Gamma-Ray Absorption in Graphite

Slug S. McPhysics
The University of California,
Santa Cruz.

Physics 133
Lab 1

March 2, 2004

Include partner's name:

with partner
Banana B. Cruzin

Although you can work with your lab partner on the data analysis, you must write up your report independently.

Note that this is <u>not</u> a particularly good example of a lab report. It might get a "C," with some luck. The comments indicate where it needs improvement.

Contents

List of Tables

List of Figures

no table of contents for a paper
as short as a lab report

~~Abstract~~

no abstract needed - will be in Phys 134

1 Introduction

~~1.1 Purpose~~

Generally intro should not be large enough to require subdivision

The goal of this experiment is to determine the γ-ray absorption coefficient of graphite. This was accomplished by observing how the radiation intensity drops off as a function of the amount of graphite between the source and the detector. The sources used were tiny amounts of Cesium 137. Radiation from these sources were detected and measured using a Geiger-Mueller tube, oscilloscope, and counter. The oscilloscope was used to measure the pulses from the GM tube, and also to explore properties of the tube, such as dead time and charge per pulse. The counter was used to measure radiation intensity throughout the experiment, such as background radiation. The qualitative results from the experiment are:

- The GM tube works best in the "plateau" region between 860 and 900 volts.
- The net capacitance of the apparatus (GM tube, cables, and oscilloscope) is 0.24nF ± 0.01nF.
- The charge released during a pulse is 1.8nC ± 0.02nC.
- The GM tube is most sensitive , where it reads a maximum of about 450 counts per second (cps) from the source.
- Background radiation in the lab is 0.42cps ± 0.15cps
- The GM tube dead time was 0.390ms ± 0.010ms by direct measurement, and 1.16ms ± 10.5ms by analysis of "skipped" counts.
- The absorption coefficient of graphite is $\mu = 0.0014~~777~~mm^{-1} \pm 0.00027~~819~~mm^{-1}$.

You can write the number ± error and units so: 0.24 ± 0.01 nF without repeating the unit, so long as both numbers have the same unit.

1.80 ± 0.02? significant figures of value and error need match

1 ± 10, 0.16 is insignificant with error of ±10.

The rest of this report will consist of the data, analysis of the data, and a description of the experiment itself taken step by step.

~~outline of rest of report~~

Number of significant digits is determined by the size of the error. Last 4 digits of both numbers are not

Statement like this ends the introduction. Next section on Equipment is not introductory.

~~1.2~~ Equipment   Not part of introduction

Tektronics TDS210 oscilloscope The oscilloscope was used to observe the configuration of the pulses coming from the G-M tube directly. When the G-M tube is in equilibrium the oscilloscope reads zero, so what was displayed on the screen was the voltage from equilibrium.

LND Inc. 7232 Geiger-Mueller tube The G-M tube consists of an enclosed hollow metal cylinder kept at ground, with a thin wire running along its axis. This tube is filled with argon and some "quenching" agent. When in use, a high voltage difference is applied between the cylinder and the wire. Ions knocked free by the passage of high-energy particles are pulled to the wire and sides. This collection of charge creates a secondary, non-equilibrium, voltage that can be seen as a pulse of current. The G-M tube was used at every stage of this experiment to detect radiation.

Power Designs Inc. model 2K20 voltage source The voltage source provided the voltage difference necessary to run the G-M tube.

Hewlett-Packard 5314A universal counter The counter allows the number of pulses to be measured, rather than the shape of the pulses. The counter registers one count every time a voltage above some pre-set limit is detected. Since it was connected in parallel with the oscilloscope the same available data was observed by both.

connection box The box allows the interconnection of the counter, oscilloscope, G-M tube, and voltage source while maintaining a divide between the high-voltage environment of the tube and the low-voltage environment of the oscilloscope and counter. This is done by means of an interposing capacitor. A capacitor allows the transmission of changes in voltage, but not voltage itself.

