General Chemistry I
Tutorial 02

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Outline

Basis of wave

Expression for electromagnetic wave:

$$\boldsymbol{E} = \boldsymbol{E}_m \cos(\boldsymbol{k} \cdot \boldsymbol{x} - \omega t + \phi)$$

$$\boldsymbol{B} = \boldsymbol{B}_m \cos(\boldsymbol{k} \cdot \boldsymbol{x} - \omega t + \phi)$$

Relations between related parameters:

$$k = \frac{2\pi}{\lambda}$$

$$\omega = \frac{2\pi}{T} = 2\pi\nu$$

$$v = \frac{\omega}{k}$$

Velocity of light equals to 3×10^8 only when it is transmitted in **vacuum**.
When transmitted into a medium:

$$v = \frac{c}{n}$$

where n is refractive index.

Wave-particle Duality

Particles

$$
\begin{tikzcd}
\lambda \arrow[r, dash, "p = \frac{h}{\lambda}"] \arrow[d, dash, "\lambda = \frac{v}{2\nu}"'] & p = mv \arrow[d, dash, "E = \frac{p^2}{2m} = \frac{1}{2}mv^2"] \\
\nu \arrow[r, dash, "E = h\nu"'] & E
\end{tikzcd}
$$

Photons

$$
\begin{tikzcd}
\lambda \arrow[r, dash, "p = \frac{h}{\lambda}"] \arrow[d, dash, "\lambda = \frac{c}{\nu}"'] & p = mc \arrow[d, dash, "E = pc = mc^2"] \\
\nu \arrow[r, dash, "E = h\nu"'] & E
\end{tikzcd}
$$

Phase velocity(u) $= v/2$

Equations applicable for both photons and physical particles:

$$p = \frac{h}{\lambda}$$

$$E = h\nu$$

The function of standing wave is given by:

$$y(x,t) = A_0 \sin(\frac{2\pi}{\lambda}x)\cos(\frac{2\pi}{T}t)$$

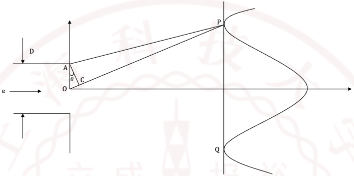
Energy of wave is given by:

$$E(x) = \frac{1}{2}k[y(x,t)]^2 + \frac{1}{2}m[v(x,t)]^2 = |\psi(x,t)|^2 \tag{1}$$

From equation (1), $\psi(x,t)$ can expressed in complex equation:

$$\begin{aligned}
\psi(x,t) &= \sqrt{\frac{k}{2}}y(x,t) + \sqrt{\frac{m}{2}}v(x,t)i \\
&= \sqrt{\frac{k}{2}}A_0 \sin(\frac{2\pi}{\lambda}x)\cos(\frac{2\pi}{T}t) - \frac{2\pi}{T}\sqrt{\frac{m}{2}}A_0 \sin(\frac{2\pi}{\lambda}x)\sin(\frac{2\pi}{T}t)i \\
&= A_0 \sin(\frac{2\pi}{\lambda}x)\left[\sqrt{\frac{k}{2}}\cos(\frac{2\pi}{T}t) - \sqrt{\frac{m}{2}}\sqrt{\frac{k}{m}}\sin(\frac{2\pi}{T}t)i\right] \\
&= A_0\sqrt{\frac{k}{2}}\sin(\frac{2\pi}{\lambda}x)\left[\cos(\frac{2\pi}{T}t) - \sin(\frac{2\pi}{T}t)i\right] \\
&= \psi(x,0)\exp\left[\frac{2\pi}{T}t \cdot i\right]
\end{aligned}$$

Uncertainty Principle (an Example of Electron Diffraction)



At the first concealing point:

$$\overline{OP} - \overline{AP} = \frac{\lambda}{2} = \overline{OC}$$

$$\sin\theta = \frac{\overline{OC}}{\overline{AO}} = \frac{\lambda/2}{D/2} = \frac{\lambda}{D}$$

Uncertainty of momentum:

$$\Delta p = p\sin\theta = p\frac{\lambda}{D} = \frac{h}{D}$$

Product of uncertainty:

$$\Delta x \Delta p = h$$

Problem 2.1

The wavelength of the sodium D-line is centered at 589.3 nm.

(a) Calculate the energy change per Na atom emitting a photon at the D-line wavelength.
(b) Calculate the energy change per mole of Na atoms emitting photons at the D-line wavelength.

Problem 2.2

A beam of laser enters water from air. How do its properties change?

(a) Color: redder, unchanged, or bluer?
(b) Frequency: ν_2 ($<$, $=$, or $>$) ν_1
(c) Photon energy: E_2 ($<$, $=$, or $>$) E_1?
(d) Speed: c_2 ($<$, $=$, or $>$) c_1?
(e) Wavelength: λ_2 ($<$, $=$, or $>$) λ_1?