9-5. (a) Total potential energy: $U(r) = -\frac{ke^2}{r} + E_{ex} + E_{ion}$ (Equation 9-1)

attractive part of $U(r_0) = -\frac{ke^2}{r_0} = -\frac{1.44eV\cdot nm}{0.267nm} = -5.39eV$

(b) The net ionization energy is:

$E_{ion} = (\text{ionization energy of } Rb) - (\text{electron affinity of } Cl)$

$= 4.18eV - 3.62eV = 0.56eV$

Neglecting the exclusion principle repulsion energy E_{ex},

dissociation energy $= -U(r_0) = 5.39eV - 0.56eV = 4.83eV$

(c) Including exclusion principle repulsion,

dissociation energy $= 4.37eV - U(r_0) = 5.39eV - 0.56eV - E_{ex}$

$E_{ex} = 5.39eV - 4.37eV - 0.56eV = 0.46eV$

9-6. $U_c = -\frac{ke^2}{r_0} + E_{ion} = -\frac{1.440eV\cdot nm}{0.282nm} + (4.34eV - 3.36eV) = -4.13eV$

The dissociation energy is $3.94eV$.

$E_d = |U_c + E_{ex}| = 3.94eV = |-4.13eV + E_{ex}|$

$E_{ex} = 0.19eV$ at $r_0 = 0.282nm$

9-12. Dipole moment $p_{ionic} = er_0$ (Equation 9-3)

$= (1.609\times10^{-19}C)(0.0917nm)$

$= 1.47\times10^{-20}C\cdot nm\times10^{-9}m/nm$

$= 1.47\times10^{-29}C\cdot m$

if the HF molecule were a pure ionic bond. The measured value is $6.64\times10^{-29}C\cdot m$, so

the HF bond is $(6.40\times10^{-30}C\cdot m)/(1.47\times10^{-29}C\cdot m) = 0.44$ or 44% ionic.

9-19. (a) $NaCl$ is polar. The Na^+ ion is the positive charge center, the Cl^- ion is the negative

charge center.

(b) O_2 is nonpolar. The covalent bond involves no separation of charges, hence no

polarization of the molecule.

9-21. $E_{0r} = \frac{\hbar^2}{2I}$ (Equation 9-14) where $I = \frac{1}{2}mr_0^2$ for a symmetric molecule.

$$E_{0r} = \frac{\hbar^2}{mr_0^2} = \frac{(\hbar c)^2}{mc^2 r_0^2} = \frac{(197.3 eV\cdot nm)^2}{(16uc)^2 (931.5\times10^6 eV/uc^2)(0.121nm)^2} = 1.78\times10^{-4} eV$$

9-22. For Co: $f = 6.42\times10^{13} Hz$ (See Example 9-6)

$E_V = (v + 1/2)hf$ (Equation 9-20)

(a) $E_1 - E_0 = 3hf/2 - hf/2 = hf$

$$= (4.14\times10^{-15} eV\cdot s)(6.42\times10^{13} Hz)$$

$$= 0.27eV$$

(b) $\frac{n_1}{n_0} = e^{-(E_1 - E_0)/kT}$ (from Equation 8-2)

$$0.01 = e^{-(0.27)/(8.62\times10^{-5})T}$$

$$\ln(0.01) = -(0.27eV)/(8.62\times10^{-5} eV/K)T$$

$$T = \frac{-(0.27eV)}{\ln(0.01)(8.62\times10^{-5} eV/K)}$$

$$T = 680K$$

9-23. For LiH: $f = 4.22\times10^{13} Hz$ (from Table 9-7)

(a) $E_V = (v + 1/2)hf = E_0 = hf/2 = (4.14\times10^{-15} eV\cdot s)(4.22\times10^{13} Hz)/2$

$E_0 = 0.087eV$

(b) $\mu = \frac{m_1 m_2}{m_1 + m_2}$ (Equation 9-17)

$$\mu = \frac{(7.0160u)(1.0078u)}{(7.0160u) + (1.0078u)} = 0.8812u$$

(c) $f = \frac{1}{2\pi}\sqrt{\frac{K}{\mu}}$ (Equation 9-21)

$$K = (2\pi f)^2 \mu = (2\pi)^2 (4.22\times10^{13} Hz)(0.8812)(1.66\times10^{-27} kg/u)$$

$$K = 117 N/m$$

(d) $E_n = n^2h^2 / 8mr_0^2 \rightarrow r_0^2 = n^2h^2 / 8mE_n$

$$r_0 \approx h / (8mE_0)^{1/2}$$

$$r_0 \approx \frac{6.63\times10^{-34} J\cdot s}{\left[8(0.8812u)(1.66\times10^{-27} kg/u)(0.087eV)(1.60\times10^{-19} J/eV)\right]^{1/2}}$$

$$r_0 \approx 5.19\times10^{-11} m = 0.052nm$$

9-25. (a) $\mu = \frac{m_1 m_2}{m_1 + m_2} = \frac{(39.1u)(35.45u)}{39.1u + 35.45u} = 18.6u$

