Fortgeschrittenen Praktikum II

Moessbauer effect

04.04.2016

Benjamin Winkelmann
Peter Spalthoff

Tutor: Veronika Magerl

Contents

List of Figures **II**

1 physical principles **1**

1.1 Gamma Decay and and resonance Absorption 1

1.2 Interaction of Gamma radiation with matter 2

1.3 Moessbauer effect 2

2 References **3**

List of Figures

1.1 spontaneous γ emission 1
1.2 Lorentz distribution 1
1.3 Compton effect: A photon is scattered by a (quasi) free electron changing its direction by an angle φ 2
1.4 Co-57 decay 4

1 physical principles

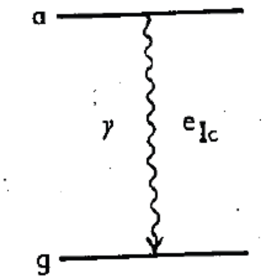

Figure 1.1: principle of spontaneous γ emission of excited nuclei. Transitioning from an excited state (E_a) to the ground state (E_g) the nucleus emits a photon with energy $E_a - E_g = \hbar\dot{\omega}$ or transmits that energy directly to an electron of the atomic shell.[1]

1.1 Gamma Decay and and resonance Absorption

Nuclei in excited states (energy E_a) can spontaneously transition into the ground (energy E_g) state. The energy difference $\Delta E = E_a - Eg$ is either directly gained by a shell electron (inner conversion), or carried by a emitted photon (spontaneous emission). The frequency ω of the photon is given by:

$$\Delta E = h \cdot \omega \tag{1.1}$$

where $\hbar = 6.582119514 \cdot 10^{-16} eVs$ is the Planck constant over 2π [3]. The Reverse process is also possible, namely a nucleus can transit into an excited state by absorbing a photon. However the emission (and absorption) spectrum is not infinitely sharp, but a Lorentz distribution with natural line width Γ (see figure 1.2) [1]:

$$I(\omega) \propto \frac{1}{(\omega - \omega_0)^2 + (\Gamma/2)^2} \tag{1.2}$$

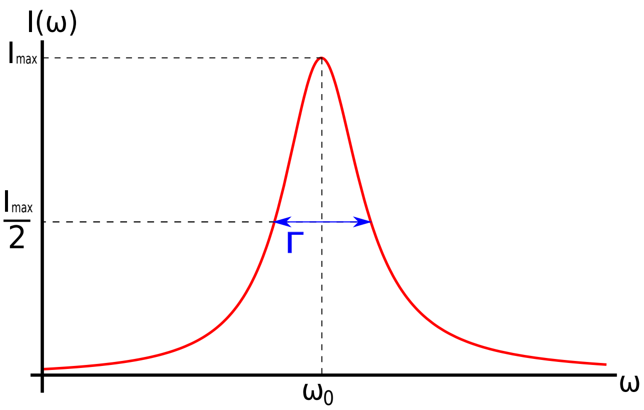

Figure 1.2: Illustration of a Lorentzian curve

The line width is related to the mean life-time $\mathcal{T}$ of the excited state via Heisenberg's uncertainty relation (here energy-time uncertainty):

$$\hbar = \Gamma \cdot \mathcal{T} \tag{1.3}$$

1.2 Interaction of Gamma radiation with matter

Photons interact with matter in three major ways[2]:

Photoelectric effect

Shell electrons of atoms absorb photons and gain its energy, leaving the potential well of the atom and exiting the shell with the energy $E_e = E_\gamma - E_B$ with E_B being the binding energy of the electron.

