SOVIET PHYSICS JETP VOLUME 37 (10), NUMBER 1 JANUARY, 1960

ON THE MECHANISM OF CAPTURE OF STOPPED K^- MESONS

D. K. KOPYLOVA, Yu. B. KOROLEVICH, N. I. PETUKHOVA, and M. I. PODGORETSKIĬ

Joint Institute of Nuclear Studies

Submitted to JETP editor February 27, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **37**, 289-291 (July, 1959)

The problem considered is that of the mechanism of capture of stopped K^- mesons by the nuclei of a photographic emulsion. On the assumption of a surface model of one-nucleon capture it is found that the fraction of two-nucleon captures is close to 30 percent.

It is well-known that the capture of K^- mesons by nuclei occurs through one-nucleon (reactions of the type $K^- + N \rightarrow Y + \pi$) and two-nucleon (reactions of type $K^- + 2N \rightarrow Y + N$) interactions of the K^- mesons. A direct indication of the existence of reactions of the second type is found in cases of the emission of fast hyperons ($E_\Sigma > 60$ Mev) in σ_K stars, and cases of the simultaneous emission of a fast hyperon and a fast proton. It is usually assumed that the two-nucleon captures of K^- mesons make up not more than 10 to 12 percent of the total number of interactions of stopped K^- mesons.[1-4*]

In the present paper we make an estimate of the fraction of two-nucleon captures on the basis of an analysis of the observed number of π mesons emitted in σ_K stars.

Let x be the unknown fraction of two-nucleon interactions, α the expected percentage of emerging π mesons (calculated from the known mean free path against interactions of π mesons in nuclear matter on the assumption of a definite model for the capture of K^- mesons), and β the experimentally observed fraction of the interactions of stopped K^- mesons in which π mesons are emitted. Then we have the relation: $(1-x)\alpha = \beta$.

According to the data given in reference 2, charged π mesons are emitted in 34 ± 2 percent of all nuclear captures of stopped K^- mesons. If we take account of neutral π mesons, the fraction of π mesons is increased to 51 ± 3 percent ($\beta = 0.51$).*

One of the immediate consequences of this fact is that the number of two-nucleon captures cannot exceed 49 ± 3 percent of the total number of interactions. The expected fraction α of emerging π mesons is calculated in reference 7 for π mesons accompanying Σ and Λ^0 hyperons, on the assumptions of surface and volume models for the capture of K^- mesons.†

The fraction of π mesons that have not undergone any interaction can be obtained if one knows the mean free path of π mesons in nuclear matter. It is harder to calculate what part of the π mesons that have been inelastically scattered in the first collision will still get out of the nucleus without being absorbed.

It was decided to estimate upper and lower limits on α (and correspondingly, upper and lower limits on x) by assuming that all the π mesons that undergo inelastic scattering get out of the nucleus (upper limit), or that they are all absorbed in the nucleus (lower limit). It must be noted that the absorption coefficient of π mesons that have undergone inelastic scattering is rather small, and consequently a large fraction of them actually get

*There are indications that two-nucleon interactions play a much more important part (30 to 50 percent).[5,6] Unfortunately the estimates given in the preprint of Eisenberg et al. are evidently not final results, and the brief indication contained in the report of Kaplon[6] is not accompanied by supporting evidence.

*It can easily be shown, from general considerations of isotopic invariance, that in the interaction of K^- mesons with nuclei of zero isotopic spin, the number of charged π mesons (Σ hyperons) produced is twice the number of neutral π mesons (Λ hyperons), independent of the type of interaction. It is natural to assume that the nuclei of a photographic emulsion satisfy this condition, since for them $[(N-Z)/A] \ll 1$.

†This same question has been discussed in a paper by K. Lanius, whom the writers thank for sending them a preprint.

out of the nucleus. Therefore the upper limit found as described differs only a little from the true value of α.

For the calculation of α it was necessary to choose a definite ratio between the number of reactions of the type $K^- + N \rightarrow \Lambda^0 + \pi$, and the number of the type $K^- + N \rightarrow \Sigma + \pi$. In accordance with reference 7, we assume that $\Lambda^0/\Sigma^{\pm,0} = 0.21$ for the surface model and $\Lambda^0/\Sigma^{\pm,0} = 0.50$ for the volume model.

To find the sensitivity of the results to small changes of the surface-absorption model, a special examination was made of the case in which the K^- mesons are absorbed at a depth of one-nucleon radius inside the surface of the nucleus.[4]

The results of the calculations are as follows:

Surface absorption:	$0.64 < \alpha < 0.75$	$0.20 < x < 0.32$
Absorption of the K-mesons at a depth of one-nucleon radius:	$0.62 < \alpha < 0.72$	$0.18 < x < 0.29$
Volume absorption:	$0.32 < \alpha < 0.52$	—

It can be seen from this that the first two models do not differ much from each other. It can also be seen that the volume model leaves no room for two-nucleon capture. Since, according to direct estimates (fast hyperons), the quantity x is at least 10 to 12 percent, the result obtained here can be regarded as an indication that the volume model actually has no relevance for one-nucleon capture of stopped K^- mesons. This is in complete agreement with the idea that has come to be accepted in the literature, that one-nucleon capture of stopped K^- mesons occurs mainly at the surface of the nucleus (see, in particular, references 5 and 6). In this case, the fraction of two-nucleon capture is evidently close to 30 percent, but does not exceed that amount.

