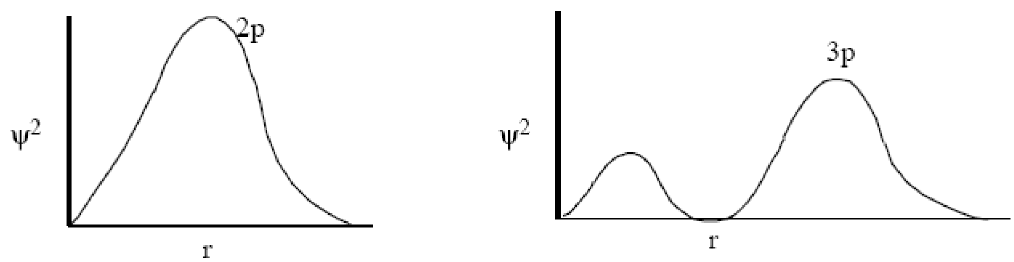
Assignment 9 – Solutions

Problems: Chapter 12: 60,62, 65, 66, 70, 78, 80

Orbitals and Quantum Numbers

60.



62. A node occurs when $\psi = 0$. $\psi_{300} = 0$ when $27 - 18\sigma + 2\sigma^2 = 0$.

Solving using the quadratic formula: $\sigma = \dfrac{18 \pm \sqrt{(18)^2 - 4(2)(27)}}{4} = \dfrac{18 \pm \sqrt{108}}{4}$

$\sigma = 7.10$ or $\sigma = 1.90$; because $\sigma = r/a_o$, the nodes occur at $r = (7.10)a_o = 3.76 \times 10^{-10}$ m and at $r = (1.90)a_o = 1.01 \times 10^{-10}$ m, where r is the distance from the nucleus.

Polyelectronic Atoms

65. a. $n = 4$: ℓ can be 0, 1, 2, or 3. Thus we have s (2 e^-), p (6 e^-), d (10 e^-) and f (14 e^-) orbitals present. Total number of electrons to fill these orbitals is 32.

b. $n = 5$, $m_\ell = +1$: for $n = 5$, $\ell = 0, 1, 2, 3, 4$; for $\ell = 1, 2, 3, 4$, all can have $m_\ell = +1$. Four distinct orbitals, thus 8 electrons.

c. $n = 5$, $m_s = +1/2$: for $n = 5$, $\ell = 0, 1, 2, 3, 4$. Number of orbitals = 1, 3, 5, 7, 9 for each value of ℓ, respectively. There are 25 orbitals with $n = 5$. They can hold 50 electrons, and 25 of these electrons can have $m_s = +1/2$.

d. $n = 3$, $\ell = 2$: these quantum numbers define a set of 3d orbitals. There are 5 degenerate 3d orbitals that can hold a total of 10 electrons.

e. $n = 2$, $\ell = 1$: these define a set of 2p orbitals. There are 3 degenerate 2p orbitals that can hold a total of 6 electrons.

f. It is impossible for $n = 0$. Thus no electrons can have this set of quantum numbers.

g. The four quantum numbers completely specify a single electron.

h. $n = 3$: 3s, 3p, and 3d orbitals all have $n = 3$. These orbitals can hold 18 electrons, and 9 of these electrons can have $m_s = +1/2$.

i. $n = 2$, $\ell = 2$: this combination is not possible ($\ell \neq 2$ for $n = 2$). Zero electrons in an atom can have these quantum numbers.

j. $n = 1$, $\ell = 0$, $m_\ell = 0$: these define a 1s orbital that can hold 2 electrons.

66. Si: $1s^2 2s^2 2p^6 3s^2 3p^2$ or $[Ne]3s^2 3p^2$; Ga: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^1$ or $[Ar]4s^2 3d^{10} 4p^1$

As: $[Ar]4s^2 3d^{10} 4p^3$; Ge: $[Ar]4s^2 3d^{10} 4p^2$; Al: $[Ne]3s^2 3p^1$; Cd: $[Kr]5s^2 4d^{10}$

S: $[Ne]3s^2 3p^4$; Se: $[Ar]4s^2 3d^{10} 4p^4$

70. a. Both In and I have one unpaired 5p electron, but only the nonmetal I would be expected to form a covalent compound with the nonmetal F. One would predict an ionic compound to form between the metal In and the nonmetal F.

