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P. Cuzzocrea, S. Notarrigo and E. Perillo: (n, p) CROSS SECTIONS FOR ~14 MeV NEUTRONS. -

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Istituto Nazionale di Fisica Nucleare
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INTRODUCTION. -

In recent years several attempts have been made[75, 42, 48, 23] to discover some trends, regularities or structure effects in (n, p) reaction cross sections against the mass number, the atomic number and the neutron number.

The basis of these attempts are the compilations of the published data, mainly by Erba et al.[42], by Gardner[48], and brought up to December 1964 by Chatterjee[23, 24].

Erba et al.[42] report average cross sections without giving errors nor indicating the averaging method.

Gardner[48] reports the original data, pointing out the minimum and maximum values, but he does not give the mean values.

Chatterjee[23] adds further experimental data to Gardner's compilation, giving weighted means and errors, but sometimes he repeats the same data (see for example ^{11}B, ^{16}O, ^{19}F, ^{27}Al, etc.). Moreover he obtains the means using all the data of excitation functions around 14 MeV, giving in such a way a heavy and incorrect weight to the results of these experiments. In a further compilation[24] he often reports data published by the same authors in various papers (Bullettins

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(x) - Work supported by Euratom-CNEN contract.

of Meetings, Reports, Reviews) as different data. These data are therefore not suitable to attain correct average values.

In order to perform a good analysis it is necessary to start from means obtained by eliminating these above mentioned incorrect procedures i. e., using accurate criteria for the choice of the sets of values.

COMPILATION. -

We have collected in the table shown the data from the literature in the range 13. 9 ÷ 15. 0 MeV available up to June 1967 according to the following criteria:

1) - only data quoting the experimental errors were taken.
2) - In the case of excitation functions the result at 14. 5 MeV neutron energy was taken; if no measurement was reported at this energy, the cross section nearest 14. 5 MeV was accepted.
3) - When various data for the same reaction had been given from the same authors, only the most recent one was taken.
4) - Data showing certain systematic errors (see for example differential measurements at the peak) were rejected.

Column 1 of the table gives the target nucleus. Column 2 gives the stated neutron energy. Column 3 shows the experimental techniques used by the various authors, abbreviated thus: A = activation measurements, E = emulsion-track experiments, D = direct (spectrum) measurements and C = cloud chamber experiments. Columns 4 and 5 give respectively the cross section values and the references to the experimental works.

In column 6 are reported the weighted means which we have calculated, assuming as weights the square reciprocal of the quoted errors:

$$\sigma_{av} = \frac{\sum_i (1/\Delta\sigma_i)^2 \sigma_i}{\sum_i (1/\Delta\sigma_i)^2} .$$

The errors associated with σ_{av} are the internal ones

$$S_{int} = \sqrt{\frac{1}{\sum_i (1/\Delta\sigma_i)^2}}$$

or the external ones

$$S_{ext} = \sqrt{\frac{\sum_i (1/\Delta\sigma_i)^2 (\sigma_i - \sigma_{av})^2}{(N-1)\sum_i (1/\Delta\sigma_i)^2}}$$

(N is the number of measurements), whichever the larger.

The Birge's[x] consistency criterium was adopted i. e., a set of results was taken as consistent if the ratio between the external and the internal error was included in the range $1 \pm (1/\sqrt{2(N-1)})$.

When the sets of experimental data were not consistent we still calculated σ_{av} but these are not reliable values and are shown in brackets. In these cases the value of

$$\sigma_{rel} = \frac{\sum_i (\sigma_i/\Delta\sigma_i)^2 \sigma_i}{\sum_i (\sigma_i/\Delta\sigma_i)^2}$$

can be assumed as the mean[o]. σ_{rel} were calculated using all the data and assuming as weights the square reciprocal of the relative reported errors. The values are shown in column 7. The errors associated with σ_{rel} are the relative ones

$$S_{rel} = \frac{\sum_i (\Delta\sigma_i/\sigma_i)^2}{N-1}.$$

In the last column are shown the ratios ε between the maximum and the minimum values, calculated by taking into account all the experimental data and their errors. They give a clear indication of the spread, sometimes vary large, of the various measured cross sections. The average value of ε, obtained from the table eliminating the case of ^{197}Au is about 5.

REMARKS AND COMMENTS. -

The first thing which is evident from our compilation is the lack of data for a large set of nuclei, mainly the noble gases and the isotopes in the regions between Ga(Z=31) and Se(Z=34), Rh(Z=45) and Te(Z=52) and from Nd(Z=62) on. Further, in these regions the few measurements performed have not been repeated. Therefore it would be advisable to get experimental data on all these isotopes in order to have a more complete set to recognize trends or regularities.

(x) - See the original paper of Birge published in Physical Review 40, 207 (1932).

