β-ray absorption spectrum indicates an upper limit of about 1 MV. Little if any gamma-radiation is associated with this period. It is more strongly activated with slow than with fast neutrons, and was proved to be chemically Cs.

A long period (20 ± 1 month) isotope,[7] chemically identified as Cs and apparently isomeric with the 3-hour Cs^{134}, was prepared by neutron or deuteron bombardment of Cs. Its normal β-ray spectrum has an upper limit of 0.9 MV, and there is fairly strong gamma-radiation.

Cs^{132} evidently has a very short period, a very long period, or one close to three hours, as nothing new appeared with fast neutron bombardment.

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1 D. C. Kalbfell, Phys. Rev. **54**, 543 (1938).
2 Pool, Cork and Thornton, Phys. Rev. **52**, 239 (1937).
3 M. L. Pool and J. M. Cork, Phys. Rev. **51**, 1010 (1937).
4 E. Amaldi *et al.*, Proc. Roy. Soc. **A149**, 522 (1935).
5 McLennan, Grimmet, and Read, Nature **135**, 505 (1935).
6 Latimer, Hull and Libby, J. Am. Chem. Soc. **57**, 781 (1935).
7 Alexeeva, Comptes rendus USSR **18**, 553 (1938).

Photo-Fission of Uranium and Thorium

We have observed fission recoils from uranium and thorium produced by γ-rays from CaF_2 and AlF_3 targets bombarded with protons. A rough estimate of the cross section, based on our data, gives 10^{-26} cm^2 for the photo-fission cross section in comparison with the theoretical estimate of 10^{-27} cm^2 given by Bohr and Wheeler.[1]

A beam of 0.5 microampere of analyzed protons of 2 to 3 Mev energy was used to bombard CaF_2 and AlF_3. With Ca and Al targets, no fissions were observed, indicating the absence of neutron fissions. Although a few neutrons are obtained when Ca is bombarded with protons, these were found to be too few to give fissions. Even fewer neutrons were found from proton bombardment of CaF_2 when a BF_3-filled ionization chamber was used to detect the neutrons. No appreciable decrease in the fission rate was observed with 4 cm of paraffin between the target (γ-ray source) and the ionization chamber containing uranium. This amount of paraffin was shown to cut down the fission rate by one-half when neutrons from Li(p,n) were used instead of γ-rays. The fission rate was cut down by a lead absorber by roughly the right amount for high energy γ-rays. Further indication that the fissions are due to γ-rays is the observed proportionality of fission rate to high energy γ-ray intensity as this is increased by a factor of 5 on raising the proton beam energy from 2 to 3.2 Mev. Below 2 Mev the fission rate was too low for observation.

With 2.9-Mev protons, the observed fission rate in uranium was about one fission per 3×10^{13} protons hitting CaF_2. The γ-ray intensity measured by a Geiger counter 5 feet away and shielded with 1 inch of lead was about 150 counts per fission. Assuming the counter efficiency to be 2 percent[2] and allowing for scattering and absorption in the lead shield around the counter, we estimate a high energy γ-ray yield from CaF_2 of 10^8 γ-quanta per 3×10^{13} protons or per fission. It is to be noted that this estimate of 3 quanta per 10^6 protons at 2.9 Mev is higher than is obtained by taking the value of 1.2 γ-quanta per 10^9 protons[3] at 1.0 Mev and multiplying by 60, our observed factor of increase in intensity from 1 Mev to 2.9 Mev. This suggests that the above value for F(p, γ) yield at 1.0 Mev and also the Li(p, γ) cross section from which it was derived may be too low.

The fractional solid angle subtended by the uranium is 0.07, which gives about 7×10^6 γ-quanta passing through the uranium per fission. Assuming an effective thickness of 3 mg/cm^2 for the uranium whose fission recoils would be counted in the ionization chamber, we obtain about 2×10^{-26} cm^2 for the photo-fission cross section for fluorine γ-rays. The effect in thorium is roughly equal in intensity. Previous attempts[4] to observe photo-fission have not given positive results.

It has been suggested that photo-fission be referred to as "phission" to distinguish it from neutron fission.

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1 N. Bohr and J. A. Wheeler, Phys. Rev. **56**, 426 (1939).
2 J. V. Dunworth, Rev. Sci. Inst. **11**, 167 (1940).
3 M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 316 (1937).
4 Roberts, Meyer and Hafstad, Phys. Rev. **55**, 417 (1939); Heyn, Aten and Bakker, Nature **143**, 516 (1939).

Accurate Solution of the Thomas-Fermi-Dirac Equation.

The Thomas-Fermi-Dirac equation

$$d^2\psi/dx^2 = x[\beta+(\psi/x)^{\frac{1}{2}}]^3,$$

$\beta=(3/32\pi^2)^{\frac{1}{3}}Z^{-\frac{2}{3}}$ with the boundary condition $\psi(0)=1$, has been hitherto solved for Li($Z=3$), Na($Z=11$), Ar($Z=18$), Cu($Z=29$), Kr($Z=36$) and Xe($Z=54$),[1] expanding ψ in series for small values of x with an assumed value of the initial slope, and integrating numerically from there out. The most important case is that where ψ curve becomes tangent to the x axis. In this case, however, the numerical integration is very sensitive to small errors, as well as to small changes in the initial slope, so that it is very difficult to determine accurately the tangent point X_0 and consequently the value of the initial slope $-B_0$. By carrying out the calculation in the reversed direction to the above we were able to determine the relation of the tangent point X_0 to the atomic number Z as follows. We expanded for a chosen element whose atomic number is Z' in a series in the neighborhood of an assumed tangent point X_0', and integrated numerically from there out towards the ψ axis. This integration curve meets the ψ axis with a finite angle, not tangentially nor rectangularly, so that the