Chem 115 POGIL Worksheet - Week 10 - Solutions
Periodic Trends

Key Questions

1. Using only a periodic table, predict the order of increasing atomic radius for each of the following sets of elements:

Ca, Mg, Be	**Be < Mg < Ca**	Ga, Br, Ge	**Br < Ge < Ga**
Al, Tl, Si	**Si < Al < Tl**	Zn, Cd, Fe	**Fe < Zn < Cd**

2. The experimentally determined Bi–Cl bond distance in bismuth trichloride is 2.48 Å. Given the tabulated value of 0.99 Å for the atomic radius of Cl, predict the atomic radius of Bi. If the experimentally determined Bi–I distance in bismuth triiodide is 2.81 Å, predict the atomic radius of I. How well does your calculated value agree with the tabulated value for iodine in Fig. 7.7 in your book?

   From $BiCl_3$, $r_{Bi} = d_{Bi–Cl} - r_{Cl} = 2.48$ Å $- 0.99$ Å $= 1.49$ Å

   From BiI_3, $r_I = d_{Bi–I} - r_{Bi} = 2.81$ Å $- 1.49$ Å $= 1.32$ Å

   The tabulated value for r_I in Fig. 7.7 is 1.33 Å, so our calculated value is very good.

3. For each of the following sets of atoms and ions, arrange the members in order of increasing size.

Se^{2-}, Te^{2-}, Se	**$Se < Se^{2-} < Te^{2-}$**	Co^{3+}, Fe^{2+}, Fe^{3+}	**$Co^{3+} < Fe^{3+} < Fe^{2+}$**
Ca, Ti^{4+}, Sc^{3+}	**$Ti^{4+} < Sc^{3+} < Ca$**	S^{2-}, Se^{2-}, Ar	**$Ar < S^{2-} < Se^{2-}$**

4. Based on position in the periodic table, which element of the following pairs has the higher first ionization energy?

   O, **Ne**   **Ca**, Sr   K, **Cr**   **Br**, Sb   In, **Sn**

5. First ionization energies tend to increase across a period. But in period 2, Be has a higher first ionization energy than B, and N has a higher first ionization energy than O. Explain, [Hint: Look at the valence configurations, and recall that half-filled and fully filled subshells have extra stability.]

   Compare the valence configurations of the atoms and the ions formed by removing one electron, as shown in the following table:

Element	X	X^+
Be	$2s^2$	$2s^1$
B	$2s^2 2p^1$	$2s^2$
N	$2s^2 2p^3$	$2s^2 2p^2$
O	$2s^2 2p^4$	$2s^2 2p^3$

Be has a stable closed subshell configuration, which is disrupted by losing an electron. By contrast, B can achieve a fully-filled subshell configuration by losing the lone electron in the $2p$ subshell. This makes ionization of Be a little higher than usual, and ionization of B a little lower than usual. This causes the reversal of trend (the "jog" in the plot) across these two elements. A similar thing occurs between N and O. N has a stable half-filled $2p$ subshell, and O can achieve a stable half-filled subshell by losing an electron. Thus, the ionization energy of N is higher than O, resulting in a "jog" in the plot of ionization energies across these two elements.

6. On the basis of electronic configurations or any other appropriate considerations, explain the differences in the electron affinities of the following pairs of species.

Na, $A_1 < 0$; Mg, $A_1 > 0$	N, $A_1 > 0$; O, $A_1 < 0$
Br, $A_1 << 0$; Kr, $A_1 > 0$	O, $A_1 < 0$; O^-, $A_2 > 0$

Na, $A_1 < 0$; Mg, $A_1 > 0$	Adding an electron to Na results in a stable closed-subshell $3s^2$ configuration, but with Mg it goes beyond this to $3p^1$, which has no special stability.
N, $A_1 > 0$; O, $A_1 < 0$	The additional electron disrupts the stable $2p^3$ half-fill subshell configuration of N. The $2p^4$ configuration of O has no special stability, but the higher nuclear charge of O makes acquiring the extra electron favorable.
Br, $A_1 << 0$; Kr, $A_1 > 0$	When Br acquires an electron it completes its $4p$ subshell, resulting in a stable $4s^2 4p^6$ closed-subshell configuration. Kr already has that configuration, and an extra electron must be added to the next shell, resulting in the configuration $5s^1$.
O, $A_1 < 0$; O^-, $A_2 > 0$	The first electron affinity of oxygen is negative because of the small size and relatively high nuclear charge. Once O^- is formed, the next electron must overcome charge repulsions to be added, which makes the second electron affinity unfavorable and positive.

7. Calcium is generally less reactive than potassium but more reactive than magnesium. Explain.

   Potassium has a lower ionization energy, and only a single electron loss is needed to make its stable ion, K^+. Calcium must lose two electron to form its stable ion, Ca^{2+}, and the energy cost of the two ionizations is vastly greater than the single ionization of potassium. The two ionizations of magnesium to form Mg^{2+} are even higher, because magnesium is smaller than calcium. Therefore, magnesium is the least reactive of the three.

8. For each of the following oxides, indicate whether it is ionic or molecular and whether it is acidic or basic. Then, write a balanced equation for the reaction expected between each oxide and water.

$$SO_2(g),\ CaO(s),\ Li_2O(s),\ SeO_3(s),\ P_4O_6(s)$$

   $SO_2(g)$ – molecular, acidic

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$

   $CaO(s)$ – ionic, basic

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$$

   $Li_2O(s)$ – ionic, basic

$$Li_2O(s) + H_2O(l) \rightarrow 2\ LiOH(aq)$$

   $SeO_3(s)$ – molecular, acidic

$$SeO_3(s) + H_2O(l) \rightarrow H_2SeO_4(aq)$$

   $P_4O_6(s)$ – molecular, acidic

$$P_4O_6(aq) + 6\ H_2O(l) \rightarrow 4\ H_3PO_3(aq)$$