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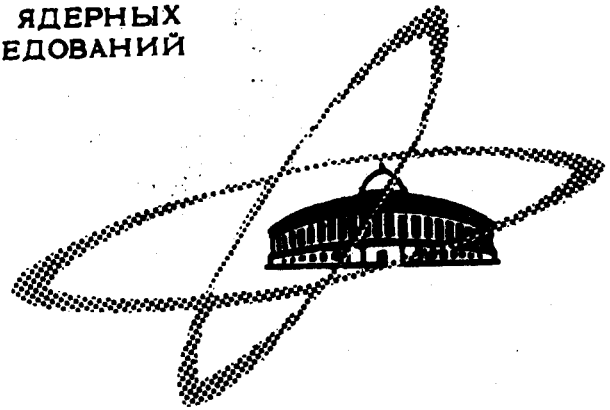

E7 - 5499

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THE VALIDITY OF THE ALEXANDER AND SIMONOFF SEMIEMPIRICAL RULE IN THE REGION $100 \leq A \leq 150$

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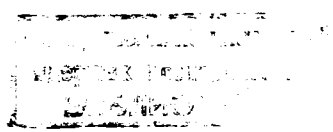

Heavy ion induced compound nuclear reactions with following evaporation of neutrons have a large cross section for medium heavy nuclei and therefore appear to be suitable to synthesize neutron deficient nuclei.

The mass spectrometer allows an unambiguous identification of the mass number of the reaction products. There is in this case a distinct advantage in using an on-line mass spectrometer capable of recording isotopes of practically any half-life from milliseconds to long-lived activities. However, there is a lower limit of about 5 millisecond half-life caused by the diffusion and ionisation of the reaction products /1/. The mass number for short--lived isomeric states in the microsecond or nanosecond region or even for prompt radiation following (H.I., xn) reactions can be drown only from the measured excitation function.

The cross-section for a heavy-ion compound reaction with following evaporation of x neutrons is given by

$$\sigma\,(\mathrm{H.I.},\,xn) = \sigma_c \prod_{i=1}^{x} G_i\, P_{xn} \approx \sigma_c\, \overline{(G)}^{x}\, P_{xn} \quad ,$$

where σ_c is the total cross-section for compound nucleus formation; above the Coulomb barrier σ_c increases slightly with increasing the beam energy. The second factor is the ratio of the neutron width to the sum width $\frac{\Gamma_n}{\sum_i \Gamma_i}$ for possible other reaction channels. We believe this factor is averaged over the neutron evaporation cascade. The third factor is the probability of the evaporation of exactly x neutrons. Assuming a constant nuclear temperature during the evaporation cascade Jackson /3/ has calculated this probability. This function has a sharp maximum at a given excitation energy and it is responsible for the typical shape of excitation functions for (H.I., xn) reactions. Therefore, it is possible to determine the number of evaporated neutrons for this maximum position. The fundamental study has been made by J.M. Alexander and G.N. Simonoff /2/. From the analysis of different reactions leading to the α -active product nuclei 149, 150, 151 Dy they have established that the following relation is valid

$$\bar{\epsilon} = \frac{E_{exc} - \sum_{i=1}^{x} B_{in}}{x} = 5.0 - 6.5\ \mathrm{MeV} \quad .$$

The excitation energy E_{exc} one obtains from the experimentally measured maximum position of the cross section E_{lab} from the equation

$$E_{exc} = E_{lab}\,\frac{m_T}{m_c} + [(M-A)_T + (M-A)_I - (M-A)_c]$$

with T = target, I = ion, C = compound nucleus and $M - A$ = mass excess in MeV.

B_{in} is the neutron binding energy of the i-th neutron in the decaying compound nucleus taken from P.A. Seegers table /1/ The validity of this limit has been established for all combinations of targets and ions from ^{12}C up to ^{22}Ne .

