Conversion Electrons of ^{116}In following Neutron Capture

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The reaction ^{115}In(n,e)^{116}In has been measured with the beta spectrometer at the FRM reactor in Munich. Multipolarities of 44 transitions up to 600 keV have been determined. The spin and parity assignments in the level scheme of Rabenstein et al. are verified by this measurement. New spins and parities could be assigned to 6 levels.

1. Introduction

The nucleus ^{116}In has been examined recently by (n,γ) and (n,$\gamma\gamma$) experiments[1–4]. But few results of the ^{115}In(n,e)^{116}In reaction were available[2, 5]. Therefore, spins and parities could not be assigned to several levels. A check of the spin and parity assignments by Rabenstein et al.[1] was desirable.

The structure of ^{116}In can be calculated assuming one proton hole and a quasineutron coupled to ^{116}Sn. If the spin and parity of a level has been determined experimentally, it may be possible to decide to which multiplet of states the level belongs.

2. Experiment and Evaluation

Conversion electrons of the ^{115}In(n,e)^{116}In reaction were measured with the beta spectrometer at the FRM reactor at Munich[6–8]. The spectrum was scanned repeatedly in the energy range between

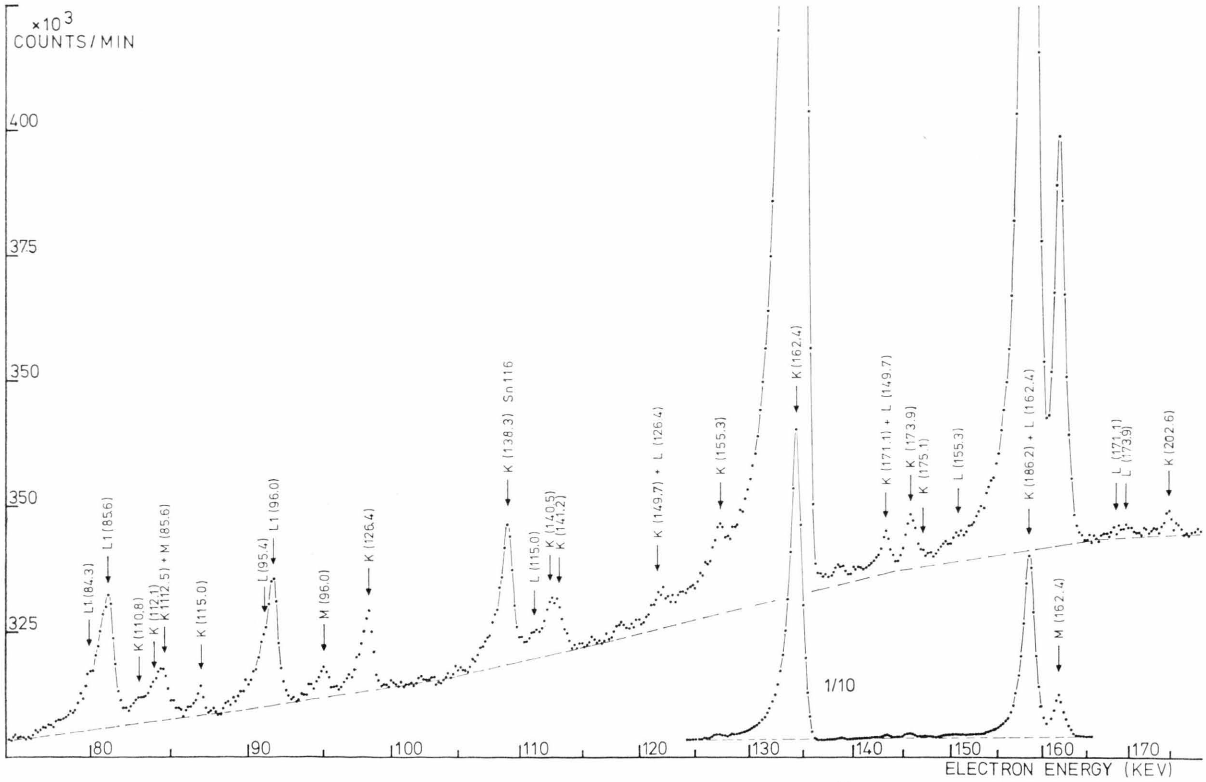

Fig. 1. Part of the conversion electron spectrum of ^{116}In.

