King Fahd University of Petroleum and Minerals
College of Science
Physics Department

PHYSICS 304 LAB

TERM 152

Experimental Physics lab

Dr. Akhtar Abbas Naqvi
Professor

Mr. Tyrence Engalla
Lab Technician

King Fahd University of Petroleum and Minerals
College of Science
Physics Department

PHYSICS 304 LAB
TERM 152

List of Experiments

1. Counting Statistics
2. Poison Distribution
3. Inverse Square Law of Radiation Intensity Variation
4. Compton Edge Energy Measurement
5. Gamma Rays Attenuation through Absorbers
6. Energy Resolution of NaI Detector

King Fahd University of Petroleum and Minerals
College of Science
Physics Department

Experiment in

Counting Statistics

EXPERIMENT. Counting Statistics

Purpose

As is well known, each measurement made for a radioactive sample is independent of all previous measurements, because radioactive decay is a random process. Repeated individual measurements of the activity vary randomly. However, for an ensemble comprising a large number of repeated, individual measurements, the deviation of the individual counts from what might be termed the "ensemble average count" behaves in a predictable manner. Small deviations from the average are much more likely than large deviations. 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 a certain degree of confidence. Fifty independent measurements will be made, and some rather simple statistical treatments of the data will be performed. The experiment utilizes a ^{60}Co source which has a half-life that is very long compared to the measurement time. The 5.26-year half-life ensures that the activity can be considered constant for the duration of the experiment.

Relevant Equations

The average count for n independent measurements is given by

$$N_{av} = \frac{N_1 + N_2 + N_3 + \dots\dots\dots + N_n}{n} = \sum_{i=1}^{n} \frac{N_i}{n}$$

where N_1, N_2, N_3, …… N_n and N_i are the counts in the n independent measurements. The deviation of an individual count from the mean is $(N_i - N_{av})$. Based on the definition of N_{av}

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

For cases where the percent dead time losses are small, it can be shown that the expected standard deviation, σ_N, can be estimated from

$$\sigma_N \approx \sqrt{N_{av}} \approx \sqrt{N_i}$$

with the estimate from N_{av} being more precise than the estimate from the individual measurement N_i. See references 10 and 11 for details. Thus, σ_N is the estimate of the standard deviation expected for the distribution of the measured counts, N_i, around the true mean.

Frequently, one is dealing with counting rates, rather than counts. If the true counting rate is defined by the number of counts accumulated in the counting time T, i.e.,

$$r_i = \frac{N_i}{T}$$

then, the estimated standard deviation in the counting rate can be calculated from

$$\sigma_r = \frac{\sigma_N}{T} \approx \frac{\sqrt{N_{av}}}{T} \approx \frac{\sqrt{N_i}}{T} = \sqrt{\frac{r_i}{T}}$$

A meaningful way to express the statistical precision of the measurement is via the percent standard deviation, which is defined by

$$\sigma\% = \frac{\sigma_r}{r_i} \times 100\% = \frac{\sigma_N}{N_i} \times 100\% = \frac{100\%}{\sqrt{N_i}}$$

Note that achieving a 1% standard deviation requires 10,000 counts.

Procedure

1. Set the operating voltage of the detector at the value determined previously

2. Place the ^{60}Co source far enough away from the detector so that ~ 1000 counts can be obtained in a time period of 0.5 min.

3. Without moving the source, take 50 independent 0.5 minute runs and record the counts for each run in Table 2.2. (Note that you will have to extend Table 2.2; only ten entries are illustrated.) The counter values, Ni, may be recorded directly in the table since, for this experiment, Ni is defined as the number of counts recorded for a 0.5 minute time interval.

4. With a calculator determine N_{av} from Equation (21). Fill in the values of $N_i - N_{av}$ in Table 2.2. It should be noted that these values can be either positive or negative. You should indicate the sign in the data entered in the table.

EXERCISES

a. Calculate σ_N, and fill in the values for σ_N and $(Ni - N_{av})/\sigma_N$ in the table, using only two **decimal places**. Next, round off the values for $(N_i - N_{av})/\sigma_N$ to the nearest **0.5** and record the values in the "Rounded Off" column of the table. Note that in Table 2.2 we have shown some typical values of $(N_i - N_{av})/\sigma_N$ and the rounded-off values for guidance.

Table 2.2*

				$(N_i - N_{av})/\sigma_N$		$(N_i - N_{av})/\sigma_N$ (Rounded Off)	
Run	N_i	σ_N	$N_i - N_{av}$	Typical	Measured	Typical	Measured
1				–0.15		0	
2				+1.06		+1.0	
3				+0.07		0	
4				–1.61		–1.5	
5				–1.21		–1.0	
6				+1.70		+1.5	
7				–0.03		0	
8				–1.17		–1.0	
9				–1.67		–1.5	
10				+0.19		0	

*Typical values of $(N_i - N_{av})/\sigma_N$ and $(N_i - N_{av})/\sigma_N$ Rounded Off; listed for illustrative purposes only.

b. Make a plot of the frequency of the rounded-off events $(N_i - N_{av})/\sigma_N$ vs. the rounded-off values. Fig. 2.3 shows this plot for an ideal case. Note that at zero there are eight events, etc. This means that in our complete rounded-off data in Table 2.2 there were eight zeros. Likewise, there were seven values of +0.5, etc.

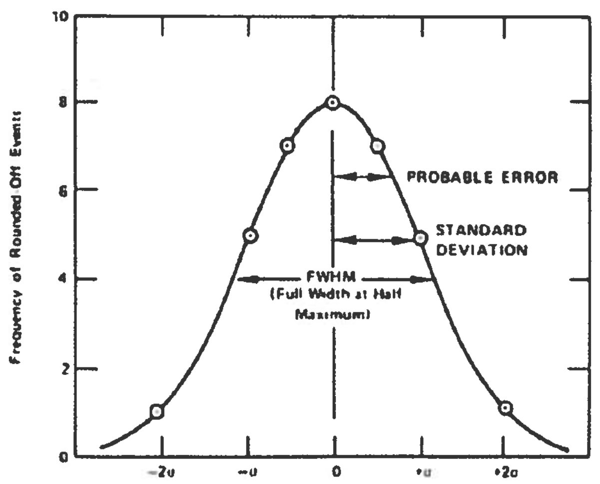


Fig. 2.3. Typical Plot of Rounded-Off Events versus the Rounded-Off Values.

c. Does your plot follow a normal distribution similar to that in Fig. 2.3?

