9-20) The characteristic rotational energy for the N₂ molecule is 2.48e-4 eV. From this, find the separation distance of the nitrogen atoms in N₂.

9-33) Determine the ratio of the number of molecules in the ν=1 state to the number in the ν=0 state for a sample of O₂ molecules at 273K. Repeat the calculation for 77K. (Ignore rotational motion.) [Answer: 2.4e-4]

9-41) The equilibrium separation of the K⁺ and Cl⁻ ions in KCl is about 0.267 nm. Calculate the potential energy of attraction of the ions assuming them to be point charges at this separation. The ionization energy of potassium is 4.34 eV and the electron affinity of Cl is 3.61 eV. Find the dissociation energy for KCl, neglecting any energy of repulsion. The measured dissociation energy for KCl is 4.40 eV. What is the energy due to repulsion of the ions at the equilibrium separation? [Answer: 0.23 eV]

9-51) The potential energy between two atoms in a molecule can often be described rather well by the Lenard-Jones potential:

\[ U(r) = U_0 \left( \frac{2}{r} \right)^{12} - \left( \frac{2}{r} \right)^{6} \]

where \( U_0 \) and \( a \) are constants. Find the interatomic separation \( r_0 \) in terms of \( a \) for which the potential energy is a minimum. Find the corresponding value of \( U_{\text{min}} \). Use Figure 9-8 to obtain numerical values for \( r_0 \) and \( U_0 \) for the H₂ molecule. Express your answer in nm and eV. Make a plot of the potential energy \( U(r) \) versus the interatomic spacing \( r \) for the H₂ molecule. Plot each term separately, together with the total.

10-19) What is the Fermi speed, i.e., the speed of a conduction electron whose energy is equal to the Fermi Energy, for Na, Au, and Sn? (See Table 10-3.)

10-21) At what temperature is the heat capacity due to the electron gas in copper equal to 10% of that due to lattice vibrations? [Answer: 4980 K]

10-47) The density of electron states in a metal can be written \( g(E) = AE^{1/2} \), where \( A \) is a constant and \( E \) is measured from the bottom of the conduction band. Show that the total number of states is \( (2/3)AE^{3/2} \). About what fraction of the conduction electrons are within \( kT \) of the Fermi energy? Evaluate this fraction for copper at 300 K? [Answer: 0.55%]

10-54) The quantity \( K \) is the force constant for a “spring” consisting of a line of alternating positive and negative ions. If these ions are displaced slightly from their equilibrium separation \( r_0 \) they will vibrate with a frequency \( \omega = (K/m)^{1/2} \). Use equation 10-5 along with values of \( \alpha, n, \) and \( r_0 \) given in the text for NaCl to calculate this frequency. Calculate the wavelength of electromagnetic radiation
corresponding to this frequency, and compare your result with the characteristic strong infrared absorption bands in the region of about $\lambda = 61 \mu m$. [Hint: Use the Taylor series to find an approximation to equation 10-5 in the vicinity of $r_0$ that follows the form for a simple harmonic oscillator, $U = 1/2Kx^2$.]