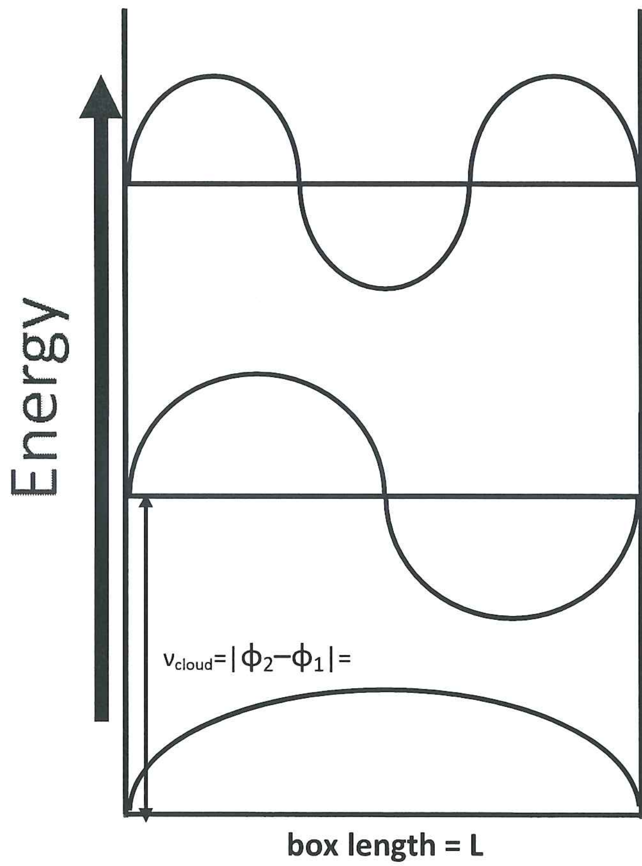
CH 101 - Practice problems – 2/12/2013

Waves and quantum mechanics II.

1. Fill up the diagram below.



$E_3= \frac{9h^2}{8mL^2}$

$\phi_3= \rightarrow \frac{9h}{8mL^2}$

$\lambda_3= \frac{2}{3}L$

$E_2= \rightarrow \frac{h^2}{2mL^2}$

$\phi_2= \frac{h}{2mL^2}$

$\lambda_2= L$

$E_1=\frac{h^2}{8m_eL^2}$; $j^2=1$

$\phi_1=\frac{E_1}{h}=\frac{h}{8m_eL^2}$;

$\lambda_1=2L$; $L=\frac{\lambda_1}{2}$

$$\text{Energy} = \frac{n^2h^2}{8mL^2}$$

$$\Phi_n = \frac{E_n}{h} = \frac{n^2h}{8mL^2}$$

where: n = Energy level quantum #.

h = Planck's constant

E_n = Energy of the level

Φ_n = Wave Function

L = length of the box

2. Using the one-dimensional particle in a box model calculate the wavelength of an electron wave that will have an energy 25x greater than that of the ground state energy; the size of the box equals 10 Å.

@ Ground state $\lambda = 2L = 2 \times 10 = 20. \mathring{A}$

if E is 25x greater, λ is 25x shorter.

New $\lambda = \frac{1}{\cancel{25}} \cdot \cancel{20}\,4\, \mathring{A} = \mathring{A} = 0.8\ \mathring{A}$

3. Neutron diffraction is used in determining the structure of molecules.
   a. Calculate the De Broglie wavelength of a neutron moving at 1.00% of the speed of light.

$$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \text{Kg} \, (0.01) \cdot 3 \times 10^{8}} = 1.32 \times 10^{-13} \text{ m}$$

1%

   b. Calculate the velocity of a neutron with a De Broglie wavelengths of 75pm.

$$v = \left(\frac{p}{m}\right) = \frac{h/\lambda}{m} = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34}}{7.5 \times 10^{-11} \cdot 1.67 \times 10^{-27}} = 0.52 \times 10^{4} \frac{m}{s}$$

4. Calculate the shortest and longest wavelength of light emitted by electrons in the hydrogen atoms falling to lower levels from n=6.

