Notas de Física - Volume I - Nº 11

NOTE ON THE DIFFUSION OF RADIOELEMENTS IN NUCLEAR EMULSION

by

Elisa Frota-Pessôa*
Centro Brasileiro de Pesquisas Físicas
Rio de Janeiro, D.F.

December 30, 1952.

In a previous paper[1] we considered determination of the Uranium content of radioactive minerals in solution using nuclear emulsion. An analysis of the observed stars was made and we have shown that the number of 4-branch stars formed by -particles emitted by the elements Ra_{226}, Rn_{222}, Po_{218} and Po_{214}, successively, was less than 1% of the number of Ra_{226} which disintegrated during the exposure (three days). This result is in contradiction to R. Flament's[2] prevision of 20% for the referred time of exposure. We justified this small number of such stars by the diffusion of radon in the nuclear emulsion, in analogy with the known[3] diffusion of Rn_{220} (Thoron).

Although it was assumed in Flament's computations that no diffusion of radioelements occurred, her results have been used, and methods for titration of radioactive elements from minerals in solution have been proposed[4] which are based upon those results.

In the present Note, we put in evidence the existence of such diffusion of the radon. Furthermore, we show that one or both of the descendants of the radon, Pb_{214} and Bi_{217}, suffer diffusion in the nuclear emulsion, although much less than the radon. The existence of diffusion in the family of U_{235} is also pointed out.

The following experiments were made in order to prove these results.

(*) Also of the Faculdade Nacional de Filosofia.

Experiment I

We soaked an Ilford G5 plate, 100 micra thick, in a 1/4000 neutral solution of Brejaubas mineral[5], which contains only radioelements of the Uranium family[1], and let it dry. Another such plate was put in contact with the first, the emulsion coatings facing each other. After 8 days' exposure at about 5° C, the plates were developed and observed. Although the purpose of the experiment was to put in evidence the existence of three-branch stars in the unloaded plate (produced by the radon escaped from the loaded one), practically no such stars were observed.

We justified this negative result by the fact that the radon would have escaped through the very thin layer of air between the plates, as the air would have a much larger coefficient of diffusion than the emulsion. So we repeated the experiment, putting vaseline between the emulsions and pressing the plates against each other so as to reduce the thickness of the vaseline layer to a minimum. After 8 days' exposure, the vaseline was taken from the surface by the use of Xilol and the plate was developed. We then found that the unloaded plate had about the same number of 3-branch stars as the loaded one.

Figs. 1-2 show some of these stars, found in the unloaded plate.

