Final Exam Review Problems

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

   number of photoelectron spectroscopy peaks: 5
   covalent radius of neutral atom: 0.099 nm
   first ionization energy: 1.251 MJ/mol
   average valence electron energy: 1.59
   core charge: +7

   Identify the element and explain your reasoning. Having 5 PES peaks means that the element has 1s, 2s, 2p, 3s, and 3p electrons. The element has 10 core electrons, so the core charge of +7 means that it must have 17 protons; thus, the element is Cl.

   How many valence electrons does the element have? Chlorine has 7 valence electrons.

   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 with a valence shell of $3s^2 3p^6$ in contrast to that for Cl of $3s^2 3p^5$. The AVEE is the average of the ionization energy for each valence electron. Since ionization energies increase across a row, due to the increase in core charge, the AVEE also increases across a row; thus, the AVEE for Ar is greater than that for Cl.

   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*? Having the same core charge means that *Z* is in the same group as *X*. A larger first ionization energy means that *Z*'s valence electrons are closer to the nucleus; 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. The elements are Ar (*X*), Mg (*Y*), and K (*Z*). Of the three, K has the largest covalent radius and the smallest first ionization energy because it's valence shell is furthest from the nucleus, and Ar has the smallest covalent radius and the largest first ionization energy because, in comparison to Mg, it has the greatest core charge.

   Which, if any, of the elements is (are) paramagnetic? Potassium is the only one of the three elements that is paramagnetic as it has an unpaired electron.

3. The first four ionization energies for an element are (in MJ/mol):

   0.899 1.757 14.848 21.006

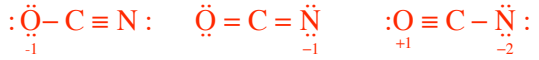
   How many valence electrons does this element have? The big jump from the second to the third ionization energies suggests that this element has two valence electrons.

4. The compound XO_2 has a bent geometry, a double bond to one oxygen and a single bond to the other oxygen, and a single lone-pair of electrons on *X*. Limiting yourself to the first 18 elements, identify the possible choices for *X*. The Lewis structure for the compound is displayed to the right and shows that there are 18 total valence electrons. Each of the two oxygens supplies six valence electrons, for a total of 12, leaving six valence electrons for *X*. Of the first 18 elements, both oxygen and sulfur are possible choices.

5. Suggest a possible element for *X* in the compound XF_4^- if there are two lone-pairs of electrons on *X*. For *X* to be bound to four fluorines and to have two lone pairs, it must have a square planar bonding geometry and an octahedral electron domain geometry. Each of the fluorines has three lone-pairs of electrons and a single bond to *X*, or a total of 4×8 or 32 electrons. Including the two lone-pairs on *X* increases the total number of valence electrons to 36. Each fluorine brings in seven valence electrons, for a total of 28. This leaves eight valence electrons unaccounted for, of which one is for the anionic charge. Element *X*, therefore, has seven valence electrons. Possible elements are Cl, Br, I, and At, but not F since it cannot expand beyond an octet.

6. Consider the polyatomic anion OCN^-.

   Draw all possible Lewis structures for this anion and give the formal charge on each atom in each structure. There are 16 valence electrons in this polyatomic anion and three possible Lewis structures, as shown below (with formal charges below the elements).



   Rank the structures from best to worst and explain your reasoning? The best of these structures is the one on the left as it places the formal charge on the most electronegative element. For several reasons, the worst of these structures is the one on the right: it has more elements with formal charges; it separates positive and negative formal charges; and, it has a positive formal charge on the most electronegative element.

7. Draw the best Lewis structure for each of the following compounds and circle the compound that will have the larger dipole moment. The Lewis structures for these compounds are shown below.

$$\ddot{S} = C = \ddot{S} \qquad \ddot{O} = \ddot{S} = \ddot{O}$$

CS_2 has a linear geometry and is, therefore, non-polar with no dipole moment. On the other hand, SO_2 has a bent geometry, and is polar and has a dipole moment.

8. An area of active research in inorganic chemistry is the synthesis of compounds containing metal-metal bonds. For example, the ions

$$Re_2Cl_8^{2-} \qquad Cr_2Cl_9^{3-} \qquad Mo_2Cl_8^{4-}$$

each contain a metal-metal bond. What are oxidation states of the metals in each? The sum of the oxidation states for the elements must equal the charge on the anion. In each anion, the chlorines have oxidation states of -1. For $Re_2Cl_8^{2-}$, this means that the chlorines provide a net charge of -8 and the two rheniums must supply a net charge of +6; thus, each rhenium has an oxidation state of +3. The same process gives the chromiums as +3 and the molybdenums as +2.

9. Consider the following compounds: HgO, ZrO, SrO, and SeO_2. Which of these compounds is likely to have the highest melting point? Explain your reasoning. SeO_2 is a covalent species (two non-metals) and will have the smallest melting point. The other three compounds are ionic and the simplest way to evaluate the relative melting points for ionic compounds is to consider Coulomb's law, which states that the force of attraction between the ions is directly proportional to their charges and inversely proportional to the distance between the ions. Since the charges of the ions are the same in each case, and since each has the same anion, it is the size of the cation that is the determining factor. Of the three cations, Zr^{2+} is the smallest; thus, ZrO has the highest melting point.

10. Consider the reaction

$$4NaCl + 2H_2SO_4 + MnO_2 \rightarrow Na_2SO_4 + MnCl_2 + 2H_2O + Cl_2$$

Is this an oxidation-reduction reaction and, if so, what is being oxidized and what is being reduced? Yes, it is an oxidation-reduction reaction. Manganese is being reduced from an oxidation state of +4 in MnO_2 to +2 in $MnCl_2$. Chlorine is being oxidized from -1 in NaCl to 0 in Cl_2.

Is this an acid-base reaction and, if so, what is the acid and what is the base? Yes. Sulfuric acid, H_2SO_4, is an acid and is donating protons to oxide anions, O^{2-}, which is a base. Note: the oxide actually becomes OH^-, which then picks up an H^+ to become H_2O.