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THE HARMONIC MEAN ENERGY FOR PHOTON ABSORPTION BY NUCLEI

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THE HARMONIC MEAN ENERGY FOR PHOTON ABSORPTION BY NUCLEI*

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In their paper on the nuclear photo-effect, Levinger & Bethe [1] derive an expression for the harmonic mean energy W_H for photon absorption as a function of the expectation value of the squared displacement of a nucleon in the nuclear ground state, $\langle r^2 \rangle_\infty$

$$W_H = \frac{\int \sigma(E)\, dE}{\int \frac{\sigma(E)}{E}\, dE} = \frac{3}{2}\frac{\hbar^2}{M}\frac{1+0.8x}{\langle r^2 \rangle_\infty} \qquad (1)$$

Here $\sigma(E)$ is the nuclear absorption cross-section of photon with energy E, x is the fraction of neutron-proton exchange force, M the

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nucleon mass. Since the integrals which occur in equation (1) can be obtained from experiment, it is possible thereby to compute $\langle r^2 \rangle_\infty$ and thus gain some insight on the nuclear structure.

We wish to report here computations which were carried out by utilizing extensive experimental results available from the work of Montalbetti, Katz and Goldemberg[2] and Goldemberg and Katz[3]. The experimental data refer to (γ,n) cross sections for nuclei C, Ca, V, Ni, Zn, Br and Rb of Table I; and to $(\gamma,n) + (\gamma,2n) + (\gamma,np)$ cross sections for the nuclei Na, Al, P, S, Co, Cu, As, Mo, Nb, Ag, In, Sb, I, La, Ta, Au, Pb and Bi of the same table. For medium and heavy nuclei we may reasonably expect that such processes represent the major contribution to the cross section for photon absorption.

In Table I are the harmonic mean energies W_H for a number of nuclei and the corresponding values of $\langle r^2 \rangle_\infty$ as obtained from relation (1) for x = 0 and x = 1. The last column gives the values of $\langle r^2 \rangle_{oo}$ obtained from the plane wave model of the nucleus:

$$\frac{3}{4} (r_o A^{1/3})^2, \quad \text{with } r_o = 1.5 \times 10^{-13} \text{cm};$$

The points in figure 1 reproduce the values of $\langle r^2 \rangle_\infty$ for x = 0, against A; the straight line parallel to the abcissae is the value of $\frac{3}{5} (r_o A^{1/3})^2$ for the alpha-particle, A = 4. The ascending curve represents the last column of the Table.

It is seen that the available experimental data strongly substantiate the model of a nucleus in which the nucleons are most of the time clustered in α- particles as sub-units: $\langle r^2 \rangle_\infty$ does not increase with A and its value is of the order of magnitude expected for the mean square displacement of a nucleon inside an α-particle: $3.5 \times 10^{-26} \text{cm}^2$. This model was already suggested by Levinger and Bethe for Ge^{76}.

[1] J. S. Levinger and H. A. Bethe, Phys. Rev. 78, 115 (1950)

[2] R. Montalbetti, L. Katz and J. Goldemberg, Phys. Rev. 91, 659 (1953)

[3] J. Goldemberg and L. Katz, Can. J. Phys. 32, 49 (1954)

TABLE I

Nucleus	A	W_H	$\langle r^2 \rangle_{oo} \cdot 10^{-26}$ cm^2		$\langle r^2 \rangle_{oo} = \frac{3}{5}(r_o A^{1/3})^2 \cdot 10^{-26}$ cm^2
			x = 0	x = 1	
C	12	20 Mev	3.12	5.62	7.06
Na	23	19.7	3.34	6.02	10.9
Al	27	19.1	3.27	5.88	12.4
P	31	20.9	3.00	5.40	13.3
S	32	20.4	3.06	5.50	13.6
Ca	40	19.8	3.15	5.68	15.9
V	51	17.6	3.54	6.38	18.1
Co	59	17.2	3.63	6.54	20.5
Ni	58	18.4	3.40	6.12	20.3
Cu	63	17.2	3.64	6.55	21.4
Zn	64	18.0	3.46	6.23	21.6
Cu	65	17.3	3.61	6.50	21.8
As	75	19.2	3.25	5.85	24.0
Br	81	18.0	3.46	6.22	25.0
Rb	87	20.8	3.00	5.40	26.6
Mo	92	17.9	3.86	6.95	27.5
Nb	93	16.1	3.88	7.00	27.8
Ag	109	15.8	3.95	7.05	30.8
In	114	16.3	3.83	6.90	31.7
Sb	122	16.4	3.80	6.84	33.2
I	127	16.3	3.80	6.84	34.1
La	139	16.3	3.80	6.84	36.2
Ta	181	12.0	5.20	9.36	43.3
Au	198	15.2	4.10	7.38	46.0
Pb	207	13.8	4.54	8.17	47.2
Bi	209	10.0	6.25	11.20	47.5

