

GAMMA SPECTRUM OF ^{106m}Ag

J. A. MORAGUES, P. REYES-SUTER and T. SUTER

Espectroscopia Nuclear, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina

and

M. PÉREZ

Fundación Bariloche, Argentina

Received 8 September 1967

Abstract: The gamma spectrum of the decay of ^{106m}Ag (8 d) was measured with a Ge(Li) detector.

The following energies in keV and relative intensities (in parentheses) were determined: 194.93 (6), 221.51 (83), 228.53 (29), 328.27 (18), 375.1 (3), 390.90 (43), 406.00 (152), 418.6 (7), 429.46 (161), 450.80 (310), 474.2 (12), 511.77 (1000), 586.0 (9), 600.88 (23), 616.05 (236), 645.5 (18), 680.3 (25), 703.3 (52), 717.1 (320), 748.2 (227), 792.8 (65), 803.9 (124), 807.5 (42), 824.5 (160), 847.5 (45), 875 (7), 956 (8), 1019.7 (9), 1045.7 (285), 1053 (11), 1121 (9), 1127.8 (106), 1199.1 (106), 1222.8 (61), 1394.2 (17), 1527.0 (155), 1565 (8), 1572.1 (70), 1691 (0.5), 1722.1 (15), 1770 (0.6), 1793 (0.6), 1837.9 (20) and 2082 (0.2).

All but two of the transitions were placed into a decay scheme with the following levels (in keV): 511.77 (2^+), 1127.8 (2^+), 1228.9 (4^+), 1557.3 (3^+ , 4^+), 1931.8 (3^- , 4^+), 2076.7 (3^+ , 4^+), 2083.8 (3^-), 2282.0? (3^- , 4^+), 2305.3 (4^-), 2350.2 (3^+ , 4^-), 2365.2? (3^+ , 4^+), 2756.2 (5^+) and 2951.1 (5^+).

E

RADIOACTIVITY ^{106m}Ag [from $^{107}\text{Ag}(n, 2n)$]; measured E_γ , I_γ . ^{106}Pd deduced levels, cc, J , π , log ft . Natural target, Ge(Li) detector.

1. Introduction

The levels of the even nucleus ^{106}Pd are fed in the $^{106,106m}\text{Ag}$ and $^{106,106m}\text{Rh}$ decays (1^{-6}). The radioactivity of all these parent nuclei has been the subject of many investigations, but the most extensive information has been obtained ($1,2$) from the decay of ^{106}Ag (8d). However, the level schemes thus far proposed cannot be considered definitive, and spin and parities are undetermined in many cases. Since no precise measurements of the gamma spectrum have been reported, a measurement with a Ge(Li) detector may lead to a better knowledge of the level scheme.

2. Experiments

The source was obtained by the $^{107}\text{Ag}(n, 2n)^{106}\text{Ag}$ reaction produced by bombarding a natural target with fast neutrons from the $^3\text{H}(d, n)^4\text{He}$ reaction. Experiments started one day after irradiation. No long-lived activities other than ^{106m}Ag were observed.