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* Extracted from Ph. D. thesis.

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Table 1. Conversion electron lines of ^{116}In.

										α theor.				
E_γ	I_γ ^{d}	shell	E_e	ΔE_e	E_{trans}	I_e ^{d}	ΔI_e	α_{exp}	$\Delta\alpha_{exp}$	E_1	E_2	M1	Multipolarity	Comment ^{a}
22.78 ^{e}	45 (15)	L1	18.57	0.02	22.81	80	10	(1.8)	(0.6)	0.67	2.70	3.88	M1	$I_\gamma = 22 \pm 4$ ^{b}
		L2				<6		<0.3		0.26	134.6	0.315		
		L3				<6		<0.3		0.42	205.6	0.084		
		M	22.01	0.02	22.84	19	2	(0.42)	(0.15)	0.26	28.0	0.81		
42.20	1.3 (3)	K	14.13	0.10	42.07	7	3	5.4	2.5	1.67	13.9	5.39	M1(+<3% E2)	
		L1	37.80	0.10	42.04	2.0	1.0	1.5	0.8	0.15	1.16	0.63		
		L3				<0.5		<0.4		0.050	9.23	0.012		
45.11	1.1 (3)	K	17.08	0.10	45.02	10	3	9.	4.	1.39	11.96	4.44	M1(+<5% E2)	$I_\gamma = 2.3 \pm 0.8$ ^{b}
		L1	40.84	0.07	45.08	1.2	0.4	1.1	0.4	0.12	0.99	0.52		
		L3				<0.7				0.040	6.60	0.010		
60.916 $^{e, i}$	115 (20)	K	32.97	0.01	60.91	210	5	1.9	0.2	0.61	5.42	1.85	M1(+<2% E2)	
		L1	56.68	0.01	60.92	31	8	0.27	0.10	0.057	0.45	0.22		−K (84.307)
		L3				<7		<0.06		0.014	1.46	0.041		
		M	60.17	0.03	60.99	7	1	0.06	0.02	0.015	0.61	0.045		
76.757	2.7 (4)	K	48.86	0.05	76.80	6.5	2	2.4	0.8	0.32	2.69	0.95	M1+E2	
		L				<0.5		<0.2		0.041	1.05	0.12		
82.312	0.9 (2)	K	54.34	0.03	82.28	2.8	1.5	3.0	1.5	0.26	2.16	0.77	E2 (+M1)	
		L				<0.4		<0.5		0.033	0.77	0.097		
84.307	4.5 (6)	K				<5		<1.0		0.25	2.00	0.72	M1(+<25% E2)	
		L1	80.08	0.15	84.32	0.5	0.2	0.1	0.04	0.024	0.18	0.084		
		L3				<0.3		<0.06		0.004	0.29	0.0015		
		M				<0.3		<0.06		0.006	0.14	0.018		