References

1. G. F. Knoll, Radiation Detection and Measurement, John Wiley and Sons, New York (1979).

2. E. W. Emery, Geiger-Mueller and Proportional Counters in Radiation Dosimetry, II, F. H. Attix and W. C. Roesch, Eds., Academic Press, NewYork, (1966).

3. A. Peeva and T. Karatoteva, Nucl. Instrum. Methods 118, 49 (1974).

4. H. L. Andrews, Radiation Biophysics, Prentice-Hall, New Jersey (1974).

5. V. Arena, Ionizing Radiation and Life, The C. V. Mosby Co. Missouri (1971).

6. G.D. Chase and J. L. Rabinowitz, Principles of Radioisotope Methodology, 3rd Edition, Burgess Publishing Co., Minnesota (1967).

7. C. M. Lederer and V. S. Shirley, Eds., Table of Isotopes, 7th Edition, John Wiley and Sons, Inc. New York (1978).

8. Radiological Health Handbook, U.S. Dept. Of Health, Education, and Welfare, PHS Publication 2016. Available from National Technical Information Service, U.S. Dept. Of Commerce, Springfield, Virginia.

9. J. H. Hubbell and S. M. Seltzer, Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients from 1 keV to 20 MeV for Elements Z = 1 to 92 and 48 Additional Substances of Dosimetric Interest, NISTIR 5632, 1996, http://www.nist.gov/physlab/data/xraycoef/index.cfm.

10. D. A. Gedcke, How Counting Statistics Controls Detection Limits and Peak Precision, ORTEC Application Note AN59, www.ortec-online.com.

11. Ron Jenkins, R. W. Gould, and Dale Gedcke, Quantitative X-ray Spectrometry, Marcel Dekker, Inc., New York, 1981.

King Fahd University of Petroleum and Minerals
College of Science
Physics Department

LABORATORY EXPERIMENT IN LAB 304

Experiment in

Poison Distribution

Poisson Distribution

Purpose

To verify the statistical nature of counting experiments such as radioactive decay, and to extract the parameters of the corresponding statistical distributions.

Background

This is a continuation of the experiment "Introduction to Geiger Muller Tube", but is computer aided. See the attached Leybold page.

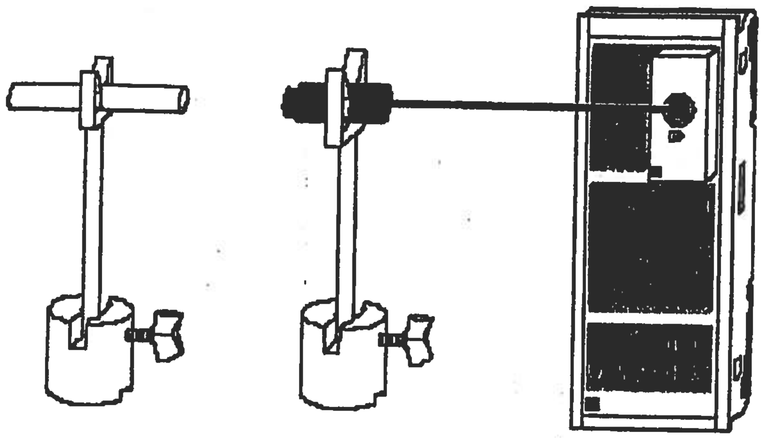
Procedure

1. Arrange the experimental set up as shown, and get familiar with the CASSY Lab program.
2. Adjust the distance between the radioactive source and the GM tube so that a convenient rate of about 5 counts per second is obtained.
3. In the CASSY Lab program, select x-axis = RA1 (count rate in input A), y-axis = HA1 (frequency in A) with bars and n = 1000 for frequency distribution. Double click on RA1 and set gate time (Δt) = 1s. Start measuring by clicking on the clock icon or F9.
4. Save and print the data and the histogram at the end of the measurements.
5. Repeat steps 3 & 4 for n = 500 and Δt = 10 s.
6. Decrease the distance between the source and the detector so that about 50 counts per second is obtained.
7. Repeat steps 3, 4 and 5.

Analysis

1. Fit your low-count rate data with a Poisson distribution and extract its parameter μ using any data fitting software.
2. Fit your high-count rate data with a Gaussian distribution and extract its parameters μ and σ.
3. What is the effect of increased gate time?

Poisson distribution



Load example

Experiment description

The number x of decay events of a radioactive preparation over a time interval Δt is not constant. A large number of individual measurements can be represented as a frequency distribution H(x) scattered around the mean value μ. By comparing this frequency distribution with the Poisson distribution, we can confirm that x shows a Poisson distribution around the mean value μ.

Equipment list

1	Sensor-CASSY	524 010
1	CASSY Lab	524 200
1	GM box	524 033
1	End-window counter	559 01
1	Set of radioactive preparations	559 83
1	Large clip plug	591 21
1	Small clip plug	590 02
2	Connection rods	532 16
2	Bases	300 11
1	PC with Windows 95/98/NT	

Experiment setup (see drawing)

The end-window counter is connected to the GM box at input A of Sensor-CASSY. Handle the counter tube and the preparation with care.

Carrying out the experiment

Load settings

- If necessary, modify the gate time Δt (Settings RA1).
- Preset the measurement if necessary. Enter the number of measurements as the measuring condition in the Measuring Parameters dialog opened with **F5** (e.g. **n < 1000** for 1000 individual measurements).
- Start the measurement series with **F9**, and stop it again with **F9** after recording the series.

Evaluation

In the evaluation, you can compare the measured frequency distribution with a Poisson distribution. For higher mean values μ the Poisson distribution develops into a Gaussian distribution.

King Fahd University of Petroleum and Minerals
College of Science
Physics Department

LABORATORY EXPERIMENT IN LAB 304

Experiment in

Inverse Square law of Radiation Intensity Variation

Inverse Square Law of Radiation Intensity Variation

Purpose and Relevant Equations

There are many similarities between ordinary light rays and gamma rays. They are both considered to be electromagnetic radiation; hence they obey the classical Equation **1**:

$$E = hv \qquad (1)$$

Where
E = energy of the photon in ergs,
v = the frequency of the radiation in cycles/second,
h = Planck's constant (6.624 x 10–27 ergs • s).

