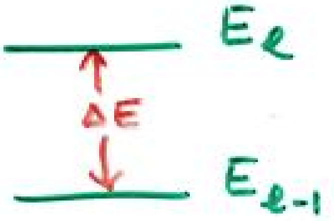
Molecules can store rotational energy as well as vibrational energy.

$$E_{rot} = \frac{\hbar^2}{2 I_{cm}} \ell(\ell+1) \qquad \ell = 0, 1, 2, \ldots$$

ℓ: rotational quantum number. $\quad I_{cm} = \mu R_0^2$ (μ ← reduced mass; R_0 ← bond length)



$$\Delta E = \frac{\hbar^2}{I_{cm}} \ell$$

ℓ ← quantum number of the higher energy state.

Photons should be observed at the frequencies

$$\omega_0 = \frac{\Delta E}{\hbar} = \frac{\hbar}{I_{cm}}, \quad 2\omega_0, \quad 3\omega_0, \ldots$$

nsitions: $0 \rightarrow 1$, $\quad 1 \rightarrow 2$, $\quad 2 \rightarrow 3$ ....

$$E_{vib} = \left(v + \frac{1}{2}\right)\hbar\omega \qquad v = 0, 1, 2, \ldots$$

v: vibrational quantum number.

ω: frequency of vibration and related to the force constant by: $k = \mu\omega^2$

k ← a measure of the bond strength

μ ← reduced mass $= \dfrac{m_1 m_2}{m_1 + m_2}$