and the chamber, neutrons were observed as long as $1\frac{1}{2}$ minutes after the bombardment of the uranium, the initial intensity being about one neutron per second. The decay period of these neutrons was observed to be $12.5 \pm 3$ sec.

Since delayed neutron emission could be due to photo-disintegration by gamma-rays we looked for and found a hard gamma-ray of approximately the same period. If these gamma-rays are the cause of the neutron emission, separate intensity tests showed that they must be at least 1000 times as effective as the lithium or fluorine gamma-rays produced by proton bombardment. No neutrons were observed with the same arrangement during proton bombardment of lithium or fluorine targets, although several photoneutrons per second were observed from a few grams of heavy water.

The period of the neutrons and gamma-rays is close to one of the beta-ray periods observed by Meitner, Hahn, and Strassmann.[1] It is possible that the gamma-ray emission follows the 10-sec. beta-ray emission observed by them, and causes or is accompanied by the emission of neutrons.

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[1] L. Meitner, O. Hahn, and F. Strassmann, Zeits. f. Physik **106**, 249–270 (1937).

## Presence of the Nitrogen Forbidden Line $^2P \rightarrow {}^4S$ in the Auroral Spectrum

I have recently reported the probable presence of the N I line $^2P \rightarrow {}^4S$ in the spectrum of diffuse aurorae.[1] A preliminary study of my plates had caused me to ascribe to this radiation a wave-length near 3470A, deduced from the approximate dispersion curve given by the $N_2$ bands of the second positive system. However, I had also at my disposal a plate with a comparison spectrum from a small luminescence lamp containing a mixture of neon and argon. The identification of all the lines appearing on the plate enabled me to make sure that the auroral radiation practically coincides with the neon line $\lambda = 3{,}466{,}575$A, and also that, in the proper spectral region, my spectrograph is capable of distinguishing clearly lines only 3A apart. Under these conditions, I can affirm that the true wave-length of the line attributed to N I is: $\lambda = 3466.5 \pm 1$A.

This value is in good accordance with the theoretical wave-length $\lambda = 3466.6$A deduced from the ionization potential of N I (14.48 v, or 117,375 $cm^{-1}$, according to Hopfield). Besides, using Edlèn's still unpublished results concerning the excitation potentials of the N I levels, M. Nicolet[2] computes the value $\lambda = 3466.5$A. On the other hand, J. Kaplan[3] now finds, for the line observed by him in the laboratory, the corrected wave-length $\lambda = 3466.3$A, with an approximation of a few tenths of an angstrom. Thus, the best measurements of the lines found, near 3466A, in the afterglow and aurora spectra, indicate that their identity is highly probable, as well as the presence of $^2P$ nitrogen neutral atoms in the upper atmosphere.

According to B. Stepanoff,[4] the splitting of the $^2P$ level of N I would be nearly 2.15 $cm^{-1}$. It corresponds to a difference of one-fourth of an angstrom between the components of the line $^2P \rightarrow {}^4S$. Such a structure will be shown only by the interference method.

No night-sky radiation can be actually identified with the N I line $\lambda = 3466.5$A, unless by assuming an error of 4 to 5A in the measurement of the strong sky line found at $\lambda = 3471$A.

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[1] R. Bernard, Nature **141**, 1140 (1938).
[2] M. Nicolet, private communication.
[3] J. Kaplan, Phys. Rev. **54**, 541 (1938).
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## The Fission of Uranium*

This letter is a preliminary report of some of the experiments which we have undertaken on the fission process of the uranium nucleus by neutron bombardment.

The phenomenon was discovered by Hahn and Strassmann[1] who were led by chemical evidence to suspect the possibility of the splitting of the uranium nucleus into two approximately equal parts. Through the kindness of Professor Bohr we were informed of these results some days before receiving them in published form, as well as of the suggestion of Meitner and Frisch that the process should be connected with the release of energy of the order of 200 Mev.

It seemed worth while to attempt the detection of the fragments by their high ionization. The interior of a parallel plate ionization chamber was coated with a thin layer of uranium oxide. When this chamber was connected to a linear amplifier a large number of small pulses from the alpha-particles of uranium were observed, but when exposed to the bombardment of neutrons from the cyclotron or from a Rn-Be source very large pulses occurred in addition. From the ratio of the maxima of these large pulses to the maxima of those due to the alpha-particles it was estimated that the energies of the fragments of uranium range up to about 90 Mev. This value of the energy seems to be somewhat smaller than the theoretical expectation. If we assume that the energy release in the fission is approximately 200 Mev, and that the two fragments may have somewhat different masses, then fragments with energies up to 120 or 130 Mev might be expected in some cases. However, these values probably do not lie outside our experimental error since lack of linearity in the amplifier and incomplete collection of the ions might explain the difference.

After this experiment had been performed, Professor Bohr received a cable from Dr. Frisch stating that he had obtained the same results some days before.

A number of measurements have been made of the cross section for the fission process for neutrons of different energies. For this the interior of an ionization chamber

was coated, by electrolytic deposition, with a layer of uranium oxide of only 0.5 mm air equivalent, so that all the fission processes could be observed. In order to know the number of neutrons, a Rn-Be source of known intensity was utilized in a standard position inside a paraffin block.[2] In order to obtain the contributions of the thermal neutrons only, the difference in the number of fissions was measured with and without a cadmium absorber. These experiments gave a cross section of thermal neutrons for the fission process alone of about $2\times10^{-24}$ cm$^2$. Fast neutrons from a Rn-Be source have instead an average cross section of about $0.1\times10^{-24}$ cm$^2$.

By using a similar chamber with a thicker uranium oxide coating, the changes in the fission activity due to the interposition of cadmium and boron filters were determined and compared with those obtained when the same chamber was coated with boron instead of uranium. Within the limits of the experimental error the behavior for slow neutrons of the absorbers for the fission process and for the boron disintegration was the same. This suggests that the efficiency of slow neutrons for the fission process follows a $1/v$ law. As mentioned above, fast neutrons are relatively more efficient in producing the fission process than they are in the boron disintegration.

The validity of the $1/v$ law makes it probable that the levels of the compound nucleus are broadened by the short lifetime (probably not more than $10^{-17}$ sec.) of the fission process. There seems to be some contradiction between this result and the known fact that uranium has a sharp resonance for slow neutrons of about 25 ev that does not lead, however, to the fission but to the formation of $U^{239}$. As suggested by Professor Bohr a possible explanation is that the fission does not occur from $U^{238}$ but from $U^{235}$, which is present in an amount of somewhat less than 1 percent.

The range of the fragments has been measured by allowing the fragments to enter a shallow ionization chamber 1.0 cm from the uranium through a grid. By varying the pressure the maximum range has been determined to be approximately 1.7 cm.

The recoil fragments from irradiated uranium have been collected upon a Cellophane foil placed next to it. After a ten-minute irradiation with slow neutrons from the cyclotron, the Cellophane foil showed an activity of about 400 counts per minute when wrapped around a counter. The decay of this activity indicated the presence of several periods which have not yet been analyzed. Interposition of an 0.0012 Cellophane foil between the uranium and the collecting foil showed that a small fraction of the recoil fragments passes through, in fair agreement with the range measurement. While these experiments were in progress we were informed by Professor Bohr that a similar experiment had been suggested by Miss Meitner.

We are indebted to Dr. J. Steigman, H. B. Hanstein and E. Haggstrom for their assistance in carrying out these experiments.

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[2] E. Amaldi and E. Fermi, Phys. Rev. **50**, 899 (1936).