Radiation and Life
99.102-801
Spring 2008

Laboratory 5: Time, Distance, and Shielding

Name: ____________________

Introduction:

During the fourth lab, you learned that a Geiger-Mueller detector has an efficiency that depends on both the type of radiation being counted and its energy. In this experiment you will learn that the counting efficiency also depends on two other factors- distance and shielding- and learn the concept of "Time, Distance, and Shielding".

Distance

You probably have an intuitive feeling that the measured net counting rate should *decrease* as a detector's distance from a radioactive source *increases*; recall "Discussion" question 2) from the fourth lab. If the radioactive source is small enough, it can be considered a "point source" of radiation. For a point source, the net source counting rate will obey the following mathematical relationship:

net source counting rate α $1/d^2$;

that is, the counting rate is inversely proportional to the square of the distance between the source and the detector; where d is the distance between the two. This is known as an "inverse-square" relationship. Simply put, if you double the distance between the source and the detector, the measured net counting rate will drop by a factor of four; if you triple the distance, the counting rate will drop by a factor of nine, etc…

If the counting rate decreases, then the efficiency will decrease as well, because of the following:

efficiency = net source counting rate / source activity.

For a point source, the same inverse-square relationship described above is true for counting efficiency.

Shielding

You probably also have an intuitive feeling that the measured net counting rate should *decrease* as the amount of shielding between a source and a detector *increases*. If the counting rate decreases, then the efficiency will decrease as well.

This effect is dependent upon the type of radiation emitted by the source. For example, alpha particles have the lowest penetrating ability; a sheet of paper will stop most of them. If the shield is thick enough, no alpha particles will penetrate it, and the

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detector efficiency will be 0 for this configuration. A moderately thick piece of plastic will stop beta particles, while gamma radiation requires a modest thickness of lead or another relatively dense material to serve as an effective shield.

Time, Distance, and Shielding

If you are being exposed to the radiation emitted by a source you receive an absorbed dose equivalent measured in rem (refer to the second and third labs). To minimize this dose, you can take certain precautions. Based on the above discussions about distance and shielding, you would expect the following relationships to be true:

1) absorbed dose equivalent rate in rem/hr (or mrem/hr) will decrease if you increase your distance from a radioactive source, and
2) absorbed dose equivalent rate in rem/hr (or mrem/hr) will decrease if you increase the amount of shielding between you and a radioactive source.

These relationships are indeed true; in fact, individuals who receive occupational exposures use these factors to reduce the amount of radiation to which they are exposed over the course of their work.

Additionally, a third factor can be used to minimize absorbed dose: time. Quite simply, minimizing exposure time will minimize the absorbed dose in rem. The mantra of Health Physicists (Radiation Protection Specialists) is “Time, Distance, and Shielding”.

Procedure:

Distance

You will count background and the radiation emitted by the gamma source.

1) Count background (no source present) for 5 minutes and record the number of counts. Be sure that the gamma source isn’t near the detector while counting background.
2) Count the radiation emitted by the gamma source (Co-60) for two minutes with the source in the top shelf position and with one plastic sheet between the source and the detector window (to block beta particles).
3) Repeat step 2) for all five of the other shelf positions.

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<u>Shielding</u>

You will count the radiation emitted by the three radiation sources.

1) Count the radiation emitted by the alpha source (Po-210) for two minutes with the source in any of the shelf positions.
2) Count the radiation emitted by the alpha source (Po-210) for two minutes with the source in the same shelf position and with a sheet of paper between the source and the detector window.
3) Count the radiation emitted by the beta source (Sr-90) for two minutes with the source in any of the shelf positions.
4) Count the radiation emitted by the beta source (Sr-90) for two minutes with the source in the same shelf position and with a sheet of paper between the source and the detector window.
5) Repeat step 4) using a plastic or glass sheet as the shield.
6) Repeat step 4) using a lead sheet as the shield.
7) Count the radiation emitted by the gamma source (Co-60) for two minutes with the source in the bottommost shelf position.
8) Count the radiation emitted by the gamma source (Co-60) for two minutes with the source in the bottommost shelf position and with one sheet of lead shielding between the source and the detector window.
9) Repeat step 8) for two, three, and four, five, and six sheets of lead. Please note: there are only ten sheets available for use, so some of the groups will have to wait until sheets become available to complete this step.

Data:

<u>Distance</u>

Perform the following calculations for each of your two-minute source counts.

1) Background counting rate = background counts / background counting time
2) Gross counting rate = measured counts / counting time (2 minutes for each source count).
3) Net source counting rate = gross counting rate – background counting rate
4) Efficiency = net source counting rate / source activity (you will have to convert the source activities from curies to decays per minute to calculate the efficiencies).
5) Graph the efficiency (y-axis) vs. shelf position (x-axis). Consider the top shelf position to be position #1; number each of the other shelf positions sequentially from there.

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Shielding

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3) Net source counting rate = gross counting rate – background counting rate
4) Efficiency = net source counting rate / source activity (you will have to convert the source activities from curies to decays per minute to calculate the efficiencies).

Ensure that the data you enter in your lab notebook is examined by the TA (and initialed) before you leave.

Discussion:

1) Do the efficiencies that you calculated (and graphed) exhibit an inverse square relationship based on distance? Is this expected? Explain. (Hint: Shelf 2 is twice as far from the detector as shelf 1; shelf 4 is twice as far from the detector as shelf 2; and shelf 6 is twice as far from the detector as shelf 3.)

2) Comment on the shielding used to absorb the alpha and beta sources. Did you expect these results? Explain.

Discussion:

3) The half-value layer is the amount of shielding material required to stop one-half (50%) of the gamma rays impinging on the shield. Each of the lead sheets you used was about 1/16th in. thick. Estimate the half-value layer of lead when used to shield the gamma rays emitted by the Co-60 source.

4) What fraction of the gamma rays would be *stopped* if you added more sheets of lead to your shielding such that the total thickness of lead amounted to two half-value layers? Hint: think of the concept of half-life when answering this question.

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APPENDIX A

Sample Data for Distance Effects

background counts:	192
counting time (min):	5
counting rate (CPM):	38.4
source activity (μCi):	1
sourc activity (DPM):	2.22E+06

shelf position	gross counts	Counting time (min)	gross ct. rate (CPM)	net ct. rate (CPM)	efficiency (c/d)
1	5177	2	2588.5	2550.1	1.15E-03
2	3037	2	1518.5	1480.1	6.67E-04
3	2018	2	1009	970.6	4.37E-04
4	1458	2	729	690.6	3.11E-04
5	1146	2	573	534.6	2.41E-04
6	926	2	463	424.6	1.91E-04

Sample Data for Shielding Effects (Position #6)

background counts:	206
counting time (min):	5
counting rate (CPM):	41.2
source activity (μCi):	1
sourc activity (DPM):	2.22E+06

number of Pb sheets	gross counts	counting time (min)	gross ct. rate (CPM)	net ct. rate (CPM)	efficiency (c/d)
0	884	2	442	400.8	1.81E-04
1	743	2	371.5	330.3	1.49E-04
2	668	2	334	292.8	1.32E-04
3	590	2	295	253.8	1.14E-04
4	578	2	289	247.8	1.12E-04
5	533	2	266.5	225.3	1.01E-04
6	449	2	224.5	183.3	8.26E-05