Mass attenuation coefficient

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We all know the so-called "linear" attenuation coefficient. Here I set the symbol λ for that. Let x to be the symbol for the thickness of homogeneous layers, where the beam transmits perpendicular with the intensity I_0. After the layer x we have the intensity

$$I = I_0 \exp(-\lambda x)\,. \qquad (1)$$

This exponentially decreasing function of attenuation has first found by Pierre Bouguer (1698–1758) [1]. In his figure [1, Fig. 2] we can numerate the layers i = 1,2… He found log I_{i-i} – log I_i = $c(x_i - x_{i-1})$, which agrees with (1), c is a constant. The logarithmus of intensity is a linear function of the thickness of the transmitted layer.

The λ is not the basic quantity of attenuation. The basic is the mass attenuation. Let us set the symbol μ for the mass attenuation coefficient. This μ is important in practice.

Let us suppose the beam of the intensity I has the cross area A. It goes through a layer dx with density ρ (here of one-element matter), which has the atomic mass M and cross section σ. There the change of intensity is

$$dI = -I\,\frac{\frac{\rho}{M} N\, dxA\,\sigma}{A} = -\mu\rho\, I\, dx., \qquad (2)$$

N is Avogardo's number. $\frac{\rho}{M}$ is the number of moles in volume unite. $\frac{\rho}{M}N$ is the number of atoms in volume unite. Then $\frac{\rho}{M}NAdx$ is the number of atoms in the differential volume $dV = Adx$. The

cross section σ is the interaction (reaction or scattering) area for an atom. The numerator in the middle of (2) is the sum of the areas where the interaction occurs. Its relation to A is the probability of the interaction.

$$\mu = \frac{N\sigma}{M} \qquad (3)$$

is the mass attenuation coefficient. It is an important radiation quantity.

For the molecule, which has n elements, an element k times, we have

$$\mu = N\sum_{i=1}^{n}\frac{k_i\sigma_i}{M_i} \qquad (4)$$

μ can also be written for a mixture of elements and molecules. For both σ and μ of photons NIST has tabulation [2]. There the mass attenuation coefficient μ is in the unit cm^2/g.

In neutron physics the mass attenuation coefficient is called the macroscopic cross section [3]. The cross section σ then you find in the tabulation [4].

The integration of (2) over a homogenous layer x gives the intensity

$$I = I_0 \exp(-\mu \rho x), \qquad (5)$$

when I_0 is the intensity before the layer.

Gardner and Ely [5] use the symbol μ as in (5) for the attenuation.

In the XIV International Symposium on Radiation Physics, 2018 in Cordoba in Argentina, the discrepancy about symbols of attenuation coefficients still was alive. In the encyclopaedia [6] the different *μ's* are discussed.

If we have *n* homogeneous layers then

$$I = I_0 \exp(-\sum_{i=1}^{n} \mu_i \rho_i x_i), \qquad (6)$$

and if the density varies in *x*-direction, then

$$I = I_0 \exp(-\mu \int_0^x \rho(x)\, dx). \qquad (7)$$

But when x is large then build-up considerations are needed, [7] for gamma photons.

We have $\lambda = \mu\rho$ as the relation between linear attenuation coefficient and mass attenuation coefficient in homogeneous matter with the density ρ.

When one determines λ, then also μ and its accuracy should be determined.

I think (1) should be called the absorption law of Bouguer.

References

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