I: $[Kr]5s^2 4d^{10} 5p^5$ $\quad \underbrace{\underline{\uparrow\downarrow}\ \underline{\uparrow\downarrow}\ \underline{\uparrow}}_{5p}$

b. From the periodic table, this will be element 120. Element 120: $[Rn]7s^2 5f^{14} 6d^{10} 7p^6 8s^2$

c. Rn: $[Xe]6s^2 4f^{14} 5d^{10} 6p^6$; note that the next discovered noble gas will also have 4f electrons (as well as 5f electrons).

d. This is chromium, which is an exception to the predicted filling order. Cr has 6 unpaired electrons, and the next most is 5 unpaired electrons for Mn.

Cr: $[Ar]4s^1 3d^5$ $\quad \underbrace{\underline{\uparrow}}_{4s} \quad \underbrace{\underline{\uparrow}\ \underline{\uparrow}\ \underline{\uparrow}\ \underline{\uparrow}\ \underline{\uparrow}}_{3d}$

78. O: $1s^2 2s^2 2p_x^2 2p_y^2$ ($\underline{\uparrow\downarrow}$ $\underline{\uparrow\downarrow}$ $\underline{}$); there are no unpaired electrons in this oxygen atom. This configuration would be an excited state, and in going to the more stable ground state ($\underline{\uparrow\downarrow}$ $\underline{\uparrow}$ $\underline{\uparrow}$), energy would be released.