A compilation for values in the $100 \leq A \leq 150$ regio is given in fig. 1. This summary contains results on excitation functions of several cerium activities from ^{134}Ce up to ^{137}Ce studied by Choppin and Klingen /6/. The other points compiled in fig. 1 were obtained by the Dubna groups and applied for the identification of short-lived nuclear states. In the most cases ne activities were produced and it was desirable to have any other arguments which clearly exclude a possible ambiguity of the assignment of the final product. Such arguments are:

A = 111 The identification of the reaction product ^{111}Te is surel established by measuring the daughter isotope in an recoil experiment /5/.

A = 122 The reaction product ^{122}Cs is unambiguously identified by observing the $2^+ \rightarrow 0^+$ 331 KeV transition in ^{122}Xe .

A = 123 The mass number of the reaction product follows surel by comparison with the excitation functions for ^{122}Cs and ^{124}Cs .

A = 124 In the ground state decay of the reaction product ^{124}Cs there the $2^+ \rightarrow 0^+$ 354 KeV-transition in ^{124}Xe was observed.

A = 128 The excitation function was measured for the known 283 keV line in the $^{128}La \rightarrow {}^{128}Ba$ decay. (Fig. 2).

A = 130 ^{130m}Ba is unambiguously identified by its well known 357.2 keV $2^+ \rightarrow 0^+$ transition. (Fig. 3).

A = 137 An independent argument for this mass assignment follows from the level systematics of N = 77 isotones.

A = 138 The 9 msec isomeric state in ^{138}Ce is well identified by radioactive decay work.

A = 143 The mass-assignment of the three-particle isomeric state is supported by comparison with the excitation function for the known $11/2^-$-isomeric state in ^{143}Sm and by missing the known $2^+ \rightarrow 0^+$ transitions in the even-even isotopes ^{142}Sm and ^{144}Sm .

From the data complication in fig. 1 it follows that the Alexander and Simonoff relation is valid in this mass region. However, the values $\bar{\epsilon}$ for our neon induced reactions lie somewhat higher.

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Table 1

mass number	reaction	E_{lab} (MeV)	E_{exc} (MeV)	(MeV)	(MeV)	references
111	$^{102}Pd(^{12}C,3n)^{111}Te$	64	51,2	33	6,1±0,5	4
122	$^{109}Ag(^{18}O,5n)^{122}Cs$	92	76,0	49,1	5,4±0,9	7
123	$^{109}Ag(^{18}O,4n)^{123}Cs$	73	60	37,9	5,5±1,0	8
124	$^{115}In(^{12}C,3n)^{124}Cs$	59	49	29,2	6,6±0,8	7
128	$^{115}In(^{18}O,5n)^{128}La$	92	74	48,4	5,1±0,8	this work
129	$^{121}Sb(^{12}C,4n)^{129}La$	72	62,2	37,5	6,2±0,7	10
130	$^{122}Sn(^{12}C,4n)^{130}Ba$	60,5	54,5	34,4	5,0±0,3	this work
134	$^{128}Te(^{12}C,6n)^{134}Ce$	-	85,0	51,8	5,5	6
	$^{130}Te(^{12}C,8n)^{134}Ce$	-	104,5	64,5	5,0	6
	$^{124}Sn(^{16}O,6n)^{134}Ce$	-	80	51,8	4,7	6
135	$^{128}Te(^{12}C,5n)^{135}Ce$	-	70,5	43,7	5,4	6
	$^{130}Te(^{12}C,7n)^{135}Ce$	-	85,9	56,4	4,2	6
	$^{124}Sn(^{16}O,5n)^{135}Ce$	-	65	43,7	4,25	6
137	$^{130}Te(^{12}C,5n)^{137}Ce$	-	68,4	38,7	5,9	6
	$^{122}Sn(^{20}Ne,5n)^{137}Nd$	107	81	46,9	6,8±0,8	9
	$^{112}Sn(^{22}Ne,4n)^{137}Nd$	90	62,7	37,1	6,4±0,8	9
138	$^{130}Te(^{12}C,4n)^{138}Ce$	56	47,3	29,2	4,5±0,5	10
143	$^{126}Te(^{22}Ne,5n)^{143}Sm$	113	78,2	41,2	7,1±1,0	11
	$^{130}Te(^{20}Ne,7n)^{143}Sm$	130	95	55,3	5,9±0,4	11

