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FRAGMENTS A = 8 AS PRODUCTS OF INTERACTION OF STOPPED K$^-$ — MESONS WITH EMULSION NUCLEI

M. K. JURIĆ

Institute of Physics, Beograd, Yugoslavia

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Among $2.8 \cdot 10^5$ of stoped K^- meson-interactions with emulsion nuclei, 453 cases of stars with one hammerlike prong have been found. (This prong belongs to ^{8}He, ^{8,9}Li or ^{8}B nuclei). It has been found that 77% of the cases come from interactions of K^- mesons with light emulsion nuclei. The ratio $R = N_{\pi^-}/N_{\pi^+}$ of stars in which π^- and π^+ are produced is $R = 1.3$. Most of the hammer fragments belong to Li nucleus, but rather different from interactions caused by other incident particle. The number of ^{8}B is not small It has been found that the lower limit for ^{8}B and ^{8}He nuclei emission is about 13% and 5%, respectively.

1. Introduction

In this paper reactions induced by stopped K^- mesons with nuclear emulsion nuclei are studied, i.e. reactions that have one unstable fragment in the final channel like ^{8,9}Li, ^{8}B or ^{8}He. The decay of these nuclei, due to the colinearity of the momenta of alfa particle products, has in nuclear emulsion the characteristic configuration of a hammer prong (H) and it is easily recognizable.

$$\left.\begin{matrix} {}^{8}\text{Li} \xrightarrow{\beta^-} \\ {}^{8}\text{B} \xrightarrow{\beta^+} \\ {}^{8}\text{He} \xrightarrow{\beta^-} \end{matrix}\right\} {}^{8}\text{Be} \rightarrow {}^{4}\text{He} + {}^{4}\text{He} \quad , \quad {}^{9}\text{Li} \xrightarrow{\beta^-} {}^{9}\text{Be} \rightarrow {}^{4}\text{He} + {}^{4}\text{He} + n$$

Fig. 1.

Extensive analysis of reactions induced by stopped π^- mesons $(R\pi^-)$[1-3] showed that the emission of ^{8}Li fragment is dominating, and that out of 7145 stars with (H) fragment only 3(H) fragments with two beta particles were emitted that were attributable to (H) — ^{8}He. Up to now, the studies of these reactions with K^- mesons have been done mostly with high momenta mesons[4–8] whereas in reactions with stopped K^- mesons the data were statistically poor[9,10]. Thus in reactions induced by K^- mesons of 1.5 GeV/c measuring the widths of the fragments tracks there was obtained 11% and 2.4% (H) — fragments with $Z = 2$ and $Z = 5$, respectively. In the case of identifying (H) fragment with $Z = 2$ by emission of two beta particles, there was obtained about 2% of (H) — ^{8}He. Both for $R\pi^-$ and RK^- reactions, the emission of ^{9}Li nuclei was not relevant.

TABLE 1.

N_k	Tar-get	Inclusive final channel with ^{8}B, *^{8}Li and ^{8}He (Charged particles only)		
1	C N O	^{8}B	— — —	— — —
2	C N O	— ^{8}B+1(H)$^{+}$ ^{8}B+He	^{8}Li+He — ^{8}Li+^{7}Be	— — ^{8}He+^{8}B
3	C N O	^{8}B−1+1(H) ^{8}B−1+He ^{8}B−1+Li ^{8}B+1(H)+H	^{8}Li+1(H)+H ^{8}Li+1(H)+He ^{8}Li+He+He ^{8}Li+1(H)+^{6}Li	^{8}He+1+He — — —
4	C N O	— ^{8}B−1+1(H)+H ^{8}B−1+1(H)+He	^{8}Li−1+1(H)+He +^{8}Li+1(H)+H+H +^{8}Li+1(H)+H+He	^{8}He+1(H)+H+H ^{8}He+1(H)+H+He ^{8}He+1(H)+He+He
5	C N O	— — ^{8}B−1+1(H)+H+H —	^{8}Li−1+1(H)+H+H ^{8}Li−1+1(H)+H+He ^{8}Li−1+1(H)+He+He ^{8}Li+1(H)+H+H+H	— ^{8}He+1(H)+H+H+H ^{8}He+1(H)+1(H)+H+He —
6	C N O	— — — —	— ^{8}Li−1+1(H)+H+H+H ^{8}Li−1+1(H)+H+He —	^{8}He−1+1(H)+H+H+H ^{8}He−1+1(H)+H+H+He ^{8}He−1+1(H)+H+He+He ^{8}He+1(H)+H+H+H+H
7	C N O	— — —	— — ^{8}Li−1+1(H)+H+H+H+H	— ^{8}He−1+1(H)+H+H+H+H ^{8}He−1+1(H)+H+H+H+H
8	C N O	— — —	— — —	— — ^{8}He−1+1(H)+H+H+H+H