(o) - See note added in proof.

Also, the situation is not clear for other elements, as the existing data are greatly scattered. Moreover the partial series of measurements performed sometimes show different trends against N (see for example the case of Sn with the results of Chursin et al. [27] and of Brzoski et al. [20, 21]). Complete series of measurements performed under the same experimental conditions are needed to obtain more reliable data.

The region of Barium, Lanthanium, Cerium, Praseodimium and Neodimium is also a dark one as these elements do not follow the general trends described by Gardner[48]. Also in this case complete series of measurements under the same conditions are needed to clarify the situation and we are now making them[36, 37].

In conclusion we can say that, in spite of the large number of published data, the situation is not as good as one would expect.

In fact, as the data are not sufficient on wide ranges of Z, the possibility of checking the existence of trends, regularities or structure effects for all the stable isotopes becomes especially difficult.

NOTE ADDED IN PROOF.

The correct statistical method to calculate means and errors in the cross sections if the experimental data are not consistent, is to introduce average systematic errors (see for instance: Parrat-Probability and Experimental Errors in Science - Wiley (1961); P. G. Guest-Numerical Methods of Curve Fitting - Cambridge Univ. Press (1961)). This leads with complicated calculations to results very similar to those obtained as σ_{rel}. Therefore these average values are reliable. A more detailed explanation will be given in a next report on the (n, α) cross sections.

Table: Experimental and averaged (n, p) cross sections

Target nucleus	E_n (MeV)	Tecnique	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{6}Li	14. 1 ± 0. 1	A	6.7 ± 0.8	(7, 8)	6.6 ± 0.7	6.6 ± 2.3	2. 0
	14. 1 ± 0. 5	E	6 ± 2	(45)			
^{11}B	14. 7 ± 0. 15	A	3.3 ± 0.6	(67)	3. 3 ± 0. 6		---
^{12}C	14. 8	?	19 ± 4	(43)	(2. 06)	9.3 ± 2.1	13. 7
	14. 7 ± 0. 15	A	19 ± 4	(67)			
	14.92± 0. 48	A	1.93 ± 0.25	(74)			
^{14}N	14. 7	A	77 ± 14	(34)	77 ± 14		---
^{16}O	14. 1 ÷ 14. 8	A	83 ± 25	(80)	(35. 1)	37.8 ± 10.4	3. 33
	14. 5	A	49 ± 25	(90)			
	14. 7 ± 0. 1	A	40.1 ± 2.7	(84)			
	14.53± 0. 14	A	38.9 ± 4.0	(14)			
	14. 7 ± 0. 15	A	38.2 ± 5	(67)			
	14. 4	A	34 ± 6	(111)			
	14.76± 0. 16	A	33.3 ± 2.4	(39)			
	14. 1	C	15 ± 5	(31)			
^{19}F	14. 5	A	135 ± 50	(90)	(17. 5)	18.8 ± 2.6	15. 7
	14. 7 ± 0. 1	A	23.3 ± 2.8	(84)			
	14. 7	A	21 ± 3	(34)			
	14. 1 ± 0. 3	A	19.9 ± 1.3	(13)			
	14. 3 ± 0. 2	A	18.2 ± 2	(94)			
	14. 7	A	16.4 ± 0.7	(89)			
	14. 7 ± 0. 15	A	14.3 ± 2.5	(67)			
^{23}Na	14. 8	A	45 ± 5	(71)	(37. 9)	40.3 ± 10.5	10. 0
	14. 7 ± 0. 1	A	41.8 ± 3.8	(84)			
	14. 7	A	41 ± 1. 2	(89)			
	14. 3 ±0. 2	A	39 ± 8	(94)			
	14. 7	A	39 ± 4	(34)			
	14. 5	A	34 ± 15	(90)			
	14. 8	A	29 ± 3	(85)			
	14	D	9 ± 4	(10)			
^{24}Mg	15. 0 ± 0. 4	A	203 ± 11	(38)	(183)	185 ± 21	2. 09
	.14 ÷ 14. 6	A	195 ± 10	(29)			
	14. 5	A	191 ± 35	(90)			
	~14. 5	A	189 ± 12	(91)			
	~14. 5	A	182 ± 10	(22)			
	14. 7	A	182 ± 5	(89)			
	14. 5	A	180 ± 30	(63)			
	14. 5 ± 0. 2	A	177 ± 18	(47)			
	14	E	118 ± 16	(2)			

6.