Therefore, in explaining the inverse square law it is convenient to make the analogy between a light source and a gamma-ray source. Let us assume that we have a light source that emits light photons at a rate, n_0 photons/second. It is reasonable to assume that these photons are given off in an isotopic manner, that is, equally in all directions. If we place the light source in the 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 Equation **2**:

$$I_0 = \frac{n_0}{4\pi r_s^2} \qquad (2)$$

Where
n_0 is the total number of photons per second from the source,
r_s is the radius from the central source of light to the surface of the sphere,
and $4\pi r_s^2$ = the total area of the sphere in cm^2.

Since n_0 and 4π are constants, I_0 is seen to vary as $1/r_s^2$. This is the inverse square law.

$$I_0 = \frac{n_0}{4\pi}\left(\frac{1}{r_s^2}\right)$$

$$\frac{4\pi I_0}{n_0} = \frac{1}{r_s^2}$$

$$\ln\left(\frac{4\pi I_0}{n_0}\right) = -2\ln(r_s)$$

For a radioisotope, whose half-life is extremely long compared to the time taken to implement the series of measurements in this experiment, n_0 is synonymous with the activity, A_0, of the radioactive source. Consequently, Equation **2** can be expressed as Equation 3:

$$r_0 = \frac{N}{T} = A_0 \frac{a_d}{4\pi r_s^2} \epsilon_{int} \qquad (3)$$

Where
r_0 is the true counting rate derived from the GM tube,
N is the number of counts measured in the counting time T (corrected for dead time and background),
A_0 is the activity of the radioactive source,
ϵ_{int} is the intrinsic efficiency of the GM tube for detecting the gamma rays,
a_d is the effective sensitive area of the detector at its entrance window, and
r_s is the distance from the point source to the entrance window of the detector.

The factors in Equation (3) can be understood as follows. The effective sensitive area at the input to the detector intercepts a fraction, $a_d/4\pi r_s^2$, of the total area of the sphere of radius r_s. Consequently, the detector intercepts that same fraction of the isotropic radiation emitted by the source. Only a fraction, ϵ_{int}, of the photons impinging on the sensitive area of the detector window are actually counted by the detector, due to window attenuation and the efficiency of converting photons into ionized atoms in the GM tube. The purpose of this experiment is to verify the $1/r_s^2$ dependence predicted by Equation (3).

Procedure

1. Set the GM tube at the proper operating voltage, and place the 1-μCi ^{60}Co source 1 cm away from the face of the window.
2. Count for a period of time long enough to get reasonable statistical precision (≥4000 counts).
3. Move the source to 2 cm, and repeat the measurement for the same amount of time. Continue for the distances listed in Table 1.
(Note that for the longer distances the time will have to be increased to obtain the minimum number of counts necessary for adequate statistical precision.)

EXERCISES

Serial #	Distance -D0 (cm)	Corrected -Distance D	Ln(D)	N1-counts	N2-counts	N2-counts	N4-counts	N5-counts	N_{avg}	Ln (N_{avg})
1	1									
2	2									
3	3									
4	4									
5	5									
6	6									
7	7									
8	8									

Table 1

1 On linear graph paper, plot the corrected counting rate (y axis) as a function of distance D (x axis). This plot should have the $1/r_s^2$ characteristics exhibited by Equations (1) and (2).

c. Is there another way to plot this data so that the exponent for rs in Equations (3) can be confirmed to be 2? Plot another graph between Ln (D) vs Ln(N_{avg}) and find the value of exponents and error in this value?

King Fahd University of Petroleum and Minerals
College of Science
Physics Department

LABORATORY EXPERIMENT IN LAB 304

Experiment in

Compton Edge Energy Measurement

Compton Edge Energy Measurement

Purpose

The purpose of this experiment is to explain some of the features, other than the photo peaks, usually present in a pulse-height spectrum. These are the Compton edge and the backscatter peak. The Compton interaction is a pure kinematic collision between a gamma photon and what might be termed a free electron in the NaI(Tl) crystal. By this process the incident gamma gives up only part of its energy to the electron. The amount given to the recoil electron (and the intensity of the light flash) depends on whether the collision is head-on or glancing. For a head-on collision the gamma imparts the maximum allowable energy for the Compton interaction. The energy of the scattered gamma can be determined by solving the energy and momentum equations for this billiard ball collision. The solution for these equations in terms of the scattered gamma can be written approximately as

$$E\gamma' \cong \frac{E\gamma}{1 + 2E\gamma\,(1-\cos\theta)'} \qquad (1)$$

where
$E\gamma'$ = energy of the scattered gamma in MeV, θ = the scattered angle for γ',
$E\gamma$ = the incident gamma energy in MeV. If $\theta = 180°$ due to a head-on collision in which γ' is scattered directly back, Eq. (1) becomes

$$E\gamma' \cong \frac{E\gamma}{1 + 4E\gamma} \qquad (2)$$

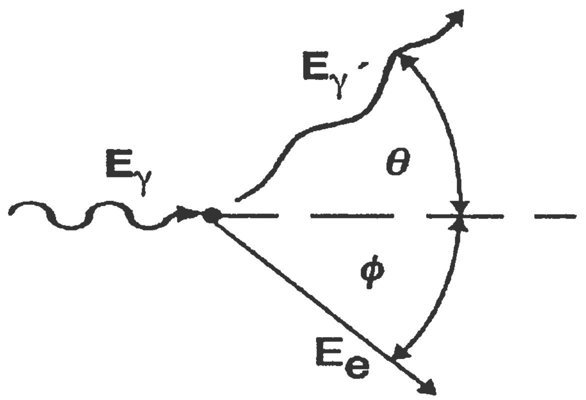


Fig. IV-10.1. Angles and Energies Defined for the Compton Scattering Process.

