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Introduction.

The possibility of U^{238} fission with μ^- mesons was first predicted by Wheeler [(1)]. Theoretically this may be realised in two different ways:

a) the capture of the μ^- meson on one of the optical orbits followed by transitions in the 2s-2p-1s states. During these transitions an energy of about 7 MeV is eliberetedₓ energy which is greater than the photofission thresold;

b) nuclear capture in which through the reaction $\mu^- + p \to n + \nu$ [(2)] the nucleus recives an energy of about 15 MeV [(3,4)].

There was done an experimental attempt [(5)] to detect uranium fission by μ^- mesons in cosmic rays, but it led to a negative result. In the same work there was given an upper limit for the fission probability of 0.25 imposed by consideration of statistical accuracy. W.John and W.F.Fry [(6)] found 7 events of fission from 3573 μ^- mesons endings in Ilford C2 plates loaded with 0.052 g/cm^3 uranium.

In the present work there were considered 26,975 μ^- mesons endings in nuclear plates loaded with uranium.

Experimental details.

NIKFI-R 200 μ plates were previously presoaked in water for 25 minutes, then in a saturated solution of uranyl acetate for 40 minutes. Afterwards the plates were dried during an hour and exposed at the μ^- mesons beam for 3 hours. Including developing, the total time from uranium loading up to fixing was of 6 hours.

The uranium concentration in the emulsion was determined by α tracks counting and was found to be 0.055 g/cm^3. The plates were exposed at one of the $\pi^- + \mu^-$ mesons beams of the JINR synchrocyclotron from Dubna. The μ^-mesons beam was separated from the 150 MeV π^- mesons one, using 11.6 cm copper filter. Scanning was done with MBI-3 microscopes at the magnification of 300x; fission events were analysed at 1350x.

Results.

26,975 μ^- mesons ends were found out of which 59 fission events. In 4 cases the meson track was found to stop in a 4 prong star. Taking into account that π^- mesons stopping in the emulsion give 4 prong stars in 8.7 % [7] and assuming that all our 4 prong stars were produced by π^- mesons, we found an upper limit of contamination with π^- mesons of 0.002 ± 0.001. This means that in our case, considering the results of [8], about 0.5 fissions were due to π^- mesons.

We have found the probability that a μ^- meson stopping in our plates produces a fission equal to $P = (2.2 \pm 0.3)10^{-3}$. The range of fission fragments was measured with an accuracy of ± 1 μ. In histogram R the ratio of fission fragments is represented. In histograms D and F there are given respectively the differences and the lenghts of short and long tracks, for comparison with the results of [9]. The average lenghts of 10.5 μ and 13.4 μ is found for short and long ranges respectively.

Analysis of the results.

The experimentally determined probability P permits the calculation of the probability of fission $Pf = \frac{P}{Pa}$, under certain assumptions about the probability of atomic capture Pa. In calculation we have utilised that the uranium enters only in gelatin [10] and that 40 % of μ^- mesons stop in gelatin [11]. Pa was calculated in two cases:

1) on the basis of the Fermi-Teller Z law [12];

2) taking into account the experimental results of [13] (extrapolated to great difference of Z) in which it is shown that the probability of atomic capture does not depend on Z. In these two cases there were found the values $(6.75 \pm 0.8)\ 10^{-2}$ and $(5.55 \pm 0.7)\ 10^{-3}$ respectively. For Pf the values 0.08 ± 0.01 and 1.13 ± 0.14 result in these two cases.

Discussion.

A rigourous analysis of the fission probability of uranium with μ^- mesons cannot be made at present because experimental data on atomic capture for great Z do not exist. From the comparison of histograms D and F with those of [9], where ranges of fragments from U^{235} fission with slow neutrons are measured, it seems that the fission of U^{238} through process (a) may occur in significant amount. Assuming that the entire process goes through the channel (a), the probability of fission will be about 20 %, in agreement with [14]. For the process (b) one may compute the fission probability of Pa^{238} by extrapolating the photofission data and using the empirical relation [15]:

$$\frac{X_z}{X_u} = 1.3 \left(\frac{Z^2}{A} - 34.7 \right)$$

between the branching ratio X_z of a nucleus with given Z and the branching ratio X_u for uranium 238. Taking $X_u = 0.4$ at 15 MeV in agreement with [16,17] one finds 0.06 for the fission probability of Pa^{238}.

The value of 0.08 calculated in the Z law assumption appears more reasonable than the value 1.13 obtained on the basis of [13]. In this case to obtain values within the limits 0.06-0.20, one must assume that uranium enters in calculation with a supplementary statistical weight between 5-10.

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References.

1. U.A.Wheeler, Rev.Mod.Phys., 21, 113, (1949).

2. B.M.Pontecorvo, Phys.Rev., 72, 246, (1947).

3. J.Tiomno, J.A.Wheeler, Rev.Mod.Phys., 21, 153, (1949).

4. H.Morinaga, W.F.Fry, Nuovo Cimento, 10, 308, (1953).

5. W.Galbraith, W.J.Whitehouse, Phil.Mag., 44, 77, (1953).

6. W.John, W.F.Fry, Phys.Rev., 91, 1234, (1953).

7. F.L.Adelman, S.B.Jones, Phys.Rev., 75, 1468, (1949).

8. G.E.Belovitski, T.A.Romanova, Z.V.Suhov, I.M.Frank, JETP, 28, 729, (1955); N.A.Perfilov, N.S.Ivanova, JETP, 28, 733, (1955).

9. P.Demers, Phys.Rev., 70, 974, (1946).

10. O.V.Lozhkin, V.P.Shamov, JETP, 28, 739, (1955).

11. W.F.Fry, Phys.Rev., 85, 676, (1952).

12. E.Fermi, E.Teller, Phys.Rev., 72, 399, (1947).

13. J.C.Sens, R.A.Swanson, V.L.Telegdi, D.D.Yovanovitch, Nuovo Cimento, 8, 536, (1958).

14. J.E.Gindler, J.R.Huizenga, R.A.Schmitt, Phys.Rev., 104, 425, (1956).

15. J.R.Huizenga, J.E.Gindler, R.E.Duffield, Phys.Rev., 95, 1009, (1954).

16. J.S.Levinger, H.A.Bethe, Phys.Rev., 85, 577, (1952).

17. G.A.Price, D.W.Kerst, Phys.Rev., 77, 806, (1950).

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