Measuring Radiation
Experiments with a Geiger-Müller Tube

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History Behind Measuring Radiation

Geiger

- In 1908, Hans Geiger theorized that one could detect radiation by the ionized particles in its wake...

Müller

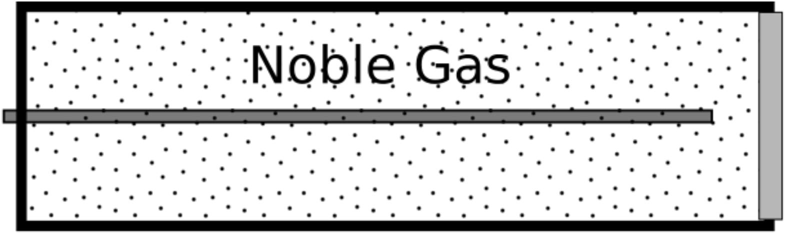
- Walther Müller devised a cheap and reliable apparatus using Geiger's theory...

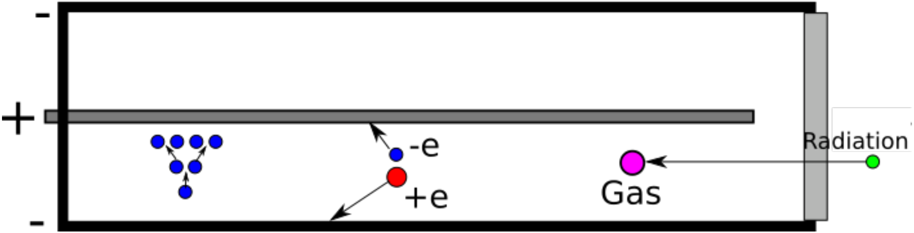
Hans Geiger

Walther Müller

Geiger-Müller Tube

The basis for all Geiger Counters





Relevant Information

Pros

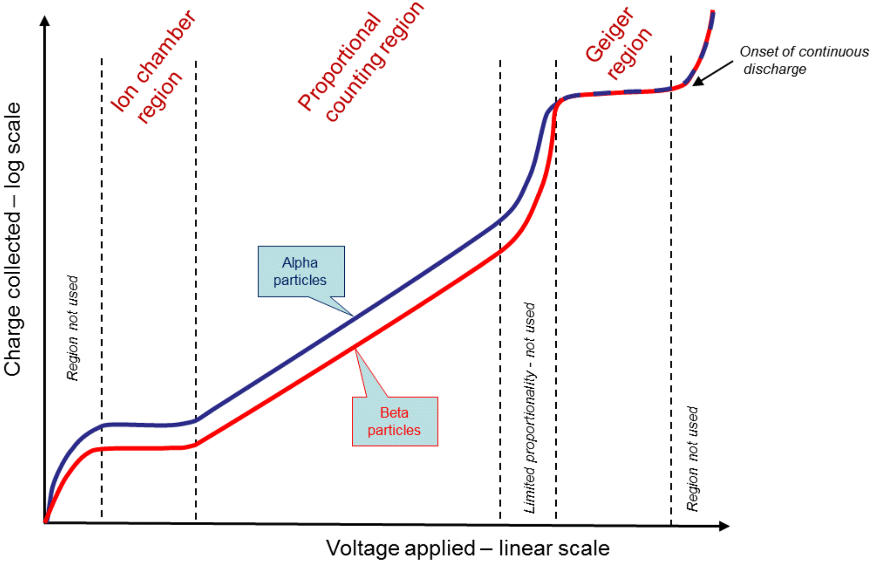
- In a sufficiently strong electric field, Townsend discharge effect ensures a count.
- Cheap to manufacture and simple to operate.

