than the kinetic energy of the alpha-particle because at the top of the periodic system the process of emitting alpha-particles from the nucleus is exothermic. On account of this fact the excitation energy of the compound nucleus is probably from 5 to 10 Mev less than the kinetic energy of the alpha-particle. This leaves an excitation which may vary according to the energy of the primary particle from 15 to 27 Mev, and is therefore amply sufficient to produce the fission of the compound nucleus. Indeed it is so large that 2 or 3 neutrons may be evaporated, still leaving a sufficient energy available for the fission.

In conclusion, we wish to thank Professor E. O. Lawrence for his interest in this work, the Research Corporation for financial support and the Hitchcock Foundation for providing the opportunity for one of us to visit the Radiation Laboratory.

Excitation of Gamma-Rays by Fast Neutrons of Different Energy

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ATOMIC cross sections of Al, Si, Fe, Co, Cu, Ag, Cd and Pb for gamma-ray excitation by fast neutrons of different energies from 2.25 to 2.90 Mev were determined. The neutron source used was a *D–D* type with 200-kv acceleration, and the neutron energy was varied by changing the angle φ between the paths of the neutrons and the deuterons. The gamma-rays emitted were measured by a thin-wall Geiger-Müller counter surrounded by a sheet of lead 1 mm in thickness.

In a *D–D* neutron source, not only the energy but also the number of neutrons emitted depends on φ. Therefore, the number was measured by an ionization chamber filled with a mixture of hydrogen and nitrogen to 14.1 atmospheres pressure, the purpose of adding nitrogen being to make the range of recoil protons short compared with the dimension of the chamber.

The results obtained for the cross sections σ_γ are shown in Fig. 1, where the neutron energy was calculated by taking $Q=3.32$ Mev[1] and assuming the deuteron beam to be 40 percent atomic and 60 percent molecular and that the heavy water ice target was thick. General features of the curves for Al, Fe, Cu and Cd agree qualitatively with the results of H. Kallmann and E. Kuhn,[2] but precise comparison cannot be made, as they have made measurements only at three different values of neutron energy. In the present experiment, anomalies were observed in most cases. The absolute magnitude of the cross section for Cu at 90° ($E_n=2.52$ Mev) was estimated to be 2×10^{-24} cm^2 by calculating the absolute number of neutrons incident on the measuring system from the absolute value of the ionization current in the chamber and by taking the efficiency of the counter for the gamma-rays to be one percent.[3] This absolute value of σ_γ is about seven times greater than the value estimated by H. Aoki,[4] and is about 80 percent of the total cross section σ_t. As the mean number of gamma-ray quanta emitted per one inelastic collision of a *D–D* neutron is considered to be not so large (perhaps smaller than two, because of the comparatively low excitation of the residual nucleus), σ_γ may be only a little larger than the cross section of inelastic collision σ_{inelast}. From these considerations and the above results, it may be said that for nuclei of medium weight such as Fe, Co, Cu, Ag or Cd a considerable part of the scattering of *D–D* neutrons is inelastic.

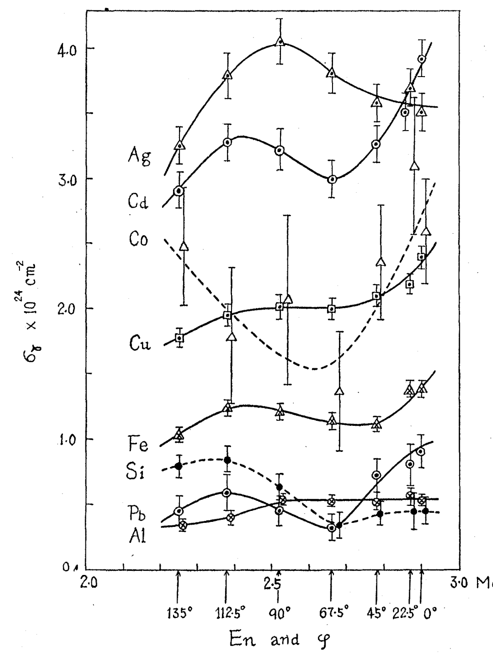

FIG. 1. Energy cross section curves.

H. Aoki[5] has observed many anomalies in the total cross sections of Si, Al, Fe, Pb, etc. The positions of anomalies observed in σ_γ lie near those of σ_t (when we recalculate E_n by taking $Q=3.32$ Mev), and the magnitudes of the variations are almost equal in both cases; especially for Pb the variations of σ_γ and of σ_t are very similar in the positions of maximum and minimum and in the magnitude. At any rate, the anomalies in σ_t observed by H. Aoki or M. R. MacPhail[6] cannot be considered to be entirely due to elastic scatterings.

A detailed report will be published in the *Proceedings of the Physico-Mathematical Society of Japan.*

[1] L. G. Bonner, Nature **143**, 681 (1939).
[2] H. Kallmann and E. Kuhn, Naturwiss. **26**, 107 (1938).
[3] F. Norling, Phys. Rev. **58**, 277 (1940).
[4] H. Aoki, Proc. Phys.-Math. Soc. Japan **19**, 369 (1937).
[5] H. Aoki, Proc. Phys.-Math. Soc. Japan **21**, 232 (1939).
[6] M. R. MacPhail, Phys. Rev. **57**, 669 (1940).