Lab 4: Gamma, Beta, and Alpha Particle Attenuation

J.R. Powers - Luhn
09 February 2017
Thursday
Lab Partner:

Pre-Laboratory Questions:

1. How long does it take for Y-90 to become in secular equilibrium with Sr-90? What is the ratio of their activities?

```
(* half life of Y-90 64.1h *)
Y90HalfLife = 64.1;
(* half life of Sr-90 28.79y *)
Sr90HalfLife = 28.79 * 365.241 * 24; (*convert to hours*)
8 * Y90HalfLife
```

```
512.8
```

The two isotopes reach secular equilibrium in 8 half-lives of the daughter nuclide, $t_{(1/2)} = 512.8\, h$. At this point their activities are equal, $A_{\text{Sr}-90} = A_{Y-90}$

2. Using the NIST ESTAR database, determine the range of the most probable and maximum emission energy for the beta particles from Sr-90 and Y-90 in Aluminum and plastic. Provide the answer in units of mass thickness (mg/cm^2).

```
(* From https://www.nndc.bnl.gov/chart/decaysearchdirect.jsp?nuc=90SR&unc=nds *)
Sr90BetaEnergy = {195.88} (* keV *);
(* From https://www.nndc.bnl.gov/chart/decaysearchdirect.jsp?nuc=90Y&unc=nds *)
Y90BetaEnergy = {25.07, 185.61, 933.7} (* keV *);
```

```
(* Ranges in Aluminum *)
```

Beta Energy (keV)	Stopping Power (cm^2/g)	Range (mg/cm^2)
195.8	2.204	88.84
25.07	8.328	3.010
185.61	2.261	82.09
933.7	1.489	627.1

;

```
(* Ranges in Plastic (Polyethylene) *)
```

Beta Energy (keV)	Stopping Power (cm^2/g)	Range (mg/cm^2)
195.8	3.001	29.60
25.07	11.89	0.2532
185.61	3.081	26.64
933.7	1.950	321.6

;

The 933.7keV beta is the most probable decay for Y-90; The 195.8keV beta is the most probable decay for Sr-90.

3. Where are gamma rays on the electromagnetic spectrum? What are the characteristics of their wavelength, frequency, and energy?

Gamma rays are the most energetic photons on the electromagnetic spectrum. Their wavelength is on the order of tenths of angstroms (10^{-11} *m*), making their frequency on order of 10^{19} Hz. Their energies are normally in the range of tens to hundreds of keV, but can reach the MeV range.

4. Using the NIST X-ray Mass Attenuation Coefficient Database (http://www.nist.gov/pml/data/xraycoef/), use linear interpolation to find the mass attenuation coefficient of 88keV gamma-rays in Aluminum. Provide the answer in units of cm^2/mg.

```
e0 = 80 (* keV *);
e1 = 100 (* keV *);
mu0 = 0.2018 * 10^-3 (* cm^2/mg *);
mu1 = 0.1704 * 10^-3 (* cm^2/mg *);
mu = mu0 + (mu1 - mu0)/(e1 - e0) * (88 - e0)
```

```
0.00018924
```

Mass attenuation coefficient for 88keV gammas in Aluminum is $1.892 * 10^{-4} \frac{cm^2}{mg}$.

5. Using the value found in question 4, calculate the thickness of Aluminum required to absorb between 10-80% of the 88keV gamma-rays in steps of 10%.

```
density = 2700 (* mg/cm^3 *);
ap = Table[i, {i, 0.1, 0.8, 0.1}] (* Attenuation Percentages *);
at = Table[-1/(mu * density) * Log[1 - ap[[i]]], {i, Length[ap]}];
Multicolumn[Join[ap, at], 2]
```

```
0.1 0.206206
0.2 0.436725
0.3 0.698065
0.4 0.99976
0.5 1.35659
0.6 1.79332
0.7 2.35635
0.8 3.14991
```

See above for the thickness (in cm, second column) to attenuate the gamma-rays to the fractions in the first column.

6. Calculate the mass thickness of an aluminum shim 0.080±0.005 inches thick. Report your answer in cm^2/mg.

$$\frac{1}{\text{density}} * \frac{1}{0.080 * 2.54}$$
$$\frac{1}{\text{density}} * \frac{1}{(0.080 * 2.54)^2} * 0.005 * 2.54$$

0.00182269

0.000113918

The mass thickness of an aluminum shim is 0.0018±0.00011 $\frac{\text{cm}^2}{\text{mg}}$