SALAHADDIN UNIVERSITY – ERBIL

COLLEGE OF EDUCATION

DEPARTMENT OF PHYSICS

Laboratory Manual:

Nuclear Science Experiments

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Table of Contents:

Foreword

The purpose of this laboratory manual is to describe nuclear physics experiments utilizing the latest counting electronics that are in broad use in today's industry.

Precautions with Radioactive Sources

Several types of radioactive sources are required to perform the experiments described in this Laboratory Manual. These include both sealed and unsealed sources with a range of activity. When working with radioactive sources, utilize the three basic principles as low as reasonably achievable:

- **Time:** The simplest way to reduce exposure is to keep the time spent around a radioactive source to a minimum. If time is cut in half, so is the exposure, with all the other factors remaining constant.
- **Distance:** Distance is another effective means to reduce radiation exposure. The formula is known as the "inverse square law" relates the exposure rate to distance. Doubling the distance from a radioactive source reduces the exposure to one-fourth its original value. If the distance is tripled, the exposure is reduced by a factor of nine.
- **Shielding:** Shielding is any material used to reduce the radiation reaching the user from a radioactive source. While a single sheet of paper may stop some types of radiation such as alpha particles, other radiation such as neutrons and photons require much more shielding. Dense materials, such as lead or steel, are used to shield photons. Materials containing large amounts of hydrogen, such as polyethene, are used to shield neutrons.

Theoretical Overview:

Radioactivity:

Radioactive nuclei decay by emitting beta or alpha particles. Often the decay is to an excited state in the daughter nucleus, which usually decays by emission of a gamma-ray. The energy level sequence and therefore the gamma-ray energy spectrum for every nucleus is unique and can be used to identify the nucleus. The energy levels and decay process of ^{22}Na, ^{60}Co and ^{137}Cs are given in Figure 1-1. The term beta decay means β- (electron), β+ (positron) emission or electron capture by the nucleus.

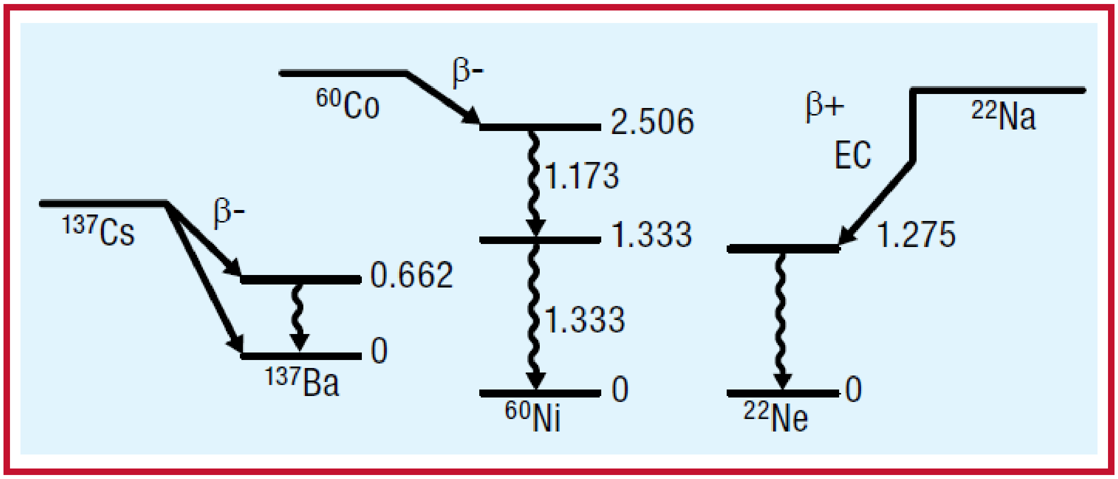


Fig. 1-1: Energy level sequences for ^{137}Cs, ^{60}Co and ^{22}Na (energy levels in MeV)

NaI(Tl) detectors:

The thallium-activated sodium iodide detector, or NaI(Tl) detector, responds to the gamma-ray by producing a small flash of light, or a scintillation. The scintillation occurs when scintillator electrons, excited by the energy of the photon, return to their ground state. The detector crystal is mounted on a photomultiplier tube which converts the scintillation into an electrical pulse. The first pulse from the photocathode is very small and is amplified in 10 stages by a series of dynodes to get a large pulse. This is taken from the anode of the photomultiplier and is a negative pulse.

The NaI(Tl) crystal is protected from the moisture in the air by encasing it in aluminium, which also serves as a convenient mounting for the entire crystal/photomultiplier unit. A schematic is shown in Figure 1-2.

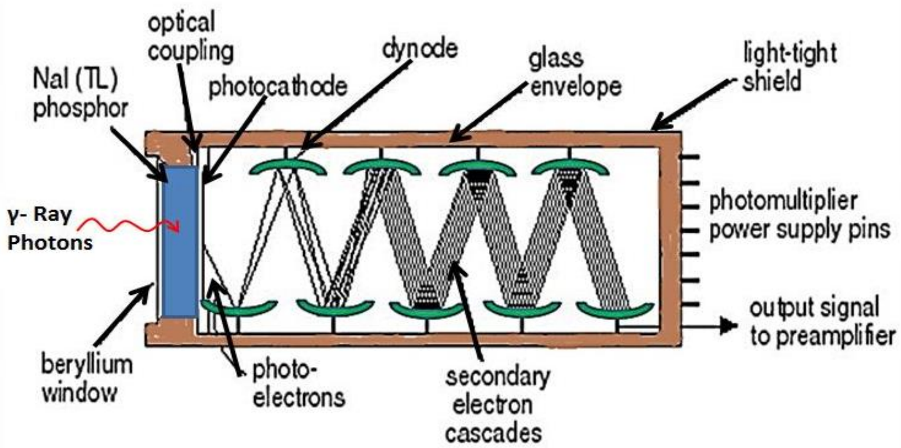
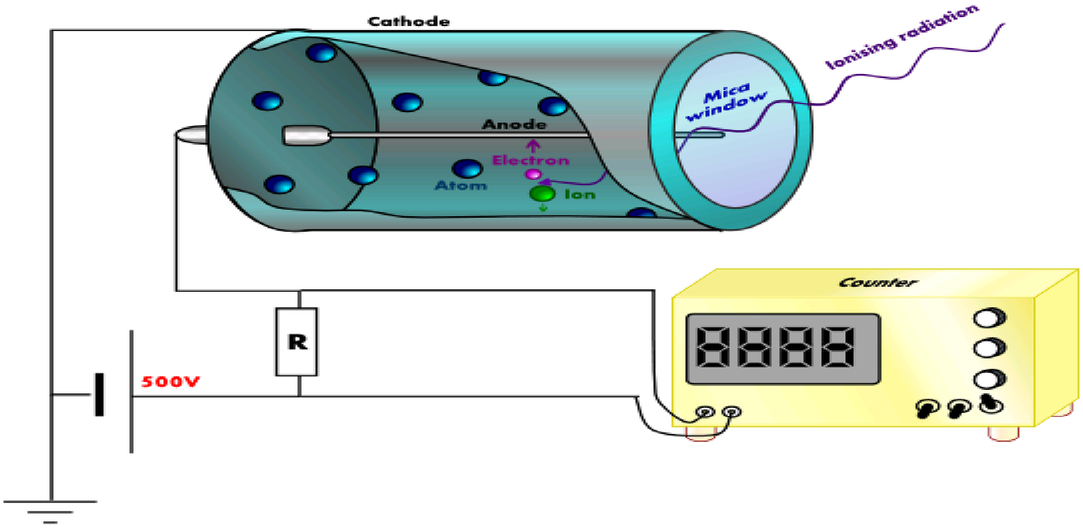