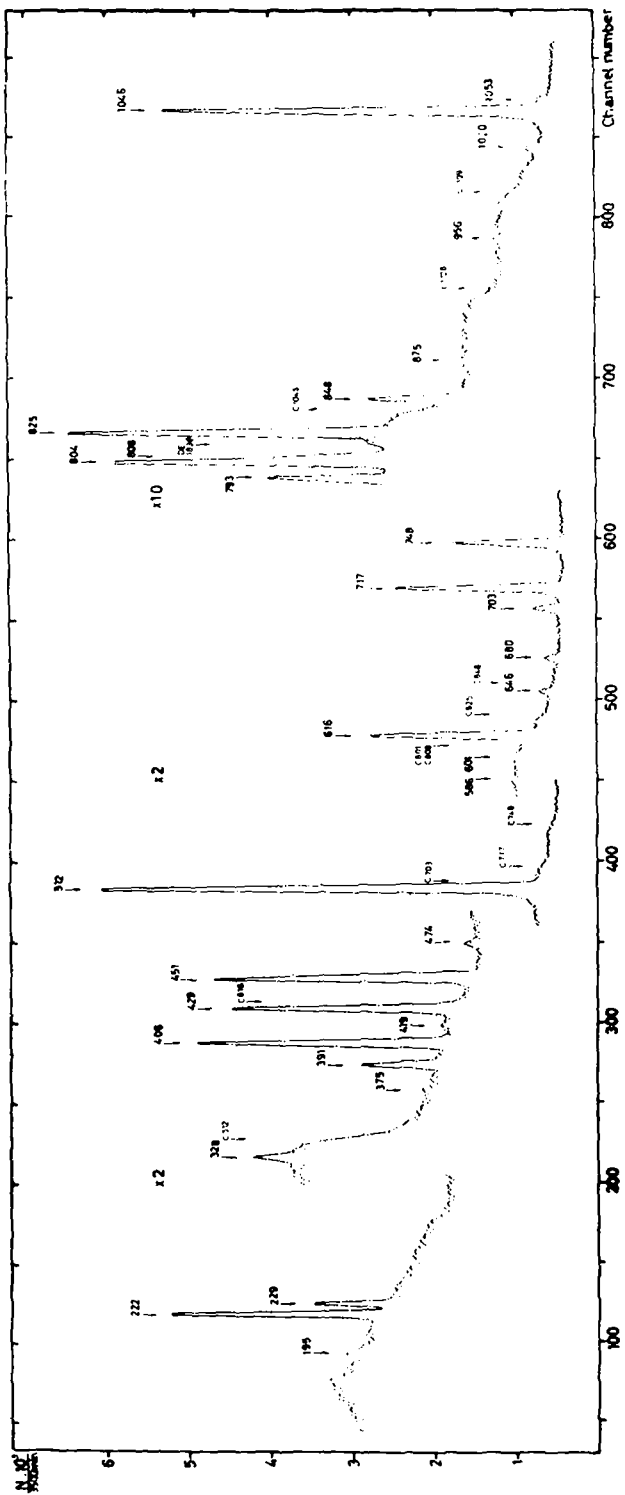


Fig. 1a.