$n = 6 \longrightarrow n = 1$ shortest

$$\lambda = c \cdot \nu^{-1} = c\left[R\left(\frac{1}{1} - \frac{1}{6^2}\right)\right]^{-1} = 0.94 \times 10^{-7} \text{ m}$$

$n = 6 \longrightarrow n = 5$ longest

$$\lambda = 7.46 \times 10^{-6} \text{ m}$$

5. Using the Heisenberg principle...

   a. Calculate Δx for an electron having Δv=0.100 m/s

$$\Delta x \Delta p \geq \frac{1}{2}\hbar$$

$$\Delta p = m\Delta v = 9.109 \times 10^{-32}\ Kg \cdot \frac{m}{s}$$

$$\Delta x \geq \left(\frac{h}{4\pi}\right) \cdot \frac{1}{\Delta p} = 5.8 \times 10^{-4}\ m$$

   b. Calculate Δx for a baseball (m=145g) having Δv=0.100m/s

$$\Delta x \geq \frac{h}{4\pi} \cdot \frac{1}{0.0145\ Kg\ \frac{m}{s}} = 3.6 \times 10^{-33}\ m$$

   c. How does the answer in part a compare with the size of an hydrogen atom?

Roughly 10^{6} times bigger.

   d. How does the answer in part b correspond to the size of a baseball?

Roughly 10^{32} times smaller!

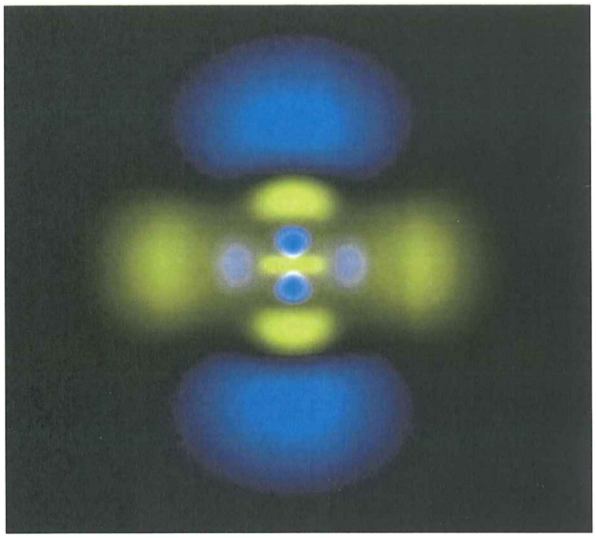
6. What is the physical significance of Ψ^2 at a particular point in an atomic orbital?

Probability Density

7. Which of the following sets of quantum numbers are NOT allowed?

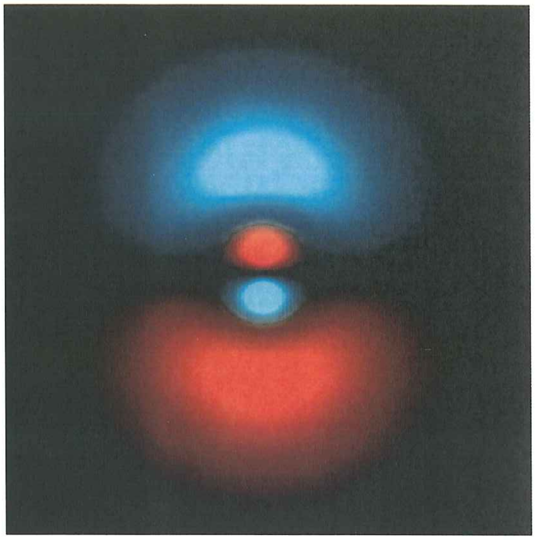
   a. n=3, l=3, m_l=0, m_s=-1/2
   b. n=4, l=3, m_l=2, m_s=-1/2
   c. n=4, l=1, m_l=1, m_s=+1/2
   d. n=2, l=1, m_l=-1, m_s=-1
   e. n=5, l=-4, m_l=2, m_s=+1/2
   f. n=3, l=1, m_l=2, m_s=-1/2

8. Counting the number and type (angular v. radial) nodes, identify each of the following orbitals, and determine *n* and *l* values.



