Introduction:

Atoms, once thought to be the basic building blocks of nature, are now known to be built from smaller constituents: a positive massive nucleus surround by electrons in orbitals. The nucleus itself is composed of neutrons and protons bound together by the strong nuclear force. Certain nuclei are unstable and transform or decay by emitting radiation. There are three types of radiation: alpha particles, beta particles and gamma particles. Alpha particles are actually doubly ionized helium nuclei. Beta particles are electrons that have been emitted from the nucleus when a neutron decays to a proton. Gamma rays are high energy photons that are emitted when a nucleus changes from an excited state – usually because it was left in this state after one of the other decays..

Each type of unstable nucleus has a particular probability of decaying in a given amount of time. This probability is constant, independent of time and internal conditions. Given *N* nuclei the rate of decay is given by

$$\frac{dN}{dt} = -\lambda N$$

Where λ is the probability a nucleus will decay per unit time and is called the decay constant

The solution to this differential equation is

$$N = N_0 e^{-t\lambda}$$

Where N_0 is the initial number of nuclei. The rate at which radiation is emitted from a sample of *N* nuclei is called the activity of *R,* where $R = \lambda N$. It therefore follows that activity decays in the same way as *N.*

$$R = R_0 e^{-t\lambda}$$

Radiation samples with high activity are more damaging than those, but the type and energy of the radiation is also a factor. Alpha radiation, being massive and charged, is highly damaging, although it because it is charged and relatively large and alpha particle is stopped before it penetrates too deeply. Beta particles and gamma particles do not interact as much, and so penetrate the body more deeply. The more energetic a beta particle is the more deeply it penetrates a body. This is also generally true for gamma rays, although very high energy gamma rays tend to interact more strongly and so do not penetrate as deeply.

This lab consists of two parts. In the first part you will investigate the absorption of different types of radiation by different thickness of aluminum and lead. For a given type of radiation the thickness of material that is necessary to stop the radiation is a measure of the energy of that radiation. In the second part of the lab you will measure the decay constant for the decay of Barium 137M, which is an excited state of Barium 137 that emits gamma radiation. Ba137M results when Cesium 137 decays to Ba137 by beta decay, leaving the nucleus in an excited state.

Part A: Absorbtion of Radiation

Procedure:

1. The main instrument you will use to measure the radiation is a Geiger counter, which register the number of radiation events entering a small window over a period of time. Hook up the Gieger counter to the logger pro and attach the Gieger counter to a ring stand so that the window is facing down, about 3 cm from table top. Set the logger pro to sample every 30 seconds. Then allow it to run for 5 minutes. This will give 10 measurements of the amount of background radiation in 30 second intervals. The average of these results is the background radiation level. When doing the quantitative analysis of your radiation data you should subtract this background level from your measurements.
2. Now obtain an alpha source. Place the source under the Geiger counter and measure the radiation for a few minutes. Then place paper between the source and the Geiger counter. Approximately how much paper do you need until the radiation is back down to background levels?
3. Now obtain a beta source (Strontium 90) and place it under the Geiger counter. Notice that paper does not significantly reduce the radiation count. Instead use the disks of aluminum to absorb the radiation. Starting from the thinner disks of aluminum find the thinnest disk that blocks all the radiation. The thickness of the disks is measured in mg/cm^2 , and the values are given in the box containing the disks*. With this value consult the graph below to determine the energy of the beta particles from your source. Compare with the expected value. Note: the scales are logarithmic.