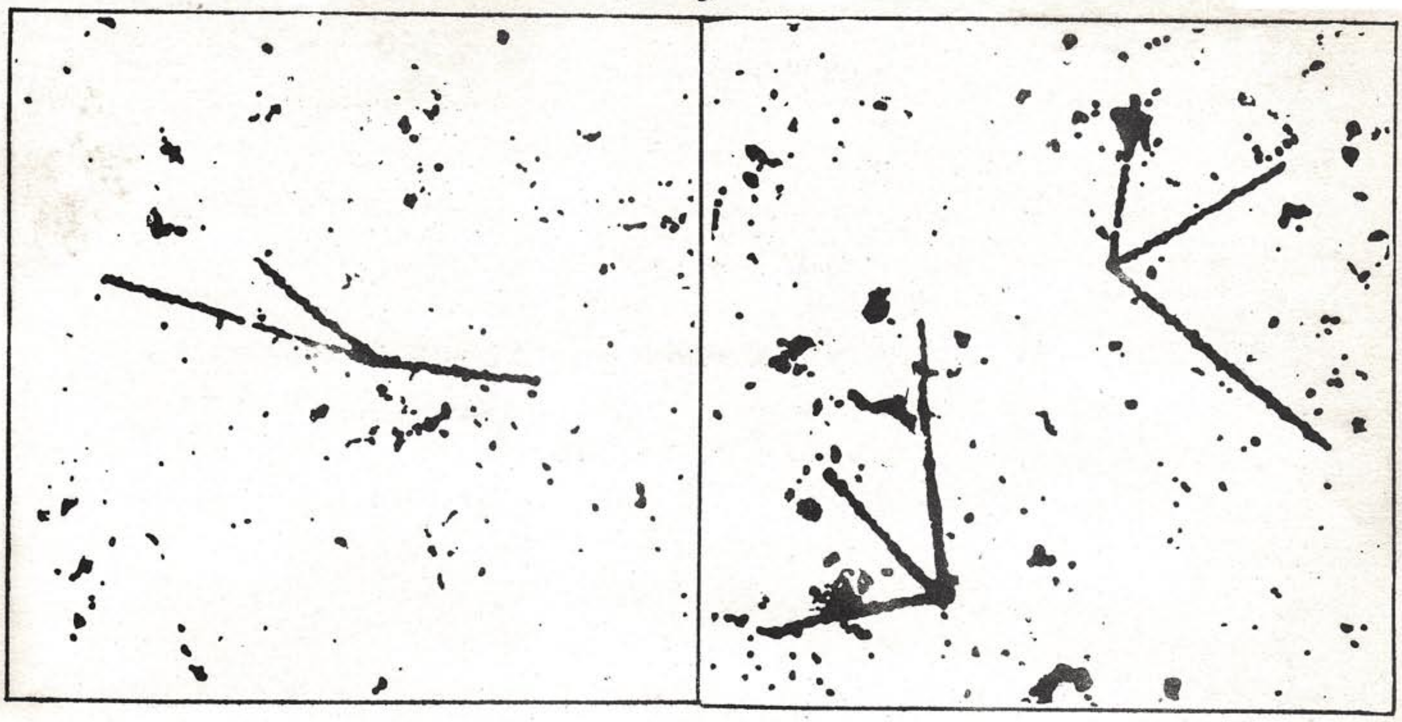
Fig. 5 gives the histogram of the number of α-particles in such stars against their range. Group A corresponds to the α from Rn_{222}, group B to the α from Po_{218} and group C to the α from Po_{214}, showing that such stars were really produced by the disintegration of radon coming from the loaded plate.