In connection with this estimate of the fraction of two-nucleon captures, the question of direct production of Λ^0 particles in one-nucleon capture reactions of surface absorption is of interest. According to references 2, 4, 7, and 8, reactions of the type $K^- + N \rightarrow \Lambda^0 + \pi$ make up 15 to 35 percent of all one-nucleon capture reactions.

Charged Σ hyperons of energy $E_\Sigma < 60$ Mev are emitted in 14 percent of all cases of interactions of K^- mesons with nuclei.[6]* Taking account of the neutral hyperons we find, on the assumption of a surface model, that slow Σ hyperons are produced in less than 42 percent of all interactions.* Consequently, Λ^0 would have to occur in more than 58 percent of all interactions, which contradicts the results of the papers cited here. The assumption of about 30 percent of two-nucleon captures removes this contradiction. It reappears if we assume that slow Σ hyperons ($E_\Sigma < 60$ Mev) are weakly absorbed in nuclei. In fact, in this case it is necessary to assume that direct production of Λ^0 particles occurs in the great majority of captures.

Thus if we work with the surface model of one-nucleon capture, we must accept the idea that two-nucleon capture occurs in about 30 percent of all cases and that Σ hyperons with $E_\Sigma < 60$ Mev are strongly absorbed inside the nucleus.

A direct indication that Σ hyperons with $E_\Sigma < 60$ Mev are absorbed more strongly than the accompanying π mesons comes from a comparison of the experimental data on the yields of π mesons and Σ hyperons from the capture of K^- mesons. As has already been said, charged π mesons are emitted in 34 percent, and charged Σ hyperons with energies $E_\Sigma < 60$ Mev in 14 percent, of all interactions of stopped K^- mesons. It follows from this that the absorption of Σ hyperons with $E_\Sigma < 60$ Mev is stronger than that of the accompanying π mesons by a factor of 1.5 to 2.†

According to the data of Kaplon,[6] the number of fast Σ hyperons with $E_\Sigma > 60$ Mev (charged and neutral) is about 3.5 percent of the total number of captures of K^- mesons. A comparison of this number with the estimate given here of the fraction of two-nucleon captures (~ 30 percent) shows that either the overwhelming majority of two-nucleon captures leads to direct production of Λ^0 particles, or else the fast Σ hyperons that are formed have a high probability of going over into Λ^0 particles in their subsequent passage through the nucleus, or that they lose energy and become slow particles. In other words, in the second case we have to assume a large cross-section for interaction of fast Σ hyperons with nucleons. Furthermore we must also conclude that two-nucleon capture does not occur at the surfaces of nuclei, since not over half of the fast Σ hyperons could be absorbed in the case of surface capture.

The writers thank M. Ya. Danysh for participating in discussions and for making it possible for us to learn of the critical comments of E. Markit.

*The number of Σ hyperons produced in one-nucleon capture reactions is smaller than 14 percent, since some of the hyperons with $E_\Sigma < 60$ Mev have come from the slowing down of fast Σ hyperons ($E_\Sigma > 60$ Mev) produced in two-nucleon captures.

*For surface absorption of K^- mesons, the fraction of emerging hyperons (or π mesons) must be $\geqslant 0.5$.

†Here it is assumed that $\Lambda^0/\Sigma^{\pm 0} = 0.25$ and $0.20 < x < 0.32$.

[1] C. Dilworth, Proc. of Seventh Annual Rochester Conference, 1957, p. VI-19.

[2] K^--stack Collaboration, Intl. Conf. on Mesons and Newly Discovered Particles, Padova-Venezia, 1957, p. II-15.

[3] S. Goldhaber, Proc. of Sixth Annual Rochester Conference, 1956, p. V-26.

[4] J. Hornbostel and G. T. Zorn, Phys. Rev. **109**, 165 (1958).

[5] Eisenberg, Roch, Nicolic, Schneeberger, and Winzeler, preprint, 1958.

[6] M. F. Kaplon, CERN Annual Intl. Conf. on High Energy Physics, 1958, p. 171.

[7] Webb, Iloff, Featherston, Chupp, Goldhaber, and Goldhaber, Int. Conf. on Mesons and Newly Discovered Particles, Padova-Venezia, 1957, p. II-69; same authors, Nuovo cimento **8**, 899 (1958).

[8] Fry, Schneps, Snow, Swami, and Wold, Phys. Rev. **107**, 257 (1957).

Translated by W. H. Furry
42