JUSTIN: OFFICE HOURS MONDAY 5:30 – 7 PM
LOCATION TBA

Chem E-1a
Friday Review Problems
Chapter 7: The Electronic Structure of Atoms

1. Light having a wavelength of 2.50 x 10^{-7} m strikes the surface of a piece of chromium metal, causing electrons with a *minimum* deBroglie wavelength of 1.80 x 10^{-9} m to be emitted from the surface of the metal via the photoelectric effect. Determine the photoelectric binding energy of chromium metal.
(Note: Mass of an electron = 9.109 x 10^{-31} kg)

$$E_{PHOTON} = B.E. + KE_{e^-}$$

← WANT TO SOLVE FOR BINDING ENERGY

FIND E_{PHOTON}: $E = h\nu = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\ J\cdot s)(3.00\times10^{8}\ m/s)}{(2.50\times10^{-7}\ m)}$

$$E_{PHOTON} = 7.956\times10^{-19}\ J$$

FIND KE_{e^-}: $KE = \frac{1}{2}mu^2$

$$\lambda = \frac{h}{mu}$$

$J = \frac{kg\,m^2}{s^2}$

$$1.80\times10^{-9}\ m = \frac{(6.63\times10^{-34}\ J\cdot s)}{(9.109\times10^{-31}\ kg)(u)}$$

$$u = 4.04\times10^{5}\ m/s$$

$$KE_{e^-} = \frac{1}{2}mu^2 = \frac{1}{2}(9.109\times10^{-31}\ kg)(4.04\times10^{5}\ m/s)^2$$

$$KE_{e^-} = 7.447\times10^{-20}\ J$$

$$E_{PHOTON} = BE + KE_e$$

$$7.956\times10^{-19}\ J = BE + 7.447\times10^{-20}\ J$$

SOLVE: $B.E. = 7.21\times10^{-19}\ J$

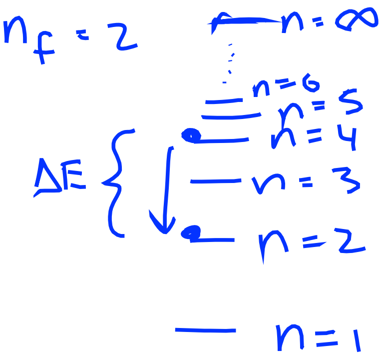
IF WE WANTED BE IN kJ/MOL:

$$\frac{7.21\times10^{-19}\ J}{e^-\ \text{OR ATOM}} \times \frac{1\ kJ}{1000\ J} \times \frac{6.02\times10^{23}\ e^-}{1\ \text{MOL}\ e^-} = 434\ kJ/MOL$$

$n_i = 4$

2. A hydrogen atom in an excited state has its electron in a $4p_x$ orbital.

   a) The excited electron undergoes a transition into a 2s orbital. Calculate the energy *and* the wavelength of light emitted by this process. ← $n_f = 2$



$$\Delta E = R_H \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

$$\Delta E = (2.18 \times 10^{-18}\,J) \left(\frac{1}{4^2} - \frac{1}{2^2} \right)$$

$$\Delta E = -4.0875 \times 10^{-19}\,J$$

NEGATIVE SIGN MEANS ENERGY IS EMITTED (AS LIGHT)

E OF LIGHT = 4.0875×10^{-19} J $= h\nu = \frac{hc}{\lambda}$

PLUG IN $4.0875 \times 10^{-19}\,J = \frac{hc}{\lambda}$

SOLVE **$\lambda = 4.86 \times 10^{-7}$ m**

   b) Calculate the energy required to completely remove the electron from a ground-state hydrogen atom. ← $n_i = 1$, $n_f = \infty$

$$\Delta E = R_H \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

$$\Delta E = 2.18 \times 10^{-18}\,J \left(\frac{1}{1^2} - \frac{1}{\infty^2} \right) \quad \left(\frac{1}{\infty^2} \rightarrow 0\right)$$