Fig. 2: illustration of a scintillation event in a photomultiplier tube

Geiger-Müller counter:

A Geiger-Müller counter is a pulse-type radiation detector which gives rise to negative pulses due to radiations incident on it. The negative pulses are counted using the counter.

It consists of a cylindrical metallic tube filled with an inert gas like Argon or Neon mixed with some organic vapour at a pressure of about 10 cm of mercury. When any radiation is incident on the GM counter, it sets out a primary ionizing event in the sensitive volume of the counter. The electrons so released are accelerated by the electric field and cause further ionization. The collective effect of such phenomena develops into a progressive avalanche spreading throughout the length of anode causing momentary discharge. This spontaneous discharge lowers down the potential of the anode, giving rise to a negative pulse. During the interval of this negative pulse, which is of the order of l00-200 μ seconds, the counter is inoperative for any radiation incident on it. Hence it is called dead time. This is approximately equal to resolving time. For an accurate assessment of activity, the observed count rate must be corrected for the resolving time.



Gamma-ray interactions with matter:

There are three dominant gamma-ray interactions with matter:

1. Photoelectric effect.
2. Compton effect.
3. Pair production.

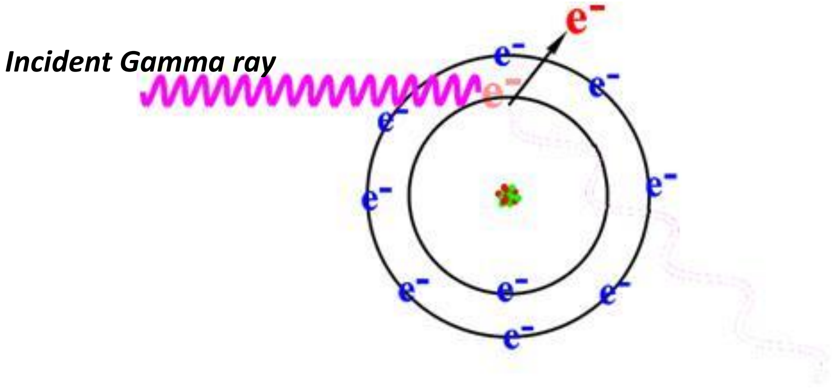
(1) The photoelectric effect is a common interaction between a low-energy gamma-ray and a material. In this process, the photon interacts with an electron in the material losing all of its energy. The electron is ejected with an energy equal to the initial photon energy minus the binding energy of the electron. This is a useful

process for spectroscopy since an output pulse in a detector is produced that is proportional to the gamma-ray energy, as all of the energy of the gamma-ray is transferred to the detector. This produces a characteristic full-energy peak in the spectrum that can be used for the purpose of identifying the radioactive material.

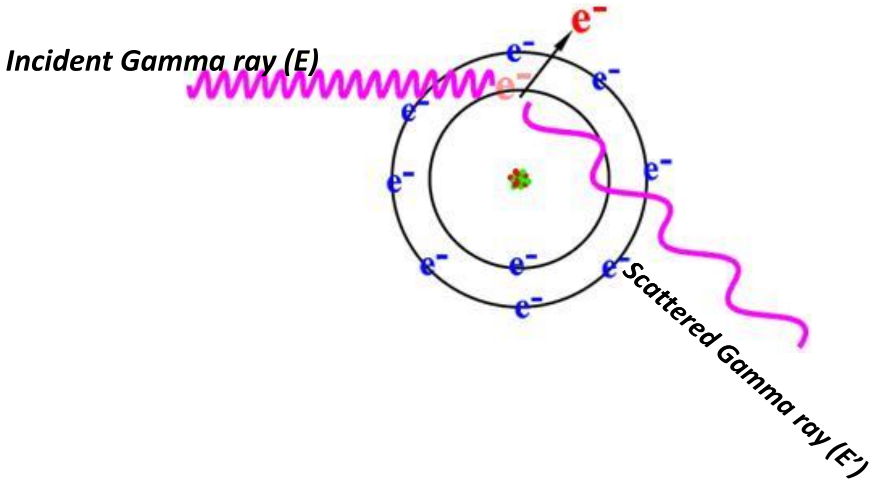
(2) The photon can scatter by a free electron and transfer an amount of energy that depends on the scattering angle. This process is called Compton scattering.

(3) Pair production can occur when the gamma-ray energy is greater than 1.022 MeV and is a significant process at energies above 2.5 MeV. The process produces a positron and electron pair that slow down through *Fig. 3* scattering interactions in the material. When the positron comes to rest, it annihilates with an electron producing a pair of 511 keV gamma rays that are produced back-to-back. These can be absorbed through the photoelectric effect to produce full-energy peaks at 511 keV. A component due to Compton scattering can also be observed. When a photon interacts with the crystal through pair production, one or both of the annihilation photons can escape undetected from the crystal. If one of the photons escapes undetected, then this will result in a peak in the spectrum at an energy of 511 keV less than the full-energy peak. This is called the single escape peak. Similarly, if both photons escape undetected, a peak will appear 1022 keV below the full energy peak, called the double escape peak.

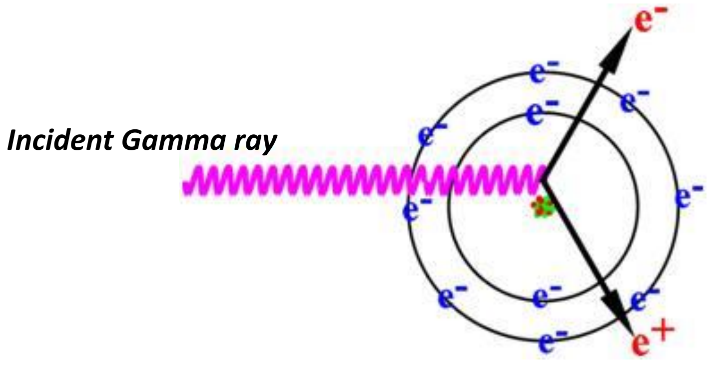
Photo electric



Compton scattering



Pair production



Experiment (1):

Study of Gamma-Ray Spectrum by Using Scintillation Detector and Single Channel Analyzer

❖ Apparatus

- NIM Bin and Power Supply
- High Voltage Power Supply
- Scintillation Detector
- Scintillation Preamplifier
- Linear Amplifier
- Single-Channel Analyzer
- Timer & Counter
- Oscilloscope,
- ^{22}Na radioactive source
- Connecting Cables.