Target nucleus	E_n (MeV)	Tecnique	σ exp (mb)	Ref.	σ av (mb)	σ rel (mb)	ε
^{25}Mg	14	E	67 ± 10	(2)	(57.1)	61.7 ± 14.5	2.85
	14.7	A	66 ± 3	(89)			
	14.8	A	60 ± 10	(88)			
	14.5	A	45 ± 18	(90)			
	14.74 ± 0.20	A	40 ± 4	(14)			
^{26}Mg	14.8	A	50 ± 5	(88)	(42.2)	47.0 ± 13.1	2.75
	14	E	27 ± 7	(2)			
^{27}Al	14	A	115 ± 10	(69)	(74.0)	80.9 ± 11.4	4.46
	14.7 ± 0.1	A	97 ± 10	(83,84)			
	14.4	D	93 ± 10	(58)			
	14.1	D	90 ± 18	(112)			
	13.9	A	88 ± 13	(16)			
	14	E	87 ± 11	(2)			
	14.5 ± 0.8	A	87 ± 8	(66,67)			
	14.1 ± 0.2	A	87 ± 7	(121)			
	14.1 ± 0.2	A	85 ± 3	(109)			
	14.8	A	81 ± 10	(61)			
	14.1	A	81 ± 5	(95)			
	14.1	A	79 ± 6	(44)			
	14.8	A	77 ± 8	(85)			
	14.6	A	72 ± 5	(33)			
	~14	?	71 ± 10.6	(115)			
	~14	E	70 ± 14	(1)			
	14.5 ± 0.5	A	62 ± 8	(78)			
	14.1 ± 1.0	E	61 ± 14	(56)			
	15.0 ± 0.4	A	59 ± 6	(38)			
	14.8	A	53 ± 5	(97)			
	14.5	A	52.4 ± 10	(90)			
	14.4 ± 0.2	A	42 ± 10	(47)			
	14	D	36 ± 6	(116)			
^{28}Si	14.2 ÷ 14.8	A	355 ± 40	(68)	(205)	217 ± 26	2.74
	14	E	243 ± 22	(2)			
	14.8 ± 0.1	A	222 ± 12	(83,84)			
	14.7	A	222 ± 12	(89)			
	14.5	A	220 ± 50	(90)			
	14.5 ± 0.4	A	190 ± 15	(29)			
	14.8	A	180 ± 18	(71)			
	14.8	A	170 ± 20	(65)			
	14.4	D	160 ± 16	(58)			

Target nucleus	E_n (MeV)	Tecnique	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{29}Si	14.5	A	101 ± 30	(90)	(22.8)	24.4 ± 7.3	6.04
	14.7	A	22.7 ± 1	(89)			
^{31}P	~14	E	184 ± 14	(2)	(70.2)	84.2 ± 8.9	3.19
	~14	A	120 ± 12	(28)			
	14.1	A	91 ± 9	(44)			
	14.10 ± 0.04	A	86 ± 7	(55)			
	14.7 ± 0.15	A	82 ± 10	(67)			
	14.5	A	64 ± 9	(90)			
	14.7	A	64 ± 2	(89)			
^{32}S	14.5	A	369 ± 45	(90)	(227)	243 ± 31	2.67
	14	E	365 ± 25	(2)			
	14.8	A	352 ± 40	(71)			
	14.1 ÷ 14.9	A	230 ± 15	(3)			
	14	A	220 ± 40	(76)			
	14.7	A	215 ± 6	(89)			
	14.1	D	185 ± 30	(41)			
^{34}S	14.5	A	85 ± 40	(90)	(78.2)	78.3 ± 37.6	2.78
	14.00 ± 0.22	A	78 ± 7.5	(14)			
^{35}Cl	14.3	?	140 ± 35	(62)	(125)	126 ± 46	2.69
	14	E	125 ± 38	(2)			
	14.8	A	122 ± 56	(110)			
	14.6 ± 0.2	A	121 ± 20	(86)			
^{37}Cl	14.8	A	40 ± 4	(71)	(25.7)	27.2 ± 4.2	2.39
	14.4 ± 0.3	A	38 ± 8	(29)			
	14.5	A	33 ± 7	(90)			
	14.7	A	25.5 ± 1.2	(89)			
	14.8	A	25.4 ± 2.1	(110)			
	14.8 ± 0.1	A	21.3 ± 2.1	(84)			
^{40}Ar	~14	?	25 ± 2	(52)	25 ± 2		---
^{39}K	14	D	354 ± 54	(10)	354 ± 54		---
^{41}K	14.8	A	88 ± 9	(71)	(35.5)	54.6 ± 15.6	4.07
	14.5	A	81 ± 33	(90)			
	14.7 ± 0.2	A	69 ± 17	(18)			
	14.7	A	30.5 ± 2.5	(89)			
^{40}Ca	14	E	451 ± 38	(2)	451 ± 38		

