University of Salahaddin-Erbil

College of Science

Department of Environmental Science

Nuclear laboratory

Experiments in Nuclear Physics

For 2rd Stage Student of Environmental Science

(Second Semester)

Prepared by:

Laboratory Staff

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Contents

Introduction to Laboratory Safety

Radiation Safety:

Radiation like anything else can be dangerous. The sources used for this experiment are exempt sources, which mean that they give off very little radiation compared to dangerous sources. Exempt sources, as long as they are not in quantities of hundreds, require no special shielding, storage, or disposal. We suggest that they be securely stored so that students or non-authorized personal do not take them. (These could be storing them out of sight in your desk.) We also suggest that common sense be used when handling these sources. Basic laboratory safety procedures should be followed. Treating a source in the same manner as a chemical is a good idea. Not eating and not inhaling the source or any part of it will eliminate the two worst ways to have radiation exposure. Also, no special disposal is required. However, government regulations do require that you deface or remove the label before disposing of them in normal trash containers.

General Nuclear Substances Safety Precautions:

Every worker shall comply with the measures established to protect the environment, the health and safety of persons, maintain security, control the levels and doses of radiation, and control releases of nuclear substances into the environment. A poster listing some of these precautions is posted in every laboratory designated as a radioactive work area.

1. Only persons properly trained to work with nuclear substances and informed of the hazards involved are permitted to work with nuclear substances or operate devices containing nuclear substances.
2. Keep external radiation exposure as low as reasonably achievable.
3. Minimize internal radiation exposure by limiting removable contamination and preventing personal contamination.
5. Do not eat, drink, store food or smoke in laboratories.
6. Do not pipette radioactive solutions by mouth.
7. No nuclear substances shall be used in or on human beings.
8. Wear a dosimeter at all times while in a radioactive work area, if recommended by

the Permit. Dosimeters shall be stored away from sources of radiation exposure.

9. In case of a radioactive spill, follow emergency procedures and notify the Radiation Safety Manager.
10. Never leave nuclear substances unattended, unless in a locked room or enclosure.
11. Store radioactive waste in a secure area.
12. All containers used to contain nuclear substances shall be labeled with the radiation warning symbol, radioisotope, activity and date. This does not apply to containers that are:
    - used to hold nuclear substances for current or immediate use and are under the continuous direct observation;
    - used to hold nuclear substances in quantities less than 10 kBq (270 nCi);
    - used exclusively for transporting nuclear substances and labelled in accordance with the Packaging and Transport of Nuclear Substances Regulations.
13. Clearly identify and mark working surfaces used for handling nuclear substances.
14. All equipment and other items used during a procedure with nuclear substances shall be labeled with the appropriate radiation warning labels.
15. Workers shall ensure the meter used to monitor for radiation contamination is working properly and function tested every 12 months.
16. Monitor the laboratory for removable contamination immediately following radioactive work or at least weekly. Decontaminate any surface where contamination was found as soon as possible. Keep a record of all monitoring and decontamination results.
17. Monitor equipment used for radioactive work to ensure that it is not contaminated prior to being used for non-radioactive work.
18. No worker shall transfer any nuclear substances to any person without the approval of the Radiation Safety Manager.
19. Maintain up-to-date inventory, usage and disposal records of all nuclear substances.
20. In the use of nuclear substances for teaching or research, consideration must be given to other physical, chemical and biological hazards, which may arise during the procedure .

Experiment No. (1)

Verification of Inverse Square Law for Gamma-Ray

Apparatus:

- NIM Bin and Power Supply
- High Voltage Power Supply
- Scintillation Detector
- Scintillation Preamplifier
- Linear Amplifier
- Single-Channel Analyzer
- Timer & Counter
- Oscilloscope,
- ^{137}Cs radioactive source
- Connecting Cables.

Purpose:

The student will verify the inverse square relationship between the distance and intensity of radiation.

Theory:

There are many similarities between ordinary light rays and gamma rays. They are both considered to be electromagnetic radiation, and hence they obey the classical equation

$$E = h\nu$$

Where

E ≡ photon energy in Joules.

ν ≡ the frequency of radiation in cycles/s.

h ≡ planks constant (6.624×10^{-34} Joule. s)

Therefore in explaining the inverse square law it is convenient to make the analogy between a light source and gamma-ray source.

Let us assume that we have a light source that emits light photons at a rate N photons/s. it is reasonable to assume that these photons are given off in an isotropic manner, that is, equally in all directions. If we place the light source in center of a clear plastic spherical shell, it is quite easy to measure the number of light photons per second for each cm^2 of the spherical shell. This intensity is given by

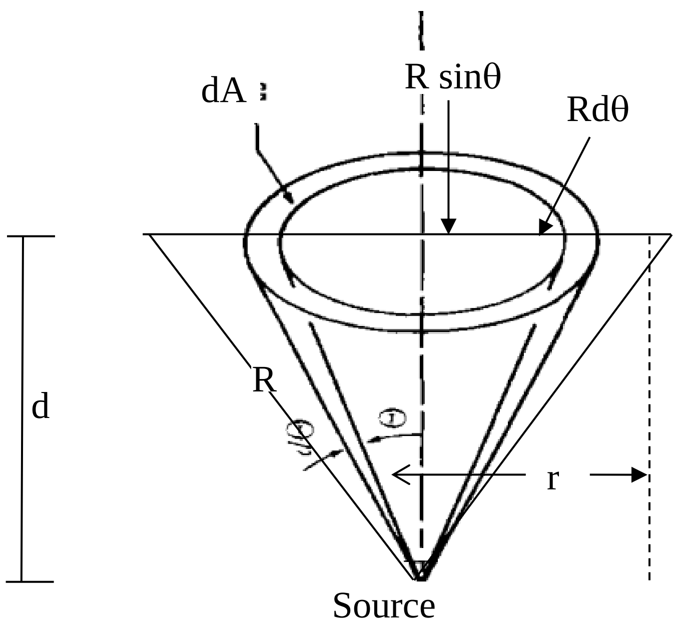
$$n = \frac{N}{A} ....(1)$$

where N is the total number of photons /s from the source, and A is the total area of the sphere in cm^2. Then equation (1) can be rewritten as:

$$n = \frac{N}{A(=4\pi r^2)} ....(2)$$

From eq.(2) we find that (n) is inversely proportional to the square of the distance. This equation is in term of the fraction of solid angle subtended on a point source by the counter entrance window. This is illustrated in the figure below.

