X-Ray Attenuation Experiment

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July 14, 2001

Research Experiences for Teacher – South African Exchange
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1 Introduction

This is an experiment to measure the attenuation of X-rays as they pass through material. The reason for doing this experiment is that the most popular method of lead detection in lead inspection and abatement work is the so-called X-Ray Fluoresence (XRF) detector, which is based upon detection of X-rays. Therefore a knowledge of their attenuation in passing through matter is important to the interpretation of the measurements.

2 Equipment and Procedures

The equipment used was the following:

1. Stop watch
2. Scintillation Counter and Amplifier item Brass disk - 8mm thick
3. Aluminum disk - 8mm thick

The procedure used was to take 5 runs (each) of the x-ray yield: a) without shielding, b) with brass and c) with aluminum disks in place.

The counts of the runs without shielding were different where they were expected to be aproximately the same (with variation of of one aproximately $\sqrt{N}$ Refer to Table 1:

Standard deviation root mean square deviation is about 3times what it should be. This could be due to the fact that counts which were taken at manually timed 30 second intervals were not timed accurately, due to my reaction time. We would also be able to determine the attentuation length more reliably if disks of different widths were used. The use of different disks would allow us to check to the expected exponential dependence on absorber thickness.

3 Data

The data taken are shown in Tables 1 , 2, and 3

Table 1: Data taken with no shielding. All measurements are for 30 sec.

Trial No.	No. of Counts	Δ(Diff. from Avg.)	Δ^2
1	14341	211	44521
2	13774	-356	126376
3	14127	-3	9
4	14606	476	226576
5	13800	330	108900
sum			506382
avg	14130		101276.40
ln	9.56		

From the above information we can calculate the σ_{RMS} : $\sigma_{RMS} = \sqrt{101276.40} = 318.$ This leads to the uncertainties shown below.

Quantity	Uncertainty
δ(indiv. meas.)	$\sigma_{RMS} = 318.$
δ(mean)	$\sigma_{RMS}/\sqrt{5-1} = 159.$
δ(ln(mean))	≈ 0.02

Table 2: Data taken with 8mm Aluminum. All measurements are for 30 sec.

Trial No.	No. of Counts	$Delta$(Diff. from Avg.)	Δ^2
1	12690	-272	75076
2	13319	355	126025
3	13476	512	262144
4	12698	-266	70756
5	12638	-326	106276
sum			640277
avg	12964		128055
ln(avg)	9.47		

From the above information we can calculate the σ_{RMS} :
$\sigma_{RMS} = \sqrt{128055}$ =357.85 This leads to the uncertainties shown below.

Quantity	Uncertainty
δ(indiv. meas.)	$\sigma_{RMS} = 358.$
δ(mean)	$\sigma_{RMS}/\sqrt{5-1} = 179.$
δ(ln(mean))	≈ 0.02

Table 3: Data taken with 8mm brass. All measurements are for 30 sec.

1	11136	92	8484
2	11258	214	45796
3	104444	-600	360000
4	11239	195	38025
5	11143	99	9801
sum			462086
avg	11044		92417.20
ln(avag)	9.30		

From the above information we can calculate the σ_{RMS} :
$\sigma_{RMS} = \sqrt{92417.20} = 304.00$
This leads to the uncertainties shown below.

Quantity	Uncertainty
δindiv.meas.	σRMS =304.00
δ(mean)	$\sigma_{RMS}/\sqrt{5-1}$ =152
δ(ln(mean))	≈ 0.02

The results of these measurements and tables are given in Table 3.

Condition	Quantity (Avg. No. X-rays)	Uncertainty
No absorber	14130	159
8mm Aluminum	12964	179
8mm Brass	11044	152

4 Analysis

From the data taken we can determine the attenuation lengths of aluminum and brass. The data (average number of counts for no absorber, 8mm aluminum, and 8 mm brass) are shown in Figure 1.

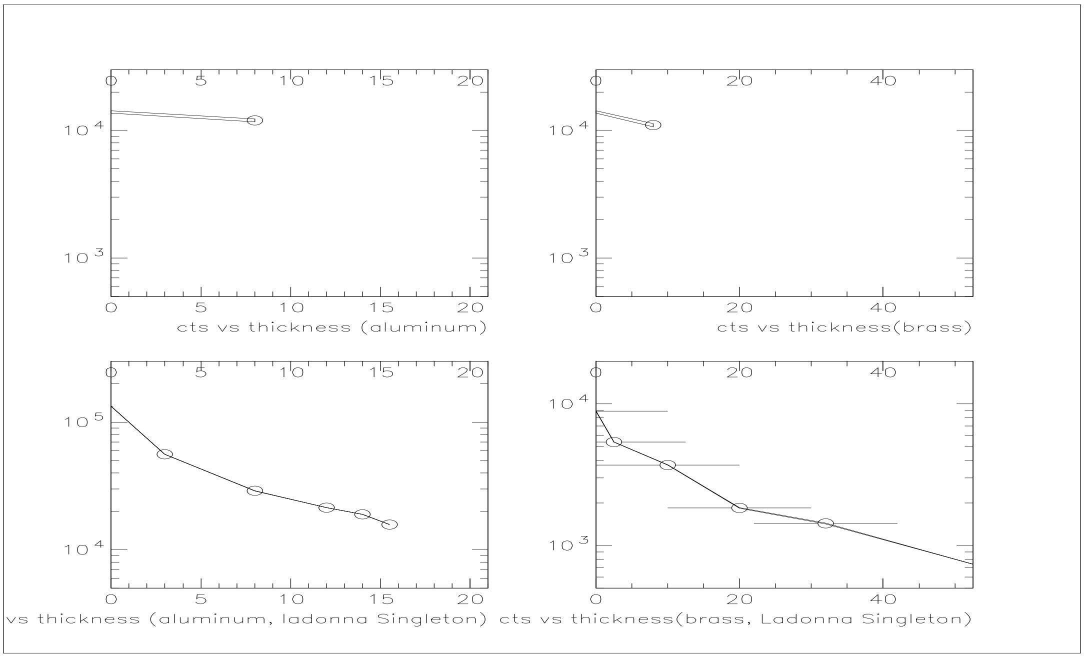

Figure 1: Collected X-rays from sodium source: no absorber, 8 mm aluminum, and 8 mm brass

