RECOIL RANGE OF Na^{24} *AND THE MECHANISM OF* Al^{27} *(p, 3pn),* Si^{28} *(p, 4pn) AND* P^{31} *(p, 5p 3n) FOR 660-Mev PROTONS*

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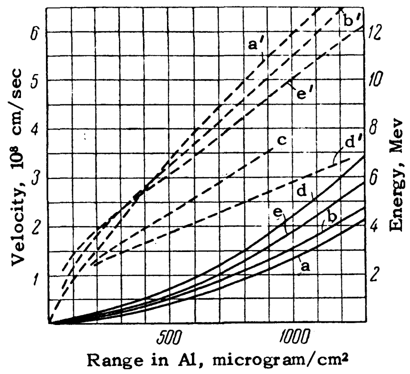
ACCORDING to the Serber model of high-energy nuclear reactions, which has been widely discussed in the literature, the products of deep nuclear disintegration result from two successive processes, a nucleonic cascade and evaporation.[1,2] As a test of this model we have measured the recoil range of Na^{24} nuclei produced when Al, Si and P were bombarded with 660-Mev protons. This experiment was performed in the external proton beam of the synchrocyclotron of the Joint Nuclear Research Institute. The experimental method and the treatment of the data have been described in detail in reference 3.

The table contains the mean ranges of Na^{24} in terms of the effective specimen thickness t (reference 3). The range-energy relation for Na^{24} must be known for an interpretation of the results.

Effective thicknesses for recoil Na^{24} emitted from specimens placed parallel to the proton beam (t_p), and from specimens placed perpendicular to the beam, forward (t_f) and backward (t_b)

Reaction	t_f ($\mu g/cm^2$), experimental	t_b ($\mu g/cm^2$), experimental	t_p ($\mu g/cm^2$)	
			Experimental	Serber model
Al^{27} (p, 3pn)	180 ± 2	46 ± 1	112 ± 2	170 ± 30
Si^{28} (p, 4pn)	158 ± 3	25 ± 2	63 ± 2	200 ± 40
P^{31} (p, 5p3n)	134 ± 2	29 ± 1	127 ± 4	200 ± 40

In the present work the range-velocity relation for Na^{24} was obtained by comparing the experimental range-velocity relations for a large number of ions, from light nuclei to fission fragments.[4-7] The figure shows the experimental range-velocity and range-energy curves in Al for several nuclides and the corresponding interpolated curves for Na^{24}. The table gives the experimental thicknesses t and the effective thicknesses for recoil nuclides ejected from a sample positioned parallel to the proton beam (t_p); these



Experimental range-energy relations (solid lines) and range-velocity relations (dashed lines) for the following ions: a and a′ – F_9^{19} (reference 4), b and b′ – Ne_{10}^{20} (reference 5), c – Ar_{20}^{40} (reference 6), d and d′ – light fission fragments (reference 7), and the corresponding interpolated relations e and e′ for Na_{11}^{24}. The information in the review article by Allison and Warshaw[10] was used to relate the experimental ranges in the various substances to the range in Al.

were calculated by means of the Serber model, using the range-energy relation for Na^{24} (which is shown in the figure) and the results obtained by Turkevich et al.[8] in a detailed calculation of the nucleonic cascade. It can be seen that the calculated values of t_p are considerably larger than the experimental values. This discrepancy can be removed by assuming that the incident high-energy proton beam interacts with a group of nucleons in the nucleus whose momenta are correlated so that the combined momenta of all these nucleons does not exceed 5 $Mev^{1/2}$ for reactions in Al, 3.2 $Mev^{1/2}$ for reactions in Si and 5.5 $Mev^{1/2}$ for reactions in P (the momenta being expressed in terms of the unit $\sqrt{ME_k/m}$, where E_k is the kinetic energy of the particle in Mev, M is its mass and m is the nucleon mass).