The total solid angle subtended by a shell on its center is 4π, if Ω is a solid angle corresponding to a given segment of this shell then



$$n = \frac{N\Omega}{4\pi}$$

If (r) is the radius of detector window or the scintillator crystal face (d) is the vertical distance of source (S) from the detector, we presume that (d>r) which is practically possible.

From the definition of solid angle,

$$\Omega = \frac{dA}{R^2}$$

$$d\Omega = \frac{Area\ of\ annular\ ring}{R^2} = \frac{\pi(Rd\theta + R\sin\theta)^2 - \pi R^2 \sin^2\theta}{R^2}$$

Since θ is small, $(d\theta)^2$ can be neglected.

$$d\Omega = 2\pi \sin\theta\, d\theta$$

$$\Omega = 2\pi \int_o^{\propto} \sin\theta\, d\theta = 2\pi\, (1 - \cos\alpha)$$

$$\cos\alpha = \frac{d}{\sqrt{r^2 + d^2}}$$

$$\Omega = 2\pi\left(1 - \frac{d}{\sqrt{r^2 + d^2}}\right) = 2\pi[1 - (1 + \frac{r^2}{d^2})^{-1/2}]$$

By using binomial theorem $(1 + x)^n$ = 1+ nx + n(n-1)/n! x^2+……

$$\Omega = 2\pi[1 - \left(1 - \frac{1}{2}\left(\frac{r^2}{d^2}\right) + \cdots\right)] = 2\pi.(\frac{1}{2}).\frac{r^2}{d^2}$$

$$\Omega = \frac{\pi r^2}{d^2}$$

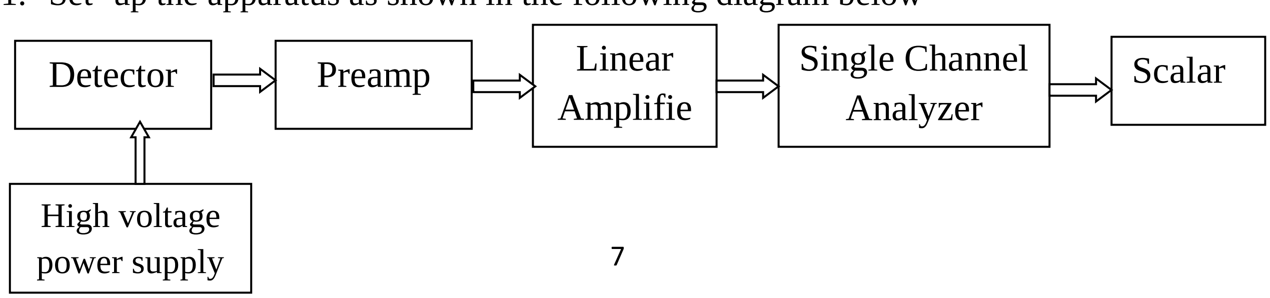
But $= \frac{\Omega}{4\pi}$; where (G) is the geometry factor $G = \frac{r^2}{4d^2}$

$$n = NG = \frac{Nr^2}{4d^2} \ldots\ldots\ldots.(3)$$

Equation (3) is required form of the inverse square law

Procedure:

1. Set- up the apparatus as shown in the following diagram below



2. Place the Cs^{137} source at suitable distance (satisfy d > r) from the detector face.
3. Set the scintillation counter voltage at the proper value (≅ 950 V).
4. Count for period of time sufficient to get reasonable statistics.
5. Change the distance between source and counter face in regular step (1 cm) and repeat the counting rate with each change in distance.
6. Find the background count rate (without source) and tabulate data as follows:

d/cm	Count / sec			$n = n_{ave} - n_b$	$1/d^2$ (cm^{-2})
	n_1	n_2	n_{ave}		
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					

8. Plot a graph between n (y-axis) and $1/d^2$ (x-axis), then from the slope evaluate N using eq. (3).
9. Compare the obtained value of N with the current activity of radioactive source Calculated from ($A = A_o e^{-\lambda t}$, A_o = 25 μCi, λ (decay const.) = ln2/($t_{1/2}$=30y) , and t = 41y).

Questions

1. Why it is necessary that the distance between the source and the detector should be greater than the radius of the detector?
2. Give the reason, why the graph between n and $1/d^2$ do not pass through the origin.
3. Is the calculated value of N represents the exact activity of the radioactive source? Explain your answer.

Experiment No. (2)

Deflection of Beta Particles in a Magnetic Field

Apparatus:

Geiger-Müller tube, Holder for Geiger-Müller tube, Holder for radioactive source, strontium-90 (^{90}Sr) beta source, deflecting magnets for plate holder, angular scale and Stopwatch.

Theory:

Any charged particle moving through a magnetic field will experience a force ***F***. This force is called the "Lorentz force" and will be perpendicular to the directions of both the magnetic field **B** and the velocity **V** of the charged particle and is given by:

$$\vec{F} = q\ \vec{v} \times \vec{B}$$

The exact direction of the force is given by the right hand rule. If θ is the angle between **V** and **B**, we can right for the magnitude of :

$$F = q\ vB \sin\theta$$

Hence, for a magnetic field that is perpendicular to the direction of motion of the charged particles

$$F = q\ vB$$

If the particle has a negative charge, as does a conventional Beta particle, the force will be in the opposite direction from that experienced by the positive charged particle. When the magnetic field remains constant, the charged particle will continue to experience the Lorentz force which will be constant in magnitude but with a direction that is always perpendicular to its velocity vector. This force will change the direction of the charged particle and force it to follow a circular path in the magnetic field. Therefore, if we put a detector that can be rotated in front of the beta source after applying the magnetic field, we should observe that the path of the particles is indeed deflected.

