STUDENT’S HANDBOOK

RADIOACTIVITY

Student’s name: ....

Group: ....

Rules and regulations concerning a course in Biophysics can be found at the webpage https://www.umb.edu.pl/en/s,7120/Rules_and_regulations

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3.3. Lab Exercise

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Lab Exercise 3.1

RADIOACTIVITY. PRINCIPLES OF DOSIMETRY. DETERMINING ACTIVITY WITH USE OF STANDARD.

Objective
you will calculate activity of an unknown sample using a standard
you will calculate the mass of previously found radioisotope in a sample

Materials
system for measuring gamma rays with scintillation well-type detector and lead shield
standard Cs-137 sample
unknown sample (polluted with Cs-137)
electronic calculator
Procedure

1. Switch on the measuring system and leave it for 5 minutes heating (it is necessary for stable work of the system).
2. Measure the background (without any sources inside the lead shield) for t_B = 5 minutes. Calculate the count rate. Write the result in Table 1

Table 1

Time of measurement t_B [min]	Number of counts N_B [counts]	Count rate $I_B=N_B/t_B$ [min^{-1}]

3/ Put the standard source into the well of the counter. Make 3 measurements of the number of counts (each measurement lasting for 1 minute). Calculate the average number of counts, count rate, net count rate (without background) and statistical error of count rate and write the results in *Table 2*.

Table 2

Number of counts [counts]		Average number of counts $N_S = \frac{N_{S1}+N_{S2}+N_{S3}}{3}$ [counts]	Count rate $I_S = \frac{N_S}{t_S}$ $\left[\frac{counts}{min}\right]$	Net count rate $I_S - I_B$ $\left[\frac{counts}{min}\right]$	Error of count rate $\sigma_S = \sqrt{\frac{I_S}{t_S}+\frac{I_B}{t_B}}$ $\left[\frac{counts}{min}\right]$
N_{S1}					
N_{S2}					
N_{S3}					

4. Place an unknown sample into the detector and measure it for 5 minutes. Calculate the count rate, net count rate (without background), error of net count rate and write the results in Table 3. Repeat it for another sample.

Table 3

Number of the sample	Number of counts N_x [pulses]	The count rate $I_X = \frac{N_X}{t_X}$ $\left[\frac{\text{pulses}}{\text{min}}\right]$	Net count rate $I_X - I_B$ $\left[\frac{\text{pulses}}{\text{min}}\right]$	The error of net count rate $\sigma_p = \sqrt{\frac{Ix}{t_X} + \frac{I_B}{t_B}}$

5. Calculate the activity and errors of determined activity of the unknown samples. Write the results of calculations in Table 4.

Activity of the sample (A_X) equals:

$$A_X = \frac{I_X - I_B}{I_S - I_B} \cdot A_S$$

Error of the determined activity (ΔA_X) can be calculated as follows:

$$\Delta A_X = \frac{A_S}{I_S - I_B} \cdot \sigma_p + \frac{I_X - I_B}{(\ I_S - I_B\ )^2} \cdot A_S \cdot \sigma_S + \frac{I_X - I_B}{I_S - I_B} \cdot \Delta A_S$$

Standard activity (A_S) and error of the standard activity (ΔA_S) equal:

$$A_S \pm \Delta A_S = 4000 \pm 120 \text{ [Bq]}$$

Table 4

Number of the sample	Net count rate $I_X - I_B$ $\left[\frac{\text{counts}}{\text{min}}\right]$	Activity $A_X = \frac{I_X - I_B}{I_S - I_B} \cdot A_S$ [Bq]	Activity error ΔA_X [Bq]	% activity error $\Delta A_{X\%} = \frac{\Delta A_X}{A_X} \cdot 100\%$ [%]

6/ Half-life of Cs-137 equals: $T_{1/2}$= 30.08 years, calculate the decay constant **λ.** Calculate the (estimated) number of atoms of Cs-137 for the standard and unknown samples and write the results in Table 5.

$$\lambda = \frac{\ln 2}{T_{1/2}} = \ldots\ldots\ldots\ldots\ldots\ldots[s^{-1}] \qquad\qquad A = \lambda \cdot N \rightarrow N = \frac{A}{\lambda}$$

7/ Calculate the mass of Cs-137 for the standard and unknown samples and write the results in Table 5.

We calculate the mass of Cs-137 in the sample with the use of Avogadro's formula.

$N_A = 6.023 \cdot 10^{23}$ [mol^{-1}] (Avogadro's number) - is the number of atoms in a mole.

