

RADIOACTIVITY

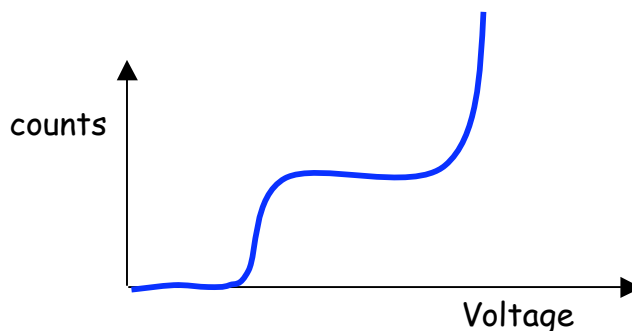
Things to find out:

See whether you can find an explanation of how a smoke detector works. Hint: it contains a small quantity of americium, a radioisotope. Find what you can about the isotopes of americium: what are their half-lives, how do they decay? If you were designing a smoke detector, which isotopes of americium would you rule out, and why?

Find out what you can about Geiger-Müller tubes. How do they work? What is "dead time"? How do you measure an instrument's dead time? What is a voltage "plateau"? Why is it useful to know about, why is it a good thing?

Geiger-Müller (G-M) tube operating voltage:

Set up a Geiger-Müller tube. Figure out the optimal operating voltage for the G-M tube by plotting its count rate vs voltage. You will notice that there is a turn on voltage below which you register no counts. Then you should reach a flat region called the plateau, and finally an avalanche region where the counts increase dramatically. You don't want to stray too far into the "avalanche" region, so keep the voltage under 1000V. You may use the contents of a smoke detector as your source. If you aren't seeing the avalanche region, try moving the detector further from the source.



DEAD TIME.

Some radiation detectors, like the Geiger tube, suffer from 'dead time'. After an event has triggered the tube, it is 'dead', or unresponsive, for some time thereafter, and cannot respond to further events.

You will determine the dead time of your detector in three ways.

1) Have your instructor find the semicircular shaped "half" sources or split source. Measure the activity of source A with a blank, source B with a blank, and sources A and B together. Use these measurements to calculate the 'dead time' of your Geiger tube, and of the computer-controlled detector. Make sure that you take multiple readings so that you can estimate your uncertainty. Use the equations in Melissinos' Experiments in Modern Physics to calculate the dead time.

2) A simpler way to estimate the dead time is to measure the maximum count rate of your detector. Clearly, the count rate cannot be any faster than one count per dead time. Make sure you estimate the uncertainty.

3) Connect an oscilloscope to the counter, and display the pulses from the G-M tube. Using the time scale of the scope, you can measure the deadtime. Make sure you estimate the uncertainty.

Compare these alternate measures of dead time including uncertainties. Are they in agreement? Which method do you have the most confidence in? The least?

Activity and Type of Radiation:

Use your G-M tube to determine the most likely type of radiation being emitted from the split source by placing various materials in between the source and the G-M tube as you measure the number of counts (paper, thin metal, thicker lead). Based on your observations, what is the most likely type of radiation. Look in the table in your book to check your conclusions.

Repeat for the Americium source.

Determine the Activity of the Americium source and the split source by making measurements of the count rate. Take enough measurements to calculate an uncertainty. Once you find the measured count rate, you need to determine the actual activity by taking the following factors into account.

1) The dead time of your detector makes the measured count rate lower than the actual one. . Use the equations in Melissinos' Experiments in Modern Physics to factor out the dead time.

2) The source emits radiation isotropically, and you are only measuring the fraction of that radiation that hits your detector. You need to factor out the geometry.

3) The source is about four years old, so it is no longer as active as it claims.

Determine the half-life of the source from a table.

Finally compare your calculated activity to the activity listed on the source.

Cloud Chamber

Setting up the cloud chamber (adapted from the manual)

CAUTION: The chamber uses denatured ethyl alcohol, which is flammable. Do not permit smoking, or open flame near the chamber while filling, or when it contains ethanol.

Remove the glass top and saturate the felt with 90% pure ethanol. **DO NOT USE METHANOL OR ANY OTHER LIQUID.** Pour remaining ethanol on chamber bottom. Alcohol should cover chamber bottom to provide a uniform, low-glare surface. Alcohol with a water content exceeding 30% will freeze on chamber bottom and impede track observation. The cloud chamber uses approximately one pint of ethanol.

Replace glass top; verify that it rests flatly in the groove on top of chamber. Clean the outside glass surface with the anti-fogging solution provided. Note that it is important to fill the chamber and treat glass before cooling!

Caution: Liquid nitrogen will cause frostbite. Use caution when handling. Avoid touching the aluminum pans once they have cooled down. Have well insulated gloves available in case it becomes necessary to move trays. Allow liquid nitrogen to evaporate and trays to warm to room temperature before moving trays.

To use the cooling tray, place foam perimeter on top and in the center of the insulating base. Arrange the pans in the center hole of perimeter. Level the insulating base by twisting the feet if necessary. Make sure the chamber is charged with ethanol in the usual manner before proceeding. Partially fill the tray with liquid nitrogen, leaving about 1/2 inch between the top of the tray and the fluid level. Place the chamber on top of the tray, and verify that the tray edges are all in contact with the chamber bottom side. Do not allow any liquid nitrogen to come in contact with the cloud chamber itself, as the materials may not withstand such extreme cold. Place the elastic skirt around the chamber itself, and lower the skirt until it covers the foam perimeter, and the chamber window is exposed.

Darken the room lights and illuminate chamber from the blackened wall by shining a slide projector or a dedicated light source beam towards the two-inch high transparent band. Always keep light source at least 18 inches from chamber wall. Adjust feet on base by turning them until the chamber is level and stable. When the chamber is level, droplets in the chamber center will fall straight down.

You should begin to see tracks after about five minutes of cooling. If the bottom of the chamber begins to appear white, from freezing ethanol, be certain that the chamber is not in direct contact with liquid nitrogen. Alternatively, you may need to use a higher purity ethanol if it begins to freeze. The nitrogen will last about one hour.

It is best to view tracks by looking at a 60 degree angle with respect to the incident light, although observations are tolerant of wide variations in this angle. Focus your eyes on the fiducial marks in the chamber bottom, and you should see tracks.

If the chamber ceases operation, first verify that the metal bottom is in contact with dry ice; then make certain that the felt is soaked with ethanol. It is also important to illuminate the chamber with a bright light source, such as a slide projector, in a darkened room.

An electric field within the chamber can change the sensitive layer depth. A downward field of 150 to 250 V/cm is sufficient to push positive ions from above into the sensitive layer. A field of this magnitude can be produced by grounding the chamber bottom and rubbing the glass top with a (preferably silk) cloth. This can be repeated periodically to compensate for leakage currents.

Things to do with the cloud chamber

1. Place the alpha emitter needle source in the cloud chamber and observe the tracks. The needle contains thorium salts. You can estimate the range of the tracks to get an idea of the energies of the alpha particles.
2. Replace the needle source with a beta source. You should try Carbon 14 and/or Cesium 137. Once again observe the tracks. How are they different from the alpha tracks? Again, estimate the length of the tracks to get an idea of the energies of the beta particles.
3. Remove the cloud chamber, and put the large rare earth magnet onto a piece of foam in the liquid nitrogen. Use gloves so you do not get LN_2 on your hands. Be careful not to drop the magnet, it is very fragile. Replace the chamber, and watch the beta tracks. Do they curve as expected? Which direction? Try both beta sources and the alpha source. Try turning the magnet over to see if the tracks switch directions.