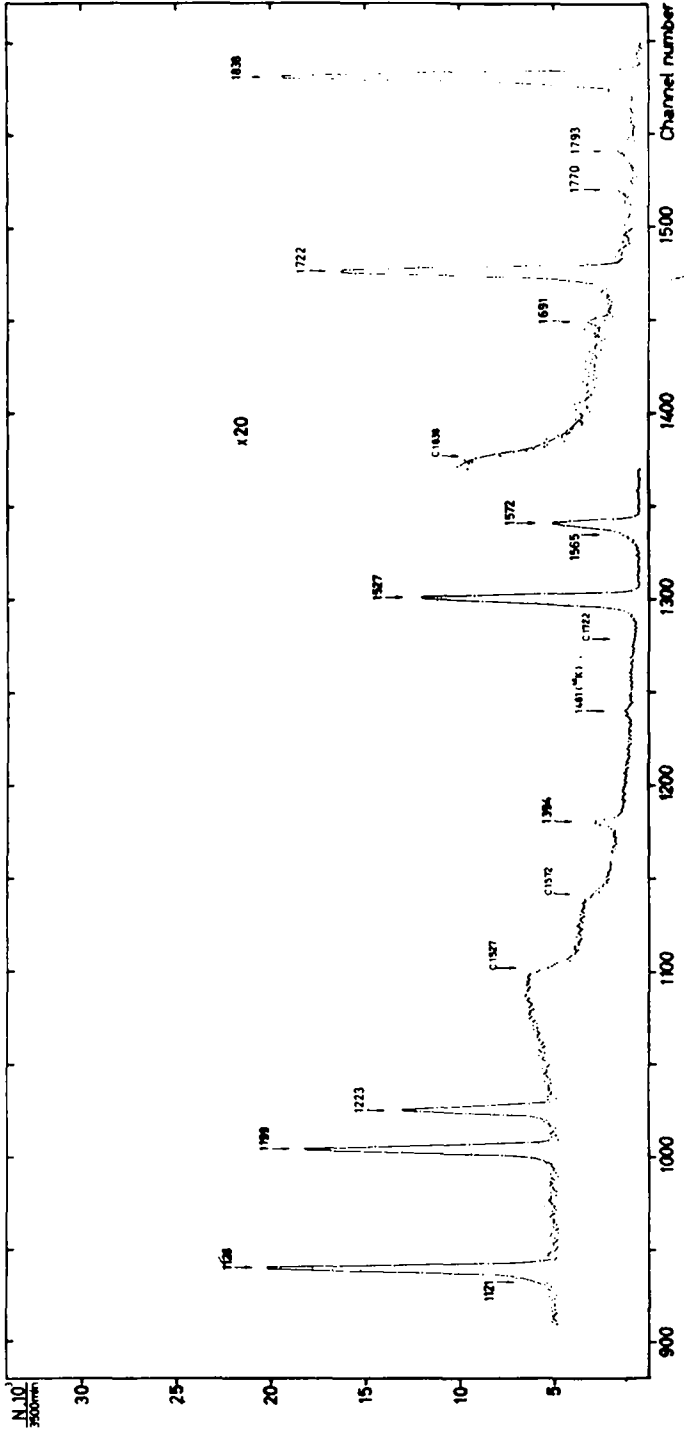


Fig. 1b. Gamma spectrum obtained with a $4 \text{ cm}^2 \times 5 \text{ mm Ge(Li)}$ detector. The position of the Compton edges is shown.

TABLE I
Energies, relative intensities and conversion coefficients

Transition energy (keV)		Gamma-ray intensity	Conversion electron intensity ^{a)}	K-conversion coefficients ($\times 10^3$)				
measured	adjusted			experiment ^{c)}	theory ^{d)}			
					E1	M1	E2	
194.93 \pm 0.15 ^{a)}	194.9	6 \pm 3	44 \pm 6	36 \pm 18	19.5	54	101	
221.51 \pm 0.10 ^{a)}	221.5	83 \pm 8	630 \pm 50	37 \pm 5	13.1	38	70	
228.53 \pm 0.12 ^{a)}	228.5	29 \pm 5	67 \pm 8	11.3 \pm 2	11.8	36	64	
328.27 \pm 0.25 ^{a)}	328.4	18 \pm 3	32 \pm 16	9 \pm 5	4.6	14	18	
375.1 \pm 0.7 ^{b)}	374.5	3 \pm 1						
390.90 \pm 0.20 ^{a)}	391.0	43 \pm 3	98 \pm 25	11 \pm 3	3.0	9.1	10.7	
406.00 \pm 0.15 ^{a)}	406.0	152 \pm 10	300 \pm 20	9.6 \pm 0.7	2.7	8.2	9.5	
418.6 \pm 0.7 ^{b)}	418.4	7 \pm 3						
429.46 \pm 0.15 ^{a)}	429.5	161 \pm 14	260 \pm 20	7.9 \pm 0.8	2.4	7.2	8.1	
450.80 \pm 0.20 ^{a)}	450.9	310 \pm 16	160 \pm 15	2.5 \pm 0.3	2.1	7.4	7.0	
474.2 \pm 0.3 ^{a)}	474.2	12 \pm 3	17 \pm 5	7.2 \pm 2.5	1.87	5.6	6.0	
511.77 \pm 0.20 ^{a)}	511.77	1000 \pm 30	1000 \pm 40	4.87			4.87	
586.0 \pm 0.8 ^{b)}	585.9	9 \pm 3						
600.88 \pm 0.25 ^{a)}	600.9	23 \pm 7	15 \pm 4	3.2 \pm 1.0	1.07	3.2	3.1	
616.05 \pm 0.25 ^{a)}	616.05	236 \pm 20	155 \pm 15	3.2 \pm 0.4	1.02	3.0	2.9	
645.5 \pm 1.0 ^{b)}	645.6	18 \pm 3						
680.3 \pm 0.6 ^{a)}	679.5	25 \pm 8						