The mole of Cs-137 is 137g so the mass of $6.023 \cdot 10^{23}$ atoms of Cs-137 is 137g.

The mass of N-atoms of Cs-137 can be estimated as follows: $m = \frac{137 \cdot N}{N_A}$

8/ Calculate the efficiency of measurements using the following formula and place the result in Table 5.

$$\eta_{\%} = \frac{I}{A} \cdot 100\,[\%]$$

Where: I – net count rate of the measured sample [s^{-1}]

A - activity of the measured sample [Bq]

Table 5

Number of sample	Number of atoms of Cs-137 $N = \frac{A}{\lambda}$	Mass of Cs-137 [g]	Efficiency $\eta_{\%} = \frac{I}{A} \cdot 100\,[\%]$

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Lab Exercise 3.2.1

INTERACTION OF PHOTONS WITH MATTER. METHODS OF DETERMINING OF COEFFICIENT OF ATTENUATION.

Objective

you will find a half-thickness ($d_{1/2}$) and calculate the attenuation coefficient (μ) and mass attenuation coefficient (μ_m) of gamma rays emitted by Co-60 ($E_{average}$=1.25MeV) for two absorbers: zinc and lead

Materials

- NaI scintillation gamma detector connected to pulse counting system
- lead shield
- source of gamma-rays (Co-60)
- absorbing discs (made of zinc, aluminium and lead)
- electronic calculator

Procedure

1. Measure the background of a measuring system in 5 minutes. Calculate the background for 1 minute. Write the results in Table 1
2. Measure the number of pulses from source without absorber in 1 minute (3 times). Write the results in Table 2
3. Measure the number of pulses from source covered in zinc absorber in 1 minute (3 times). Use different number of absorbing discs from 1 to 5. Write the results in Table 2
4. Draw a chart of frequency of pulses as a function of the thickness of the absorber *(Chart 1)*
5. Find a half-thickness $d_{1/2}$ of zinc (use the Chart 1)
6. Calculate the attenuation coefficient (μ) and mass attenuation coefficient (μ_m).
Write the results in Table 3
7. Measure the number of pulses from source covered in aluminium absorber and lead absorber in 1 minute (3 times). Write the results in Table 2
8. Calculate the attenuation coefficient (μ), the mass attenuation coefficient (μ_m) and half-thickness $d_{1/2}$ of aluminium and lead. Write the results in Table 4