As an example, we will calculate $E\gamma'$ for an incident gamma energy of 1 MeV:

$$E\gamma' \cong \frac{1\ \text{MeV}}{1+4} = 0.20\ \text{MeV} \qquad (3)$$

The energy of the recoil electron, Ee, for this collision would be 0.80 MeV. This is true since

$$E_e = E\gamma - E\gamma' \qquad (4)$$

Then the position of the Compton edge, which is the maximum energy that can be imparted to an electron by the Compton interaction, can be calculated by Eq. (4).

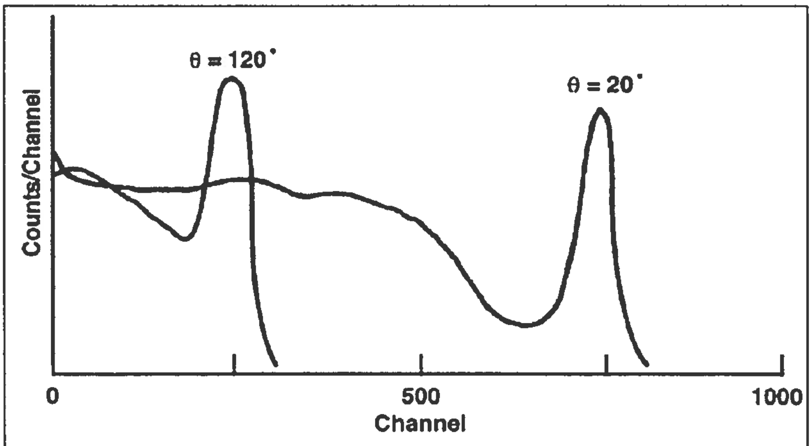


Fig. IV-10.12. Overlapped Spectra Obtained at Two Scattering Angles.

Gamma Rays Photo peaks and Compton edge measurement.

Setup the electronics as shown in Fig. 3.1. There are two parameters that ultimately determine the overall gain of the system: the high voltage furnished to the phototube and the gain of the spectroscopy amplifier. The gain of the photomultiplier tube is quite dependent upon its high voltage. A rule of thumb for most phototubes is that a 10% change in the high voltage will change the gain by a factor of 2. The high voltage value depends on the phototube being used. Consult your instructor to set the setting of the electronics (The instructor may wish to recommend a value).

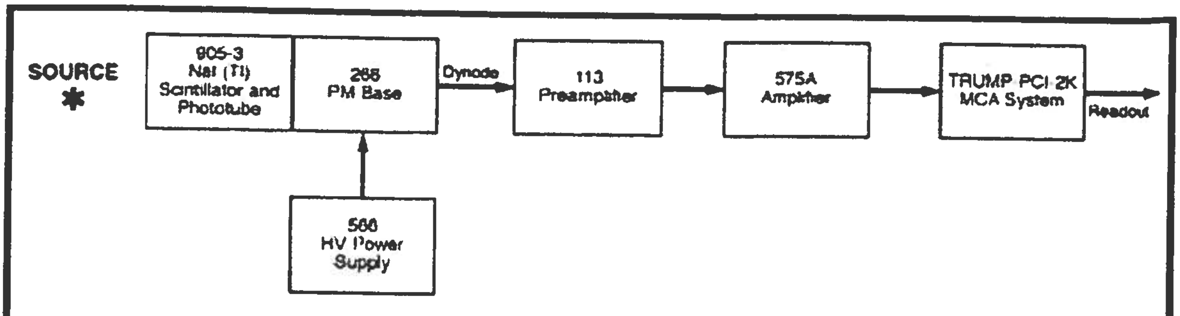


Fig. 3.1. Electronics Block Diagram of Gamma-Ray Spectroscopy System with NaI(Tl) Detector.

1. Place the ^{60}Co source from the gamma source kit (Eγ = 1.117, 1.330 MeV) ~2 cm in front of the NaI(Tl) detector.

2. Adjust the coarse and fine gain controls of the amplifier so that the 1.33 MeV photopeak for ^{60}Co falls at approximately channel 480. For the illustrations shown in Figs. 3.2 and 3.3, the gain of the system has been set so that 1.33 MeV falls at about channel 447 to 490. Since the system is linear, 2 MeV would therefore fall at approximately channel 840 to 850.

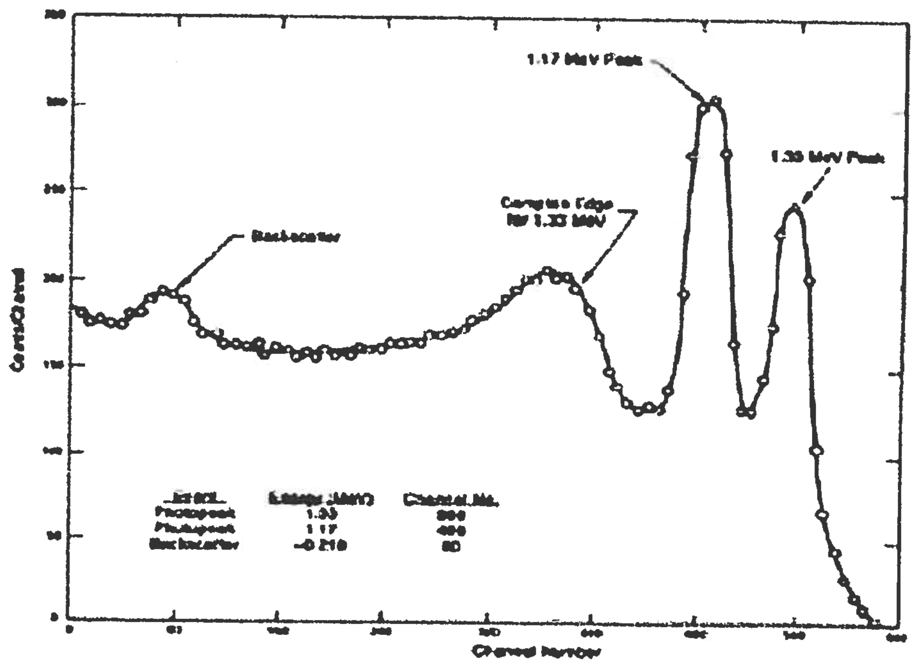


Fig. 3.3. NaI(Tl) Spectrum for ^{60}Co.