Target nucleus	E_n (MeV)	Tecni que	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{42}Ca	14.6 ± 0.2	A	182 ± 21	(86)	(172)	173 ± 40	2.14
	14.7	A	173 ± 12	(34)			
	~14	A	160 ± 30	(76)			
	14.9	A	140 ± 45	(59)			
^{43}Ca	14.6 ± 0.2	A	110 ± 14	(86)	103 ± 7	103 ± 16	1.33
	14.7	A	101 ± 8	(34)			
^{44}Ca	14.8	A	91 ± 20	(71)	(41.7)	50.8 ± 16.9	8.54
	14.7	A	45 ± 6	(34)			
	~14	A	37 ± 7	(76)			
	14.9	A	25 ± 12	(59)			
^{45}Sc	14.7	A	57 ± 8	(34)	(57)	57 ± 8.9	1.33
	14.54± 0.20	A	57 ± 4	(101)			
^{46}Ti	14.7 ± 0.7	A	324 ± 100	(73)	(254)	262 ± 46	2.33
	~14.5	A	295 ± 20	(77)			
	14.1 ± 0.3	A	257 ± 17	(13)			
	14	E	203 ± 21	(2)			
	14.8 ± 0.1	A	253 ± 24	(126)			
^{47}Ti	14.8 ± 0.9	A	230 ± 40	(97)	(115)	123 ± 22	3.42
	14	E	112 ± 15	(2)			
	14.5 ± 0.5	A	99 ± 20	(60)			
	14.8 ± 0.1	A	114 ± 7	(126)			
^{48}Ti	14.5	A	93 ± 33	(90)	(38.2)	50.6 ± 10.5	4.67
	14.1 ÷ 14.6	A	65 ± 10	(47)			
	14	A	58 ± 8	(97)			
	14.5 ± 0.5	A	55 ± 11	(60)			
	14	E	29 ± 2	(2)			
	14.8 ± 0.1	A	63 ± 4	(126)			
^{49}Ti	~14	A	97 ± 16	(69)	(34.5)	44.1 ± 9.5	4.71
	14	E	29 ± 8	(2)			
	14.8 ± 0.9	A	29 ± 5	(97)			
	14.8 ± 0.1	A	35 ± 3	(126)			
^{50}Ti	~14	A	147 ± 13	(69)	(17.5)	92 ± 30	26.67
	14.7 ± 0.2	A	28 ± 12	(18)			
	14.7 ± 0.7	A	9 ± 3	(73)			
	14.8 ± 0.1	A	17.9 ± 2	(126)			

Target nucleus	E_n (MeV)	Tecni que	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{51}V	14.7 ± 0.2	A	55 ± 12	(18)	(25.4)	31.9 ± 6.4	5.15
	14.8	?	53 ± 5	(96)			
	14.5	A	27 ± 5	(90)			
	14.8	A	25 ± 3	(71)			
	14.7 ± 0.1	A	24.7 ± 2.2	(83,84)			
	14.2 ± 0.1	A	21 ± 2	(12)			
	14	E	20 ± 7	(2)			
^{50}Cr	14	E	265 ± 21	(2)	265 ± 21		---
^{52}Cr	14.8	A	118 ± 16	(71)	(86)	88.9 ± 11.3	2.09
	14.8	A	105 ± 11	(85)			
	14.55	A	90 ± 10	(68)			
	14.8	?	83 ± 9	(25)			
	14.7 ± 0.1	A	82.8 ± 5.8	(83,84)			
	14.5	A	78 ± 11	(90)			
	14	E	74 ± 10	(2)			
^{53}Cr	14	E	44 ± 7	(2)	38.7 ± 3.5	39.2 ± 7.5	1.54
	14.8	?	37 ± 4	(25)			
^{55}Mn	~14	A	110 ± 15	(4)	(38.9)	56.7 ± 8.3	4.63
	14.7 ± 0.1	A	60 ± 6	(83)			
	14	E	43 ± 7	(2)			
	14.7	A	30 ± 3	(82)			
^{54}Fe	14	E	382 ± 13	(2)	(353)	363 ± 47	1.88
	13.5 ± 1	E	376 ± 50	(79)			
	~14	?	368 ± 29	(107)			
	14.1	D	333 ± 67	(112)			
	14.5	A	310 ± 25	(32)			
	14.1	A	254 ± 28	(95)			

