1. True or false? If a statement is false, explain why.
   a. Most of the radiation emitted during fluorescence is usually at longer wavelengths than the radiation exciting the fluorescence.
   b. Excited electronic states of a molecule usually have equilibrium geometries quite close to that of the ground electronic state.

2. Which of the following vibrations are IR active?
   a. \( \text{C} \equiv \text{O} \rightarrow \text{H}_2\text{C} \)
   b. \( \text{H}_3\text{C} \rightarrow \text{C} = \text{O} \rightarrow 
   c. \text{H}_{\bullet} \text{C} \rightarrow \text{C} = \text{C} \rightarrow 
   d. \text{H}_3\text{C} \rightarrow \text{C} = \text{C} \rightarrow 

3. If you wish to study the anti-Stokes portion of the Raman spectrum of a sample, should you heat or cool the sample to increase the intensity of the anti-Stokes lines? Explain your answer.

4. The average speed of a molecule is given by \( \langle \nu \rangle = \left(8kT/\pi m\right)^{1/2} \) where \( m \) is the mass of the molecule. If a CO molecule absorbs at a central wavenumber of \( \tilde{\nu}_0 = 2000 \) cm\(^{-1}\), estimate the width of the line at 300 K. Give your answer in three different units: wavenumber (cm\(^{-1}\)), wavelength (\( \mu \)m), and frequency (Hz).

5. Draw a schematic vibronic absorption spectrum of a diatomic molecule for a case in which the minima of the potential wells which describe the ground and excited states occur at the same internuclear distance.

6. Two common idealized band shapes are the Lorentzian and Gaussian functions. The equations for these curves are:
   \[
   L(\tilde{\nu}) = \frac{\varepsilon_0 \left(\delta/2\right)^2}{\left(\delta/2\right)^2 + (\tilde{\nu} - \tilde{\nu}_0)^2} \quad \text{and} \quad G(\tilde{\nu}) = \varepsilon_0 \exp\left[-\left(4\ln 2\right)\left(\tilde{\nu} - \tilde{\nu}_0\right)^2/\delta^2\right]
   \]
   where \( \varepsilon_0 \) is the molar absorptivity at the absorption maximum, \( \tilde{\nu}_0 \) is the position of the absorption maximum, and \( \delta \) is the width of the peak at half-height.
   a. Derive the expression for the integrated absorption coefficient of each. Consult a table of integrals if necessary.
   b. The 0 – 0 transition of a particular molecule has \( \varepsilon_0 = 3100 \text{ M}^{-1} \text{ cm}^{-1}, \delta = 46 \text{ cm}^{-1}, \tilde{\nu}_0 = 30840 \text{ cm}^{-1} \)

   Calculate the integrated absorption coefficient for each bandshape.

7. A widely used laser is the Nd:YAG (where YAG stands for yttrium aluminum garnet). A typical YAG laser produces 10 pulses per second at a wavelength of 1064 nm. Each pulse is \( \sim 10 \) ns long and has an energy of 350 mJ. What are the peak and average powers? How many photons are produced per pulse per minute?

8. The lifetimes of vibrationally excited states of molecules of a liquid are limited by the collision rates in the liquid. If 1 in 10 collisions deactivates a vibrationally excited state, what is the broadening of vibrational lines if a molecule undergoes \( 10^{13} \) collisions per second?