Notas de Física Vol. III - Nº 10

ON THE INTERPRETATION OF HIGH ENERGY FISSION*

L. Marquez.

Centro Brasileiro de Pesquisas Físicas

Rio de Janeiro, D.F.

(February 27, 1957)

The process of high energy fission has been the subject of many research works. The process has usually been explained by a mechanism that assumes that the excitation energy is dissipated by evaporation of neutrons with fission then taking place[1]. It has been pointed out that there is an alternative mechanism in which the fission takes place as a consequence of the excitation energy left in the nucleus and that the neutrons are

---

* Submitted for publication to the Proceedings of the Physical Society.

emitted from the excited fission fragments[2].

All the experiments on high energy fission carried out until recently were not directly sensitive to one or the other mechanism, but there has been done a very important experiment by Harding and Farley[3] which goes directly into the mechanism of high energy fission. The experiment was to measure the ratio of the intensity N_0 of neutrons emitted parallel to the fission fragments to the intensity N_{90} of neutrons perpendicular to the fission fragments. They irradiated U with a beam of 147 Mev protons and found a ratio N_0/N_{90} of 1.27 ± 0.11.

In the interpretation of their result, they use a spectrum of neutrons emited by the fission fragments calculated according to Le Couteur[4]. This spectrum has an average energy of 2.7 Mev and they conclude from this spectrum that the ratio N_0/N_{90} has to be 2.25 if the neutrons were emitted from the fission fragments. From there they go on with the spectrum of neutrons from the fission of U^{235} with thermal neutrons and conclude that, from the 13.1 ± 1.6 neutrons emitted in the fission of U with 147 Mev protons[5], 2.5 ± 1 are emitted from the fragments.

We would like to point out in this note that the average energy of the neutrons emitted in the fission of U with 147 Mev protons is much greater than 2.7 Mev and that the ratio N_0/N_{90} of 1.27 ± 0.11 is compatible with the emission of all the neutrons from the fragments.

It has been shown by Belovitskii et al.[6] that when U is irradiated with 150 Mev neutrons, only one from every 16 fissions shows a proton with an average energy of 18 Mev. They found a similar result when negative pi mesons produce fission when captured by U, and in this case the excitation energy is 140 Mev. If we assume that something similar happens when 147 Mev protons produce fission in U, we can estimate the average energy dissipated in protons as 1.5 Mev per fission.

In the thermal neutron fission of U^{235}, about 5 Mev per fission are dissipated in the emission of gamma rays. Since it is expected that gamma ray emission does not compete with neutron emission when this is energetically possible, we will take in our case 5 Mev for the energy of gamma rays.

If we assume that the kinetic energy of the fragments in the fission of U with 147 Mev protons is the same as in the fission with 90 Mev neutrons, we get from the data of Jungerman and Wright[7], after applying the correction of Leachman[8] the kinetic energy of 178 ± 6 Mev.

We can calculate now the average energy E of the emitted neutron in the laboratory by conservation of energy:

$$147 + m\,(U^{238}) + m\,(p) = 178 + 6.5 + m\,(Pd^{112}) + \\ + m\,(Ag^{114}) + 13\,m\,(n) + 13\,E$$

The masses in the equation are in Mev units. These masses are known fairly accurately from beta decay data and from masses of stable nuclides. This equation gives for the kinetic energy of the neutrons 6.15 ± 1.5 Mev in the laboratory and 5.4 ± 1.5 Mev in the system of the moving fragments.

If we calculate what should be the ratio N_0/N_{90} for neutrons of this energy if they are emitted from fragments with the average fragment energy, we get 1.23. The energy distribution of the neutrons emitted and the energy distribution of the fragments will change this ratio, probably making it greater, but it seems that the ratio 1.27 ± 0.11 is compatible with having all the neutrons emitted from the fragments. We have not tried to fit the data with a given spectrum because the ratio N_0/N_{90} depends critically on the low energy part of the spectrum. Any spectrum with an average energy of 5.4 Mev that does not have many neutrons on the low energy side will give the right ratio, and if it has many neutrons on the low energy side it will give a high ratio. This critical low energy region is the region from 0 to 1.5 or 2 Mev.

In conclusion, it seems that the experimental data are compatible with the emission of most of the neutrons from the fragments, that it would be desirable to have a measurement of the energy distribution of the neutrons in the case discussed, and of the energy going in protons and gamma rays.

ACKNOWLEDGMENTS

We are indebted to the Conselho Nacional de Pesquisas of Brazil under whose auspices this work was done.

1. Goeckermann, R. H., and Perlman, I., Phys.Rev., 76, 628 (1949)

2. Marquez, L., Nuovo Cim., 12, 288 (1954)

3. Harding, G. N., and Farley, F. J. M., Proc. Phys. Soc. A, 69 853. (1956)

4. Le Couteur, K. J., Proc. Phys. Soc. A, 63, 259 (1950)

5. Harding, G. N. Proc. Phys. Soc. A, 69, 330 (1956)

6. Belovitskii, G. E., Romanova, T. A., Soukhov, L. V., and Frank, I, M., Zh. Exper. Teor. Fiz., 29, 537 (1955)

7. Jungerman, J., and Wright, S. C., Phys. Rev., 76, 1112 (1949)

8. Leachman, R. B., Phys. Rev., 87, 444 (1952)