Gamma Ray Emission

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1 Pair Anhilation Data Analysis

The data was collected by the MCA overnight, and Professor Doret handed over the .spe files containing the data. For each count, the corresponding voltage was retrieved by the calibration data and the following formula.

$$\#1 + \#2 \times (\text{Bin}\# - 1) + \#3 \times (\text{Bin}\# - 1)^2$$

The calibration constants #1, #2, and #3 are given as follows:

$$\#1 = 4.942828 \times 10^1, \quad \#2 = 2.629989 \times 10^0, \quad \#3 = 5.826260 \times 10^{-4}$$

If all the coincidece detection indeed comes from pair anhilation of electron and positrons, the emission spectrum must be centered at 511keV, which is the rest energy of the electron. Our observations indicate a peak at 511keV, and we validate that the detection comes from pair anhilation.

2 Compton Scattering Analysis

2.1 Extacting the Linear Relation

We wish to use the collected data to confirm Compton scattering, i.e.,

$$\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

where $f_i = 662\,\text{keV}$.

We can deduce the frequency of the incident and exiting photon by the equation $E = hf$. Furthermore, we can deduce λ and λ' from this information.

$$c = \lambda f \Rightarrow \lambda_i = \frac{c}{f_i} \quad \text{and} \quad \lambda_o = \frac{c}{f_o}$$

Therefore,

$$\Delta\lambda = \left(\frac{1}{f_i} - \frac{1}{f_o}\right) = \frac{h}{m_e c}(1 - \cos\theta)$$

Let $E_e = m_e c^2$ be the rest energy of the electron.

$$\left(\frac{1}{hf_i} - \frac{1}{hf_o}\right) = \frac{1}{E_e}(1 - \cos\theta) \quad \text{or} \quad \left(\frac{1}{E_i} - \frac{1}{E_o}\right) = \frac{1}{E_e}(1 - \cos\theta)$$

From the collected data, we can compute the two quantities inside the parantheses for a linear fit. Also, there is an uncertainty in the measured frequency

f_o. To do a linear regression analysis, we must convert the uncertainty of f_o to that of $\frac{1}{f_i} - \frac{1}{f_o}$.

The uncertainty of a compound variable is computed by the weighted RMS of the uncertainties. In our case,

$$\Delta\left(\frac{1}{E_i} - \frac{1}{E_o}\right) = \sqrt{(\Delta E_o)^2 \left(\frac{1}{E_o^2}\right)^2} = \frac{\Delta E_o}{E_o^2}$$

2.2 Slope Prediction

The slope of the plot $1/E_i - 1/E_0$ verses $1 - \cos(\theta)$ is expected to be

$$\frac{1/E_i - 1/E_o}{1 - \cos\theta} = \frac{1}{m_e c^2} = \frac{1}{511keV} == \boxed{1.96 \cdot 10^{-3}\mathrm{keV}^{-1}}$$

2.3 Data Analysis

The observed slope of the fit is $-2.14{\cdot}10^{-}3\mathrm{kev}^{-1}$, which is close to the theoretical slope. Moreover, the p-value is in the order of -7, which indicates that the relation is likely linear.