KJM 5900 Exercise 7
Absorption of γ-radiation

Learing goal:

To understand how γ-radiation is absorbed in different media.

The theory behind this exercise can be found in chapter 6.4 in the course book. Please read it before you do the exercise.

Attached to this text is a short summary (in Norwegian) from an old, but similar exercise. You do not need to read it if you are happy with chapter 6.4 (from the course book).

RoboLab

You are going to use the RoboLab again in this exercise. Remember that you are actually performing a real experiment. Thus, only one student can access the remote controlled laboratory at a time. Please do not interrupt an ongoing experiment - make an appointment (with JPO) and stick to your allotted time.

You access the RoboLab through this link: http://sievert.uio.no/RoboLab7.html
It's running under LabView version 7.1 and you need the corresponding LabView plug-in. But most likely you already have this installed by now.

If you want to, you can perform the exercise on one of the computers in the counting room (but not during the KJM 1060 lab exercise on Wednesday 10. November between 8:00 and 17:00 or Thursday 11. November between 12:00 and 17:00).

On the exercise web-page there is a screen shot of the virtual instrument you get on your screen. On this screen shot the different buttons are explained. Please note that you might be required to keep the buttons down a little while for them to engage (keep the mouse button down 1-2 seconds). When you have asked to move the absorption ladder left or right you should get a corresponding light in the "Valve Open" indicator.

Pay attention to the video feed (even if it's a bit slow to update) - the positioning of the absorption ladder is not always performed as you asked. If you got the wrong absorber then just try again.

Also take care to request only one position at a time - otherwise you will confuse the RoboLab program (not very user friendly at it's current stage, I'm afraid...). If you do this by accident no harm to the system will be caused, but it will not move either. Deselect positions until only one is selected and try again.

The exercise

Step 1:
Remove all the absorbers by moving the two ladders to the far left (position marked "none"). Then count the radiation intensity from the ^{137}Cs source placed behind the slit in the blue lead-bricks in the back of the video picture.

Step 2:
If the background level has not been stated (message from JPO or on the exercise web-page), measure it by moving as much lead as you can manage between the detector and the source and count the background until you have a decent number of counts (less than 5% uncertainty).

Step 3:
The difference between your measurement in step 1 and 2 will be your reference count. I.e. we regard this as 100% activity. All other measurements will be related to this value (as a percentage).

Step 4:
Measure the amount of absorption in lead for as many thicknesses as you can manage. Observe that you can add the lead-absorbers on the two ladders in many different ways. Thus, even if you only have 6 lead-absorbers on the two ladders, you should be able to get more points on the absorption curve than this by making various combinations!

Step 5:
(You might want to perform all measurments first, in that case do step 6 and 7 before step 5.)
Plot the absorption curve on semi-logarithmic paper and calculate the half-value thickness for the ^{137}Cs γ-ray. What is the energy of this γ-ray? Make two plots, one where you state the absorber thickness in mm and one where you use grams/cm^2.

Step 6 (voluntarily):
Measure the absorption for 10 and 20 mm aluminum. How do they compare to the values you measured for lead? Do you expect the ratio between the absorption of aluminium and lead for the two thicknesses to be equal? Why or why not?

Step 7 (voluntarily):
Measure the absorption for 6 mm cupper. Compare it to absorption of lead and aluminium (you can extrapolate the measured values for aluminium to 6 mm). Is this as you expected?

Step 8:
You do not need to write complete report for this exercise. Mark each point in your report with "Step 1", "Step 2", etc. and write down your results and answers. You do not need any introduction, conclusion or similar - this exercise is meant to be short and quick.

Vedlegg: Teori for γ-absorpsjon

Intensiteten av γ-stråling som går gjennom materie er gitt ved:

$$I = I_0 e^{-\mu d}$$

Hvor I er intensiteten etter absorbatoren, I_0 er intensiteten uten absorbatoren, μ kalles den lineære absorpsjonskoeffisienten og d er tykkelsen av absorbatoren. Analogt med desintegrasjonslikningen definerer vi en halvtykkelse: $d_{1/2} = \ln 2/\mu$.

Absorpsjonskoeffisienten er sammensatt av sannsynlighetene for hver av de tre prosessene som γ-strålingen vekselvirker ved. Vi kaller absorpsjonskoeffisienten for fotoelektrisk effekt τ, for comptoneffekten σ og for pardannelse κ, og kan skrive:

$$\mu = \tau + \sigma + \kappa$$

Den lineære absorpsjonskoeffisienten, μ, dividert med absorbatorens tetthet, ρ, kalles masseabsorpsjonskoeffisienten. Denne avhenger bare av hvilke elementer som absorbatoren består av og fotonets energi. Den er dermed uavhengig av absorbatorens fysiske tilstand. Analogt med μ, kan μ/ρ deles opp som:

$$\mu/\rho = \tau/\rho + \sigma/\rho + \kappa/\rho$$

Masseabsorpsjonskoeffisienten for fotoelektrisk effekt, τ/ρ, er sterkt avhengig av både fotonenergi(E) og absorbatorens atomnummer(Z):

$$\frac{\tau}{\rho} = k \cdot \frac{Z^5}{E^3}$$

Sjansen for comptonspredning er avhengig av elektrontettheten. Dette tallet er nesten konstant for alle grunnstoffene bortsett fra hydrogen. For energier over 0.5 MeV er absorbsjonskoeffesienten proporsjonal med E_γ^{-1}:

$$\frac{\sigma}{\rho} = \frac{k}{E_\gamma}$$

Dersom fotonenergien er over terskelenergien for pardannelse, 1022 keV, er masseabsorpsjonskoeffisienten for pardannelse avhengig av både fotonenergi og atomnummer:

$$\frac{\kappa}{\rho} = k \cdot Z^2 \log E$$