Target nucleus	En (MeV)	Tecnique	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{56}Fe	14.1 ± 0.2	A	144 ± 19	(121)	(106)	108 ± 11	2.51
	15.3	?	131 ± 15	(43)			
	15.0 ± 0.4	A	128 ± 13	(38)			
	14.8 ± 0.9	A	128 ± 13	(26)			
	14.1	A	124 ± 12	(44)			
	14.0 ± 0.3	A	113 ± 5	(11)			
	14.1	A	112 ± 6	(95)			
	14.2 ÷ 14.5	A	110 ± 4	(22)			
	14.4 ± 0.2	A	108 ± 10	(47)			
	14.5	A	106 ± 6	(32)			
	14.7 ± 0.4	A	105 ± 3	(114)			
	14.5	A	97 ± 10	(90)			
	14.1	D	90 ± 18	(112)			
	14	E	82 ± 7	(2)			
	14.1	A	72 ± 7	(80)			
	14.42 ± 0.26	A	100 ± 6	(124)			
^{57}Fe	14.8 ± 0.9	A	71 ± 7	(26)	(61.9)	65.2 ± 12.2	1.86
	14.1	A	50 ± 8	(95)			
^{58}Fe	14.8 ± 0.9	A	23 ± 4	(26)	23 ± 4		---
^{59}Co	14.9 ± 0.2	A	122 ± 15	(64)	(80.4)	88.2 ± 18.2	3.34
	14.8 ± 0.9	A	82 ± 8	(100)			
	14	E	81 ± 10	(2)			
	14.5	A	80 ± 23	(118)			
	14.1	D	75 ± 15	(112)			
	14.8	A	53 ± 12	(117)			
^{58}Ni	14.1	A	560 ± 110	(103)	(392)	409 ± 52	2.73
	14.1	D	534 ± 110	(112)			
	14.9 ± 0.2	A	534 ± 70	(64)			
	14.8 ± 0.3	D	490 ± 55	(49)			
	14	E	440 ± 27	(2)			
	14.1 ± 0.25	A	411 ± 30	(14)			
	14.1 ÷ 14.9	A	393 ± 40	(50)			
	14.5	A	316 ± 20	(32)			
	14.8 ± 0.5	A	290 ± 32	(6)			
	14.8 ± 0.9	A	280 ± 35	(100)			
	14.59 ± 0.08	A	418 ± 11	(125)			

Target nucleus	E_n (MeV)	Tecni-que	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{60}Ni	14. 5	A	180 ± 25	(32)	(127)	132 ± 21	1. 86
	14. 1	D	158 ± 32	(112)			
	14	E	124 ± 9	(2)			
	~14. 5	A	120 ± 10	(77)			
^{61}Ni	14. 5	A	181 ± 27	(90)	(25. 9)	79.8 ± 11.3	10. 40
	14. 5	A	103 ± 10	(32)			
	14. 8 ± 0. 9	A	22 ± 2	(100)			
^{62}Ni	14. 5	A	24 ± 6	(32)	(5. 9)	9.4 ± 2.0	6. 25
	14.10± 0.15	A	14.7 ± 2.2	(14)			
	14. 8 ± 0. 9	A	5.3 ± 0.5	(100)			
^{64}Ni	14. 8 ± 0. 9	A	4.5 ± 0.5	(100)	4. 5 ± 0. 5		---
^{63}Cu	14. 1	D	149 ± 30	(112)	120 ± 8.6	122 ± 26	1. 64
	14. 0	E	118 ± 9				
^{65}Cu	14. 1	D	30 ± 6	(112)	(22. 2)	23.7 ± 5.5	2. 77
	14. 7 ± 0. 2	A	29.3 ± 3. 2	(18)			
	14. 1	A	29 ± 5	(95)			
	14. 8	A	29 ± 3	(85)			
	14. 8 ± 0. 9	A	27 ± 11	(97)			
	14. 1 + 14.5	A	25 ± 7	(12)			
	14.	A	20.4 ± 1.1	(108)			
	14. 1	A	19 ± 4	(44)			
	15. 0 ± 0. 4	A	17 ± 4	(38)			
^{64}Zn	14. 5	A	386 ± 60	(90)	(210)	230 ± 34	2. 88
	14	E	295 ± 60	(105)			
	14. 8 ± 0. 9	A	284 ± 20	(100)			
	14. 1	D	277 ± 55	(112)			
	14. 7 ± 0. 2	A	230 ± 30	(18)			
	~14	A	210 ± 40	(76)			
	14. 1 + 14.8	A	210 ± 20	(47)			
	14. 1 ± 0. 1	A	205 ± 15	(12)			
	14	E	179 ± 18	(2)			
	14. 4 + 14.6	A	170 ± 15	(119)			
^{66}Zn	14. 5	A	101 ± 17	(90)	(54)	69 ± 9.6	3.93
	14. 8 ± 0. 6	A	77.4 ± 6.5	(13)			
	14. 8 ± 0. 9	A	77 ± 10	(100)			
	~14	A	75 ± 10	(76)			
	14. 1 ± 0. 2	A	60 ± 7	(121)			
	14	E	34 ± 4	(2)			