3. Accumulate the ^{60}Co spectrum for a time period long enough to determine the peak position. Fig. 3.2 shows a typical ^{60}Co spectrum that has been plotted. Although these spectra are usually plotted on semilog graph paper, the figures shown in this experiment are plotted on linear paper to point out some of the features of the spectra.

4. Record the peak centroid and full width at half maximum of 1.17 and 1.33 MeV gamma rays from ^{60}Co in Table 1. Also record full width at half maximum (FWHM) of 1.17 and 1.33 MeV gamma rays peaks in Table 1.

5. Then record the channel corresponding to Compton edge energy and backscattered gamma rays of ^{60}Co sources in the Table 1. Backscatter occurs when gammas make Compton interactions in the material that surrounds the detector. If the backscatter peak is not very pronounced in your spectrum, it can be improved by accumulating a spectrum with a sheet of lead absorber placed slightly to the left of the source in Fig. 3.1.

6. After the ^{60}Co spectrum has been read from the MCA erase it and replace the ^{60}Co source with unknown source from the gamma source kit.

7. Accumulate the spectrum for a period of time long enough for the spectrum to be similar to that in Fig. 3.3.

8. Plot the ^{60}Co spectrum.

9. From items 1, 2, in Table 1, make a energy calibration plot of photopeaks energy (y-axis) vs. channel number (x-axis) as shown in Fig. 3.4

10 Make a lest square linear fit to the data to obtain energy calibration equation shown in fig. 3.4.

Table 1

Item #	**Peaks**	**Energy (MeV)**	**Channel No**	**FWHM (Channels)**
1	**1.17 MeV Photopeak**	1.17		
2	**1.33 MeV Photopeak**	1.33		
3	**Compton Edge E_e for 1.17 MeV**			
4	**Backscattered Gamma Energy E' for 1.17 MeV**			
5	**Compton Edge E_e for 1.33 MeV**			
6	**Backscattered Gamma Energy E' for 1.33 MeV**			

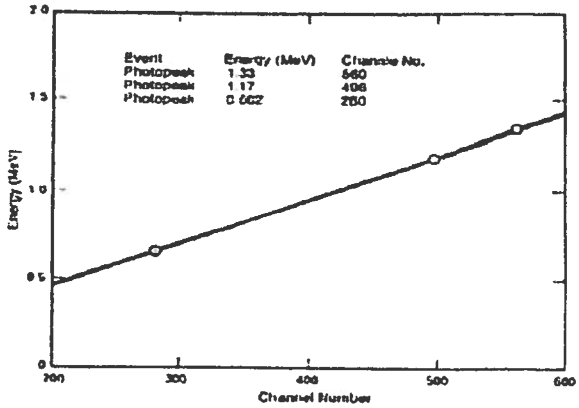


Fig. 3.4. Energy Calibration Curve for NaI(Tl) Detector.

10. Calculate the energy of the Compton edge and backscattered gamma rays for the 1.17 and 1.33 MeV gammas from ^{60}Co source using equations 1 and 2 and enter these values in Table 1.

11. Use the energy calibration equation to convert Compton edge and backscattered gamma rays channels of the ^{60}Co spectrum into energy.

12. Enter these values in Table 1. Does this calculation agree with your measured value? Calculate percentage error in Compton edge and backscattered gamma rays for ^{60}Co gamma rays.

King Fahd University of Petroleum and Minerals
College of Science
Physics Department

LABORATORY EXPERIMENT IN LAB 304

Experiment in

Gamma Rays Attenuation through Absorbers

Gamma Rays Attenuation through Absorbers

Purpose

When gamma radiation passes through matter, it undergoes absorption primarily by Compton, photoelectric, and pair-production interactions. The intensity of the radiation is thus decreased as a function of distance in the absorbing medium. The purpose of this experiment is to measure the attenuation of the intensity with absorber thickness, and to derive the half-thickness and the attenuation coefficient.

Relevant Equations

The mathematical expression for the surviving intensity, I, is given by the following:

$$I = I_0 e^{-\mu x} \qquad (13)$$

Where
I0 = original intensity of the beam,
I = intensity transmitted through an absorber to a distance, depth, or thickness, x,
μ= linear absorption coefficient for the absorbing medium.

If we rearrange Eq. (13) and take the logarithm of both sides, the expression becomes

$$\ln\left(\frac{I}{I_0}\right) = -\mu x \qquad (14)$$

The half-value layer (HVL) of the absorbing medium is defined as that thickness, $x_{1/2}$, which will cut the initial intensity in half. That is, $I/I_0 = 0.5$. If we substitute this into Eq. (14),

$$\ln(0.5) = -\mu x_{1/2} \qquad (15)$$

Putting in numerical values and rearranging, Eq. (15) becomes

$$x_{1/2} = \frac{0.693}{\mu} \text{ or } \mu = \frac{0.693}{x_{1/2}} \qquad (16)$$

Experimentally, the usual procedure is to measure $x_{1/2}$ and then calculate μ from Eq. (16). If the thickness of the absorber is expressed in cm, then the units of μ are cm^{-1}, and it is known as the linear attenuation coefficient. Often, the thickness of the absorber is expressed in g/cm^2. In that case, the attenuation coefficient has units of cm^2/g, and is identified as the mass attenuation coefficient.

Procedure

1. Set the voltage of the detector at its operating value.

2. Place the ^{60}Co source (any other gamma source) about 3 cm from the detector, and make a 2-minute count. Record the number of counts. Take four more reading and record the data in the Table.

3. Note the various thicknesses of the lead sheets in the absorber kit. Incrementing the absorber thickness will require using the various absorbers in suitable combinations to achieve the desired thickness increments.

4. Place the thinnest sheet of lead from the absorber kit between the source and the detector and record its thickness in the Table. Then take a 2-minute count. Record the count value N in the Table. Take four more readings of Ns and record in the Table.

5. Repeat step number with four more absorber thickness of lead. For each absorber thickness record five times the 2-minutes counting interval counts N in the Table.

