1. \( \nu_{vib} = \frac{1}{2\pi} \sqrt{\frac{k}{\mu}} \) so \( \lambda = \left( \frac{2\pi \nu}{\lambda} \right)^2 \mu \\

(a) \( \mu = \frac{(12.01 \times 15.999)}{12.01 + 15.999} \frac{1}{N_A} = 1.14 \times 10^{-23} \text{ g} \)

\[ \lambda = \frac{1}{2170 \text{ cm}^{-1}} = 4.608 \times 10^{-4} \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} = 4.608 \times 10^{-6} \text{ m} \]

\[ \nu_{vib} = \frac{\nu_{photon}}{\lambda} = \frac{3.0 \times 10^{8} \text{ m/s}}{4.608 \times 10^{-6} \text{ m}} = 6.51 \times 10^{13} \text{ s}^{-1} \]

\[ \lambda = \left( \frac{2\pi \nu_{vib}}{6.51 \times 10^{13} \text{ s}^{-1}} \right)^2 \left( 1.14 \times 10^{-23} \text{ g} \right) \]

\[ = 1.9 \times 10^6 \text{ g} \]

Units: \( \frac{g}{s^2} = \frac{g}{s^2 \text{ cm}} = \frac{\text{dyne}}{\text{cm}} \)

\[ = 1.9 \times 10^6 \text{ dynes/cm} \]

(b) Assume that the force constant is the same.

\[ \mu = \frac{14 \times 15.999}{14 + 15.999} \frac{1}{N_A} = 1.24 \times 10^{-23} \text{ g} \]

\[ \nu_{vib} = \frac{1}{2\pi} \sqrt{\frac{1.9 \times 10^8 \text{ g}/\text{s}^2}{1.24 \times 10^{-23} \text{ g}}} = 6.2 \times 10^{13} \text{ Hz} = \nu_{photon} \]

\[ \nu_{photon} = \frac{c}{\lambda_{photon}} = \frac{3.0 \times 10^8 \text{ m/s}}{6.2 \times 10^{13} / s} = 4.8 \times 10^{-6} \text{ m} \]

\[ 1 \text{ cm}^{-1} = \left( \frac{4.8 \times 10^{-6} \text{ m} \times 100 \text{ cm}}{\text{m}} \right) = 2080 \text{ cm}^{-1} \]
3. \[ \gamma = \frac{12.01 \cdot 1.008}{12.01 + 1.008} N_A = 1.54 \times 10^{-29} g = 1.54 \times 10^{-27} \text{kg} \]

\[ \gamma = 5.0 \times 10^2 \text{ N/m}, \text{ using MKS units instead of CGS} \]

\[ \nu_{\text{vib}} = \frac{1}{2\pi} \sqrt{\frac{5.0 \times 10^2 \text{ N/m}}{1.54 \times 10^{-27} \text{ Kg}}} = 9.07 \times 10^{13} \text{ s}^{-1} \]

Units: \( N = \text{Kg m/s}^2 \) so \( N/m \cdot \text{Kg} = \frac{\text{Kg m}}{s^2 \cdot \text{Kg}} = \frac{1}{s^2} \)

\[ \nu_{\text{photon}} = \nu_{\text{vib}} = \frac{c}{\lambda} \]

so \( \lambda = \frac{c}{\nu} \)

\[ \lambda = 3.0 \times 10^8 \text{ m/s} = 3.3 \times 10^{-6} \text{ m} \]

\[ \text{cm}^{-1} = \frac{1}{(3.3 \times 10^{-6} \text{ m} \times 100 \text{ cm/m})} = 3020 \text{ cm}^{-1} \]

From correlation charts, C-H @ 2850 - 3300 cm\(^{-1}\)

For deuterated bond, \( \gamma = 2.85 \times 10^{-27} \text{ kg} \)

Assume \( \gamma \) is the same

\[ \text{cm}^{-1} = 2200 \text{ cm}^{-1} \]
6. \( 3N - 6 = 3(s) - 6 = 3 \) normal modes so 3 peaks

\[
\text{symmetric stretch} \quad \text{asymmetric stretch} \quad \text{scissor mode}
\]

7. (a) inactive  (e) inactive  
(b) active  (f) active  
(c) active  (g) inactive  
(d) active

8. Multiplex advantage = speed and increased signal-to-noise ratio

9. (a) \( \Delta \bar{\nu} = \frac{1}{2x} \)

\[
x = \frac{1}{2 \Delta \bar{\nu}} = \frac{1}{2(0.050 \text{cm}^{-1})} = 10 \text{ cm}
\]
1. A virtual state is an unquantized energy level that lies between quantized levels where scattering occurs.

   electronic level 2
   virtual level
   electronic level 1

2. Normally, most of the population is in the ground vibrational level where Stokes scattering occurs, so the Stokes peaks are larger. With increasing temperature, higher vibrational levels start to populate and the anti-Stokes peak increases in intensity.

   Upper electronic level
   virtual state
   excited vibrational level
   lower electronic state

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Ch 313 Homework
Chap. 18
Skoog, 6th ed
6. (a) $\text{HeNe} = 632.8 \text{ nm}$ and $\text{Ar}^+ = 488 \text{ nm}$ or $514.5 \text{ nm}$

There are several reasons to select a higher wavelength,
(1) the analyte absorbs at the $\text{Ar}^+$ wavelength
(2) $\text{HeNe}$ are less intense, so use it if the sample photodegrades easily
(3) there's less likelihood of fluorescence

(b) to avoid fluorescence (occurs in the UV-Vis range)
(c) even more fluorescence and high-$E$ photons can damage the sample

9. (a) IR active then there must be a change in dipole moment
- Raman active requires a change in polarizability
- They differ because absorption in IR requires that the vibrating electron cloud have a oscillating charge before the oscillating electric field vector can go into "resonance" with it, followed by absorption of the photon. In Raman, light is scattered off of the oscillating electron cloud, which requires the electron cloud to be easily deformed,