SOLUTION MANUAL FOR HW # 5

7.17)

$^{1}H^{19}F$

$E_l = \frac{\hbar^2}{2I} l(l+1) \quad \& \quad I = \mu r^2$

$m_H = 1.008 * 1.67 * 10^{-27}\, kg = 1.68 * 10^{-27}\, kg$

$m_{Cl} = 34.98 * 1.67 * 10^{-27}\, kg = 58.42 * 10^{-27}\, kg$

$\mu = \frac{m_H m_{Cl}}{m_H + m_{Cl}} = 1.586 * 10^{-27}\, kg \Rightarrow I = 1.33 * 10^{-47}\, kgm^2$

$E_l = 4.16 * 10^{-22}\, l(l+1) J$

a) $E_0 = 0 J$

b) $E_1 = 8.33 * 10^{-22}\, J \Rightarrow \Delta E_{0\to 1} = 8.33 * 10^{-22}\, J$

7.20)

$E_J = BJ(J+1) \quad \& \quad \frac{n_J}{n_0} = \frac{g_J}{g_0} e^{-\Delta E_{J-0}/kT} \quad \& \quad B = \frac{\hbar^2}{2I} \quad \& \quad g_J = 2J+1$

$I = 2.644 * 10^{-47}\, kgm^2 \Rightarrow B = 2.10 * 10^{-22}\, J \quad \& \quad T = 298K \Rightarrow kT = 4.13 * 10^{-21}\, J$

$E_0 = 0 \Rightarrow \Delta E_{J-0} = E_J = BJ(J+1) \Rightarrow \therefore \frac{\Delta E_{J-0}}{kT} = \frac{B}{kT} J(J+1) = 0.05085 J(J+1)$

$\frac{n_J}{n_0} = (2J+1) e^{-\Delta E_{J-0}/kT} = (2J+1) e^{-0.05085 J(J+1)}$

$J = 0 \Rightarrow \frac{n_J}{n_0} = 1$

$J = 5 \Rightarrow \frac{n_J}{n_0} = (2*5+1) e^{-0.05085*5(5+1)} = 2.38$

$J = 10 \Rightarrow \frac{n_J}{n_0} = (2*10+1) e^{-0.05085*10(10+1)} = 0.077$

$J = 20 \Rightarrow \frac{n_J}{n_0} = (2*20+1) e^{-0.05085*10(10+1)} = 2.08 * 10^{-8}$

7.24)

a)

$$\mu = (\frac{1*35}{1+35})*1.066*10^{-27}\,kg = 1.61*10^{-27}\,kg$$

$$E_{Vibrationa\,l} = \hbar\sqrt{\frac{k}{\mu}} = (1.055*10^{-34}\,J)\sqrt{\frac{516\,Nm^{-1}}{1.61*10^{-27}\,kg}} = 2.98*10^{-20}\,J$$

$$I = \mu r^2 = 2.60*10^{-47}\,kgm^2$$

$$E_{10} = \frac{\hbar^2}{2I} = 2.14*10^{-22}*10*(10+1) = 2.55*10^{-20}\,J$$

$$kT = 4.14*10^{-21}\,J \Rightarrow \frac{E_V}{kT} = 7.20 \quad \& \quad \frac{E_{10}}{kT} = 6.16$$

b)

$$\upsilon_V = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}} = 0.88*10^{14}\,s^{-1} \Rightarrow \tau = 1.125*10^{-14}\,s$$

$$\upsilon_r = \frac{E_r}{h} = 3.85*10^{13}\,s^{-1} \Rightarrow \tau = 2.59*10^{-14}\,s$$

7.26)

$$p_x = \sqrt{\frac{3}{4\pi}}\sin\theta\cos\varphi \quad \& \quad d_{xz} = \sqrt{\frac{15}{4\pi}}\sin\theta\cos\theta\cos\varphi \quad \& \quad \hat{l}_z = -i\hbar\frac{\partial}{\partial\varphi}$$

$$\hat{l}_z p_x = -i\hbar\frac{\partial}{\partial\varphi}(\sqrt{\frac{3}{4\pi}}\sin\theta\cos\varphi) = i\hbar\sqrt{\frac{3}{4\pi}}\sin\theta\sin\varphi \Rightarrow NO$$

$$\hat{l}_z d_{xz} = -i\hbar\frac{\partial}{\partial\varphi}(\sqrt{\frac{15}{4\pi}}\sin\theta\cos\theta\cos\varphi) = i\hbar\sqrt{\frac{15}{4\pi}}\sin\theta\cos\theta\sin\varphi \Rightarrow NO$$