80. a. Excited state of boron

B ground state: $1s^2 2s^2 2p^1$

b. Ground state of neon

c. Excited state of fluorine

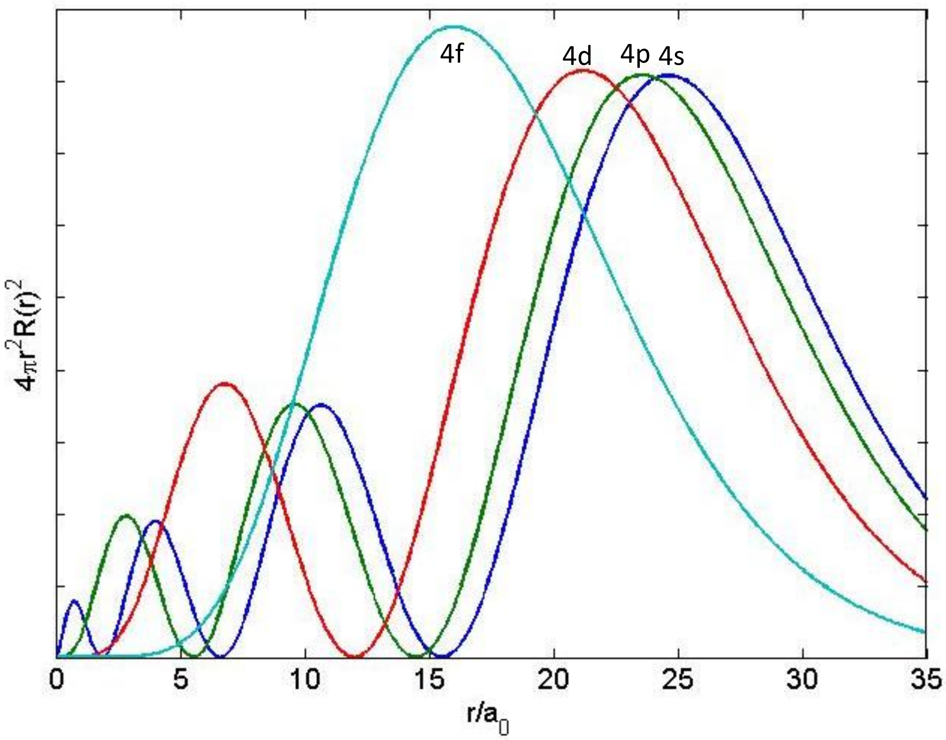
F ground state: $1s^2 2s^2 2p^5$

d. Excited state of iron

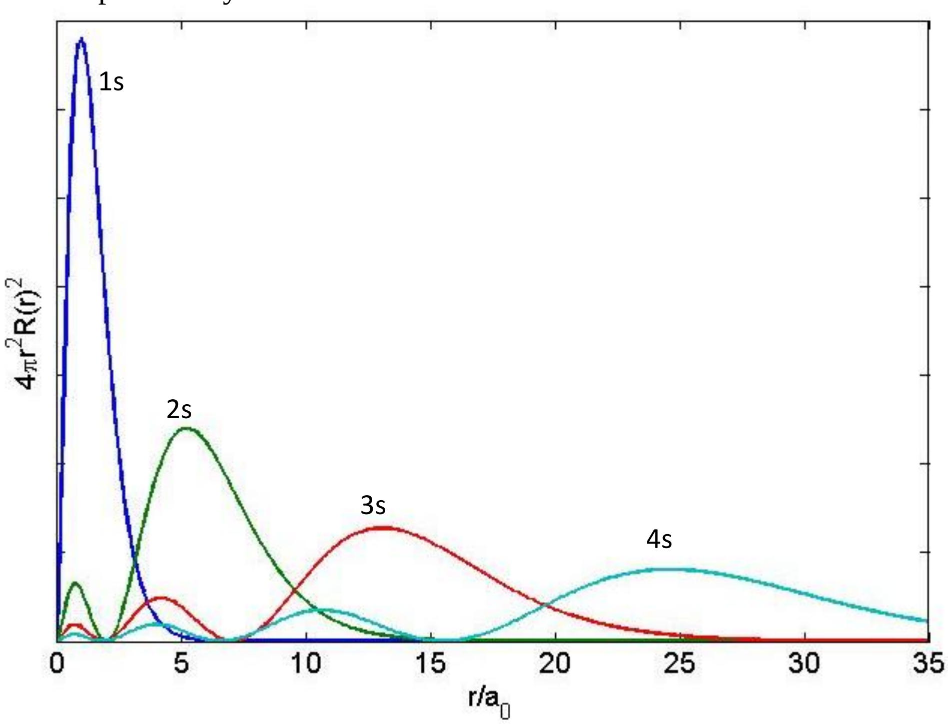
Fe ground state: $[Ar]4s^2 3d^6$

Additional Problems:

A1. For n = 4, there are four possible types of orbitals: *s* (l = 0), *p* (l = 1), *d* (l = 2), and *f* (l = 3). The radial probability distributions are:



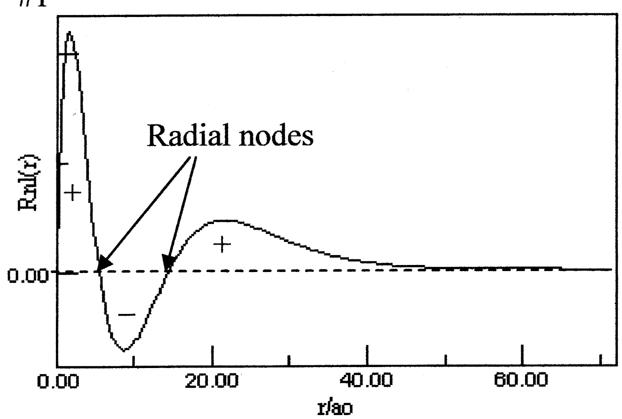
A2. The radial probability distributions of the s orbital for n = 1 to 4 are shown below:



Assignment 8 Challenge Problem - Solutions

1a) Note: the dashed line is where the wavefunction is equal to zero in each case.

#1



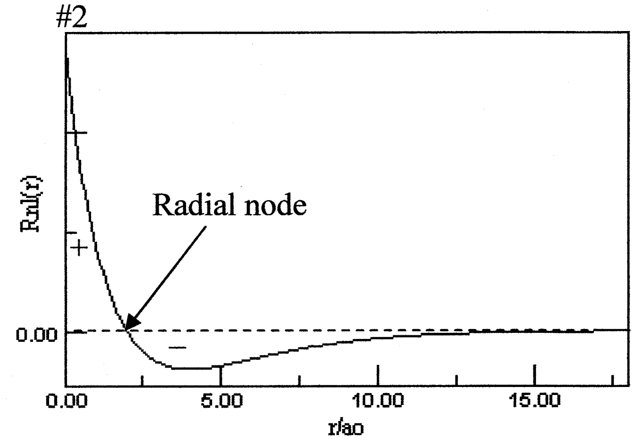
Identity: 4p

Number and type of nodes:

