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SHELL EFFECT ON PHOTONUCLEAR REACTIONS

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SHELL EFFECT ON PHOTONUCLEAR REACTIONS*§

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A previous analysis of some experimental data on photonuclear reactions led the authors[1] to point out that the mean-square displacement of nucleons in the nuclear ground state presents evidence in favor of an alpha-particle structure of nuclei. Although the theoretical basis for this conclusion is not free of criticism-since correlations were neglected in the formula for the harmonic mean energy[2] of photon absorption, which we used —this evidence might be investigated experimentally in a more direct way at higher energies.

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On the other hand, the shell structure of nuclei has been revealed, in the energy region of the photonuclear effect, by Nathans and Halpern[3]. Features of different nuclear models are expected to be presented by nuclear matter. The predominance of one special model over the others depends on the energy and mass number regions and probably on the manner of excitation. It is, therefore, desirable to look for information extracted from experiment and independent, whenever possible, from "a priori" theoretical views and disputable assumptions.

Nathans and Halpern found that the width of the giant resonance, as given by the total neutron yield, is smaller for magic nuclei. This criterion seems to us not very satisfactory since the width might depend on the relative importance of (γ, 2n and (γ,np) reactions, and also on the threshold of these reactions. A way to avoid this ambiguity is to plot the energy distance from the threshold for (γ,n) reactions to the first point where the cross section is half maximum, against A. This quantity Δ gives a measure of the steepness of rise of the (γ,n) cross-section curve as a function of the energy, as shown in Fig. 1. For magic nuclei and neighbors, one expects Δ to be larger than for the others. This is indeed the case, as indicated in Fig. 2 and in Table I, where Δ is plotted against A. The shell structure is clearly exhibited in this curve and the effect is neater for higher mass numbers.

For very light nuclei, there are marked deviations from the expected curve; this might be accounted for by the fact that for such nuclei the (γ, n) process is not dominant. Thus, whereas carbon, which has a complete subshell, has a low Δ, nitrogen has an anomalously high Δ. Magic nuclei with N = 20,28,82, and 120 show their shell structure very clearly in the graph. At N = 50, we find an anomaly: Nb (N = 52), which is not a magic nucleus, shows a value $\Delta = 5.8$, although Rb (N = 50), which is magic, has a $\Delta = 5.4$, and Mo (N = 50), also a magic nucleus, has $\Delta = 2.1$. This anomaly suggests that new measurements should be made with these elements.

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TABLE I. Values of Δ (the difference between the energy at which the (γ,n) cross section is half-maximum and the threshold) or several nuclei.

Element	Z	N	A	Threshold	$E(\frac{1}{2}\sigma max)$	Δ(Mev)	Reference
C	6	6	12	18.70	20.6	1.9	a, b
N	7	7	14	10.54	19.3	8.8	c
O	18	18	16	15.60	21.8	6.2	c
Na	11	12	23	12.10	15.4	3.3	a
Mg	12	12	24	16.0	18.2	2.2	d
Al	13	14	27	14.0	17.5	3.5	a
Si	14	14	28	16.9	18.8	1.9	e
P	15	16	31	12.4	16.2	3.8	f
S	16	16	32	15.0	18.0	3.0	g
Cl	17	18	35	13.0	16.8	3.8	h
A	18	20	38	10.5	15.0	4.5	i
K	19	20	39	12.5	17.5	5.0	h
Ca	20	20	40	15.8	18.0	2.2	e
Cr	24	26	50	13.4	16.8	3.4	j
V	23	28	51	10.8	15.5	4.7	j
Mn	25	30	55	10.0	14.5	4.5	a
Fe	26	28	54	11.7	17.7	6.0	k
Co	27	32	59	10.2	15.0	4.8	a
Ni	28	30	58	12.0	15.5	3.5	l
Cu	29	34	63	10.6	14.5	3.9	m
Cu	29	36	65	10.2	14.1	3.9	m
Zn	30	34	64	11.6	14.5	2.9	n
As	33	42	75	10.1	13.0	2.9	a
Br	35	46	81	10.0	14.0	4.0	o
Rb	37	50	87	9.3	14.7	5.4	p
Nb	41	52	93	8.7	14.5	5.8	a

TABLE I (Cont.)

