Assignment#4, Fundamentals in BioPhotonics 2013

1) % 25 (Hint: check slides)

A. Velocity distribution of some atoms in gas is given as $p(v) = \frac{1}{\sigma_v \sqrt{2\pi}} e^{(-\frac{v^2}{2(\sigma_v)^2})}$, $\sigma_v = \frac{KT}{m}$

where T is temperature, m is atomic mass, K is Boltzmann constant. If the line shape function width is Δv for each atom find an expression for the average line shape function, $\bar{g}(v)$.

B. Assuming $\Delta v << \frac{v_0 \sigma_v}{v}$ show that it can be estimated as $\bar{g}(v) = \frac{1}{\sigma_D \sqrt{2\pi}} e^{(-\frac{(v-v_0)^2}{2(\sigma_D)^2})}$,

$\sigma_D = \frac{v_0 \sigma_v}{c} = \frac{1}{\lambda} \sqrt{\frac{KT}{m}}$ and find Doppler linewidth Δv_D.

C. Find Δv_D for CO_2 laser operating at $\lambda_0 = 9.8$ um.

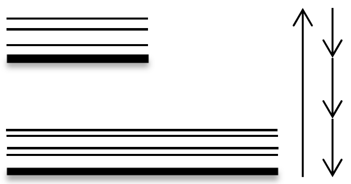
D. Demonstrate that the maximum transition cross section for $\bar{g}(v)$ is $\sigma_0 = \frac{\lambda^2}{4\pi \Delta v_D t_{sp}} \sqrt{\frac{\ln(2)}{\pi}}$

2) % 20

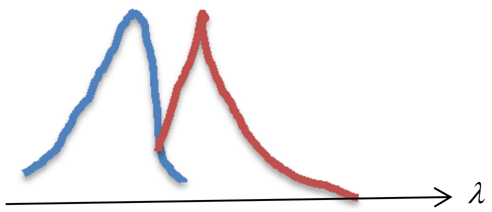
In general, a molecule with N atoms has 3N-6 normal modes of vibration, but a linear molecule has 3N-5 such modes (can be derived but it is not necessary). For a transition between modes there should be change in dipole moment.

A. Find number of vibrational modes for $CO_2, H_2O, O_2, N_2, CH_4, C_4H_2, NO$
B. Considering the absorption capability of the molecules given above, explain why we are not concerning about the molecules in air as potential source of global warming? What about H_2O?
C. Is that possible that we excite the symmetric stretching mode of C_2H_2 ?
D. Given that NO molecule is in the lowest vibrational state ($K = 0.16x10^7 g/s^2$) find the vibrational energy and the wavelength of the photon that excites it to the next level.
E. For a molecule the population ratio of i^{th} and j^{th} levels is τ_1 for electronic states, τ_2 for vibrational states and τ_3 for rotational states. Find the relation between τ_1, τ_2, τ_3.

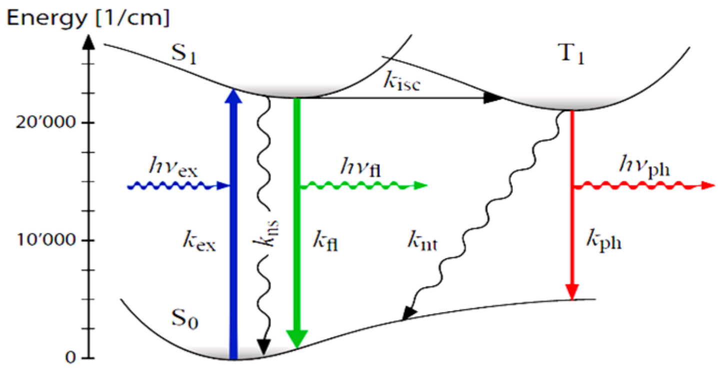
3) % 10 (Hint: check slides)



A. For the Jablonski diagram given above explain what each arrow is representing.
B. The spectrum of a molecule is given below. Which one represents the excitation spectrum (verify with your answer in part A)? Why emission is mirror image of the excitation?



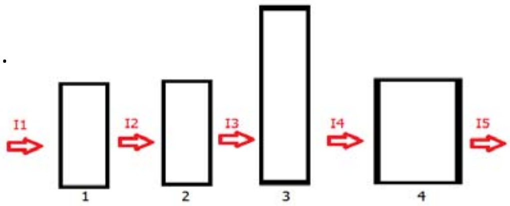
4) % 15



A. For the triplet state given above find an expression for the population ratio in T_1 for steady-state excitation and an expression for quantum yield.
B. Propose a way to measure k_{fl} experimentally. Can you measure k_{nt} in a similar way?

5) % 5

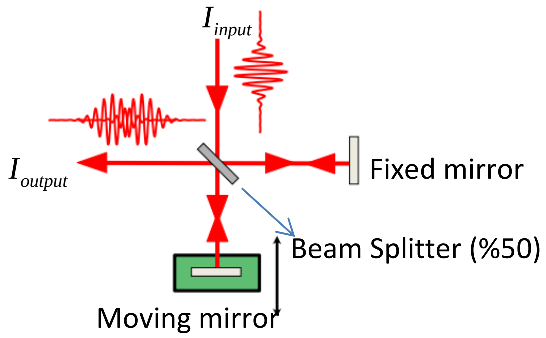
Let's imagine a beam propagates through many cuvettes as shown. The cuvettes differ from each other with different reasons. Here are the specs:



1) The concentration of the cuvette#2 is double of the others.
2) The height of the cuvette#3 is double of the others.
3) The width of the cuvette#4 is double of the others.

For cuvette#1, given that I_2/I_1 =0.01 and the concentration=2 M what are the ratios for succeeding intensities? (Hint: use Beer's Law)

6) % 25



Schematic of Fourier Transform Infrared (FTIR) Spectroscopy

A. Describe the operating principle of this technique qualitatively (in a few words).
B. If the input is monochromatic (λ_0), find the intensity of the output beam as a function of mirror phase, $I_{output}(\Delta, \frac{1}{\lambda_0})$ (Hint: Check homework assignment#1, 3rd question).
C. Given that the input is not monochromatic find the total intensity at the output as a function of mirror phase, $I_{output}(\Delta)$ (Hint: integrate the result you find in B over all wave numbers). Show that it is Fourier transform of the intensity at the input, $I_{output}(\Delta) = \Im\{I_{input}(\frac{1}{\lambda})\}$
D. How can we access the intensity distribution of wavelengths available in the input beam, $I_{input}(\frac{1}{\lambda})$ using the intensity recorded at the output while the mirror is moving?