the 1221.8 kev W^{182} level

Transition energy, kev	Experimental relative value	Theoretical relative intensity					
		according to Davydov		by Alaga's rule			
						$K=2$	
		$\gamma=11,40°$	$\gamma'=11,20°$	$K=0$	$K=1$	uncorrected	corrected
892.4	⩽0.6	3.8	3.7	53.6	23.8	1.46	3.2
1121.6	122	131	130	93.2	23.5	93.2	122
1221.8	100	100	100	100	100	100	100

on the quantum number K of the 1221.8 kev level. The reduced relative intensities calculated according to reference 15 for $K = 0$, 1, and 2 are given in the table. $K = 0$ and $K = 1$ are completely excluded by the experimental data. For $K = 2$, the theory of axial nuclei gives results which are closer to the experimental data, but still outside the limits of error.

Not so long ago Hansen, Nielsen, and Sheline[16] proposed that the relative intensities of the transitions should be corrected by considering the mixing of $K = 2$ states into the $K = 0$ band and the mixing of $K = 0$ states into the $K = 2$ band. This mutual mixing is characterized by a parameter z, which is the same for all states in a band, and which must be found experimentally. We can determine z so that the relative intensities of the 1121.6 and 1221.8 kev transitions agree with experiment; this gives $z = 0.046$. Then the relative intensity of the 892.4 kev transition increases from 1.46 to 3.2 (see table). Thus, this correction increases the discrepancy between theory and experiment.

5. We should mention that the enigmatic absence of the $2_2^+ \to 4_1^+$ transition is not a general rule. For example, in the $Tb^{156} \to Gd^{156}$ and $Ho^{160} \to Dy^{160}$ decays transitions of this type are observed[11,16,17] with an intensity approximately in agreement with both theories; the experimental ratio of the reduced transition probabilities, $B(E2, 2_2^+ \to 4_1^+)/B(E2, 2_2^+ \to 2_1^+)$, are 0.12 for Cd^{156} and 0.08 for Dy^{160}; the theory of nonaxial nuclei gives 0.095 and the theory of axial nuclei gives $0.080 - 0.087$ (for $z = 0.04 - 0.05$).

[1] Murray, Boehm, Marmier, and Du Mond, Phys. Rev. **97**, 1007 (1955).

[2] R. Williams and K. Roulston, Can. J. Phys. **34**, 1087 (1956).

[3] Alkhazov, Grinberg, Gusinskii, Erokhina, and Lemberg, JETP **35**, 1325 (1958), Soviet Phys. JETP **8**, 926 (1959).

[4] F. E. O'Meara, Phys. Rev. **79**, 1032 (1950).

[5] Fowler, Kruse, Keshishian, Klotz, and Mellor, Nucl. Sci. Abstr. **9**, 24B, 102 (1955).

[6] Fowler, Kruse, Keshishian, Klotz, and Mellor, Phys. Rev. **94**, 1082 (1954).

[7] Voinova, Dzhelepov, and Zhukovskii, Izv. Akad. Nauk SSSR, Ser. Fiz. **23**, 828 (1959), Columbia Tech. Transl. p. 822.

[8] Gvozdev, Rusinov, and Khazov, Izv. Akad. Nauk SSSR, Ser. Fiz. **24**, No. 12 (1960), Columbia Tech. Transl., in press.

[9] Gallagher, Newton, and Shirley, Phys. Rev. **113**, 1298 (1959).

[10] A. S. Davydov, Izv. Akad. Nauk SSSR, Ser. Fiz. **23**, 792 (1959), Columbia Tech. Transl. p. 788.

[11] A. S. Davydov and V. S. Rostovskii, JETP **36**, 1788 (1959), Soviet Phys. **9**, 1275 (1959).

[12] Müller, Hoyt, Klein, and Du Mond, Phys. Rev. **88**, 775 (1952).

[13] G. Backström, Arkiv Fysik **10**, 387 (1956).

[14] A. S. Davydov and A. A. Chaban, Nuclear Phys., in press.

[15] Alaga, Alder, Bohr, and Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. **29**, 9 (1955).

[16] Hansen, Nielsen, and Sheline, Nuclear Phys. **12**, 389 (1959).

[17] Voinova, Dzhelepov, and Zhukovskii, Izv. Akad. Nauk SSSR, Ser. Fiz. **24**, 852 (1960), Columbia Tech. Transl., in press.

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