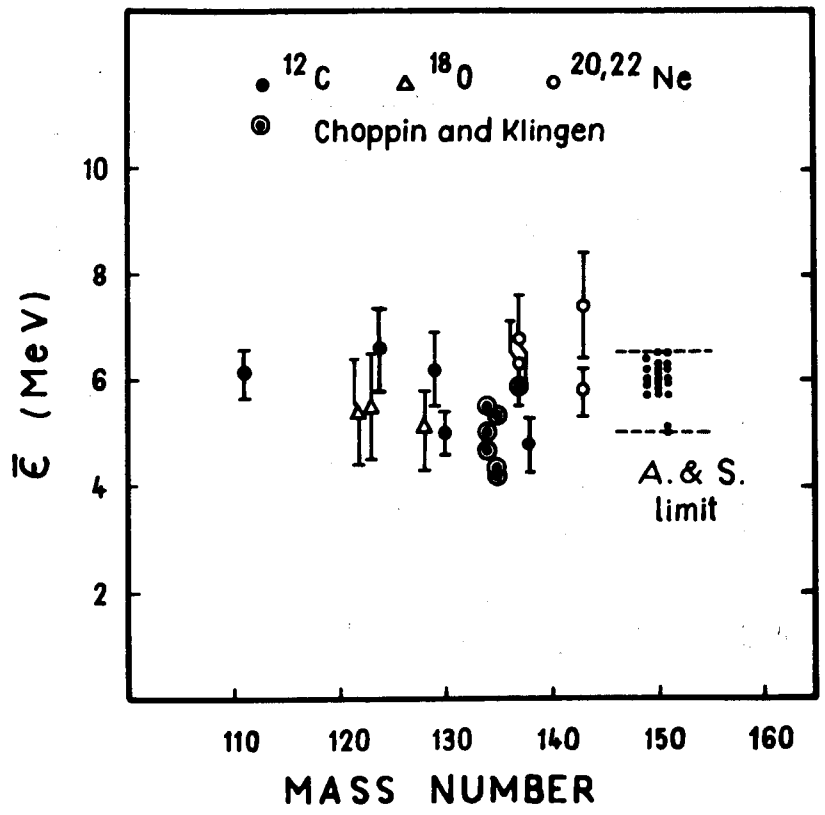

Fig. 1. The characteristic value $\bar{\varepsilon}$ versus mass number for medium heavy product nuclei.

