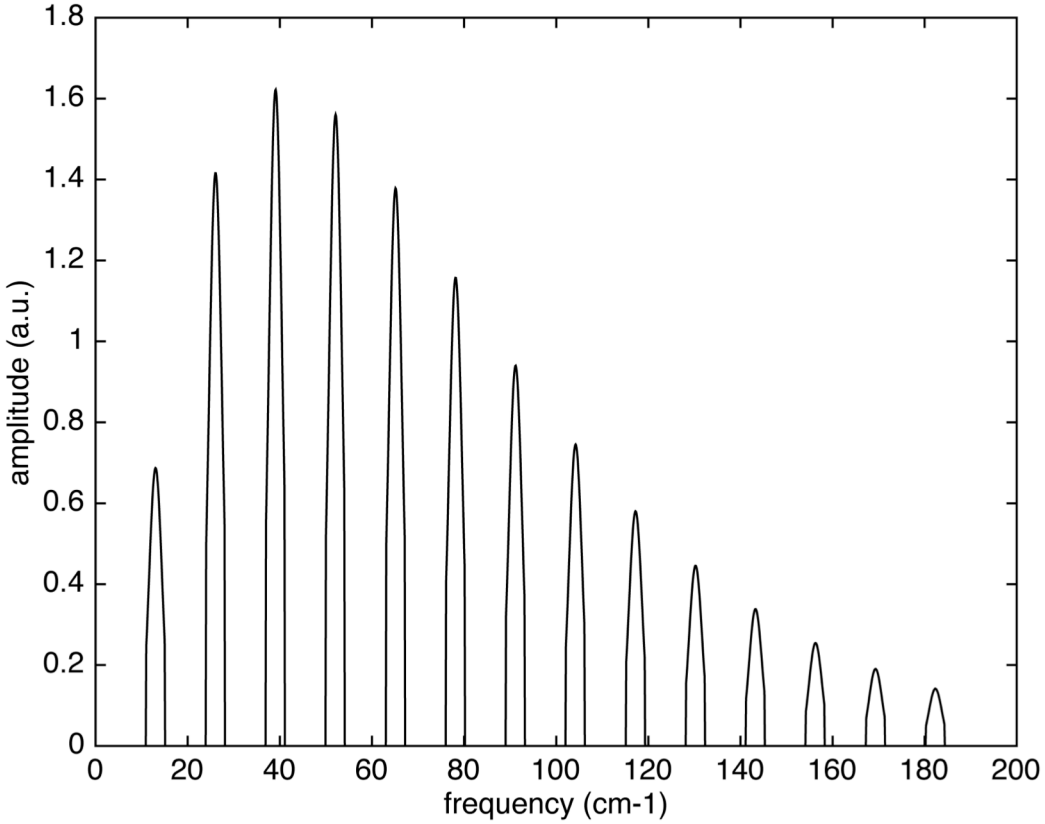
1. (20 points) The fundamental vibrational frequencies for $^{14}N^{14}N$ and $^{12}C^{16}O$ are 2330 cm^{-1} and 2170 cm^{-1}, respectively. Using these data, predict which molecule has the strongest bond? **Show your reasoning!**

Circle one: N_2 CO

b) Does N_2 have an IR spectrum? Why or why not?

Circle one: yes no

2. (30 points) The pure rotational spectrum of $^{1}H^{127}I$ is shown below.



a) Using these data, determine the length of the HI bond.

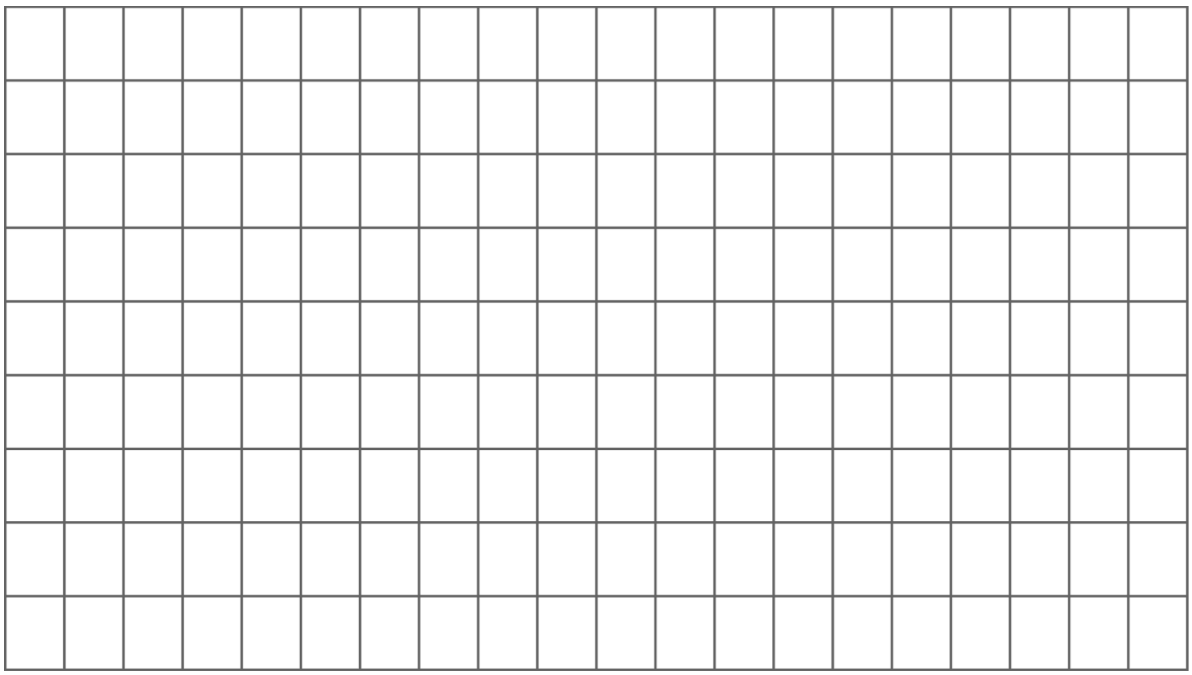
Bond length =

b) Using the HI rotational spectrum on the previous page, estimate the temperature of the sample.

Temperature =

c) Briefly describe what happens to the HI molecules when the probing radiation excites them from the J =1 to J = 2 state?

3. (20 points) a) Draw the IR spectrum of ^{1}H-^{35}Cl gas taking the fundamental vibrational frequency to be 2886.0 cm^{-1} and the rotational constant to be 10.0 cm^{-1}. Label the frequency axis with the peak positions of the first 3 transitions in the P- and R-branches. You can show the absorbance lines in your drawing using "sticks" or vertical lines. For the purpose of this drawing you can make the sticks the same length.



b) Construct an energy level diagram that illustrates the six transitions shown in the above IR spectrum. Use numbers to label the transitions and their corresponding peaks in the stick spectrum that you drew for part a. Label the energy levels with the appropriate quantum numbers.

4. (10 points) Derive an expression for the classical limits of bond stretching and bond compression for a harmonic oscillator in the v = 10 vibrational energy state.

Stretching =

Compression =

5. (20 points) In class, we described the intensity of a spectroscopic transition as being proportional to

$$I(\nu) \propto (N_a - N_b)\left|\int_\tau \psi_b^* \hat{H}_1 \psi_a \, d\tau\right|^2 \delta(E_b - E_a - h\nu)$$

a) Define the terms in the above equation. (N_a, N_b, ψ_a, ψ_b, $\hat{H}_1$, E_a, E_b, ν) A drawing may help you with your definitions.

b) What is the physical significance of the integral in the above expression?

c) What is the purpose of the delta function at the end of the expression?