(b) $E_{0r} = \frac{\hbar^2}{2I}$ (Equation 9-14) $I = \mu r_0^2$

$$E_{0r} = \frac{\hbar^2}{2\mu r_0^2} = \frac{(\hbar c)^2}{2\mu c^2 r_0^2} \rightarrow r_0^2 = \frac{(\hbar c)^2}{2\mu c^2 E_V}$$

$$\therefore r_0 = \frac{\hbar c}{(2\mu c^2 E_V)^{1/2}} = \frac{197.3 eV\cdot nm}{\left[2(10.6uc^2)(931.5\times10^6 eV/uc^2)(1.43\times10^{-5} eV)\right]^{1/2}}$$

$$r_0 = 0.280nm$$

9-26. $f = \frac{1}{2\pi}\sqrt{\frac{K}{\mu}}$ (Equation 9-21)

(a) For $H^{35}Cl$: μ = 0.980u and $f = 8.97\times10^{13} Hz$.

$$K = (2\pi f)^2 \mu = (2\pi)^2 (8.97\times10^{13} Hz)^2 (0.980u)(1.66\times10^{-27} kg/u) = 517 N/m.$$

(b) For $K^{79}Br$: $\mu = \dfrac{m_1 m_2}{m_1 + m_2} = \dfrac{(39.102u)(78.918u)}{39.102u + 78.918u} = 26.147u$ and

$f = 6.93 \times 10^{12}\,Hz$

$$K = (2\pi f)^2 \mu = (2\pi)^2 \left(6.93 \times 10^{12}\,Hz\right)^2 (26.147u)\left(1.66 \times 10^{-27}\,kg/u\right) = 82.3\,N/m$$

9-27. $E_{0r} = \hbar^2/2I$ Treating the *Br* atom as fixed,

$$I = m_H r_0^2 = (1.0078u)\left(1.66 \times 10^{-27}\,kg/u\right)(0.141nm)^2$$

$$E_{0r} = \frac{\left(1.055 \times 10^{-34}\,J \cdot s\right)^2}{2(1.0078u)\left(1.66 \times 10^{-27}\,kg/u\right)(0.141nm)^2\left(10^{-9}\,m/nm\right)^2}$$

$$= 1.67 \times 10^{-22}\,J = 1.04 \times 10^{-3}\,eV$$

$E_\ell = \ell(\ell + 1)E_{0r}$ for $\ell = 0, 1, 2, \cdots$ (Equation 9-13)

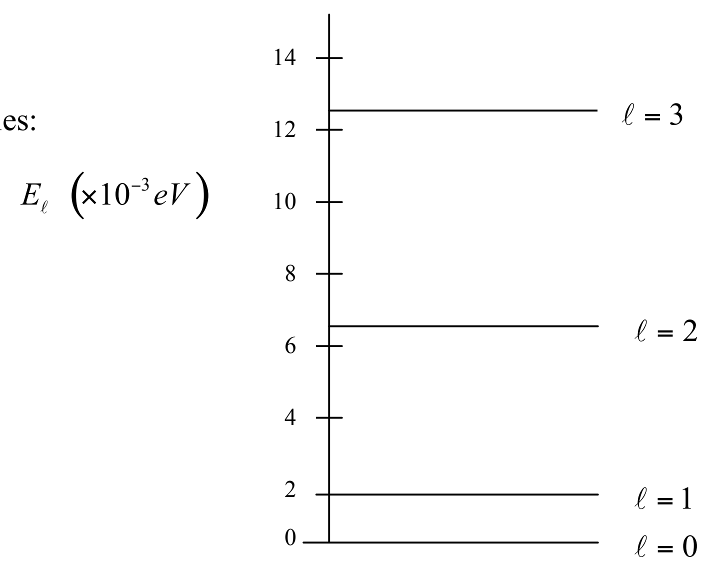
The four lowest states have energies:

$E_0 = 0$

$E_1 = 2E_{0r} = 2.08 \times 10^{-3}\,eV$

$E_2 = 6E_{0r} = 6.27 \times 10^{-3}\,eV$

$E_3 = 12E_{0r} = 12.5 \times 10^{-3}\,eV$



9-29. $E_{0r} = \dfrac{\hbar^2}{2I}$ where $I = \mu r_0^2$ (Equation 9-14)

For $K^{35}Cl$: $\mu = \frac{(39.102u)(34.969u)}{39.102u + 34.969u} = 18.46u$

For $K^{37}Cl$: $\mu = \frac{(39.102u)(34.966u)}{39.102u + 34.966u} = 19.00u$

$r_0 = 0.267nm$ for KCl.

$$E_{0r}\left(K^{35}Cl\right) = \frac{\left(1.055\times10^{-34}J\cdot s\right)^2}{2(18.46u)\left(1.66\times10^{-27}kg/u\right)\left(0.267\times10^{-9}m\right)^2}$$

$$= 2.55\times10^{-24}J = 1.59\times10^{-5}eV$$

$$E_{0r}\left(K^{37}Cl\right) = \frac{\left(1.055\times10^{-34}J\cdot s\right)^2}{2(19.00u)\left(1.66\times10^{-27}kg/u\right)\left(0.267\times10^{-9}m\right)^2}$$

$$= 2.48\times10^{-24}J = 1.55\times10^{-5}eV$$

$\Delta E_{0r} = 0.04\times10^{-5}eV$

9-40. (a) Total potential energy: $U(r) = -\frac{ke^2}{r} + E_{ex} + E_{ion}$

the electrostatic part of $U(r)$ at r_0 is $-\frac{ke^2}{r_0} = -\frac{1.44eV\cdot nm}{0.24nm} = -6.00eV$

(b) The net ionization energy is:

$E_{ion} = (\text{ionization energy of } Na) - (\text{electron affinity of } Cl)$

$= 5.14eV - 3.62eV = 1.52eV$

dissociation energy of $NaCl$ =4.27eV (from Table 9-2)

$4.27eV = -U(r_0) = 6.00eV - 1.52eV = 4.67eV - E_{ex}$

$E_{ex} = 6.00eV - 4.27eV - 1.52eV = 0.21eV$

(c) $E_{ex} = \frac{A}{r^n}$ (Equation 9-2)

At $r_0 = 0.24nm$, $E_{ex} = 0.21eV$

At $r_0 = 0.14nm$, $U(r) = 0$ and $E_{ex} = \frac{ke^2}{r} - E_{ion} = 8.77eV$

At $r_0 : E_{ex} = 0.21eV = \dfrac{A}{(0.24nm)^n} \rightarrow A = (0.21eV)(0.24nm)^n$

At $r = 0.14nm : E_{ex} = 8.77eV = \dfrac{A}{(0.14nm)^n} \rightarrow A = (8.77eV)(0.14nm)^n$

Setting the two equations for A equal to each other:

$$\frac{(0.24nm)^2}{(0.14nm)^n} = \left(\frac{0.24}{0.14}\right)^2 = \left(\frac{8.77eV}{0.21eV}\right) \rightarrow (1.71)^n = 41.76$$

$n \log 1.71 = \log 41.76$

$n = (\log 41.76)/(\log 1.71) = 6.96$

$A = 0.21eV\,(0.24nm)^n = 0.21eV\,(0.24nm)^{6.96} = 1.02 \times 10^{-5}\, eV \cdot nm^{6.96}$

9-52. (a) $\dfrac{dU}{dr} = U_0\left[-12a^{12}r^{-13} - 2(-6a^6)r^{-7}\right]$

For U_{min}, $dU/dr = 0$, so $-12a^{12}r^{-6} + 12a^6 = 0 \rightarrow r^{-6} = a^{-6} \rightarrow r = a$

(b) For $U = U_{\text{min}}$, $r = a$ then $U_{\text{min}} = U_0\left[\left(\dfrac{a}{a}\right)^{12} - 2\left(\dfrac{a}{a}\right)^6\right] = (1-2)U_0 = -U_0$

(c) From Figure 9-8(b): $r_0 = 0.074nm\ (= a)$ $\quad U_0 = 32.8eV$

(d)

r/r_0	$(r_0/r)^{12}$	$-2(r_0/r)^6$	U
0.85	7.03	−5.30	+56.7
0.90	3.5	−3.8	−9.8
0.95	1.85	−2.72	−28.5
1.00	1	−2.0	−32.8
1.05	0.56	−1.5	−30.8
1.10	0.32	−1.12	−26.2
1.15	0.19	−0.86	−22.0
1.20	0.11	−0.66	−18.0