6. Make a 2-minute background run with the ^{60}Co source (gamma ray source) removed to a long distance from the counting station for 5 times and record this data in Table 1. Check this background count at the maximum absorber thickness employed and without any absorbers. The result should be the same, or close enough to the same that the average of the two background readings can be used for background subtraction from all the corrected counting rates with the source in the counting position

7. Subtract average background from each of the five absorbers counts and record net count N_{net} in **Table 2.**

Serial #	Absorber-Thickness(mg/cm2)	Absorber - Thickness (cm)	N1-counts	N2-counts	N2-counts	N4-counts	N5-counts	Navg
1	0							
2								
3								
4								
5								
6								
Background-measurement	0							

Table 1:

EXERCISE

a. Record the total density of the lead in g/cm^3 · Divide the absorber thickness with density of lead to get absorber thickness in cm. Record this data for each absorber thickness in the Table 1.

Serial #	Absorber-Thickness (cm)	Navg	$N_{net}=N_{avg}-N_{bkgd}$	Ln(Nnet)

Table 2:

b. On linear graph paper, plot the Ln(Nnet) (y axis) as a function of absorber thickness (cm) (x axis).

c. Draw the best straight line through the points, and determine $x_{1/2}$ and μ from the slope of the line. Calculate percentage error in $x_{1/2}$?

d. Also calculate intensity I_0 from the y-intercept of the graph. Compare it with $N_{net}(0)$ counts corresponding to zero thickness of the absorber. Calculate the percentage error in I_0 and $N_{net}(0)$ counts.

King Fahd University of Petroleum and Minerals
College of Science
Physics Department

LABORATORY EXPERIMENT IN LAB 304

Experiment in

Energy Resolution Measurement Of NaI Detector

Energy Resolution Measurement of NaI Detector

Purpose

To measure the energy of unknown gamma rays using ^{60}Co source and study $1/\sqrt{E}$ behavior of energy resolution (FWHM/E) of a NaI detector for the gamma rays of energy E.

Procedure

1. Place the ^{60}Co source at a distance of ~2 cm in front of the NaI(Tl) detector.

2. Adjust the coarse and fine gain controls of the amplifier so that the 1.33 and 1.17 MeV photopeaks for ^{60}Co falls at approximately channel 650.

3. Accumulate the ^{60}Co spectrum for a time period long enough to determine the peak position. Fig. 3.2 shows a typical ^{60}Co spectrum that has been plotted. Although these spectra are usually plotted on semi log graph paper, the figures shown in this experiment are plotted on linear paper to point out some of the features of the spectra.

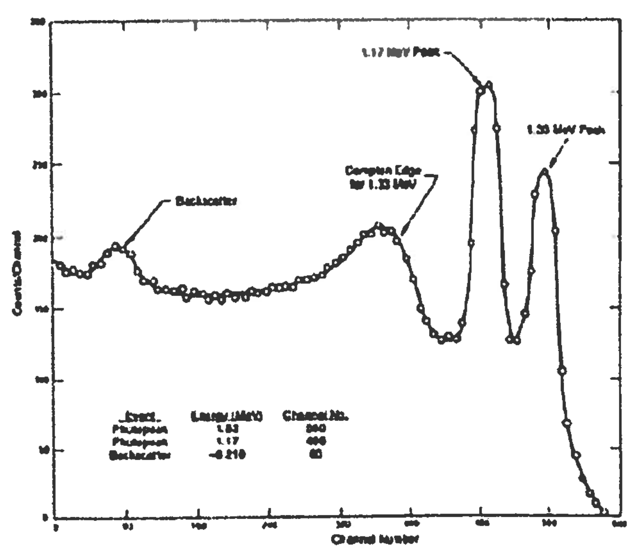


Fig. 3.3. NaI(Tl) Spectrum for ^{60}Co.

4. Read out the MCA.

5. Enter the ^{60}Co peaks positions and corresponding energy resolutions (FWHM) in channels in the data Table 1.

6 . Remove ^{60}Co source and place Ba source in front of the NaI detector.

7. Accumulate the Ba source spectrum for a time period long enough to determine the peak position.

8. Enter the Ba peaks position and corresponding energy resolutions (FWHM) in channels in the data Table 1.

9. From items 1, 2 and 3 in Table 1, make a plot of energy of the Peak Energy vs. channel number. Fig. 3.4 shows this calibration for the data taken from Fig. 3.3.

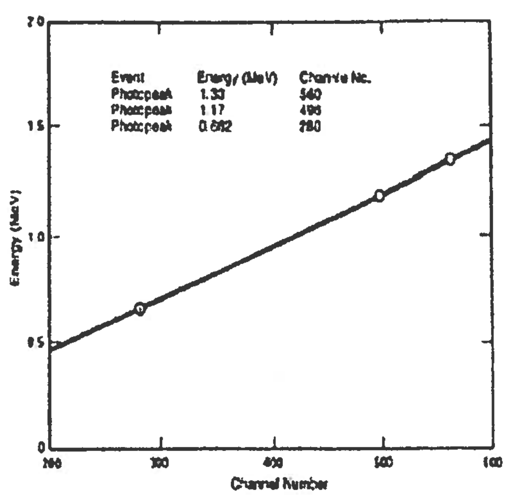


Fig. 3.4. Energy Calibration Curve for NaI(Tl) Detector.

10. Make a linear regression fit to the peak energy and peak channels data and write down the linear regression equation.

11. Obtain an Radon gamma source from the instructor. Accumulate a spectrum for the unknown source for a period of time long enough to clearly identify its photopeak(s).

12. Enter its peaks channel number and corresponding energy resolution (FWHM) in the data Table 1.

13 Using the calibration curve of ^{60}Co source, determine the energy corresponding to peak channel of unknown source. Enter this energy in the data Table 1.

14. Calculate percent energy resolution $\Delta E/E(\%) = 100*[\text{FHWM (keV)} / \text{E(keV)}]$ for each gamma ray energy and enter the data in the data Table 1.

Table: 1

Item	Event	Peak Energy (MeV)	Peak Centroid Channel	FHWM (Channel)	ΔE/E(%) =100*[FHWM(keV) / E(keV)]
1	^{60}Co Photo peak	1.17			
2	^{60}Co Photo peak	1.33			
3	Barium	0.356			
4	Radon (^{214}Bi)	?			
5	Radon (^{214}Bi)	?			
6	Radon (^{214}Bi)	?			
7	Radon (^{214}Bi)	?			

