GAMMA RAY SPECTROSCOPY

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ABSTRACT

Gamma spectroscopy is a method that can be used to identify the nuclei present in different radioactive materials. Gamma rays are emitted as the result of an excited nucleus relaxing back down to a lower energy state, with an energy equal to the difference between the energies of each state. Since each energy state is physically determined by the physical composition of an atom, each nucleus emits gamma rays of specific energies. In this experiment, a sodium-iodide (NaI) scintillation detector coupled with a photomultiplier tube (PMT) was used to measure the energy distributions of six unknown materials. The data from these materials was used to set a calibration curve. Then, a compound of two unknown nuclei was measured and analyzed. The calibration curve was then used to determine the energies of each of the unknown source's apparent gamma rays. These energies were then compared to known values in a nuclide database and determined to be Cesium-137 and Zinc-65.

MAIN IDEA

Gamma Rays are generated through various processes in nuclear decay. Two of the most common processes are **alpha** and **beta decay**. In **alpha decay**, an unstable nucleus emits an alpha particle. The resulting daughter nucleus is often in an excited energy state, which results in the emission of a gamma ray as it relaxes. **Beta decay** involves conversion of either a proton into a neutron or a neutron into a proton and the subsequent emission of a beta particle. Similarly, this can also result in the daughter nucleus being in an excited state which leads to the emission of a gamma ray.

Gamma rays can be measured because their energy can be transferred to electrons. Sufficiently low energy gamma rays may be totally absorbed by the **photoelectric effect**, producing a single electron with almost all the energy of the initial gamma ray photon. **Compton scattering** is the predominant interaction of gamma rays from about 100 keV to well above 1 MeV. In Compton scattering, a photon scatters off an electron at some angle from its original trajectory at a lower energy. This serves the purpose of reducing the gamma ray photon's energy to the point where it can be absorbed by the photoelectric effect. **Pair production** also plays an important role for energies above 1.022 MeV. This involves the creation of a positron/electron pair near a nucleus due to an incident gamma ray. Pair production only contributes when this positron/electron pair undergoes positron annihilation and is relatively uncommon in the energy range of this experiment.

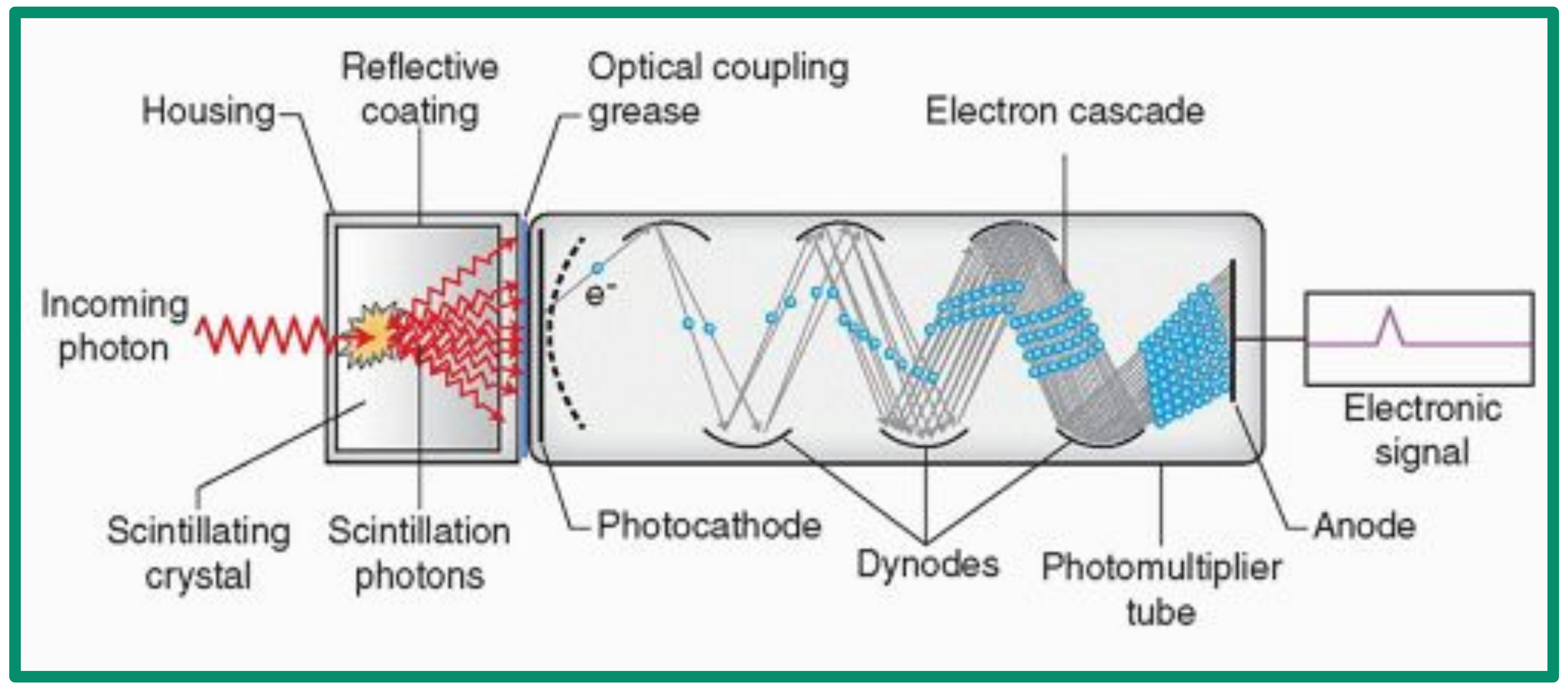
INSTRUMENTATION

Scintillator (Sodium Iodide 'Crystal')

- A gamma ray enters the scintillation material and passes its energy onto atoms within, causing its electrons to become excited.
- The electrons then return to their relaxed state while emitting visible light photons which then hit the backside of a photocathode.

Photomultiplier Tube (PMT)

- The photocathode emits photoelectrons from its surface and are accelerated through a series of dynodes.
- The electrons bounce off each dynode, causing the emission of even more electrons, creating an amplified electric pulse.
- The pulses are digitized and plotted (Counts vs Channel Number) using a computer software.



DATA ANALYSIS

Beginning with the data for the known materials, each energy peak was identified and fit with a modified **Gaussian Curve**. This returned the approximate channel number. To find the peaks, general features of gamma ray spectra were used (e.g. Compton Backscatter, Compton Edge, etc.). Some peaks were more obvious, while other were more subtle. To find the less obvious peaks, the ratio of energy and channel number for an identified peak was set equal to the ratio of energy and channel number for an unidentified peak. Then the equality was solved for the unknown channel number w. This returned an approximate value that could be used as a parameter in the Gaussian fit, which in turn returned the real channel number.

Once each channel number and gamma ray energy were correlated, they were plotted as Energy vs. Channel. Linear regression was used to find a linear fit, which was used as the **Calibration Curve**.

Finally, the data for the unknown compound was analyzed using general gamma ray spectrum features.. These features had to be relied on since the number and energies of the emitted gamma rays were unknown. Once the peaks were identified, they were fit with a Gaussian curve to determine the channel number. The calibration curve was used to solve for their energies. These energy values were then compared with gamma ray energies in a nuclide database and determined to be **Cesium-137** and **Zinc-65**.