Ω is the unit of resistance

1kW resistor The G-M tube produces pulses of current. As those pulses discharged through the resistor they created a voltage that could be measured by the oscilloscope and counter.

0.01mF capacitor This capacitor was used in place of the resistor so that the total charge released in each pulse could be measured.

probably should be μ (micro) rather than m (milli)

Casio Databank 150 The stopwatch function on this watch was used to measure long time intervals.

Cesium 137 The cesium137 provided the radiation for most of the experiment. Cesium has a half-life of approximately 30.2 years, and the primary form of radiation produced by Cs_{137} is γ-rays. Cs_{137} is often found in nuclear fallout, but is not a naturally occurring isotope.

Strength of the source

2 Procedure

The first stage of the experiment was to find the plateau region of the G-M tube. This was done by increasing the voltage until the counter began to trigger, and then continuing to increase the voltage until the counts were relatively independent of voltage. The voltage was left in the middle of this region for the rest of the experiment. The experimental set-up has some natural capacitance. This was evaluated by discharging the "capacitor" through a known resistance and measuring the decay rate by finding the time it takes for the maximum voltage to fall to 1/e of its original value. The total charge released in each pulse was found placing a known capacitance across the inputs of the oscilloscope. Since $Q = CV$ measuring the peak voltage of the pulses immediately yields the total charge. By moving all the sources to the other side of the room and reading the counter every second for 12 seconds the background radiation can be estimated. Bringing the source directly under the G-M tube and setting the counter to refresh every second gives a good estimate of the maximum counting rate.

To study the Poisson distribution it was first necessary to take one hundred, one second samples. Since the process is completely random there was no need to read every consecutive second. Averaging these values yields λ, the one determining constant of the poisson distribution. By grouping the values m and counting the redundency of each the experimental frequency $F(m)$ was found.

There are two methods to find the dead time. Both involve putting sources so close to the G-M tube that the tube doesn't have time to recover from one particle before another particle hits. The simpler, and probably more accurate, method is to watch the oscilloscope screen. After every major hit the screen shows the usual decay of voltage, then near zero voltage, then a slow build up of spikes from the incoming particles. The time, as measured

Provide a diagram of the setup (hand drawn is fine). If a different set-up is used for differ parts/steps either discuss how the setup changed or provide multiple drawings.

The discussion of the procedure is too brief. Your description should be understandable to someone who has not read the manual. An exception is the alignment procedure for atomic spectroscopy, where you should discuss the purpose of the alignment (what is being aligned and why) but can refer to the manual for the details.

directly from the oscilloscope screen, between the tip of the big spike and the begining of the smaller spikes is the counter dead time. It is easiest to see where each region is when the oscilloscope is set to average over 16 cycles or so. The second method is to assume a dead time τ, with m incident particles, n of which register in the tube. Then the average output of two sources, A and B, are measured, both one at a time and together. After some analysis and math τ can be found in terms of these three average values (denoted N_A, N_B, and N_{AB}).

In order to measure the absorption coefficient of graphite several measurements of the radiation intensity through varying thicknesses of graphite were taken. In order to decrease the error each graphite slab was exactly the same thickness, and measurements were of the form "time to one thousand counts" rather than "counts per time interval". By counting to one thousand every time a relative error of 3.2

this is data

this is the result of analysis and belongs in the next section

3 Data

Pulses: $C = \Delta T/R = (2.4mS \pm 0.1mS)/(1k\Omega) = 0.24nF \pm 0.01nF$

$Q = C\Delta V = (0.01mF)(180mV \pm 2mV) = 1.8nC \pm 0.02nC$

Background radiation: $BG = 0.42 \pm 0.15$

The Poisson distribution: $\lambda = 6.07$

$\sigma_x = \sqrt{\lambda/N_O} = 0.246$

Counter dead time: $N_A = 687 \pm 8$

$N_B = 478 \pm 15$

$N_{AB} = 722 \pm 13$

Absorbtion coefficient: thickness of 7 slabs $= 52.5mm \pm .2mm$

thickness of 1 slab $= 7.5mm \pm .05mm$

$\mu = 0.0122863mm^{-1} \pm 0.00097296mm^{-1}$

$\chi^2 = 5.06$

$\alpha = 0.41$

There are two ways to present data, as text or in a table. This is neither one, and gives the numbers without explanation. Instead:

We measured the decay time of the pulse (using a 1 kΩ resistor) to be 2.4 ± 0.1 ms. The pulse amplitude...