Procedure:

- Connect the apparatus as shown in **Fig.1**.
- Insert the source of radiation in the source holder. Place the source holder in front of the plate holder and slide the source of radiation until its exit opening is in front of the deflecting magnets, Place the plate holder with the deflecting magnets on the center point of the angular scale.

- Carefully remove the protective cap from the counter tube, start the first measurement by pressing the enter button. Note the first count rate in Table 1 on the Results page.
- Move the counter tube holder to the 10° graduation on the angular scale, making absolutely sure that the distance of the counting tube from the source of radiation does not change and that the axis of the counter tube is exactly aligned along the angle graduation. Start the next measurement and enter the count rate in Table 1.
- Repeat this measurement with all of the angles from +90° to -90° listed in Table 1.
- Remove the deflecting magnets, and then determine the count rates for all listed angles as before.
- On completion of this measurement series, replace the protective cap on the counter tube and replace the source of radiation in the container.
- Plot a graph between the angle (θ) on x-axis and the count rate per 60s on y-axis.

Table 1.

Angle(θ) degrees	**Without magnets N counts /min**	**With magnets N counts /min**
90		
80		
70		
60		
50		
40		
30		
20		
10		
0		
-10		
-20		
-30		
-40		
-50		
-60		
-70		
-80		
-90		

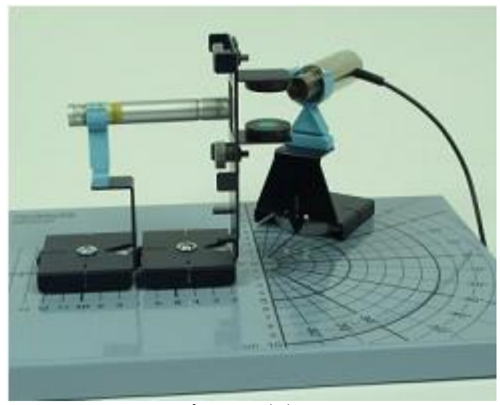


Figure (1).

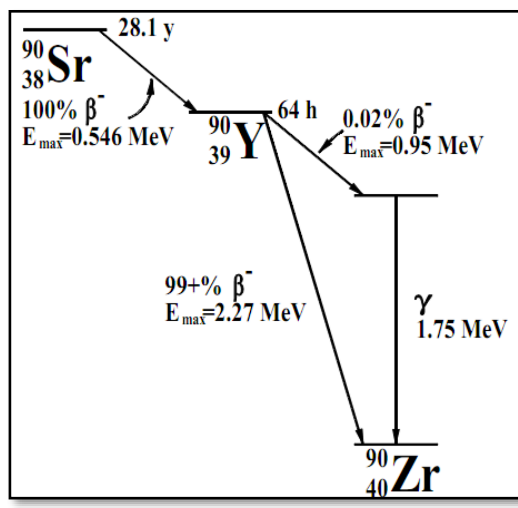


Figure (2). Decay scheme for strontium-

Attention:
The counter tube window of the Geiger-Müller counter is not guarded. The danger that touching the counting tube window can destruct it should be particularly stressed. As a matter of principle, the students should therefore only remove the protective cap shortly before beginning the measurements and replace it directly after they are finished.

Exp. (3)

Activity Measurement of Gamma – Source (Relative Method)

Apparatus

- NIM Bin and Power Supply
- High Voltage Power Supply
- Scintillation Detector
- Scintillation Preamplifier
- Linear Amplifier
- Single-Channel Analyzer
- Timer & Counter
- Oscilloscope,
- Two ^{137}Cs, radioactive sources
- Connecting Cables.

Purpose

The purpose of this experiment is to outline one procedure by which the activity of a source can be determined, called the relative method.

Introduction

Radio–active decay cover the processes of α, β and γ decay for unknown radioactive nuclei, the radiation of parent nuclei goes on decreasing which described by an exponential law. If at a time (t=0) there are radioactive nuclei parent then at time t = t (second) their number will be N(t)

$$N(t) = N_o \exp^{-\lambda t}$$

here λ is the decay constant.

The activity is defined as the number of disintegration per second in radioactive sample.

$$A = \left| \frac{dn}{dt} \right| = \lambda N_o \exp^{-\lambda t} = N\lambda$$

The unit of activity is curie, which is equivalent to 3.7×10^{10} disintegrations per second.

But more practical is 1 μcurie = 3.7×10^4 dis./sec.

In relative method of measuring activities, we must use a unit standard source (with known activity) in order to compare it with a source of unknown activity. But since decreasing efficiency depends on the energy, so the source of unknown activity must be identified in order to know the γ-energy. For this reason it is more precise to use a standard source of the same isotope:

The unknown activity can be calculated by the following equation.

$$\frac{A_s}{A_u} = \frac{\sum N_s - \sum B_s}{\sum N_u - \sum B_u} \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

A_S: activity of known source.

A_u : activity of unknown source.

$\sum N_s$: Sum of counts under the photo peak of known source.

$\sum B_s$: Sum of background counts under the photo peak of known source.

$\sum N_u$: Sum of counts under the photo peak of unknown source.

$\sum B_u$: Sum of background counts under the photo peak of unknown source.

The resolution of photo peak is found by this equation:

$$R = \frac{dE}{E} x100 \qquad \ldots\ldots\ldots\ldots\ldots (2)$$

R; is the resolution percent.

dE: **F**ull **W**idth at **H**alf **M**aximum (**FWHM**) of the peak measured by the voltage at centered photo peak.

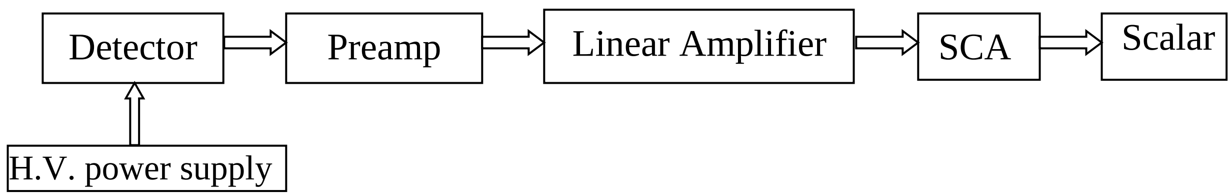
E: base line voltage at centered photo peak.

