Internal Conversion from Resonance Absorption (*).

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The classical investigations on optical resonance fluorescence and on nuclear resonance fluorescence (1) were performed as scattering experiments. In contrast, nearly all the recent experiments on recoilless emission and absorption of nuclear γ-rays (Mössbauer effect) were done in a transmission geometry (2), partly because of the higher intensities obtainable. The effect of internal conversion further reduces the intensity in scattering experiments: the Mössbauer effect is most pronounced in γ-decays of low-lying states with long lifetimes occurring in nuclei of high atomic number. These are just the conditions where internal conversion, characterized by the conversion coefficient α, competes effectively with γ-ray emission. Thus when γ-rays are resonantly absorbed, only a fraction 1/(1+α) of the excited states will decay again by γ-emission while a fraction α/(1+α) will emit conversion electrons. The competition by internal conversion impedes the observation of the recoil-free scattered γ-rays.

We have observed the Mössbauer re-emission spectrum in 57Fe, taking advantage of the large internal conversion. The basic idea is not to look for the re-emitted 14.4 keV γ-rays, but to observe the K X-rays (6.3 keV) following internal conversion. The cross sections in iron for the 14.4 keV γ-ray and for the iron K X-ray are such that the experiment is easy to perform: the cross section for resonance absorption of the 14.4 keV γ-ray, σγ = 1.5·10−18 cm² is much larger than the photoelectric absorption of either the 14.4 keV γ-ray (σp = 6·10−21 cm²) or the 6.3 keV X-ray (σp = 7·10−21 cm²). The scattering foil (4.6 mg/cm² 57Fe, 75% enriched) chosen for the present experiment is evidently many mean-free paths thick for resonant γ-rays, but is thin for X-rays.

The experimental arrangement is sketched in Fig. 1. The source, approximately 10 mC of 57Co plated onto Armco iron sheet and annealed in vacuum for 1 h at 900 °C, is mounted on an 8-in high-compliance speaker. A stable audio
oscillator and amplifier provide a sine-wave velocity drive at a frequency of 11 s⁻¹. The absorber-scatterer is attached to a thin sheet of polystyrene held rigidly at approximately 45° to the beam. The transmitted beam is detected by means of a NaI scintillation crystal and photomultiplier tube. These photomultiplier pulses are amplified and the 14.4 keV γ-ray selected using a single-channel analyzer. Pulses of constant amplitude from the single-channel analyzer are modulated with a sawtooth voltage locked in with the speaker drive. The modulated pulses are displayed on a 400-channel analyzer giving directly the 57Fe hyperfine overlap spectrum (see Fig. 2). This transmission experiment serves to calibrate the velocity drive using the results of HANNA et al. (3).

The second counter, as shown in Fig. 1, is a proportional counter designed to respond to 6.3 keV radiation with an internal efficiency of about 95%. A 6 mm sheet of Lucite in front of the source filters out the iron X-rays in the primary beam so that the gas counter detects mostly those soft X-rays created by the absorption of the 14.4 keV γ-ray in the absorber. Lead shielding helps to reduce the background count. As before, the output of the proportional counter is gated, modulated, and then displayed on the 400 channel analyzer as a Mössbauer absorption-emission spectrum.

Fig. 1.—Experimental arrangement. The source is mounted on a loud speaker which is driven by an 11 s⁻¹ sine wave. A NaI crystal and photomultiplier detects the transmitted 14.4 keV γ-rays. The proportional counter detects the 6.3 keV X-rays associated with the internal conversion.

Fig. 2.—Recoilless resonance absorption in 57Fe. The upper curve shows the transmission spectrum of the 14.4 keV γ-ray. The lower curve shows the resonance peaks as detected by the proportional (X-ray) counter.

Fig. 2 shows the spectra obtained with the two counters. The lower curve is the data taken with the proportional counter and scattering geometry, corresponding to the re-emission and the observation of the X-rays; it shows the resonances as maxima in the counting rate. The upper curve displays the pattern taken under the same conditions of velocity drive, but in the transmission geometry with the γ-ray counter. The resonances appear at the same velocities