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Inelastic Neutron Scattering in Iron*

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The gamma-ray spectrum from the inelastic scattering of *D-D* neutrons in iron has been obtained using an unshielded single-crystal NaI spectrometer. A ring-type geometry permitted subtraction of the background rate from the total rate: this yields a complex spectrum attributed to the inelastic scattering in iron. Energies have been assigned to the peaks of the complex spectrum indicating gamma-rays of 2.66, 2.10, 1.76, 1.59, 1.42, 1.24, 0.989, 0.851, 0.634, and 0.462 Mev.

MONOENERGETIC neutrons of 2.7 Mev were used to excite iron nuclei through inelastic collision. The de-excitation gamma rays were detected by a single-crystal NaI spectrometer consisting of a 1 in. by $1\frac{1}{2}$ in. diameter NaI crystal mounted on a Du Mont 6292 photomultiplier tube. A ring-type geometry, previously described,[1] permitted the subtraction of the background counting rate from the total rate. The iron ring had an inside diameter of 3 in., an outside diameter of 6 in., and a thickness of 1 in. The neutron flux, about 10^7–10^8 neutrons per second, was monitored by a pair of BF_3 counters and all counting rates were normalized to this monitor rate.

The energy calibration was obtained from the 0.661-Mev line of Cs^{137} and the 0.511-Mev line of Na^{22}. The resolution is about 9 percent as determined from the 0.661-Mev line of Cs^{137} and should improve with increasing energy to the extent that the resolution at 2.5 Mev should be about 4–5 percent; this is the order of the closest line spacing observed.[2] The pulse-height distribution as determined by a single-channel analyzer is given in Fig. 1. The number and intensity of the lines differ somewhat from those contained in a previous report;[3] however, some indication of the complexity of the iron spectrum is given in a more recent work.[4]

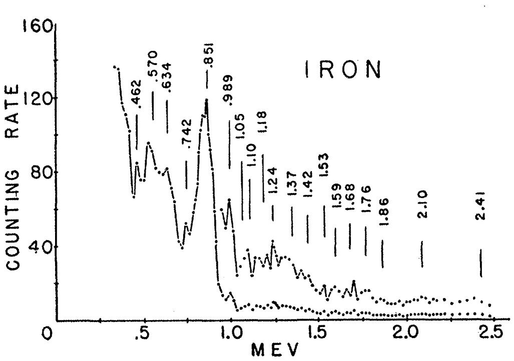

FIG. 1. The energy distribution of the gamma rays from inelastic scattering of fast neutrons in iron. The probable errors in the counting rates are about the magnitude of the dots denoting the experimental points. Energies assigned the individual peaks are as indicated.

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[1] Rayburn, Lafferty, and Hahn, Phys. Rev. **94**, 1641 (1954).
[2] G. G. Kelley, Nucleonics **10**, No. 4, 34 (1952).
[3] Garrett, Hereford, and Sloope, Phys. Rev. **92**, 1507 (1953).
[4] R. M. Kiehn and C. Goodman, Phys. Rev. **93**, 177 (1954).

Figure 1 also shows the energies assigned the individual peaks and presents the higher energy portion of the spectrum in greater detail. The curves of Fig. 1 represent the average of a number of independent runs; the individual runs show no essential differences. In several of the independent runs the broad peak at 0.570 Mev breaks into two single peaks of energies of 0.527 and 0.570 Mev. Also, the 1.05-Mev peak frequently appears resolved. Although the break at the top of the large 0.851-Mev photoelectric peak appears consistently it has not been separated as a single peak. There is considerable evidence of further structure; however, the limit imposed by resolution does not permit analysis of these unresolved peaks. The probable errors of the energy assignments are about 2 or 3 percent.

The possibility that some of the peaks might arise from elastic scattering into the crystal from the iron has been investigated. The iron spectrum was obtained under the same conditions except that a carbon ring was substituted for the iron ring during background counting. The spectrum obtained in this manner is similar to the curves of Fig. 1; in particular it does not allow any of the original peaks to be discarded.

Difficulties of interpretation are an ineluctable consequence of the complexity of the spectrum. However, an analysis based on a knowledge of the energies of the peaks and the relative cross sections for the photoelectric, Compton, and pair processes in NaI as a function of gamma-ray energy enables one to make judicious choices concerning the origin of certain of the experimental peaks. The division of the peaks among the three fundamental processes is indicated in Table I.

TABLE I. Probable energy assignments for the peaks of Fig. 1. Values denoted by * indicate peaks that do not appear resolved. Energies are in Mev.

Photoelectric	Compton	Pair
2.66*	2.41	1.68
2.10	1.86	1.10
1.76	1.53	0.74
1.59	1.37	0.57
1.42	1.18	...
1.24	1.05*	...
0.989	0.770*	...
0.851	0.656*	...
0.634	...	...
0.462	...	...