The counting rates measured to find the G-M tube plateau are given in Table 1. etc.

4 Data Analysis and Results

Error analysis was a big part of this experiment. The following equations deal with determining error. The equation for the deviation of the mean, $\sigma_{\bar{x}}$, is:

$$\sigma_\mu^2 = \frac{1}{n}\sigma^2 = \frac{1}{n(n-1)}\sum_{k=1}^{n} x_k - \bar{x}^2 \tag{1}$$

To find compound error for a function of several variables the required function is:

$$\sigma_f^2 = \sum_{i=1}^{n} \frac{\partial f}{\partial x_i}^2 \sigma_{x_i}^2 \tag{2}$$

where $f = f(x_1, x_2, ..., x_n)$

In the case of the Poisson distribution the deviation of the mean is given by:

$$\sigma_\lambda = \frac{\sigma}{\sqrt{n}} = \sqrt{\frac{\lambda}{n}} \tag{3}$$

And the Poisson distribution itself is:

$$P(m) = \frac{\lambda^m}{m!}e^{-\lambda} \tag{4}$$

where λ is the mean.

To derive the dead time by counting one can use the following equation:

$$\tau = \frac{1}{N_{AB}}\left(1 - \sqrt{1 - \frac{N_{AB}(N_A + N_B - N_{AB})}{N_A N_B}}\right) \tag{5}$$

The size and akwardness of this equation makes propigation of error (from $N_A, N_B, and N_{AB}$) difficult.

The equation for the radiation intensity through x meters of graphite is:

$$I = I_0 e^{-\mu x} \tag{6}$$

where μ is the absorption coefficient of graphite. And

$$\ln I = \ln I_0 - \mu x \tag{7}$$

This form allows μ to be calculated as the negative slope of the best straight-line fit. The y-intercept is unimportant since it depends only on I_0, the unshielded intensity of γ-rays, which of course changes radically from experiment to experiment.

Introduce formulas and equations as you need them. Don't do a brain dump like this. Explain what you are going to calculate, then give the formula, if needed. The give the result of the calculation.

Even though results are given in Intro, they all need to obtained explicitly in the discussion in this section.

5 Summary and Conclusions

In the course of this lab it was shown that the Poisson distribution is a good aproximation for the frequency distribution of a radioactive source, and found the absorbtion coefficient of graphite. It was also seen that the radiation does fall off exponentialy with thickness, exactly as the molecular model predicts.

What molecular model? Some discussion of any model used to compare to the data would belong in the Introduction or Data Analysis and Results.

6 References

http://www.ex.ac.uk/ yszhang/ceasium/welcome.htm

7 Tables and figures

Every Table and Figure needs to referred to somewhere in the text — e.g. Table 1 is cited now in comments on p. 6. If any are not, then either the figure or table is extraneous, or some additional text is needed to give it the proper context.

Table 1: Plateau voltage

Voltage	pulses/second (aprox.)
830	3
840	35
850	35
860	40
870	40
880	40
890	40
900	40

Every figure & table needs a caption, too. Caption on Table 3 is good. Captions on Tables 1 and 2 are probably to short, unless they are well explained in the text.

