Exam comments. The exam will cover section 6.6 (transition and reflection of waves), Chapter 7, Chapter 9 through molecular spectra, and related material from the HW and lecture. The exam will again be a mix of challenging questions, interpretation of the answers to those questions, and simpler computation questions.

1) Molecular energy levels. The large number of energies levels and the order of magnitude differences in energy levels for the different types of transitions lead to a densely filled energy spectrum.

Some notes on allowed transitions.

Rotational level transitions respect the selection rule $\Delta l = \pm 1$

Vibrational levels respect the selection rule $\Delta n = \pm 1$ except when you have a simultaneous atomic and vibrational level transition. Changing atomic levels changes the molecule, for instance altering the separation distance, and the energy structure of the vibrational levels. This will create overlap between the wave functions of more widely spaced vibrational levels and allow transitions.

You see rotational transitions, simultaneous rotational and vibrational transitions, or atomic transitions and simultaneous atomic and other transitions. All of these transitions can involve a change in total angular momentum of $\pm 1$, which occurs via the absorption or emission or a spin one photon.
Also there are a large number of processes via which and molecule can interact. These processes can involve photons with energies exactly consistent transition energies or the cases of Compton effect and (inverse) photo electric effect involving energy photons. The later type and their inverse versions are important since can absorb and emit arbitrary energy photons filling the in the spectrum.

Note we already discussed absorption, emission and stimulated emission in lecture 3.

2) Spectral analysis molecular transitions to determine properties.

Simultaneous vibrational and rotational transitions give a tool to analyze molecular properties.

Since exciting a molecule into a high vibrational energy state takes substantial energy typically molecules will be in their ground vibrational energy state at common temperatures. Rotational states are the same order as thermal energy and can be excited via kinematic collection. As a result, you will see distribution rotational energies depending on temperature.

Analyzing transitions from the ground vibrational state to the next energy state and simultaneous $\Delta l = \pm 1$ transition.

$$E_{0,l} = \frac{1}{2} \hbar \omega + l(l + 1)E_{0r}$$
\[ E_{0r} = \frac{\hbar^2}{2l} \]

\[ E_{1,l+1} = \frac{3}{2} \hbar \omega + (l + 1)(l + 2)E_{0r} \]

\[ E_{1,l-1} = \frac{3}{2} \hbar \omega + (l - 1)lE_{0r} \]

\[ \Delta E_{0,l \rightarrow 1, l+1} = \hbar \omega + 2(l + 1)E_{0r}, \quad l = 0, 1, 2, \ldots \]

\[ \Delta E_{0,l \rightarrow 1, l+1} = \hbar \omega - 2lE_{0r}, \quad l=1, 2, 3, \ldots \]

\[ \Delta E = \hbar \omega + (\ldots -6, -4, -2, 2, 4, 6 \ldots)E_{0r} \]

You can measure the vibrational level transition energy from the gap in the center of the distribution and \(2E_{0r}\) from any of the other gaps between rotational states. The vibrational energy can be used to extract the “size” of the potential well and rotational energy transition can be used extract the separation distance given the mass of the atoms.