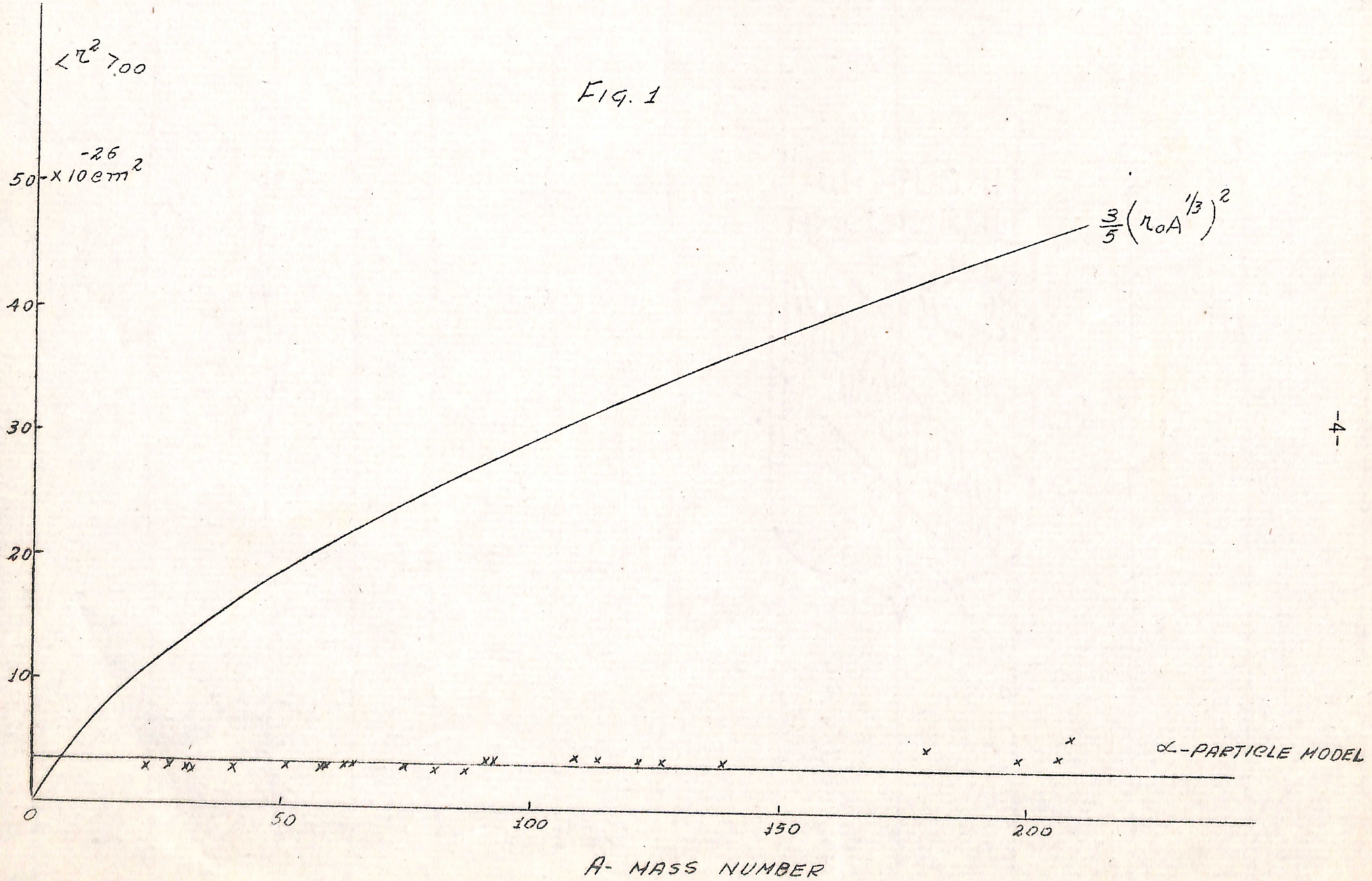
$\langle r^2 \rangle_{00}$
$\times 10^{-26} cm^2$
50
40
30
20
10
0
50
100
150
200
$\frac{3}{5}(r_0 A^{1/3})^2$
α-PARTICLE MODEL
A- MASS NUMBER

Fig. 1