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ABSTRACT

An investigation was carried out to locate the rest position of fission fragments from Cf^{252} in Ilford K5 emulsion with respect to the end of the fragment track. This was found to be $0.131 \pm .05 \mu$ before the end of the fragment track, showing no clear indication of an extended range due to an ionization defect.

The range of the fission fragments was $13.64 \pm .19 \mu$, with a standard deviation of 0.161μ . The Cf^{252} was found to decay $97.33 \pm 1.41\%$ by α decay and $2.67 \pm .17\%$ by spontaneous fission.

STOPPING OF Cf^{252} FISSION FRAGMENTS IN EMULSIONKenneth D. Sevier[†]Lawrence Radiation Laboratory
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INTRODUCTION

The range of a charged particle in nuclear research emulsion is often used to determine the particle's energy or identity. When one is attempting to make an accurate measurement of the range of a particular particle of a certain energy in an emulsion, a number of corrections must be made in order to obtain the true range from the observed range. Shrinkage and any density changes of the emulsion must be taken into account,¹ as well as extension of range due to neutralization of the ionic charge.² Also, there must be a correction made to account for the fact that a heavy ionizing particle traverses, in the average, only about one-half of the first and last grains of the track.² At the time of the investigation by Heckman et al.,² there was some question as to just where the ion came to rest with respect to the position of the last grain, and how this should be corrected for.

Knipp and Ling³ have discussed ionization in gases caused by heavy charged particles. They have introduced a nuclear recoil effect: since energy loss of a slow heavy particle is predominantly due to recoiling atoms, ionization by secondary heavy particles contributes a large fraction to the total ionization resulting from a slow heavy particle that is stopped in a gas;

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if secondary ionization efficiency is low, the over-all efficiency for production of ion pairs is greatly reduced for low energies of the principal particle.

The experimental results of Schmitt and Leachman⁴ agree with the above theory in that toward the end of the range of a heavy charged particle, energy loss by nonionizing processes becomes increasingly important, and this energy appears only inefficiently in a measurement of ionization. This gives rise to the concept of the "ionization defect."

The present investigation was carried out to determine whether or not a fission fragment will proceed appreciably beyond the end of its visible range in an emulsion as a result of the ionization defect.

EXPERIMENTAL PROCEDURE

Electron-sensitive Ilford K5 emulsion plates were exposed in vacuum to one of three C^{252} fission sources. The strengths of the sources were 750, 1,300 and 28,000 fissions per minute. The thickness of the emulsion was 50 μ , and the decay products entered at a very small grazing angle.

After the exposure, the plates were allowed to stand for 12 hr so that the shorter-lived fragments would have time to decay. The plates were then developed and scanned. There was no obvious "gap" present between the ends of the fission fragment tracks and the origins of the beta or internal-conversion electron tracks. Photomicrographs of two fragment decays are presented in Fig. 1, showing that one and three electrons have been emitted, respectively.

In order to obtain a more quantitative determination of the origin of the decay electrons, the coordinates of the grains of the electron tracks as well as of a few positions along the fragment track, including those of the end point—were measured by using a Koristka MS-2 microscope with a digitized filar micrometer eyepiece.⁵ Only cases in which high-energy electrons were emitted perpendicular to the fragment track were considered. Then, with the

aid of the IBM 650 computer, the intersection of the two tracks was computed. This intersection was then compared with the position of the end point of the fragment track.⁶

RESULTS

The mean position of the intersection of the two tracks was found to be $0.131 \pm .053 \mu$ before the end of the fragment track.

Because of the complexity of the calculation for the most probable rest position of an ion, in an emulsion, with respect to the last developed grain, only a very rough value will be considered here. Assuming that the emulsion crystals are spherical, that they make up 50% of the emulsion by volume, that the crystals develop and expand about their own centers, that all crystals threaded by the ion are made developable, and that the stopping powers of the gel and the crystals are the same, one can calculate the most probable rest position of an ion to be about $1/3 \langle D \rangle$ beyond the center of the last crystal, where $\langle D \rangle$ is the mean crystal diameter. Taking the average crystal diameter to be $\langle D \rangle \approx 0.2 \mu$ and the developed expanded grain diameter to be 0.5μ , the ion will most probably come to rest at about 0.24μ before the end of the track. Most of the refinements of this calculation tend to increase this value, but again, because of the complexity of a detailed calculation, the discrepancy between this and the measured rest position of the ion is not considered to be significant.

Since Cf^{252} was the fission source, it was possible to calculate the ratio of α decay to spontaneous fission of the isotope by counting the relative yields of particles and fission fragments observed on the exposed emulsion plates. This showed that Cf^{252} decays $97.33 \pm 1.41\%$ by α decay and $2.67 \pm .17\%$ by spontaneous fission. This is in agreement with other reported values.^{7,8}

A measurement of the ranges of the fission fragments of Cf^{252} showed a continuous distribution having a mean value of $13.64 \pm .19 \mu$, with a standard deviation of 1.61μ . Any expected separation of the fragments into the lighter, more energetic and the heavier, less energetic groups suggested by the analysis of the spontaneous fission yield⁹ and by the velocity distribution of these fragments¹⁰ was obscured by range straggling. These values are based on the corrected measured ranges, adjusted to an emulsion density of 3.815 g/cm^3 . The alpha particle ranges were checked and found to be of the range expected for alpha particles of energy $\approx 6.1 \text{ Mev}$.²

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Fig. 1. Tracks of Cf^{252} fission fragments and of their emitted electrons.

Right

Left

Fig. 1