1 Morning class week 4 day 2: Periodic trends

These sheets will allow you to explore three important periodic trends. Periodic trends are the ways in which elements behave differently from one another based on their location in the periodic table.

1.1 Ionization energies

1. We use our understanding of effective nuclear charge and atomic orbitals to deduce periodic trends for ionization energies. Please take five to ten minutes to examine the pictures from the relevant sections of your textbook, Sections 4-1 and 4-2.

   (a) Compare Li $2s$ electrons vs. Be $2s$ electrons. Which of the two electrons is lower in energy?

   (b) Which of these two electrons has a higher ionization energy?

   (c) Review the effective nuclear charges of the $2p$ orbitals in elements B through Ne. Which of these elements has the lowest energy $2p$ electron?

   (d) Rank from lowest to highest, the ionization energies of these elements.

   (e) Examine the graph given below. The horizontal axis on this graph is the atomic number while the vertical axis is the ionization energies of the different elements. Are your results in the previous two questions in general agreement with the results shown in the graph?

   (f) For the series Li-Ne, what trends in ionization energies have you accounted for, and what trends have you not accounted for?

   (g) Review your answers for the effective nuclear charges for the elements Na through Ar. Rank the ionization energies of these elements from lowest to highest. Verify that your answers agree with the information in the graph above.

   (h) The Li outermost electron is in a $2s$ orbital, while the H outermost electron is in a $1s$ orbital. Li has a slightly greater effective nuclear charge. Assume that Li has the same effective nuclear charge as H. In Figure 8-36, the relative energies of these two orbitals are given. Which of these two orbitals has lower energy?

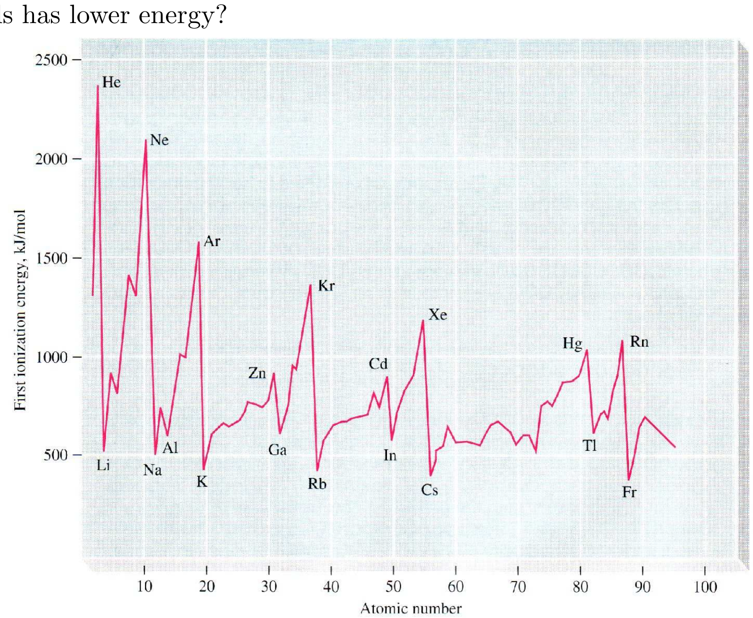


Figure 1: Ionization energies of the elements

(i) Examine Figure 8-35. Is the outermost electron in Li or H on-the-average closest to the nucleus?

(j) Based on Coulomb's Law, deduce whether the outermost electron in Li or H has the most negative electrostatic energy. Using the virial theorem deduce whether the outermost electron in Li or H has the lowest total energy?

(k) In exactly the same manner, rank the ionization energies of all the elements in the first column of the periodic table. These elements, H, Li, Na, K, Rb, and Cs, are the alkali metals.

(l) Examine the graph showing the ionization energies of the elements. Explain why the the ionization energies increase from K to Zn, Rb to Cd, Ga to Kr, and In to Xe.

(m) Memorize the following two facts: (1) ionization energies increase as one travels from left to right in a row of the periodic table, and (2) ionization energies decrease in going down a column of the periodic table. Review in your mind the rationalizations for these periodic trends.

1.2 Atomic size

2. We use our understanding of effective nuclear charge and atomic orbitals to deduce periodic trends for atomic and ionic size. Please take five to ten minutes to examine the pictures from the relevant sections of your textbook, Sections 5-12 and 6-6.

   (a) As the effective nuclear charge increases on an orbital, the orbital becomes smaller. Based on this fact, deduce the trends in the size of the $2p$ orbital in going from B to Ne. Similarly, deduce the trends in size of the $3d$ orbital in going from Sc to Ni, and the $4p$ orbital in going from Ga to Kr.

   (b) The size of an atom is determined by the size of its outermost filled orbital. Deduce the trends in atomic size in going from B to Ne, Sc to Zn, and Ga to Kr. Sizes of atoms are reported in terms of *atomic radii*. Compare these trends with the actual atomic sizes shown in the graph of atomic radii below. Do your deductions correspond to the data?