❖ Purpose

Collect the gamma spectrum from ^{22}Na radioactive source and identifying the gamma energies of the photoelectric, Compton, and annihilation peaks detected by the NaI(Tl) detector.

❖ Theory

When excited nucleus makes transition to excited or ground state which is lower in energy than the initial one, the nucleus emits energy in these transitions, this energy comes out in the form of α, β *and* γ-ray, standard sources like Co, Na and Cs …etc, which are available in our laboratory have nuclei already excited to some energy states having long half-life. In this experiment, we investigate the gamma spectrum of the ^{22}Na standard source.

The energy spectrum of gamma source represents both the characteristic of source and the characteristic of the detector since gamma-ray is quite penetrating, hence it will pass through the aluminium light shield and reach the detector crystal easily and interact with crystal material in three different ways:

1- Photoelectric Effect (PE)
2- Compton Scattering (CS)
3- Pair Production (PP)

The probability of each event depends on the energy of the incident photon and the atomic number of detector medium. This probability of the interaction by these effects is usually expressed by their cross-sections.

Photoelectric Effect

In the photoelectric effect, the total number of radiation appears as the kinetic energy of the photoelectron minus the energy with which the electron was bound to the atom or molecule. The cross-section of this effect falls off rapidly with energy, as first as about $E^{-3.5}$ eventually as E^{-1}, also approximately proportional to Z^5, where Z is the atomic number of crystal matter.

Compton Scattering

In Compton scattering, the photon transfer only a part of its energy to any loosely bound electron, therefore it deflected from its original path and keeps the remaining energy. The energy of the scattered photon is given by,

$$E_s = \frac{E_\gamma}{(1 - cos\theta)\frac{E_\gamma}{Mc^2}}$$

While the energy of the recoil electron is given as

$$E_r = \frac{E_\gamma(1 - cos\theta)}{(1 - cos\theta) + \frac{Mc^2}{E_\gamma}}$$

where $E_{(r)}$ is the incident photon energy,

M: electron rest mass.

The cross-section for Compton scattering is proportional to (Z) and decreases as E^{-1} for energies above 0.5 MeV. This process, therefore, is predominant in the energy region between 0.6 and 4 MeV.

Pair Production

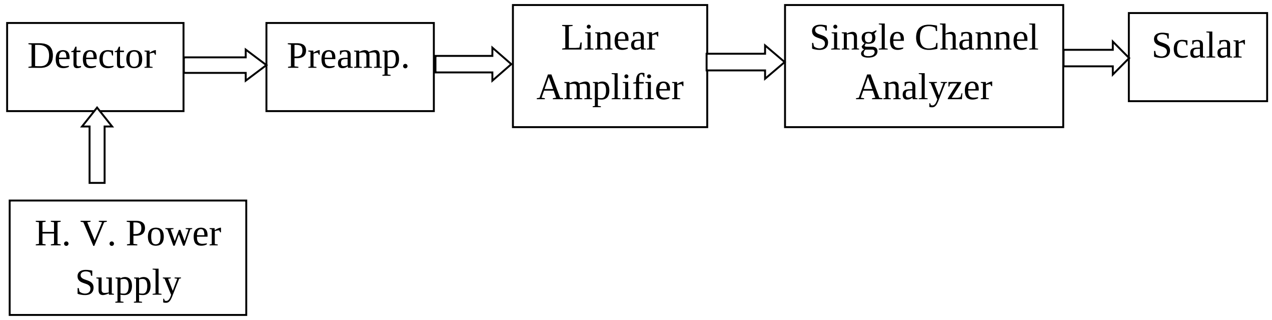
The incident γ- ray photon will interact with a crystal through pair production if its energy is greater than 1.022 MeV and in this process the gamma-ray energy (E_γ) produces a pair of electron and positron.

The kinetic energy of the composite pair will be (E_γ - 1.022) MeV. The crystal stops the electron in this process and the positron is annihilated and is accompanied by two oppositely directed gamma rays each have the energy of 0.511 MeV.

The gamma-ray in this process either stopped by the process of the photoelectric effect and by Compton Effect or will escape. The cross-section of the pair production increases rapidly from zero at 1.022 MeV (threshold energy) to the maximum at few tens of MeV.

Procedure

1. Connect the electronic equipment as shown below



2. Place the gamma source ^{22}Na at a suitable distance from the detector.
3. Set operating voltage at 950 V, and window width at 0.2 V
4. Adjust the amplifier gains so that the photopeak of ^{22}Na appears at 8 V baseline voltages (BLV).
5. Increase BLV in step 0.2 so that close the range (0.2-9.8)V and then record the count rate for an interval 60 s for each step of BLV.
6. Plot a graph between count/sec and BLV, you will get the spectrum of ^{22}Na as in Figure (2).
7. Put the energy of photo peak, annihilation peak, and X-ray peak on the spectrum.

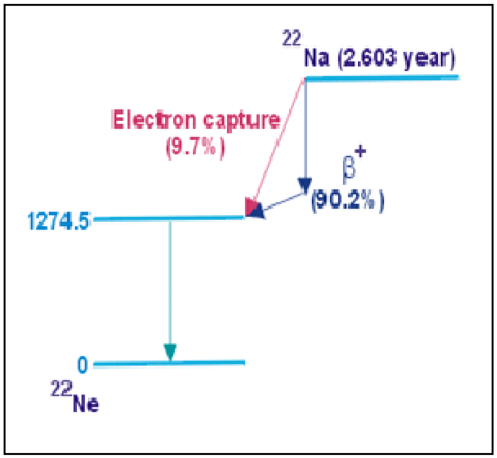


Fig.(1): ^{22}Na Decay Scheme

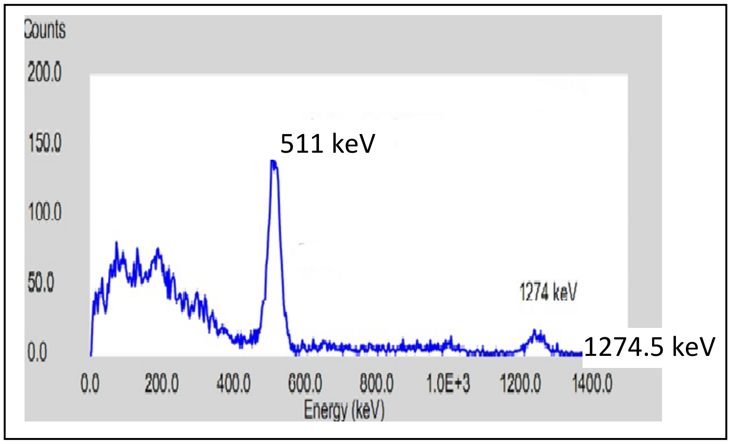


Fig.(2): ^{22}Na Spectrum [NaI(TI) Counter]

❖ Questions

1. What is the annihilation peak? How it is produced?
2. Which one is better for the nuclear spectroscopic measurements PE, CS, or PP?
3. Define each of the Compton backscattering and Compton edge.
4. Interpret the existence of intense x-ray lines within the radioactive sources spectra.

