

NAME _____

SECTION _____

PARTNER(S) _____

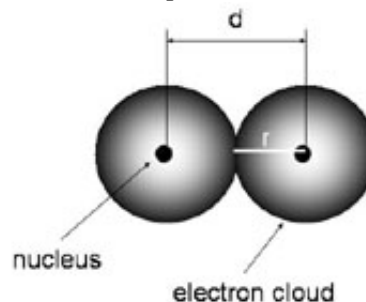
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DISCOVERING PERIODIC TRENDS: A GRAPHICAL APPROACH

This activity investigates the trends in a series of atomic properties by analyzing data plotted using a spreadsheet program.

I. Atomic Size

If you could see a single atom, the sum of the overlapping orbitals would result in an overall spherical shape. It is very difficult to say where the outer edge of the atom is as the orbitals are *probable* areas where electrons may be found and the distance from the center of the nucleus to the edge will depend on whether there is anything in the environment of the atom that is attracting the negative cloud of electrons or repelling it. Nevertheless, we can think about the ideal situation where there is one isolated atom, and the radius or the distance from the center of the nucleus to the edge is an average distance. Chemists have been able to measure these tiny distances using x-ray diffraction techniques.



1. Write the electron configurations for each of the following atoms. Use this to draw a simple atom diagram for each.

Na

Mg

Al

Ar

K

Ca

Ga

Kr

Which atom do you think has the larger atomic radius, Na or K? Explain why.

Which atom do you think has the larger atomic radius, Na or Ar? Explain why.

Circle your prediction:

As you go down a Group on the Periodic Table, atomic radius:

increases decreases remains the same.

As you go across a Period from left to right on the Periodic Table, atomic radius:

increases decreases remains the same.

2. Let's check out your predictions by plotting the values for atomic radius as a function of atomic number.

Position yourself at a computer designated by the instructor. On the desktop, double-click on the icon named "Atomic Properties" (see note on pg. 96). This will launch Excel and bring up a spreadsheet with data on atomic properties. Plot atomic number and atomic radius as a **connected scatter plot (not smoothed)**. Save the resulting chart as a **new sheet**. If you are unfamiliar with Excel, ask the instructor for a set of directions.

3. Locate the beginning of each period on the plot to assist you in the questions below.

Were your predictions correct? Explain

Looking at the plot how would you describe the variation of atomic radius:

across a period?

down a group?

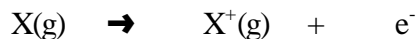
4. Without consulting a textbook, attempt an explanation for the variation in atomic radius:

down a group

across a period

II. Ionization Energy (Ionization Potential)

Electrons are attracted to the nucleus due to opposite charges; hence, energy is required to remove an electron from an atom. The **ionization energy**, IE, is a measure of the energy for the following process:



IE₁ is the designation for the first ionization energy (energy to remove the first electron).

Is this an endothermic or exothermic process? Explain.

For hydrogen:

$$IE_1 = 2.18 \times 10^{-18} \text{ J/atom or } 1.31 \text{ MJ/mole} \quad \text{where MJ} = 10^6 \text{ J}$$

Verify the conversion from J/atom to MJ/mole. Show your calculations.

In the spreadsheet, locate the first ionization energies, IE (in units of MJ/mole). The valence electrons or outermost electrons are removed first. Looking at the data for the first twenty elements (all Group A elements), find the element with:

easiest electron to remove _____ hardest electron to remove _____

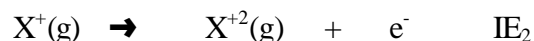
1. In Excel, generate a **connected scatter plot** of IE₁ as a function of atomic number. Save the graph as a **new sheet**.
2. Locate the points that represent the beginning of a new period. Describe the **general** variation of first ionization energy:
across a period

down a group

Locate the B Group elements (transition elements) on the graph. The B Group elements have

partially filled d orbitals. Even though electrons go into a 4s orbital before the 3d, the first electron removed from the transition elements is a 4s electron. How do the first ionization energies for the Group B elements compare to each other? To the Group A elements?

Successive electrons can be removed from an ion. The second ionization energy, IE_2 would be given by:



3. For the second ionization energy which of the following relationships would hold? Circle your choice and explain why.

$$IE_2 < IE_1$$

$$IE_2 = IE_1$$

$$IE_2 > IE_1$$

In the Excel spreadsheet, plot the first and second ionization energies as a function of atomic number. Use the **connected scatter plot** and save as a **new sheet**.

In general, what can you say about the values of IE_2 compared to IE_1 for each element?