85.568 ^{i}	154 (11)	K	57.61	0.02	85.55	101	5	0.66	0.005	0.24	1.91	0.69	M1(+<5% E2)	
		L1	81.38	0.04	85.62	11.8	1.0	0.08	0.01	0.023	0.17	0.08		
		L3				<0.9		<0.006		0.004	0.27	0.001		
		M	84.67	0.04	85.50	4.0	1.0	0.026	0.006	0.005	0.13	0.017		+K (112.45)
95.378	4.3 (4)	K				<4		<0.9		0.17	1.34	0.51	M1, E2	
		L	91.0	0.2	95.24	0.6	0.3	0.07	0.07	0.022	0.40	0.065		
96.038	68 (4)	K	68.10	0.02	96.04	82	1	0.47		0.17	1.31	0.50	M1	−K (95.38)
96.065	107 (6)	L1	91.85	0.02	96.09	10	1	0.057	0.006	0.017	0.12	0.058	M1	
		L3				<0.8				0.003	0.15	0.001		
		M	95.23	0.04	96.06	1.8	0.4	0.010	0.003	0.004	0.078	0.012		
110.776	1.8 (2)	K	82.97	0.10	110.91	1.0	0.3	0.5	0.2	0.11	0.82	0.33	M1 (+E2)	
112.454	6.9 (6)	K	84.6	0.1	112.5	4.0	0.5	0.58	0.08	0.11	0.78	0.32	(M1)	+M (85.57)
		L				<0.3		<0.034		0.013	0.20	0.040		
114.995	3.3 (3)	K	87.0	0.1	114.94	2.2	0.3	0.67	0.10	0.10	0.72	0.30	E2 (+<20% M1)	
		L	111.1	0.4	115.3	0.4	0.15	0.13	0.05	0.012	0.18	0.038		
126.370	25.5 (12)	K	98.43	0.02	126.37	5.1	0.3	0.20	0.02	0.078	0.53	0.23	M1 (+<10% E2)	
		L1	122.10	0.05	126.34	1.3	0.3	0.05	0.02	0.0078	0.049	0.027		+K (149.668)
		L3				<0.3		<0.01		0.001	0.039	0.0004		
140.454	13.7 (15)	K	112.50	0.05	140.44	4.1	0.5	0.14	0.06	0.058	0.37	0.17	M1	
141.169	15.2 (17)	K	113.24	0.05	141.18								M1	
		L				<0.3		<0.02		0.007	0.079	0.021		
149.668	4.0 (3)	K	122.10	0.05	150.04	0.6	0.2	0.15	0.06	0.048	0.30	0.14	M1 (+E2)	−L1 (126.37)
155.267	14.6 (20)	K	127.29	0.04	155.23	1.7	0.2	0.12	0.02	0.043	0.26	0.13	M1(+<10% E2)	
		L	150.9	0.1	155.14	0.4	0.15	0.03	0.01	0.005	0.052	0.016		

