Chapter 8: Atomic Structure

#4. a) 3d $\Rightarrow$ $n=3$; $l=2$; $m_l = 2, 1, 0, -1, -2$; $m_s = \pm 1/2$ for each m_l value.

b) 3p $\Rightarrow$ $n=3$; $l=1$; $m_l = 1, 0, -1$; $m_s = \pm 1/2$ for each m_l value.

#9. The spin quantum number $s = 3/2$. The magnitude of the spin angular momentum is $|\vec{S}| = \sqrt{s(s+1)}\,\hbar = \sqrt{\frac{3}{2}\left(\frac{3}{2}+1\right)}\,\hbar$

$$\Rightarrow \boxed{|\vec{S}| = \frac{\sqrt{15}}{2}\hbar}.$$

Since $m_s = \pm 3/2, \pm 1/2 \Rightarrow S_z = \pm \frac{3}{2}\hbar, \pm \frac{\hbar}{2}$

There are two orientations of the spin angular momentum.

$$\cos\theta_1 = \frac{3/2}{\sqrt{15}/2} = \frac{3}{\sqrt{15}} \Rightarrow \theta_1 = \cos^{-1}\left(\frac{3}{\sqrt{15}}\right)$$

$$\boxed{\theta_1 = 39.2^\circ}$$

$$\cos\theta_2 = \frac{1/2}{\sqrt{15}/2} = \frac{1}{\sqrt{15}} \Rightarrow \theta_2 = \cos^{-1}\left(\frac{1}{\sqrt{15}}\right)$$

$$\boxed{\theta_2 = 75^\circ}$$

$$\cos\theta_3 = \frac{-1/2}{\sqrt{15}/2} = -\frac{1}{\sqrt{15}}$$

$$\boxed{\theta_3 = 105^\circ}$$

$$\cos\theta_4 = \frac{-3/2}{\sqrt{15}/2} = -\frac{3}{\sqrt{15}}$$

$$\boxed{\theta_4 = 140.8^\circ}$$

13. a) $4F_{5/2} \Rightarrow n=4\ ;\ l=4\ ;\ j=5/2$

b) $|\vec{J}| = \sqrt{j(j+1)}\,\hbar = \sqrt{\frac{5}{2}(\frac{5}{2}+1)}\,\hbar$

$= \frac{\sqrt{35}}{2}\hbar$

c) $m_j = 5/2,\ 3/2,\ 1/2,\ -1/2,\ -3/2,\ -5/2.$

$J_z = \pm\frac{5}{2}\hbar\ ,\ \pm\frac{3}{2}\hbar\ ,\ \pm\frac{\hbar}{2}$ (6 values).

23. Filled subshells are more stable than unfilled subshells.

$\Rightarrow$ $[Kr]4d^{10}$ has lesser energy than $[Kr]4d^{9}5s^{1}$ and therefore is more favorable. The element is palladium.

25.

a) $E_{K\alpha} = -13.6\,(Z-1)^2\left(-\frac{1}{1}+\frac{1}{4}\right) = 13.6\,(Z-1)^2 \times \frac{3}{4}$

$E_{K\alpha} = hf \Rightarrow f = \frac{3}{4}(Z-1)^2 \times \left(\frac{13.6}{h}\right)$

$\Rightarrow \sqrt{\frac{3}{4}\left(\frac{13.6}{h}\right)}\,(Z-1) = \sqrt{f}$ —— (1)

b) The slope of $\sqrt{f}$ vs. Z is

$\text{slope} = \frac{\Delta\sqrt{f}}{\Delta(Z-1)} = \sqrt{\frac{3}{4} \times \frac{13.6\,eV}{4.14\times10^{-15}\,eV.s}} = 0.496\times10^{8}\,\sqrt{Hz}$

Let us calculate the slope of the K_α line from Fig. 8.20 page 333. $\sqrt{f}$ (22, 8)
Z (45, 17) $\Rightarrow \left(\frac{\Delta Z}{\Delta\sqrt{f}}\right)^{-1} = \left(\frac{45-17}{(22-8)\times10^{8}}\right)^{-1} = 0.5\times10^{8}\,\sqrt{Hz}$

The y-intercept for the K_α line in Fig. 8.20 is y.

$\sqrt{f} = 0.5(Z - y)$. Let us find y:

$\uparrow$

$8 = 0.5(17 - y) \Rightarrow y = 17 - 16 = 1$ In agreement with equation (1).

$\Rightarrow$ Theory $\Rightarrow$ $0.496 \times 10^8 (Z - 1) = \sqrt{f}$

experiment $\Rightarrow$ $0.5 \times 10^8 (Z - 1) = \sqrt{f}$

$\Rightarrow$ The theory and experiment are in good agreement.

c) yes, according to the theory and experiment, the L shell electron does see a nuclear charge of (Z - 1).