It is still not clear whether the incident nucleon interacts with each nucleon of the group separately or essentially with the group as a whole. An answer to this question would be of considerable interest in connection with interactions between high-energy nucleons and nuclear fragments which are being discussed in the literature.[9]

In conclusion the authors wish to thank Professor P. A. Cerenkov for his interest, Professor V. P. Dzhelepov for placing the synchrocyclotron of the Joint Nuclear Research Institute at our disposal, and G. A. Leksin for valuable discussions.

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ABSORPTION OF SLOW π^- MESONS BY NUCLEI

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EXPERIMENTS on nuclear disintegrations induced by slow π^- mesons[1-6] so far do not permit drawing final conclusions with respect to the primary distribution of the rest energy of the π^- meson. In particular, the assumption that the meson rest energy is distributed primarily among a small group (2 to 4) of nucleons cannot be regarded as experimentally proven.

We have tried to explain the possible influence of collective interactions between nucleons in the nucleus on the above process. We have investigated nuclear disintegrations induced by the absorption of slow π^- mesons by light emulsion nuclei. The data are being reduced and the results will be published in a forthcoming article.

At present we shall limit ourselves to one specific example of a disintegration in which collective interactions are displayed especially prominently. The reaction in question is of the type

$$A + \pi^- \rightarrow B + n, \qquad (1)$$

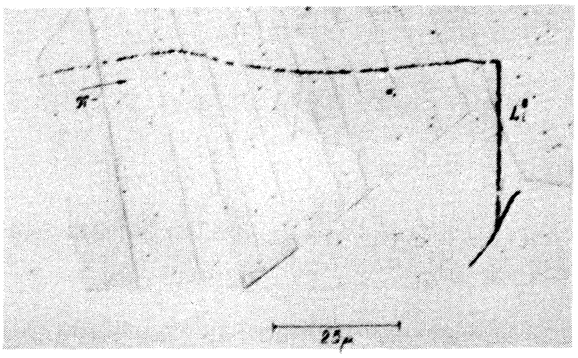
in which the absorption of a slow π^- meson by the nucleus A is accompanied by the production of a fast neutron and a residual nucleus in ground state (or a slightly excited state, leading to the release of a low-energy gamma ray). The attempt of finding a reaction of the above type was undertaken after a detailed study of disintegrations of a wider class. It was found that the absorption of a slow π^- meson by a nucleus leads often to a reaction of the type

$$A + \pi^- \rightarrow B^* + n, \qquad (2)$$

in which the momentum of a fast (~80 to 100 Mev) neutron is compensated by an excited residual nucleus which disintegrates emitting several secondary particles. Reaction (1) can be evidently considered as a particular case of a more general reaction (2). After finding a considerable contribution due to disintegrations corresponding to reactions (2) we tried, therefore, to find also disintegrations corresponding to reactions (1). Unfortunately, identification of disintegrations corresponding to reactions (1) is in general difficult. However, in the special case of π^--meson capture by the Be_4^9 nucleus, the reaction

$$\begin{array}{l} Be^9 + \pi^- \rightarrow Li^8 + n_0^1 \\ \qquad\qquad\quad \beta^- \searrow \\ \qquad\qquad\qquad Be^{8*} \rightarrow 2\alpha \end{array} \qquad (3)$$

can be easily detected in emulsion by means of characteristic "lithium hammers." Twelve stars corresponding to reaction (3) were found in nuclear emulsions NIKFI type 1a and NIKFI type K loaded with BeF_2 and irradiated by slow π^- mesons in the meson beam from the synchrocyclotron of the Joint Institute of Nuclear Research. A typical example of such a star is shown in the figure. The range of Li^8 fragments was found to be equal to $34\,\mu$ in all cases, with a spread of $\pm 1\,\mu$. The mean value of the Li^8 fragment energy amounts to 14.4 ± 0.3 Mev.* The corresponding neutron energy, calculated from momentum conservation law, is 108 ± 2 Mev (accounting for relativistic correc-



Microphotograph of a star corresponding to the reaction $Be^9 + \pi^- \rightarrow Li^8 + n_0^1$.