Note:

In using the relative method, it is assumed that the unknown source has already been identified from its gamma energies. For example, assume that the source has been found to be ^{137}Cs. Then all that is necessary is to compare the activity of the unknown source to the activity of the known ^{137}Cs source that will be supplied by the laboratory instructor.

Procedure

1. Connect the electronic equipment as shown below:



2. Place the ^{137}Cs radioactive source at 4 cm from the face of detector.
3. Setup the operating voltage of 950 V and window width at 0.2.
4. Adjust gains of amplifier so that the photo peak of ^{137}Cs at about 3 $\longrightarrow$ 4 volts of BLV is obtained.
5. Obtain the spectrum of ^{137}Cs by taking counts/sec for every setting of Bias Line Voltage.
6. Calculate sum of counts under peak of the standard source.
7. Evaluate background counts rate.
8. Repeat step (5) for another ^{137}Cs source (with unknown activity).
9. Use equation (1) to calculate the activity of unknown source.
10. Use equation (2) to determine the resolution of your detector.

Exp. (4)

Absorption Coefficient for γ - rays

Apparatus

- Geiger-Muller Tube
- Timer & Counter
- ^{137}Cs radioactive source
- Connecting Cables.
- Lead and copper absorber sheets

Purpose

The purpose of the experiment is to measure experimentally the linear and mass absorption coefficient in lead and copper for 662 KeV gamma rays.

Introduction

Gamma rays are highly penetrating radiation and interact in matter primarily by photo electric, Compton, or pair production interaction. In this experiment we will measure the number of gammas that are removed by photo electric or Compton interaction that occur in a lead or copper absorber placed between the source and the detector.

From the Lambert law equation the decrease of intensity of radiation as it passes through an absorber is given by

$$I = I_0\, e^{-\mu x} \quad \text{……………………..(1)}$$

Where
I: intensity after the absorber.
I_0: intensity before the absorber.
μ: linear mass absorption coefficient in cm^{-1}.
x: is the thickness in cm .

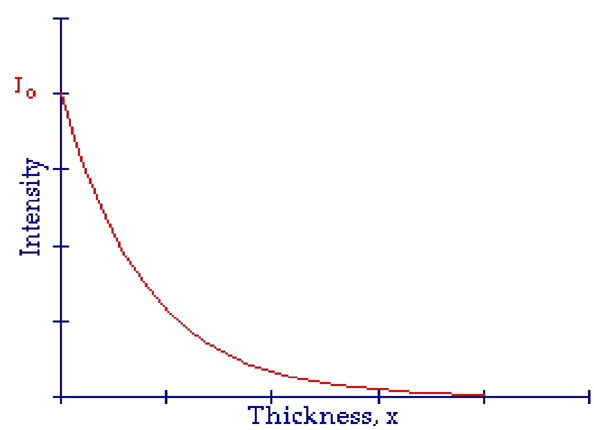


Fig. (1): intensity Vs. thickness for gamma ray energy of 662 KeV.

The half-value layer ($X_{1/2}$) is defined as the thickness of the absorbing material that will reduce the original intensity by one-half. From equation (1)

$$\ln\frac{I}{I_0} = -\mu x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

If $I/I_0 = 1/2$ and $x = X_{1/2}$, the $\ln(1/2) = -\mu(X_{1/2})$ and hence

$$X_{1/2} = 0.693/\mu \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

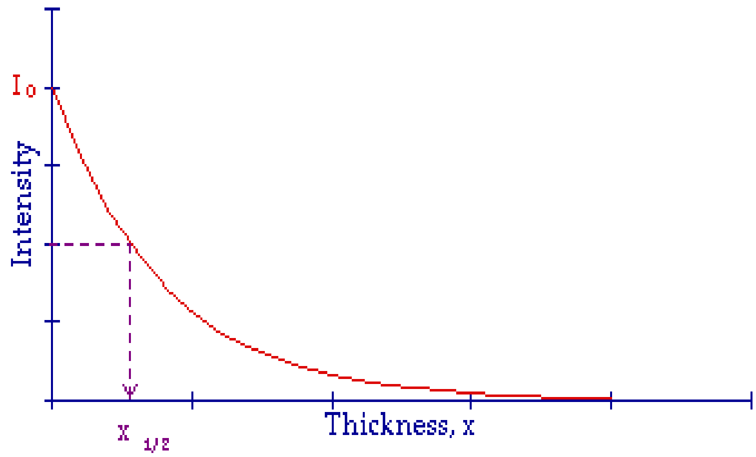


Fig. (2): The Half Value Layer for a range of absorbers.

If μ_m represents the mass absorption coefficient, it's the ratio of the corresponding linear attenuation coefficient to the density of the attenuator in gm/cm^2, then $\mu_m = \mu/\rho$, where ρ is the density of medium.

$$I = I_0 e^{-\left(\frac{\mu}{\rho}\right)\rho x}$$

$$I = I_0 e^{-(\mu_m) x'}$$

The density thickness is the product of the density in g/cm^3 times the thickness in cm. $x^- = \rho x$

$$\text{In}\,(I/I_0) = -\mu_m x^-$$

In this experiment we will measure μ and μ_m in lead and copper for 662 KeV gammas from ^{137}Cs. The accepted value of μ_m for lead is 0.105 cm^2/g.

Procedure

1. Connect the electronic equipment and place the radioactive source (^{137}Cs) at some distance far from the detector face.
2. Take counts for one minute without absorber.
3. Place a first sheet between source and detector, and take counts for the same time interval.
4. Place a second, third,…… sheets on the top of the first one and record counts for the same time interval for each case, and continue adding the sheets until the number of counts reach 25% of the number recorded without absorber.
5. Plot a graph between intensity and thickness as shown in Fig.(1).
6. Evaluate $X_{1/2}$, μ and μ_m for each of lead and copper.