Experiment (2):

Level control (Foundation of material height in closed containers)

Fig. 1: Experimental set-up.

Purpose

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

Principle

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 the 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.

Equipment

Geiger-Müller-Counter	13606-99
Demo Physics board with stand	02150-00
Geiger-Mueller counter tube, type B	09005-00
Clamp on holder	02164-00
Plate holder on fixing magnet	09203-00
Counter tube holder on fix. magn.	09203-00
Source holder on fixing magnet	09202-00
Support clamp for small case	02043-10
Specimen tube with holder	09203-01
Steel pellets, d = 2 mm, 120 g	03990-00
plastic pellets, d = 2 mm, 120 g	03990-00
Support rod,stainl.steel, 100mm	02030-00

Experiment Guide

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 the stand where the top of the 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)

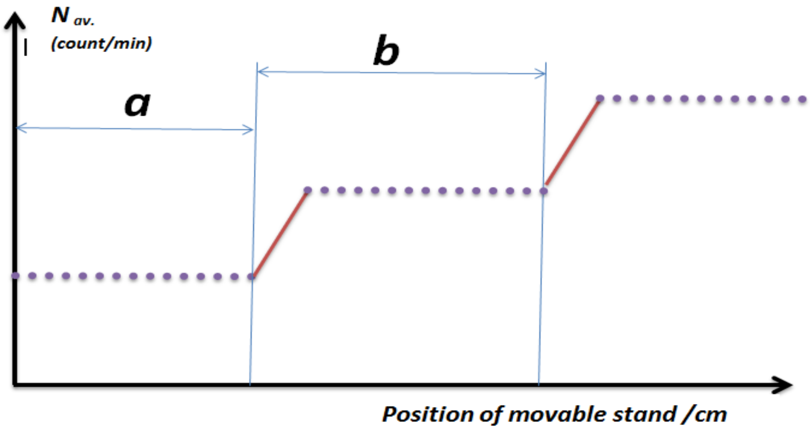


Fig (2): Gamma-quanta rate versus movable stand level.

❖ Questions:

- Why we use γ-ray instead of α and β rays to perform this experiment?
- Is it possible to replace the G-M counter by the Scintillation detector?
- Why the background corrections do not take into account in this experiment?

Mention three practical applications of this experiment.

Experiment (3):

Determination of dead time (resolving time) of G.M. counters by two –source method

❖ Purpose

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

❖ Principle

The time following the entry of the ionizing event in the counter during which the later remain insensitive to the next event is called the dead time T of the counter. This arises from the slow-motion of positive ion sheath from the anode. The presence of positive ion cloud in the vicinity of the anode lowers 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 the 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 the background.

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

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

N_b ≡ background count rate only.

The resolving time is given by,

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

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

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

Equipment

Geiger-Müller-Counter	13606-99
Geiger-Mueller counter tube, type B	09005-00
Base plate for radioactivity	09200-00
Plate holder on fixing magnet	09203-00
^{241}Am radioactive sources	
Timer & Counter	
Support rod -PASS-, square, l = 250 mm	02025.55

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 besides 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 minutes 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 a difference in your result? Explain briefly.

Questions

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

Experiment (4):

Determination of Operating Voltage for Scintillation Detector

Apparatus

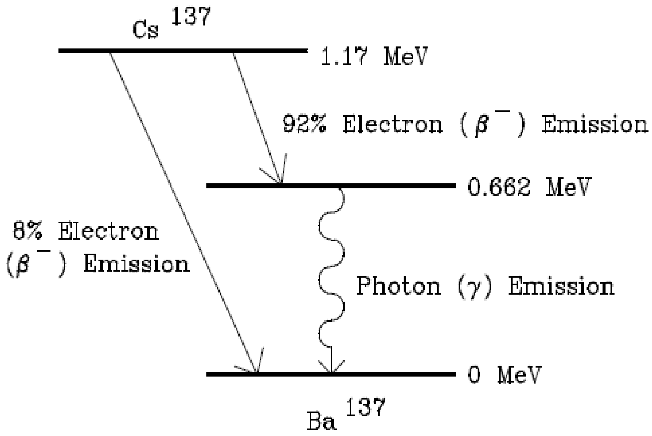
- NIM Bin and Power Supply
- High Voltage Power Supply
- Scintillation Detector
- Scintillation Preamplifier
- Linear Amplifier
- Single-Channel Analyzer
- Timer & Counter
- Oscilloscope,
- ^{137}Cs radioactive source
- Connecting Cables.

Purpose

In this experiment, you will determine the Operating Voltage for Scintillation Detector

Theory

Radioactive nucleus decay by emitting β^- or α particles, often the decay leads to an excited state of the daughter nucleus which usually decays by emission of γ -ray. The energy level sequence (decay scheme of ^{137}Cs is given in the figure below) and the γ -ray energy spectrum for every nucleus is unique, and can be used in studying different detector properties.