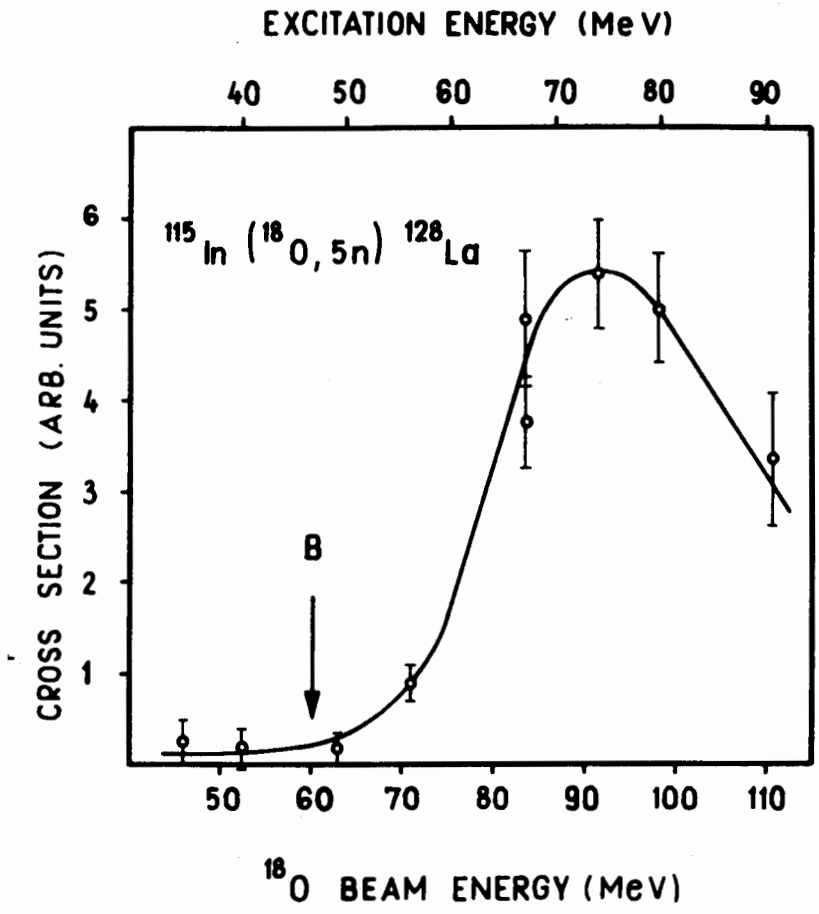

Fig. 2. Excitation function for the reaction ^{115}In (^{18}O, 5n) ^{128}La target thickness: 2,3 mgcm^{-2} In on 5 μ m AL foil.

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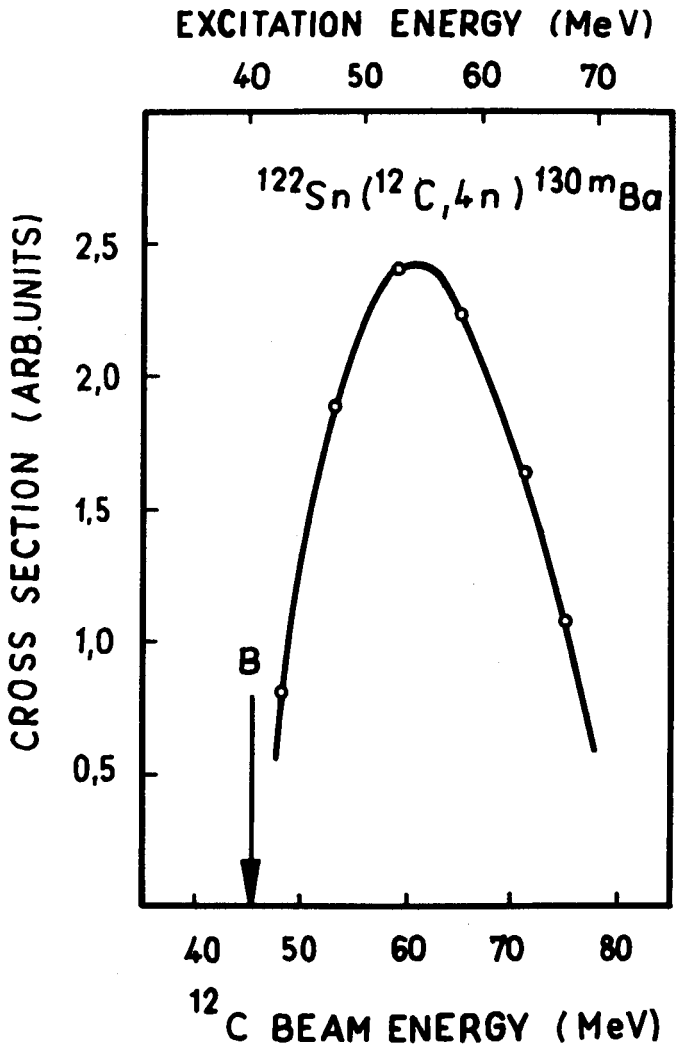

Fig. 3. Excitation function for the reaction $^{122}Sn(^{12}C,4n)^{130}Ba$. 4,5 mgcm^{-2} self-supporting target, 80% enriched in ^{122}Sn.