Experiment No. (5)

Counting Statistics

Apparatus:

- Geiger-Muller Tube
- Timer & Counter
- ^{137}Cs radioactive source
- Connecting Cables.

Purpose:

To investigate the statistics (Specifically the Gaussian distribution) related to measurements with a Geiger counter.

Theory:

We can never know the true value of something through measurement. If we make a large number of measurements under (nearly) identical conditions, then we believe this sample's average to be near the true value. Sometimes the underlying statistics of the randomness in the measurements allows us to express how far our sample average is likely to be from the real value. Statistics is an important feature especially when exploring nuclear and particle physics. In those fields, we are dealing with very large numbers of atoms simultaneously. We cannot possibly deal with each one individually, so we turn to statistics for help. Its techniques help us obtain predictions on behavior based on what most of the particles do and how many follow this pattern. These two categories fit a general description of mean (or average) and standard deviation.

Radiation nucleus appear to decay at random process, each measurement of decay of given nucleus does independents on the previous measurement, and also is not affected by the decay of neighboring atoms. Consequently, any measurement, which is based on observing the radiation emitted in nuclear decay, is subjected to some degree of statistical fluctuation. These inherent fluctuation in nuclear radiation produce an unavoidable source of uncertainty in all nucleus measurements and often can be the predominant source of imprecision or error. Therefore for large number of individual measurements, the deviation of individual count rate from what might be termed the ″average count rate″ behaves in random manner, small deviation from the average are much more likely than large deviation.

In this experiment we will see that the frequency of occurrence of a particular deviation from this average, within a given size interval, can be determined with certain degree of confidence. One hundred independent measurements will be made, and some rather simple statistical treatments of the data will be performed.

The average count rate for n independent measurement is given by:

$$N_{ave} = \frac{N_1 + N_2 + \cdots + N_n}{n} \quad \text{..............(1)}$$

N_1: count rate for first measurement

N_2: count rate of second measurement

In summation notation N_{ave} can be written as:

$$N_{ave} = \sum_{i=1}^{n} \frac{N_i}{n}$$

The deviation of individual count from mean is (N_i – N_{ave}). From deviation of N_{ave} it is clear that

$$\sum_{i=1}^{n} (N_i - N_{ave}) = 0$$

So the standard deviation (SD)

$$\sigma_{th} = \sqrt{N_{ave}}$$

and the experimental mean square deviation σ_{exp} evaluated from

$$\sigma_{exp} = \sqrt{\sum_{i=1}^{n} \frac{(N_i - N_{ave})^2}{n-1}} \quad \text{..............(2)}$$

On the other hand, the statistical theory of error is usually based on the normal (Gaussian) distribution function. The normal distribution function $W(N_i)$ is a continuous function of N_i

defined in such a manner that the quantity $W(N_i)$ gives the probability that the value of N_i lies between N_i and $N_i + dN_i$.

The normal distribution function $W(N_i)$ can be written a

$$W(N_i) = \frac{1}{\sigma\sqrt{2\pi}} exp^{\frac{-(N_{ave}-N_i)^2}{2\sigma^2}} \quad \text{……………(3)}$$

Figure (1) illustrates the form of the distribution along with its most important properties.

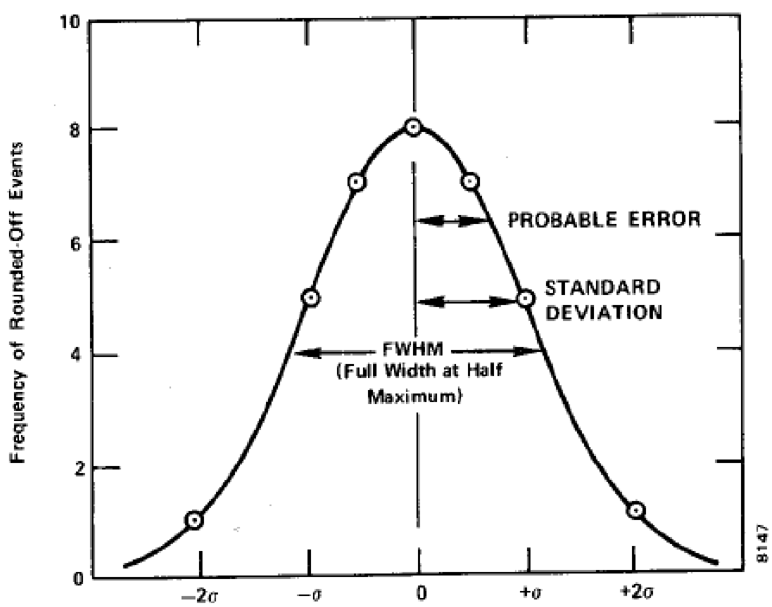


Fig.(1): Typical plot of frequently of rounded–off events vs. rounded–off value.

Procedure:

1. Experimental set-up is the same as shown in Figure (2).

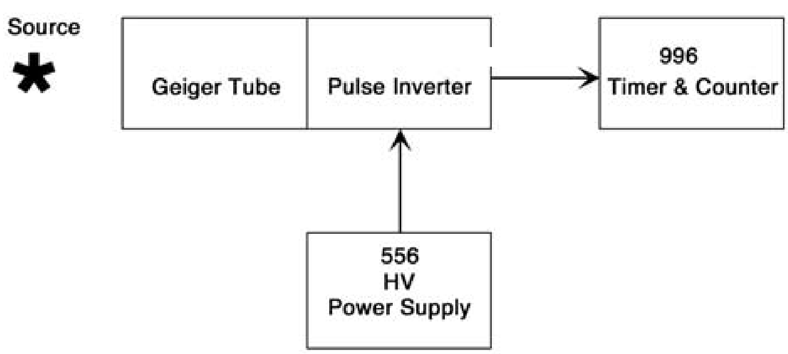


Fig. (2): Electronics for Geiger Counting

2. Set up high voltage power supply at the operating voltage and put the radioactive source at few centimeters from center window.
3. Take 100 independent counts for 0.5 min. and record your values in Table (1). The scalar value N_i may be directly in the table since for this experiment N_i is defined as the number of counts recorded for 0.5 min. time interval, and then find N_{ave} from eq. (1).

