

From Theory to Reality

Consider a scenario where the goal is to measure the absorption spectrum of a thin layer of material (Figure figure1A). The incident radiant power is given by Φ_o , in the form of a collimated beam. The radiant power transmitted through the layer, Φ_t , is detected. If $\Phi_t = \Phi_o$, there is no loss of radiant power and therefore no attenuation. If however the medium absorbs some quantity of radiant power, Φ_a , then $\Phi_t < \Phi_o$, and $\Phi_o = \Phi_t + \Phi_a$ (Figure figure1B). In the case of material that both absorbs and scatters (Figure figure1C), the scattered radiant power is given by Φ_b , and $\Phi_o = \Phi_t + \Phi_a + \Phi_b$.

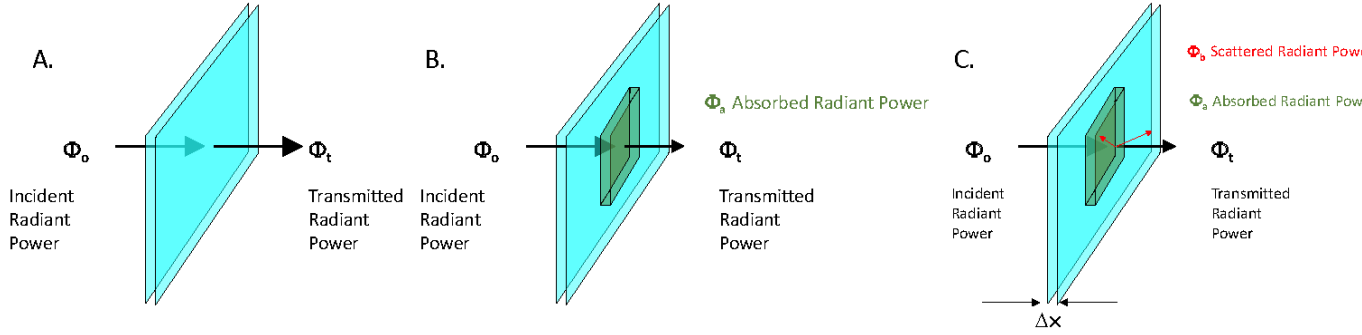


Figure 1: Diagrammatic representation of theoretical attenuation by a thin layers of non-attenuating (panel A), absorbing (panel B), and absorbing and scattering (panel C) material. The thickness of the layer is given by Δx .

To quantify the absorbed radiant power only, it is necessary to measure both the transmitted and scattered radiant power. This is a requirement for an absorption meter. Consider first a nonscattering material. The measured dimensionless transmittance, T , is the fraction of incident power transmitted through the layer:

$$T = \frac{\Phi_t}{\Phi_o}.$$

The absorptance, A , is the fraction of incident radiant power that is absorbed ($1 - T$):

$$A = \frac{\Phi_a}{\Phi_o} = \frac{\Phi_o - \Phi_t}{\Phi_o}.$$

The absorption coefficient a (with units of m^{-1}) is the absorptance per unit distance

$$a = \frac{A}{\Delta x}$$

which, for an infinitesimally thin layer can be expressed as:

$$a = \frac{\frac{\Delta \Phi}{\Phi}}{\Delta x} = \frac{\Delta \Phi}{\Phi \Delta x},$$

Rearranging this expression and taking the limit as $\Delta x \rightarrow 0$ yields:

$$a\Delta x = \lim_{\Delta x \rightarrow 0} \left(\frac{\Delta \Phi}{\Phi} \right)$$

Assuming that the absorption coefficient is constant over the layer of thickness x and integrating gives

$$\int_0^x a \, dx = \& - \int_{\Phi_o}^{\Phi_t} \frac{d\Phi}{\Phi} \quad ax|_0^x = \& - \ln \Phi|_{\Phi_o}^{\Phi_t} \quad ax = \& - [\ln(\Phi_t) - \ln(\Phi_o)] = -\ln \left(\frac{\Phi_t}{\Phi_o} \right) \quad a = \& - \frac{1}{x} \ln \left(\frac{\Phi_t}{\Phi_o} \right)$$

This equation provides a guide toward designing instruments to accurately measure absorption. The Level 2 pages beginning at Benchtop Spectrometry of Solutions give the specifics on techniques to measure absorption by dissolved and particulate constituents in seawater.