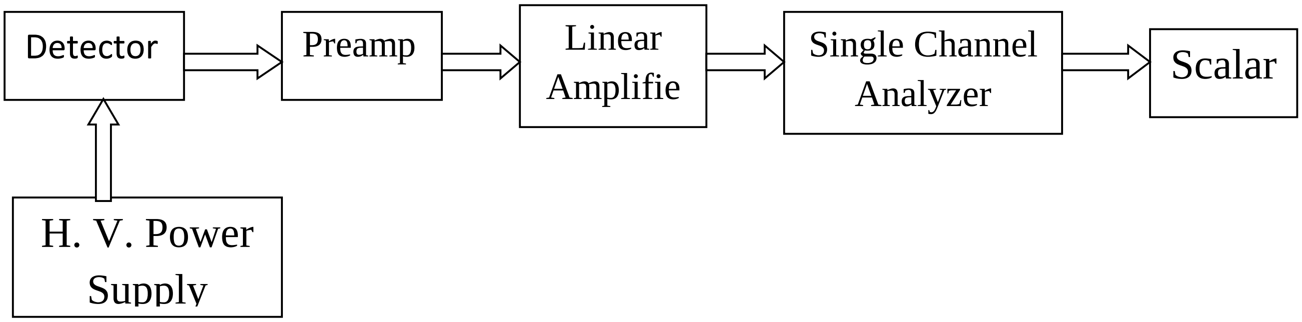


The decay scheme of ^{137}Cs

The thallium-activated sodium iodide detector or NaI(Ti) detector responds to γ -ray by producing a small flash of light, a scintillation. The scintillation occur when electrons, and in some cases positrons, given energy by the incident γ -ray and are stopped by crystal. The crystal is mounted on a photomultiplier tube that converts the scintillation to an electrical pulse. High energy γ - ray will produce an intense light in the crystal and will give rise to large size pulse in comparison to that of less energetic γ - ray, as the high voltage applied to photomultiplier, the gain of latter increasing and those pulses which were weaker before are sufficiently amplified to get registered. It is therefore apparent that are increase in the photomultiplier voltage will result in an increase in the sensitivity of the scintillation detector to smaller energy γ-ray. Unfortunately, the increase in voltage also increases the random electronic noise which originates in the photomultiplier (known as dark current pulse) which limits sensitivity. Thus at higher voltage the background noise pulse mix appreciably with genuine γ - ray pulse. The suitable choose of the photomultiplier voltage is therefore one at which genuine pulse rate is appreciable and the background count rate is normal. The voltage at which the ratio of the activity pulses to background (like the signal to noise) is large will therefore determine the operating voltage.

❖ Procedure

1- Make the experimental set- up as below:



2- Fix the gain of the amplifier at a suitable level. We remember that at high gain the suitably of the amplifier will reduce, and therefore, as possible should be avoided.

3- Place ^{137}Cs source at a suitable distance (5 cm) away from the crystal face. Note the counting rate for different value of high voltage.

4- Remove the source and take the background counting rate at the same of high voltages in step 2 above.

5- Tabulate the obtained data as in the following table

Voltage (1)	Count/min (2)	Background (3)	Correction (2)-(3)	R=$\frac{(2)-(3)}{(3)}$
700 . . 1200				

6- Plot a graph between voltage and ratio (R). the voltage corresponding to the maximum value of (R) representing the operating voltage.

7- Repeat step (1-3) by using single-channel analyzer (SCA) between (LA) and (S) in the electronic circuit. The main advantage of (SCA) is to eliminate all counts originating at energies below the photopeak energy (by adjusting the lower level discriminator), and at energies above the photopeak energy (by adjusting the upper-level discriminator).

8- Compare the results of the operating voltage with and without (SCA) and discuss all physical points.

❖ Questions

1- What is the physical meaning of operating voltage of detectors?

2- Why the NaI crystal is activated by TI?

3- Explain the work of the PMT tube within the scintillation detector.

4- Describe the advantages and disadvantages of the NaI(Tl) scintillation detector.

Experiment (5):

The study of Compton scattering for gamma rays using MCA

Fig. 1: Experimental set-up.

Purpose:

- Demonstrate how the gamma-ray energy varies following Compton scattering.
- Measure the energy of the Cs-137 (661.6 keV) peaks scattered at different angles and calculate the Compton wavelength from the readings taken.

Principle:

When photons are scattered on electrons their momentum and energy gets changed. The photon can scatter by a free electron and transfer an amount of energy that depends on the scattering angle, this process is called Compton scattering.

The energy of the scattered photon E′ is:

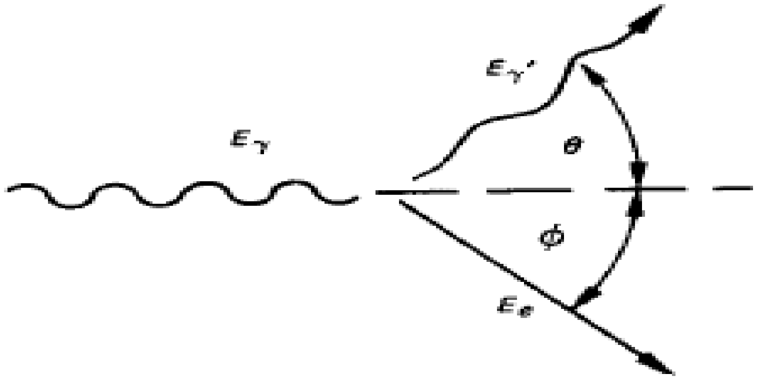
$$E' = E - \left[\frac{E}{1 + \frac{E}{m_0 c^2}(1 - \cos\theta)} \right] \quad \text{..........................} \ (1)$$

All values of energy are expressed in MeV.

where E is the incident gamma-ray energy and θ is the angle of scatter. The term m_0c^2 is the rest mass of the electron, equal to 511 keV. The energy is given to the electron is:

$$E_e = E - E' \qquad \text{……………………… ……………. (2)}$$

$E_e = m_oc^2 = 0.511$ MeV .and $E = E_\gamma = 0.662$ MeV for ^{137}Cs.



Equipment

Multi-Channel-Analyzer, Extended version	13727.99
Software for Multi-Channel-Analyzer	14452.61
Radioactive Source Cs-137, 37kBq	09096.01
Gamma detector (Scintillation detector)	09101.00
Operating unit for gamma detector	09101.93
High voltage connecting cable	09101.10
Shielding cylinder for gamma-detector	09101.11

Rod, iron, d = 25 mm, l = 200 mm	09101.13
Lead block, 200 x 100 x 50 mm	09029.11
Lead brick with hole	09021.00
Screened cable, BNC, l = 750 mm	07542.11
PC, Windows® XP or higher	

