μ^- *MESON CAPTURE IN CARBON WITH FORMATION OF* B^{12*}

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Approximately 500 two-prong stars produced in the capture of μ^- mesons by light emulsion nuclei are examined. The probability for emission of an Auger electron in a capture of this type is of the order of a tenth of a percent. Nine stars of the type $\mu^- + C^{12} \rightarrow B^{12*} + \nu$; $B^{12*} \rightarrow Li^8 + He^4$ have been detected. The probability of such a reaction is 2×10^{-3} per capture in a carbon nucleus. It is shown that there should exist excited levels in the B^{12} nucleus with an energy $\sim 19 - 26$ Mev, from which breakup into Li^8 and He^4 is possible.

In the study of stars from μ^- meson capture in nuclear emulsion one's attention is attracted to characteristic two-prong stars, consisting of approximately collinear tracks. The short prong of the star represents the track of the recoil nucleus, whose range is, as a rule, under $10\,\mu$. The presence of visible tracks of the recoil nuclei shows that these stars are produced as a result of μ^- meson capture by light, and not heavy, emulsion nuclei. Occasionally the recoil nucleus turn out to be β-active (Fig. 1), and in a few cases, discussed in detail below, we have observed its decay into two α particles. Additional evidence in favor of the hypothesis that the stars in question arise from capture in light nuclei is provided by the absence of Auger electrons from the center of the star. Among the ~ 500 stars of the type under consideration only 2 electron tracks with energy $\gtrsim 25$ kev were found, whereas approximately 20% of captures in heavy nuclei are accompanied by the emission of such electrons.

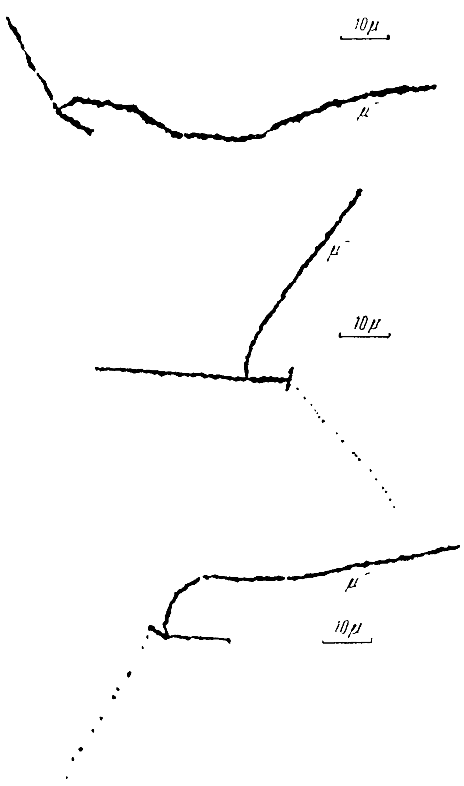

FIG. 1

We remark that the practical absence of Auger electrons among the 500 stars considered by us has additional meaning in connection with the well known experiments of Stearns et al,[2] who noted a considerable deficiency of radiative transitions in μ^- meson captures by light nuclei. According to their data this deficiency amounts to respectively ~ 40 and 20% on C and N nuclei.

It is reasonable to assume that this decrease in the probability of radiative transitions is accompanied by a corresponding increase in the probability of emission of Auger electrons. If this assumption is correct we should have observed ~ 100 Auger electrons with energy > 25 kev, instead of the two that were seen. The number of Auger electrons seen by us is in agreement with that expected from the theory of radiationless transitions,[3,4] and we conclude that there are no additional radiationless transitions to compensate for the deficiency of radiative transitions observed by Stearns et al.[2]

As a rule the two particles observed by us are emitted in approximately opposite directions. This can be seen from the distribution of the projection of the angles ϑ between the directions of the tracks of the recoil nucleus and the other, lighter, particle (Fig. 2). The small deviation from colline-

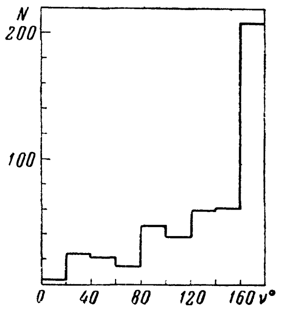

FIG. 2. Distribution of the angles between the tracks of the α particle and the recoil nucleus.

