CH 101 Fall 2018
Discussion #11
Chapter 8

Your name: ______________________ TF's name____________________ Discussion Day/Time: __________________

Things you should know when you leave Discussion today:

- Atomic (matter) Emission and absorption of light.
  - Energy Conservation and interaction between light and matter: $\mathbf{\Delta E_{light} + \Delta E_{matter} = 0}$
  - Amount of energy exchange (and sign of **ΔE**)
- Calculating the wavelength and frequency of light, and energy of a photon.
- Read: Hydrogen atom family album, PDF, 7 pages, http://goo.gl/XPkcxv
- Plank constant is h=6.62607004·10^{-34} J·s

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 e^- cloud (gains / gives off) energy.

   b. ΔE_{light} = (+ / -) ΔE_{cloud} = (+ / -)

   c. During ***absorption***, light (gains / gives off) energy and an e^- cloud (gains / gives off) energy.

   d. ΔE_{light} = (+ / -) ΔE_{cloud} = (+ / -)

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.
   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 only. 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 give off two lights

6. Red light emitted by an atom has wavelength of 650 nm. A typical IR frequency is $\nu_{IR} \sim 1 \times 10^{13}$ Hz. This means that compared to the mass of what is moving in response to visible light, m_{atom}, the moving mass in IR spectra, m_{IR}, is…

7. We have a light bulb that gives off light with the wavelength of 500. nm and produces 120. W of power. 1W=1J/s, 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 a single electron resonant with that light? *Hint: How much is one unit of energy transferred?* At home recalculate the energy in eV.

   b. How many electron clouds will it take to absorb all the light provided by the bulb per second? *Hint: any one electron absorb only ones.*

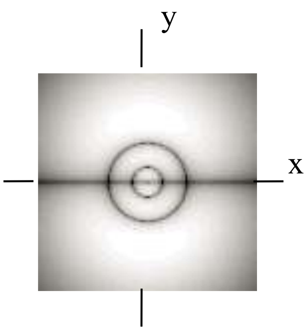
   c. How many moles of the electrons absorb that amount of energy per second?

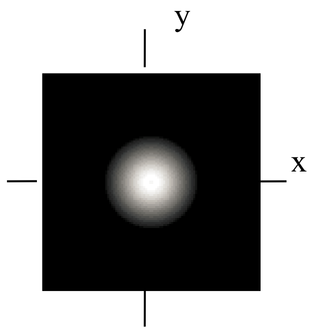
8. Fill the table below

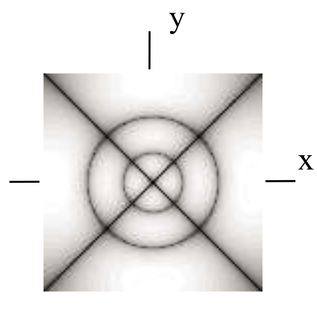
Orbital	l	n=j+l	j= n-l	Shape	Number of orbitals in a subshells(m_l) $m_l=2l+1$	# e^- that can fit
s	0	1 2 3 etc		Sphere		
p	1	2 3 4 etc		Dumbbell		
d	2	3 4 etc		Cloverleaf		
f	3	4 5 etc				

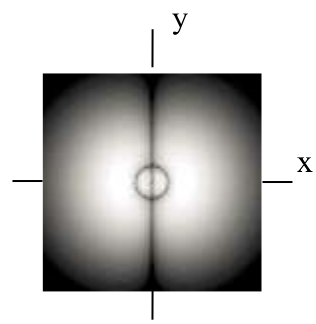
9. Shown below are displays of the *density* in the *xy* plane of an electron in several hydrogen atom orbitals. The brightness of the displays is proportional to the probability density. For each display, correctly name the orbital. (For example: 1s, $2p_x$, etc.) Remember: *S: l=0, P:l=1, D;l=2 and* ***n=j+l***

Display A: ____ Display B: ____ Display C: ____ Display D: ____





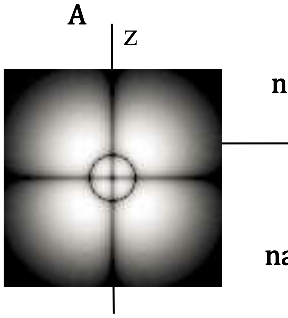




a. Which orbital represent the highest energy e^- cloud and lowest energy e^- cloud.

10. For the two hydrogen electron clouds below identify the quantum number “n”, the quantum number “l” number of nodal planes, the number of radial loops “j”, and the specific name of the orbital and the specific name of the orbital (you must indicate orientation, e.g. $3d_{xy}$). Remember: *S: l=0, P:l=1, D;l=2 and* ***n=j+l***

