Intensities of Spectral lines :-

$J=0 \rightarrow J=1$
$J=1 \rightarrow J=2$
} Which transition lines are more intense?

It depends on the population of the level. (Boltzmann distribution)

Rotational energy in the lowest energy is 0.

Because $J=0$

If population is N_0, then number of molecules in any other higher state is given by

$$N_J/N_0 = e^{-E_J/KT} = e^{-BhcJ(J+1)/KT}$$

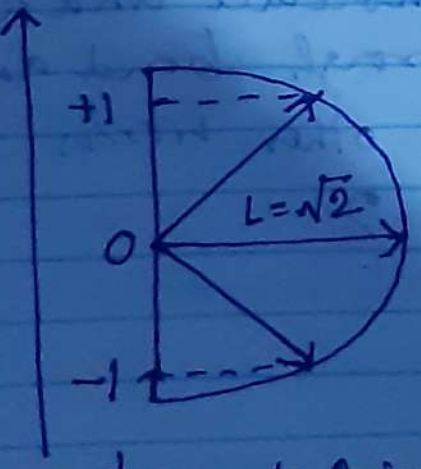
Calculating we get,

$$\frac{N_1}{N_0} \simeq 0.98 \quad (\text{When } J=1)$$

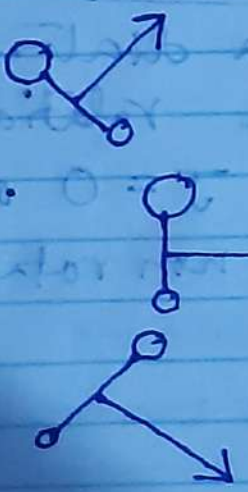
From this data we see that there are nearly same molecules in $J=1$ level as in $J=0$.

Another factor is degeneracy in the energy states.

Degeneracy :- Two or more energy state which have exactly same energy.