Table 1.

										α theor.				
E_γ	I_γ [d]	shell	E_e	ΔE_e	E_{trans}	I_e [d]	ΔI_e	α_{exp}	$\Delta\alpha_{exp}$	E_1	E_2	M1	Multipolarity	Comment [a]
162.390 [e, i]	147 (10)	K	134.44	0.02	162.38	161	7	1.1	0.1	0.038	0.22	0.12	E3 [c]	
		L	158.43	0.02	162.67	86	3	0.59	0.06	0.005	0.043	0.014		+K (186.207)
		M	161.76	0.04	162.56	17.8	2	0.12	0.02	0.001	0.0086	0.0028		
171.071	18.0 (15)	K	143.12	0.04	171.06	1.5	0.3	0.08	0.03	0.033	0.19	0.10	M1(+<20% E2)	
		L				<0.5		<0.03		0.004	0.035	0.012		
173.89	20 (3)	K	145.83	0.06	173.77	2.1	0.2	0.11	0.03	0.032	0.18	0.096	M1(+<15% E2)	
		L				<0.3		<0.015		0.004	0.033	0.012		
175.063	5.3 (6)	K	147.3	0.2	175.2	0.32	0.15	0.06	0.03	0.031	0.17	0.094	E1 (M1)	
186.207 [i]	138 (8)	K	158.43	0.02	186.37	12	3	0.09	0.02	0.026	0.14	0.080	M1(+<10% E2)	−L (162.390)
		L	182.06	0.06	186.30	1.4	0.1	0.010	0.001	0.003	0.025	0.010		
202.602	10.6 (6)	K	174.4	0.2	202.34	0.7	0.2	0.07	0.02	0.02	0.106	0.064	M1 (+E2)	
213.635	3.0 (4)	K	185.65	0.15	213.59	0.2	0.15	0.06	0.05	0.018	0.088	0.055	M1, E2, E1	−M (186.207)
216.485	3.4 (4)	K	188.5	0.2	216.44	0.5	0.2	0.14	0.05	0.017	0.084	0.054	E2	−K (190.5) ^{114}In
234.599	4.9 (6)	K	207.17	0.08	235.11	1.04	0.10	0.047	0.008	0.014	0.064	0.043	M1, E2	
235.274	17.3 (9)												M1 (+E2)	
272.962 [e]	197 (9)	K	245.05	0.04	272.99	5.3	0.2	0.027	0.002	0.0091	0.039	0.029	M1	
		L	268.6	0.2	272.84	0.81	0.1	0.004	0.001	0.001	0.0060	0.0035		
284.898	27 (1)	K	256.8	0.1	284.74	0.71	0.05	0.026	0.003	0.008	0.034	0.026	M1(+<15% E2)	
290.945	13.6 (6)	K	263.0	0.2	290.94	0.62	0.10	0.045	0.010	0.008	0.032	0.025	E2	
293.65	5.2 (10)	K	265.7	0.4	293.64	0.21	0.08	0.04	0.02	0.008	0.031	0.024	E2, M1	
295.49	17.2 (11)	K	267.5	0.4	295.44	0.35	0.1	0.020	0.006	0.007	0.030	0.023	M1 (+E2)	
298.654 [e]	55 (3)	K	270.75	0.10	298.69	1.3	0.1	0.024	0.002	0.007	0.029	0.023	M1 (+<20% E2)	
		L	294.3	0.5	298.54	0.23	0.1	0.004	0.002	0.0008	0.0042	0.0028		
320.902	8.5 (6)	K	292.7	0.3	320.6	0.45	0.05	0.05	0.01	0.0059	0.023	0.019	M1, E2	+K(319.4, 321.6)
335.45	59 (4)	K	307.6	0.10	335.5	0.93	0.06	0.016	0.002	0.0053	0.020	0.017	M1(+<30% E2)	
337.700	16.1 (16)	K	310.2	0.5	338.1	0.28	0.06	0.018	0.004	0.0052	0.020	0.017	M1, E2	
384.425	15.5 (15)	K	357.14	0.1	385.08	0.73	0.07	0.009	0.001	0.0037	0.013	0.012	(E1)	
385.091	64 (6)	L	381.0	1.0	385.24	0.3	0.1	0.0040	0.0015	0.0004	0.0018	0.0014	M1, E2	
433.706	35.4 (16)	K	405.3	0.4	433.3	0.3	0.1	0.008	0.003	0.0028	0.0091	0.0090	M1, E2	
471.822	25.2 (13)	K	443.3	0.5	471.2	0.2	0.1	0.008	0.004	0.0022	0.0071	0.0073	M1, E2	
492.516	17.7 (13)	K	464.0	0.7	492.0	0.13	0.06	0.007	0.004	0.0020	0.0063	0.0066	M1, E2	
517.95	17 (2)	K	489.0	0.9	517.0	0.10	0.07	0.006	0.004	0.0018	0.0055	0.0058	M1, E2	
556.15	10 (5)	K				<0.08		<0.003		0.0015	0.0045	0.0049		
556.8	20 (5)												E1	

[e] used for energy calibration
[i] used for intensity calibration
[a] + means that the intensity of this line has not been substracted — means that the intensity of this line has been substracted
[b] values of I_γ obtained by extrapolation of the intensity calibration
[c] E3 conversion coefficient: K: 1.10; L: 0.51; M: 0.10
[d] per 1000 neutron-capture

