INTERNATIONAL STANDARD SERIAL NUMBER
eISSN: 2789-858X

SCIENTIFIC JOURNAL FOR THE FACULTY OF SCIENCE - SIRTE UNIVERSITY

DOI: 10.37375/issn.2789-858X - Indexed by Crossref, USA

VOLUME 3 ISSUE 2 OCTOBER 2023

Bi-annual, Peer- Reviewed, Indexed, and Open Accessed e-Journal

Legal Deposit Number@NationaL Library (Benghazi): 990/2021

1.02/2022

jsfsu@su.edu.ly
journal.su.edu.ly/index.php/JSFSU

Scientific Journal for the Faculty of Science-Sirte University Vol. 3, No. 2 (2023) 177-181

Scientific Journal for the Faculty of Science-Sirte University

Journal home page: http://journal.su.edu.ly/index.php/JSFSU/index
DOI: 10.37375/issn.2789-858X

Spectroscopy of Alpha-Particles Using the Thermally Diffused p-i-n Detector

Abduljalil E. Abdulhadi and Haniya S. Alhoweij

physics Department, Sciences Faculty, Baniwaleed University, Libya.

DOI: https://doi.org/10.37375/sjfssu.v3i2.1662

ARTICLE INFO:

Received: 03 September 2023

Accepted: 15 September 2023

Published: 26 October 2023

Keywords: alpha particles, absolute activities, ^{241}Am, ^{244}Cm ,^{239}Pu.

A B S T R A C T

The goal of this experimental work is to learn more about the characteristics of alpha particles, how they interact with matter, and their range. A thermally diffused detector and a triple alpha source with the isotopes ^{239}Pu, ^{241}Am, and ^{244}Cm were employed in the experimental work. The primary aim was to obtain three main energy peaks and then determine the absolute activities of these isotopes. The absolute activities were calculated, and they were 1652.38±40.6 Bq, 936.38 ±30 Bq, and 706.8±26 Bq for ^{239}Pu, ^{241}Am and ^{244}Cm respectively. The second aim was to calibrate the Multi-channel analyser at lower energies known as attenuation output using the initial pulser peak that covered the Am^{-241} peaks at an energy of 5.49MeV. The FWHM was estimated using counting statistics to be 11.23.35 kev. Then, it was determined when the alpha emission for three isotopes started to stop, using an extrapolated range of alpha particles. In order to draw the graphs of each radioisotope's peak energy versus air pressure and the FWHM versus six spectra of gas pressures, air pressures of various m-bar air pressures were measured. The procedure should ultimately be completed by measuring the intensity of -particles and documenting the peak count rate for a particular element, in this case ^{244}Cm.

1 Introduction

The radiation emitted by naturally occurring materials has been shown to have the least penetration when it comes to alpha particles. Coulomb repulsion is the cause of alpha emission. It is crucial for interactions with matter, especially with heavy nuclei, which take place because the disruptive Coulomb force accelerates with increasing size (Knoll et al, 2010). The technique used to assess the energy of particles and their activity is known as alpha particle spectrometry. It could identify the radiation's source. In light of this, charged particle spectrometry dominates radiation physics (Lilley, 2013).
Alpha particles consist of one proton and two neutrons. They have a strong electron charge and high energy. They have substantially greater masses when compared to beta and gamma particles. They are not particularly piercing, though. For instance, 5 MeV of -particles can pierce common paper with a penetration depth of only 3.6 cm in air (Knoll et al, 2010). The emission of alpha particles produces elements that have a high atomic number. For example, alpha particles are emitted throughout the decay of radium.

$^{266}\text{Ra} \rightarrow \; ^{222}\text{Rn} + \alpha$

The next figure shows how radium degrades from a high energy state to a lower energy state, which results in a reduction of protons and the emission of alpha particles.