Experiment Guide

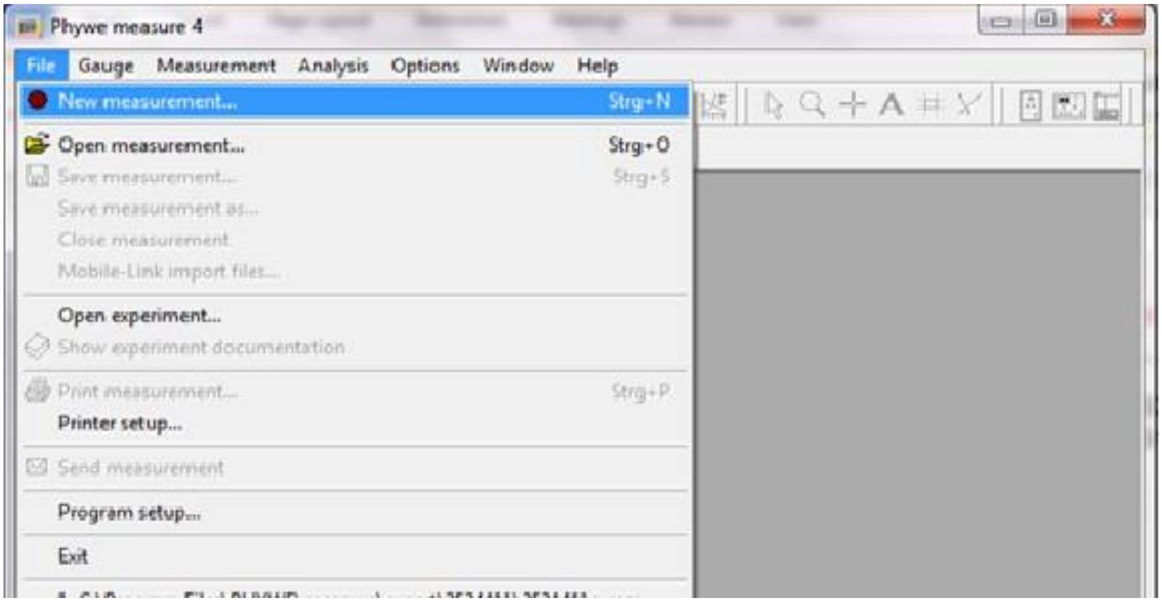
1- Set up the apparatus as shown in Fig. 1.

2- Before turning on the operating unit for the scintillation detector, connect the high voltage cable correctly to the operating unit and photomultiplier.

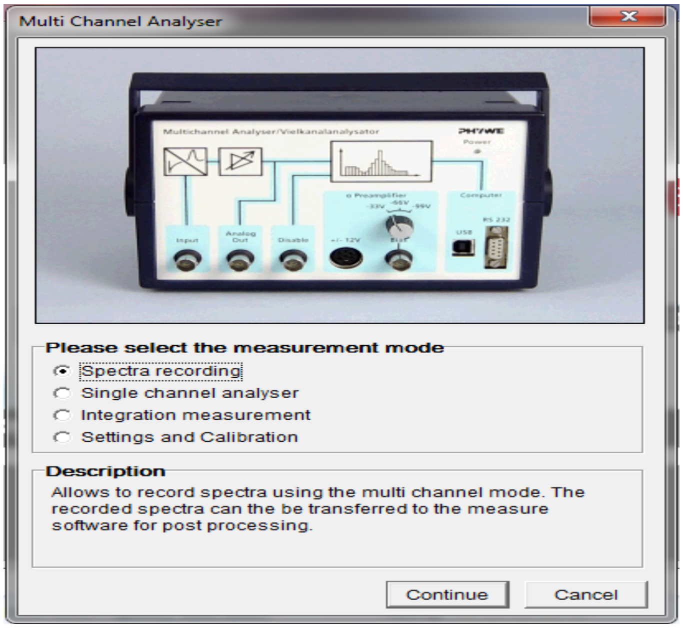
3- Connect the multichannel analyzer (MCA) to the computer's using the USB port.

4- Set the multiturn potentiometer of the operating unit to **700 volts** (read the instructions in the manual of gamma detector).

5- start the "Measure" program, select the gauge "**multi-channel analyzer**" and start "File → **New measurement** ".



6- Select “ **spectra recording**” (see Fig. 3).



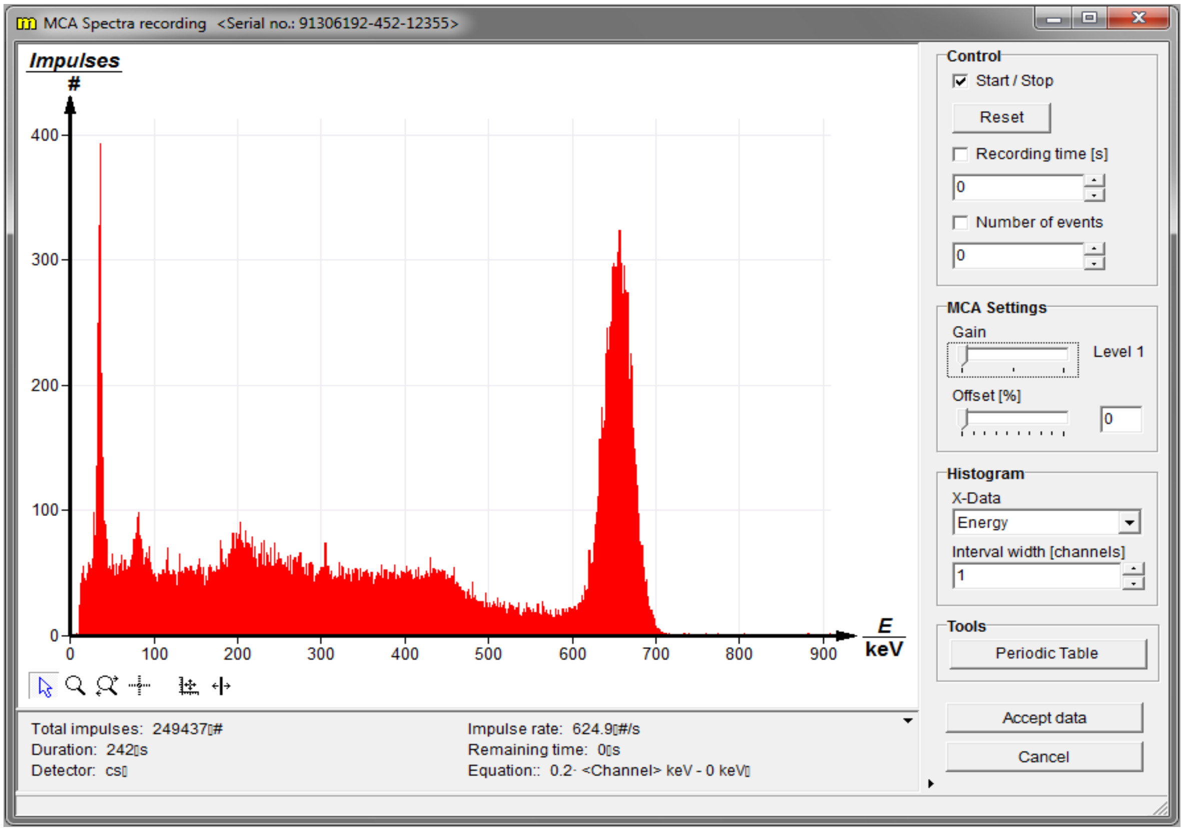
Please select the measurement mode

- ● Spectra recording
- ○ Single channel analyser
- ○ Integration measurement
- ○ Settings and Calibration

Description

Allows to record spectra using the multi channel mode. The recorded spectra can the be transferred to the measure software for post processing.

