CHEM 524

Fall 2005—Problem Set #1--Keiderling

1. Introduction: Text reading this section covers: Chapter1, Chapter 2-2, 2-3, 2-5

Read on your own: ***Chap.2-4*** Selection of information (we will do later), ***Chap.2-5*** Analytical signal — Sorting out various contributions to the signal measured from background, etc. — This topic will recur and be tested.(also Sect. 7-10)

Homework: (**For discussion only**: Chap. 1:#3, 4, 6, 10; Chap. 2 #5, 10; Chap2: #1, makes a good model test question, style is often used on 1st exam—this means for your practice)

* **Problems to hand in**: **Chap.2: # 3, 4** (assume all light hits detector), **15, 16 & Calculate** population of molecular states for vibrations at 100, 600 cm^{-1} and 3000 cm^{-1} for T=300K

2. Incoherent Light Sources: Read and study: Chapter 4.1-4.2 and the associated Web pages suggested in notes on line: “kaist” pages and associated Oriel pages

Homework for discussion only: Chap. 4: 11, 12

* **Problems to hand in**: **Chap 4: 1, 13**

3. Laser light sources: Read and study the text, Chap 4-3, and the Kansas State site suggested in the notes, plus handouts on theory.

Homework for discussion only: Chap. 4: 2, 18

* **Problems to hand in**: Chap 4: 14, Plus those below:

a. from O. Svelto and D.C. Hanna (trans.) *Principles of Lasers, 2nd Edition*, Plenum, 1982.

6.15 Collision broadening of the CO_2 laser transition is $\Delta\nu_e = 7.58\,(X_{CO2} + 0.73\,X_{N2} + 0.6\,X_{He})\,p\,(300/T)^{1/2}$ in MHz, where X is partial function of each component and p is total pressure. If the ratio of CO_2:N_2:He is 1:1:8 calculate p when all rotational lines merge together. (<u>HINT</u>: For CO_2 energy levels you will need B, the rotational constant—look it up or calculate it.)

1.4 If two levels at 300^o K are in thermal equilibrium with $n_2/n_1 = 1/e$, calculate the frequency of the transition from $1\rightarrow2$. In what part of the spectrum does this occur?

2.0 Calculate the number of longitudinal modes that occur in $\Delta\lambda$=1 nm at λ^0=1.06 μ for a 1 m long laser cavity.

b. from Kansas State site **Question 4.4: Ar+ Ion laser**

The difference between adjacent modes in Ar+ Ion laser is 100 MHz. The mirrors are at the end of the laser tube.

Calculate:

1. The length of the laser cavity.
2. The mode number of the wavelength 488 [nm].

3. The change in difference between adjacent modes when the tube is shortened to half its length.

***Homework** for discussion purposes, Not to hand in*:

Question 2.3: The difference between population numbers

Prove that the difference in population numbers (N1, N2) between two energy levels E2 and E1 is given by:

N1-N2 = N1*(1-exp(-hν/kT)

$\nu = \nu 2 - \nu 1$ is the frequency which corresponds to the energy difference between the two levels E2 and E1.

In the equation in question 2.2, the second term inside the parenthesis is always less than 1. So, the parenthesis are always less than 1. Thus the very important conclusions:

1 **In a thermodynamic equilibrium, the population number of higher energy level is always less than the population number of a lower energy level.**

2 **The lower the energy difference between the energy levels, the less is the difference between the population numbers of these two levels.**

Physically, the electrons inside the atom prefer to be at the lowest energy level possible. Even when they are excited to a higher level, they return back to the lowest energy level after a short time.

Extra Problems for discussion only (from O. Svelto and D.C. Hanna (trans.)) *Principles of Lasers, 2nd Edition*, Plenum, 1982.

6.7 & 8 Suggest lasers for surgery, cw > 20 W, absorb. Suggest lasers for welding, cw > 1kW.

1.1 – 1.3 Clarify in your head and be able to convent between spectral regions and units: (Å, nm, μ, cm^{-1}, Hz) for uv – vis – near IR – IR and for IR.

1.5. A medium absorbs or emits (stimulates) as

$d\Phi = \sigma\Phi (n_2 - n_1)\, dz$ — ϕ = flux, σ = cross section

if $n_2 > n_1$ amplify — n_1, n_2 = population, z = distance (path)

To get an oscillation, need positive feedback from cavity (stimulate more emission), mirrors <u>reflect</u> R_1, R_2

$(n_2 - n_1)_C = -\frac{\lambda n(R_1 R_2)}{\partial\sigma\lambda}$ — λ = length gain medium, $(n_2 - n_1)_C$ = critical inversion pop.

$R_1 R_2 \exp[2\sigma (n_2 - n_1)] = 1$ — sometimes called lasing threshold.

Show that threshold condition matches critical population. If $R_1 = 1$ and $R_2 = 0.5$ and λ = 7.5 cm, calculate the threshold inversion if $\sigma = 8.8 \times 10^{-19}$ cm^2. Relate these values to E (M^{-1} cm^{-1}). Select appropriate examples to see effect of increasing length, concentration, and reflectivity on threshold.

1.6. Ultimate limit of divergence of a laser is diffraction $\theta d = \beta\lambda / D$ where

θd = divergence, λ = wavelength, $\beta \sim 1$ optimal design, D = diameter

If a YAG:Nd laser beam (λ = 1.06 μ) is sent to the moon (384,000 km) from an oscillation of 1m = D, calculate its diameter on arrival.