Target nucleus	E_n (MeV)	Tecnique	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{67}Zn	~14 14	A E	48 ± 8 41 ± 7	(76) (2)	44.0 ± 5.3	44.6 ± 10.6	1.65
^{68}Zn	14.8 ± 0.9	A	25 ± 10	(100)	25 ± 10		---
^{69}Ga	15.2 14.5	A A	42 ± 3m)? 24 ± 19m)?	(12) (90)	41.6 ± 3.0	42 ± 33	9.00
^{70}Ge	14.5 14.8	A A	129 ± 65 64 ± 13	(90) (71)	66.5 ± 12.7	73 ± 40	3.80
^{72}Ge	14.5	A	65 ± 26	(90)	65 ± 26		---
^{73}Ge	14.5	A	137 ± 70	(90)	137 ± 70		---
^{75}As	14.1 14.1 ± 0.2 14 ~14.5 14.5 ± 0.16 14.5 14.59 ± 0.08	A A E A A A A	115 ± 15 35 ± 7 27 ± 5 18.1 ± 1.3 14.2 ± 1.3 12 ± 2 24.4 ± 1.3	(4) (46) (2) (9) (15) (90) (125)	(18.6)	27.8 ± 4.2	13.0
^{74}Se	14.1 ± 0.25	A	105 ± 20	(14)	105 ± 20		---
^{77}Se	14.5	A	45 ± 23	(90)	45 ± 23		---
^{81}Br	14.6 ± 0.3	A	57 ± 10	(113)	57 ± 10		---
^{86}Sr	14.6 ± 0.3 ~14.5 ~14	A A A	64 ± 7 42 ± 5 39 ± 7	(113) (9) (76)	(47)	51.4 ± 8.8	2.22
^{88}Sr	14.6 ± 0.3 14.5 ~14 14.4 ± 0.2 14.8	A A A A A	30 ± 2 18 ± 4 18 ± 3 17.5 ± 2 11 ± 0.5	(113) (90) (76) (29) (17)	(12.6)	17.1 ± 2.7	3.05
^{89}Y	14.7 ~14.5 14	A A ?	53 ± 5 24 ± 2 14.5 ± 1.5	(34) (9) (57)	(19.8)	30.8 ± 3.5	4.46

m) = only to the metastable state.

Target nucleus	E_n (MeV)	Tecnique	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{90}Zr	14.5	A	247 ± 100	(90)	(45.8)	70.4 ± 18.6	11.57
	14.6 ± 0.3	A	233 ± 29	(113)			
	~14	A	54 ± 10	(76)			
	~14.5	A	44.5 ± 2.2	(9)			
	~14	A	40 ± 10	(19)			
^{91}Zr	14.6 ± 0.3	A	180 ± 43	(113)	(32.1)	37.4 ± 8.3	7.38
	~14	A	40 ± 8	(76)			
	14.1	?	31.7 ± 1.5	(104)			
^{92}Zr	14.6 ± 0.3	A	76 ± 16	(113)	(21)	23 ± 4.6	5.11
	~14	A	25 ± 5	(76)			
	14.7 ± 0.2	A	22 ± 4	(18)			
	14.1	?	20.7 ± 0.9	(104)			
^{94}Zr	14.6 ± 0.3	A	48 ± 12	(113)	(11.0)	21.2 ± 9.1	20.00
	14.5	A	11 ± 4	(90)			
	~14	A	11 ± 2	(76)			
	14.7 ± 0.2	A	7 ± 4	(18)			
^{92}Mo	14.5	A	108 ± 55	(90)	63.3 ± 14.5	69.3 ± 27.4	3.62
	14.7 ± 0.2	A	60 ± 15	(18)			
^{96}Mo	14.7 ± 0.2	A	37 ± 9	(18)	(19.4)	23.3 ± 7.5	3.54
	14.6 ± 0.3	A	21 ± 7	(113)			
	14.1 ± 0.2	A	16 ± 3	(35)			
^{97}Mo	14.8	A	110 ± 20	(17)	(24.4)	55.9 ± 17.5	10.00
	14.5	A	108 ± 54	(90)			
	14.6 ± 0.3	A	68 ± 4	(113)			
	14.1 ± 0.2	A	17.7 ± 1.5	(35)			
^{98}Mo	14.7 ± 0.2	A	9 ± 2	(18)	(7.0)	7.6 ± 1.7	2.74
	14.1 ± 0.2	A	6.7 ± 0.5	(35)			
	14.8	A	14 ± 3	(123)			
^{99}Tc	~14	A	7.0 ± 1.1	(51)	7.0 ± 11		---
^{96}Ru	~14	?	170 ± 30	(53)	170 ± 30		---
^{101}Ru	14.5	A	2.0 ± 1.4	(90)	2.0 ± 1.4		---
^{102}Ru	~14	?	6.7 ± 2.5	(53)	6.7 ± 2.5		---
^{104}Ru	~14	?	7.2 ± 1.0	(53)	7.2 ± 1.0		---