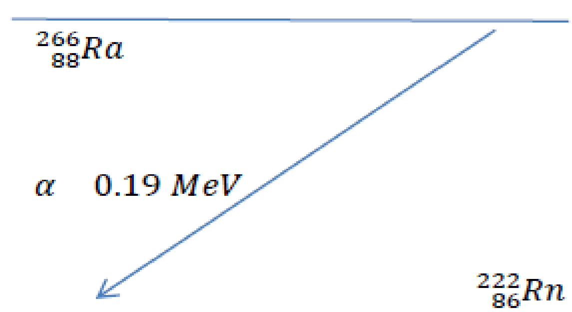

Figure (1): the decay of Ra^{-266}

Corresponding author: **E-mail: abduljalile570@gmail.com**

2 Theory

In alpha decay, the parent atom ejects a defined daughter nucleus with a double charged particle (4He-nucleus) and a release of heavy particles. Alpha particles can be stopped by a layer of skin or a sheet of paper (Knoll et al, 2010). Also, if an alpha particle emitter is inhaled or ingested, it can cause very serious damage to a human's health. Alpha decay can be represented as (Knoll et al, 2010. Lilley, 2013).

$$ {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha + \gamma $$

Alpha particles can interact with either nuclei or orbital electrons in any absorbing medium, such as air, water, tissue, and metal. There is an amount of alpha emission passing through the nucleus that could be deflected with no change in energy (Rutherford scatting). However, defects could occur with a small change in energy or be absorbed by the nucleus, causing transformation. This process is called negligible for alpha particles (Cember, 2009). The most likely process in the absorption of alpha is the ionization and excitation of orbital electrons. Ionization occurs when the alpha particles are close to electron and pull it out from orbit though coulomb attraction, as the result α- particles lose kinetic energy and become slow. They can lose their kinetic energy by exciting orbital electrons with interactions that are inadequate to cause ionization. As the alpha closes to the end of its way, its rate of ionization peaks, and within a very short distance, it stops, collects two electrons, and becomes a helium atom (Cember, 2009).
The absolute activity can be estimated using the equation below:

$$ I = \frac{C\alpha}{f} \times \frac{4\pi d^2}{A} \qquad Eq\ 1 $$

Where I is the absolute alpha activity, f is the fractional intensity of a particular alpha peak energy, Cα is count rate , A is the area of the detector active surface, which is 1.3 cm^2 and d is the source detector distance, ,which is 1.5cm. The alpha particle range is the distance where it travels in the air and has the lowest penetration because of its short range and attenuation.
The empirical equation below is used to calculate the predicted range of alpha particles:

$$ R_{\alpha} = 0318E^{1.5} \qquad Eq\ 2 $$

STP is Standard Temperature and Pressure
MCA is Multi Channel Analyser
Where Rα is the range of alpha particles in air at STP in cm, Eα is the energy of alpha particles in MeV.

Accurate calibration with low energies at the MCA scale is required. The pulsar injection is likely to be used; the width of the pulsar peak is obtained through the MCA. The width of the peak due to statistical noise can only be calculated via the equation below:

$$ \mathrm{FWHMtot}_{total} = \sqrt{(\mathrm{FWHM_{elec}})^2 + (\mathrm{FWHM_{stat}})^2} \; Eq3 $$

Where $\mathrm{FWHMtot}_{total}$ is the width of the ^{241}Am peak which used in the experiment and $\mathrm{FWHM_{stat}}$ is the width of the pulser peak that is in jested into the MCA (Regan, 2014).
When the pressure increases, the widths of α-peaks increase due to energy straggling, which is an increase in the energy distribution of α-particles reaching the detector due to fluctuations in the number of atomic collisions.
A theoretical prediction may be written in the form:

$$ \mathrm{FWHM} = 41.6(\Delta x)0.5\ \mathrm{KeV} \qquad \mathrm{Eq}\ 4 $$

Where is the air-path thickness expressed in mg cm^{-2}. In this experiment, this prediction could be obtained by drawing a graph of the FWHM of the ^{241}Am peak versus the square root of the air thickness (Regan, 2014).

3 Experimental Methods

The thermally diffused p-i-n detector was used to obtain alpha spectrometry, and the triple-alpha source consisting of ^{239}Pu, ^{241}Am, and ^{244}Cm is placed on the source holder at a distance of approximately 1.5cm from the detector within a vacuum chamber. The operating voltage was set at 24 volts, the time live was 300 seconds, the shaping amplifier was 1 sec, the gain was 100, and the vacuum pump was at zero m-bar.
The first spectrum was recorded, and the three main peaks were accumulated.