3 nodes total, 2 radial and 1 planar

Quantum numbers: 4 1 1 +½

#2



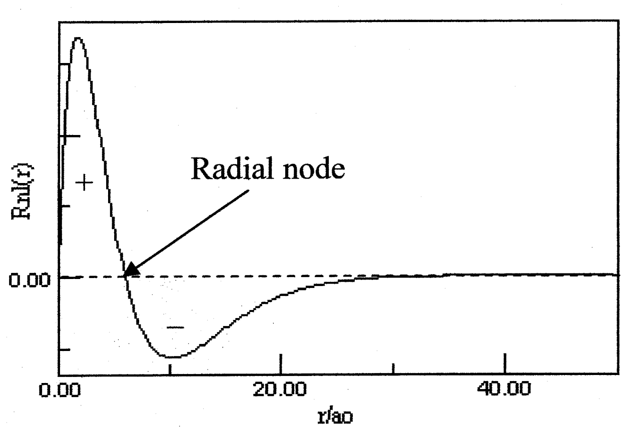
Identity: 2s

Number and type of nodes:

1 radial node

Quantum numbers: 2 0 0 +½

#3



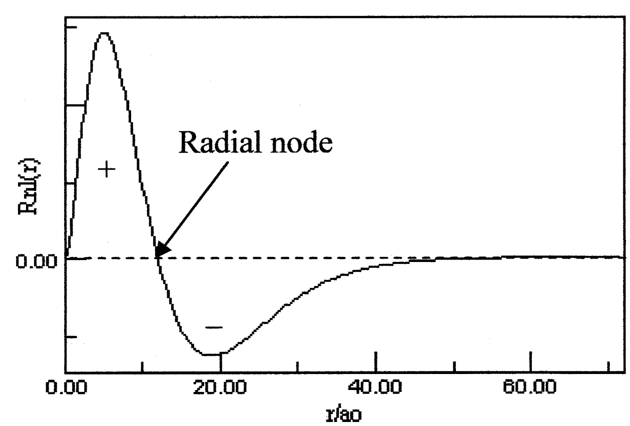
Identity: 3p

Number and type of nodes:

2 nodes total, 1 radial and 1 planar

Quantum numbers: 3 1 0 +½

#4



Identity: 4d

Number and type of nodes:

3 nodes total, 1 radial and 2 planar

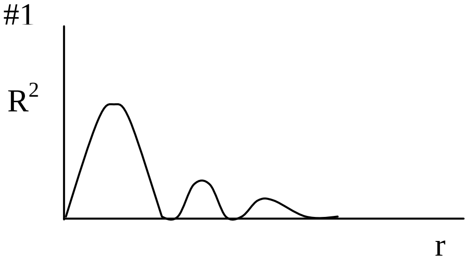
Quantum numbers: 4 2 0 +½

1b)

Probability Density vs. r:

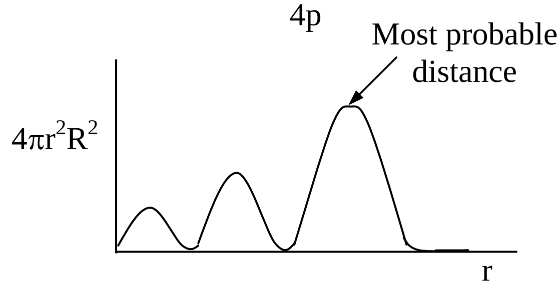
4p

#1



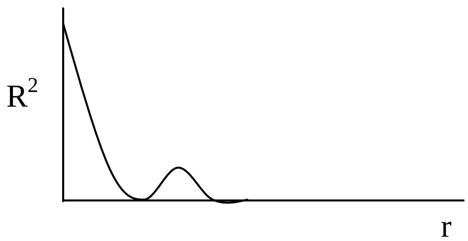
Radial probability distribution vs. r:

4p

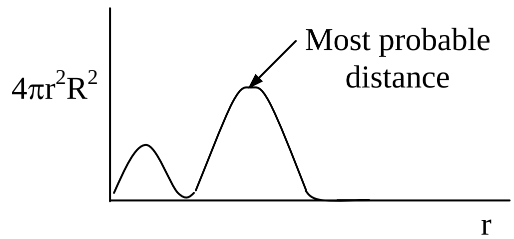


#2

2s



2s



1c) The fact that the yz plane has no probability density indicates that the yz plane is a nodal plane. Of all orbitals with a principle quantum number equal to 3, this is true for the $3p_x$, $3d_{xy}$, and $3d_{xz}$ orbitals.