Cons

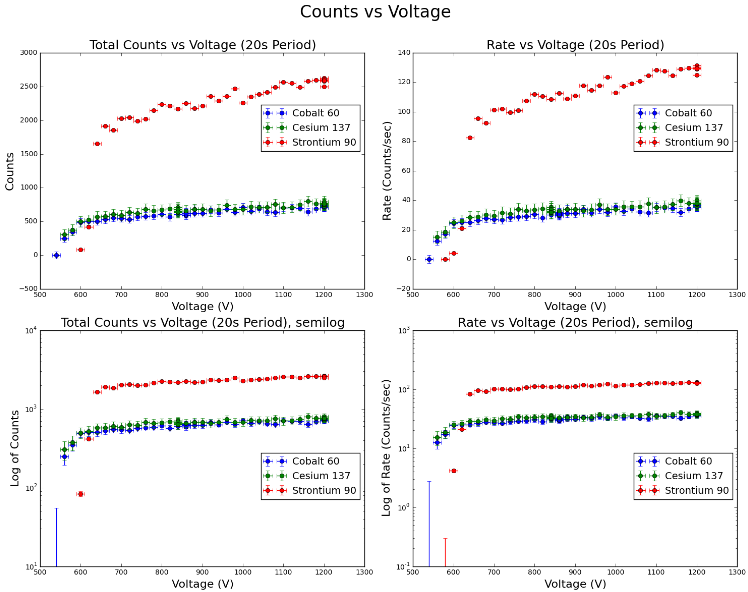
- Has a dead time after a each pulse, potentially missing ionizing radiation.
- Cannot distinguish between radiation types, though this can be somewhat worked around by applying filters.

Two Experiments:
Finding Ion Chamber Region Plateau
&
Determining Mass Attenuation Coefficient

Detector regions



Our Data



Counts vs Voltage
Total Counts vs Voltage (20s Period)
Rate vs Voltage (20s Period)
Total Counts vs Voltage (20s Period), semilog
Rate vs Voltage (20s Period), semilog
Counts
Rate (Counts/sec)
Log of Counts
Log of Rate (Counts/sec)
Voltage (V)
Cobalt 60
Cesium 137
Strontium 90

Theory in Absorption and Mass Attenuation Coefficient

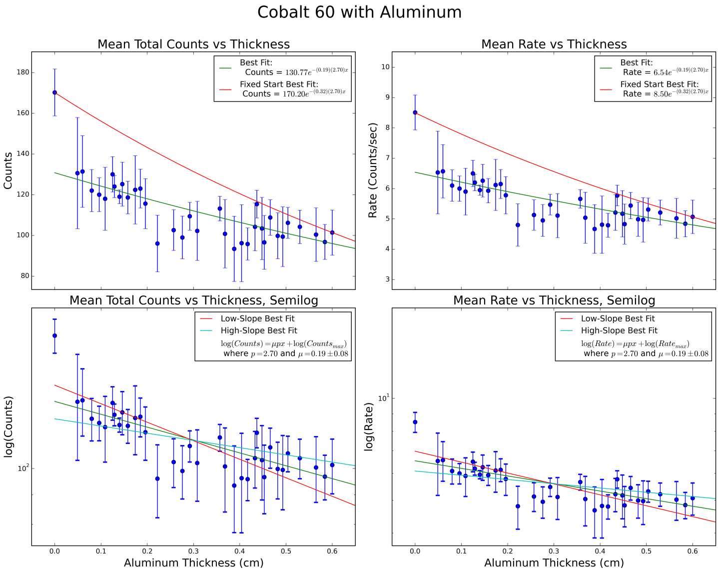
Mass attenuation coefficient is a measure of how easily a material is pierced by a beam of particles, wave, energy or matter.
Follows the formula:

$$I(x) = I_o e^{-\mu\rho x}$$

$$\ln(I(x)) = -\mu\rho x + \ln(I_o)$$

- I_o: The intensity or counts with no absorption material.
- μ: Mass attenuation coefficient (in $\frac{cm^2}{g}$).
- ρ: Density of material (in $\frac{g}{cm^3}$).
- x: Thickness of material.