703.3 \pm 0.5 ^{a)}	702.9	52 \pm 4	30 \pm 10	2.8 \pm 0.3	0.76	2.2	2.0	
717.1 \pm 0.4 ^{a)}	717.1	320 \pm 12	130 \pm 10	2.0 \pm 0.2	0.73	2.1	1.92	
748.2 \pm 0.3 ^{a)}	748.2	227 \pm 10	37 \pm 4	0.8 \pm 0.1	0.66	1.85	1.7	
792.8 \pm 0.3 ^{a)}	792.9	65 \pm 13	24 \pm 3	1.8 \pm 0.4	0.60	1.65	1.47	
803.9 \pm 0.3 ^{a)}	804.0	124 \pm 10	40 \pm 4	1.6 \pm 0.2	0.59	1.60	1.43	
807.5 \pm 0.5 ^{a)}	807.9	42 \pm 8	12 \pm 3	1.4 \pm 0.4	0.58	1.57	1.40	
824.5 \pm 0.3 ^{a)}	824.4	160 \pm 14	54 \pm 5	1.6 \pm 0.2	0.56	1.50	1.35	
847.5 \pm 0.4 ^{a)}	847.8	45 \pm 10	14 \pm 4	1.5 \pm 0.5	0.53	1.43	1.22	
875 \pm 2 ^{b)}	874.4	7 \pm 3						
956 \pm 2 ^{b)}	956.0	8 \pm 3						
1019.7 \pm 0.8 ^{b)}	1019.3	9 \pm 5						
1045.7 \pm 0.4 ^{a)}	1045.5	285 \pm 25	48 \pm 4	0.82 \pm 0.10	0.35	0.94	0.80	
1053 \pm 3 ^{b)}	1053.1	11 \pm 3						
1121 \pm 2 ^{b)}	1121.3	9 \pm 3						
1127.8 \pm 0.5 ^{a)}	1127.8	106 \pm 6	13 \pm 3	0.60 \pm 0.15	0.30	0.76	0.66	
1199.1 \pm 0.6 ^{a)}	1198.9	106 \pm 8	13 \pm 4	0.60 \pm 0.20	0.27	0.66	0.58	
1222.8 \pm 0.6 ^{a)}	1222.4	61 \pm 6	8 \pm 3	0.65 \pm 0.25	0.26	0.63	0.56	
1394.2 \pm 1.0 ^{b)}	1393.8	17 \pm 6						
1527.0 \pm 1.0 ^{b)}	1527.3	155 \pm 5						
1565 \pm 2 ^{b)}	1564.9	8 \pm 4						
1572.1 \pm 1.0 ^{b)}	1572.0	70 \pm 5						
1691 \pm 2 ^{b)}		0.5 \pm 0.2						
1722.1 \pm 1.2 ^{b)}	1722.2	15 \pm 1						
1770 \pm 2 ^{b)}	1770.2	0.6 \pm 0.2						
1793 \pm 2 ^{b)}	1793.5	0.6 \pm 0.2						
1837.9 \pm 1.2 ^{b)}	1838.4	20 \pm 2						
2082 \pm 2 ^{b)}		0.20 \pm 0.06						

