Neutron Inelastic Scattering*

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The neutron inelastic scattering of iron has been studied as a function of neutron energy from the threshold at 850 kev to 2.0 Mev. The yield of 850-kev gamma rays emitted by de-excitation of the first excited state has been measured by means of a NaI scintillation spectrometer. Similar work is in progress on Al, Pb, Bi, and other elements.

USING the Rockefeller Generator[1] and the $Li^7(p,n)Be^7$ and the $T(p,n)He^3$ reactions as sources of monoenergetic neutrons, the neutron inelastic scattering cross sections σ_i for Fe, Al, Pb, Bi, and other elements are being studied as a function of neutron energy by observing the line spectrum of gamma rays[2] emitted from the excited target nucleus.

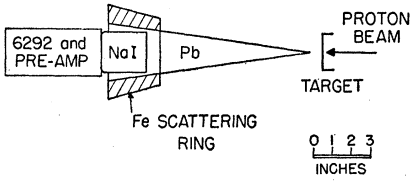

FIG. 1. Experimental geometry. The single-crystal NaI spectrometer is shielded from the direct neutron beam by an 8-inch cone of Pb. A DuMont 6292 Photomultiplier was used.

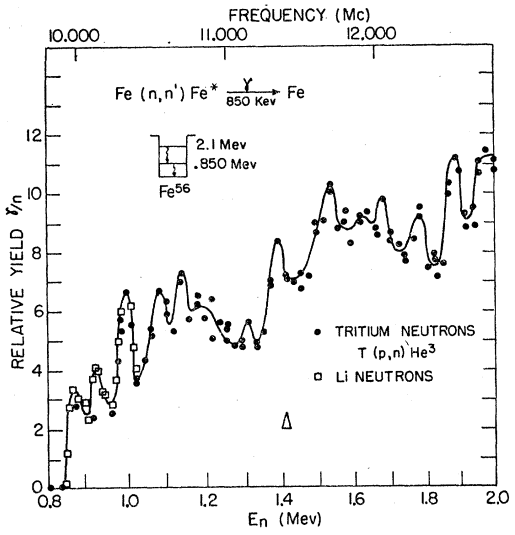

FIG. 2. Relative peak yield per neutron of the 850-kev gamma ray of Fe^{56*} as function of neutron energy E_n as determined by pulse-height analysis. Effects of "poor" geometry have been neglected. Neutron energy spread ≃25 kev. The upper scale gives proton resonance frequency used in the deflection magnet.

A single crystal NaI spectrometer is placed within a hollow truncated cone of scattering material at 0° with respect to the proton beam, see Fig. 1. The crystal is shielded from the direct neutron beam and gamma rays produced in the target assembly by an 8-inch cone of Pb. By analyzing the pulse-height distribution produced by the gamma rays absorbed in the crystal, the peak value of the line spectrum can be determined. The counting rate per incident neutron at the peak is proportional to σ_i, provided the neutron energy is below that of the second excited state (2.1 Mev).

Figure 2 shows the results of such an investigation of the 850-kev[3] level in Fe^{56} (91.6 percent abundance). The ordinate is the relative peak-height distribution maximum above background of the 850-kev gamma ray

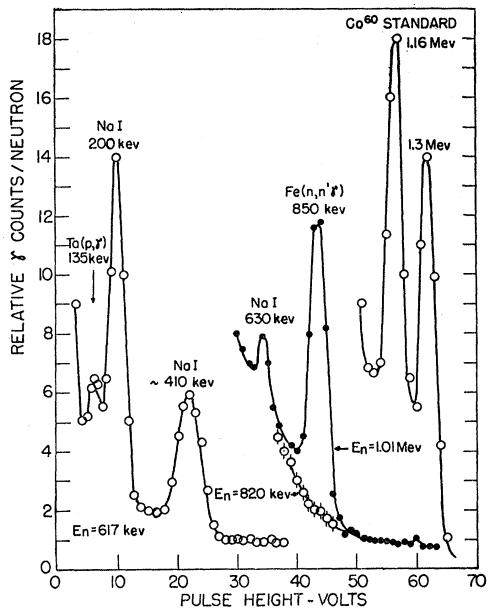

FIG. 3. Pulse-height spectrum of single-crystal NaI spectrometer. The first curve on the left was taken with Li neutrons of 617-kev energy; the crystal was shielded with Pb. The gamma at 135 kev is attributed to the electric excitation of the Ta backing of the target. The other two gamma rays are attributed to $(n,n'\gamma)$ reactions in NaI. The second curve, in two parts, is a typical spectrum of $Fe(n,n'\gamma)Fe$ taken below the first excited level in Fe^{56} at 850 kev (E_n=820 kev; $T(p,n)He^3$), and above the first level (E_n=1.01 Mev). The third curve, of Co^{60}, serves as an energy calibration and gives an indication of the spectrometer resolution.

