# *FISSIONABILITY OF NUCLEI BY HIGH ENERGY PROTONS*

N. A. PERFILOV

Radium Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor April 5, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **41**, 871-873 (September, 1961)

Experimental data on fission of nuclei induced by high energy protons are analyzed and the relation between the limiting value of the fission cross section $\sigma_f$ and the parameter $Z^2/A$ is established.

FROM consideration of the dependence of the cross section $\sigma_f$ for the fission of $U^{238}$, $Th^{232}$, and $Bi^{209}$ on the proton energy (see [1]) it follows that at a sufficiently high proton energy the value of the ratio $\sigma_f/\sigma_t$ attains a value which, within the limits of experimental error, does not depend on the further increase in the proton energy.

The total cross section of the inelastic interaction $\sigma_t$ for a proton energy $E_p \sim 300$ Mev and higher can be estimated[2] from the expression

$$\sigma_t = \pi (aA^{1/3} + r')^2 \cdot 10^{-26} \text{ cm}^2,$$

where A is the mass number, the constant a equals 1.26 cm and $r' = -0.41$ cm.

For uranium and thorium $\sigma_f/\sigma_t$ becomes independent of the energy when $E_p > 100$ Mev, and the values of $\sigma_f$ at $E_p = 300$ Mev are equal to 1.3 and 0.8 b, respectively.[1] For 9-Bev protons the fission cross section for uranium is also $\sim 1.3$ b.[3]

For bismuth and lead[1,4,5] the maximum measured fission cross sections are $\sim 0.2$ and 0.1 b. The fissionability attains saturation at a proton energy $\sim 350$ Mev.

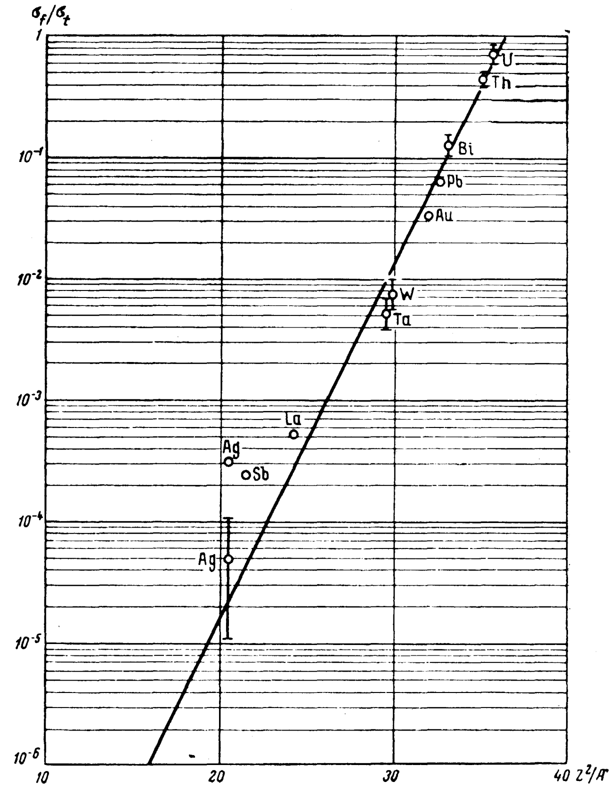
The fission cross section for $Au^{197}$ has been measured up to $E_p \approx 350$ Mev,[1] and at this energy is 0.05 b. The fissionability at 350 Mev does not yet attain the maximum value, but is apparently close to it.

For tungsten and tantalum $\sigma_f$, at $E_p = 660$ Mev, is $11 \pm 3$ and $8 \pm 3$ mb, respectively, according to measurements by photographic[6] and radiometric[7] methods.

$La^{134}$ and $Sb^{122}$ at $E_p = 660$ Mev have fission cross sections of 0.6 and 0.25 mb.[8,9]

The fission cross section for silver is 0.3 mb according to Shamov,[10] and about 0.05 mb according to Kofstad.[11]

In the figure, values of the fissionability $\sigma_f/\sigma_t$ are shown on a semilogarithmic scale as a function of $Z^2/A$. It is seen that the experimental




points do not lie smoothly on a straight line. Three values of the fissionability (for lanthanum, antimony, and silver, data from[10]) are far from the line. Perhaps in this region of nuclei a fission mechanism occurs which is different from the classical one, or there is a large contribution from fragmentation processes in the experimentally observed cross sections. The latter is probable, since the cross section seems to increase with a decrease in Z.

If it assumed that the line correctly reflects the dependence of $\sigma_f/\sigma_t$ on $Z^2/A$, then this dependence can be written in analytic form:

$$\sigma_f / \sigma_t = \exp \{0.682 [Z^2 / A - 36.25]\},$$

from which it follows that for $Z^2/A \approx 36.25$ the inelastic cross section should be entirely determined by fission.

The possibility of representing the dependence of the ratio $\sigma_f/\sigma_t$ on $Z^2/A$ in exponential form over a large interval of values of Z is, perhaps, an indication that there is only one fission mechanism in this interval.

[1] H. M. Steiner and J. A. Jungerman, Phys. Rev. **101**, 807 (1956).

[2] Millburn, Birnbaum, Crandall, and Schecter, Phys. Rev. **95**, 1268 (1954).

[3] Perfilov, Darovskikh, Denisenko, and Obukhov, JETP **38**, 716 (1960), Soviet Phys. JETP **11**, 517 (1960).

[4] Vinogradov, Alimarin, Baranov, Lavrukhin, Baranova, and Pavlovskaya, Sessiya AN SSSR po mirnomu ispol'zovaniyu atomnoĭ énergii, Otd. Khim. Nauk, (Session of the Acad. Sci., U.S.S.R. on the Peaceful Uses of Atomic Energy, Chem. Sci. Sec.) July, 1955, AN SSSR, 1955.

[5] Wolfgang, Baker, Caretto, Cumming, Friedlander, and Hudis, Phys. Rev. **103**, 394 (1956).

[6] Perfilov, Ivanova, Lozhkin, Ostroumov, and Shamov, loc. cit.[4].

[7] Baranovskii, Murin, and Preobrazhenskii, Radiokhimiya (Radiochemistry) (in press).

[8] Lavrukhina, Krasavina, and Pozdnyakov, DAN SSSR **119**, 56 (1958), Soviet Phys.-Doklady **3**, 283 (1958).

[9] Lavrukhina, Rakowski, Su, and Chojnacki, JETP **40**, 409 (1961), Soviet Phys. JETP **13**, 280 (1961).

[10] V. P. Shamov, JETP **35**, 316 (1958), Soviet Phys. JETP **8**, 219 (1959).

[11] K. Kofstad, UCRL-2265, 1953.

Translated by E. Marquit
150