Chem 101 2017 Discussion #11 Chapter 8

Your name/ TF's name:________________Key__________Discussion Day/Time: _______________

Things you should know when you leave Discussion today:

1. Atomic (matter) Emission and absorption of light.
   a. Energy Conservation and interaction between light and matter: $\mathbf{\Delta E_{light} + \Delta E_{matter} = 0}$
   b. Amount of energy exchange (and sign of **ΔE)**
2. Calculating the wavelength and frequency of light, and energy of a photon,
3. Use an energy-level diagram for an atom

1. If light is in resonance with matter what must be true:

a. $|\Delta E_{light}| < |\Delta E_{cloud}|$ **$|\Delta E_{light}| = |\Delta E_{cloud}|$** $|\Delta E_{light}| > |\Delta E_{cloud}|$

b. $|\Delta E_{cloud}| < h\nu_{light}$ **$|\Delta E_{cloud}| = h\nu_{light}$**_________ $|\Delta E_{cloud}| > h\nu_{light}$

2. Absorption verses ***emission***:

a. During ***emission***, light (**gains** / gives off) energy and an atom (gains / **gives off**) energy.

b. $\Delta E_{light} = h\nu$ $\Delta E_{atom} = -h\nu$

c. During ***absorption***, light (gains / **gives off**) energy and an atom (**gains** / gives off) energy.

d. $\Delta E_{light} = -h\nu$ $\Delta E_{cloud} = h\nu$

3. When a molecule of substance A is resonant with the red light 700nm and a molecule of substance B is resonant with the blue light (400nm). Which statement is the most accurate? (Hint: unit of energy transferred is equal to $h\nu = \frac{hc}{\lambda} = E_{photon}$)

a. When substance A absorbs light it absorbs more energy than substance B.
b. When substance B absorbs light it absorbs more energy than substance A.
c. Because each molecule absorbs one quantum of light, the amount of energy absorbed by each substance is the same.
d. There is no energy absorbed because temperature of the surrounding does not change.

4. Without doing any calculations which of the following beams of electromagnetic radiation transfers the greatest amount of energy per second when one electron is resonant with the light? A watt is an intensity of the light that represent total amount of energy available per second W=1J/s. (Hint: unit of energy transferred is equal to $h\nu = \frac{hc}{\lambda} = E_{photon}$)

a. 0.01 J/s (watt) with wavelength λ = 11000 nm
b. 100 J/s (watt) with wavelength λ = 600 nm
c. 1 J/s (watt) with wavelength λ = 400 nm
d. 0.01 J/s (watt) with wavelength λ = 0.01 nm

5. An atom's emission spectrum contains lines of red light and green light (and nothing else). The reason why there is no orange light in the spectrum is because …

a. The atom would need more energy to emit orange light
b. The atom does not have an energy level corresponding to that of an orange light
c. The atom is not resonant with the orange light
d. Atoms always only can give off two lights

6. We have a light bulb that gives off light with the wavelength of 500. nm and produces 120. W of power. (1W=1J/1s, h=6.62607004·10^{-34} J·s , 1eV= 1.6021766 × 10^{-19}J)

a. How much energy in J is transferred to matter when the cloud of one electron resonant with that light? (Hint: How much is one unit of energy transferred?)(At home recalculate the energy in eV) (Answer:3.97*10^{-19} J)

$$\frac{h \cdot c}{\lambda} = E_{photon} = 3.97*10^{-19} \text{ J}$$

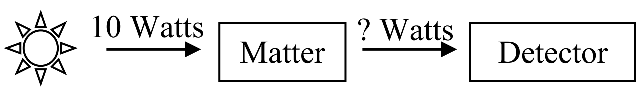
b. How many electron clouds will it take to absorb all the light provided by the bulb per second? (Answer:3.02*10^{20} electron clouds /s)

$$\frac{120W}{E_{photon}} = \frac{120J}{1s}\frac{1photon}{3.97 \cdot 10^{-19}J}\frac{1e^{-}cloud}{1photon} = 3.02 \cdot 10^{20}\frac{e^{-}clouds}{1s}$$

c. How many moles of the electrons absorb that amount of energy per second? (Answer:5.02*10^{-4})

$$3.02 \cdot 10^{20}\frac{e^{-}clouds}{1s}\frac{1mol}{N_A} = 5.02*10^{-4}\text{moles}$$