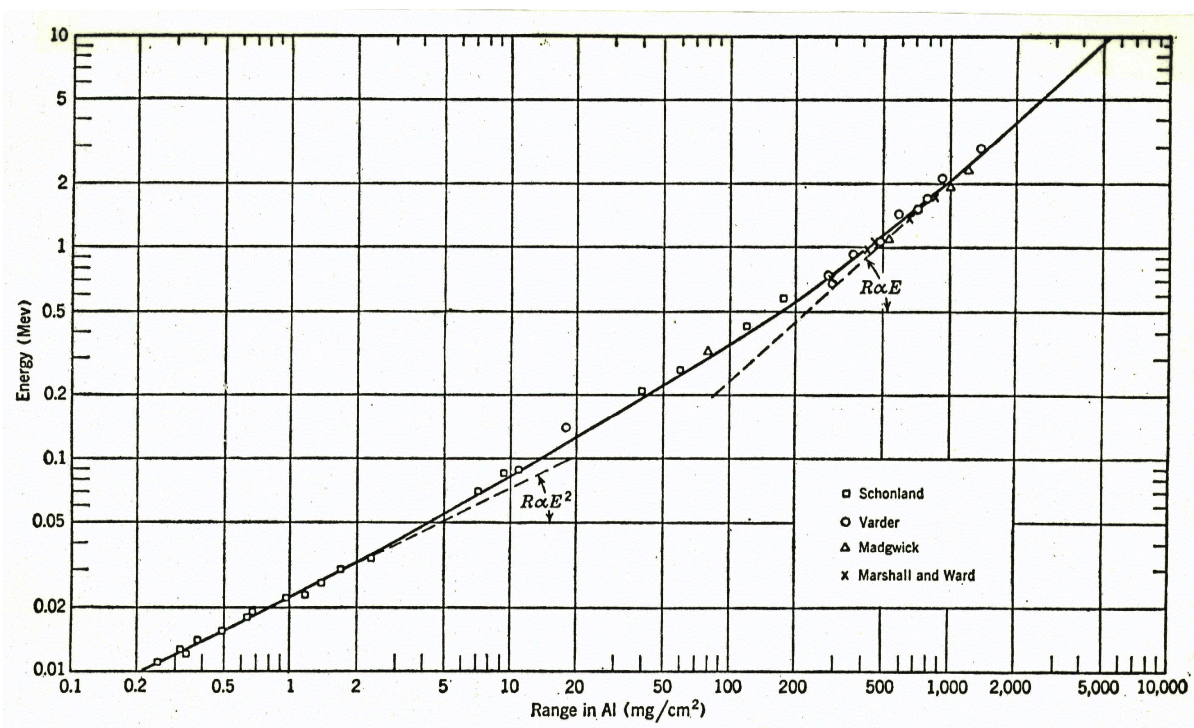


Fig. 3.3 Empirical range-energy relationship for electrons absorbed in aluminum. Experimental values by several observers (S16, V4, M4, M17) on monoenergetic electrons are shown. For *monoenergetic electrons*, the range coordinate refers to the *extrapolated range* R_0 of Fig. 3.2. For *continuous β-ray spectra* the energy coordinate refers to the end-point energy E_{max}, and the range coordinate becomes the *maximum range* R_m of Fig. 3.4. The smooth curve represents the empirical relationship, Eqs. (3.3) and (3.4), developed by Katz and Penfold (K7).