Besides the 3-branch stars, we found in the unloaded plate a number of 2-branch stars, each having a single track very near its vertex. The ratio of 2-branch to 3-branch stars was approximately one to four.

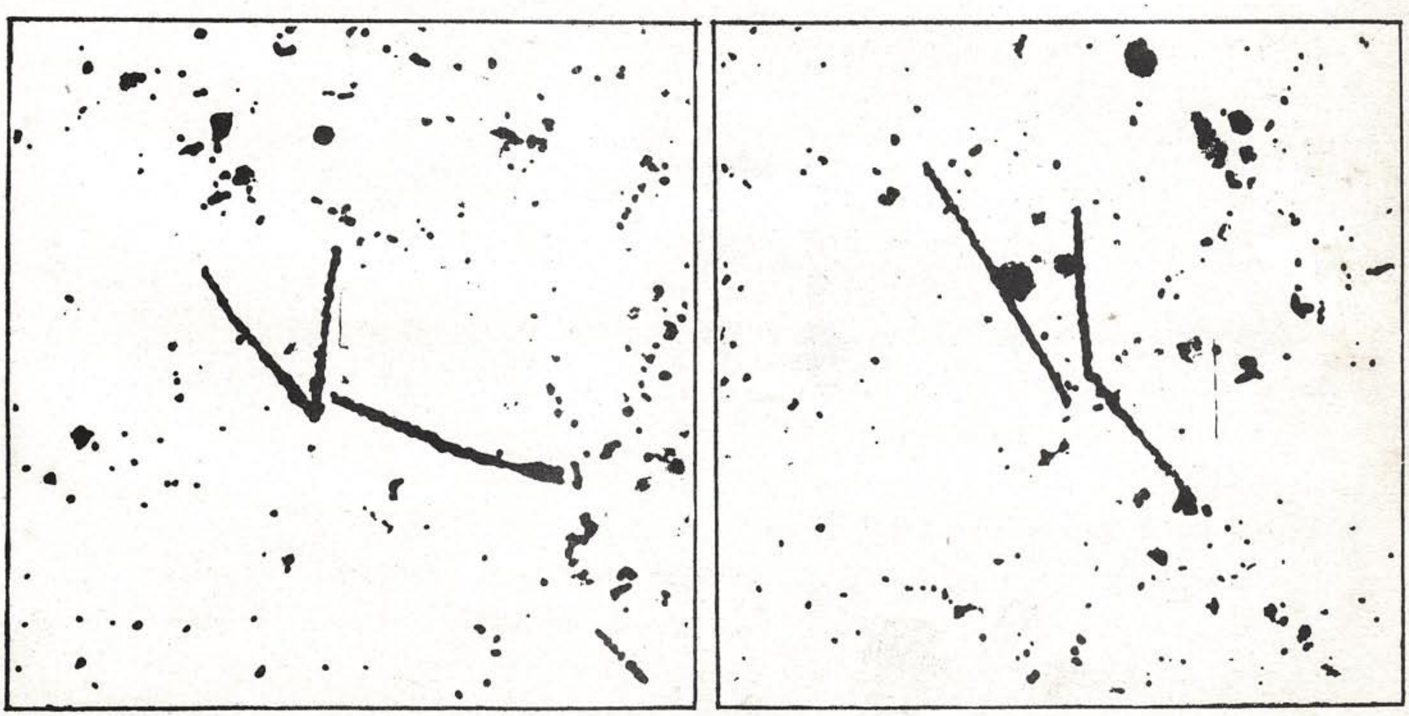
Figs. 3-4 show two of such events.