7. A light beam of 10 Watts and 500nm illuminates a sample of matter. The matter is able to absorb 1.5x10^{19} photons of light every second at 500nm. What intensity of light (in Watts) is seen at the detector? (Answer:4W)



$E_{photon} = \frac{hc}{\lambda} = 4 \cdot 10^{-19}$J/photon

Matter is able to absorb $1.5 \cdot 10^{19}$ photons of light every second hence:

$$1.5 \cdot 10^{19}\frac{photons}{s} * 4 \cdot 10^{-19}\frac{J}{photons} = 6\text{J/s} = 6 \text{ Watts absorb by matter}$$

10 Watts - 6 Watts=4Watts is left and will be detected

8. Red light emitted by an atoms has wavelength at 650nm. A typical IR frequency is ν_{IR}~ 1 × 10^{13} Hz. This means that, compared to the mass, m_{atom}, of what is moving in response to visible light, the moving mass in IR spectra, m_{IR}, is …(Answer: 2000 times heavier)

$$\nu_{atom} = \frac{c}{\lambda} = 4.62 \cdot 10^{14} Hz$$

$$\frac{\nu_{atom}}{\nu_{IR}} = \sqrt{\frac{m_{IR}}{m_{atom}}}; \quad \frac{m_{IR}}{m_{atom}} = \left(\frac{\nu_{atom}}{\nu_{IR}}\right)^2 = 2130 \approx 2000 times$$

9. A red laser of 700nm and a violet laser of 350nm are both pointed at the same detector. The detector reads that the same amount of red red light is absorbed per second as the amount of violet light is absorbed per second. If the violet laser is 10 Watts, then what the intensity of the red laser?(Answer:5)

$$\frac{\#watts(red)}{\frac{hc}{\lambda_{red}}} = \frac{10W}{\frac{hc}{\lambda_{violet}}}$$ # of watts (red)=10W*350nm/700nm=5Watts

10. You have light with an intensity of 10.0 Watts and frequency of $6.00\cdot10^{14}$ Hz. Calculate the change of energy of the light, in Joules, if the electron clouds of one trillion (10^{12}) atoms are excited. ($h=6.626x10^{-34}$ J·s). (Answer:$-39.6\cdot10^{-8}$J)

Energy change when one photon of energy is transferred:

$\Delta E_{light}=E_{photon}= h\cdot \nu_{light}$ $= 6.6\cdot10^{-34}\cdot6\cdot10^{14}\ s^{-1}=39.6\cdot10^{-20}$J/photon

To jiggle 10^{12} atoms we need 10^{12} photons of energy transferred**:**

$\Delta E_{light}=E_{photon}$ $\cdot10^{12}= 39.6\cdot10^{-20}$(J/photon)$\cdot10^{12}$(photons)$= 39.6\cdot10^{-8}J=4\cdot10^{-7}$J per second is lost.