Results



Accepted Value:

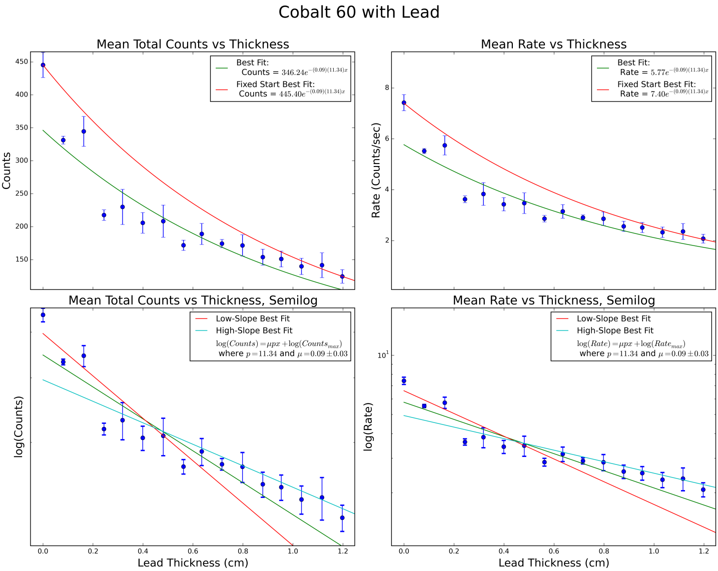
$\mu = 0.055 \frac{cm^2}{g}$

Our Value:

$\mu = 0.19 \pm 0.08$

Error: 245.5%

Results

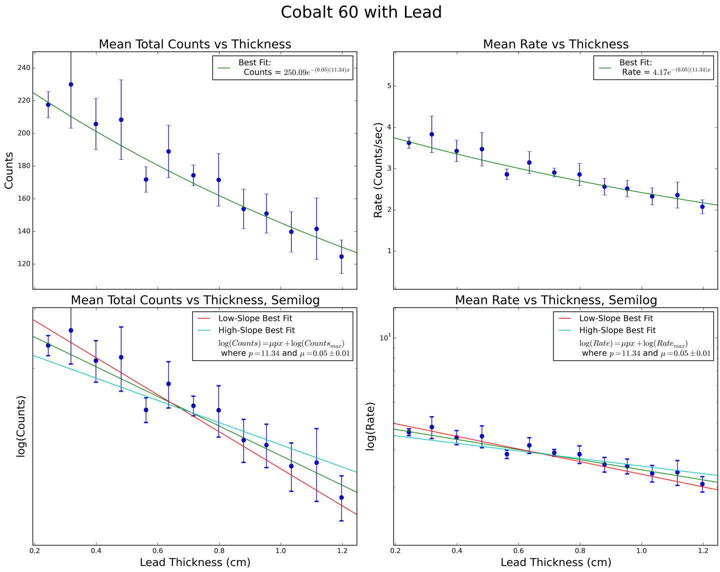


Accepted Value:
$\mu = 0.059 \frac{cm^2}{g}$

Our Value:
$\mu = 0.09 \pm 0.03$

Error: 52.5%

Results



Accepted Value:
$\mu = 0.059 \frac{cm^2}{g}$

Our Value:
$\mu = 0.05 \pm 0.01$

Error: 15.3%

Uncertainties

Largest error source was variation in each data collection run.

- To minimize, once can take more data over shorter intervals. One research project followed this method and used a Poisson distribution to determine the best value for each point.

There was some error during low voltages, as the potential difference was not enough to clean the ion build-up that diminished the internal electric field. This effect ceased when the voltage entered the ion chamber region.

Conclusion

Overall, this was an experiment to understand and use a new apparatus. We explored various types of experiments that can be done using this equipment, and found both positive and negative approaches. Our experiment produced either good data that was reasonably close to the expected value, or good insight into how to approach the experiment next time.

Some particulars:

- A β radiation source would be a better to calculate the mass attenuation coefficient for aluminum. γ radiation proved to be less than effective. Our strontium source would be sufficient for this.
- All radiation was emitted below 2MeV, which meant the only effect was ionization. From this, we did not have to consider the possibility of any other kind of radiation reactions in the tube.
- A computer program to take many data points automatically would drastically improve the uncertainty for this experiment. The limiting factor for us was simply time. Each run took from 20-60 seconds, which limited how many we could reasonably take.