Fig. 6 gives the histogram of the number of tracks in these events against the range of the α-particles. The groups A and B correspond to branches of the star and the group C to the single track. The mean ranges show that the first and second groups correspond, respectively, to alphas from Rn_{222} and Po_{218}; the third group corresponds to alphas from Po_{214}.

In the U_{238} series, between Po_{218} and Po_{214} there are two beta-em-



Figs. 1 - 2
Three-branch stars of radon in the unloaded plate.



Figs. 3 - 4
Two-branch stars with a near-by alpha particle, in the unloaded plate.

Fig. 6. Histogram showing the range distribution of α - particles in two-branch stars plus single tracks.

Total number of particles : 65

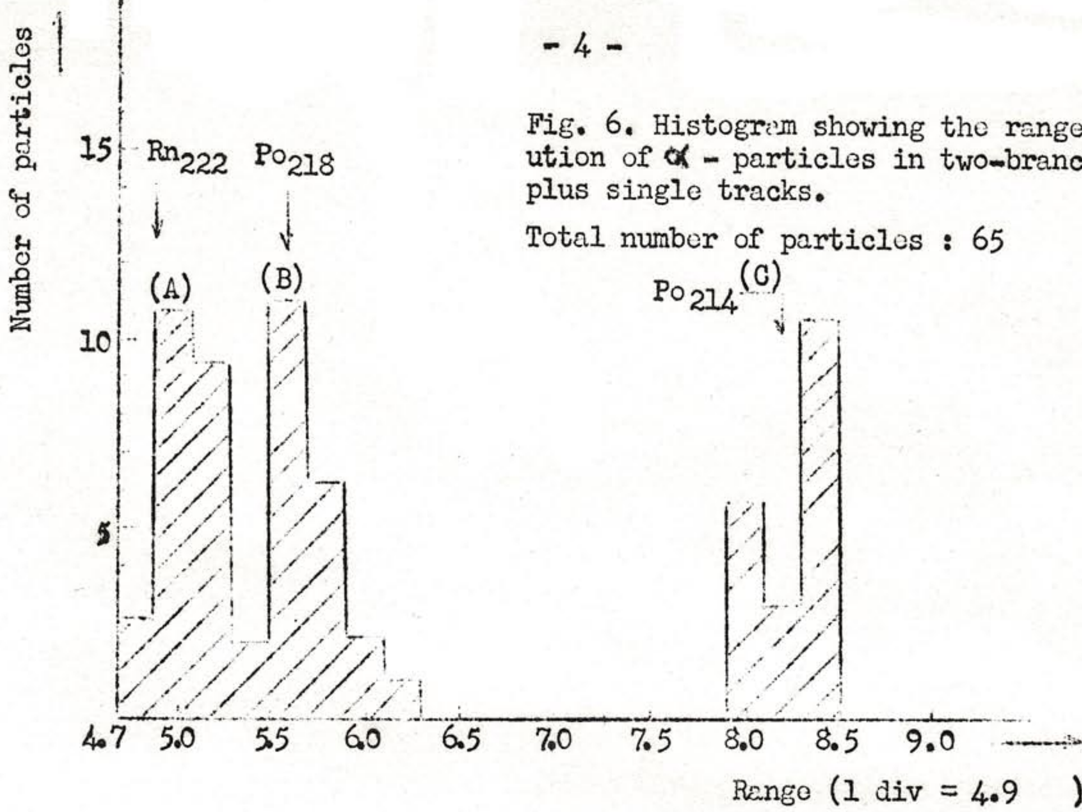
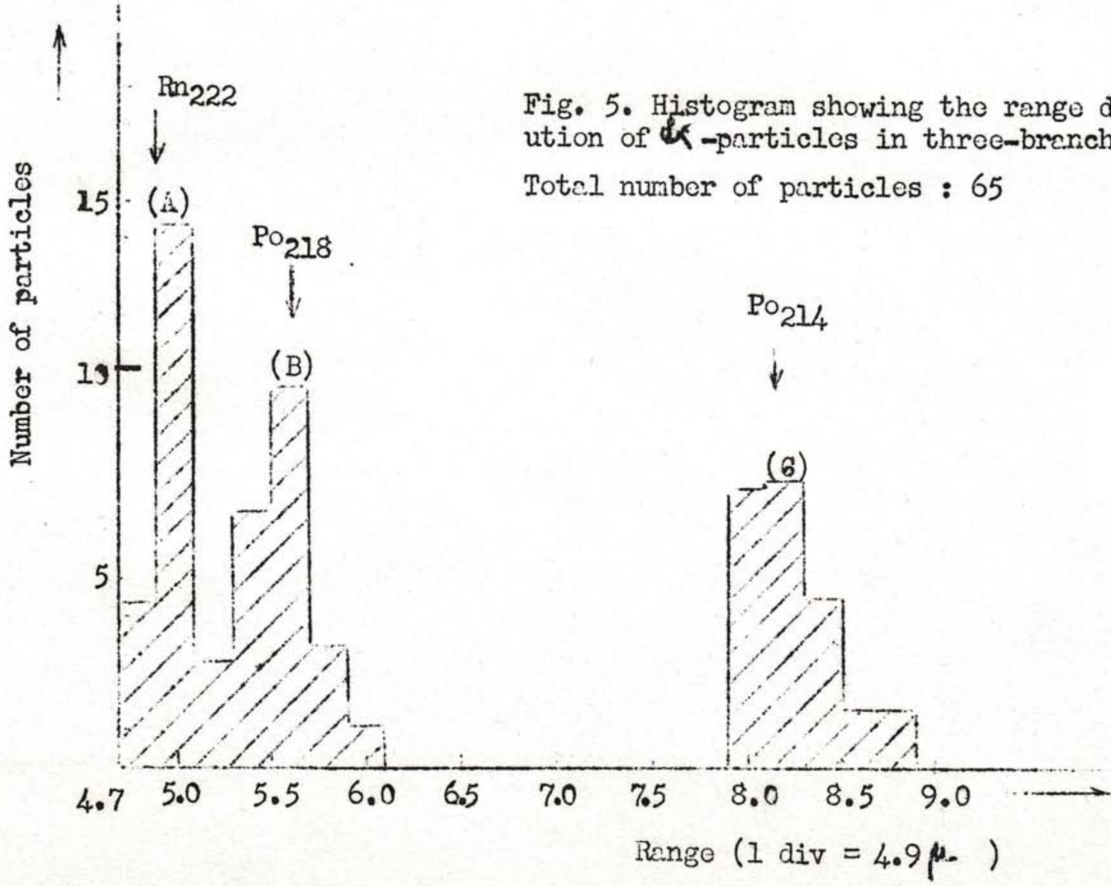


Fig. 5. Histogram showing the range distribution of α -particles in three-branch stars.