Orbital : 5d

n = 5 l = 2

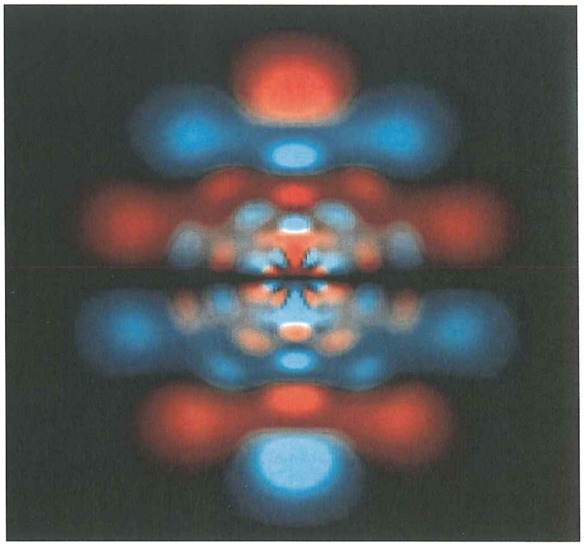


Orbital : 3p

n = 3 l = 1

Orbital : 8p

n = 8 l = 1



Orbital : 10h

n = 10 l = 5

You can keep playing with this simulation. It is free and open access on-line at http://www.falstad.com/qmmo/ *, once on the page, click on Hydrogen atom applet. The applet itself is a Java pop-up window.*

corresponds to n for particle in the box in some textbooks.

9. Draw the following orbitals and name them:

   a. n=2, l=0
   b. n=3, l=2
   c. n=2, l=1
   d. n=2,l=2
   e. l=2, j=1
   f. l=0, j=3
   g. l=1, j=2

a. 

c. 

b. 

d. IMPOSSIBLE

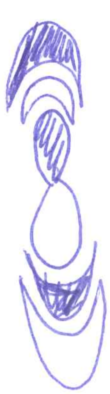
e. IMPOSSIBLE

g. 

f.

Also consider these other examples:

$n = 4$, $l = 1$



$n = 4$, $l = 2$

10. Rank the orbitals from question 9 in increasing order of size.

$a < c = g < f < b$

11. Rank the orbitals from question 9 in increasing order of Ionization energies.

$b < f < g = c < a$

12. Write the electron configuration of the atoms of the first 2 periods:

H: $1s^1$

He: $1s^2$

Li: $1s^2\ 2s^1$

Be: $1s^2\ 2s^2$

B: $1s^2\ 2s^2\ 2p^1$

C: $1s^2\ 2s^2\ 2p^2$

N: $1s^2\ 2s^2\ 2p^3$

O: $1s^2\ 2s^2\ 2p^4$

F: $1s^2\ 2s^2\ 2p^5$

Ne: $1s^2\ 2s^2\ 2p^6$

13. Building-up principle and electronic configuration.

a. Fill in the boxes with the electrons (arrows up = spin +1/2 ; arrows down = spin -1/2).

Sb^{3+}

6s							
5p							
3d							
4f							
5s							
5p							
4d	↑↓	↑↓	↑↓	↑↓	↑↓		
5s	↑↓						
4p	↑↓	↑↓	↑↓				
3d	↑↓	↑↓	↑↓	↑↓	↑↓		
4s	↑↓						
3p	↑↓	↑↓	↑↓				
3s	↑↓						
2p	↑↓	↑↓	↑↓				
2s	↑↓						
1s	↑↓						

Ar* (* means it is in its first excited state)

6s							
5p							
3d							
4f							
5s							
5p							
4d							
5s							
4p							
3d							
4s	↑						
3p	↑↓	↑↓	↑				
3s	↑↓						
2p	↑↓	↑↓	↑↓				
2s	↑↓						
1s	↑↓						

b. Write the electron configurations for the species in problem 13a.

Configuration Sb3+: [Kr] $5s^2 4d^{10}$

Configuration Ar*: [Ne] $3s^2 3p^5 4s^1$

c. In the diagrams in problem 13a, circle the following electrons (If it does not exist, say so):

Doesn't Exist.

Sb^{3+} (n, l, m_l, m_s) = (4, 3,-2, +1/2) and (2, 0, 0, -1/2)

Empty

Impossible

Ar* (n, l, m_l, m_s) = (3, 2, -2, +1/2) and (3, 0, -1, -1/2)

Doesn't Exist

Doesn't Exist

14. Periodic table and periodic properties of elements:

(biggest, smallest)

a. Rank the following species according to their properties. (1 = highest, 4 lowest)

	Se^{2-}	H	Se	C
Radius	1	4	2	3
Ionization Energy	2	4	1	3
Electron Affinity	2	4	1	3
Electonegativity	2	4	1	3

Q14. is not included in the Exam #1 as we have not covered the last paragraph of Ch. 1 yet.