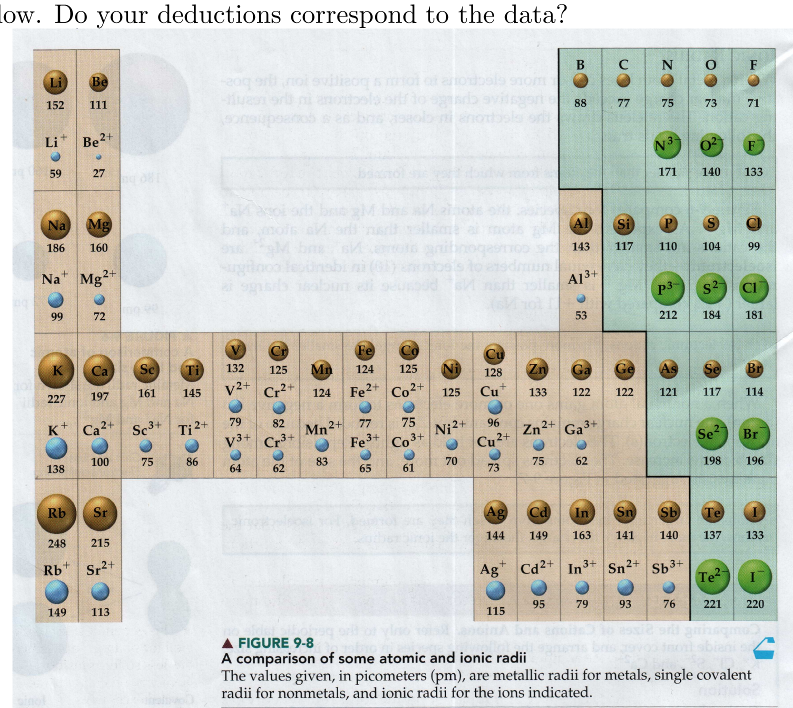


Figure 2: Atomic radii of the elements as ions

(c) Also presented in the atomic radii graph are the ionic radii. The atomic radius of P is 110 pm, while the ionic radius of P^{3-} is 212 pm. For the main group elements, compare the ionic radii with their corresponding atomic radii. Is there a general trend? What is this trend? Can you use the concept of estimated effective nuclear charge to account for this variation?

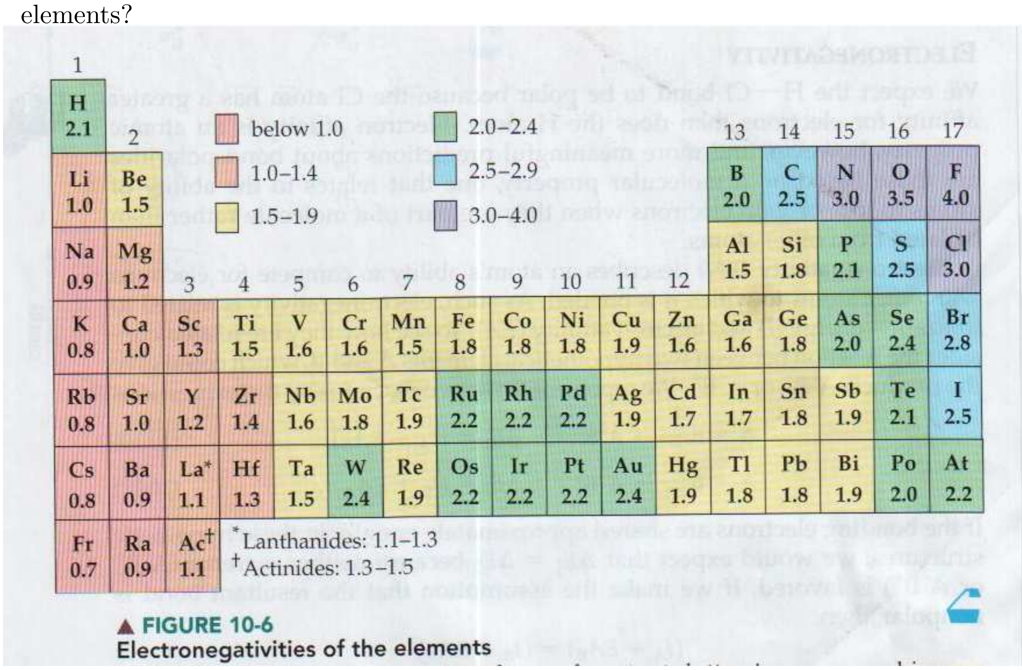
(d) In addition to anionic radii (anions are negatively charged ions), the figure presents cationic radii (cations are positively charged ions). Compare cationic radii with their corresponding atomic radii. What trend do you observe? Account for this trend using the concept of estimated effective nuclear charge.

(e) Memorize the following facts: (1) elements become smaller as one travels to the right in a row of the periodic table, (2) elements become bigger as one goes down a column of the periodic table, (3) anions are larger than their corresponding neutral element, and (4) cations are smaller than their corresponding neutral element. Review in your mind the rationalizations for these periodic trends.

1.3 Electronegativity

3. We use our understanding of effective nuclear charge and atomic orbitals to deduce periodic trends embraced in the electronegativity scale. Please take five to ten minutes to examine the pictures from the relevant section of your textbook, Section 7-9.

(a) The Pauling electronegativity scale gives a rough measure of the degree to which an element can attract and retain electrons. Elements which readily retain and attract electrons have a high electronegativity value; conversely elements which can not easily retain or attract electrons have a low electronegativity value. Examine the electronegativity scale given below. Which column of the periodic has the most electronegative elements? Which column has the least electronegative elements?



▲ FIGURE 10-6
Electronegativities of the elements

Figure 3: The Pauling electronegativities of the elements

(b) The simplest measure of the ability to retain electrons is the ionization energy. Which column of the periodic table has the lowest ionization energies? Excluding the noble gases, which column has the highest ionization energies? Can ionization energies be used to account for the electronegativity scale?

(c) The main group is comprised of columns 1-2 and 13-18 of the periodic table. Which main group element has the highest electronegativity? Which main group element has the lowest electronegativity?

(d) Memorize the following periodic trend: the closer a *main group* element is to F in the periodic table, the more electronegative it is.

4. Please review all the trends which you have been asked to memorize in this problem set.

5. Please review the rationalizations for all the trends you have been asked to memorize in this problem set.