1 Morning class week 3 day 5: Shielding

1.1 Day 4: Coulomb's law and Gauss's law

1. *Coulomb's Law:* The potential energy between two charges, q_1 and q_2, is

$$E_{potential} = C\frac{q_1 q_2}{r},$$

where C is the Coulomb constant and r is the distance between the two charges.

2. *Gauss's law:* One consequence of Coulomb's Law is another important law, Gauss's Law. Gauss's Law tells us that for spherical arrangements of electron densities, that for a given electron, (1) charge densities which lie farther away from the nucleus than the given electron do not exert any net force on the given electron and (2) charge densities which lie closer to the nucleus exert the same net force on the given electron as these same charge densities would have exerted had they been placed one on top of another at the nucleus itself.

   (a) Consider the Li atom. Write down the electron configuration for this atom. Write down the nuclear charge of this atom. Based on the graphs in Figure 8-35, we can make the fairly good approximation that the $1s$ orbital lies entirely on the inside of the $2s$ orbital. In Li there is just one electron in the $2s$ orbital. We apply Gauss' Law, and place all the electron densities inside the $2s$ orbital at the nucleus. We add up all the charges at this reconfigured nucleus. This addition of charges is termed the *effective charge*, Z_{eff}.

   (b) In a lithium atom in its ground state, What is the Z_{eff} exerted on the electron in the Li $2s$ orbital?

   (c) Please now consider the Be atom. In this atom there are two $2s$ electrons. On average, the first electron in the $2s$ orbital spends half its time closer to the nucleus than the second electron, and vice-a-versa: the second electron spends half its time closer to the nucleus than the first electron. Based on Gauss's Law, please estimate the effective charge, Z_{eff}, which a $2s$ electron in the Be atom experiences.

   (d) Using exactly the same assumptions as those given above, estimate the effective charge which the $1s$ electrons feel for Li and for Be. These two effective charges are both different from one another and are different from the previous answers.

   (e) In the previous problems you have estimated that an electron in a Be $2s$ orbital experiences a greater effective charge than an electron in a Li atom $2s$ orbital. What effect does a greater nuclear charge have on the size of an orbital?

   (f) Would a greater Z_{eff} cause electrons to come closer to the nucleus?

   (g) Based on Coulomb's Law, which electron has a more negative electrostatic charge, an electron in the Li or the Be $2s$ orbital?

(h) The size of an atom depends on the size of its outermost electrons. Based on this fact, and on your answers in the previous question, decide which atom has a bigger volume: the Li atom or the Be atom?

(i) For which of the two $2s$ orbitals, is the electrostatic potential experienced by the electron in the $2s$ orbital greater: the Li or the Be atom?

(j) Applying the virial theorem, for which of these two atoms is the electron in the $2s$ orbital moving faster?

(k) The energy of the outermost electron in an atom is called the *ionization energy*. Does Li or Be have a greater ionization energy?

(l) Review what you have just learned.