

Radiation Shielding & Half-Value Thickness

Half-Thickness

- Half-value thickness is the thickness of an absorber that reduces the intensity of beam of gamma or x-radiation to half its value.
- Dependent on absorber material and energy of the radiation.
- Can be measured in cm or in mg/cm².
- If x is measured in cm, μ must have units cm⁻¹
- If x is measured in mg/cm², μ must have units cm²/mg

The half-value thickness, $x_{1/2}$ is related to the absorption coefficient μ . Find $I = \frac{1}{2}I_0$:

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

$$\frac{I_0}{2} = I_0 e^{-\mu x} \Rightarrow \frac{1}{2} = e^{-\mu x}$$

$$\ln\left(\frac{1}{2}\right) = \ln(e^{-\mu x})$$

$$\ln\left(\frac{1}{2}\right) = -\mu x$$

$$x = -\frac{\ln\left(\frac{1}{2}\right)}{\mu}$$

$$\boxed{x_{\frac{1}{2}} = \frac{\ln 2}{\mu}}$$

Example:

For 2 MeV gamma rays in Al, $\mu = .166/\text{cm}$.

Find the half-value thickness.

$$x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$$

$$x_{\frac{1}{2}} = \frac{\ln 2}{.166/\text{cm}}$$

$$x_{\frac{1}{2}} = 4.18 \text{ cm}$$

4.18 cm of Al will reduce the intensity to one half the original amount.

Absorber thicknesses are sometimes given in mg/cm^2 .

Example:

^{137}Cs γ rays in Al, $\mu = .0008 \text{ cm}^2/\text{mg}$.

Find the half-value thickness.

$$x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$$
$$x_{\frac{1}{2}} = \frac{\ln 2}{.0008 \text{ cm}^2/\text{mg}}$$
$$x_{\frac{1}{2}} = 866 \text{ mg}/\text{cm}^2$$

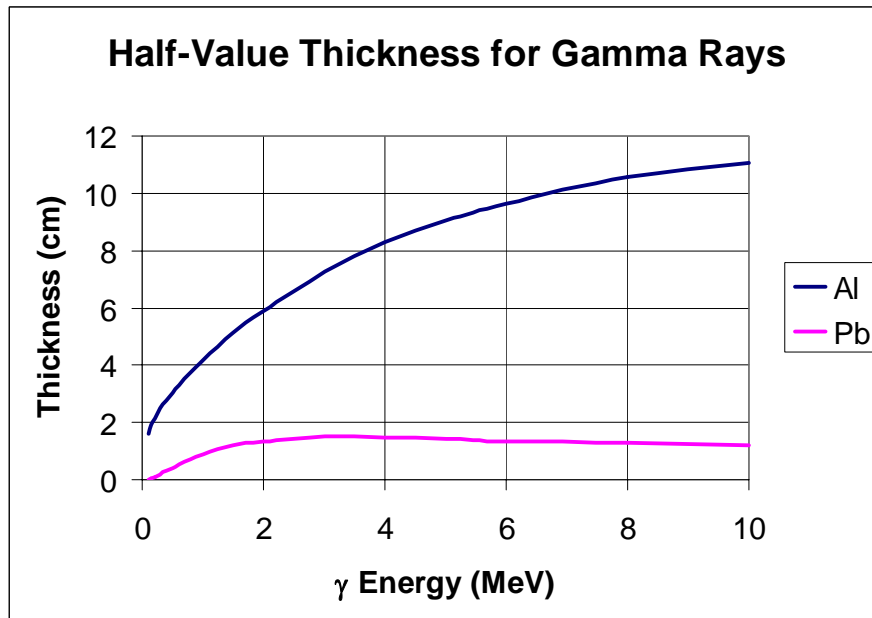
What is this thickness in centimeters of Al?

$$\frac{\text{thickness in mg}/\text{cm}^2}{\text{density in mg}/\text{cm}^3} = \text{thickness in cm}$$
$$\frac{866 \text{ mg}/\text{cm}^2}{2700 \text{ mg}/\text{cm}^3} = .32 \text{ cm}$$

.32 cm of Al will reduce the intensity to one half the original amount.

More on Half-value thickness:

The half-value thickness depends on two factors, the type of shielding and the energy of the gamma or x-rays. This graph illustrates the difference between gamma rays in Al and in Pb.



Additional Example:

You have a radioactive gamma source emitting 10000 counts/minute. $\mu = .166/\text{cm}$. What is the intensity if you surround the source with 2.54 cm (1 in) of Al?

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

$$I = (10000 / \text{min}) e^{-(.166 / \text{cm})(2.54 \text{ cm})}$$

$$I = (10000 / \text{min}) e^{-.422}$$

$$I = (10000 / \text{min})(.656)$$

$$I = 6560 / \text{min}$$

What is this thickness in mg/cm^2 ?

$$\text{thickness in } \text{mg}/\text{cm}^2 = (\text{density in } \text{mg}/\text{cm}^3)(\text{thickness in cm})$$

$$\text{thickness in } \text{mg}/\text{cm}^2 = (2700 \text{ mg}/\text{cm}^3)(2.54 \text{ cm})$$

$$= 6858 \text{ mg}/\text{cm}^2$$

Note that .25 in of Pb ($\mu = 7435 \text{ mg}/\text{cm}^2$) will provide *more* shielding than 1 in of Al.