LETTERS TO THE EDITORS

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Fission and Nuclear Shell Model

THE importance of the 'magic' neutron numbers 50 and 82 has been repeatedly stressed[1]. It has been suggested that these numbers of neutrons form shells of considerable stability, and that additional neutrons, if present, are more loosely bound. It seems possible that such a shell may persist as a definite structure at moderate excitation of the nucleus, the excitation energy being shared by the nucleons not contained in the closed shell.

The purpose of the present communication is to point out that this shell model suggests an interpretation of observed features of the fission process, both in uranium-235 and bismuth-209.

When uranium-235 suffers fission upon impact of a slow neutron, the two fragments formed contain altogether 144 neutrons, of which a few are afterwards evaporated. This makes it possible to give each fragment a complete shell, one of 50, the other of 82 neutrons. In the most probable form of fission the remaining neutrons will presumably be distributed more or less equally between the two fragments. Actually it is known that the mass ratio of the two fragments formed in the most probable mode of fission of uranium-235 is not far from 82 : 50.

It is reasonable to assume that, if the shells of 50 and 82 neutrons persist in the most probable mode of fission, the division of charge of a pair of primary fragments is conditioned by this persistence of the neutron shells. This means that only those charges are possible which possess a closed shell of 50 and 82 neutrons respectively. As the closed shell of 50 neutrons is found connected with $Z \geqslant 36$ and of 82 neutrons with $Z \geqslant 54$, and as the sum of the charges of the two primary fragments must be equal to 92, it follows that, for the lighter fragment, the charge can only be $Z = 36$–38, and the corresponding charge of the heavier fragment 56–54. The agreement of this conclusion with the experimental results[2] is striking. In the range of fission yields between 4·6 and 6·3 per cent, eight chains of the light fission fragment begin with $Z = 36$, and seven chains of the heavy fragment with $Z = 54$.

That the charge of a given mass of primary fragment may vary by some units can easily be derived from the stable end-products in corresponding chains. For example, for the mass pair 91 and 143, the sum of β-disintegrations derived from the charges of the stable end-products is eight, while experimentally ten β-disintegrations were found. What actually is measured in the experiments is the superposition of three fission processes beginning with $Z = 36$, 37 or 38 for the lighter primary fragment, and with $Z = 56$, 55 or 54 for the corresponding heavier primary fragment. These different charges of the primary fragments, that is, different lengths of chains, may account for the observed variation in kinetic energy of a given mass[3].

I should also like to point out that the fission yield curve is rather symmetrical relative to the two maxima belonging to the most probable mode of fission.

In the fission of bismuth[4] by deuterons of 200 MeV. energy, it seems that an average of about twelve neutrons evaporate before fission occurs. Hence only about 116 neutrons are available for the two fragments, and it is not possible to form a shell of 82 in addition to a shell of 50. It seems plausible, then, that both fragments should contain a shell of 50, and again the additional neutrons are distributed more or less equally between the two fragments. Indeed, it was found that the most probable mode of fission of bismuth is symmetrical at charges which are connected with a closed shell of 50 neutrons.

It is interesting to point out what happens when uranium is bombarded by very fast particles. One might then expect a more symmetrical distribution of fission fragments, because the shell structure cannot persist in a highly excited nucleus. Moreover, if a considerable number of neutrons (say, twenty) can be evaporated before fission occurs, the symmetrical mode would also be the most probable one. Bombardment with α-particles of 360 MeV. produced, indeed, predominantly symmetrical fission[5].

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Radar Reflexions from Auroras

RADIO echoes on a frequency of 46 Mc./s. have been reported by Lovell, Clegg and Ellyett[1]. They have been observed also on a frequency of 32·7 Mc./s. by McKinley and Millman[2], incidental to their studies of meteor ionization. More recently, a systematic search for such echoes has been made at Saskatoon, Canada, using radar equipment having frequencies of 3,000 Mc./s. and 106·5 Mc./s. During this search, echoes have been observed regularly on the lower frequency but not at all on the higher one.

The 3,000-Mc./s. unit is equipped with an aerial system consisting of two paraboloids with apertures of 150 cm. and giving an approximate beam-width of 3·5°. Orientation of the aerial system about horizontal and vertical axes is under the control of the radar operator. The peak transmitter power is 50 kW. The 106·5-Mc./s. unit is equipped with a directive aerial which can be rotated only about a vertical axis. The maximum power from the primary and secondary lobes of the beam is radiated at about 4·0° and 14·3° respectively with the horizontal. The horizontal beam-width is about 25°. The peak transmitter power is 50 kW. It is estimated that the power in the secondary lobe is about one-third that in the primary. As a result, the search for echoes with this unit is limited to auroras at distances of 600–1,000 km. For both systems the electric vector is horizontal. An auroral camera, modified to use 35-mm. film, is used to photograph the sky in front of each aerial system.

A careful search for echoes with the 3,000-Mc./s. unit during seventeen auroral displays (including the very active and intense one of January 24, 1949[3]) failed to show any that could be distinguished on the receiver from the 3,000-megacycle pulses of radiation emitted by the aurora[4]. On the other hand, persistent and well-defined echoes are observed with the