Inverse square law for gamma radiation

While conducting this experiment, you will be assessed for CPAC3: Working safely. Your lab report will be assessed for CPAC4: Correctly tabulating sufficient data and CPAC5: Analysis with log graph.

The Aim of the Experiment

This experiment uses a gamma source to investigate the inverse square law. Gamma radiation is the least ionising, but it is very penetrating. Although many of the safety preacutions are the same as for the first year radioactivity experiment, there are some specific differences for handling a gamma source.

The College's radioactive sources are not strong and if treated with care will not harm you. However, the metal casing of the gamma source will not absorb much radiation. It is a Health and Safety requirement that a lab coat be worn whenever you are working with a radioactive source. You need to log out the source from the prep. room. The inverse square law describes how count rate decreases with distance.

With this in mind, before starting the experiment, describe below how the safety precautions for gamma vary from beta, and explain 2 precautions you will take with this source.

Apparatus

Scalar timer
Gamma source
Perspex source holder
Baseboard
Geiger-Muller tube HANDLE WITH CARE
Scalar to Geiger-Muller tube connector
Geiger-Muller tube holder with brass hoop
Rubber tipped tongs (long)

The set up is basically the same as in the first year – ask your teacher if you need help.

Theory

The inverse square law applies for any kind of radiation and describes how the intensity decreases with distance from the source, d. In the case of gamma radiation, the intensity is given by the count rate, A.

$A = k / d^2$ or $A = k\, d^{-2}$, where k is a constant of proportionality

Taking logs of both sides gives: $\log A = \log k - 2 \log d$

A graph of log A against log d should therefore be a straight line with a negative gradient.

Method

Set up the Geiger tube on one end of the baseboard with the counter connected. Use the counter in "frequency rate" mode such that it records the average count rate over 10 second intervals. Carefully place the gamma source in the source holder and position this on the board facing the Geiger tube. Use the markings on the baseboard to measure as accurately as possible the distance from the centre of the source to the Geiger tube window. This may introduce a systematic error, but for safety reasons you should NOT bring a ruler close to the apparatus! Record several readings of the count rate at this distance - radioactive decay is a random process, so random errors are unavoidable. Remember that "background radiation" is always present, so your readings will never become zero. Repeat the procedure for as many distances as possible with the baseboard. When you have finished the experiment, make sure you return the source to the locked cabinet, sign the log book and wash your hands.

Analysis

Record your repeat values of count rate and corresponding distance in a table and calculate the average values. **Also subtract the average background count rate from all the count rate values – this may seem negligible, but becomes significant for the smaller values once logged.**

Tabulate log values for your corrected average count rate readings and plot a graph of $\log(A/s^{-1})$ against $\log(d/cm)$ or $\log(d/m)$.

Draw a best fit straight line and measure the gradient of your graph.

What is the expected value of the gradient from a “y = mx + c” analysis of the logged expression in the theory?

Do you get a good straight line graph and does your result agree with this value?

Discuss this in the light of the errors associated with this experiment. **Remember that 2 potential sources of systematic error have already been identified, as well as the random nature of radioactivity**.