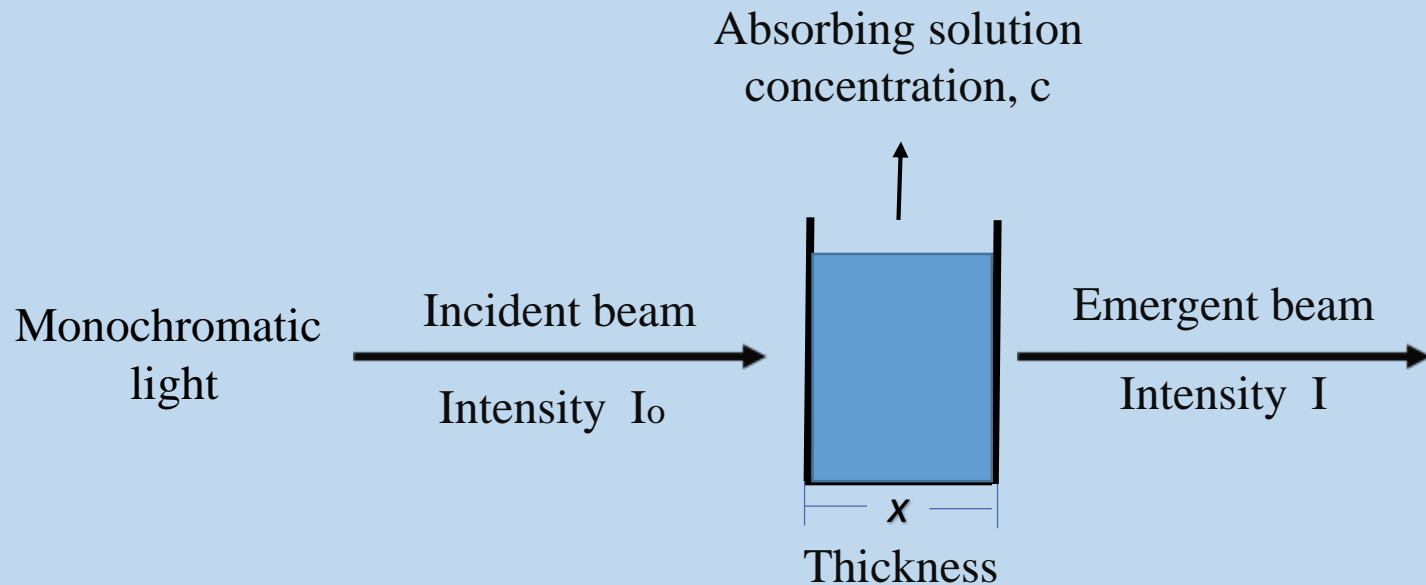


Beer-Lambert's law derivation

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If material bodies are exposed to radiation, part of the incident radiation is absorbed, a part is scattered and a part is transmitted. As a result of absorption the intensity of light passing through material bodies, i.e. the intensity of transmitted light, decreases. The fraction of incident light absorbed depends on the thickness of the absorbing medium. Lambert derived a quantitative relationship between the decrease in intensity of a monochromatic light due to the passage through a homogeneous medium of thickness dx and the intensity of light I . This law is known as Lambert's law, and may be stated as

The decrease in intensity of light with thickness of the absorbing medium at any point is directly proportional to the intensity of light.



Mathematically it can be expressed as

$$-\frac{dI}{dx} \propto I \quad \text{--- --- --- --- ---} \quad (1)$$

Where dI is a small decrease in intensity of light upon passing through a small distance dx and I is the intensity of the monochromatic light just before entering the medium. Equation (1) may be written as

$$-\frac{dI}{dx} = aI \quad \text{--- --- --- --- ---} \quad (2)$$

Where $-\frac{dI}{dx}$ is the rate of decrease of intensity with thickness dx , a is called the *absorption co-efficient*. Integration of equation (2) after rearrangement gives,

$$-\ln I = ax + C \quad \text{--- --- --- --- ---} \quad (3)$$

Where C is a constant of integration. At $x=0$, $I=I_0$. So, $C = -\ln I_0$. Introducing this in equation (3) we get,

$$\ln \frac{I}{I_0} = -ax \quad \text{--- --- --- --- ---} \quad (4)$$

Equation (4) can also be written as,

$$I = I_0 e^{-ax} \quad \text{--- --- --- --- ---} \quad (5)$$

Equation (5) can also be written as,

$$\log \frac{I}{I_0} = \frac{-a}{2.303} x \text{ ----- (6)}$$

or, $\log \frac{I}{I_0} = -a' x \text{ ----- (7)}$

Where a' ($= \frac{a}{2.303}$) is called *extinction co-efficient* and $-\ln \frac{I}{I_0}$ is termed absorbance of the medium. Absorbance is represented by **A**.

Lambert's law was extended by Beer who showed that when light passes through a solution of a given thickness the fraction of incident light absorbed is dependent not only on the intensity I of light but also on the concentration c of the solution. This is known as the Beer's law.

$$-\frac{dI}{dx} \propto c \text{ ----- (8)}$$

The two laws may be combined to write

$$-\frac{dI}{dx} \propto I \times c$$

Or, $-\frac{dI}{dx} = b \times I \times c \text{ ----- (9)}$

When the concentration, c , is expressed in *mol /L*, b is called the molar absorption co-efficient.

As in the case of Lambert's law equation (9) may be transformed into,

$$\log \frac{I}{I_0} = \frac{-b}{2.303} \times c \times x \text{ --- --- --- --- --- (10)}$$

$$\log \frac{I}{I_0} = - \epsilon \times c \times x \text{ --- --- --- --- --- (11)}$$

Where $\epsilon (= \frac{b}{2.303})$ is called the molar *extinction co-efficient* which is expressed in $L/mol/cm$. The molar *extinction co-efficient* ϵ is dependent on the nature of the absorbing solute as well as on the wave length of the incident light used.

The expression (equation 11) is commonly known as Beer-Lambert's law.

Limitation of Beer-Lamber's law:

- The electromagnetic radiation should be monochromatic.
- The light beam should not be scattered.
- The solution should be diluted.

Reference:

Principles of Physical Chemistry. Dr. Muhammad Mahbubul Huque and Dr. Mohammad Yousuf Ali Mollah. Page no. (352-354).