The MCA was calculated via the three main peaks, and report information was obtained for each peak in order to calculate the absolute activity of three isotopes. To obtain the range of alpha particles, it must calibrate the MCA at lower energies, and that mainly depends on the initial energy pulser that was injected into the MCA and the known attenuation of the pulser output. Then the dates were obtained, graphs plotted, and the alpha range demonstrated. The predicted range of alpha particles to three isotopes was estimated.

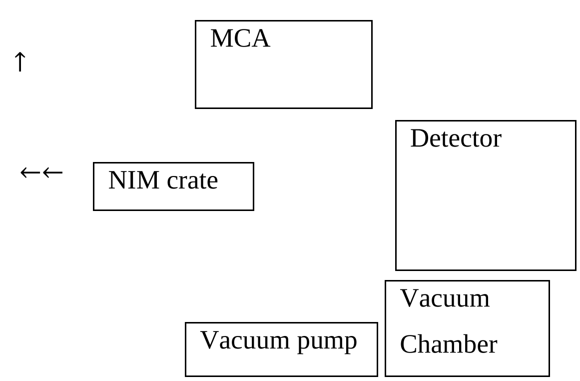

Figure (2): The thermal diffused p-i-n detector and vacuum chamber

4 Result

The three main peaks were obtained on the MCA from the triple alpha source, as will be shown in Appendix 1. Figure 2 shows the calibration between the FWHM of the three main peaks of ^{239}Pu, ^{241}Am, and ^{244}Cm versus their peak energies.

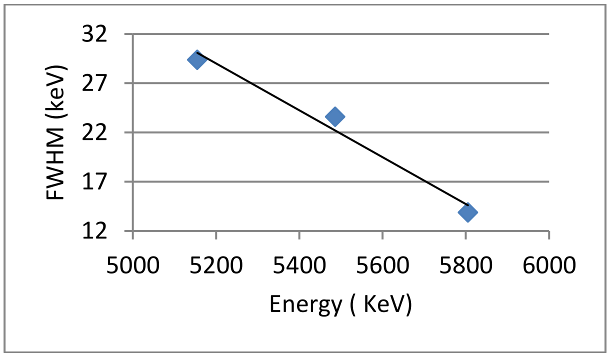

Figure (3): describes inverse relationship between an increase of energy and the decease of the FWHM.

The absolute activities of the three isotopes were determined from equation 1 and are displayed in Table1.

Table (1): the absolute activity of the three isotopes

Isotopes	Count rate with errors(cps)	Fractional intensity	Absolute activity with errors(Bq)
^{239}Pu	4.16	0.73	1652.38±40.6
^{241}Am	2.78	0.86	936.38±30.6
^{244}Cm	1.78	0.73	706.8±26.5

The MCA was calibrated at lower energies, which depend on the initial energy pulser where it was injected into the MCA and the known attenuation of the pulser output.

Table (2): shows the calibration of the MCA at low energies. The pulser output versus reference energy is plotted in figure3.

Attenuation Pulser out-put	Reference Energy(KeV)
0.5	2743
0.2	1097.2
0.14	783.7

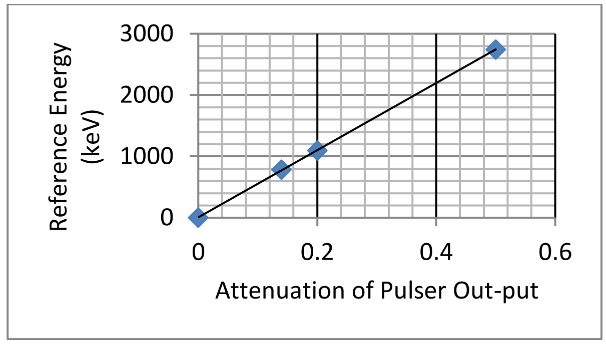

Figure (4): Calibration of the MCA via the Known pulser peaks

The FWHM is statistically calculated from equation 3. The ^{241}Am isotope is selected to present other isotopes.

