Ministry of Higher Education & Scientific Research
University of Technology
Laser & Optoelectronic Eng. Department
Branch: Laser Engineering
Class: 3rd Year:
**Subject: Spectroscopy**

Final Examination
Time: THREE HOURS
Date: June 7th 2016
Examiner: Dr. Fareed
Code: LE3308
Academic Year: 2015-2016

**Attempt (*FIVE*) questions only**

**Q1) a)** Convert (1.9) e.v into $cm^{-1}$ into then into joules.

**b)** A Laser beam of light is incidented on a target, if only 32% of the incident light is absorbed; find the thickness of the sample if the absorption coefficient ($\alpha$) is 10 $cm^{-1}$, and the intensity of the incident light is $11 w/cm^2$. **(12 marks)**

**Q2) a)** State and draw the components of a typical absorption spectroscopic system.

**b)** State the three Bohr postulates.

**(12 marks)**

**Q3) a)** Find the value of the energy difference between the n=3 and n=4 levels for lithium atom (z=3) in electron volts (ev), then convert it into ($cm^{-1}$).

**b)** Explain the differences between Zeeman and stark effects.

**(12 marks)**

**Q4) a)** Find the frequency of radiation (using Lyman series) of the third level (n=3) if the Rydberg constant ($R = 1.0966 \times 10^7 m^{-1}$).

**b)** What are the two corrections of central field model of atoms having more than one electron?

**(12 marks)**

**Q5)** Find the spin -orbit coupling energy $\Delta E_{ls}$ of a (p) electron if the electron spin is (3/ 2), $g_s = 2$, and Bohr magneton = $9.3 * 10^{-24}$ J/T.

**(12 marks)**

**Q6)** The rigid diatomic molecule treated as two masses: ($2.014*10^{-27}$) kg and ($18.998*10^{-27}$) kg, joined by a rigid bar of length (1.31) $A^0$. Find:

**(a)** The reduced mass.

**(b)** The moment of inertia.

**(c)** The rotational constant.

**(d)** The rotational energy for the sixth rotational level.

**(12 marks)**

***Useful constants***

$k=1.38*10^{-23} JK^{-1}$ $h=6.63*10^{-34} J.s$ $c = 3*10^8 ms^{-1}$

*Charge of (e)=*$1.6*10^{-19}$*coulomb* *Mass of (e )=* $9.1*10^{-31}$ *kg*

Answers to <u>Spectroscopy</u> Exam.
Third year _ Laser Eng.



**Q.1a**

$1.9\,eV \rightarrow cm^{-1}$

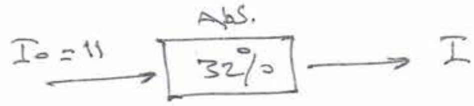
$$E = \frac{hc}{\lambda} \Rightarrow \frac{1}{\lambda} = \frac{E}{hc} = \frac{1.9 * 1.6*10^{-19}}{6.63*10^{-34} * 3 * 10^{8}}$$