15. Plot a graph of ΔE/E(%)] as a function of E(keV)] for the all gamma rays energies on a linear graph paper. Fit a a power law to the data of type

$$\Delta E/E(\%) = aE^{b}$$

16. Find the value of coefficient ***b and a*** of the fit . The expected value of $b = -0.5$. Determine the percentage error in value of coefficient ***b***.

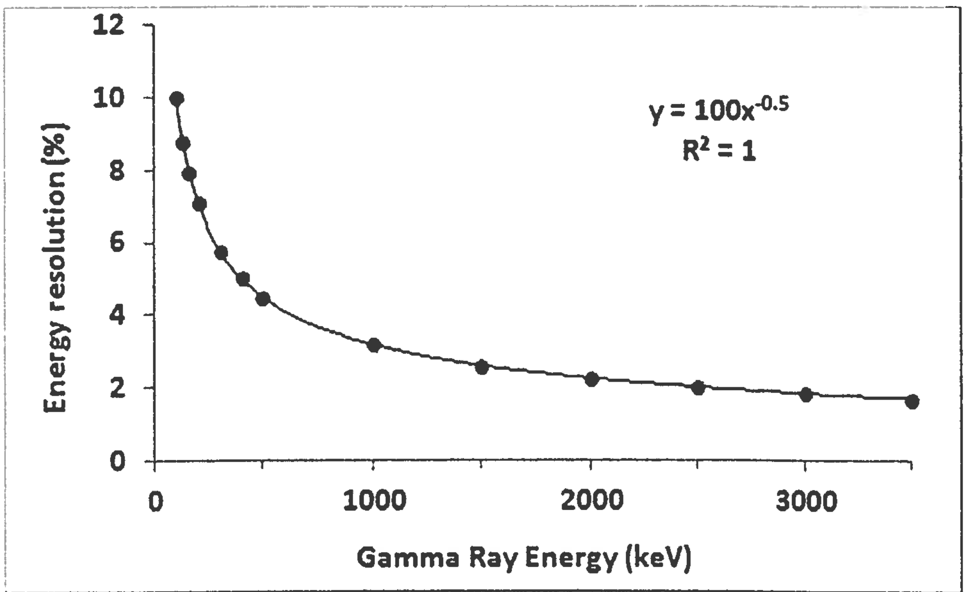


Figure 3.5

17. Plot a graph of ln[ΔE/E(%)] as a function of ln[E(keV)] for the gamma rays energies on a linear graph paper as shown Fig. 3.6.

18. Calculate the slope of the line and verify the relation (ΔE/E(%)= 1/√E(keV) by calculating the experimental uncertainty in the expected slope **(−0.5)** of ln[ΔE/E(%)] vs ln[E(keV)] plot.

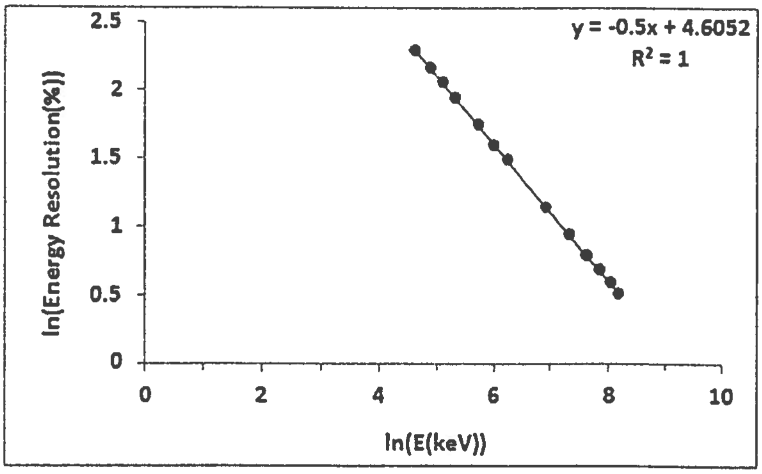
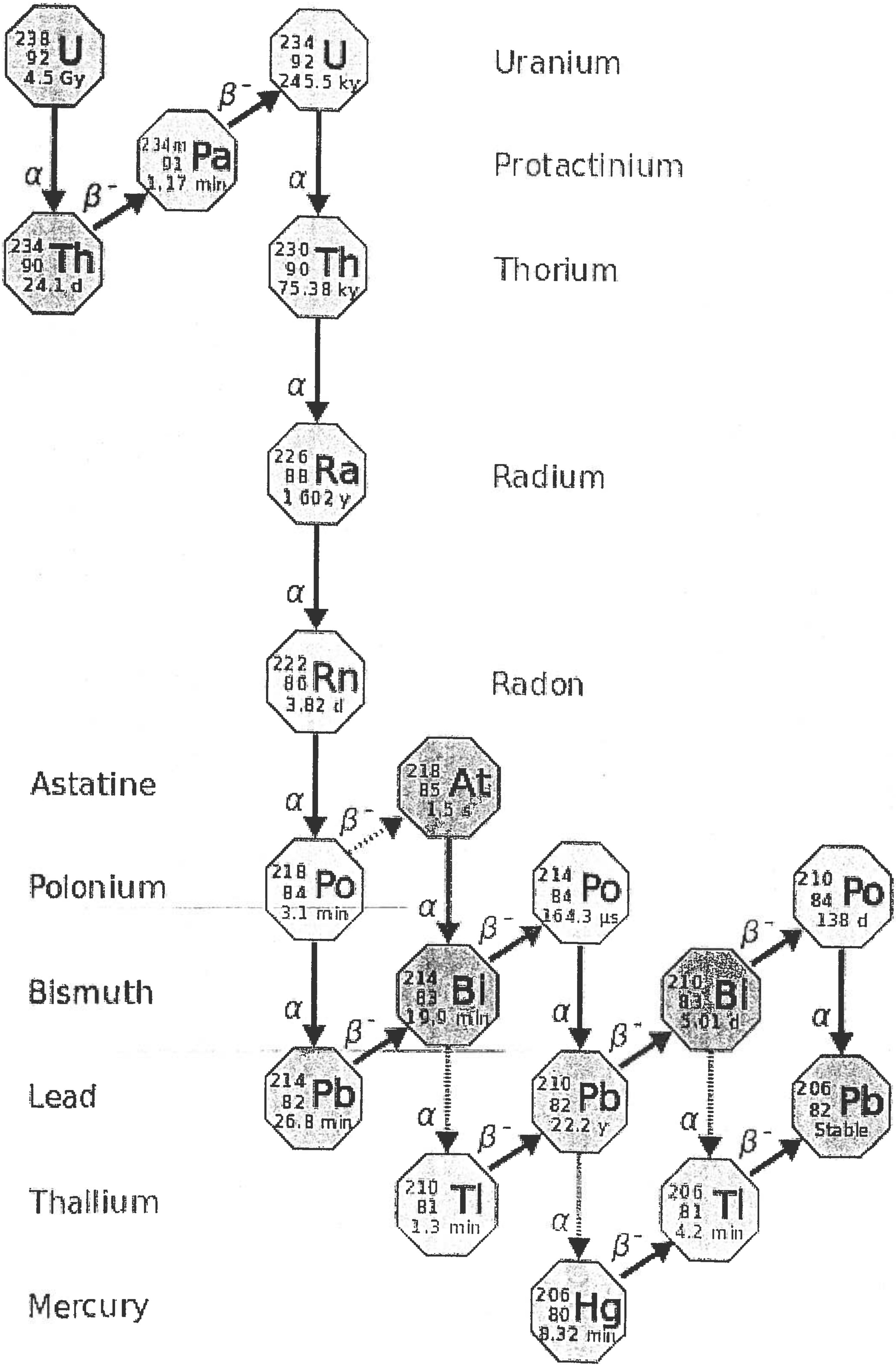