Three degenerate Orientation



$$L = \sqrt{J(J+1)}\,\frac{h}{2\pi}$$

Quantized

When $J=1$

$$L = \sqrt{2}\left(\frac{h}{2\pi}\right)$$

Likewise $J = 2$, Five degenerate level

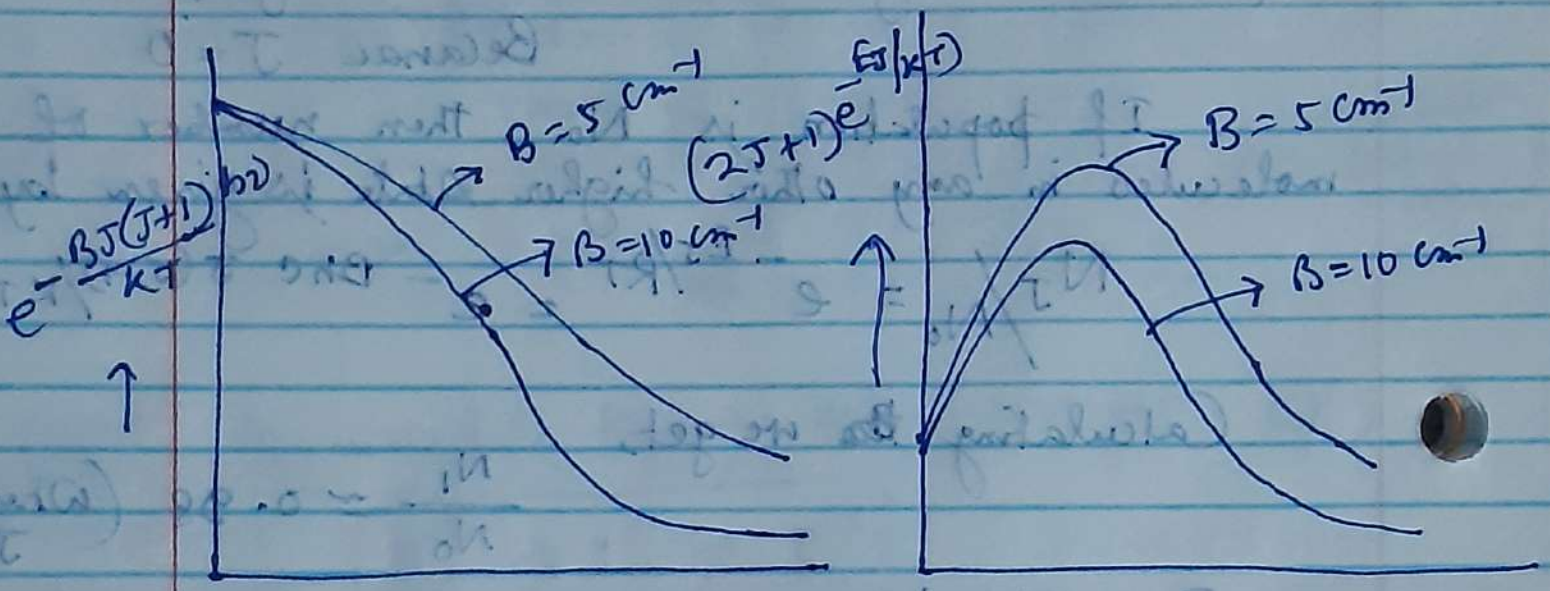
$J = 3$, Seven degenerate level

Angular momentum vector can be oriented in only three different direction (when $J = 1$).

All three rotational direction have same rotational energy.

$$\text{Population} \propto (2J+1)\, e^{-E_J/KT}$$

Plots :-



(Boltzmann populations of the rotational level)

(Relative population including degeneracy)

Related Questions :-

(1) Why for a diatomic molecule and all linear molecule the rotation through bond axis is zero when $J = 0$ or in other words the molecules is non rotating ?

Effect of Isotopic Substitution :-

CO. (Carbon Monoxide)

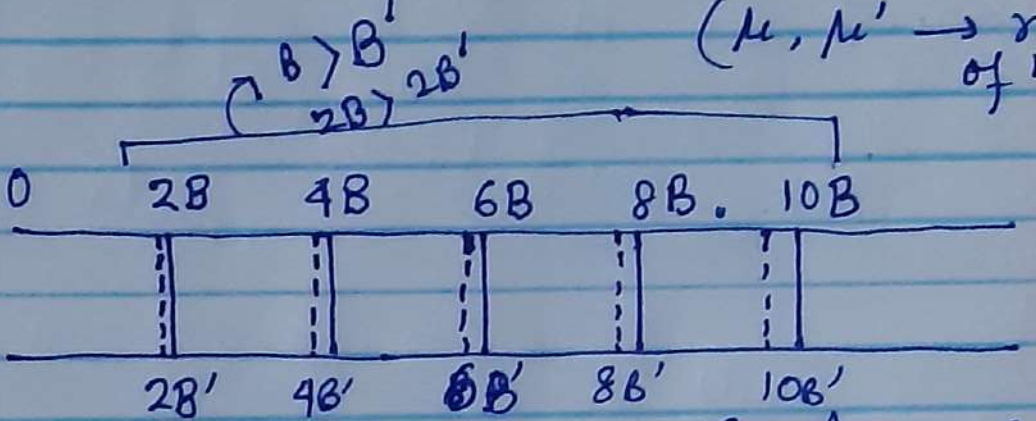
$^{12}C^{16}O$ ↙ ↘ $^{13}C^{16}O$

B value decreases
(Because mass increases)

$\left(B = \frac{h}{8\pi^2 I c}\right)$

$\frac{B}{B'} = \frac{I'}{I} = \frac{\mu'}{\mu} = 1.046$ (Detailed Calculation is excluded here)

(μ, μ' → reduced mass of $^{12}C^{16}O$ and $^{13}C^{16}O$)



(Shifting of spectral lines in higher energy lines predominates)

Non-rigid rotator :- (Continue - - - -)

Bond length increases with J value.

↳ elastic bond

(rigid rotator, the bond length is same)

Next lecture topic :-

1. Energy expression for non rigid rotator
2. Instrumentation & applications
3. Introduction of vibrational Spectroscopy