Vibrational - Rotational Spectra

$$E_{n,l} \approx E_e + \left(n - \frac{1}{2}\right)\hbar w + \frac{l(l+1)\hbar^2}{2I}$$

$$\Delta l = \pm 1$$
$$\Delta n = \pm 1$$

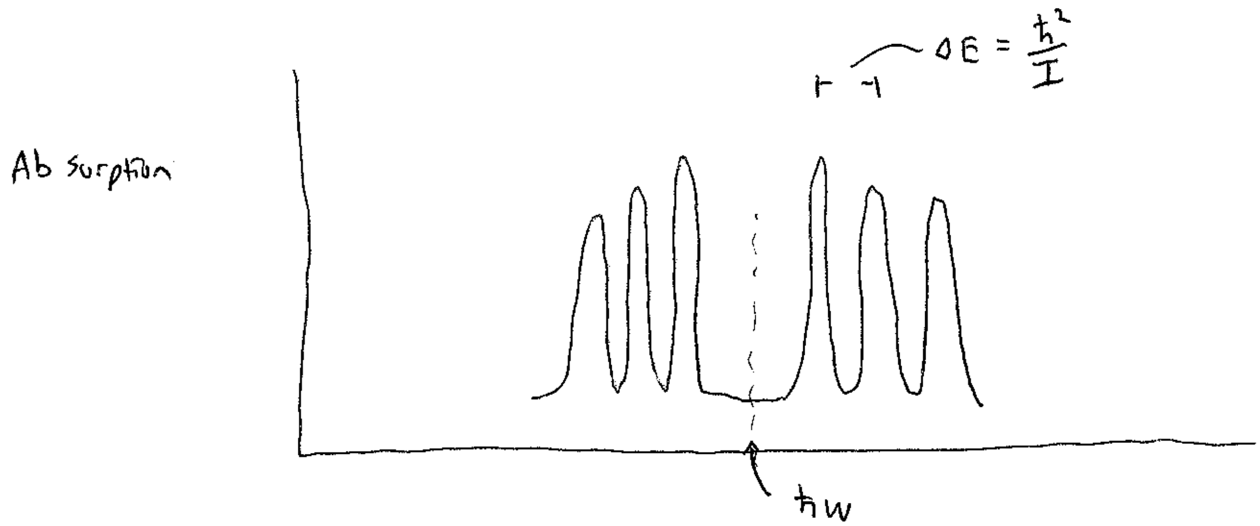
$n=1 \rightarrow n=2$

$$E_\gamma = E_{2,l+1} - E_{1,l} = E_e + \left(2 - \frac{1}{2}\right)\hbar w + \frac{(l+1)(l+2)\hbar^2}{2I}$$
$$- \left[E_e + \left(1 - \frac{1}{2}\right)\hbar w + \frac{l(l+1)}{2I}\hbar^2\right]$$
$$= \hbar w + \frac{(l+1)\hbar^2}{I}$$

$l \rightarrow l+1$

$$E_\gamma = E_{2,l-1} - E_{1,l} = E_e + \left(2 - \frac{1}{2}\right)\hbar w + \frac{(l-1)l\hbar^2}{2I}$$
$$- \left[E_e + \left(1 - \frac{1}{2}\right)\hbar w + \frac{l(l+1)\hbar^2}{2I}\right]$$
$$= \hbar w - \frac{l\hbar^2}{I}$$

$l \rightarrow l-1$



Electronic- Vibrational Spectra

$\vec{J}$ - total angular momentum - electronic + rotational

$$E_{tot} \approx E_e + \left(n - \frac{1}{2}\right)\hbar w + \frac{j(j+1)\hbar^2}{2I} + \frac{m_j^2 \hbar^2}{2I_e}$$