Figure 3.6



Uranium
Protactinium
Thorium
Radium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
Mercury
238 92 U 4.5 Gy
234 90 Th 24.1 d
234m 91 Pa 1.17 min
234 92 U 245.5 ky
230 90 Th 75.38 ky
226 88 Ra 1 602 y
222 86 Rn 3.82 d
218 84 Po 3.1 min
218 85 At 1.5 s
214 82 Pb 26.8 min
214 83 Bi 19.9 min
214 84 Po 164.3 μs
210 81 Tl 1.3 min
210 82 Pb 22.2 y
206 80 Hg 8.32 min
210 83 Bi 5.01 d
210 84 Po 138 d
206 81 Tl 4.2 min
206 82 Pb Stable
α
β⁻

A-3.

Gamma-ray energies and emission probabilities for actinides and natural

Nuclide	Half-life 1 y = 1 year = 365.24219878 days	Energy [keV]	Emission probability [% decay]
81-Tl-208	3.060 ± 0.008 m	277.37 ± 0.03	6.6 ± 0.3
		583.187 ± 0.002	85.0 ± 0.3
		860.56 ± 0.03	12.5 ± 0.1
		2614.511 ± 0.010	99.79 ± 0.01
82-Pb-210	22.20 ± 0.22 y	46.539 ± 0.001	4.25 ± 0.04
82-Pb-211	36.1 ± 0.2 m	404.853 ± 0.010	3.78 ± 0.06
		427.088 ± 0.010	1.76 ± 0.04
		704.64 ± 0.03	0.46 ± 0.01
		766.51 ± 0.03	0.62 ± 0.02
		832.01 ± 0.03	3.52 ± 0.06
82-Pb-212	10.64 ± 0.01 h	115.183 ± 0.005	0.623 ± 0.022
		238.632 ± 0.002	43.6 ± 0.3
		300.09 ± 0.01	3.18 ± 0.13
82-Pb-214	26.8 ± 0.9 m	53.2275 ± 0.0021	1.066 ± 0.014
		241.997 ± 0.003	7.19 ± 0.06
		295.224 ± 0.002	18.28 ± 0.14
		351.932 ± 0.002	35.34 ± 0.27
83-Bi-211	2.14 ± 0.02 m	351.06 ± 0.04	12.91 ± 0.11
83-Bi-212	60.54 ± 0.06 m	727.33 ± 0.01	6.74 ± 0.12
		785.37 ± 0.09	1.11 ± 0.01
		1078.63 ± 0.11	0.55 ± 0.02
		1620.74 ± 0.01	1.51 ± 0.03
83-Bi-214	19.9 ± 0.4 m	609.316 ± 0.003	45.16 ± 0.33
		665.453 ± 0.022	1.521 ± 0.011

		768.367 ± 0.011	4.850 ± 0.038
		806.185 ± 0.011	1.255 ± 0.011
		934.061 ± 0.012	3.074 ± 0.025
		1120.287 ± 0.010	14.78 ± 0.11
		1155.19 ± 0.02	1.624 ± 0.014
		1238.110 ± 0.012	5.785 ± 0.045
		1280.96 ± 0.02	1.425 ± 0.012
		1377.669 ± 0.012	3.954 ± 0.033
		1401.516 ± 0.014	1.324 ± 0.011
		1407.993 ± 0.007	2.369 ± 0.019
		1509.217 ± 0.008	2.108 ± 0.021
		1661.316 ± 0.013	1.037 ± 0.010
		1729.640 ± 0.012	2.817 ± 0.023
		1764.539 ± 0.015	15.17 ± 0.12
		1847.420 ± 0.025	2.000 ± 0.018
		2118.536 ± 0.008	1.148 ± 0.011
		2204.071 ± 0.021	4.89 ± 0.10
		2447.673 ± 0.010	1.536 ± 0.015
86-Rn-219	3.96 ± 0.01 s	271.23 ± 0.01	10.8 ± 0.6
		401.81 ± 0.01	6.6 ± 0.4
86-Rn-220	55.8 ± 0.3 s	549.76 ± 0.04	0.115 ± 0.015
88-Ra-223	11.43 ± 0.05 d	122.319 ± 0.010	1.21 ± 0.02
		144.235 ± 0.010	3.27 ± 0.08
		154.208 ± 0.010	5.70 ± 0.16
		269.463 ± 0.010	13.9 ± 0.3
		323.871 ± 0.010	3.99 ± 0.09
		338.282 ± 0.010	2.84 ± 0.07
		445.033 ± 0.012	1.29 ± 0.05
88-Ra-224	3.627 ± 0.007 d	240.986 ± 0.006	4.12 ± 0.04