Introduction

Radioactive isotopes are species with the same chemical element with different masses whose nuclei are unstable and dissipate excess energy by spontaneously emitting radiation in the form of alpha, beta, and gamma rays. The rate of decay of these isotopes leads to a formulation of the exponential law of radioactive decay. (Krane)

$$N(t) = N_0 e^{-\lambda t} + B$$

This equation gives the number ($N(t)$) of present nuclei of a radioactive sample at time t given that the initial number of present nuclei at $t = 0$ is N_0 and the decay factor λ is a constant. B is the average background radiation. The half life ($T_{\frac{1}{2}}$) is the time it takes for half of the nuclei of the radioactive isotope to decay. $T_{\frac{1}{2}} = \frac{\ln(2)}{\lambda}$

Aim: This experiment aims to determine the half-life of Aluminium-28.

The methods and apparatus used in this experiment are detailed in the (Hutton, 2021) document.

Results and Analysis

Figures 1 and 2 (on the next page) show the calibrated gamma ray spectra of Aluminium-28 (28Al)using a log scale on the vertical axis. According to (Basunia, 2013) a full energy photopeak should be expected at 1778keV. As expected, a photopeak is seen in figure 1 at the expected energy. Another photopeak at around 835keV and there is no evidence that this results from the decay of 28Al. Hence, to obtain a plot for the radioactive decay of 28Al careful attention is paid to the region (from 1400keV to 2000keV) around the photopeak at 1778keV. A step plot of this region can be seen in figure 2. The choice of region was made to avoid much of the background noise that can be seen in figure 1 at energies higher that 2000keV and to avoid energies and features resulting from the radioactive isotope responsible for the photopeak at 835keV and any other contributions (that are not from 28Al) that result in the noise observed in the Compton continuum. Hence this report considers the data from just before the Compton edge to 2000keV.

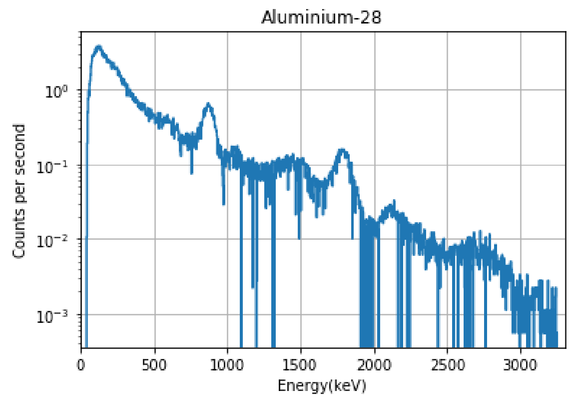

Figure1: Step plot showing the calibrated gamma spectrum of 28Al with energy given in keV on the horizontal axis and counts per second given on a log scale on the vertical axis. Since the decay of nuclei is random the decay follows a poisson distribution hence, the uncertainties of each of the points is taken to be the square root of each data point. The noise seen on this spectrum is a result of average background radiation subtraction measured over three ten second periods.

Decay of 28Al

Figure 3 below represents the decay of 28Al as a function of time. This was obtained by summing the number of gamma rays detected (and subtracting the average background count rate) within the region specified by figure 2 in 10 second intervals for 30 minutes. Along with this summation an uncertainty propagation was performed as shown below.

If x_i represents the counts obtained in a 10 second time interval for at energy, and $u(x)$ in the uncertainty associated with x_i then $u(x) = \sqrt{\sum_{i=1}^{n} x_i u(x_i)^2}$ where n is the number of data points at each time interval.

In the first few seconds (>720seconds) the average number of points generated to produce the gamma ray spectrum seen in figure 2 was 180 and the sum of these points were on average 461 counts per 10 seconds. In the final 1080 seconds the number of data points produced to generate the gamma ray spectrum was on average 50 and the sum each of these points per 10 second time interval was on average 50 counts per 10 second interval for the whole gamma ray spectrum. For this reason the plot and half-life is determined for the points in figures 3 obtained for the first 720 seconds.

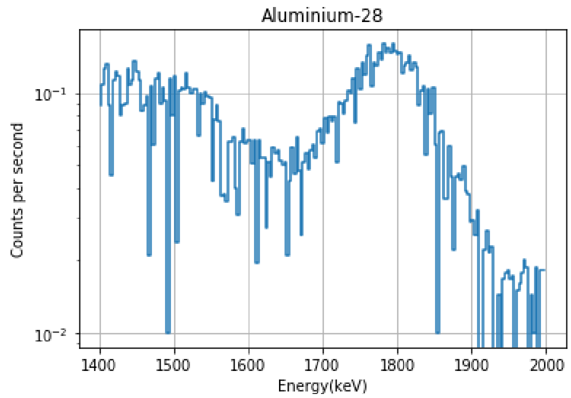

Figure2: Step plot showing the same calibrated gamma spectrum of 28Al as shown in figure 1 with the energy ranging from 1400keV to 2000keV

Half-Life of 28Al

To obtain the half life of 28Al, the data points in figure 3 were linearized and this was done by ting the natural log of each of the data points in figure 3 and fitting them to

$$\ln(N(t) - B) = lnN_0 - \lambda t$$

Using the python curve_fit function from the scipy.optimize module, each of the data points in figure 3 were fitted and to propagate their uncertainties the uncertainty of the data points were updated to be the uncertainty of the data point as seen in figure 3 divided by the count per second.

From this the value of the half-life was determined to be $T_{\frac{1}{2}} = 195.96 \pm 0.00012\ seconds$

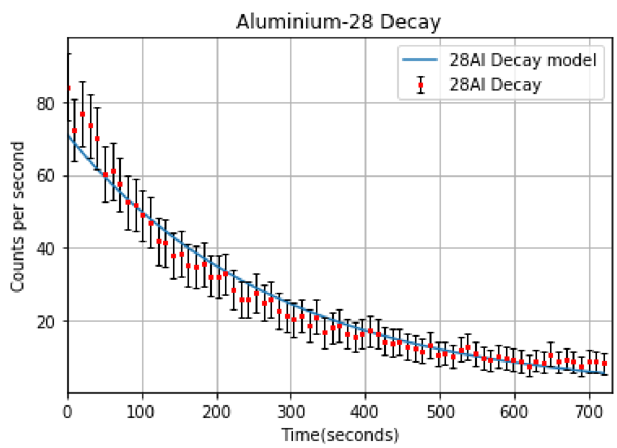

Figure3: Errorbar plot showing the decay of 28Al as a function of time. The 28Al Decay model shows the expected trend. The figure shows counts per second on the verical axis of the summed sets of 28Al and time on the horizontal axis.

Bibliography

Basunia, M. S. (2013). *Nuclear Data Sheets 114.* Retrieved from Nudat 2.8: https://www.nndc.bnl.gov/nudat2/decaysearchdirect.jsp?nuc=28AL&unc=nds

Hutton, T. (2021, July 8). *HalfLifeLabManual.* Retrieved from Vula: PHY3004W: Resources: https://vula.uct.ac.za/access/content/group/275677d7-258c-4507-b368-7cb674c91ca0/Laboratory/Lab%204%20Half-life/HalfLifeLabManual.pdf

Krane, K. S. (n.d.). *Introductory Nuclear Physics.* Retrieved July 19, 2021, from Vula: PHY3004W: Resources: https://vula.uct.ac.za/access/content/group/275677d7-258c-4507-b368-7cb674c91ca0/Laboratory/Lab%204%20Half-life/Resources/Krane_IntroductoryNuclearPhysics.pdf