Total number of particles : 65



itters, Pb_{214} and Bi_{214} whose half-lives are 26.8 and 19.7 minutes, respectively. The fact that the α from Po_{214} is separated from those emitted by Rn_{222} and Po_{218} shows that either Bi_{214} or Pb_{214}(or both), suffers diffusion in the emulsion. This diffusion explains the 2-branch stars observed in plates loaded with uranium minerals[6].

We should point out that in a plate loaded with a solution of uranium mineral a few cases of 3-branch stars were observed which had an isolated track at a distance of a few micra from the star vertex. The fact that one, at least, of the branches of such stars had a mean range of 32 μ, corresponding to Bi_{211} and Rn_{219}, evidences the existence of diffusion in the family of U_{235}.

As a final observation we would like to indicate the possibility of using a method, similar to that used in this experiment, in order to determine the radium content of a mineral, even when it contains Thorium. This would consist of counting Radon stars in the unloaded plate. Such a possibility is being studied.

Experiment II

In order to eliminate the other radioelements which are not of interest to the present work, we soaked a plate for 3 hours in a neutral solution of radium salt with a radium content of about 2×10^{-10} gr/cc. The solution was prepared from radium chloride less than two years old; the plate was G5, 100 μ thick. The solution should also be free of Ra_{223}, the half-life of which is 11.2 days and which could produce 4-branch stars. Therefore, all observed 4-branch stars should originate from Ra_{226}. Care was taken that the amount of Rn_{222} in the solution at the time the exposure started should be negligible.

Fig. 7 gives the histogram of the single α-tracks observed against the range; it shows a large group of α-particles (A) from Ra_{226}(confirming the purity of the salt). The small group (B), is not the result of impurities, but is due to alphas from Po_{214}, and has a 2-branch star nearby (as referred to in Experiment I).

Therefore, if we assume that there is no diffusion of radio-elements[2] we should find no 2 or 3-branch stars. Furthermore, after the 7 days' expo

