Review of Unit I

In which we develop a model for the atom and explore the structure of the periodic table.

1. The following data are available for the element *X*:

   photoelectron spectrum: five peaks

   covalent radius: 0.099 nm

   first ionization energy: 1.251 MJ/mol

   core charge: +7

   (a) Identify the element and explain your reasoning. In PES, each peak represents a unique atomic orbital. The peak's energy gives the ionization energy of an electron in the associated atomic orbital and the peak's height is proportional to the number of equivalent electrons occupying the atomic orbital. Because *X* has five PES peaks we know it 1*s*, 2*s*, 2*p*, 3*s*, and 3*p* electrons. The 10 electrons in the 1*s*, 2*s*, and 2*p* orbitals are core electrons that screen the valence electrons from "seeing" the full nuclear charge. The element's atomic number, *Z*, is the sum of the core charge as "seen" by the valence electrons and the number of valence electrons; in this case the atomic number is 17 and *X* is chlorine.

   (b) How many valence electrons does the element have? Chlorine has seven valence electrons.

   (c) Element *Y* has one more proton than *X*. Is the AVEE for *Y* larger than, smaller than, or the same as the AVEE for *X*? Element *Y* is Ar, which as a valence shell of $3s^2 3p^6$ in contrast to that for chlorine of $3s^2 3p^5$. The AVEE is the average of the ionization energy for an element's valence electrons. Argon has one more proton than does chlorine, which increases the ionization energies of both the 3*s* and the 3*p* electrons; thus, argon has the greater AVEE.

   (d) Element *Z* has the same core charge as *X*, but its first ionization energy is larger. What can you conclude about the identity of *Z*? Elements with the same core charge are in the same column, so *Z* is F, Cl, Br, I, or At. Ionization energies decrease down a column as the valence electrons are further from the nucleus and, according to Coulomb's law, the ionization energy is inversely proportional to the distance between the electron and the nucleus. We know that *Z*'s first ionization energy is greater than that for chlorine; thus, *Z* is fluorine.

2. The elements *X*, *Y*, and *Z* have the following electron configurations:

   X: $1s^2 2s^2 2p^6 3s^2 3p^6$ *Y*: $1s^2 2s^2 2p^6 3s^2$ *Z*: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

   The first ionization energies of the elements (in MJ/mol, and in no particular order) are 0.4188, 0.4958, and 1.5205. The covalent radii of the elements (in nm, and in no particular order) are 0.157, 0.094, and 0.202. Identify each element and match it to the appropriate ionization energy and covalent radius. Which, if any, of the elements is (are) paramagnetic? Based on their electron configurations, the elements are argon (*X*), magnesium (*Y*), and potassium (*Z*). Of the three, potassium has largest covalent radius and the smallest first ionization energy because its valence shell is furthest from the nucleus, and argon has the smallest covalent radius and the largest first ionization energy because, in comparison to magnesium, it has the greatest core charge. Of the three elements, potassium is the only one that is paramagnetic as it has an unpaired electron in its 4*s* orbital.

3. The first four ionization energies for an element are (in MJ/mol) 0.899, 1.757, 14.848, and 21.006. How many valence electrons does this element have? The large increase from IE_2 to IE_3 occurs as we move from the valence shell to core electrons; thus, the element has two valence electrons.