The author is grateful to Professor M. N. Saha, F.R.S., for his continued interest and guidance of this work.

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A Model for Nuclear Capture of μ-Mesons

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December 20, 1948

IT has been observed that negative μ-mesons, when stopped in materials of high atomic number, do not emit the energetic light charged particle usually associated with μ-meson decay.[1] This has been interpreted as meaning that the μ-meson in these cases is captured from its K-orbit by the nucleus.

It has further been established from photographic and cloud-chamber evidence that capture is not accompanied by formation of a "star,"[2] which excludes the possibility that a large fraction of the rest energy of the meson is converted into excitation of the nucleus. Christy has suggested that this be explained by assuming that most of the energy is carried off by a light neutral particle which is emitted in the capture.

It is the purpose of this letter to make an approximate quantitative study of the consequences of this model. We assume the nucleus to be a degenerate Fermi gas of free nucleons, with one of which the meson interacts, converting it from a proton to a neutron. The recoil energy of this nucleon is then quickly distributed throughout the nucleus by nucleon-nucleon collisions and should be regarded as an excitation energy of the nucleus.

Conservation of energy and momentum plus the condition that the neutron must go into a previously unoccupied state then determine a distribution of excitation energies which is to a first approximation independent of the details of the meso-nuclear interaction.

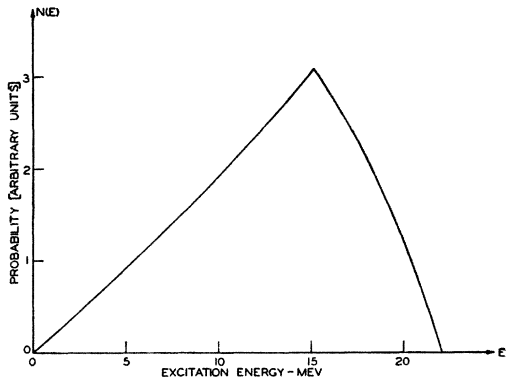

FIG. 1. Distribution of excitation energies.

We plot this distribution in Fig. 1 under the assumptions that (a) the number of neutrons and protons in the original nucleus is equal, (b) the μ-meson has a mass 210 times that of the electron, (c) the outgoing light particle has zero mass, (d) the momentum of the incident μ-meson is neglected, and (e) the nuclear radius is given by $r_0 = 1.5 \times 10^{-13} A^{\frac{1}{3}}$ cm.

The excited nucleus is the original nucleus with one proton converted to a neutron. From consideration of the binding energies of different types of particles in such a nucleus, and of the effect of the potential barrier, one is able to conclude that emission of anything but a neutron is highly improbable.

Moreover, since the binding energy of a neutron in a medium weight nucleus is about 8 Mev, one sees that the most probable number of neutrons emitted in a capture process is one—and that the average number of neutrons given off is also roughly one. It turns out that this conclusion is valid even in the case of heavy nuclei since the lowering of the neutron binding energy is compensated by the change which the large neutron excess in such nuclei causes in the distribution of excitation energies.

This model agrees with experimental evidence[3, 4] insofar as it predicts neutron emission, although the observed number of neutrons per capture seems to be larger than predicted here.

A more detailed investigation of this model is being made.

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Mass Spectrometer Determination of the Half-Life of Xe^{133}

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THE half-life of Xe^{133} was determined from mass spectrometer abundance data in the course of our investigations of the rare gas fission products produced in uranium metal irradiated with thermal neutrons. Its value was found to be 5.271 ± 0.002 days. The mass spectrometer method of determining half-lives, first used by Thode and Graham,[1] completely eliminates difficulties from contamination with other radioactive isotopes and provides a most accurate means for determining half-life values in the range from several days to several years.

A. Langsdorf, Jr.,[2] bombarded thorium with neutrons and obtained a noble gas emitting soft radiations with an apparent period of 5.5 days. Since then various experimenters[3–11] have published values ranging from 4.3 ± 0.4 days[3] to 7 days[6] for the half-life of Xe^{133}. The most likely value given in the Plutonium Project Report (D. W. Engelkemeir and N. Sugarman) is 5.3 days. These values, obtained by radio-chemical methods, are accurate to only 1 or 2 percent, whereas the mass spectrometer method