a) Energies measured by Scheuer *et al.*²⁾.

b) Present measurements.

c) Values are normalized to the E2 theoretical conversion coefficient of the 512 keV transition.

d) Theoretical values from Sliv and Band¹⁶⁾.

Most of the measurements were performed with a $4\text{ cm}^2 \times 5\text{ mm}$ Ge(Li) detector and a 1600-channel analyser (see fig. 1). A few runs were measured with a $4\text{ cm}^2 \times 3\text{ mm}$ detector. The energy of the transitions determined by Scheuer *et al.*²⁾ with a precision of about 0.05 % in internal conversion measurements was used as an internal calibration. This calibration was completed using the gamma lines of ^{110m}Ag as an energy standard⁷⁾. The results are given in table 1. We have used the gamma-ray intensities obtained here and the internal conversion intensities of Scheuer *et al.*²⁾ to calculate the K-conversion coefficients (cc) relative to the cc of the 512 keV ground-state transition for which its theoretical E2 cc was adopted.

3. Discussion

With the exception of a few weak lines reported by Smith⁸⁾ in internal conversion measurements, all the known lines were observed. It was not possible to confirm that the 717 keV transition is double, as was suggested by Scheuer *et al.*²⁾, who reported 716 keV conversion electrons. In the following discussion, we assume that all the observed gamma intensity belongs to the 717 keV transition.

Precise energy values were given to 14 transitions which had no previous internal conversion determinations or were unknown. Of 44 transitions, 42 were placed in the decay scheme of fig. 2. In table 1 we have given the "adjusted" values of the energies, which have been obtained as the difference between level energies. A comparison between measured and adjusted values shows that the fit is very good. The existence of most of the levels may now be asserted from only energy relations. With the present precision of the energy values, we have considered that a state may be definitively placed in the decay scheme when it is fed or de-excited by five or more known transitions.