Target nucleus	E_n (MeV)	Tecnique	σ exp (mb)	Ref.	σ av (mb)	σ rel (mb)	ε
^{104}Pd	14.5	A	132 ± 66	(90)	132 ± 66		---
^{105}Pd	14.5	A	743 ± 500	(90)	743 ± 500		---
^{109}Ag	~14.5 ~14.5 ~14 ~14.8	A A A A	14.9 ± 0.7 12.5 ± 1.8 10.5 ± 2 2.7 ± 0.6	(9) (30) (40) (85)	(8.2)	14.0 ± 2.7	7.43
^{106}Cd	~14	A	76 ± 24	(76)	76 ± 24		---
^{110}Cd	14.1	A	27 ± 5.4	(122)	27 ± 5.4		---
^{111}Cd	~14.5 ~14 14.1	A A A	23.7 ± 1.2 15 ± 4 14 ± 1.4	(9) (76) (122)	(19.4)	21.5 ± 4.4	2.26
^{112}Cd	14 14.1	A A	11 ± 3 11 ± 1.1	(76) (122)	(11)	11 ± 3.2	1.75
^{113}Cd	~14 14.1	A A	8 ± 2 7.9 ± 0.8	(76) (122)	(7.9)	7.9 ± 2.1	1.66
^{116}Cd	14.1	A	0.2 ± 0.1	(122)	0.2 ± 0.1		---
^{115}In	14 14.5	E A	20 ± 9 15.5 ± 4	(93) (30)	16.2 ± 3.6	16.6 ± 8.6	2.64
^{112}Sn	14.1 14.5	A A	145 ± 30 10.0 ± 2.6	(72) (27)	(11.0)	93 ± 31	23.65
^{116}Sn	14.2 ± 0.2 14.5	A A	22 ± 5 5.4 ± 1.5	(20) (27)	(6.8)	15.3 ± 5.5	6.92
^{117}Sn	14.1 14.2 ± 0.2	A A	23 ± 5 12 ± 3	(72) (20)	(14.9)	18.3 ± 6.1	3.11
^{118}Sn	14.5 14.2	A A	11.7 ± 2.5 6.2 ± 0.3	(27) (21)		6.5 ± 1.4	2.41
^{119}Sn	14.2	A	8.6 ± 2	(21)	8.6 ± 2		---

Target nucleus	En (MeV)	Tecnique	σexp (mb)	Ref.	σav (mb)	σrel (mb)	ε
^{120}Sn	14.5 14 14.8	A E A	4.6 ± 1.2 4.5 ± 0.3 3.8 ± 1.0	(27) (93) (98)	(4.45)	4.42 ± 1.19	2.07
^{124}Te	14.2 ± 0.2	A	149 ± 40	(20,21)	149 ± 40		---
^{128}Te	14.2 ± 0.2	A	68 ± 19	(20,21)	68 ± 19		---
^{130}Te	14.2 ± 0.2	A	16 ± 6	(20,21)	16 ± 6		---
^{127}I	14 14.5	D A	25 ± 15 12 ± 2	(10) (30)	12.2 ± 2.0	12.9 ± 8.0	4.00
^{133}Cs	14.1 ± 0.1	A	15.3 ± 1.5	(102)	15.3 ± 1.5		---
^{136}Ba	14.8 ± 0.8 14.5	A A	49 ± 10 38 ± 4	(120) (30)	39.5 ± 3.8	40.3 ± 9.2	1.73
^{138}Ba	14.5 14.0 ± 0.2 14.8 ± 0.8 14.5 ~14	A A A A A	6.3 ± 2 3.1 ± 0.2 2.5 ± 1 2.2 ± 0.3 1.9 ± 0.5	(90) (36) (120) (30) (76)	(2.7)	2.98 ± 0.88	5.93
^{139}La	14.5 14.8 ± 0.8 14.0 ± 0.2 14.7 14.5	A A A A A	5.7 ± 2.5 5 ± 1 4.5 ± 0.3 4.5 ± 1.1 2.3 ± 0.3	(90) (120) (36) (34) (30)	(3.5)	4.2 ± 1.2	4.10
^{140}Ce	14.5 14.8 ± 0.8 14.0 ± 0.2	A A A	12.1 ± 1.2 10 ± 2 7.7 ± 0.9	(30) (120) (36)	(9.4)	10.2 ± 1.8	1.96
^{142}Ce	14.5 14.8 ± 0.8 14.0 ± 0.2	A A A	9.4 ± 0.9 5 ± 2 2.7 ± 0.5	(30) (120) (37)	(4.3)	7.86 ± 2.51	4.68
^{141}Pr	14.0 ± 0.2 14.8 ± 0.8	A A	11.5 ± 1.1 4.5 ± 1.0	(36) (120)	(7.7)	10.4 ± 2.5	3.60
^{142}Nd	14.5 14.0 ± 0.2	A A	13.5 ± 2.7 11.9 ± 0.9	(30) (36)	12.1 ± 0.9	12.1 ± 2.6	1.50
^{143}Nd	14.5	A	11.5 ± 2.3	(30)	11.5 ± 2.3		---

