OBSERVATIONS ON THE MÖSSBAUER EFFECT IN Fe^{57}†

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The recent observation[1] of a large resonant absorption of gamma rays by the 14-kev level of Fe^{57} at room temperature has led to a subsequent study of the phenomenon in this laboratory. Because of the various interesting possibilities which this effect provides for further experimentation,[1,2] we present here some preliminary results of our investigation.

We have measured the magnitude of the Mössbauer absorption[3] for sources and absorbers in metallic form or as compounds, at room temperature and also when cooled with liquid nitrogen. These observations are summarized in Table I in which the tabulated entries indicate the observed absorption at resonance. The metal sources were prepared by co-plating iron and radioactive Co^{57} from a weak sulfuric acid solution. The Co^{57} was obtained by deuteron bombardment of iron followed by a separation[4] of inactive iron by ether extraction of $FeCl_3$. To insure the electrodeposition of a good metallic iron film on copper, an appropriate amount of $FeSO_4$ was added to the solution. The metal absorbers were usually rolled metal foils either of natural iron or of iron enriched to 76% in Fe^{57}. The thinnest rolled foil was approximately 60 microinches thick. Thinner absorbers were obtained by electroplating Fe^{57} upon thin copper foils Sources and absorbers in the form of ferrous sulfate were prepared by allowing a solution of the material to evaporate on a suitable backing.

Table 1. Maximum resonant absorption in percent for various combinations of sources and absorbers. The metal absorber is 2.5 mg/cm^2 of Fe^{57}. The metal source is a Co-Fe plated film. The salt is $FeSO_4 \cdot 7H_2O$. The symbols (RT) and (LT) stand for room temperature and low temperature, respectively. The estimated error in the numbers is about ± 5. The salt absorbers were made with enriched iron.

	Absorber		
Source	Metal (RT)	Metal (LT)	Salt (RT)
Metal (RT)	52		
Metal (LT)		75	
Salt (RT)	~0		4
Salt (LT)	10		8

For a given source and absorber, the resonant absorption was obtained by measuring the transmission with the source and absorber clamped firmly in a rigid container and comparing it with the transmission obtained when the source or the absorber was vibrating at high frequency and small amplitude. Vibration was produced by coupling to the voice coil of a loudspeaker. The absorbing foils were clamped between two disks of beryllium metal in order to obtain the necessary rigidity without undue attenuation of the counting rate. A source or an absorber could be cooled by attaching it in an evacuated space to the bottom of a metal can filled with liquid nitrogen.

It is apparent from Table I that the largest absorption at a given temperature is obtained with a metal source and a metal absorber. A Mössbauer absorption is also observed, however, for nonmetallic samples and this absorption is greatly enhanced at low temperature. Of particular note is the relatively large absorption (~10%) that is observed with the ferrous source and the ferromagnetic absorber. All of these observations suggest that the environment in the source or in the absorber plays a major role through its influence on the Debye temperature of the substance. The effect of environment on the expected hyperfine splitting of the nuclear levels,[1] on the other hand, is not sufficiently large to eliminate the resonant absorption.

In order to obtain a measure of the total strength of the absorption in the case of a metal source and a metal absorber, both at room temperature, the transmission was measured as a function of the relative velocity between source and absorber. In this work the source and the detector were mounted securely on the axis of a Monarch Model *EE* lathe and the absorber was attached to the carriage which provided apparently uniform velocities as small as 10 microns per second. Transmission curves obtained with this arrangement are shown in Fig. 1 for three different thicknesses of absorber. It is seen that the transmission curves are symmetric around zero velocity within the accuracy of the measurements. Furthermore, the fact that the areas in the transmission dips are approximately proportional to the square root of the thickness of absorber indicates that the absorbers are

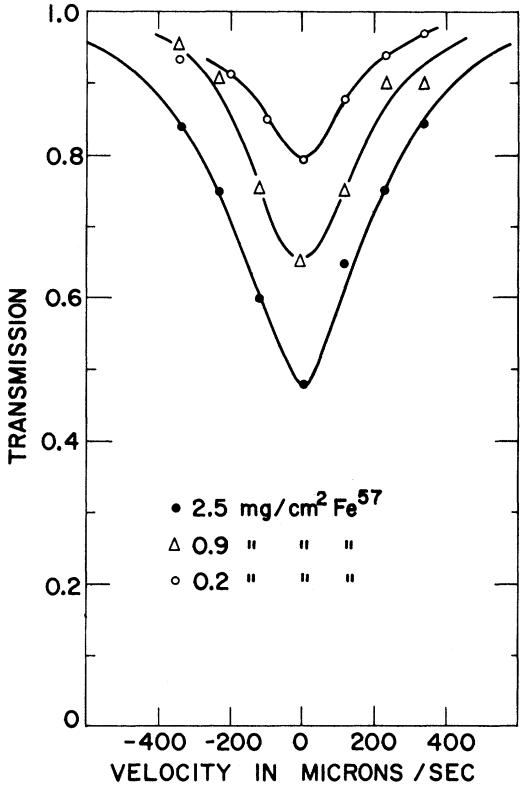

FIG. 1. Transmission curves obtained with a Co^{57} source electroplated in an iron metal environment and iron metal absorbers enriched to 76% in Fe^{57}. The two thicker absorbers were rolled foils; the thinnest sample was a film electroplated on copper. The curves are normalized to the transmission at "infinite" velocity, i.e., the transmission obtained when either the source or the absorber was vibrated at high frequency.

"thick." If one makes the simplifying but rough assumption that the fraction of nuclei in the source which emit without recoil is approximately equal to the fraction in the absorber which absorb without recoil, analysis of these curves by the area method gives a value of 0.6 for this fraction. This number is in good agreement with the theoretical value of 0.7 calculated[2] for room temperature. The measured cross section for absorption of gamma rays at resonance turns out to be approximately 1.4 megabarns, which is roughly 300 times as large as the electronic absorption per atom. An internal conversion coefficient of approximately 10 has been assumed in obtaining the cross section.[5]

The empirical widths of the transmission dips are about twice the width expected from the natural line breadth[5] (4.5×10^{-9} ev) which confirms the thick nature of the absorbers. A detailed analysis of empirical width as a function of absorber thickness with a more refined calculation of the emitting and absorbing fractions is not attempted here because of incomplete knowledge of the instrumental resolution function. There is in fact evidence in our observations that the width of the transmission dip is influenced by the environment of the emitter or the absorber, but clarification of this point must await further experimentation.

Not shown in Fig. 1 is a curve obtained with a 1-mil absorber of natural iron (2.2% Fe^{57}). The ease with which this curve was obtained confirms the qualitative fact that the nuclear cross section is indeed many times the electronic cross section.

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[4]Collected Radiochemical Procedures, Los Alamos Scientific Laboratory Report LA-1556 (unpublished).

[5]Nuclear Levels Schemes, $A=40\rightarrow A=92$, compiled by Way, King, McGinnis, and Van Lieshout, U. S. Atomic Energy Commission Report TID-5300 (U. S. Government Printing Office, Washington, D. C. 1955).