16-1. (a) $\nu = 3.00\times10^{10}\ \text{cm s}^{-1} \times 2170\ \text{cm}^{-1} = 6.51\times10^{13}\ \text{s}^{-1}$

$$\nu = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}} \qquad \text{(Equation 16-14)}$$

$$k = (2\pi\nu)^2\mu = (2\pi\nu)^2\,\frac{m_1 m_2}{m_1 + m_2} \qquad \text{(Equation 16-9)}$$

$$m_1 = \frac{12\times10^{-3}\ \text{(kg C/mol C)}}{6.02\times10^{23}\ \text{(atom C/mol C)}} = 1.99\times10^{-26}\ \text{kg C/atom C}$$

$$m_2 = \frac{16\times10^{-3}\ \text{(kg O/mol O)}}{6.02\times10^{23}\ \text{(atom O/mol O)}} = 2.66\times10^{-26}\ \text{kg O/atom O}$$

$$k = (2\pi\nu\ \text{s}^{-1})^2 \times \frac{1.99\times10^{-26}\ \text{kg}\times 2.66\times10^{-26}\ \text{kg}}{1.99\times10^{-26}\ \text{kg} + 2.66\times10^{-26}\ \text{kg}}$$

$$= (2\pi\times6.51\times10^{13}\ \text{s}^{-1})^2\times1.14\times10^{-26}\ \text{kg} = 1.91\times10^{3}\ \text{kg/s}^2$$

Multiplying the right side of this equation by m/m gives

$$k = 1.90\times10^{3}\ \frac{\text{kg m}}{\text{s}^2\ \text{m}} = 1.90\times10^{3}\ \text{N/m}$$

(b) Here $m_1 = 2.326\times10^{-26}$ kg and $\mu = 1.24\times10^{-26}$ kg

$$\nu = \frac{1}{2\pi}\sqrt{\frac{1.91\times10^{3}}{1.24\times10^{-26}}} = 6.25\times10^{13}\ \text{s}^{-1}$$

$$\bar{\nu} = 6.25\times10^{13}\ \text{s}^{-1} / 3.00\times10^{10}\ \text{cm s}^{-1} = 2083\ \text{cm}^{-1}$$

16-2. (a) We will use Equation 16-15 to obtain k

$$\bar{\nu} = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}}$$

where $\mu = \dfrac{m_1 m_2}{m_1 + m_2}$

$$m_1 = \frac{1.00\times10^{-3}\ \text{kg /mol H}}{6.02\times10^{23}\ \text{atom H/molH}} = 1.66\times10^{-27}\ \text{kg}$$

$$m_2 = \frac{35.5\times10^{-3}\ \text{kg /mol Cl}}{6.02\times10^{23}\ \text{atom Cl/mol Cl}} = 5.90\times10^{-26}\ \text{kg}$$

$$\mu = \frac{1.66\times10^{-27}\ \text{kg}\times5.90\times10^{-26}\ \text{kg}}{1.66\times10^{-27}\ \text{kg} + 5.90\times10^{-26}\ \text{kg}} = 1.62\times10^{-27}\ \text{kg}$$

Rearranging Equation 16-15 and substituting yields

$$k = (2\bar{\nu}\pi c)^2\,\mu = (2\pi\times2890\ \text{cm}^{-1}\times\ 3.00\times10^{10}\ \text{cm s}^{-1})^2\times1.62\times10^{-27}\ \text{kg}$$

$$= 4.81\times10^2\ \text{kg s}^{-2} = 4.81\times10^2\ \text{N/m}$$

(b) The force constant in HCl and DCl should be the same and

$$m_1 = \frac{2.00\times10^{-3}}{6.02\times10^{23}} = 3.32\times10^{-27}\ \text{kg}$$

$$\mu = \frac{3.32\times10^{-27}\ \text{kg}\times5.90\times10^{-26}\ \text{kg}}{3.32\times10^{-27}\ \text{kg} + 5.90\times10^{-26}\ \text{kg}} = 3.14\times10^{-27}\ \text{kg}$$

$$\bar{\nu} = \frac{1}{2\pi\times3.00\times10^{10}\ \text{cm/s}}\sqrt{\frac{4.81\times10^2\ \text{kg s}^{-2}}{3.14\times10^{-27}\ \text{kg}}} = 2075\ \text{cm}^{-1}$$

16-4. $\bar{\nu} = 1/(1.4\times10^{-4}\ \text{cm}) = 7.1\times10^{3}\ \text{cm}^{-1}$

The first overtone occurs at $2 \times \bar{\nu}$ or $14.2 \times 10^3\ \text{cm}^{-1}$ or $1.4 \times 10^4\ \text{cm}^{-1}$.

$$\lambda = \frac{1}{14.2\times10^{3}\ \text{cm}^{-1}} = 7.0\times10^{-5}\ \text{cm} = 0.70\ \mu\text{m}$$

16-7. Bonds will be inactive if no change in dipole moment accompanies the vibration.

(a) Inactive (b) Active (c) Active (d) Active (e) Inactive (f) Active (g) Inactive

16-8. The advantages of FTIR instruments over dispersive spectrometers include (1) superior signal-to-noise ratios, (2) speed, (3) higher resolution, (4) highly accurate and reproducible frequency axis, and (5) freedom from stray radiation effects.