Target nucleus	E_n (MeV)	Tecni-que	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{148}Nd	14.8 ± 0.8	A	3.5 ± 0.8	(120)	3.5 ± 0.8		---
^{152}Sm	14.8 ± 0.8	A	3.7 ± 0.2	(120)	3.7 ± 0.2		---
^{154}Sm	14.8 ± 0.8	A	3.5 ± 0.2	(120)	3.5 ± 0.2		---
^{153}Eu	14.5	A	7.4 ± 0.7	(30)	7.4 ± 0.7		---
^{157}Gd	14.5	A	11.3 ± 1.7	(30)	11.3 ± 1.7		---
^{159}Tb	14.7 ± 0.2	A	2.2 ± 1.3	(18)	2.2 ± 1.3		---
^{163}Dy	14.8 ± 0.8	A	3.0 ± 1.0	(120)	3.0 ± 1.0		---
^{165}Ho	14.1 14.1 ± 0.2	A A	41 ± 11 41 ± 10	(27) (46)	(41)	41 ± 15	1.73
^{167}Er	14.8 ± 0.8	A	3 ± 1	(120)	3 ± 1		---
^{168}Er	14.8 ± 0.8	A	2.5 ± 1	(120)	2.5 ± 1		---
^{170}Er	14.8 ± 0.8	A	1.8 ± 0.5	(120)	1.8 ± 0.5		---
^{175}Lu	14.5	A	3.4 ± 0.5	(30)	3.4 ± 0.5		---
^{181}Ta	14	?	2.5 ± 0.3	(106)	2.5 ± 0.3		---
^{182}W	14	?	2.3 ± 0.2	(106)	2.3 ± 0.2		---
^{183}W	14	?	2.8 ± 0.3	(106)	2.8 ± 0.3		---
^{184}W	14.8 14.5	? A	14 ± 4 4.8 ± 1.0	(99) (30)	(5.3)	7.99 ± 2.82	4.74
^{186}W	14.8 14.5 14.5 ± 0.3	? A A	11 ± 4 2.9 ± 0.6 1.4 ± 0.3	(99) (30) (5)	(1.7)	3.4 ± 1.1	13.64
^{187}Re	14.5	A	3.9 ± 0.4	(30)	3.9 ± 0.4		---
^{188}Os	14.6 ± 0.2 14.7	A A	8.7 ± 1.4 7.1 ± 1.9	(86) (34)	8.1 ± 1.1	8.3 ± 2.6	1.94
^{190}Os	14.7	A	2 ± 0.5	(34)	2 ± 0.5		---

Target nucleus	E_n (MeV)	Tecnique	σ_{exp} (mb)	Ref.	σ_{av} (mb)	σ_{rel} (mb)	ε
^{193}Ir	14.5	A	2.7 ± 0.6	(30)	2.7 ± 0.6		---
^{194}Pt	14.5	A	3.9 ± 0.4	(30)	3.9 ± 0.4		---
^{195}Pt	14.5	A	2.9 ± 0.3	(30)	2.9 ± 0.3		---
^{197}Au	14.0 ± 1.2 14.5 $\overline{14.1 + 14.5}$ 13.9	E A A ?	20.5 ± 8.0 2.4 ± 0.2 2.2 ± 0.1 0.20 ± 0.04	(92) (30) (9) (57)	(0.54)	2.3 ± 0.6	178
^{200}Hg	14.5	A	3.6 ± 0.4	(30)	3.6 ± 0.4		---
^{201}Hg	14.5	A	2.1 ± 0.3	(30)	2.1 ± 0.3		---
^{203}Tl	14.8	A	30 ± 10	(99)	30 ± 10		---
^{205}Tl	14.5 14.5 14.8	A A A	6.8 ± 0.7 3.0 ± 1.5 3.0 ± 0.3	(30) (90) (99)	(3.6)	4.8 ± 1.8	5.00
^{208}Pb	14.5	A	0.96 ± 1	(90)	0.96 ± 1		---
^{209}Bi	14.5 14.8 ± 0.9 14.8	A A A	1.3 ± 0.3 0.8 ± 0.4 0.7 ± 0.1	(30) (97) (85)	0.76 ± 0.12	0.81 ± 0.32	4.00
^{235}U	14.5	A	1.9 ± 0.4	(30)	1.9 ± 0.4		---
^{237}Np	14.5	A	1.3 ± 0.3	(30)	1.3 ± 0.3		---
^{239}Pu	14.5	A	3.0 ± 0.5	(30)	3.0 ± 0.5		---

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