TIME SPECTRA OF FILTERED RESONANCE RADIATION OF Fe^{57}†

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We report here on an experiment employing the Mössbauer[1,2] effect in Fe^{57}, which illustrates the connection between the observed rate of decay of a nuclear state and the spectrum of the radiation with which the observation is made. If the 14-kev gamma radiation from the first excited state in Fe^{57} is allowed to pass through a foil of Fe^{57} of appropriate thickness, the resonant absorption will be greater for the central frequencies than for the wings, and the transmitted line will no longer have the classical resonance shape. The latter, however, is a consequence of the Fourier analysis of a radiation amplitude which decays exponentially with the time. It was expected, therefore, that the filtered radiation would display a nonexponential time development. This effect has been observed by measuring the decay of the 14-kev state by means of the filtered radiation. The emission of the 123-kev gamma ray which feeds the state of interest was used as a time reference. The convenient half-life[3] (10^{-7} sec) of the state and the relatively large fraction (≈ 0.6 at room temperature) of nuclei which do not recoil on emission of the gamma ray make Fe^{57} an attractive choice for the experiment.

The measurements were made with a source of Co^{57} co-plated[4] with Fe^{56} on a thin copper foil, which was cemented to an aluminum disk. Absorbers of two thicknesses (0.9 mg/cm^2 and 2.7 mg/cm^2) were used as filters. These absorbers were rolled foils of Fe^{57} (isotopic abundance 75%) clamped between Lucite disks. The source and an absorber were mounted 3/4 in. apart on opposite ends of a piezoelectric transducer which consisted of a hollow tube of barium titanate. By making them vibrate with respect to each other by sinusoidally energizing the transducer, the resonance absorption could be destroyed by Doppler broadening. When the source and absorber are in relative motion, one would expect to observe the normal exponential decay, whereas when they are stationary relative to each other, the sought-after effect should be observed.

The time measurements were made with equipment previously used in the determination of lifetimes of excited nuclear states.[5] Both the 14-kev and the 123-kev gamma rays were detected in NaI(Tl) scintillators; the 14-kev detector being 3/4 in. from the absorber, and the 123-kev detector 3/8 in. from the source. Fast signals from each detector were sent to a time-to-pulse-height converter whose output was stored in a 256-channel pulse-height analyzer. The latter was gated by a slow coincidence system employing single-channel analyzers which were set to respond only to the photopeaks of the gamma rays of interest.

A typical measurement consisted of alternate vibrating and stationary runs of 4 min duration each, repeated for 48 hours. Half of the 256 channels were used to store the vibrating data; the other half, the stationary. The instrumental resolution was obtained by taking "prompt" measurements. This was done by filtering out the 14-kev radiation so that the single-channel analyzers responded only to coincidences from higher energy gamma rays from weak Co^{56} and Co^{58} contamination in the source. Decay data were also taken with no Fe^{57} absorber in place.

Figure 1 shows a prompt curve, which has a width at half-maximum of 25 mμsec. It also contains a plot of the data taken without absorber. The decay is a pure exponential with the expected half-life. (Each channel represents 8.5 mμsec.) Figure 2 is a plot of data with the Fe^{57} absorbers in place. The counting rate in the vibrating case is very nearly exponential, except for a slight concavity downward at early times. The stationary case, however, shows a decay which is by no means exponential. There is a marked early drop which shows that the resonant absorption is initially small and then increases with time. This may be explained qualitatively as follows. If one considers the exponentially decaying electromagnetic amplitude from the source in the time interval $0 < t < t_1$, it has a spectral distribution which broadens as t_1 decreases. Thus initially one should expect small resonance absorption. At later times when the spectral distribution from the source is sharper, the absorption increases.

The fact that the curve obtained with the vibrated source is not strictly exponential and approaches the curve with the stationary source at small

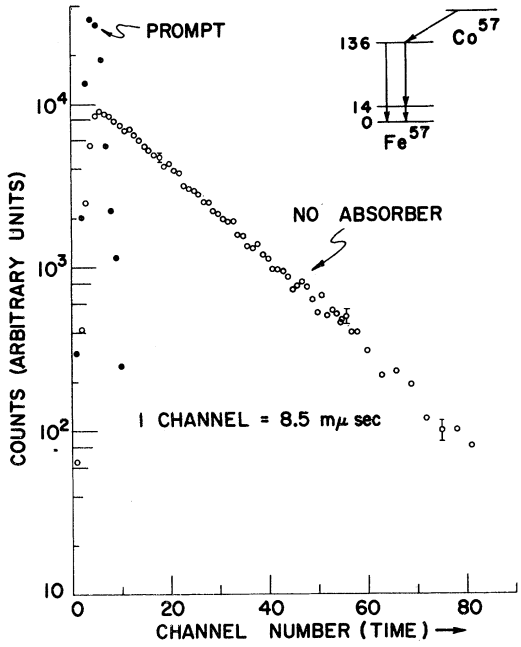

FIG. 1. A "prompt" curve, showing the time resolution, and a decay curve of the 14-kev excited state of Fe^{57}, taken without absorber to show the response of the apparatus for a normal exponential decay (1 channel = 8.5 mμsec).

times may be explained by an extension of the above argument. Since the spectral distribution is initially broad, the Doppler broadening for a given amplitude of vibration is initially less effective, and the vibrating and stationary curves (but not the curves taken with and without the resonant absorber) coalesce at small times. We have, in fact, observed that increasing the driving voltage on the transducer decreases the distortion of the curve for the vibrated source in the expected way.

A theoretical treatment based on a classical model for this phenomenon has been given by Hamermesh.[6] The results are in qualitative agreement with observations; a detailed comparison between experimental results and theory will be attempted in further work.

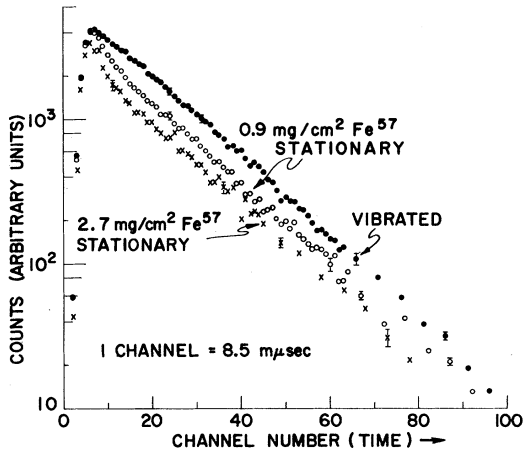

FIG. 2. Time spectra taken with source and absorber vibrated and with source and absorber stationary for two absorber thicknesses.

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