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MÖSSBAUER EFFECT RESULTING FROM THE REACTION $Fe^{56}(d,p)Fe^{57}$†

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We have observed a large Mössbauer effect in γ rays resulting from the reaction $Fe^{56}(d,p)Fe^{57}$ with a natural iron target. From the present result, together with the previously reported Mössbauer effect[1] from Coulomb-excited levels in Fe^{57}, one reaches the conclusion that the conditions for recoilless emission are relatively insensitive to the reaction process leading to the excitation, and to the amount of recoil momentum imparted to the nucleus during such reaction.

A Mössbauer effect with γ rays resulting from a nuclear reaction was previously observed,[2] but observation of a large effect with resolved hyperfine structure induced by (d,p) reaction is of particular interest in that the measurement of the hyperfine splitting in the target environment would shed additional insight into the still unknown process in which a recoilling nucleus with a large momentum is rapidly restored into a lattice before a recoilless γ emission occurs.

In the present experiment a 20-mg/cm^2 target of natural iron was bombarded with a 0.025-μA beam of 2.8-MeV deuterons from the Johns Hopkins University Van de Graaff accelerator. Due to the low beam currents employed, the target holder was merely cooled by means of room air convection.

The 14.4-keV γ rays were detected in coincidence with the preceding 122-keV γ rays in order to discriminate against the high background which was mainly due to bremsstrahlung and Compton-scattered γ rays. The experimental setup is similar to the one described earlier.[1] Both γ rays were detected using thin NaI(Tl) crystals, and the coincidence-circuit resolving time was approximately 100 nsec. With the beam current used, this gave rise to a coincidence counting rate of 2 counts per second, $\frac{1}{6}$ of which were accidental coincidences. Despite these precautions, the 14.4-keV coincidence spectrum exhibited a background counting rate roughly equal to that of the 14.4 γ rays.

The Mössbauer apparatus consisted of a loudspeaker driven by a parabolic wave form, and a multichannel analyzer operated in a multiscaling mode. A 91%-enriched Fe^{57} coil with a split absorption pattern was used as an absorber in this experiment, since such an absorber gives a very large central absorption peak in conjunction with the split emission pattern from a natural iron target.[3] The velocity range was chosen to exhibit just the central three peaks for the convenience of rapid accumulation of statistics for this initial experiment.

The width and depth of the absorption dips indicate that the difference in hyperfine splitting between source and absorber is less than 10%. The central absorption dip, uncorrected for background, is 15% of the nonresonant transmission (see Fig. 1). Comparison of the (d,p) results with those obtained using a standard split Co^{57} source placed in the same geometry

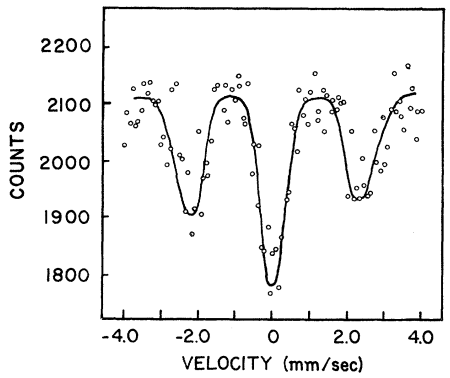

FIG. 1. Mössbauer spectrum of 14.4-keV γ rays resulting from the reaction $Fe^{56}(d,p)Fe^{57}$ taken with an enriched Fe^{57} absorber.

indicates that the Mössbauer fraction f is larger than 0.5 for the (d,p) results.

The Mössbauer spectrum obtained by (d,p) reaction in the present experiment is approximately the same as the spectrum obtained by Coulomb excitation under similar experimental conditions.[1] The main differences between the two experimental situations are that (1) the dry-ice cooling of the target used for Coulomb excitation is no longer required in the present experiment; (2) in the present experiment the majority of 14.4-keV γ rays were created in the first 300-keV thickness of the natural iron target so that self-absorption is considerably lower than in the enriched Fe^{57} target used in the case of Coulomb excitation; (3) the recoil energy is somewhat greater in the case of the (d,p) reaction. However, the linewidth, dip of the absorption peak, and the relative magnitude of the central peak to the side peaks are all comparable in the two cases.

The facts that both here and in the case of Coulomb excitation[1] the Mössbauer fraction and the hyperfine splitting show little significant deviation from those obtained with the Co^{57} source lend support to the speculation[4,5] that an appreciable fraction of the reaction recoils come to rest in a normal-lattice environment. However, the mechanism of the recoil and stopping process is at present not completely understood.

The cross section for the (d,p) reaction with an Fe^{56} target at deuteron energy of 2.8 MeV is sufficiently large that the optimum counting rate is obtained at 25-nA beam current. In the present experiment the counting rate was limited only by the consideration of the true-to-accidental ratio with a time resolution comparable to the half-life of the level. With such a low beam current the problem of target heating is minimal, and the method can be applied to targets consisting of insulators.[5]

The study of the hyperfine structure by Mössbauer effect from the recoil nucleus will permit, under certain circumstances, the direct study of nuclear polarization following a nuclear reaction.

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