# AST 300B – Spring 2017

## In-class/Take-home Problems Due: Friday Mar. 24

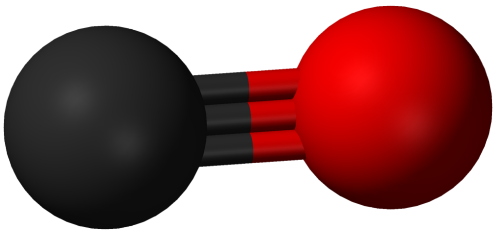
32. Consider the level populations of a 2 level system (labeled level 1 and level 2) where the density of colliding particles is very large ($n_c \rightarrow$ huge) and collisions dominate in determining the level populations. In this limit, $T_{ex} \rightarrow T_k$, the gas kinetic temperature of the colliding particles. Derive the mathematical relationship between the upward and downward collisional rate coefficients ($\gamma_{12}$ and $\gamma_{21}$ $cm^3$ $s^{-1}$). Note: due to the principle of detailed balance, the relationship you just derived is valid even when $n_c$ is not large – you can use this relationship to turn a $\gamma_{12}$ into a $\gamma_{21}$ and vice versa in statistical equilibrium calculations

33. The CO molecule has rotational energy levels quantized by the rotational angular momentum of the molecule denoted J = 0, 1, 2, etc. Observational of molecular clouds indicate that the typical CO excitation temperature is ~ 10K.

(a) Using the table below of the first few rotational energy levels of CO, calculate the "rotational partition function" at 10 K.

(b) Calculate the fraction of CO molecules that are in the J=0, J=1, and J=2 levels at 10K.

(c) What is the frequency (GHz) and wavelength (mm) of the ground state J=1-0 transition?



**CO Rotational Energy Levels**

| J | E/k (K) | g |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 5.532 | 3 |
| 2 | 16.596 | 5 |
| 3 | 33.192 | 7 |
| 4 | 55.318 | 9 |
| 5 | 82.974 | 11 |