Table 2: Background Radiation

m	F(m)
0	7
1	5

Table 3: Poisson distribution for 100 readings: counts per second m, actual occurance of m, predicted occurance of m

m	F(m)	P(m)
1	2	1.40
2	5	4.26
3	6	8.61
4	18	13.07
5	17	15.87
6	12	16.06
7	11	13.92
8	11	10.56
9	9	7.12
10	3	4.32
11	3	2.39
12	1	1.21
13	1	0.56
14	1	0.24

Table 4: Dead time count measurements for source A, source B, and source A and B together

N_A	N_B	N_{AB}
698	492	714
678	484	707
681	492	713
685	461	729
697	454	747
681	483	719

Table 5: Time for the counter to register 1000 particals through 1 to 7 graphite slabs of thickness $7.5mm \pm 0.05mm$, the natural log of the number of counts minus the expected count due to background radiation, and the error on each data point

number of slabs	seconds t	end count n	$\ln(n/t - 0.42)$	σ
1	213	1000	1.45	0.033
2	226	999	1.39	0.034
3	255	999	1.25	0.034
4	267	1001	1.20	0.034
5	292	1000	1.10	0.035
6	306	1000	1.05	0.035
7	358	1000	0.86	0.037

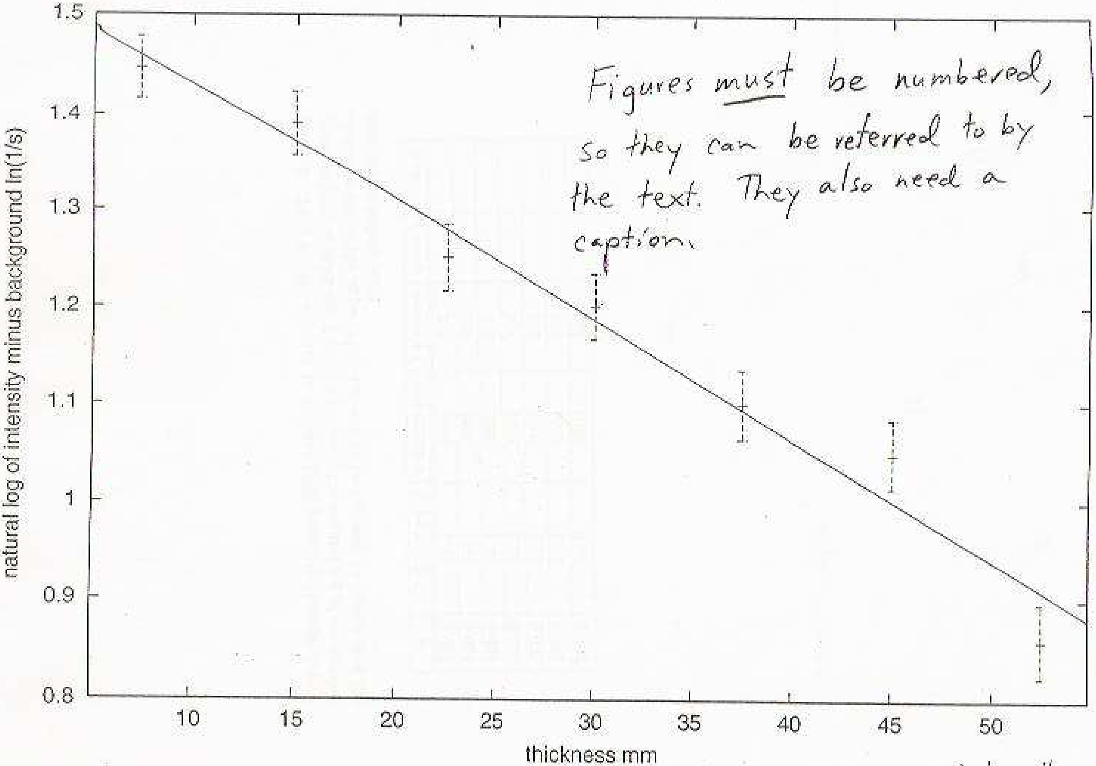

Figure 1 Graph of gamma ray intensity as a function of graphite absorber thickness