Learning Objectives and Worksheet IV

Chemistry 1B-AL Fall 2016

~~Lectures~~ (7-8) Periodic Properties of Atoms and ions

Read pp. 571-582 and 606-609 *[ionic radii]*

Supplementary video: The Electron: Crash Course Chemistry

Link: http://youtu.be/rcKilE9CdaA

In 1869 Dmitri Mendeleev published *The Dependence between the Properties of the Atomic Weights of the Elements* which was the basis of the modern Periodic Table. One of the beautiful aspects of the theory of atomic structure is that it enables one to understand, and thus predict, a great number observable chemical properties of the elements based on the concepts of the Aufbau Principle and effective nuclear charge.

I. General Periodic Trends

1. Atomic 'energies' and atomic 'size' are two important quantities in understanding the properties of atoms. Two relationships (taken from Bohr's treatment of the H atom) are:

   gas phase energy of electron with n, Z_{eff}: $E \approx -\left(2.18\times10^{-18}\ \text{J}\right)\frac{Z_{eff}^{\ 2}}{n^2}$ and

   "Bohr" radius in gas phase $r \approx (0.529\times10^{-10}\text{m})\ \frac{n^2}{Z_{eff}}$

   i. As n get higher the energy _____.

   ii. As Z_{eff} becomes larger (more positive) the energy _____.

   iii. An n gets larger the radius _____.

   iv. As Z_{eff} becomes larger (more positive) the radius _____.

2. An understanding of how n and Z_{eff} change as one adds protons and electrons s crucial. For **the electrons in the 'outermost' shell**:

   i. As one goes across a given row of the periodic table adding protons and electrons (i.e. as atomic number increases in neutral atoms) how does:

      n change _____

      Z_{eff} change _____

   ii. As one goes down a given column of the periodic table adding protons and electrons (i.e. as atomic number increases in neutral atoms) how does:

      n change _____

      Z_{eff} change _____

iii. From part i above. Why does Z_{eff} _____ for successive elements going across a given row of the periodic table?

iv. From part ii above: Why is Z_{eff} _____ for successive elements going down a column of the periodic table?

Additional resource on trends in properties and periodicity:
http://chemistry.about.com/od/periodictableelements/a/periodictrends.htm

3. How do n and Z_{eff} for an ion compare to those for the neutral atom:

i. Consider an anion where electrons have been added to attain a complete shell octet, e.g. O^{2-} from O.
How will n for the outer shell electrons in O^{2-} compare to that of the outer shells electrons in O ? n for O^{2-} _____ n for O
How will Z_{eff} for for the outer shell electrons in O^{2-} compare to Z_{eff} for the outer shell electrons in O ? Z_{eff} for O^{2-} _____ Z_{eff} for O

ii. Consider a cation where electrons have been removed to attain a complete shell octet, e.g. Na^+ from Na.
How will n for the outer shell electrons in Na^+ compare to that of the outer shells electrons in Na ? n for Na^+ _____ n for Na^-
How will Z_{eff} for for the outer shell electrons in Na^+ compare to Z_{eff} for the outer shell electrons in Na ? Z_{eff} for Na^+ _____ Z_{eff} for Na^-

II. Atomic radii

Given the relationships between the variation of n and Z_{eff} for the outer electrons of the elements in the periodic table one can generalized:

HW#3: **28, 30**

1. As one goes across a row of the periodic table the size (radius) of the atoms becomes _____ due to increasing _____.
2. As one goes down a column of the periodic table the size (radius) of the atoms becomes _____ due to increasing _____.
3. In general the radius of a negative ion (anion) will be _____ than that of its parent neutral atom.
4. In general the radius of a positive ion (cation) will be _____ than that of its parent neutral atom.

III. Ionization energies and electron affinities

1. The ionization energy (IE) is the energy need to _____ an electron from an atom or ion. Thus the IE is the _____ of the energy of the electron that is being removed and the lower the energy of the bound electron (i.e. the _____ it is held in the atom) the _____ is the IE.

2. applying the relationship: $IE = -E_{n,Zeff} \approx +\left(2.18\times10^{-18}\ J\right)\frac{Z_{eff}^{\ 2}}{n^2}$
   i. As one goes across a row of the periodic table the IE's of the atoms _____ due to increasing _____.
   ii. As one goes down a row of the periodic table the IE's of the atoms _____ due to increasing _____.

3. The electron affinity (EA) is the energy of the reaction where an atom or ion adds an electron. If the reaction is exothermic, i.e. the ion is more stable (lower energy) than the [atom + electron], the EA has a _____ sign. If the reaction is endothermic, i.e. the ion is less stable than the [atom + electron], the EA has a _____ sign.

HW#3: **29, 31, 32, S6, S7**

4. Periodic trends in EA
   i. As one goes across a row of the periodic table the magnitude of the EA's of the atoms _____ i.e. they become _____ negative.
   ii. As one goes down a row of the periodic table the magnitude of the EA's of the atoms _____ i.e. they become _____ negative.

5. Apparent exceptions:
    i. Understand why IE (N) > IE (O) even though O is in column 6 (6A) and N is in column 5 (5A). Understand why IE (N) > IE (O) even though O is in column 6 (6A) and N is in column 5 (5A).
    ii. Understand why IE (Be) > IE (B) even though Be is in column 3 (3A) and Be is in column 2 (2A).

6. Successive Ionization energies
    i. In general the second IE ($M^+ \rightarrow M^{2+} + e^-$) is _____ than the IE ($M \rightarrow M^+ + e^-$) since _____ is greater for M^+ than for M.

IV. General Categorization of the elements (metals vs nonmetals)

1. Metals
    i. Metallic elements are found on the _____ side of the periodic table.
    ii. They generally have relatively _____ ionization energies.
    iii. The generally have _____ negative or even _____ electron affinities.
    iv. Metallic elements will generally form _____ charged ions.
    v. Metallic elements are _____ conductors of heat and electricity,
2. Nonmetals
    i. nonmetallic elements are found on the _____ side of the periodic table.
    ii. They generally have relatively _____ ionization energies.
    iii. The generally have _____ negative electron affinities than do metallic elements.
    iv. nonmetallic elements will generally form _____ charged ions.
    v. nonmetallic elements are _____ conductors of heat and electricity,

Periodic table links: www.webelements.com

http://Environmentalchemistry.com/yogi/periodic/

http://www.uky.edu/projects/chemcomics