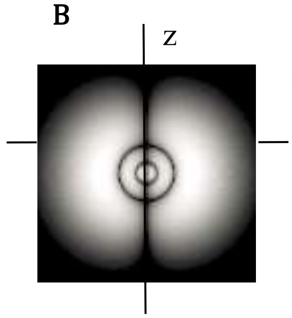
A



n = ____ l = ____ j = ____

name: ________________

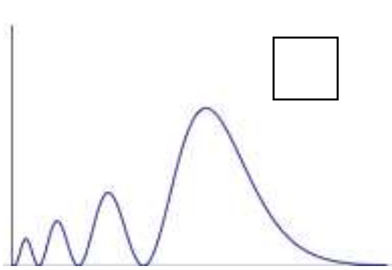
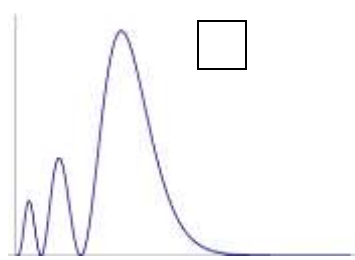
B



n = ____ l = ____ j = ____

name: ________________

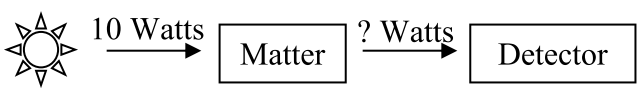
a. Match each of the electron clouds above to <u>one</u> corresponding electron cloud cross section below. Indicate your answer by writing ‘A’ or ‘B’ in the box next to the function it matches. (X-axis is distance from the nucleus, and y-axis is a probability of finding an electron at the given distance).


11. Complete the table:

n, l, j	**Name the orbital**	**Draw the orbital**
$n = 2$ $l = 0$		
$n = 4$ $l = 2$		
$n = 2$ $l = 1$		
$n = 2$ $l = 2$		
$l = 2$ $j = 1$		
$l = 0$ $j = 3$		

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



13. 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 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?

14. You have light with an intensity of 10.0 Watts and frequency of $6.00 \cdot 10^{14}$ Hz. Calculate the change of energy of the light (in Joules) if the electron clouds of one trillion (10^{12}) atoms are excited per second.

    a. What was fraction of the light that was lost in 1s?

15. Calculate the amount of energy transferred in joules when one mole of electrons absorbs red light frequency of $4.00 \cdot 10^{14}$ Hz. Hint: what is the value of one unit of energy transferred?

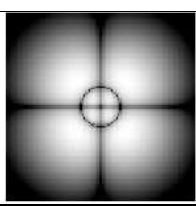
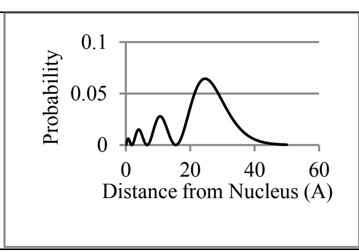
16. Would a mole of light with wavelength of 500 nm provide enough energy to vaporize 10 moles of water if $\Delta_{vap}H$ for water is 44 kJ/mol .

17. How many times more energetic is light corresponding to $\lambda = 5.0$ nm than light corresponding to $\lambda = 1.0 \times 10^2$ nm? *Hint: compare units of energy transferred.*

18. When light transfers energy it does so in finite, quantized (fixed) amounts. These amounts are called photons (they are not a physical thing, but a quantity of energy). This amount is directly related to the frequency of the light's oscillating electric field. When light transfers energy it does so in quantities of $h\nu$.
    a. What is the smallest amount of energy that light with frequency 3.5×10^{13} Hz can transfer?
    b. Can light with frequency 3.5×10^{13} Hz transfer 1.6 times as much light as you calculated in part (a)? Why or why not?
    c. What is the wavelength and frequency of light that can transfer 1.6 times as much energy as you calculated in part (a)?

19. Read the Hydrogen atom family album PDF (7 pages) http://goo.gl/XPkcxv and answer the following questions:
    a. How do the relative sizes of the ns orbitals compare?
    b. Does the size of the np and of the nd orbitals increase with n?
    c. How does the relative size of the innermost loop of the ns orbitals compare?
    d. How does the relative size of the innermost loop of the np orbitals compare?
    e. How does the relative size of the outermost loop of the ns orbitals compare?
    f. How does the relative size of the outermost loop of the np orbitals compare?
    g. Which of the orbitals 4s, 4p, and 4d is the largest, that is, has the electron density distributed over the greatest volume?
    h. Which of the orbitals 4s, 4p, and 4d is the smallest, that is, has the electron density distributed over the smallest volume?
    i. Is the relative size ordering ns > np > nd true for n = 3 as well?
    j. 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 label the orbital, for example, 1s, $2p_x$, etc.