*^{8}Li comprises also ^{9}Li

$^{+}$1 (H) may be a positively charged hyperon, π — meson or the nucleus of an isotope of H

The primary interaction of K^- meson with nuclei is a multichannel process ($Y = \lambda^0, \Sigma^+, \Sigma^-$ or Σ^0, $N =$ nucleon).

$$K^- + N \rightarrow Y + \pi \quad (1a)$$

$$K^- + nN \rightarrow Y + (n-1)\,N \quad (1b)$$

where n is integer number. The products of the primary interaction may have induced secondary reactions in the parent nucleus so that the analysis of the interaction of K^- meson with nucleus was difficult. The possible inclusive channels of K^- meson reaction with C, N and O nuclei are given in Table 1. The production of hypernuclei was not taken into account. It can be seen from Table 1 that the conservation of charge causes the emission of an (H) fragment of defined Z, so that in the channel with three charged particles where one of them was a negatively charged hadron, the emitted (H) fragment could only be a ^{8}B nucleus. We tried to identify the (H) fragment analysing the charges of outgoing hadrons.

2. *Experimental procedure and results*

The experimental data on interactions of stopped K^- mesons with nuclei of nuclear emulsion were obtained from a part of the Ilford emulsion stack exposed at Brookhaven *AGS* to the beam of K^- mesons by European K^-Collaboration[12]. During the area scanning, together with the stars induced by stopped K^- mesons, RK^-, the stars with hammer like (H) prong were recorded. As an (H) prong we considered a track consisting of two short ($R < 20$ μm) nearly collinear prongs ($\Theta > 150^0$). It has been checked for each star with (H)-prong whether the incident particle belonged to beam K^- meson. For each star with an (H)--prong we established the total number of prongs, and each of them was followed till its end in emulsion or to the points where it left the stack. Each end of the track was carefully considered in respect to the decay or an interaction.

2.1. It has been found $2.86 \cdot 10^5$ interactions of RK_σ^-. At the same time 673 stars with (H)-prong have been recorded. 453 ± 6 RK^- stars were left after elimination of stars which did not belong to RK_σ^- interaction and RK_σ^- stars with hyper--fragment which had one (H)-prong. The cited error is due to the stars with (H)--prongs in which the origins of all prongs were not established without ambiquity (DC). About 20% of stars with (H) were induced by $R\pi^-$-interaction, so that $R\pi^-$ and RK^- interactions with (H)-prong could be compared in our experimental data.

The distribution of stars with (H)-prong in the RK^- and $R\pi^-$ interaction according to the number of charged prongs (N_k) is given in Table 2 (here also a prong with $R < 3$ μm is taken into account as a prong). In Table 2 it is seen that more than a half of stars have $N_k = 3$, (what is in accordance with previous data[3,9]).

2.2. The range distribution of (H) — fragment from RK^- and $R\pi^-$ interaction is given in Fig. 2. For the sake of comparison, we gave also the ranges of hypernuclei $^8_\lambda$Li, $^8_\lambda$Be and $^{12}_\lambda$B[13] which are produced in RK^- — interaction with emulsion nuclei. It is seen that the peak of the range distribution of (H) fragment is shifted toward the shorter ranges with respect to the peak in $^8_\lambda$Li, and the peak in the $R\pi^-$ interaction.

TABLE 2.

Inter-action \ N_k	Number of stars with charged prongs (N_k) %						
	1	2	3	4	5	6	Total
RK^-	0.2	4.0	54.0	23.6	11.2	6.2	453—100 %
RK^-LN*	84		85	66.6	78	43	
R^-		5.9	51.5	37	5	0.7	133—100 %

*RK^-LN = RK^- interaction with light emulsion nuclei (in %)

2.3. According to the usual criterion (charge, Coulomb barrier, Auger effect of electron, blob) it is assumed that interactions at light emulsion nuclei (C, N, O) gave rise to pure stars which had not more that 6 prongs, out of which one had