Element	Z	N	A	Threshold	$E(\frac{1}{2}\sigma \max)$	Δ(Mev)	Reference
Mo	42	50	92	13.1	15.1	2.1	p
Ag	47	62	109	9.3	13.2	3.9	2
In	49	66	115	9.0	12.5	3.5	a
Sb	51	70	121	9.3	12.4	3.1	m
I	53	74	127	9.1	13.2	4.1	a
La	57	82	139	8.0	12.5	4.5	j
Ta	73	108	181	8.8	11.5	2.7	m
Au	79	118	197	7.9	11.4	4.1	a
Bi	83	126	209	7.4	11.6	4.2	a
U	92	146	238	6.0	9.5	3.5	r

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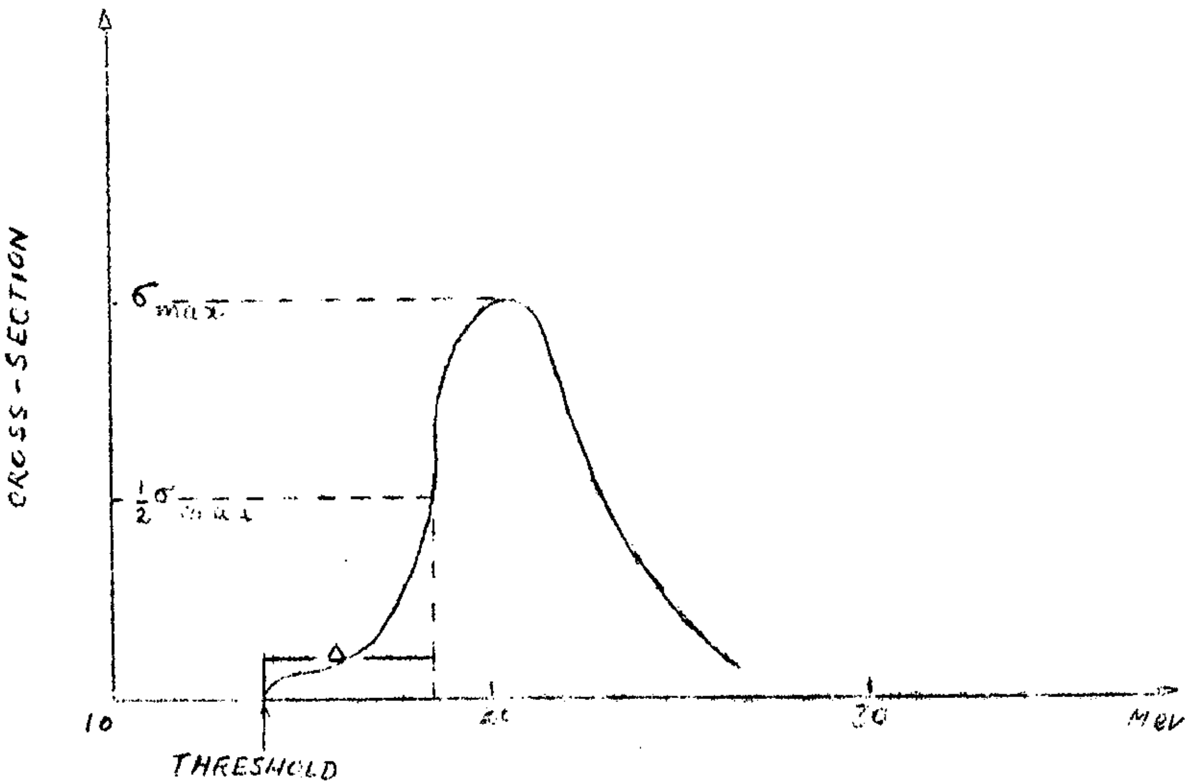
CROSS-SECTION
σ_{max}
$\frac{1}{2}\sigma_{max}$
Δ
10
20
30
MeV
THRESHOLD