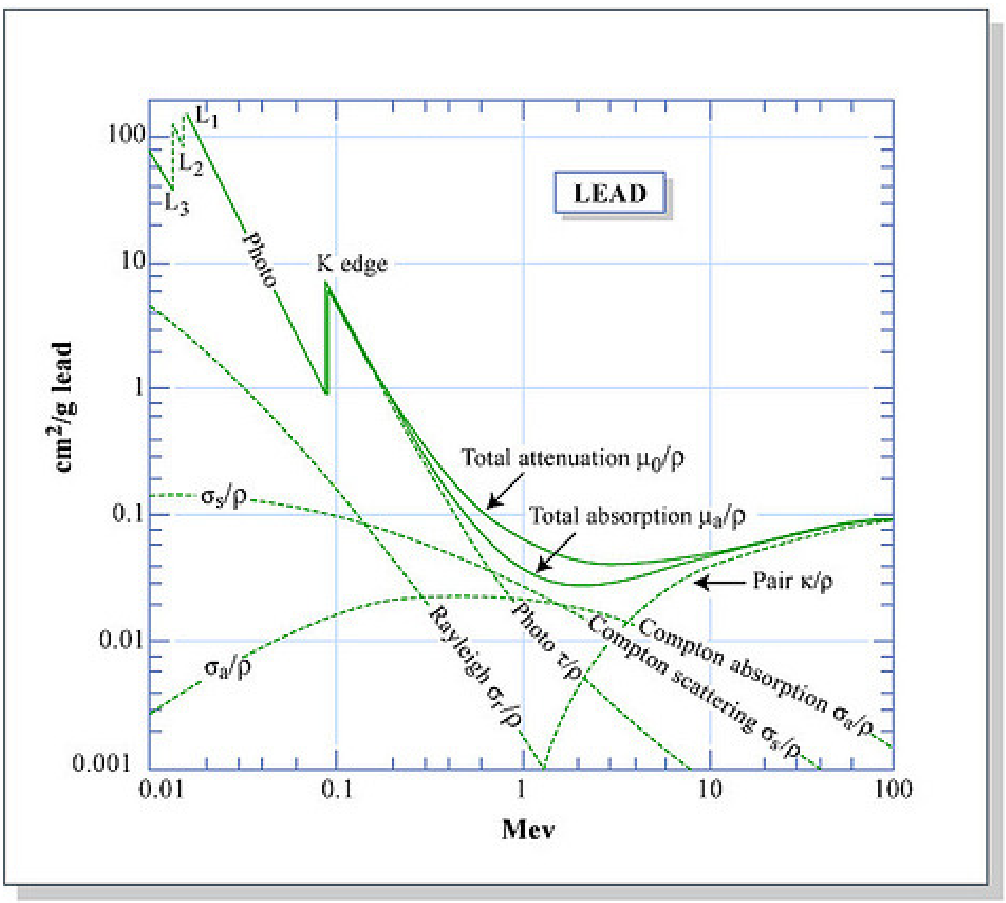
* This may seem like an odd choice of units. However, it is just thickness in cm times the density of the material. Using these units makes it easier to compare the absorption abilities of different materials.

4. Gamma sources interact differently than beta and alpha sources because they are not charged. The principle modes of interaction are the photoelectric effect, Compton scattering and pair production. Gamma rays can in principle penetrate any thickness of material, although for each unit thickness they have a certain probability of being absorbed that depends on their energy. The amount of radiation that penetrates to a thickness *x* is given by the expression

$$R = R_0 e^{-\mu x}$$

Where μ is called the absorption coefficient. If the thickness *x* is measured in mg/cm^2 then μ is measured in cm^2/mg and is called the mass absorption coefficient. The energy of the photon can be determined from the mass absorption coefficient

Obtain a gamma source (Cobolt 60) and place it under the Geiger counter and record the amount of radiation in 30 second intervals for 5 minutes. Now place the thinnest lead disk on top of the sample and record the amount of radiation in 30 second intervals for 5 minutes. Repeat for all five lead disks. For each disk thickness (including the one with no disk) find the average decay rate over 30 seconds. Subtract the average background count. Now plot *R* vs *x* , where *x* is the thickness of the disk in mg/cm^2 and fit and use Excel to fit an exponential decay curve. Find μ and then use the graph of total absorption below to find the energy of the gamma radiation. Note: It is a logarithmic scale



Part B: Measuring the Half-life of Ba137M

For this experiment we will use an isogenerator to separate a sample of Ba137M from a sample of Ce137. Ce137 continuously decays to Ba137M by beta decay with a long half life. Ba137M has a short half life and thus its decay is measureable during one lab period. However, in order to distinguish the Ba137M decay from the Ce137 decay we need to separate the two, and this is what the isogenerator does.

Procedure:

1. When you are ready ask the SIT (Shane) to run the isogenerator to obtain a fresh sample of Ba137M.
2. Place the sample under the Geiger counter and measure the radiation in 30 second intervals for 20 minutes.
3. Subtract the background radiation from each of your 40 measurements and then plot the activity vs time. Fit the data to an exponential decay function and hence find the decay constant. Include the units.
4. The half life is defined as the time it takes for the activity to be reduced by half. The half life can be determined from the decay constant by the following expression: $t_{1/2} = \frac{\ln(2)}{\lambda}$. Hence, find the half life and compare it with the expected value of 2.55 minutes.