Table (1)

Run	N_i	$N_i - N_{ave}$	$(N_i - N_{ave})^2$
1 2 . . . 100			
	N_{ave}	$N_i - N_{ave}$	$(N_i - N_{ave})^2$

4. Evaluate experiments at (SD) σ_{exp} from eq. (2) and compare it with σ_{th}.
5. Choose a class interval for your reading (not less than ten intervals), find the frequency for each interval and draw a histogram. It's obtained by drawing rectangles whose height are frequencies and widths are the interval or ranges.

Illustration

Suppose we take 100 observation of counting rate per minute of radioactive source, let this observation being as follows

21 44 45 55 67 78 96

31 46 56 63 64 73 87

74 65 41 54 42 32 48

37 54 83 … 82 74 52

… … … … 71 46 ….

… … … … … …. ….

Total = 100 observation.

The above set of data exhibits no pattern except that the counting rate differs from each other (between 20 and 96). If we present this data in different way it will provide us with useful information, for this we can divide the data in to 8 intervals, Table (2).

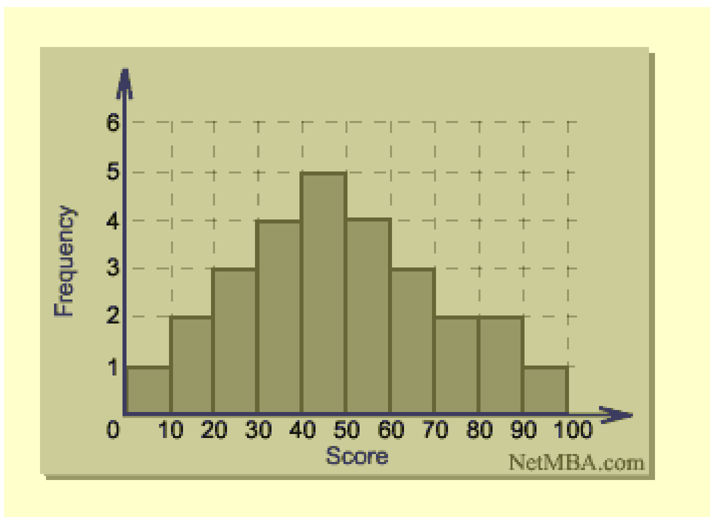
Table (2)

S	Range of counting rate	Frequency of occurrence of counting rate in that range
1	20------------------------ 30	3
2	30--------------------------40	6
3	40------------------------ 50	14
4	50--------------------------60	27
5	60--------------------------70	24
6	70--------------------------80	17
7	80--------------------------90	12
8	90-------------------------100	1

The above data called frequency table. In order to plot this data the interval taken on x-axis and frequency (f) on y–axis.

The frequency of every interval is marked at the mid-point of that interval and all the points are joined by straight lines. The figure so obtained is called frequency polygon.

6. Evaluate histogram area from:



Histogram area = width of interval X total no. of trails and match the values of total probability

P= W (Ni) X histogram area

Take midpoint data of interval and draw the distribution on the same graph paper of the histogram compare between the two graphs.

7. Calculate W(Ni) for each record value Ni, σ is taken equal to $\sqrt{N_{ave}}$ and plot W(Ni) as a function of Ni, verify that the (FWHM) as obtained from the graph is equal to 2.354 σ which representing investigation of Gaussian distribution of radioactive decay event.

Questions:

1. List the formulas for finding the means and standard deviations for the Poisson and Gaussian distribution.
2. How close are the standard deviation values when calculated with the Poisson and Gaussian distributions? Is one right (or more correct)? Is one easier to calculate?
3. If you make an experiment with the background counts, which distribution can better describe the data well, Poisson or Gaussian?
4. Which one describes the Cs-137 data, Poisson or the Gaussian distribution?

Exp.(6)

Foundation of Material Height in Closed Containers

Apparatus

- Geiger-Muller Tube
- Timer & Counter
- ^{241}Am radioactive source
- Connecting Cable
- Material container.

Purpose

The purpose of the experiment is to determine the material height in a closed container.

Introduction

The level of material (foods, dyes, oils,……) in closed containers can be determined by the γ-ray absorption method. The absorption of γ-ray in air is different from its absorption in the container walls and also through the wall + material inside. This difference can be estimated by measuring the no. of γ-ray quanta per unit time through these three different mediums. Fig.(1) shows the experimental setup.

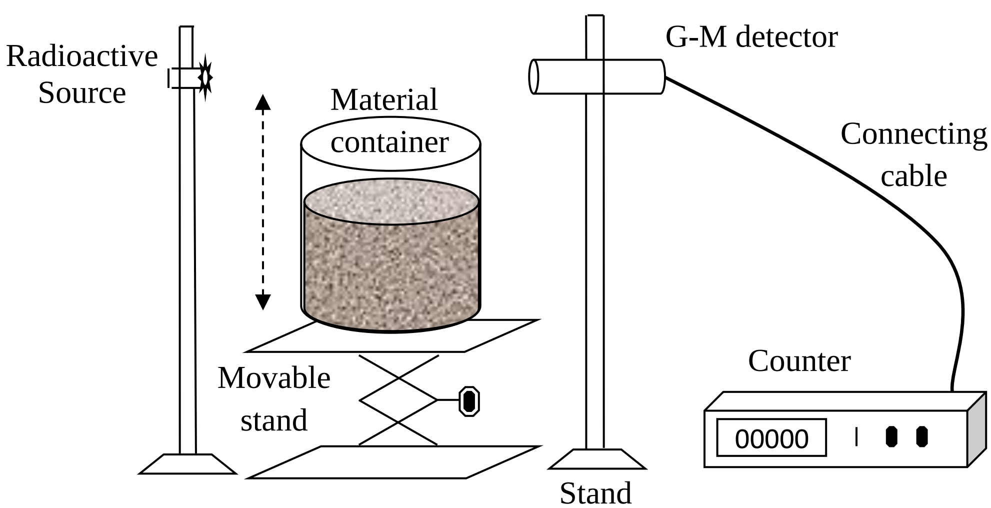


Fig. (1): The experimental setup.