$\Delta E_{light}=$ -$4\cdot10^{-7}$J/s (light was emitted)

Additional question: What was the fraction of the light energy that was lost in 1 s.?

$$\frac{\frac{\Delta E_{light} lost}{second}}{10W} = \frac{4\cdot10^{-7}\ J/s}{10J/s} = 4\cdot10^{-8}$$ or 0.00004% (very small percentage)

11. Calculate the amount of energy transferred in joules when one mole of electrons absorbs red light frequency of $4.00\cdot10^{14}$ Hz.(Hint: what is the value of one unit of energy transferred?)(Answer:159kJ)

$E_{photon} = \frac{h\cdot c}{\lambda} = h\nu = 30*10^{-20}$J ; 1 mol of photons $E_{photon} = h\cdot\nu\cdot N_A$=159kJ

12. Would a mole of light with wavelength of 500 nm provide enough energy to vaporize 10 moles of water? (ΔH_{vap} for water = 44 kJ/mol)(Answer:No)

$\Delta E_{light}=E_{photon}\cdot N_A=\frac{h\cdot c}{\lambda}\cdot N_A$=245kJ not enough. You need 440kJ

13. How many times more energetic is a light corresponding to λ = 5.0 nm than a light corresponding to λ = 1.0 x 10^2 nm light?(Hint: compare units of energy transferred?)(Answer:20)

14. Using the information in question 4, calculate the following for practice:

a. How much energy is transferred to matter when the cloud of one electron resonant with light in each beam of electromagnetic radiation.

$$E_{photon} = \frac{h\cdot c}{\lambda} = h\nu$$

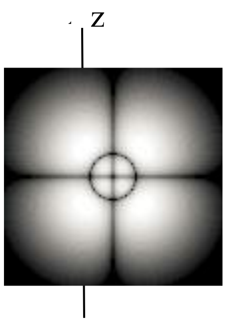
b. How many electron clouds per second will it take to absorb all the light provided by each light?

$$\frac{\#\,watts}{\frac{hc}{\lambda}}$$

15. Fill the table below

Orbital	*l*	n=j+*l*	j= n-*l*	Shape	Number of orbitals in a subshells(m_l)	# e^-
s	**0**	1 2 3 etc	1 2 3 j=n	Sphere	1 orientation in space	2
p	**1**	2 3 4 etc	1 2 3 j=n-1	Dumbbell	3	6
d	**2**	3 4 etc	1 2 j=n-2	Cloverleaf	5	10
f	**3**	4 5 etc	1 2 j=n-3		**7**	14

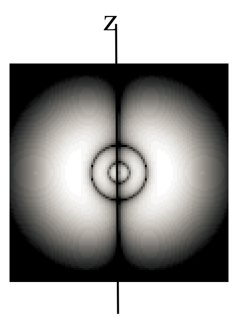
16. For the two hydrogen electron clouds below identify the quantum number "n", the quantum number "l", the number of radial loops "j", and the specific name of the orbital (you must indicate orientation, e.g. $3d_{xy}$).



n =4 l= 2 j= 2

x

name: $4d_{zx}$

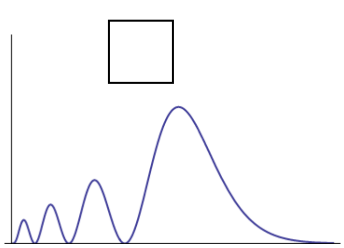


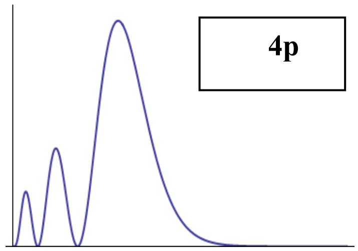
n =4 l=1 j=3

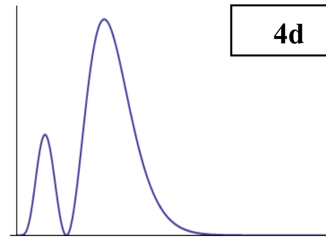
x

name:$4p_x$

a. Match each of the electron clouds above to <u>one</u> corresponding electron cloud cross section below. Indicate your answer by putting in the box next to the function.(x axis is distance from the nucleus, and y axis is a probability of finding an electron at the given distance)