$$\Delta E = 2.18 \times 10^{-18}\,J$$

ENERGY REQUIRED = 2.18×10^{-18} J

$l = 0 \Rightarrow s$

$l = 1 \Rightarrow p_x \; p_y \; p_z$

$l = 2 \Rightarrow d_{xy} \; d_{xz} \; d_{yz} \; d_{x^2-y^2} \; d_{z^2}$

3. For each of the orbitals in parts (a) through (d):

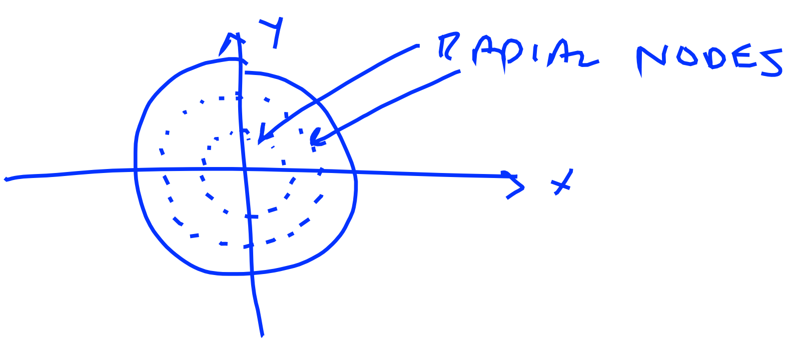
l	ORBITAL
0	s
1	p
2	d
3	f

i) Provide the *n* and *l* quantum numbers.
ii) List all the orbitals in the subshell which share the same *n* and *l* quantum numbers.
iii) Indicate the total number of nodes, the number of radial nodes, and the number of angular nodes in the orbital. Describe the location/orientation of each angular node with respect to the *x*, *y*, and *z* axes.
iv) Draw the shape of the orbital with respect to the Cartesian axes, and clearly indicate the location of all nodes.

a) 3s $n = 3$ $l = 0$ NONE OTHERS IN SUBSHELL

\# OF ANGULAR NODES = $l = 0$

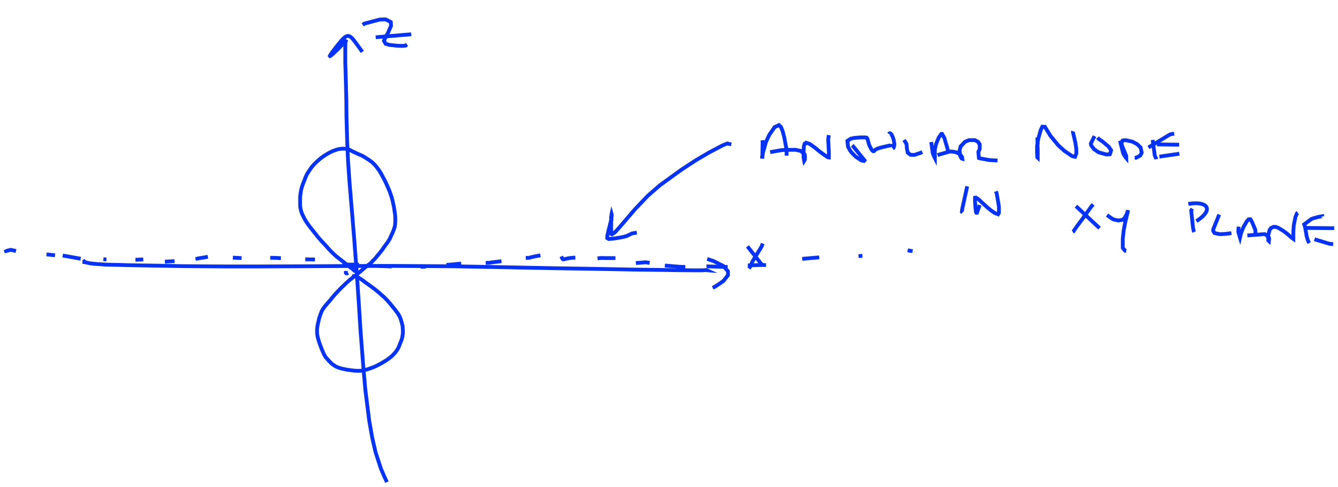
\# OF RADIAL NODES = $n - l - 1 = 3 - 0 - 1 = 2$



