Mössbauer Spectroscopy in ^{57}Fe Compounds

Jay M. Lawhorn*
MIT Department of Physics
(Dated: April 1, 2014)

1. INTRODUCTION

When an excited nucleus emits a gamma ray to transition to a lower state, the nucleus must recoil from the emission to conserve momentum. The energy of the gamma ray is then equal to the transition energy less the kinetic energy gained by the recoilling nucleus. Similarly, transition to the higher state requires a more energetic gamma ray than the true transition energy. A gamma ray emitted in this regime is unlikely to be energetic enough to excite the reverse transition in an identical nucleus.

When the excited nucleus is embedded in a lattice structure, the entire lattice recoils against the emitted gamma ray. Because the lattice is much more massive than a single nucleus, the kinetic energy imparted to the lattice is negligible compared to the energy of the gamma ray. Nuclear resonant absorption is thus much more likely to occur because the emitted gamma ray has energy much closer to the true transition energy.

Recoilless nuclear resonance absorption of gamma radiation is known as the Mössbauer effect and is used for ultra-high resolution spectroscopy with resolution $\Delta E/E \approx 10^{12}$.

natural line width associated with lifetime of excited state by uncertainty principle, low-energy nuclear excited states are shortlived and therefore produce very sharp peaks

line widths broadened by thermal excitations in source/absorber

2. APPARATUS

The apparatus consists of a specially prepared Mössbauer source mounted on an oscillating piston, a proportional gas counter, and an absorber placed between the two. The Mössbauer source is $^{57}_{27}$Co diffused in a platinum substrate that allows recoilless emission of 14.4 keV photons.

3. ^{57}Fe ZEEMAN SPLITTINGS

4. ABSOLUTE VELOCITY CALIBRATION

5. ZEEMAN AND QUADRUPOLE EFFECTS IN Fe_2O_3

6. MAGNETITE

7. LINE BROADENING

TABLE I:

Parameter	System	Value
g_1	^{57}Fe	$(1.21 \pm 0.04) \times 10^{-7}$ eV
g_0	^{57}Fe	$(2.13 \pm 0.05) \times 10^{-7}$ eV
μ_1/μ_0	^{57}Fe	-1.71 ± 0.07
g_1	Fe_2O_3	$(1.91 \pm 0.06) \times 10^{-7}$ eV
g_0	Fe_2O_3	$(3.34 \pm 0.06) \times 10^{-7}$ eV
q	Fe_2O_3	$(6 \pm 9) \times 10^{-9}$ eV
μ_1/μ_0	Fe_2O_3	-1.71 ± 0.06

[1] "Nuclear Spins, Moments, and Other Data related to NMR Spectroscopy" from *Handbook of Chemistry and Physics*, 94th ed., 2013.

[2] R. Freeman, "Spin-Lattice Relaxation" from *A Handbook of Nuclear Magnetic Resonance*, Longman, 1988.

[3] N. Bloembergen, "Nuclear Magnetic Relaxation" reprinted in *Nuclear Magnetic Relaxation*, W.A. Benjamin, 1961.