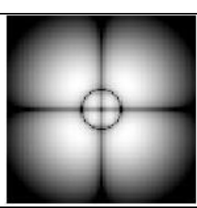


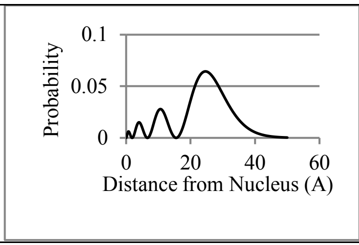


17. Fill out the table:

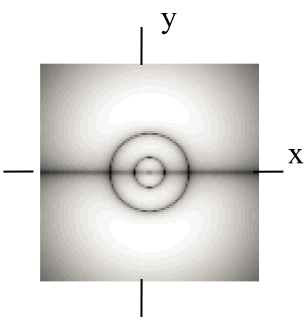
n, l, j	Name the orbital	Draw the orbital
n=2, l=0	j=2 2S	
n=4, l=2	j=2 4d	
n=2, l=1	j=1 2p	
n=2, l=2	j=0	Doesn't exist
l=2, j=1	n=3 3d	
l=0, j=3	n=3 3s	

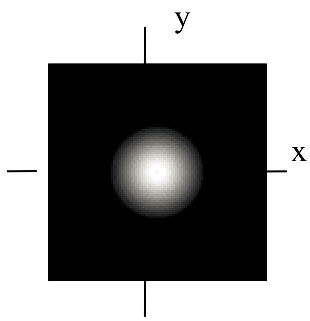
18. Complete the table below about the hydrogen atom:

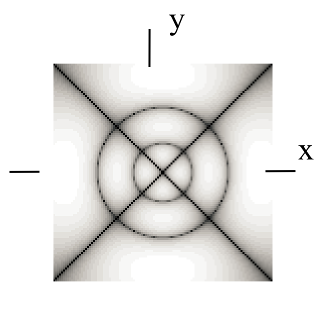
	Electron Cloud Name	**Principle quantum number, *n***	**Angular momentum quantum number, *l***	***j* (number of radial loops)**
---------	name = 2s	*n* = 2_____	*l* = 0_____	*j* = _2___
	name = _4d_	*n* = __4__	*l* = 2_____	*j* = _2___
--------	name =5d_	*n* = _5___	*l* = 2	*j* = 3

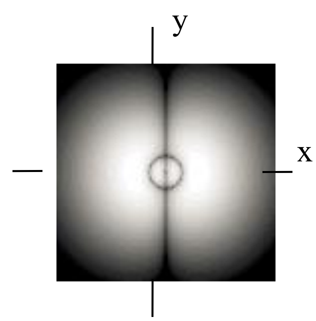
	name = __4s__	*n* = 4	*l* = ___0_	*j* = 4____
---------	name = 9f____	*n* = _9___	*l* = 3	*j* = 6

19. Display A: __4p_y___ Display B: _1S____ Display C: _5D____ Display D: _3p_x____









In preparation for next week **NOT On the exam 3**:

Read: Hydrogen atom family album, PDF, 7 pages, http://goo.gl/XPkcxv and answer the following questions:

20. How does the relative size of the *n*s orbitals compare?

21. Does the size of the *n*p and of the *n*d orbitals increase with *n*?

22. How does the relative size of the innermost loop of the *n*s orbitals compare?

23. How does the relative size of the innermost loop of the *n*p orbitals compare?

24. How does the relative size of the outermost loop of the *n*s orbitals compare?

25. How does the relative size of the outermost loop of the *n*p orbitals compare

26. Which of the orbitals 4s, 4p, and 4d is the largest, that is, has the electron density distributed over the greatest volume?

27. Which of the orbitals 4s, 4p, and 4d is the smallest, that is, has the electron density distributed over the smallest volume?

28. Is the relative size ordering *n*s > *n*p > *n*d true for *n* = 3 as well?

29. Shown below are displays of the *density* in the *xy* plane of an electron in several hydrogen atom orbitals. The brightness of the displays is proportional to the probability density. For each display, correctly name the orbital, for example, 1s, $2p_x$, etc.