1. On p. 560, Atkins & de Paula give a brief description of the helium-neon laser. Read through this description, study figure 17.35, and think about the atomic energy levels that are involved. (This item also depends on some of the ideas presented in sections 13.4 – 13.9.)
   - Refer to the atomic energy level tables that are available at the NIST Atomic Spectra Database \(\text{(information on the use of this data-base was provided in conjunction with the stellar spectra activity)}\), and determine the excitation energy \(\text{(in kJ mol}^{-1}\text{)}\) for the transition from the ground state of He to the \(^1\text{S}\) excited state and from the ground state to the \(^3\text{S}\) excited state. Give an orbital diagram for each of these states that clearly indicates the direction of electron spin. Which of these states lies lower in energy, and why?
   - Now, use the “lines” mode of the NIST Atomic Spectra Database to determine the neon levels involved in the 632.8 nm lasing transition. Specify the term symbols for the upper and lower state of the transition, and give the related orbital diagrams. Discuss this transition with respect to the selection rules for atomic spectra. (Which rules does it adhere to, which rules does it violate?)
   - In figure 17.35, it appears that the lower level of the 632.8 nm lasing transition can subsequently decay to an intermediate Ne level, and then to the ground state. It turns out that this intermediate level is associated with the excited state Ne configuration \(1\text{s}^22\text{s}^22\text{p}^53\text{s}^1\). There are actually 4 levels associated with this configuration, all located between 134,000 and 136,000 cm\(^{-1}\) above the ground level. Again consult the database to determine the term symbols associated with these 4 levels, and describe how the selection rules associated with this latter transition contribute to the formation of the population inversion that is required for lasing.
   - Figure 17.35 implies that other lasing transitions (in the IR) may be possible for this system. Use the principles given in section 17.5 to describe what sort of “design modifications” would be needed to generate an IR laser from this system.

2. Atkins and de Paula, p. 407, exer. 13.15(b), exer. 13.17(b), exer. 13.19(b), and exer. 13.22(b)

3. The aurora borealis (Northern Lights) is caused by an intricate series of physico-chemical processes occurring in the upper atmosphere. Many of these processes involve excited electronic states of atomic, molecular and ionic species. In many cases, the aurora appears green, and a prominent feature of the auroral spectrum is due to atomic oxygen emitting green light \(\left(\lambda=557.7 \text{ nm}\right)\) in a transition from the \(^1\text{S}_0\) level to the \(^1\text{D}_2\) level. The \(^1\text{S}_0\) level can also emit uv light \(\left(\lambda=297.2 \text{ nm}\right)\) in a transition to the \(^3\text{P}_1\) level of the ground term. The green emission is due to a forbidden transition, but nevertheless is prominent because of the relatively large quantity of \(^1\text{S}_0\) atoms produced in a variety of processes. Two of the more significant processes are (1) \textit{collisional energy transfer} with electronically excited nitrogen: \(\text{N}_2(A^{3}\Sigma_u^+) + \text{O} \rightarrow \text{N}_2(X^{1}\Sigma_g^+) + \text{O} \left(^1\text{S}_0\right)\); and (2) \textit{dissociative recombination} \(\text{O}_2^* + e^- \rightarrow 2 \text{O} \left(^3\text{P}, ^1\text{D}, ^1\text{S}\right)\). At typical pressures in the gas phase, an excited-state species that must undergo a forbidden transition to relax radiatively will lose its energy by colliding with another species, but at the lower pressures of the upper atmosphere, the \textit{collision frequency} is significantly reduced, and the excited-state species has time to relax by emitting light.

   Sketch an energy level diagram for atomic oxygen depicting the three terms described above, and show each of the levels of the triplet ground term. (The NIST Atomic Spectra Database may be a useful resource as well.) Give representative orbital diagrams for each of the three levels involved in the specified auroral transitions. Which selection rule(s) does the 557.7 nm transition violate? It may seem curious that the 297.2 nm transition occurs between the \(^1\text{S}_0\) and \(^3\text{P}_1\) levels, rather than between the \(^1\text{S}_0\) and \(^3\text{P}_2\) levels. Can you explain this observation in terms of the atomic spectra selection rules?

Striking photos of aurora borealis taken in the Fairbanks, AK area can be found at http://www.gi.alaska.edu/aurora_predict/links.html