

9-10.  $H_2S$ ,  $H_2Te$ ,  $H_3P$ ,  $H_3Sb$

9-11. (a)  $KCl$  should exhibit ionic bonding.

(b)  $O_2$  should exhibit covalent bonding.

(c)  $CH_4$  should exhibit covalent bonding.

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

$$E_{0r} = \frac{\hbar^2}{mr_0^2} = \frac{(\hbar c)^2}{mc^2 r_0^2} = \frac{(197.3 eV \cdot nm)^2}{(16uc)^2 (931.5 \times 10^6 eV / uc^2)(0.121 nm)^2} = 1.78 \times 10^{-4} eV$$

9-22. For  $Co$ :  $f = 6.42 \times 10^{13} Hz$  (See Example 9-6)

$$E_v = (v + 1/2)hf \quad (\text{Equation 9-20})$$

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

$$= (4.14 \times 10^{-15} eV \cdot s)(6.42 \times 10^{13} Hz)$$

$$= 0.27 eV$$

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

$$0.01 = e^{-(0.27)/(8.62 \times 10^{-5})T}$$

$$\ln(0.01) = -(0.27 eV) / (8.62 \times 10^{-5} eV / K) T$$

$$T = \frac{-(0.27 eV)}{\ln(0.01)(8.62 \times 10^{-5} eV / K)}$$

$$T = 680 K$$

9-23. For LiH:  $f = 4.22 \times 10^{13} \text{ Hz}$  (from Table 9-7)

$$(a) E_v = (v + 1/2)hf = E_0 = hf/2 = (4.14 \times 10^{-15} \text{ eV} \cdot \text{s})(4.22 \times 10^{13} \text{ Hz})/2$$

$$E_0 = 0.087 \text{ eV}$$

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

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

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

$$K = (2\pi f)^2 \mu = (2\pi)^2 (4.22 \times 10^{13} \text{ Hz})(0.8812)(1.66 \times 10^{-27} \text{ kg/u})$$

$$K = 117 \text{ N/m}$$

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

$$r_0 \approx h / (8m E_0)^{1/2}$$

$$r_0 \approx \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{\left[ 8(0.8812u)(1.66 \times 10^{-27} \text{ kg/u})(0.087 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV}) \right]^{1/2}}$$

$$r_0 \approx 5.19 \times 10^{-11} \text{ m} = 0.052 \text{ nm}$$

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

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

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

$$\therefore r_0 = \frac{\hbar c}{(2\mu c^2 E_v)^{1/2}} = \frac{197.3 \text{ eV} \cdot \text{nm}}{\left[ 2(10.6 \mu c^2)(931.5 \times 10^6 \text{ eV/} \mu c^2)(1.43 \times 10^{-5} \text{ eV}) \right]^{1/2}}$$

$$r_0 = 0.280 \text{ nm}$$

9-27. 1.  $f = \frac{1}{2\pi} \sqrt{\frac{K}{\mu}}$  (Equation 9-21) Solving for the force constant,  $K = (2\pi f)^2 \mu$

2. The reduced mass  $\mu$  of the NO molecule is

$$\mu = \frac{m_N m_O}{m_N + m_O} = \frac{(14.01\text{u})(16.00\text{u})}{14.01\text{u} + 16.00\text{u}} = 7.47\text{u}$$

3.  $K = (2\pi \times 5.63 \times 10^{13} \text{ Hz})^2 \times 7.47\text{u} \times 1.66 \times 10^{-27} \text{ kg/u} = 1.55 \times 10^3 \text{ N/m}$

(Note: This is equivalent to about 8.8 lbs/ft, the force constant of a moderately strong spring.)

9-29.  $\Delta E = hf$  where  $f = 1.05 \times 10^{13} \text{ Hz}$  for *Li*. Approximating the potential (near the bottom)

with a square well,  $\Delta E(2 \rightarrow 1) = (2^2 - 1) \left( \frac{\pi^2}{2} \right) \frac{\hbar^2}{m r_0^2} = hf$

For *Li*:  $r_0^2 = \frac{3\pi^2}{2} \frac{\hbar}{2\pi f \mu} = \frac{3\pi}{4} \frac{\hbar}{f \mu}$

$$r = \left[ \left( \frac{3\pi}{4} \right) \frac{1.055 \times 10^{-34} \text{ J}\cdot\text{s}}{(1.05 \times 10^{13} \text{ Hz})(6.939\text{u})(1.66 \times 10^{-27} \text{ kg/u})} \right]^{1/2}$$

$$= 4.53 \times 10^{-11} \text{ m} = 0.045 \text{ nm}$$