MSE228 Engineering Quantum Mechanics
Quiz 6 Duration: 30 minutes Open Book Quiz

1. (a) How many different sets of quantum numbers (n, l,m_l ,m_s) are possible for an electron in the 4f level? (b) Suppose a certain atom has three electrons in the 4f level. What is the maximum possible value of the total m_s of the three electrons? (c) What is the maximum possible total m_l of three 4f electrons? (d) Suppose an atom has ten electrons in the 4f level. What is the maximum possible value of the total m_s of the ten 4f electrons? (e) What is the maximum possible total m_l of ten 4f electrons?

a) $4f \rightarrow n=4\ l=3 \rightarrow m_l = +3,+2,+1,0,-1,-2,-3$ (7) & $m_s = +\frac{1}{2}, -\frac{1}{2}$ (2 possible combinations) $\Rightarrow 7\times 2 = \boxed{14}$

b) Three $\bar{e}$s → 7 $\bar{e}$s can have state $m_s = +1/2 \Rightarrow$ three $\bar{e}$s $m_s = 3\times +\frac{1}{2} = \boxed{+3/2}$

c) $m_l = +3 \nearrow m_s = +1/2$, $\rightarrow m_s = -1/2$ & $m_l = +2 \rightarrow m_s = +1/2 \Rightarrow 2\times(+3) + 1\times(+2) = \boxed{+8}$

d) Ten $\bar{e}$s → 7 $\bar{e}$s can have state $m_s = +1/2$ & 3 $\bar{e}$s can have state $m_s = -1/2$

$\Rightarrow 7\times(+1/2) + 3\times(-1/2) = \boxed{2}$

e) $m_l = +3 \nearrow m_s = +1/2$, $\rightarrow m_s = -1/2$ & $m_l = +2 \nearrow m_s = +1/2$, $\rightarrow m_s = -1/2$ & $m_l = +1 \nearrow m_s = +1/2$, $\rightarrow m_s = -1/2$ & $m_l = 0 \nearrow m_s = +1/2$, $\rightarrow m_s = -1/2$ & $m_l = -1 \nearrow m_s = +1/2$, $\rightarrow m_s = -1/2$

$10\bar{e}s = 2 + 2 + 2 + 2 + 2$

$\Rightarrow 2\times(+3) + 2\times(+2) + 2\times(+1) + 2\times(0) + 2\times(-1) = \boxed{10}$

2. (a) The ionization energy of sodium is 5.14 eV. What is the effective charge seen by the outer electron? (b) If the 3s electron of a sodium atom is moved to the 4f state, the measured binding energy is 0.85 eV. What is the effective charge seen by an electron in this state?

$E_n = Z_{eff}^2 \frac{E_1}{n^2}$, where $E_1 = -13.6$ eV

a) 3s, $E_3 = -5.14$ eV → $Z_{eff} = n\sqrt{\frac{E_3}{-13.6eV}} = 3\sqrt{\frac{-5.14eV}{-13.6eV}} = \boxed{1.84}$

Na: $1s^2 2s^2 2p^6 3s^1$, 11(+e) in nucleus, 10(-e) in core $\bar{e}$s } $1 = Z_{eff}$: expected

So, less screened by the inner $\bar{e}$s. 3s electron is penetrating the inner orbit.

b) 4f, $E_4 = -0.85$eV → $Z_{eff} = 4\sqrt{\frac{-0.85eV}{-13.6eV}} = \boxed{1.00}$

so, screening is complete.