FIG 1

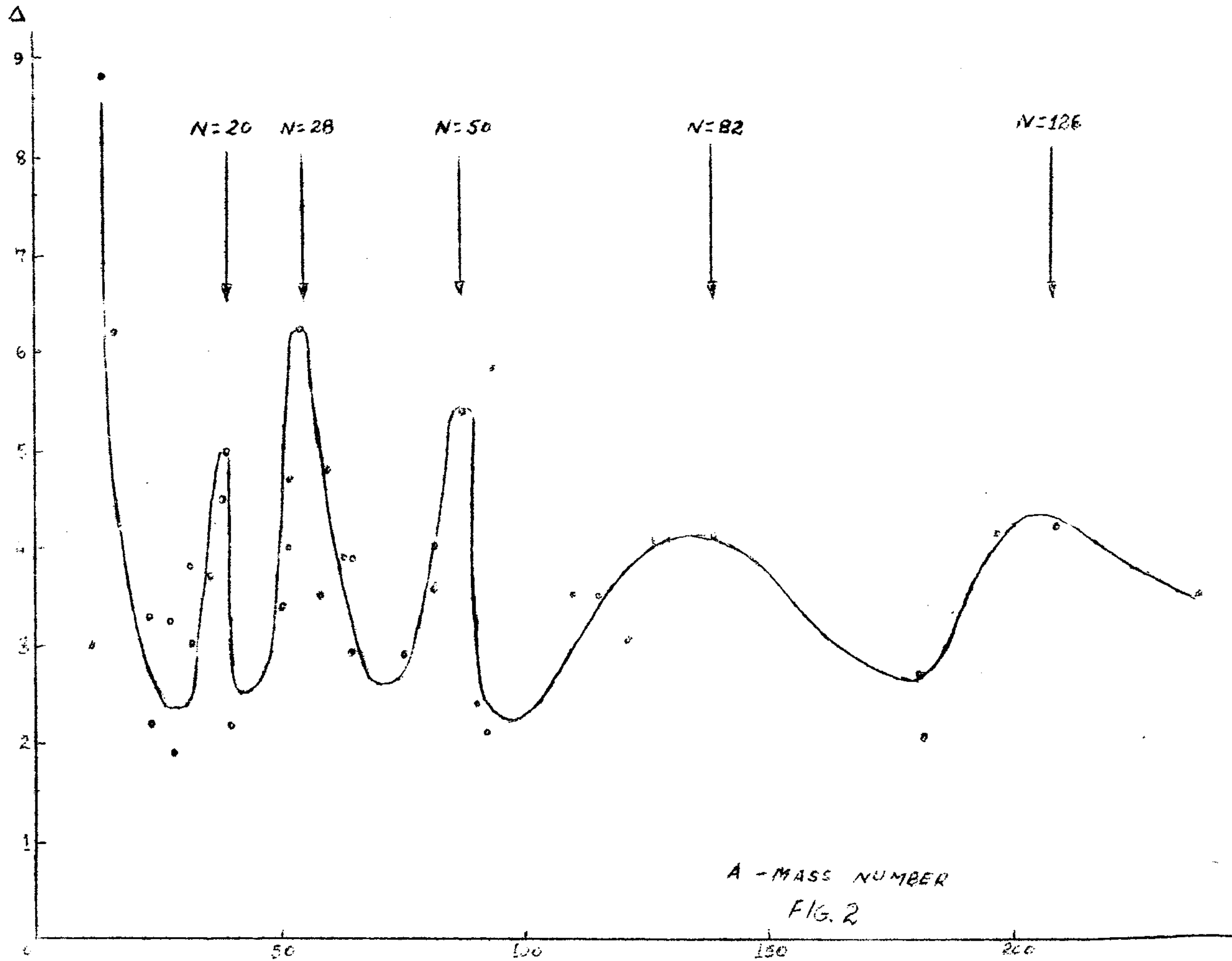

FIG. 2