Mossbauer Spectroscopy of Fe^{57}

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Introduction

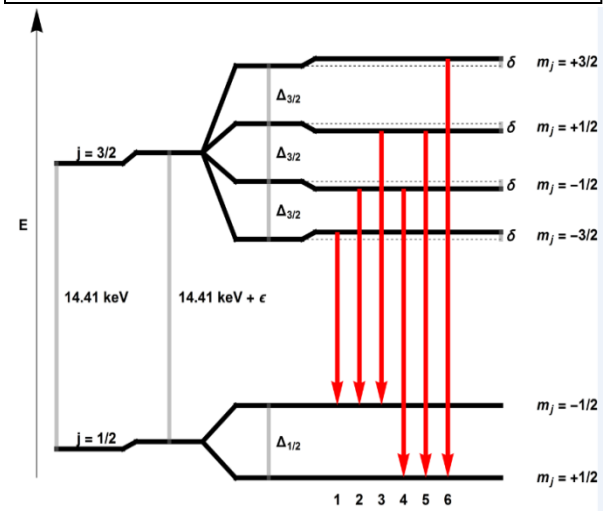
- Nuclear spectroscopy with solids: exciting ground state of nucleus with ~ 10 keV photons to investigate hyperfine nuclei structure
- Absorption and emission peaks expected to be Lorentzian
- By using nuclei embedded in a lattice, photon absorption and emission recoil is negligible, therefore peak centers are not affected by recoil

Goal

Observe hyperfine energy level splitting in the ground and first excited states of Fe^{57} containing compounds

Nuclear Energy Levels

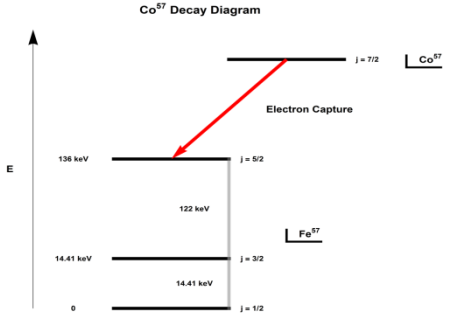
- Zeeman Effect Δ: Movement of unpaired electrons around nucleus generates internal magnetic field
- Quadropole Split δ: Interactions with surrounding atoms creates electric field gradient
- Isomer Shift ϵ: Interaction between nucleus and surrounding electrons increases energy



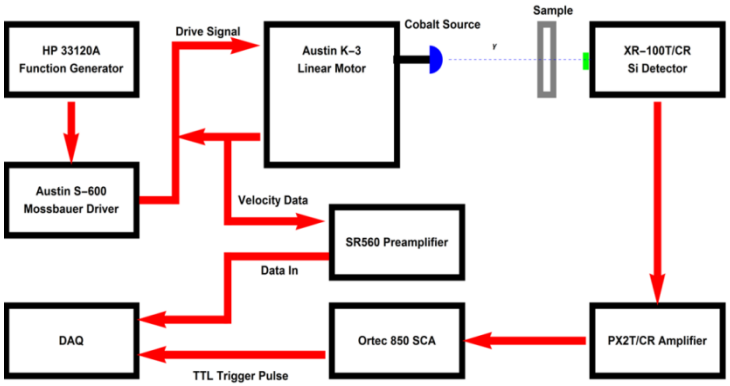
Gamma Ray Source

Doppler Shifted an 11 mC Co^{57} source to produce an incident spectrum of gamma rays about 14.41 keV, the transition energy of the first excited state

- To first order, $\Delta E = 14.41 \cdot \frac{v}{c}$ (keV)
- Linear velocity motor with $v \sim$ cm/sec allowed for 1 part in 10^{13} shift of incident gamma ray energy



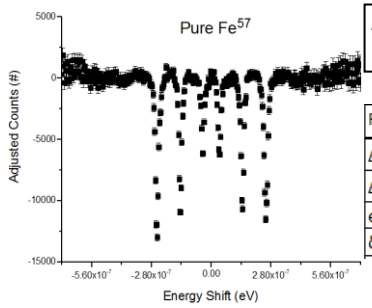
Data Collection



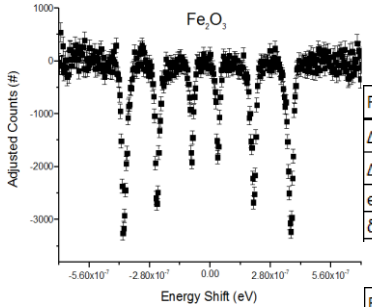
- The function generator powered the specially designed Mossbauer driver, which produced a linear velocity about zero (triangle wave).
- The linear motor held the Co^{57} source and provided velocity amplitude data to the DAQ as a proportional voltage.
- Photons were observed with the Si-detector and recorded only when a pre-calibrated single channel analyzer output a trigger pulse. This was done to ensure the DAQ was not flooded with counts from the 122 keV and 136 keV photons, which were not of interest in this experiment.

Results

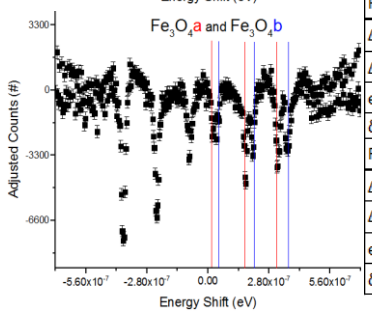
All Result values are in units of 10^{-7} eV



Fe^{57}	Result	Deviation
$\Delta_{1/2}$	1.84 ± 0.04	1.00
$\Delta_{3/2}$	1.08 ± 0.03	0.00
ϵ	----------	----------
δ	----------	----------



Fe_2O_3	Result	Deviation
$\Delta_{1/2}$	2.83 ± 0.04	2.50
$\Delta_{3/2}$	1.63 ± 0.03	0.75
ϵ	0.22 ± 0.06	0.10
δ	0.05 ± 0.02	0.40



Fe_3O_4 a	Result	Deviation
$\Delta_{1/2}$	2.79 ± 0.04	1.00
$\Delta_{3/2}$	1.59 ± 0.03	0.67
ϵ	0.24 ± 0.06	0.40
δ	----------	----------
Fe_3O_4 b	Result	Deviation
$\Delta_{1/2}$	2.61 ± 0.04	1.00
$\Delta_{3/2}$	1.48 ± 0.03	0.00
ϵ	0.69 ± 0.06	5.90
δ	----------	----------

Conclusion

The hyperfine energy levels of Fe^{57} containing compounds were successfully observed. Results were primarily limited by our choice of bin number. A larger bin number, while not allowing for as many counts to accumulate, would improve the precision of our results. In addition, we relied on a literature velocity calibration factor based on the Fe^{57} spectrum. Extensions of this work would include an attempt at measuring this calibration factor directly.