7- Set the “ **gain**” to “**level 1**”, set the “ **offset**” to “ **0%**”, choose “**Energy KeV**” as **x-data** and set the “**recording time(s)**” on “**1800** “



☑ Start / Stop
☐ Recording time [s]
0
☐ Number of events
0
Gain: Level 1
Offset [%]: 0
X-Data: Energy
Interval width [channels]: 1

Total impulses: 249437 #
Duration: 242 s
Detector: cs
Impulse rate: 624.9 #/s
Remaining time: 0 s
Equation:: 0.2· <Channel> keV - 0 keV

8- Start “data **recording**”, the spectrum should show a distinct maximum from the preferred Compton scattering angle (**$\Theta = 0^0$**), after (10 **minutes**) record a spectrum by using “Accept **data**” and **save the spectrum**.

9- Raped the steps (5,6 and 7) for each angle (**Θ**$=30^0$, 60^0 and 90^0).

10- For **each measurement** determine the **centroid energy** of the scattered peak **(E′) experimentally**.

11- Calculate the (**E′**) **theoretically by using the Equ. (1).**

12- Plot graph between the **energy** (**E′**) **(experimentally** and **theoretically**) as a function of **angles θ**.

13- Plot the reciprocal of the scattered gamma-ray energy (**1/E′**) as a function of **(1 - cos θ)**. Use the graph and **Equation 1** to determine the original gamma-ray energy and the rest mass of the electron.

❖ Questions

- Define each of the Compton shift and Compton wavelength.
- Determine the angles of maximum and minimum transfer of energy to the recoil electron.
- At which range of photon energy the Compton Effect is more predominant than PE and PP.
- Does the Compton Effect observed for the visible light photons? Explain.

Experiment (6):

Activity measurement of Gamma – Source (relative method) Using Scintillation Detector and MCA

Purpose:

- Outline one procedure by which the activity of a source can be determined called the relative method.

Principle:

Radioactive decay covers 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 the 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 $3.7 \text{x} 10^{10}$ disintegrations per second.

But more practical is 1 μcurie = $3.7 \text{x} 10^{4}$ dis./sec.

In the 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.

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

A_s: activity of the known source.

A_u: activity of the unknown source.

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

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

$\sum N_u$: Sum of counts under the photopeak of an unknown source.

$\sum B_u$: Sum of background counts under the photopeak of an unknown source.

The resolution of photopeak is found by this equation:

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

R; is the resolution per cent.

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

E: baseline voltage at centred photopeak.

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.

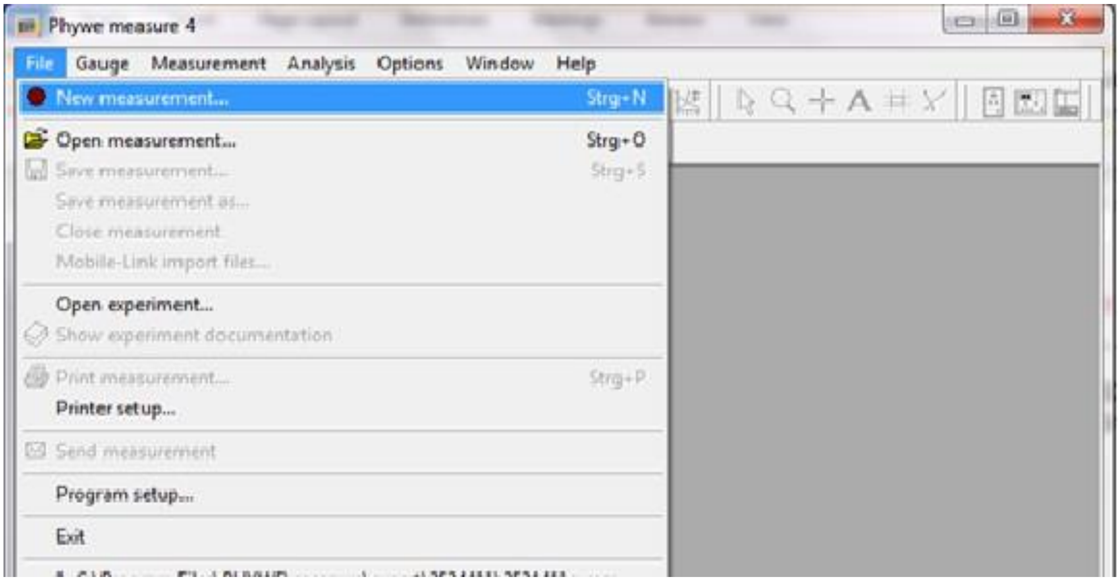
Equipment

Multi-Channel-Analyzer, Extended version	13727.99
Software for Multi-Channel-Analyzer	14452.61
Radioactive Source Cs-137, 37kBq	09096.01
Gamma detector (Scintillation detector)	09101.00
Operating unit for gamma detector	09101.93
High voltage connecting cable	09101.10
Shielding cylinder for gamma-detector	09101.11
Lead block, 200 x 100 x 50 mm	09029.11
Lead brick with hole	09021.00
Screened cable, BNC, l = 750 mm	07542.11
PC, Windows® XP or higher	

Experiment Guide:

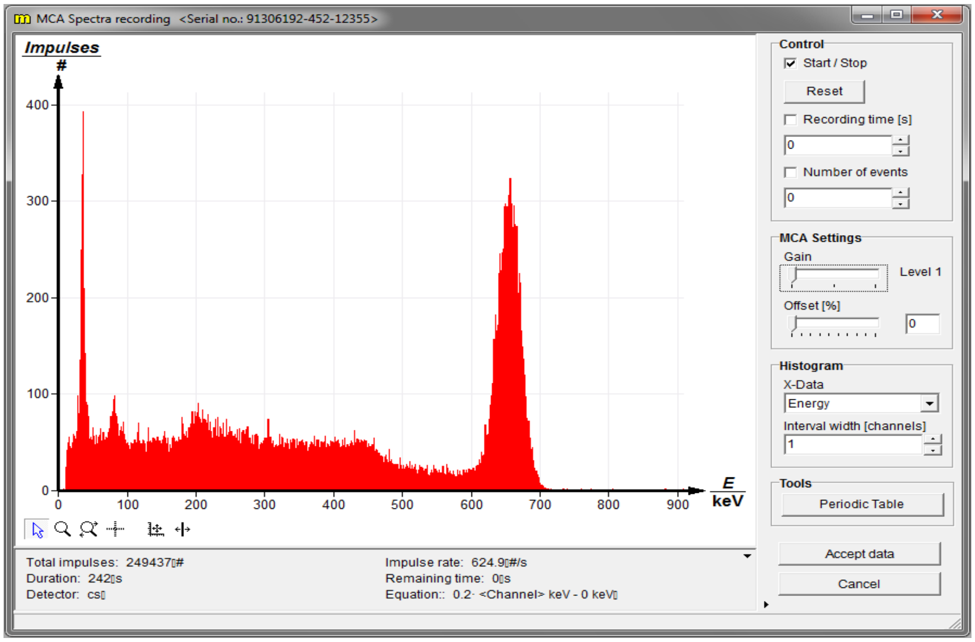
1. Set up the apparatus as shown in Fig. 1.