4.1 Mathematical Treatment of Attenuation

For any process for which the change in a quantity is proportional to the quantity itself times some small increment (of time, or distance travelled; for example), one finds an exponential dependence on the quantity incremented.

If ΔN=-kNΔt (t=time, in radioactive decay)

=-kNΔx (x= absorber thickness, for x-ray attenuation)

then ΔN/N = -k Δt,

and integration yields: ln(N) - ln(N_0) = - k Δt.

The above equation can be written as ln(N/N_0) = -kΔ t.

Raising each side to the e (where e is the base of the natural logarithm system) then yields: N/N_0 = $e^{-k\Delta t}$, giving an exponential decay (for absorption, x-ray attenuation, or radioactive decay, where k is positive; and exponential growth for population growth, where k is negative.

4.2 Determination of Attenuation Lengths for Aluminum and Brass

Using the exponential dependence described above, and taking k = $1/x_0$, where x_0 is called the attenuation length, we find the formula:

$$N = N_0\ e^{-x/x_0} \tag{1}$$

A plot of ln(N) vs x then is a straight line

$$(ln(N) - ln(N_0) = -x/x_0 \tag{2}$$

So, when x = x_0,

$$N = N_0\ e^{-1} = N_0/e \approx N0/2.78 \approx N_0/3 \tag{3}$$

The above relations can be used to find x_0.

The attentuation lengths for aluminum were approximately (7.9+-1.7)cm from our work. (La Donna Singleton, in a similar experiment in 1999 found approximately (9+-3)cm).

The attentuation lengths for brass were approximately (3.9+-0.6)cm (La Donna Singleton's were approximately 4.0cm).

In the experiment performed we only used an absorber thickness of 8mm, but it would be preferable to use varied thickness for each material in order to obtain reliable results.

5 Background of Lead Abatement

The discussion of lead background draws heavily from materials prepared for lead abatement worker, lead risk assessment and lead inspector courses. [1]. Some web sources are the HUD (www.HUD.org), EPA (www.EPA.org), and LEADLISTING (www.LEADLISTING.org) web sites. Materials prepared by EPA, and state of Illinois are also found useful, and may be ordered from the Illinois department of public health (217-782-5830, or 525 W. Jefferson St., Springfield, IL, 62761) as well as from the EPA (Illinois: 800-545-2200):

1. "Protect Your Family from Lead in Your Home" (EPA, HUD)

2. "LEAD Poisoning and Your Children" (EPA)

3. "Reducing Lead Hazards When Remodeling Your Home" (EPA)

4. "Lead in Your Home: A Parent's Reference Guide" (EPA)

5. "Get the Lead Out" , with several sub-titles: Activities to Reduce Lead Exposure; Renovation, How to Safely Remove Old Paint; Intervention, How to Lower Blood Lead Levels in Children; and Prevention, How to Protect Children Against Lead Poisoning" (all Illinois Dept. of Public Health).

Various studies have shown that elevated lead levels in the the blood of small children cause them to be at risk for cognitive and emotional development.

Adults are also at risk.

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SIGNS AND SYMPTOMS OF LEAD POISONING
*Tiredness(fatique)                 *wrist or food drop
*sleep problems                     *weakness
*dizziness                          *clumsiness
*irritability                       *joint or muscle pain
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*nervousness                      *vomiting
*headaches                        *loss of appetite
*nervousness                      *stomach aches
*difficulty concentrating         *constipation
*depression                       *metal taste in the mouth
*hyperactivity(children0          *problems having healthy children
*numbness
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As an educator and from information gained from reading about lead poisoning, I am concerned that not enough is done in our country to prevent lead poisoning. Our country is still selling fuel which contains lead and it is a cause for great concern for the health of the people(especially children) in South Africa.

6 Measurements of Lead Paint and Lead Dust: XRF Detector

The XRF detector is based upon the ideas of X-ray absorption, similar to the x-ray absorption studied in the X-ray absorption experiment. The X-rays are emitted, are absorbed by lead atoms, then re-emitted, at characteristic wavelengths. The difference in the spectrum of x-rays directed to the sample and returned from the sample gives a measure of both the amount of lead in the sample and the depth at which the lead appears. The source used by the NITON detector, a commonly used type, is a Co^{109} source, typically 10 μCurie in strength. The radiation hazard from such a source is minimal, and readings can be conveniently made without damage to paint or substrate.

[Note added by advisor jt: It had been planned to carry out some tests of lead dust measurement with a single detector NITON XL309, and also for Ms. November to participate in an inspection of a house for lead paint. However, due to a combination of factors: unexpected damage to the NITON, and a personal emergency which required Ms. November's abrupt return to South African shortly before the end of the program, neither of these was included in Ms. November's work.]

References

[1] Chris King, **Lead Based Paint Risk Assessment**, handbook prepared for course, St. Louis University School of Public Health, 15 June, 1995.

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