How do the graphs of IE_1 vs atomic number and IE_2 vs atomic number compare to each other? Where are the peaks in each?

4. Now, how are atomic radius and first ionization energy related? Explain. Generate an **unconnected scatter plot** of these two variables in Excel to assist you.
5. Consider the ionization energy for each successive electron on an atom. You know the IE increases as the number of electrons removed increases; however, does it follow a pattern?

How do you think the ionization changes as you remove electrons closer and closer to the nucleus? Why?

Let's check out your prediction. Launch an Internet browser such as Internet Explorer and go to the following address: www.webelements.com. Select the element aluminum and when the aluminum page appears, select ionization energies from the left menu. Scanning down the page you will locate a graph of the ionization energy of all aluminum electrons as a function of ionization number (# of the electron removed).

Explain the pattern.

6. Record the energy required to remove the $1s^1$ (core) electron. _____

Go to the calcium page and record the value to remove the $1s^1$ electron. _____

Obtain the same data for chlorine. _____

Why does the energy to remove the core electron change? Would this be true for the $2s^1$ or $3d^3$ electron on any atom?

How does this difference in energies relate to the unique atomic spectrum for each element?

III. Ionic Radius

Ions are formed by gaining or losing electrons and the resulting radius is called the ionic radius. Consider the electron configuration for the atom and the resulting ion. How would the ionic radius change compared to the atomic radius for the following transitions? Explain.

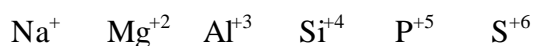
atom to anion

atom to cation

Nitrogen can occur in a variety of oxidation states. Rank these ions in various oxidation states from highest to lowest radius and explain your answer:



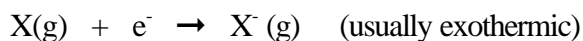
How would the ionic radius of the following ions compare?



Which ion is larger? Fe^{+2} Fe^{+3} Explain your choice.

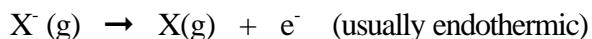
IV. Electron Affinity

Electron affinity (EA) is usually defined as the energy released for the addition of an electron to a neutral atom as shown by the reaction below:



While removing an electron is always an endothermic process, adding an electron may be endothermic or exothermic. Why do you think this is true?

If the above reaction is reversed, then the energy for the process is the energy required to remove an electron from an ion, a definition that resembles the ionization energy.



Because we are removing an electron to make a neutral atom this reaction might be said to describe the **ionization energy**.

1. On the spreadsheet you will find a column of data with the electron affinities for the first 20 elements calculated as if they were ionization energies. Plot the electron affinities as a function of atomic number using a connected scatter plot (not smoothed).

What does a positive value tell you about the energy exchange in the process?

List three elements that would prefer to lose electrons based on their electron affinities.

In general, how does electron affinity change as you go:

down a group

across a period

2. How does the amount of energy required to remove an electron from an ion compare to removal from a neutral atom? Explain the reason for the difference.

V. Electronegativity

Electronegativity (EN) is the attraction of the nucleus for the valence electrons or outermost electrons on an atom, or for the pair of electrons in a bond. In most textbooks it is classically given by the Pauling scale since Pauling was the chemist who defined and first measured this property.

1. Now based on what you know about atomic size and ionization energies, how would EN vary across a period and down a group?
2. Check your predictions by going to any element on the WebElements site (www.webelements.com) and selecting Electronegativities from the left menu. Scan down the page to find a periodic chart of values. Were you correct?

VI. Summary

Let's summarize the trends you uncovered in this activity. For each of the atomic properties listed in the table below, indicate whether, in general, the property *increases* or *decreases* across or down the Periodic table.

Property	Across the Periodic Table	Down the Periodic Table
Atomic Radius		
Ionization Energy		
Electron Affinity		
Electronegativity		

Sources of data:

- IE data taken from www.webelements.com.
- EA data taken from G.L. Miessler and D.A. Tarr, *Inorganic Chemistry*, 2nd ed., Prentice-Hall (1999).

VII. A Flashback to Spectroscopy

Ions, like neutral atoms, have characteristic spectra that are generated by the transitions of electrons between energy levels. Since ions have different radii compared to their neutral atoms, explain how the spectra of an ion would compare to that of the corresponding neutral atom.

NOTE: The data for this activity, as an Excel file, can be downloaded from: http://academic.pgcc.edu/~bgage/chm_101_activities.htm. Click on "Atomic Properties (Excel)" and save the file to the desktop. You can open it by clicking on the file on the desktop.