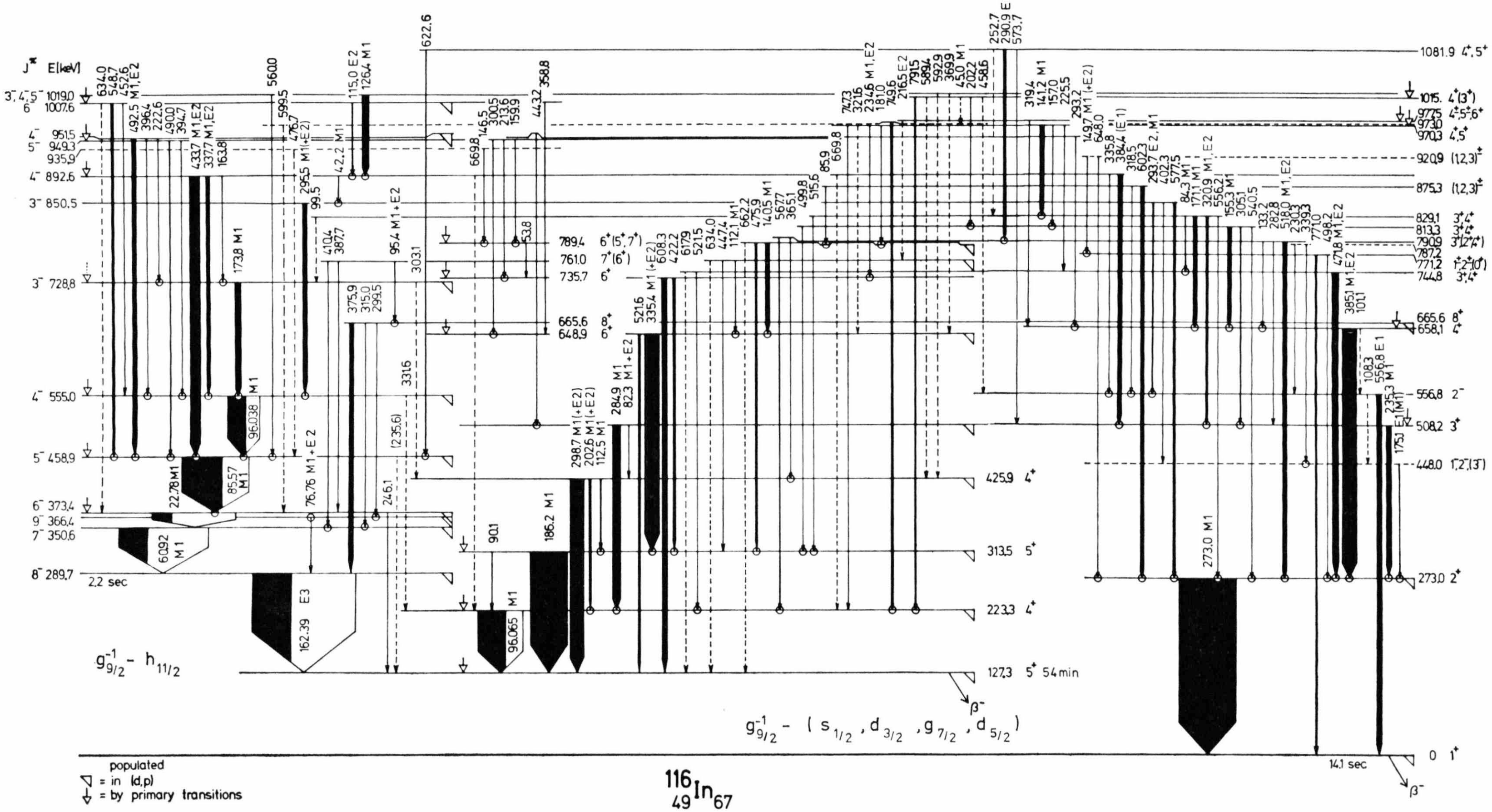

Fig. 2. Level scheme of ^{116}In from Ref. [1], extended by the multipolarities of the transitions and the new spin and parity assignments.

0 keV and 600 keV. For energies below 50 keV the target was biased with -12 kV to preaccelerate the electrons. Two targets of natural indium were used with an area of 10×80 mm^2 and a thickness of 0.29 and 0.55 mg/cm^2, respectively. The resolution was only about 0.4%, because a large slit (2×10 mm^2) was used before the detector to increase the intensity. A part of the conversion electron spectrum is shown in Figure 1.

The energies of the conversion electron lines were calibrated with the following γ lines[2]: 22.802, 60.915, 162.390, 272.962 and 298.657 keV.

