1. The dissociation energy of Cl$_2$ is 2.48 eV. Consider the formation of an NaCl molecule by the reaction 

$$ \text{Na} + \frac{1}{2} \text{Cl}_2 \rightarrow \text{NaCl}. $$

Is this reaction endothermic (requiring energy) or exothermic (releasing energy)? How much energy per molecule is required or given off?

2. The equilibrium separation of the Rb$^+$ and Cl$^-$ ions in RbCl is about 0.267 nm. (a) Calculate the potential energy of attraction of the ions, assuming them to be point charges. (b) The ionization energy of rubidium is 4.18 eV, and the electron affinity of Cl is 3.62 eV. Find the dissociation energy, neglecting the energy of repulsion. (c) The measured dissociation energy is 4.37 eV. What is the energy due to repulsion of the ions?

3. (Tipler & Mosca Problem 37-16) The equilibrium separation of the atoms in the HF molecule is 0.0917 nm, and its measured electric dipole moment is $6.40 \times 10^{-30}$ C · m. What percentage of the bonding is ionic?

4. The dipole moment $\mathbf{p}$ of the water molecule, illustrated in Figure 37-5, is actually the vector sum of two dipoles $\mathbf{p}_1$ and $\mathbf{p}_2$ of equal magnitude directed from the oxygen atom to each of the hydrogen atoms. The measured value of the angle between the two hydrogen atoms is 104.5°, the O–H bond length is 0.0956 nm, and the magnitude of $\mathbf{p}$ is $6.46 \times 10^{-30}$ C · m. Compute the fraction of the electron charge that is transferred from each hydrogen to the oxygen.

5. What type of bonding mechanism would you expect for (a) NaF, (b) KBr, (c) N$_2$, and (d) Ne?

6. We are going to explore the distance-dependence of the force between a polar and a non-polar molecule. Assume the dipole moment of the polar molecule points in the $x$ direction, and that the nonpolar molecule is a distance $x$ away. (a) In general, how does the electric field due to an electric dipole depend on the distance $x$? (b) Use the fact that the potential energy of an electric dipole of moment $\mathbf{p}$ in an electric field $\mathbf{E}$ is $U = -\mathbf{p} \cdot \mathbf{E}$ and that the induced dipole moment of the nonpolar molecule is proportional to $\mathbf{E}$ to find how the potential energy of interaction of the two molecules depends on separation distance. (c) Using $F_x = -dU/dx$, find the $x$-dependence of the force between the two molecules. – You can use simple proportionalities for all parts; you just care about the distance-dependence.

7. The CO molecule has a microwave spectrum with emission lines at 115, 230, and 345 GHz. 

(a) What are the corresponding photon energies?

(b) If transitions between adjacent levels are allowed, what energies of the molecule are implied? Are these rotational or vibrational energy levels?

(c) From the given data, if the levels are rotational, find the equilibrium separation (bond length) $r_0$; if they are vibrational, find the force constant $K$. 

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**Fall 2013**

**PY 203: Modern Physics**

**Problems on Molecular Bonding and Spectra**