b) 2p$_z$ $n = 2$ $l = 1$ OTHERS: $2p_x$ $2p_y$

ANGULAR NODES = $l = 1$

RAD. NODES = $n - l - 1 = 2 - 1 - 1 = 0$

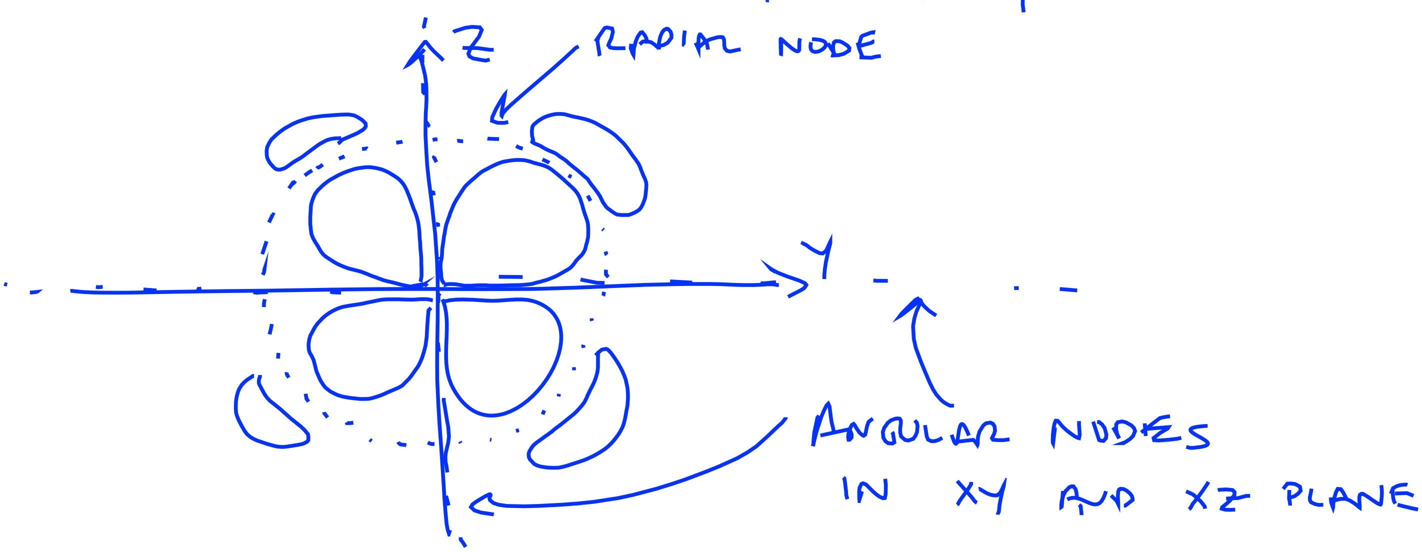


3. (cont.)

c) $4d_{yz}$ $n = 4$ $\ell = 2$ OTHERS: $4d_{xz}$ $4d_{xy}$ $4d_{x^2-y^2}$ $4d_{z^2}$

