RECOIL RANGE OF Na\(^{24}\) AND THE MECHANISM OF Al\(^{27}\) (\(p, 3pn\)), Si\(^{28}\) (\(p, 4pn\)) AND P\(^{31}\) (\(p, 5p3n\)) 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 \((t_b)\) 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 \(\sqrt{M E_k / m}\), 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.\(^5\)

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.


\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{Reaction} & \textbf{\(t_f\) (\(\mu g/cm^2\)) experimental} & \textbf{\(t_b\) (\(\mu g/cm^2\)) experimental} & \textbf{\(t_p\) (\(\mu g/cm^2\))} \\
\hline
Al\(^{27}\) (\(p, 3pn\)) & 180 ± 2 & 46 ± 1 & 112 ± 2, 170 ± 30 \\
\hline
Si\(^{28}\) (\(p, 4pn\)) & 158 ± 3 & 25 ± 2 & 63 ± 2, 200 ± 40 \\
\hline
P\(^{31}\) (\(p, 5p3n\)) & 134 ± 2 & 29 ± 1 & 127 ± 4, 200 ± 40 \\
\hline
\end{tabular}
\end{table}
Experiments on nuclear disintegrations induced by slow \( \pi^- \) mesons so far do not permit drawing final conclusions with respect to the primary distribution of the rest energy of the \( \pi^- \) 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 \( \pi^- \) 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

\[
A + \pi^- \rightarrow B + n,
\]

in which the absorption of a slow \( \pi^- \) 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 \( \pi^- \) meson by a nucleus leads often to a reaction of the type

\[
A + \pi^- \rightarrow B^* + n,
\]

in which the momentum of a fast (\( \sim \) 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 \( \pi^- \)-meson capture by the \( \text{Be}^8 \) nucleus, the reaction

\[
\text{Be}^8 + \pi^- \rightarrow \text{Li}^7 + n^0
\]

\[
\text{Be}^8 \rightarrow 2n
\]

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 \( \text{BeF}_2 \) and irradiated by slow \( \pi^- \) mesons in the meson beam from the synchrocyclotron of the Joint Institute of Nuclear Research. A typical example of a star corresponding to the reaction

\[
\text{Be}^8 + \pi^- \rightarrow \text{Li}^7 + n^0
\]

amp of such a star is shown in the figure. The range of \( \text{Li}^7 \) fragments was found to be equal to 34 \( \mu \) in all cases, with a spread of \( \pm 1 \mu \). The mean value of the \( \text{Li}^7 \) fragment energy amounts to 14.4 \( \pm 0.3 \) Mev.* The corresponding neutron energy, calculated from momentum conservation law, is 108 \( \pm 2 \) Mev (accounting for relativistic correc-