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[3] L. G. Elliott and M. Deutsch, Phys. Rev. **64**, 321 (1943).

per neutron incident upon the scatterer. The neutron beam was monitored by means of BF_3 long counters placed at 90° with respect to the proton beam. Preliminary measurements with BF_3 counters gave a calibration between the neutron flux at the scatterer and the flux incident upon the monitor counters. Experiments are in progress to determine the absolute value of σ_i.

The NaI spectrometer produces three (possibly four) relatively intense gamma rays when subjected to neutron bombardment, Fig. 3. These gamma rays are tentatively assigned to inelastic processes in the NaI crystal. The gamma energies are: 200 kev, ~410 kev (possibly two gamma rays superposed), and 630 kev. The gamma at 135 kev is attributed to the electric excitation of the Ta backing of the target.[4] A sample gamma spectrum for Fe is also shown in Fig. 3.

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A New 3.0-min Ce Fission Product and its 5.95-hr Pr Daughter*

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Rapid chemical separations of Ce from neutron-irradiated U led to identification of a 3.0-min Ce which decays to 5.95-hr Pr. The former emits β rays, whose maximum energy is approximately 2.0 Mev, and γ rays whose spectrum was not investigated. The Pr decays by emission of a single β ray whose maximum energy is 1.7 Mev; no γ rays were found. This chain has tentatively been assigned to mass 145.

I. INTRODUCTION

IN 1942–43 Ballou reported[1] a 1.8-hr Ce—4.5-hr Pr fission product chain. Recently Caretto and Katcoff showed[2] that there was no Ce fission product with a half-life between 13.9 min and 33 hr, and that previous reports of a 1.8-hr Ce probably resulted from insufficient purification of the cerium. Furthermore, it was shown that no Pr activity with a half-life between 24.4 min and 13.8 days can be isolated from pure fission product Ce which had decayed for 0.5 to 2.5 hours. Since the chemical method for Ce required a minimum of 28 minutes, it was concluded then that any undiscovered short-lived Ce fission products must decay with half-lives shorter than 6 minutes.

A new and shorter radiochemical procedure developed by Glendenin[3] was used by us in a recent scintillation spectrometer investigation[4] of the radiations from 13.9-min Ce^{146} and 24.4-min Pr^{146}. It was noticed that a 6-hr half-life appeared in Pr separated from fission Ce which had been purified in 11 to 27 minutes after irradiation. In one run where the Ce was allowed to decay for 43 minutes before its purification was completed, virtually no 6-hr component was seen. From these observations it was postulated that a Ce fission product with about a 3-min half-life was decaying to a 6-hr Pr daughter. Subsequent experiments, described below, verified this supposition.

In Ballou's early work,[1] he made separations of Ce and Y from rare earth fission products, and then he showed by a partial separation ($NaNO_3$ fusion method[5]) of La from the remaining rare earths that a 4.5-hr component was probably not associated with La and that it probably was a Pr, Nd, or Pm activity. At the present time it appears that his 4.5-hr component resulted from the 6-hr Pr plus various impurities. He did not prove that the 6-hr activity was a daughter of Ce, and therefore a Pr isotope, because his procedure for Ce was too long to permit isolation of 3-min Ce.

II. CHEMICAL PROCEDURE

Samples of uranyl nitrate (10 to 100 mg) were irradiated in the Brookhaven pile at a flux of 4×10^{12} neutrons/cm² sec for one to three minutes. The chemical separation of Ce was begun almost immediately. It is based on solvent extraction of tetravalent Ce from $10M$ HNO_3 with methyl isobutyl ketone. The trivalent rare earths as well as most of the other fission products remain in the aqueous phase. $NaBrO_3$ was used as the oxidizing agent for the Ce. The organic layer containing the Ce^{+4} was washed with $10M$ HNO_3 and then the Ce was back-extracted into an aqueous phase after reduction to Ce^{+3} with H_2O_2. This cycle was then repeated two or three more times. The Ce samples were

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