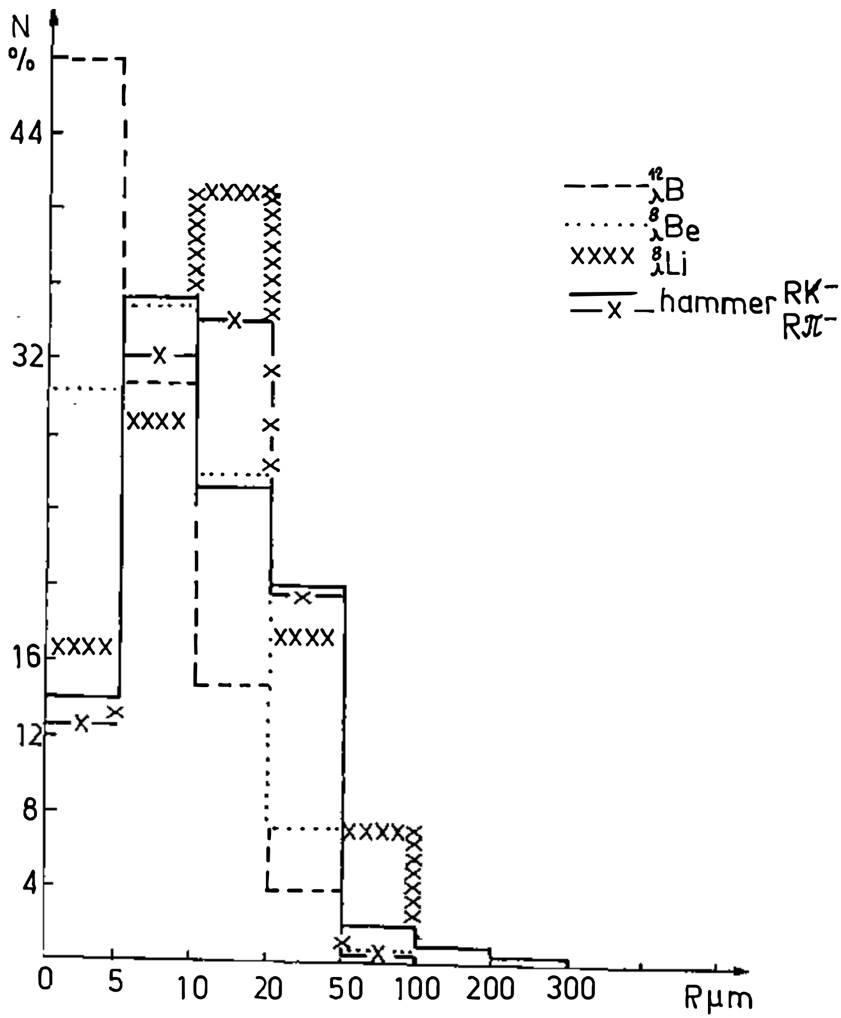

Fig. 2.

to be of the length $3 < R \leqslant 30$ μm, and if this was an (H) prong then $R_{(H)} < 25$ μm. Irrespective of the range of the prong, if there was a blob or recoil with $R < 2$ μm or an electron in the star, the event was not taken into account as RK^- interaction on light nuclei. It was found that satisfying the above criteria, 77% of RK^- interactions with emission of one (H) fragment occurred on light emulsion nuclei. In the group of stars with $N_k = 3$, interactions with light nucleus ammounted 85%. A similar result was also obtained for interaction of $R\pi^-$. In general interaction of K^- mesons with emulsion nuclei the percentage of interactions on light nuclei was 40%[14].

2.4. Identifying (H) prongs with two beta decays of (H) — fragments it was found that about 0.6% could be (H) fragment ascribed to ^{8}He-nuclei.

According to the earlier paper[15] it is shown that in RK^- reactions with (H) fragment there is the higher percentage of (H) fragments without electrons rather than in (H) fragments produced by $R\pi^-$ reactions. Thus it was confirmed that less than 5% of (H) fragment in RK^- reaction with (H) fragment could be ascribed to the decay of hypernuclei. Among all the stars in our experiment only one case was found of simultaneous emission of a hypernucleus and an (H) fragment.

2.5. Table 3 shows the results of the determination of charges of (H) fragments from the measurement of the width of its track in emulsion (54 measured cases with the range of $R_{(H)} > 20$ μm and for dip angle $\Theta < 30^0$). Omitting (H) fragments without electrons we obtained satisfying the above criteria the ratio ^{8}He : : ^{8}Li : ^{8}B = 1 : 2 : 0.67.

TABLE 3.