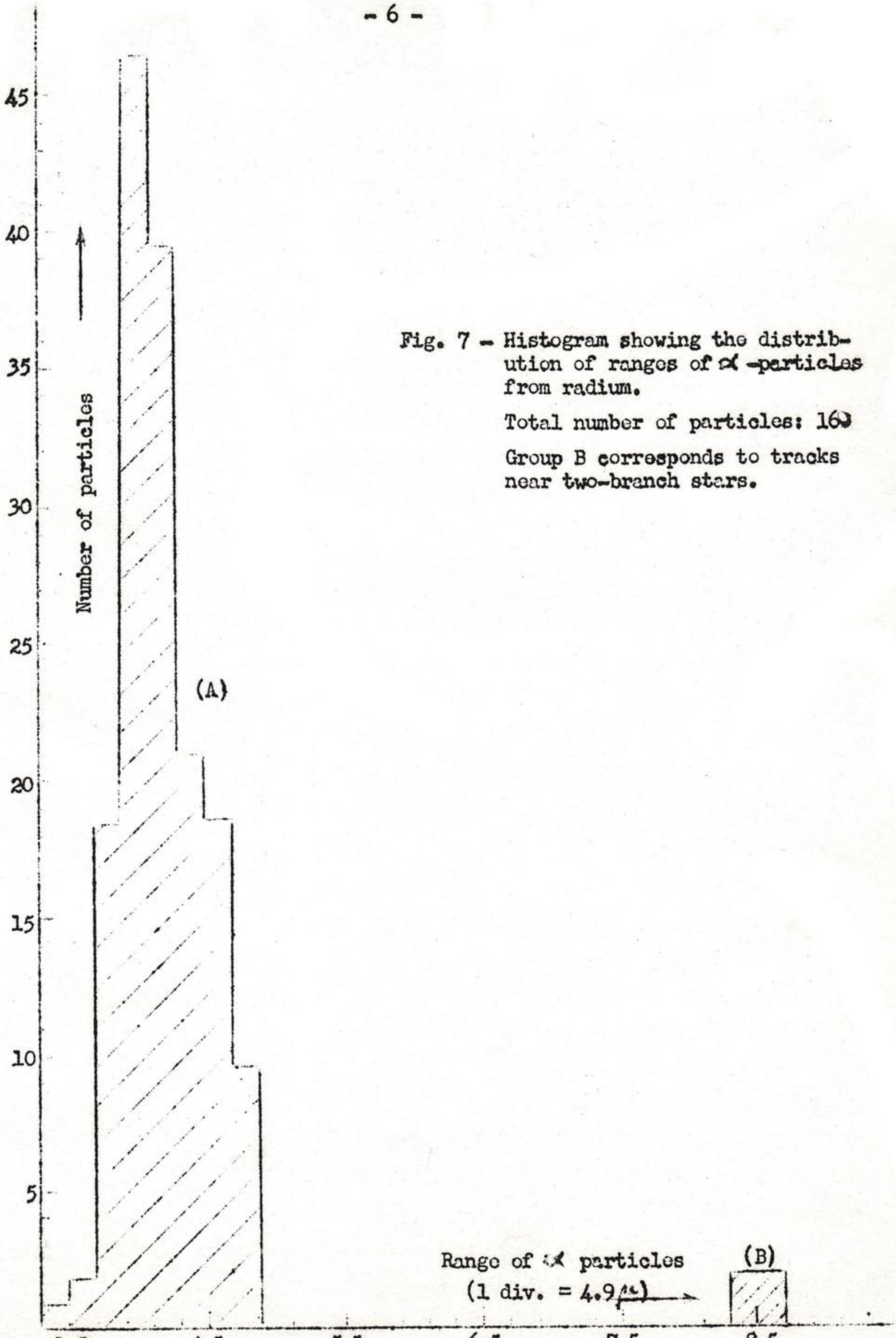


Fig. 7 - Histogram showing the distribution of ranges of α-particles from radium.

Total number of particles: 169

Group B corresponds to tracks near two-branch stars.

sure we should find 58 single track and 42 quadruple stars for a hundred atoms of Ra_{226} disintegrated.

This is in contradiction to the result of our observation, which gave a mean of 13 single particles; 0.1 2-branch stars, 0.35 3-branch stars and 0.5 4-branch stars (these last three figures are not precise, in view of poor statistics) per 340μ diameter microscopic field. This corresponds to 4 quadruple stars and 96 single tracks per 100 atoms of Ra_{226} disintegrated.

From the analysis of the results just cited, we find that only about 17% of the radon which disintegrated during the 7 day exposure (42% of the radon formed[2]) was still in the emulsion, producing 2, 3 and 4-branch stars, the remainder having escaped before disintegration.

We should observe that, although the above results prove that the radon diffuses in the emulsion, the number of 4-branch stars is inconsistent with the hypothesis that all radon formed diffuses freely, these stars being considered as corresponding to cases where the radon does not go more than a fraction of a micron away from its original position. This is so in view of the large percentage of radon escaping from the emulsion (100μ thick). So we conclude that a small fraction of the radon formed (about 8%, as 4% were observed to disintegrate producing 4-branch stars), is retained near the point where it originates, being unable to diffuse. The possible reason for this retention are being studied.

We are grateful to Dr. Antônio Todesco for help in some measurements; to Mr. Luiz Machado de Lima for photographs; to Dr. Jacques Danon who prepared the solutions and to Professor J. Tiomno for helpful discussions.

1 - F.A.G.A. Brandão, E. Frota-Pessôa, N.Margem and W.Perez, An.Ac.Bras. Ci., in press; Notas de Física, Centro Brasileiro de Pesquisas Físicas, Nº 6, 1952.

2 - R. Flament, Bull. Centre de Phys. Nucl. Univ. Brux. Nº 3, 1948.

3 - H. J. Taylor and V.D. Dabholkar, Proc. Indian Acad. Sci., 3A, 265, 1936, P. Demers, Bull. Am. Phys. Soc. 22, Nº 3, 17, 1947.

4 - F. Begemann, H.v.Buttlar, F.G. Houtermans, N.Isaac and E.Picciotto, Bull. Centre de Phys. Nucl. Univ. Brux., Nº 37, 1952.

5 - J. Costa Ribeiro, An. Acad. Bras. Ci., XII, Nº 2(Resumos), 1940.

6 - H. Yagoda, Radioactive Measurements with Nuclear Emulsions, John Wiley & Sons, New York, 1949.