2. Before turning on the operating unit for the scintillation detector, connect the high voltage cable correctly to the operating unit and photomultiplier.
3. Connect the multichannel analyzer (MCA) to the computer's using a USB port.
4. Set the multitier potentiometer of the operating unit to **700 volts** (read the instructions in the manual of gamma detector).
5. start the "Measure" program, select the gauge "**multi-channel analyzer**" and start "File → **New measurement** ".



6- Now start the MCA gauge again and select "spectra **recording**" (see Fig. 3).

7- Set the " **gain**" to "**level 1**", set the " **offset**" to " **0%**", choose "**Energy KeV**" as **x-data** and set the "**recording time(s)**" on "**1800** "



☑ Start / Stop
☐ Recording time [s]: 0
☐ Number of events: 0
Gain: Level 1
Offset [%]: 0
X-Data: Energy
Interval width [channels]: 1

Total impulses: 249437 #
Duration: 242 s
Detector: cs
Impulse rate: 624.9 #/s
Remaining time: 0 s
Equation:: 0.2· <Channel> keV - 0 keV

8- Start “data **recording**”, the spectrum should show a distinct maximum from the preferred angle (**Ɵ= 0**$^{0)}$, after (20 **minutes**) record a spectrum by using “Accept **data**” and **save the spectrum**.

9- Calculate the sum of counts under the peak of the standard source.

10- Evaluate the background counts rate.

11- Repeat steps (5-10) for another ^{137}Cs source (with unknown activity).

12- Use equation (1) to calculate the activity of the unknown source.

13- Use equation (2) to determine the resolution of your detector.

❖ Questions

- On what factors does the activity of radioactive sources depend?
- Can you use two different kind radioactive sources to perform this experiment? Explain.
- Compare between the resolution of G-M, Scintillation, and Semiconductor detectors.
- Relate the FWHM to the standard deviation.

Experiment (7):

Energy Calibration of the Scintillation Detector and Energy determination of the unknown Gamma Emitter Source

❖ Apparatus

- NIM Bin and Power Supply
- High Voltage Power Supply
- Scintillation Detector
- Scintillation Preamplifier
- Linear Amplifier
- Single-Channel Analyzer
- Timer & Counter
- Oscilloscope,
- ^{137}Cs, ^{60}Co, and ^{22}Na radioactive sources
- Connecting Cables.

❖ Purpose

The purpose is to calibrate a gamma-ray spectrometer system and then to measure the photopeak energies of unknown gamma emitter and to identify the unknown isotope.

❖ Theory

Most isotopes used for gamma measurements also have betas in their decay schemes. The typical decay scheme for the isotope will include a beta decay to a particular level followed by gamma emission to the ground state of the final isotope. The beta particles will usually be absorbed in the surrounding material and not enter the scintillator at all. This absorption is normally assured with aluminium absorbers. For this experiment the betas offer no real problem, so absorbers are not specified; there will be some beta absorption by the light shield over the phototube. The gammas, however, are quite penetrating and will easily pass through the aluminium light shield.

Radioactive nuclei decay by emitting beta or alpha particles. Often the decay is an excited state of the daughter nucleus, which usually decay by emission of gamma-ray. The energy levels (decay scheme) and therefore the gamma-ray energies for any nucleus is unique and can be used to identify the nucleus.

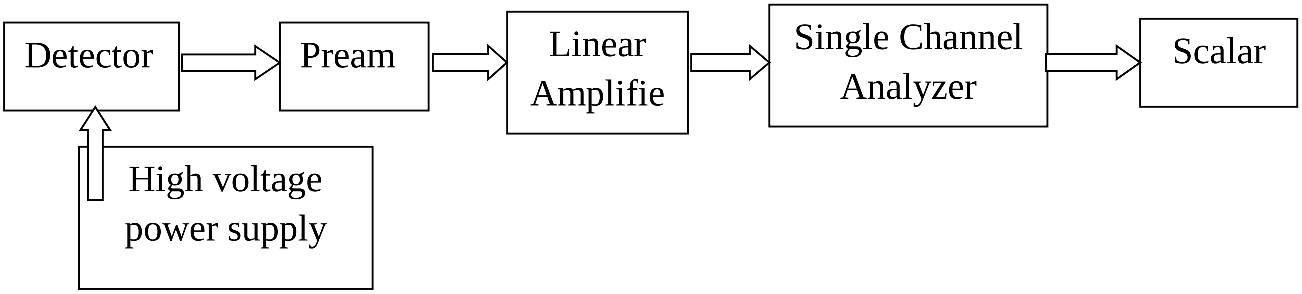
To use γ-ray spectrometer for determining the energy of unknown γ- ray, the spectrometer should be calibrated with standard radio-active sources such as ^{60}Co, ^{137}Cs and ^{22}Na which their energies are known previously. The energy levels and decay schemes of these sources are given in theoretical overview on page 5.

It is found that ^{60}Co decay by electron emission to the second excited state of ^{60}Ni which de-excited by emitting two successive γ-rays of energies 1173 KeV and 1333 KeV, while ^{22}Na decays by positron emission to first excited the state of ^{22}Ne which is de-excited by emitting gamma-ray with energy 1275KeV.

We can obtain the energy of any unknown γ-ray energy by evaluating the graph between known γ-ray energies and the BLV of SCA; drawing energy spectrum of each used standard source is necessary for plotting the calibration curve.

❖ Procedure

1. Set up the electronic equipment as shown below:



2. Place the radioactive source at about 2 cm or 3 cm far from the face of the detector.
3. Set operating voltage at 950 volts and window width of (SCA) to 0.2 volts.
4. Adjust the gain of the amplifier so that the 1333 KeV photopeak of Co at about 8 volts of BLV.
5. Obtain the spectrum of ^{60}Co by taking count per minute and different setting of BLV.
6. With the same adjustment obtain the spectrum of ^{22}Na and ^{137}Cs.
7. Determine the photopeak energy of ^{22}Na , ^{60}Co and ^{137}Cs, and draw a graph between known γ-rays energy and (BLV).
8. Find the γ-rays energies of ^{22}Na.

Questions

1- Why it is necessary to calibrate the gamma-ray spectrometers?

2- Is there any condition on selecting a proper standard source for calibration studies?

3- Within the gamma-spectrum of ^{22}Na, explain the origin of 511keV energy line.

4- Why it is better to use a multi gamma-source instead of single sources in this exp.?