$$\frac{1}{\lambda} = 0.1528 * 10^{7}\ m^{-1}$$

$$= 15280\ cm^{-1}$$

$1.9 \longrightarrow$ Joule

$$1.9 * 1.6 * 10^{-19} = 3.04 * 10^{-19}\ \text{Joule}.$$




**b/**

$$\alpha = 10\ cm^{-1}$$

$$I = I_o\, e^{-\alpha X}$$

$$11 * 0.32 = 11\, e^{-10X}$$

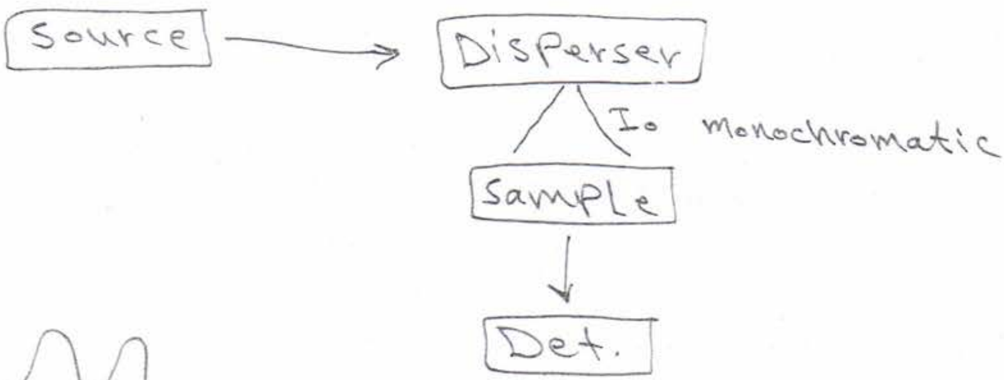
$$0.32 = e^{-10X}$$

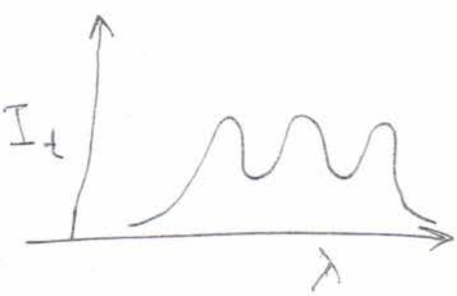
$$Ln\, 0.32 = -10X$$

$$-1.139 = -10X$$

$$X = 0.1139\ cm$$

**Q.2a/**



Q.2.b

1. Electron rotate about nucleus in a fixed orbit
2. " does not emit E.M.R
3. Radiation emitted or absorbed when electron undergoes transition to another orbit.

Q.3a

$n=3$ , $n=4$ , $Z=3$

$$E_3 = \frac{-13.6\,Z^2}{n^2} = \frac{-13.6 * 3^2}{3^2} = -13.6 \text{ ev}$$

$$E_4 = \frac{-13.6 * 3^2}{4^2} = -7.65 \text{ ev}$$

$$E_4 - E_3 = \Delta E = 7.65 - (-13.6) = 5.95 \text{ ev}$$

$$\Delta E = \frac{hc}{\lambda} \Rightarrow \frac{1}{\lambda} = \frac{\Delta E}{hc} = \frac{5.95 * 1.6 * 10^{-19}}{6.63 * 10^{-34} * 3 * 10^{8}}$$

$$\frac{1}{\lambda} = 0.479 * 10^{7} \text{ m}^{-1} = 47900 \text{ cm}^{-1}$$

Q.3b

| Zeeman effect | Stark effect |
|---|---|
| 1. splitting of energy levels due to magnetic fields | 1. due to electric fields |
| 2. Electrons has magnetic dipole | 2. Electrons has no electric dipole. |

Q.4a

Lyman Series

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

$$= 1.097 * 10^{7}\left(\frac{1}{1} - \frac{1}{3^2}\right)$$

$$1/\lambda = 0.969 * 10^{7} \text{ m}^{-1}$$

$$\therefore \lambda = 1.03 * 10^{-7} \text{ m}$$

$$f = \frac{c}{\lambda} = \frac{3 * 10^{8}}{1.03 * 10^{-7}} = 2.91 * 10^{15} \text{ Hz}$$

Q.4b (3)

1. electrostatic interaction:

a. potential due to (nucleus + core) interaction with outer electrons

b. potential due to interaction between electrons in the same sub shell.

2. magnetic interaction:

interaction between orbital & spin angular momenta

Q.5 a

p-electron $\Rightarrow l = 1$

$s = 3/2$ , $g_s = 2$

$j = l + s = 1 + \frac{3}{2} = \frac{5}{2}$

$$\Delta E_{ls} = g_s \hbar \mu_B (s^* \cdot l^*)$$

$$s^* \cdot l^* = \frac{1}{2}(j^{*2} - l^{*2} - s^{*2})$$

$$s^* = \sqrt{s(s+1)} = \sqrt{\frac{3}{2}(\frac{3}{2}+1)} = \sqrt{\frac{15}{4}}$$

$$l^* = \sqrt{l(l+1)} = \sqrt{1(1+1)} = \sqrt{2}$$

$$j^* = \sqrt{j(j+1)} = \sqrt{\frac{5}{2}(\frac{5}{2}+1)} = \sqrt{\frac{35}{4}}$$

$$s^* \cdot l^* = \frac{1}{2}\left(\frac{35}{4} - 2 - \frac{15}{4}\right)$$

$$= \frac{3}{2}$$

$$\therefore \Delta E_{ls} = 2 * \left(\frac{6.63 * 10^{-34}}{2 * 3.14}\right) * 9.3 * 10^{-24} * \frac{3}{2}$$

$$= 29.45 * 10^{-58} \text{ Joule}$$

Q.6

a/ $$\mu = \frac{m_A m_B}{m_A + m_B} = \frac{2.014 * 10^{-27} * 18.998 * 10^{-27}}{2.014 * 10^{-27} + 18.998 * 10^{-27}}$$

$$= 1.82 * 10^{-27} \text{ kg}$$

b/ $$I = \mu R_0^2 = 1.82 * 10^{-27} * (1.31 * 10^{-10})^2$$

$$= 3.12 * 10^{-47} \text{ kg.m}^2$$

c/ $$B = \frac{\hbar}{4\pi I (100c)} = 8.9$$

d/ $$E_r = \frac{1}{2I} J(J+1) \hbar^2$$

$$= \frac{6(6+1) * \left(\frac{6.63 * 10^{-34}}{2\pi}\right)^2}{2 * 3.12 * 10^{-47}} = 7.502 * 10^{-21} \text{ J}$$