Data and observations

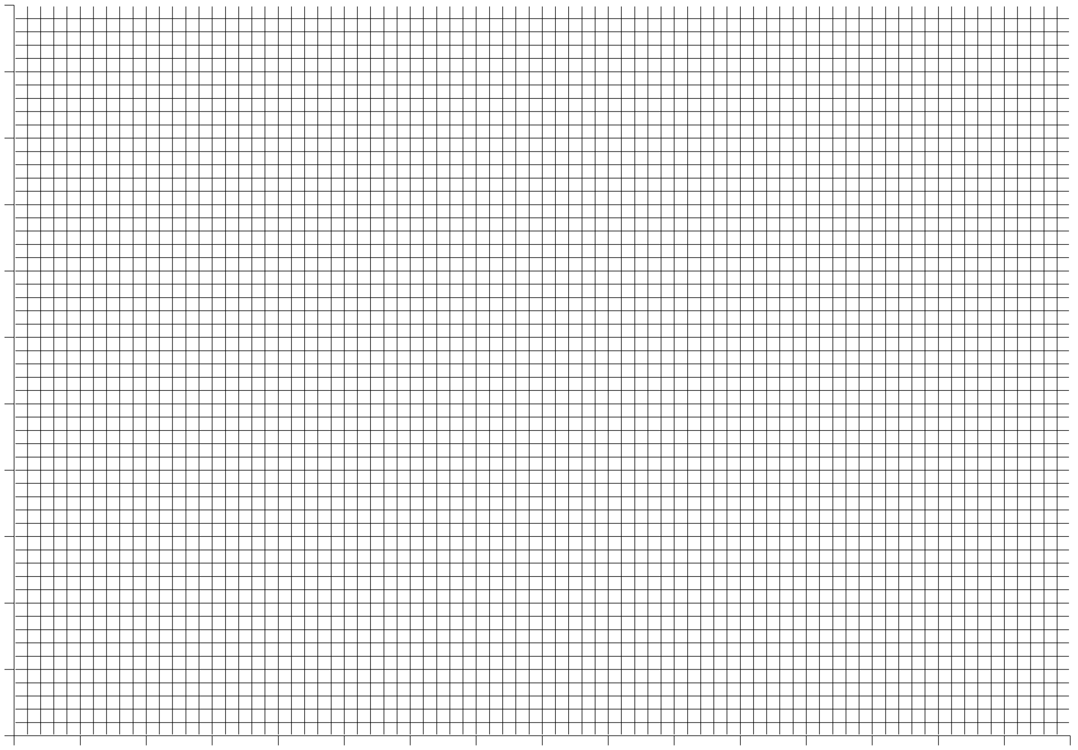
Table 1

Background N_B [pulses/5 minutes]	Background I_B [pulses /1 minute]

Table 2

Thickness of the absorber x [10^{-3} m]	Frequency of pulses I [minute^{-1}]			Average frequency of pulses I_M [minute^{-1}]	Net average frequency of pulses (I_M-I_B) [minute^{-1}]	$\frac{I_M - I_B}{I_o} \cdot 100\%$
	I_1	I_2	I_3			[%]
Without absorber					I_o =	
Zn $_{1disc}$ =						
Zn $_{2discs}$ =						
Zn $_{3discs}$ =						
Zn $_{4discs}$ =						
Zn $_{5discs}$ =						
Al $_{1disc}$ =						
Pb $_{1disc}$ =						

Chart 1



x [mm]

$d_{1/2}$=................[m]

$$\mu = \frac{\ln 2}{d_{1/2}} = \frac{0.693}{d_{1/2}} = \text{.......................}[m^{-1}]$$

$$\mu_m = \frac{\mu}{\rho} = \text{......................}[m^2 kg^{-1}]$$

Table 3

Density of zinc ρ [kg m^{-3}]	Attenuation coefficient μ [m^{-1}]	Mass attenuation coefficient μ [m^2 kg^{-1}]
$7.19 \cdot 10^3$		

Aluminium (Al) and Lead (Pb):

$$\mu = \frac{\ln \frac{I_0}{I_x}}{x} \qquad \mu_m = \frac{\mu}{\rho}$$

$$d_{1/2} = \frac{\ln 2}{\mu}$$

Table 4

Absorber	Density ρ [kg m^{-3}]	Attenuation coefficient $\mu = \frac{\ln \frac{I_0}{I_x}}{x}$ [m^{-1}]	Mass attenuation coefficient $\mu_m = \frac{\mu}{\rho}$ [m^2 kg^{-1}]	Half-thickness $d_{1/2}$ [m]
Al	$2.7 \cdot 10^3$			
Pb	$11.3 \cdot 10^3$			

Questions and conclusions

The date	**Student's name and surname**	**Lab assistant signature**

3.2.2. Lab Exercise

INTERACTION OF CHARGED PARTICLES WITH MATTER. DETERMINING OF LINEAR AND MASS COEFFICIENT OF ATTENUATION BETA PARTICLES IN DIFFERENT ABSORBERS.

Objective

you will calculate the attenuation coefficient (μ) and mass attenuation coefficient (μ_m) of beta particles emitted by Sr-90 for three absorbers: aluminium, copper and polyester (the radiographic film base)

you will calculate the thickness of aluminium foil using the Law of Attenuation

Materials

- detector connected to pulse counting system
- lead shield
- radioactive source of β radiation
- micrometer screw gauge
- foils of absorbers: aluminium, copper and polyester
- electronic calculator

Procedure

1. Measure the background of a measuring system in 10 minutes. Calculate the background for 1 minute. Write the result in Table 5
2. Measure the number of pulses from uncovered source in 1 minute (3 times). Write the results in Table 6
3. Measure the thickness of absorbers and write the values in Table 5. Measure the number of pulses from source covered in each absorber: Al, Cu and polyester) in 1 minute (3 times). Write the results in Table 6
4. Calculate the attenuation coefficient (μ) and the mass attenuation coefficient (μ_m). Write the results in Table 7
5. Measure the number of pulses from source covered by the aluminium foil in 1 minute (3 times). Write the results in Table 8
6. Use value of the previously determined attenuation coefficient (μ_{Al}) to calculate the thickness of the aluminium foil, write the result in Table 8.