The $FWHM_{total}$ of the ^{241}Am was 13.65KeV and the pulse peak (FWHMelec) was 7.74KeV. The value of $FWHM_{stat}$ was roughly 11.2±3.35 KeV. It could be seen that two peaks were almost close to each other.
Fiqure 5 plots the energy of three isotopes versus air pressure.

Table (3): The data of isotopes energies with pressure air

	Isotopes energy(kev)		
Pressure	^{239}Pu	^{241}Am	^{244}Cm
200	6661.96	7453.02	8239.44
400	6095.71	6860.13	7661.27
600	5584.27	6217.6	6982.85
800	4947.44	5746.56	6507.11
1000	4382.52	5125.89	5899.92

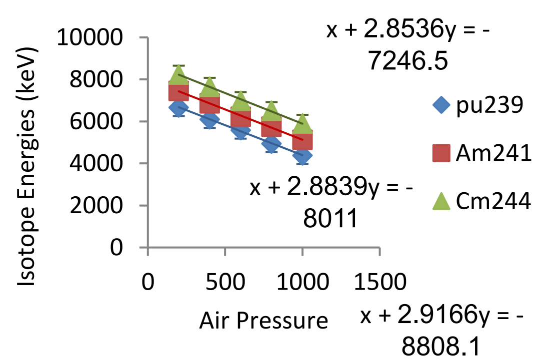

Figure (5): displays the energy of the three isotopes versus air pressure.

The equation used to calculate the extrapolated alpha particle range was:
Rα = air thickness × source to detector distance
Where Rα: is the extrapolated range of alpha particles expressed in mg/cm^2.

The source-to-detector distance is 1.5 cm, and STP is the density of the air at 1.293 mg/cm^2.

Table (4): the extrapolated range of alpha particles for the three isotopes.

Isotopes	Estimated pressure (m-bar)	Air thickness	Extrapolated range Rα cm
^{239}Pu	2539.4	3.3	4.9±2.2
^{241}Am	2777.8	3.6	5.4±2.4
^{244}Cm	3019.9	3.9	5.9±2.4

The predicted range of the same isotopes is calculated by using empirical equation 2.

Table (5): shows the predicted range of alpha particles for the three isotopes.

Isotopes	Energy of α-particles MeV	Rα cm
^{244}Cm	5.805	4.5
^{241}Am	5.486	4.1
^{239}Pu	5.155	4.5

This time, equation 4 was used to calculate the values of air thickness in order to obtain the relationship between FWHM and a small attenuation of air thickness in different positions of air pressure.

Table (6): gives data of the calculated air thickness.

	FWHM(keV)		
Air pressure (m-bar)	^{241}Am	$\Delta x^{0.5}$ mg.cm^{-2}	$\sqrt{\Delta x}$ mg.cm^{-2}
200	13.09	0.314663	0.56
400	55.2	1.326923	1.15
600	109.6	2.634615	1.62
800	67.63	1.625721	1.275
1000	66.71	1.603606	1.266

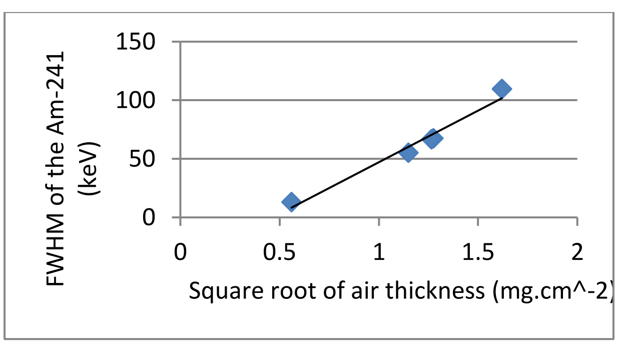

Figure (6): illustrates the direct relationship between the FWHM of ^{241}Am and the square root of the air thickness. Figure 7 illustrates the intensity of alpha particles by the count rate versus air pressure.