Z \ N_k	1,2	3	4	5	6	Total
2	1	4	4	4	3	16
3	2	10	8	2	4	26
3	—	1	1	1		3
3	—	6	2	—	1	9
Total	3	21	15	7	8	54

2.6. According to Table 1, the existence of RK^- reactions on C, N or O nuclei with emission of (H) fragment of determined Z is connected with conservation of charge in this channel. We had to find the events with negatively charged particles in final channel (π^- and Σ^-). We separated the pions from barions (by method of counting the number of grains on 100 μm depending on particle range[16]). The charge of π meson was determined only if the meson track ended in the emulsion. Table 4 gives the summary of π mesons. N_s are identified π mesons whose tracks do not end in our stack. The error was due to fast particles with great dip, which we could not identify. In the group $N_k = 3$, we obtained 12% reactions in which π^- meson was emitted.

The identification of Σ^- hyperon in emulsion is frequently not symple, and this is specially true for Σ^- hyperon in which its track may be ended in the emulsion without distinct sign of sigma decay or interaction (Σ_ϱ). In a study of the interaction $K^- + p \rightarrow \Sigma^- + \pi^+$ one found the ratio $\Sigma^- / \Sigma_\sigma^- = 3.3$[18] where for Σ_σ

TABLE 4.

N_k	N_{π^+}	N_{π^-}	N_s	total	N_{π^-}/N_{π^+}
2	—	—	—	—	—
3	13	14	31+2	58+3	1.05
4	7	5	13+1	25+1	0.71
5	3	5	7±2	16+2	1.66
6	—	5	3±1	8+1	5/0
Tot.	23	29	54±6	106±7	1.3

one took those cases of Σ^--hyperon whose track is determined by the star with at least one prong of the length in emulsion of $R > 200$ μm, or by two prongs of a length of $R > 5$ μm. In the group $N_k = 3$ according to above criterion the number of Σ_σ was $8 \pm {}^2_1$ and so in total 34 sigma hyperons were produced. Together with cases of π^- meson we obtained 26% RK^- interaction with emission of negatively charged hadron. A similar result is obtained for RK^- interaction only on light nuclei. In this manner the lower limit for producing ^{8}B fragments in the group $N_k = 3$ is 26%.

The analysis of other channels with $N_k \neq 3$ is not simple but shows the possible additional emission of (H) — ^{8}B and considerable emission of (H) — ^{8}He. Finally according to Table 1, 2, 3 and 4 taking into account emission of Σ^- hyperon it has been estimated that in RK^- reactions with emulsion nuclei the lower limit of (H) — ^{8}B emission was 13% and (H) — ^{8}He emission about 5%.

2.7. Table 5 gives a review of the ratio π^-/π^+ in RK^- reactions in relations to the different targets[10]. This ratio varies with the change of channels. The probability of formation of clusters in the nucleus certainly affected the concrete realization of the reaction.

TABLE 5.

Target	H	D	He	Emulsion			
				total	$N_k = 3 \geq 6$	Star with (H)	
					total	total	$N_k = 3$
π^-/π^+	0.45	1.95	5.5	3.9	5.5	1.3	1.1

The reaction induced with stoped K^- meson with emulsion nuclei with (H) fragment in the final channel occurred predominantly on light emulsion nuclei. The stars with three prongs $N_k = 3$ occurred in more than 50% and in the final channel of the reaction dominantly either ^{8}Li or ^{8}B was emitted. The lower limit of the emission (H) — ^{8}B in this channel was 26%. Such large percentage of emission of (H) — ^{8}B shows the specificity of the interaction of RK^- mesons as well as the effect of probability of formation of associations of nucleons in the nucleus which lead to the emission of a (H) fragment[19–20].

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FRAGMENTI S $A = 8$ KAO PRODUKTI INTERAKCIJA ZAUSTAVLJENIH K^--MEZONA S JEZGRAMA NUKLEARNE EMULZIJE

M. K. JURIĆ

Institut za fiziku, Beograd

UDK 539.12

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Izmedu $2.8 \cdot 10^5$ interakcija zaustavljenih K^- mezona sa jezgrama nuklearne emulzije, nađeno je 453 zvijezda kod kojih je jedan od krakova bio poput čekića. (Taj krak pripada raspadu jezgre ^{8}He, ^{8,9}Li ili ^{8}B). 77% ovih interakcija događa se na laganim jezgrama emulzije (C, N, O). Nađeno je da odnos broja zvijezda (R) sa emisijom π^--mezona prema emisiji π^+-mezona iznosi $R = 1.3$. Pojava fragmenta-čekića uglavnom može da se pripiše jezgru ^{8}Li, ali doprinos drugih jezgara sa $A = 8$ nije neznatan, kao što je to slučaj kod reakcija izazvanih drugim česticama. Nađeno je da je donja granica emisije ^{8}B i ^{8}He jezgra oko 13% i 5% respektivno.