Data and observations

Table 5

Background N_B(pulses/5 minutes)	Background I_B(pulses /1 minute)

Table 6

Thickness of the absorber d (10^{-3} m)		Frequency of pulses I($minute^{-1}$)			Average frequency of pulses I_x ($minute^{-1}$)	Net average frequency of pulses (I_x-I_B) ($minute^{-1}$)
		I_1	I_2	I_3		
Without absorber	0					
Al						
Cu						
Polyester						

Table 7

Density of absorber ρ(kg m^{-3})		Attenuation coefficient $\mu = \frac{\ln \frac{I_0}{I_x}}{x}$ [m^{-1}]	Mass attenuation coefficient $\mu_m = \frac{\mu}{\rho}$ [m^2 kg^{-1}]
Aluminium	$2.7 \cdot 10^3$		
Copper	$9.96 \cdot 10^3$		
Polyester	$1.4 \cdot 10^3$		

Table 8

Coefficient of attenuation	Frequency of pulses			Average frequency of pulses I_x ($minute^{-1}$)	Net average frequency of pulses (I_x-I_B) ($minute^{-1}$)	Thickness of foil
μ_{Al}[m^{-1}]	I($minute^{-1}$)					$x = \frac{\ln \frac{I_0}{I_x}}{\mu} [m]$
	I_1	I_2	I_3			

Questions and conclusions

The date	Student's name and surname	Lab assistant signature

3.3. Lab Exercise

THE METHODS OF DETECTION OF IONISING RADIATION AND ITS MEDICAL APPLICATIONS. STATISTICS AND CALCULATION OF ERRORS.

Objective

- you will calculate the Standard Deviation (σ) of ten results of measurements of the same radioactive sample using formula (2) and compare it with the value calculated by computer or scientific calculator
- you will make a histogram of values and find the statistical distribution of a hundred results of measurements of the same radioactive sample and calculate values of true mean and SD (using program "Statistica")
- you will calculate and draw on the histogram intervals of 68% and 95% confidence levels
- you will calculate the probability of getting the result of one measurement in the intervals of 1σ and 2σ confidence levels

Materials

– NaI scintillation gamma detector connected to pulse counting system
– lead shield
– source of radiation
– PC with Statistica program
– scientific calculator

Procedure

1. Measure the number of pulses from source in 10 seconds (10 times). Write the results in *Table 1*. Calculate the value of true mean and RMS σ
2. Calculate the value of SD using PC program or scientific calculator. Write the results of calculation in *Table 1*
3. Measure the number of counts from source in 10 seconds (100 times). Write the results in *Table 2*
4. Use the results of measurements to generate a Gaussian distribution, as follows (use "Statistica" software):

- put the content of *Table 2* to one column of the program's data table,
- calculate and write in *Table 3* the values of: Standard Deviation, the true mean, minimum and maximum,
- make a histogram of values (at least 100) for ten-second counts,
- calculate and mark on the histogram intervals of 68% and 95% confidence levels (1σ and 2σ confidence levels),
- count (using *Table 2*) how many results of measurements is inside the intervals 1σ and 2σ.

5. Put the results in *Table 4* as N_{σ} and $N_{2\sigma}$
6. Calculate (and write in *Table 4*) probabilities: p_{σ} and $p_{2\sigma}$

Data and observations

Table 1

Measurement number	Result (pulses)	True Mean $\bar{n}$	RMS $\sigma = \sqrt{\bar{n}}$	SD computer calculated
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Compare the two calculated values: RMS and Standard Deviation SD.

Table 2

Measurement		Measurement		Measurement		Measurement		Measurement	
Number	Pulses	Number	Pulses	Number	Pulses	Number	Pulses	Number	Pulses
1		21		41		61		81	
2		22		42		62		82	
3		21		43		63		83	
4		24		44		64		84	
5		25		45		65		85	
6		26		46		66		86	
7		27		47		67		87	
8		28		48		68		88	
9		29		49		69		89	
10		30		50		70		90	
11		31		51		71		91	
12		32		52		72		92	
13		33		53		73		93	
14		34		54		74		94	
15		35		55		75		95	
16		36		56		76		96	
17		37		57		77		97	
18		38		58		78		98	
19		39		59		79		99	
20		40		60		180		100	

Table 3

SD (σ)	True mean $(\bar{n})$	Minimum	Maximum

Place your histogram here

Table 4.

$\bar{n} - \sigma$	$\bar{n} + \sigma$	N_{σ}	$\bar{n} - 2\sigma$	$\bar{n} + 2\sigma$	$N_{2\sigma}$	$p_{\sigma} = \frac{N_{\sigma}}{100}$	$p_{2\sigma} = \frac{N_{2\sigma}}{100}$

Questions and conclusions

The date	**Student's name and surname**	**Lab assistant signature**