The levels for which additional support is required are at 2083.8, 2282.0 and 2365.2 keV.

A second test for the decay scheme is the intensity balance. The difference between incoming and outgoing intensities is less than 10 % of the latter for all levels up to the 2350 keV level. Errors in the intensity measurements and eventually weak electron capture feedings to these levels can account for these differences. The main feedings are to the two highest states. No definitive conclusions may be derived on the existence of the 2282 and 2365 keV levels.

The conversion coefficients show that the 229, 451 and 748 keV transitions have an E1 multipolarity. All other transitions for which cc are given have an M1 and/or an E2 character. Earlier studies⁸⁾ attributed an M1 and/or an E2 character to all transitions but the 808 keV gamma ray. The present results fit a level scheme where spin and parity 3^- and 4^- are given to the 2083.8 keV and 2305.3 keV levels, respectively. In a Coulomb excitation study¹⁰⁾, a value of $2086 \pm 16\text{ keV}$ was found for a 3^- state. All other levels have positive parity. The spin 5 of the 2756 keV level is based on the assignment of Robinson *et al.*⁹⁾ from angular correlation measure-

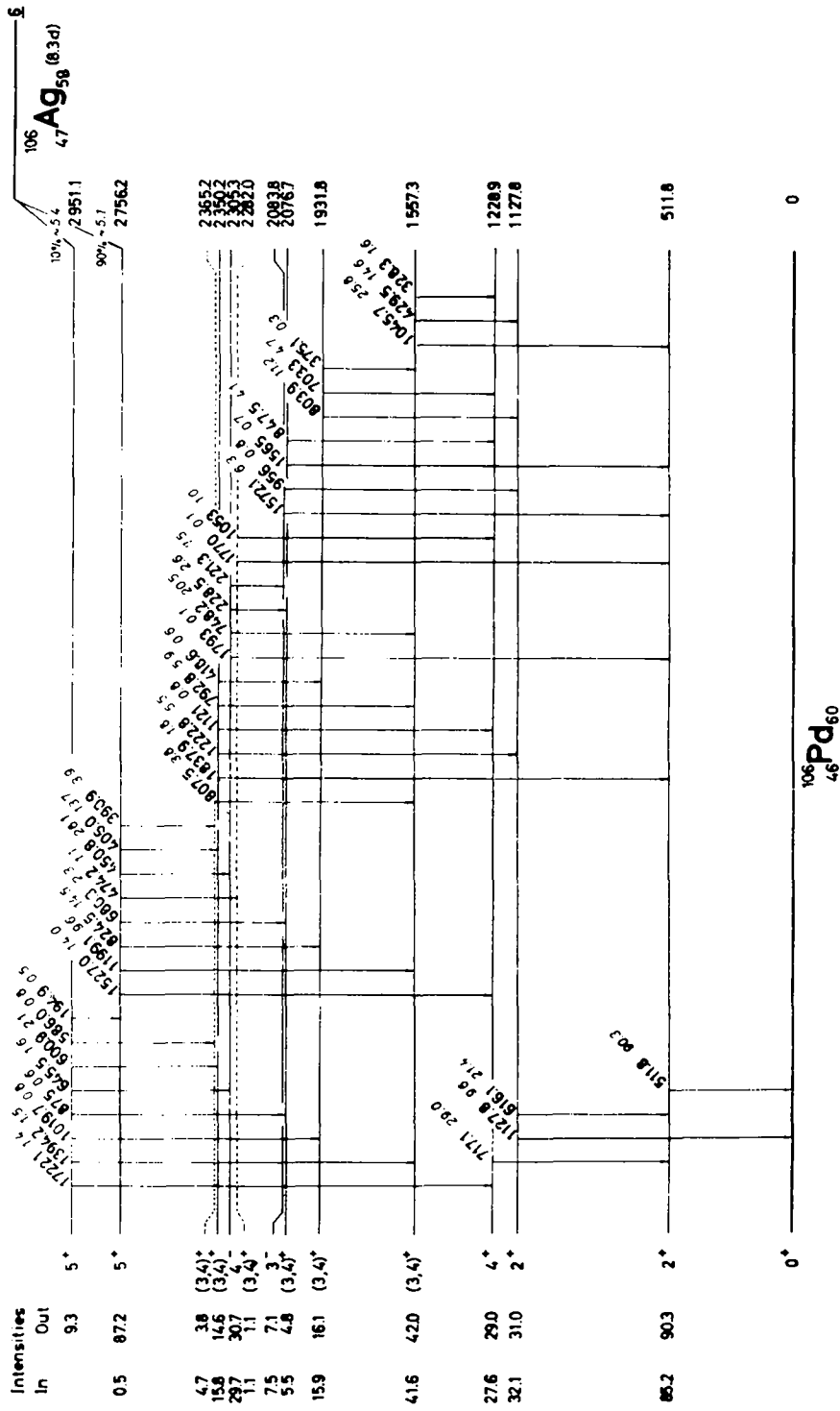


Fig. 2. Decay scheme of ^{106m}Ag . A Q -value of 3.1 MeV was assumed ⁽¹³⁾ for calculating the $\log ft$ value.

ments. The beta feeding to the 2951 keV state suggests a spin 5 or 6 for it, but we have kept the first value, since it is not probable that the 645 keV gamma ray has an M2 multipolarity. We have excluded spin 5 and 6 for the other levels, otherwise a higher feeding to these states should be expected. The spins of the three lowest excited levels are known from angular correlation and Coulomb excitation measurements ^{11,12}).

The grants of the Argentine Research Council (CNICT) and of Esso S.A.P.A., who provided electronic equipment and the Ge(Li) detector, are gratefully acknowledged.

Note added after completion of manuscript: Two studies of the decay of ^{106m}Ag have been recently reported. Gamma energies and intensities given by Strutz ¹⁴) are in close agreement with our values. In addition, he has observed weak lines at 110, 167, 282 and 1076 keV, but he does not report the lines at 1691, 1770, 1793 and 2082 keV. He presents a decay scheme similar to ours which includes two levels at 1702.8 and 2040.4 keV not shown in this paper. We have proposed instead a level at 2282 keV.

The work published by Bakhru and Preiss ¹⁵) reports the stronger lines we have observed, but several intense lines we did not detect are also shown. Based on the energies of these lines, we have concluded that they belong to the decay of ^{105}Ag .

References

- 1) Nuclear Data Sheets (National Academy of Science, National Research Council, Washington D.C., July 1964)
- 2) W. Scheuer, T. Suter, P. Reyes-Suter and E. Aasa, Nuclear Physics **54** (1964) 221
- 3) E. Y. de Aisenberg and J. F. Suárez, Nuclear Physics **83** (1966) 289
- 4) R. L. Robinson *et al.*, Nuclear Physics **74** (1965) 281
- 5) J. A. Moragues *et al.*, Boletín de la Asociación Física Argentina, 47th meeting (May 1966) and private communication
- 6) P. Reyes-Suter and T. Suter, Boletín de la Asociación Física Argentina, 46th meeting (September 1965) and private communication
- 7) J. A. Moragues, P. Reyes-Suter and T. Suter, Nuclear Physics **A99** (1967) 652
- 8) W. G. Smith, Phys. Rev. **131** (1963) 351
- 9) R. L. Robinson, F. K. McGowan and W. G. Smith, Phys. Rev. **119** (1960) 1692
- 10) R. L. Robinson, J. L. C. Ford, Jr., P. H. Stelson and G. R. Satchler, Phys. Rev. **146** (1966) 816
- 11) P. H. Stelson and F. K. McGowan, Phys. Rev. **121** (1961) 209
- 12) D. Eccleshall, B. M. Hinds, M. J. L. Yates and N. MacDonald, Nuclear Physics **37** (1962) 377
- 13) T. Enns, Phys. Rev. **56** (1939) 872
- 14) K. D. Strutz, Z. Phys. **201** (1967) 20
- 15) H. Bakhru and I. L. Preiss, Phys. Rev. **158** (1967) 1214
- 16) L. A. Sliv and I. M. Band, Coefficients of internal conversion of gamma radiation (Academy of Sciences of the USSR, Moscow-Leningrad, 1956-1958)