Procedure

1- Set up the apparatus as shown in Fig.(1)
2- Make the ^{241}Am source and the G-M detector in one level.

3- Place the counter on stand where the top of container is lower the source and G-M detector level.
4- Record the number of γ- quanta for every 1 minute.
5- Repeat step 4 for each 5 mm increase in the container level until its bottom exceeds the source and G-M detector level.
6- Plot a graph between the position of movable stand and no. of γ-quanta as shown in Fig.(2)

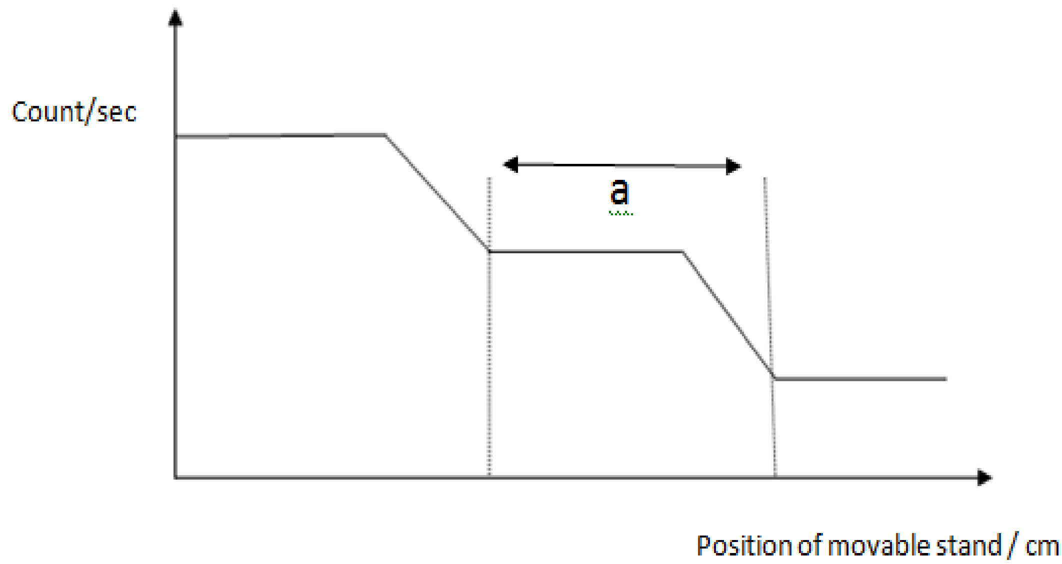


Fig (2): Gamma-quanta rate versus movable stand level.

Questions

1. Why we uses γ-ray instead of α and β rays to perform this experiment?
2. Is it possible to replace the G-M counter by the Scintillation detector?
3. Mention three practical applications of this experiment.

Experiment No. (7)

Determination of Dead Time (Resolving Time) of G.M. counters by Two –Source Method.

Apparatus:

- Geiger-Muller Tube
- Timer & Counter
- ^{241}Am radioactive sources
- Connecting Cables.

Purpose:

To determine the resolving time (dead time) of a Geiger-Muller counter

Theory:

The time following the entry of the ionizing event in the counter during which the later remain insensitive to next event is called the dead time T of the counter. This arises from slow motion of positive ion sheath from the anode. The presence of positive ion cloud in the vicinity of the anode lower the electric field to such value that the pulse of required size will not be formed if another particle, entered the counter soon after the first one and is therefore likely to be missed. After some time the positive ions, however, reach cathode and the counter recovered fully to receive another particle and develop a pulse of normal size. The time of travel of positive ions from the anode to cathode is, in principle, the dead time of the counter, but if the input sensitivity of scalar is higher so that it can also register pulses of less than normal, the dead time corresponding smaller, because in this case the next event need not wait for positive ions to go actually to cathode. As soon as the positive ions reach a point away from the anode such that electric field is recovered to a value (threshold) so as to give rise to pulse of size equal to input acceptance level of scalar, the counter will be able to receive the next event. It is therefore clear that the dead time of counter depends upon the kind of scalar used in the experimental set-up and the voltage applied to the anode.

The resolving time also can be defined as the minimum time required by the set-up to just resolve two successive pulses arising from two successive ionizing events entering the counter.
True resolving times span a range from a few microseconds for small tubes to 1000 microseconds for very large detectors. The loss of particles is important, especially when there are high count rates involved and the losses accumulate into large numbers.
In this experiment, you will perform a more accurate analysis of dead time via a method that uses paired sources. The count rates, or activities, of two sources are measured individually (N_1 and N_2) and then together (N_3). The paired samples form a rectangle into two lengthwise. A first radioactive material is placed on each half making each a "half-source" of approximately equal strength. A blank rectangle is used to duplicate the set-up geometry while using only one source.
We can calculate the dead time of G.M. counter by two-source method if we assume that:

N_{1b} ≡ count rate for the first source with background.

N_{2b} ≡ count rate for the second source with background.

N_{12b} ≡ count rate for the two sources with background.

N_b ≡ background count rate only.

The resolving time is given by,

$$T = \frac{N_1+N_2-N_{12}}{2N_1N_2} \quad \text{.....................(1)}$$

where

$N_1 = N_{1b} - N_b$

$N_2 = N_{2b} - N_b$

$N_{12} = N_{12b} - N_b$

Then the actual or the true counting rate (n) is given as

$$n = \frac{N}{1-NT}$$

Procedure:

1. Place the first source at 5 cm from the counter window, and record the count rate (N_{1b}) for 3 minute.
2. Put the second source beside the first one and record (N_{12b}) for the same time interval.
3. Replace the first source and determine the count rate (N_{2b}).
4. Find the background count rate (N_b) for 3 minute also.
5. Use eq. (1) to calculate resolving time (T)
6. Find the true counting rate for each case by using eq. (2).
7. Repeat the experiment for another different distance between sources and counter window. Do you expect difference in your result? Explain briefly.

Questions:

1. What is your GM tube's resolving (or dead) time? Does it fall within the accepted 1μs to 100 μs range?
2. Is the percent of correction the same for all your values? Should it be? Why or why not?
3. On what does the resolving time of a counter will depends?