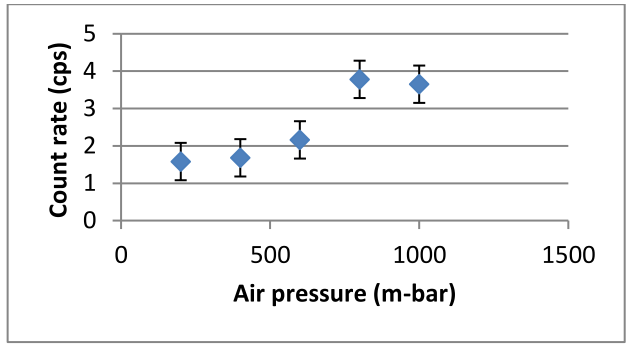

Figure (7): illustrates the intensity of alpha particles by the count rate versus air pressure.

5 Dissection

Figure 2 displays the spectrum, which has three main peaks that are relevant to the energies of the three isotopes ^{239}Pu, ^{241}Am and ^{244}Cm. The MCA calibrated the spectrum by using three dominant energies, which were 5155 keV, 5486 keV, and 5805 keV.

Figure 3 shows the inverse correlation between the dominant energy peak and the decay of the FWHM.

Figure 4 showed the correlation between the reference energy and the attenuation of pulser output. It confirms that the calibration of MCA was accurate at low energies, and that is principally due to the straggling of alpha particles.

Figure 5 illustrates the inverse relationship between the decrease in the energy of alpha particles and air pressure. The air pressure increases as the energies decrease, and this may result in the loss of energy and subsequently increase the probability of straggling alpha particles, which increase with matter in their traveling path.

The extrapolated alpha particle range is calculated via equation 3. The latter confirms the fact that the maximum alpha particle range is linked to the higher energy contained.

Figure 6 illustrates the direct correlation between the FWHM of the three isotope energy peaks and the square root of the air path thickness. It means that the probability that may occur with a small scattering of alpha particles may also be repeated in a small unit of air pressure. However, the probability of noise may increase because the straggling of alpha particles has increased.

Finally, figure 7 shows the inverse correlation between air pressure and the count rate of alpha particles, which results in the α-particles moving in a straight line with small fluctuations in energy due to their heavy mass.

6 Conclusion

The purpose of this experiment was to understand the properties of alpha particles and their interactions. The logarithmic spectrum was identified with three isotopes main energy peaks. The MCA was calibrated in order to correct the weak structures within the MCA scale at lower energies. These weak signals confirmed the straggling of alpha particles and the creation of noise within the scale. The absolute activities of the triple alpha source were determined, and they were 1652.38±40.6 Bq, 936.38 ±30 Bq, and 706.8±26 Bq for ^{239}Pu, ^{241}Am and ^{244}Cm respectively. Statistically, the full-width half maximum of ^{241}Am was calculated at 11.2±3.35 KeV. The extrapolated ranges were obtained from the curve that represented the energy peaks versus air pressure graph; they were 4.9±2.2, 5.4±2.4, 5.9±2.4.
In short, alpha particles are heavy and fully charged. They interact effectively with matter despite the fact that their penetration ability is low. In addition, they are usually not hazardous for outer exposure. One may conclude that when α-particles internally deposited, they could be more damaging than other particles due to the amount of energy deposited inside a small volume of tissue.

Conflict of Interest: The authors declare that there are no conflicts of interest.

Reference

Cember, H. (2009). *Introduction to health physics*.
Knoll, G. F. (2010). *Radiation detection and measurement*. John Wiley & Sons.
Knoll, G. F. (2000). *Radiation detection and measurement*, 3rd edition, John Wiley and sons. New York.
Lilley, J. (2013). *Nuclear physics: principles and applications*. John Wiley & Sons
Regan, p. (2014). *Laboratory Booklet,* University of Surrey, UK.

SCIENTIFIC JOURNAL FOR THE FACULTY OF SCIENCE – SIRTE UNIVERSITY

jsfsu@su.edu.ly
journal.su.edu.ly/index.php/JSFSU