Compton scattering

Compton Scattering is the elastic scattering of photons at quasi free electrons ($E_B << E_\gamma$) and its wavelength $\lambda = 2\pi c/\omega$ shifted, depending on the scattering angle φ(see figure 1.4):

$$\lambda_S - \lambda_0 = \frac{2\pi\hbar}{m_e c}(1 - cos(\varphi)) \tag{1.4}$$

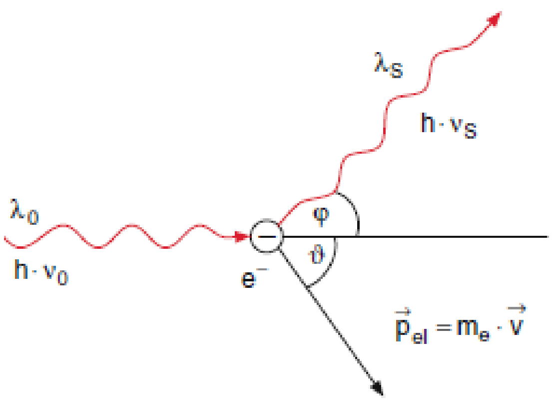

Figure 1.3: Compton effect: A photon is scattered by a (quasi) free electron changing its direction by an angle φ

1.3 Moessbauer effect

2 References

[1] Wegener, Horst. "Der Mößbauer Effekt und seine Anwendungen". Mannheim 1966

[2] Demtröder, Wolfgang. Experimentalphysik 3 Atome, Moleküle und Festkörper

[3] P.J.Mohr, D.B.Newell, and B.N. Taylor:
"CODATA Recommended Values of the Fundamental Physical Constants: 2014".
http://physics.nist.gov/cuu/Constants/index.html(26.04.2016)

[4] Jakobs, Karl. Experimentelle Methoden der Teilchenphysik. Vorlesungsskript 2014

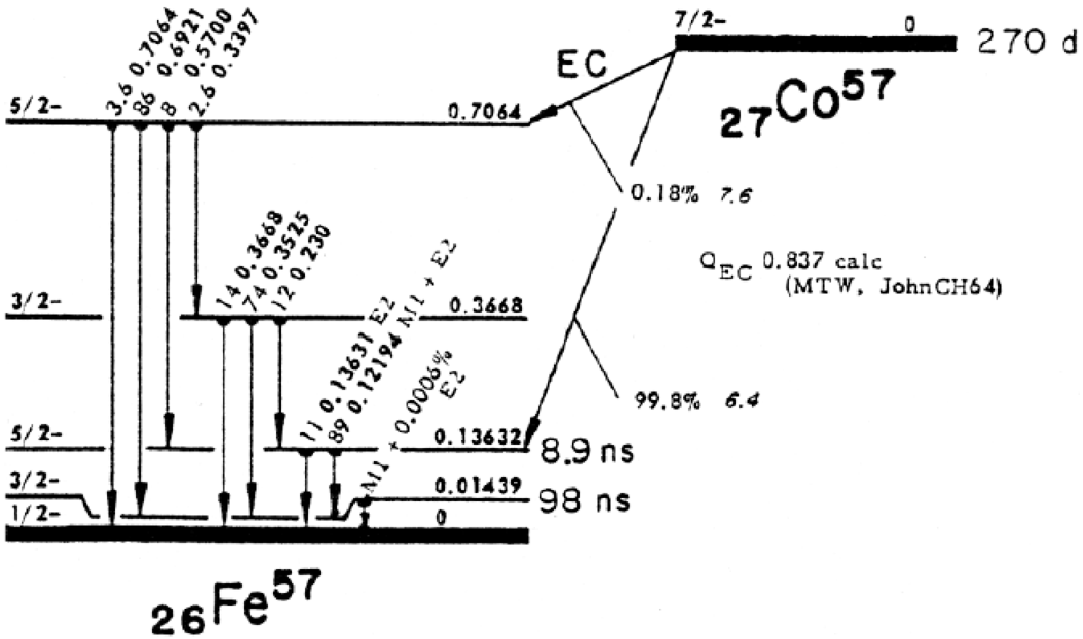

Figure 1.4: decay series of Cobalt-57