ANG. NODES = $\ell = 2$

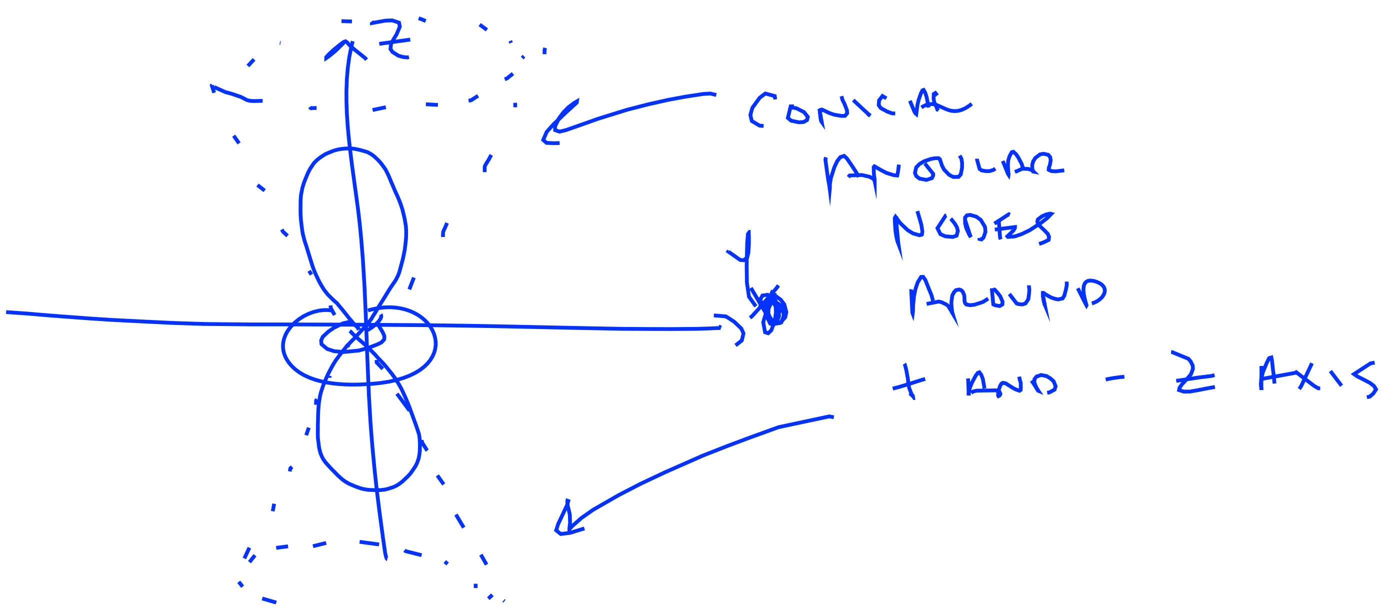
RAD. NODES = $n - \ell - 1 = 4 - 2 - 1 = 1$



d) $3d_{z^2}$ $n = 3$ $\ell = 2$ OTHERS: $3d_{xy}$ $3d_{yz}$ $3d_{xz}$ $3d_{x^2-y^2}$

ANG. NODES = $\ell = 2$

RAD. NODES = $n - \ell - 1 = 3 - 2 - 1 = 0$



4. Write the ground-state electron configuration for the following atoms, and determine the number of unpaired electrons in each atom. (Use the noble gas abbreviations.)

a) N

$[He]\,2s^2\,2p^3$ — ↿ ↿ ↿ ($2p$) — 3 UNPAIRED e^-

b) Mg

$[Ne]\,3s^2$ — ⥮ ($3s$) — 0 UNPAIRED e^-

c) Fe

$[Ar]\,4s^2\,3d^6$ — ⥮ ↿ ↿ ↿ ↿ ($3d$) — 4 UNPAIRED e^-

d) Br

$[Ar]\,4s^2\,3d^{10}\,4p^5$ — ⥮ ⥮ ↿ ($4p$) — 1 UNPAIRED e^-

e) Pb

$[Xe]\,6s^2\,5d^1\,4f^{14}\,5d^9\,6p^2$

COMBINE ($5d^1$ and $5d^9$)

↿ ↿ _ ($6p$)

$[Xe]\,6s^2\,4f^{14}\,5d^{10}\,6p^2$ — 2 UNPAIRED e^-