1. True or false?
   a. When a molecule absorbs a photon and makes a transition to a stationary quantum state \( j \) of energy \( E_j \) to a higher energy state, the absorption frequency \( \nu \) satisfies \( E_j = h\nu \).
   b. When a molecule emits a photon of frequency \( \nu \), it undergoes an energy change given by \( \Delta E = h\nu \).
   c. When a molecule absorbs a photon of frequency \( \nu \), it undergoes an energy change given by \( \Delta E = h\nu \).
   d. The longer the wavelength of a transition, the smaller the energy difference between the two levels involved in the transition.
   e. Exposing a molecule in state \( n \) to electromagnetic radiation of frequency \( \nu = (E_n - E_m)/h \) will increase the probability that the molecule will make a transition to the lower state \( m \) with emission of a photon of frequency \( \nu \).
   f. The spacing between adjacent low lying molecular translational, rotational, and vibrational levels satisfy \( \Delta E_{tr} < \Delta E_{rot} < \Delta E_{vib} \).
   g. At room temperature, many rotational levels of gas phase molecules are substantially populated.
   h. At room temperature, many vibrational levels of \( O_2(g) \) are substantially populated.
   i. A bound electronic state of a diatomic molecule has a finite number of vibrational levels.
   j. As the vibrational quantum number increases, the spacing between adjacent vibrational levels of a diatomic molecule decreases.
   k. As the rotational quantum number increases, the spacing between adjacent rotational levels of a diatomic molecule increases.
   l. Diatomic molecule vibration-rotation absorption bands always have \( \Delta \nu = 1 \).
   m. For diatomic pure-rotational absorption spectra, only \( \Delta J = +1 \) lines occur.
   n. Because only \( \Delta J = +1 \) is allowed in pure-rotational absorption spectra of diatomic molecules, a diatomic molecule pure-rotational spectrum contains only one line.

2. Use the harmonic oscillator selection rule \( \Delta \nu = \pm 1 \) to find the frequency or frequencies of light absorbed by a harmonic oscillator with vibrational frequency \( \nu_{vib} \).

3. For a certain quantum mechanical system, the wavelength for an absorption transition from level \( A \) to level \( C \) is 485 nm and the wavelength for an absorption transition from level \( B \) to level \( C \) is 884 nm. Find the wavelength of the transition between levels \( A \) and \( B \).

4. If the \( J = 2 \rightarrow 3 \) rotational transition for a diatomic molecule occurs at \( \lambda = 2.00 \) cm, find \( \lambda \) for the \( J = 6 \rightarrow 7 \) transition.

5. The \( J = 2 \rightarrow 3 \) pure-rotational transition for the ground state of \( ^{39}K^{37}Cl \) occurs at 22410 MHz. Neglecting centrifugal distortion, predict the frequency of the \( J = 0 \rightarrow 1 \) pure-rotational transition of (a) \( ^{39}K^{37}Cl \) and (b) \( ^{39}K^{35}Cl \). You may assume that the equilibrium bond lengths for both isotopes are the same.

6. Give the number of normal modes of (a) \( SO_2 \); (b) \( C_2F_2 \); and (c) \( CCl_4 \).

7. \( H_2O \) vapor has an IR absorption band at \( \nu_{origin} = 7252 \) cm\(^{-1} \). The lower vibrational level for this band is the ground vibrational state, \( \nu_1 \nu_2 \nu_3 = 000 \). What are the possibilities for the upper vibrational level?