$\Delta m_j = \pm 1, 0$

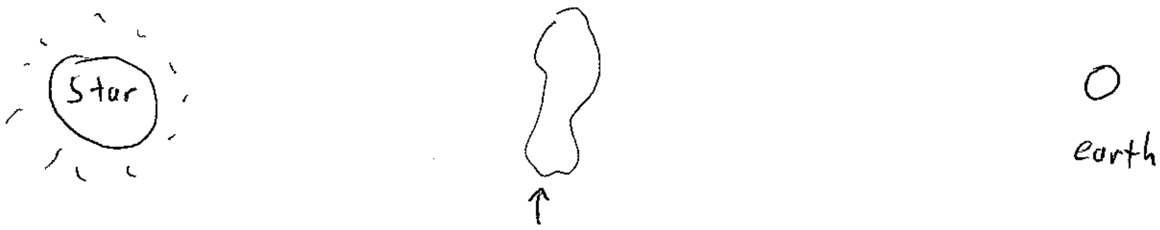
$\Delta j = \pm 1, 0$

if $m_j = \Delta m_j = 0$

$\Delta j = \pm 1$

no restriction on n

Absorption from ζ Ophiuchi



photons are absorbed by CN $j=0$, and $j=1$

$\lambda_0 = 387.5$ nm $\quad j=0$

$\lambda_1 = \lambda_0 + 0.061$ nm $\quad j=1$

$$\frac{n_1}{n_0} = \frac{1}{4}$$

Some energy source must be populating $j=1$ state

Assume there is some temperature

$$\frac{n_1}{n_0} = \frac{(2j+1)}{(2j+1)} \frac{e^{-E_1/KT}}{e^{-E_0/KT}} = 3e^{-\Delta E/KT} = \frac{1}{4}$$

$\Delta E = E_1 - E_0$

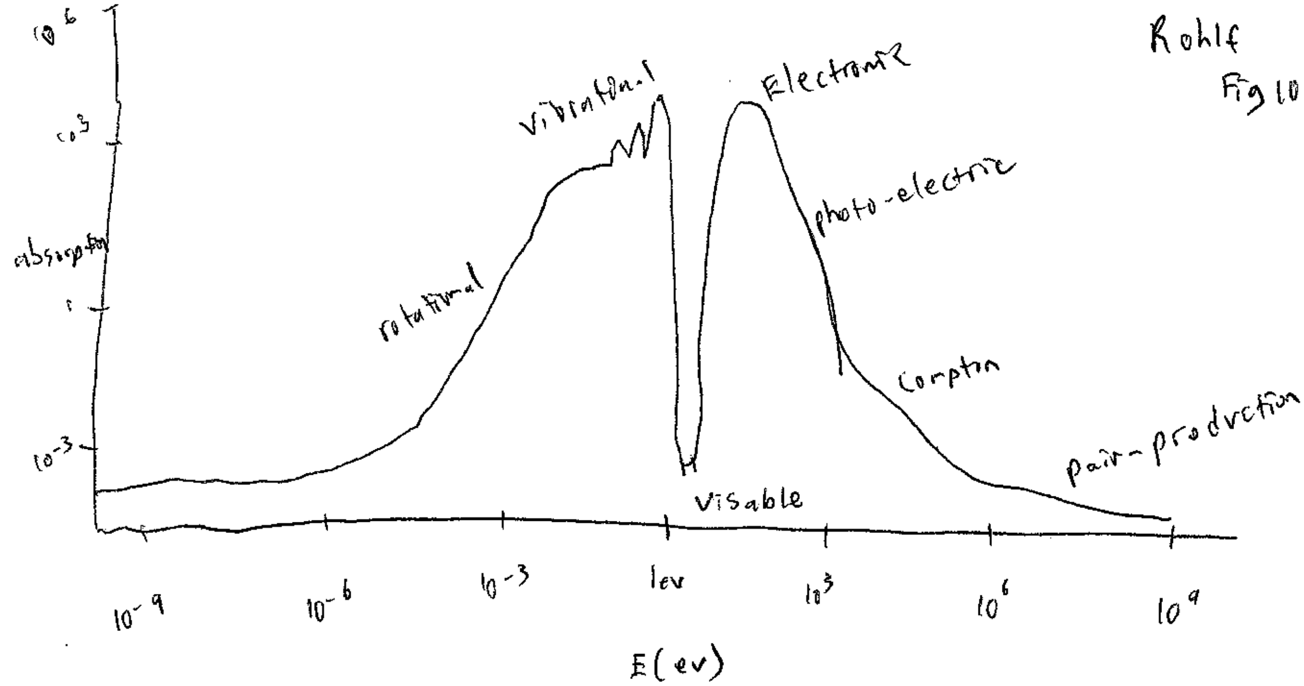
$\frac{\Delta E}{KT} = \ln(12)$

$T \approx 2.3$ K ← Space has some background temperature!

Now know this is cosmic microwave background

Absorption spectrum of water

Rohlf
Fig 10-15



In class problem:

O_2 has $r = 0.12$ nm

$Z = 8$

$A = 16$

$f = 4.7 \times 10^{-13}$ Hz

what are the vibrational and rotational energies in eV?

draw the $n=1 \rightarrow n=2$ absorption spectra