Experiment No. (8)

Operating Plateau for the Geiger-Muller Tube

Apparatus:

- SPECTECH ST-350 Counter
- Geiger-Muller Tube
- Shelf stand
- Serial cable
- Radioactive Source (e.g., Cs-137, Sr-90, or Co-60)
- Computer.

Purpose:

To determine the plateau and optimal operating voltage of a Geiger-Müller counter

Theory:

Basically, the Geiger counter consists of two electrodes with a gas at reduced pressure between the electrodes. The outer electrode is usually a cylinder, while the inner (positive) electrode is a thin wire positioned in the center of the cylinder. The voltage between these two electrodes is maintained at such a value that virtually any ionizing particle entering the Geiger tube will cause an electrical avalanche within the tube. The Geiger tube used in this experiment is called an end-window tube because it has a thin window at one end through which the ionizing radiation enters.

The Geiger counter does not differentiate between kinds of particles or energies; it tells only that a certain number of particles (betas and gammas for this experiment) entered the detector during its operation. The voltage pulse from the avalanche is typically >1 V in amplitude. These pulses are large enough that they can be counted in an Timer & Counter without amplification.

All Geiger-Müller (GM) counters do not operate in the exact same way because of differences in their construction. Consequently, each GM counter has a different high

voltage that must be applied to obtain optimal performance from the instrument. If a radioactive sample is positioned beneath a tube and the voltage of the GM tube is ramped up (slowly increased by small intervals) from zero, the tube does not start counting right away. The tube must reach the starting voltage where the electron "avalanche" can begin to produce a signal. As the voltage is increased beyond that point, the counting rate increases quickly before it stabilizes. Where the stabilization begins is a region commonly referred to as the knee, or threshold value. Past the knee, increases in the voltage only produce small increases in the count rate. This region is the plateau we are seeking. Determining the optimal operating voltage starts with identifying the plateau first. The end of the plateau is found when increasing the voltage produces a second large rise in count rate. This last region is called the discharge region.

Procedure (Creating a Plateau Chart)

I. Running the unit as stand-alone

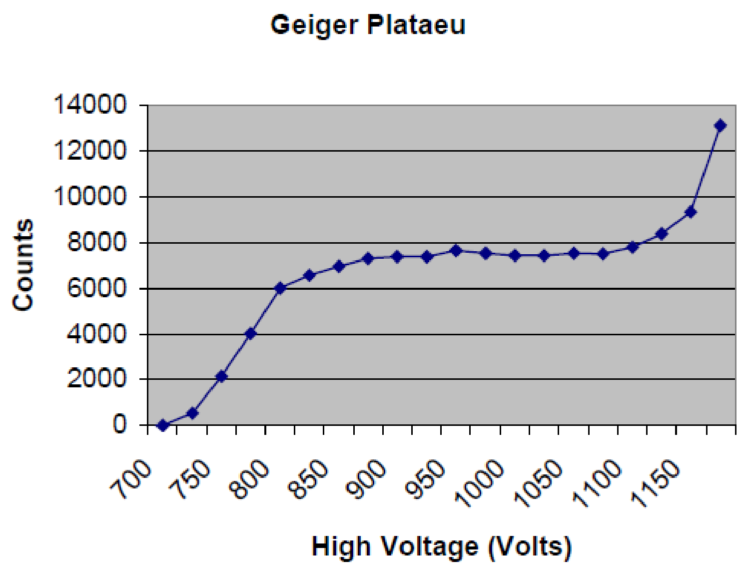
1. Place the radioactive source in a fixed position close to the window or in the well of the detector.
2. Put the ST360 into *Count* mode and slowly increase the high voltage until the first bar of the ACTIVITY barograph lights.
3. Set the Preset Time to 10 seconds and press *COUNT*.
4. When the preset time expires, record the counts and the high voltage setting.
5. Increase the voltage by 20 volts and count data again.
6. When the preset time expires, record the counts and the high voltage setting again.

7. Repeat steps 5 and 6 until the high voltage reaches its upper limit (this is determined by the upper operating voltage limit of the detector).
8. Create an X-Y graph of the data, with "Y" being the Counts, and "X" being the voltage, and plot the chart.

II. Using the ST360 Software

1. Place the radioactive source in a fixed position close to the window or in the well of the detector.
2. Put the unit in COUNT mode and slowly increase the high voltage until the first segment of the activity barograph lights. This is the *starting* voltage.
2. Determine the upper operating voltage limit of the detector. This is the *ending* voltage.
3. Subtract the *starting* voltage from the *ending* voltage. Divide the result by the high voltage step size (20 volts in this case). This will yield the number of *runs*.
4. Select *High Voltage Setting* in the *Setup* menu and set the High Voltage to the *starting* voltage and the *Step Voltage* to 20. Also, turn the *Step Voltage Enable ON*.
5. Select Preset Time in the Preset menu and set it to 10 seconds.
6. Select Runs in the Preset menu and set it to the number calculated in step 3.
7. After counting has begun, it will automatically stop when *runs* equals zero.
8. Save the data to a file. Before saving, a description of the data may be entered into the *Description* box.
9. Open the saved file version with a *.its* extension into a spreadsheet program such as *Microsoft Excel*.

The following chart shows a typical detector plateau.



10. One way to check to see if your operating voltage is on the plateau is to find the slope of the plateau with your voltage included. If the slope for a GM plateau is less than 10% per 100 volt, then you have a "good" plateau. Determine where your plateau begins and ends, and confirm it is a good plateau.

The equation for slope is

$$Slope(\%) = \frac{(R_2 - R_1)/R_1}{V_2 - V_1} X100,$$

where R_1 and R_2 are the activities for the beginning and end points, respectively. V_1 and V_2 and the voltages for the beginning and end points, respectively.

Questions

1. Where within the plateau one should select the counter operating voltage?
2. On what factors do the operating voltage of the counter will depends?
3. How does electric potential effect a GM tube's operation?
4. Will the value of the operating voltage be the same for this tube ten years from now?