PHY 251 SPR 02
HW # 11

7.18 Compute in H 1s state

$$U_{av} = \int_0^\infty U(r)\, P(r)\, dr$$

$$= -\frac{e^2}{4\pi\varepsilon_0} \int_0^\infty \frac{1}{r} \cdot r^2 \left(\frac{2}{a_0^{3/2}} e^{-r/a_0}\right)^2 dr$$

$$= -\frac{e^2}{4\pi\varepsilon_0} \frac{4}{a_0^3} \int_0^\infty r e^{-2r/a_0}\, dr$$

$$= -\frac{e^2}{\pi\varepsilon_0 a_0^3} \frac{1!}{(2/a_0)^2}$$

$$= -\frac{1}{4\pi\varepsilon_0} \frac{1}{a_0}$$

potential for electron in orbit of radius a_0

9.12 Use the figure and

$$k = \frac{2(E - E_{min})}{(R - R_{eq})^2} \stackrel{define}{=} \frac{2\Delta E}{\Delta R^2}$$

estimate

$$\Delta E = 0.25 \text{ eV}$$

for

$$\Delta R = .05 \text{ nm}$$

or

$$k \approx \frac{0.50 \text{ eV}}{(.05)^2 \text{nm}^2} = \frac{5 \times 10^{-1}}{2.5 \times 10^{-3}} \text{ eV nm}^{-2}$$

$$k \approx 2 \times 10^2 \frac{\text{eV}}{\text{nm}^2} \approx 2 \times 10^{20} \frac{\text{eV}}{\text{m}^2}$$

which gives

$$\nu = \frac{1}{2\pi}\sqrt{\frac{kc^2}{mc^2}}$$

$$m = \frac{m_{Na} m_{Cl}}{m_{Na} + m_{Cl}} = \frac{22 \times 35}{22 + 35} u \approx 14 m_p$$

$$\nu \cong \frac{1}{2\pi}\sqrt{\frac{2\times 10^{20}\,\cancel{\frac{eV}{m^2}}\times 9\times 10^{16}\,\frac{\cancel{m^2}}{s^2}}{14\times 10^{9}\,\cancel{eV}}}$$

$$\cong \frac{1}{2\pi}\sqrt{\frac{18}{14}\times 10\times 10^{26}}\ \mathrm{Hz}$$

$$\cong \frac{1}{2\pi}\,3.5\times 10^{13}\ \mathrm{Hz}$$

$$\approx 5\times 10^{12}\ \mathrm{Hz}$$

$$\lambda = \frac{c}{\nu} \simeq 6\times 10^{-5}\ \mathrm{m}$$

infrared (see figure on p. 6)

$$h\nu \approx (4\times 10^{-15}\ \mathrm{eV\cdot s})(5\times 10^{12}\ \mathrm{Hz})$$

$$\approx 2\times 10^{-2}\ \mathrm{eV}$$

$$h\nu \approx .004\ \mathrm{eV}$$

at about 0.2 eV, parabolic approx. fails

corresponds to about $n \approx 10$

9.13 The only difference between H_2 and HD is their reduced masses

$$m^{H_2} = \frac{m_p^2}{2m_p} = \frac{m_p}{2}$$

$$m^{HD} = \frac{m_p(2m_p)}{m_p + 2m_p} = \frac{2}{3} m_p = \frac{4}{3} m^H$$

Req is independent of m, since it is determined by electronic states.

The relevant formulas are

$$\nu = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$ (k is also m-independent)

$$\rightarrow \nu_{HD} = \sqrt{\frac{3}{4}}\, \nu_{H_2}$$

Similarly

$$\frac{\hbar^2}{2m^{HD}R_{eq}^2} = \frac{3}{4}\,\frac{\hbar^2}{2m^{H_2}R_{eq}^2}$$

9.3 $\quad E_{ion}^{K} = 4.34\ eV$

$E_{aff}^{Cl} = 3.06\ eV$

$$K^+ \overset{}{\underset{R}{\longleftrightarrow}} Cl^-$$

find R such that

$$U(R) = E_{aff}^{K} - E_{ion}^{K}$$

$$= (3.06 - 4.34)\ eV$$

$$= -1.28\ eV$$

$$U(R) = -\frac{e^2}{4\pi\varepsilon_0}\frac{1}{R} = -1.28\ eV$$

$$R = (1.28\ \cancel{eV})^{-1}\underbrace{\left(\frac{e^2}{4\pi\varepsilon_0}\right)}_{1.440\ \cancel{eV}\ nm}$$

$$= 1.13\ nm$$