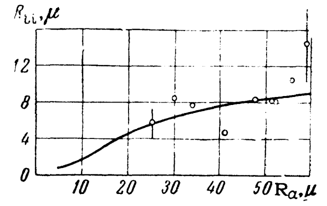

FIG. 3. Correlation between the ranges of the α particle, R_α, and the recoil nucleus, R_{Li}.

arity may be explained by the recoil of the nucleus, which captured the μ^- meson, as a result of emission of a neutrino:

$$\mu^- + N \rightarrow N^* + \nu.$$

From among all observed stars of this type we shall discuss those which could be reliably identified. Such stars (see Fig. 1) arise from capture of a μ^- meson by a C^{12} nucleus:

$$\mu^- + C^{12} \rightarrow B^{12*} + \nu$$

followed by the breakup of the excited B^{12*} nucleus into a Li^8 nucleus and an α particle:

$$B^{12*} \rightarrow Li^8 + \alpha.$$

After stopping the Li^8 nucleus decays:

$$Li^8 \rightarrow Be^8 + \nu + \beta,$$

and the resultant Be nucleus breaks up into two α particles. We have discovered nine disintegrations of this type. Their characteristics are given in the table, where we show the projection ϑ on the emulsion plane of the angle of emission of the two particles, the noncoplanarity angle $\Delta\varphi$ in the perpendicular plane, the ranges of the two particles R_α and R_{Li}, and the total range $R_{2\alpha}$ of the collinear α particles produced in the decay of Be.

If our treatment of these stars is correct then there should exist a correlation between the ranges of the α particles and the recoil nucleus. The solid curve in Fig. 3 shows the dependence between the α-particle range R_α and the recoil nucleus range R_{Li}, calculated on the assumption that in the breakup of the B^{12*} nucleus the momenta of the two particles are equal and opposite. In the construction of this curve we have made use of the range-energy relations for α particles and Li nuclei as given by Bujdoso[5] and Powell.[6] The experimental points on the graph correspond to values of R_α and R_{Li} from the table. If one keeps in mind that the errors in the measurement of the range of the recoil nucleus in the $4 - 10\,\mu$ region can amount to 25 — 30%, one concludes that the agreement found should be considered satisfactory.

Another test of the correctness of our treatment is to be found in the degree of deviation of the tracks from collinearity. If it is assumed that the momentum carried away by the neutrino is close to a 100 Mev, then it is easy to show that for the observed ranges of α particles and lithium nuclei the maximum deviation from collinearity should lie between 15 and 20°. This is in good agreement with the data in the table.

It is of interest to estimate the probability for μ^- meson capture in C^{12}, followed by a reaction of the type considered. According to an approximate estimate the nine stars were found among 160,000 μ^- decays, which can be assumed without too much of an error to be the number of μ^- mesons stopped in the gelatin (C, N, and O nuclei). Let us assume further that the stoppings are equally divided among the nuclei of C, N, and O. It is known that approximately 10% of μ^- mesons in carbon mesic atoms are captured by the nucleus.[7] In this manner we find for the desired probability

$$W \approx 9/\frac{160\,000}{3} \times 0.1 \approx 2 \times 10^{-3},$$

i.e., approximately 2×10^{-3} captures of μ^- mesons

R_α, μ	R_{Li}, μ	$E_\alpha + E_{Li}$, Mev	$R_{2\alpha}, \mu$	ϑ, degrees	$\Delta\varphi$, degrees
29.9	8.4	11.5	13	180	2
47.9	8.2	13.8	12.9	156	7
25.2	5.6	8.9	13.6	145	1
51.8	8.1	14.2	10.6	175	4
34.3	7.7	11.9	10.8	166	4
56.3	10.5	16.2	9.6	180	10
59.6	14.4	19.5	9.9	177	4
52	8.1	14.1	15.4	180	8
41.4	4.6	10.7	22.4	175	8

by carbon nuclei lead to the reaction under consideration.

If we turn to the energy level diagram of C^{12},[8] we see that the investigated levels extend all the way to the excitation energy of 5.73 Mev, whereas the rest energy of the $Li^8 + \alpha$ system exceeds this excitation energy by 4.23 Mev. The particles in our stars, resulting from the breakup of the B^{12*} nucleus, have an energy of 9 — 16 Mev. This means that in the region of excitation energies of 5.73 + 4.23 + (9 — 16) Mev, i.e., in the region of 19 — 26 Mev, there should exist levels in the B^{12} nucleus capable of decay into Li^8 and an α particle.

In principle, in addition to the reaction here considered, many of the reactions on light emulsion nuclei can be identified. To that end it is necessary to measure more precisely the range and charge of the recoil nucleus, which, apparently, can be done with the help of fine-grained and diluted emulsions. The capture of μ^- mesons by nuclei may turn out to be a tool for obtaining information on the properties of light nuclei for excitation energies of 10 — 20 Mev.

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