Development of a Mössbauer Spectrometer

Justin D. King
Union College
Schenectady, NY
Advisor: Michael F. Vineyard

Motivation

- A Mossbauer spectrometer is being developed for use in an upper-level undergraduate experimental physics course and for student research projects.

- Mossbauer spectroscopy is well-suited for undergraduates because it involves a relatively simple technique and allows the students to measure quantum mechanical effects which they study in modern physics and quantum mechanics courses.

Theory

γ-source in gas:

$$E_T = E_2 - E_1$$

- Recoil energy of emission = $E_\gamma^2 / 2Mc^2$.
- Photon energy = $E_T - E_\gamma^2 / 2Mc^2$.
- Need photon with energy = $E_T + E_\gamma^2 / 2Mc^2$ for resonant absorption in another atom.

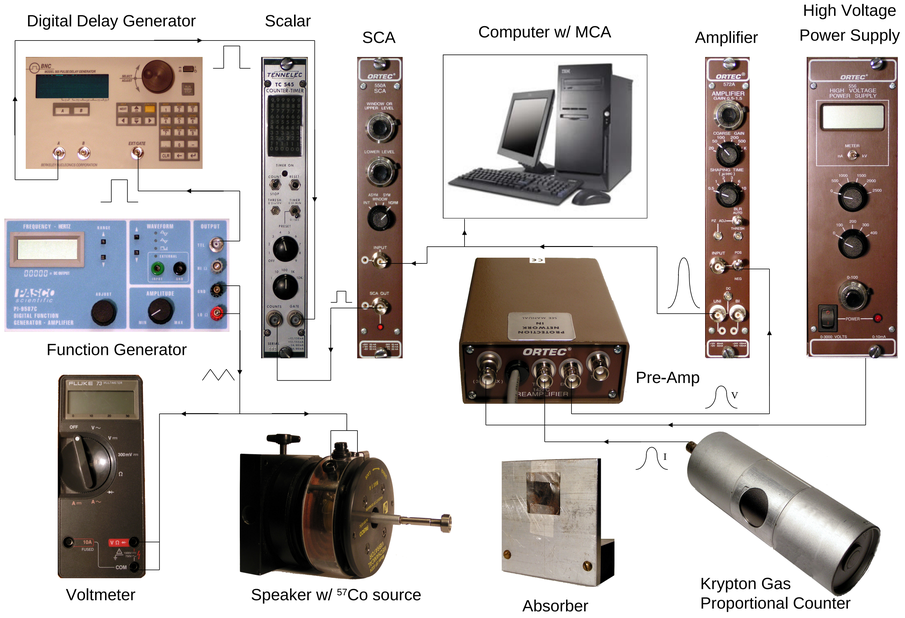
γ-source in crystal:

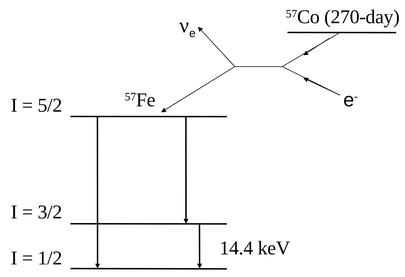
- When the recoil energy is less than the bonding energy, the atom does not recoil.
- Recoil energy is taken up by the entire crystal.
- This recoil energy is negligible and therefore the emitted photon will have energy equal to the transition energy.

Using the Doppler Effect we can create a very sensitive probe:

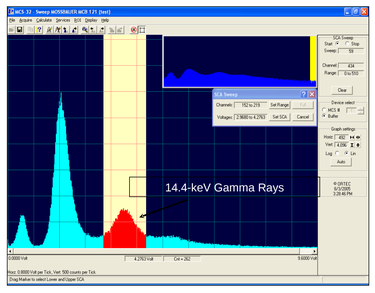
- Vary the relative velocity between the emitter and the absorber.
- This variation changes the energy of the photon.
- Allows for very precise measurements of shifts in nuclear energy levels.

Experimental Setup and Procedure





Decay scheme for ^{57}Co showing 14.4-keV transition of interest.



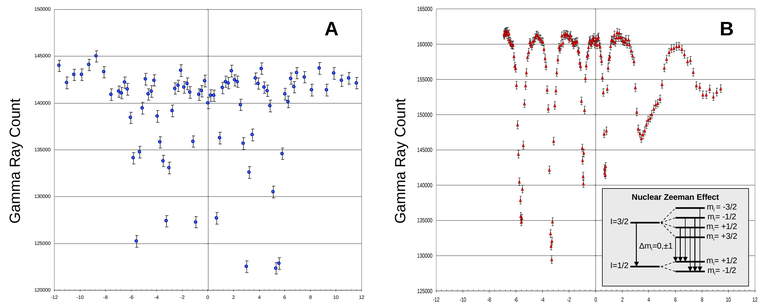
Gamma ray energy spectrum with 14.4-keV peak highlighted.

Procedure:

- Use the single channel analyzer (SCA) to gate on the 14.4-kev gamma rays.
- Drive speaker/source with a sawtooth wave at constant frequency, varying the amplitude in order to vary the velocity.
- Gate the scalar so that it counts only when the velocity is constant.
- Scan a range of velocities and record gamma ray counts for a fixed time interval at each velocity.

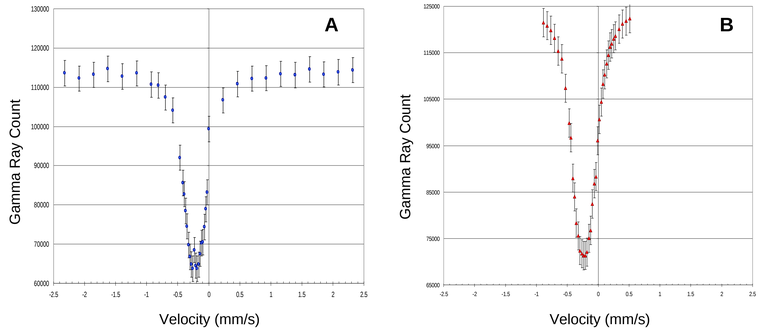
Results

Mossbauer Spectra – Natural Iron



Mossbauer spectra taken with a natural iron absorber. The six dips in the spectra correspond to the six energy transitions due to the nuclear Zeeman effect (See inset in spectrum B). Spectrum A was taken using an Austin Science Associates Mossbauer Drive and electromechanical motor. Spectrum B was taken with the equipment shown here.

Mossbauer Spectra – Stainless Steel



Mossbauer spectra taken with a stainless steel absorber each showing a single dip displaced from zero velocity due to an isomer shift. Spectrum A was taken using an Austin Science Associates Mossbauer Drive and electromechanical motor. Spectrum B was taken with the equipment shown here.

Summary

- ✓ A Mossbauer spectrometer has been developed.
- ✓ Preliminary experiments have been performed.

Future work involves the development of curricular materials for the undergraduate laboratory course.

The experiment will involve measuring:

- The ratio of the magnetic moments of the first excited and ground states of ^{57}Fe.
- The isomer shift for ^{57}Fe atoms in stainless steel.