The conversion electron intensities were corrected for absorption in the detector window and calibrated with the γ-intensities of Ref. [1] and with the calculated conversion coefficients[9] using these lines:

K 60.916 (M1 + <2% E2), $I_\gamma = 115$
$L_{1,2,3}$ 60.915 (M1 + <2% E2) +
K 84.307 (M1 + <25% E2) +
K 85.568 (M1 + <5% E2),
$I_\gamma = 115$; 4.5; 15.4
K 162.390 (E3), $I_\gamma = 147$
K 186.207 (M1 + <10% E2) +
$L_{1,2,3}$ 162.390 (E3), $I_\gamma = 137$; 147

The multipolarities of these transitions, especially the E2 admixtures, were estimated from the L intensities. In the case of the 60.915 keV transition the E2 admixture was determined from the energy of the total L line. Since the γ-intensities of Ref. [1] are absolute intensities per 1000 neutron captures with an error of 12%, the electron intensities in Table 1 correspond to absolute intensities per 1000 captures within about 14%.

The results of the measurement are listed in Table 1. The γ-energies were taken from Ref. [1, 2], the γ intensities from Ref. [1], and the theoretical conversion coefficients from Ref. [9]. The conversion electron intensities indicate that the γ-intensities[1] of the 22.78 keV and 45.11 keV lines should be changed to 22 ± 4 and 2.3 ± 8, respectively.

3. Discussion

The level scheme of Rabenstein et al.[1] is shown in Figure 2. The multipolarities confirm the spins and parities given by Rabenstein et al. New exact spin or parity assignments could be made for several levels:

556.8 keV	2^-	951.5 keV	4^-
658.1 keV	4^+ [a]	970.3 keV	$4^+, 5^+$
735.7 keV	6^+ [a]	1007.6 keV	6^- [a]
744.8 keV	$3^+, 4^+$	1019.0 keV	$3^-, 4^-, 5^-$
790.9 keV	3^+ ($2^+, 4^+$) [a]	1081.9 keV	$4^+, 5^+$
850.5 keV	3^- [a]		

[a] These spins and parities agree with the assignments of Ref. [3].

The new spin and parity assignments indicate that there is a multiplet of negative parity states near 1 MeV: 850.5 keV 3^-; 892.64keV 4^-; 949.3 keV 5^-, 6^-; 951.5 keV 4^-; 1007.6 keV 6^- and 1019.0 keV 3^-, 4^-, 5^-. These levels are connected with each other and with members of the $g_{9/2}{}^{-1} - h_{11/2}$-multiplet by strong M1, E2 transitions. They are not or only weakly populated in the (d,p) reaction. Therefore, these levels may belong to the one phonon vibration coupled to the $g_{9/2}{}^{-1} - h_{11/2}$-multiplet. This is supported by the energy difference to the multiplet.

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[1] D. Rabenstein, D. Harrach, H. Vonach, G. G. Dussel, and R. P. I. Perazzo, Nucl. Phys. **A 197,** 129 [1972].

[2] V. L. Alexeyev, B. A. Emelianov, L. P. Kabina, D. M. Kaminker, J. A. Kondurov, E. G. Lapin, Yu. E. Loginov, V. L. Rumiantsev, S. L. Sakharov, A. I. Smirnov, and Yu. L. Khazov, Conference on Nuclear Structure Study with Neutrons, publ. by Central Research Institute for Physics, Budapest, Contributions p. 82, Aug. 1972.

[3] M. Stefanon, F. Corvi, C. Coceva, and P. Giacobbe, Conference on Nuclear Structure Study with Neutrons, publ. by Central Research Institute for Physics, Budapest, Contributions p. 74, Aug. 1972.

[4] L. V. Groshev, A. M. Demidov, V. I. Pelekhov, L. L. Sokolovskii, G. A. Bartholomew, A. Doveika, K. M. Eastwood, and S. Monaro, Nuclear Data Tables **A 5,** 46 [1968].

[5] M. K. Balodis, V. A. Bondarenko, P. T. Prokofjev, and L. I. Simonova, Sov. J. Nucl. Phys. **1,** 175 [1965].

[6] T. v. Egidy, Ann. Physik **7,** 221 [1962].

[7] E. Bieber, Z. Physik **189,** 217 [1966].

[8] T. v. Egidy, E. Bieber, and Th. W. Elze, Z. Physik **195,** 489 [1966].

[9] R. S. Hager and E. C. Seltzer, Nuclear Data **A 4,** 1 [1968].