20. 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	$n =$ ___	$l =$ ___	$j =$ ___
	name = ___	$n =$ ___	$l =$ ___	$j =$ ___
--------	name = ___	$n =$ ___	$l = 2$	$j = 3$
	name = ___	$n = 4$	$l =$ ___	$j =$ ___
---------	name = ___	$n =$ ___	$l = 3$	$j = 6$

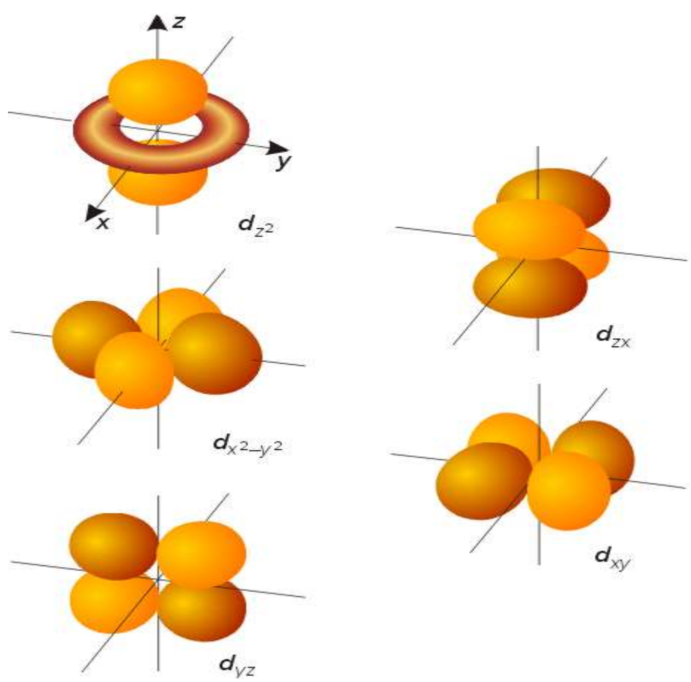
21. For each "orbital" below, list the number of radial loops (j), nodal planes (l), the principle quantum number (n), and how many different orbitals there are with that name.
   a. 2p
   b. 4s
   c. 3d
   d. 7f

Useful information:

- Atomic wave function family album
   a. Principle quantum number n=1,2,3,... specifies energy level
      $n=j+1$ (j is number of loops)
   b. Number of nodal planes (l).
   c. Angular momentum quantum number (l=0, 1, 2,...n-1) defines the shape of the orbital.
   d. $m_l = -l, \ldots 0 \ldots l$
   e. Number of loops **j** ($j=n-l$)
   f. S, P and D and F orbitals.
   g. Size of the orbital is proportional to n^2

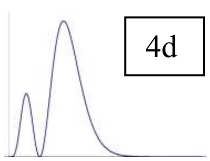
Orbital type	# nodal planes (l)	Principle Q.N. ($n=j+l$)	Radial loops ($j=n-l$)	Shape	# of orbitals in a subshell ($m_l=2l+1$)	# of e⁻ that can fit
s	0	1 2 3 etc.	1 2 3 *j=n*	Sphere	1	2
p	1	2 3 4 etc.	1 2 3 *j=n-1*	Dumbbell	3	6
d	2	3 4 etc.	1 2 *j=n-2*	Cloverleaf	5	10
f	3	4 5 etc.	1 2 *j=n-3*		7	14

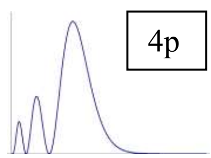
Useful Information: Below are the $3d_{xy}$, $3d_{x^2-y^2}$ and $3d_{yz}$ orbital. Be sure to correctly orient your orbitals in the xyz space.



Numerical Answers:

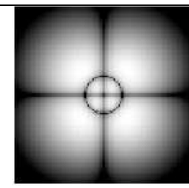
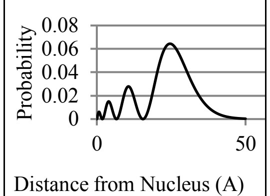
1. $|\Delta E_{light}| = |\Delta E_{cloud}|$ and $|\Delta E_{cloud}| = h\nu_{ight}$
2.
   a. Gains; gives off
   b. $\Delta E_{light} = + h\nu_{ight}$; $\Delta E_{cloud} = - h\nu_{ight}$
   c. Gives off; gains
   d. $\Delta E_{light} = - h\nu_{ight}$; $\Delta E_{cloud} = + h\nu_{ight}$
3. B
4. D
5. C
6. 2×10^{3} times
7.
   a. 3.97×10^{-19} J
   b. 3.02×10^{20} electron clouds/1s
   c. 5.02×10^{-4} moles
8. Table on pg 6
9. A: $4p_y$; B: 1s; C: $5d_{x^2-y^2}$; D: $3p_x$
   a. C, B
10. $4d_{zx}$; 4px
    a.





11. 2S, 4D, 2P,
    j=0 does not exist, 3D, 3S
12. 4 W
13. 5W
14. -3.98×10^{-7} J
    a. 0.00000397%
15. 159kJ
16. No
17. 20 times
18.
    a. 2.3×10^{-20} J/photon
    b. No, it's quantized.
    c. $\nu=5.6\times10^{-13}$ Hz; $\lambda=5351$ nm

20.

	Electron Cloud Name	n	*l*	*j*
---------	2s	$n = 2$	$l = 0$	$j = 2$
	4d	$n = 4$	$l = 2$	$j = 2$
--------	5d	$n = 5$	$l = 2$	$j = 3$
	4s	$n = 4$	$l = 0$	$j = 4$
---------	9f	$n = 9$	$l = 3$	$j = 6$

21.
   a. 2p → n=2; l=1; j=1
   b. 4s → n=4; l=0; j=4
   c. 3d→ n=3; l=2; j=1
   d. 7f→ n=7; l=3; j=4