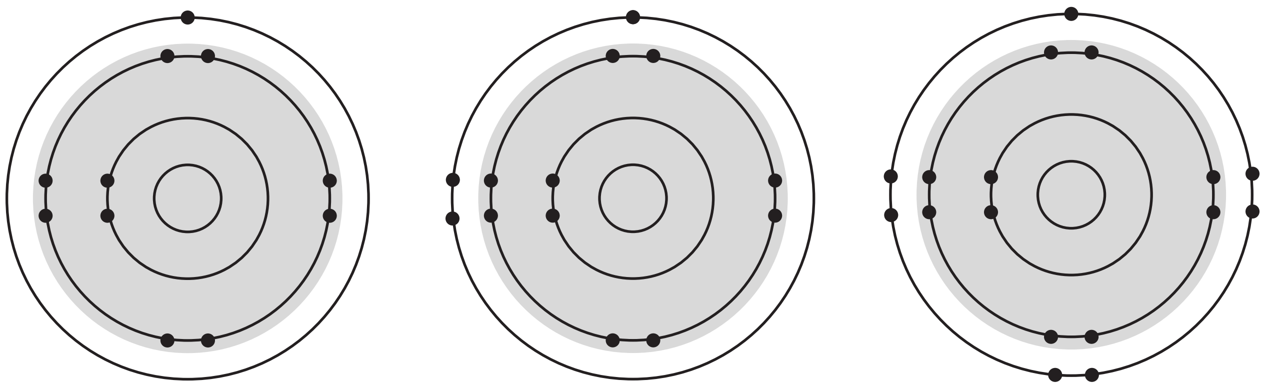
Advanced Periodic Trends

How do the particles in an atom interact to dictate periodic properties of elements?

Why?

Previously you have learned about Coulombic attraction and how it governs the trends in properties among the elements of the Periodic Table. For example, as you move across a period, atoms have more protons in the nucleus, which pulls the electrons in tighter making smaller, more electronegative atoms. As you proceed down a column of the periodic table, the valence electrons get further away, and the atoms get larger and less electronegative. Inquisitive students will always ask, “If more protons in the nucleus pull electrons in tighter, then why don’t atoms get smaller when going down a column?” That is a good question, and one that you will investigate in this activity.

Model 1 – Period 3 Elements



Sodium Aluminum Chlorine

Atomic Number			
Number of Electrons			
Number of Valence Electrons			
Core Charge			
Atomic Radius	186 pm	143 pm	99 pm
1st Ionization Energy	496 kJ/mole	578 kJ/mole	1251 kJ/mole
Electronegativity	0.9	1.5	3.0

1. Describe the relationship of the three elements in Model 1 with regard to their relative positions on the periodic table.

2. Refer to a periodic table to complete the first three rows of the table in Model 1.

3. Consider the charge and location of the protons in an atom.

   a. Indicate on the atomic drawings a total charge provided by the protons in the proper location for each atom.

   b. The number you just added to the diagrams in Model 1 is called the **nuclear charge**. Explain why this is an appropriate name for this value.

4. Circle the valence electron(s) in each of the atoms in Model 1.

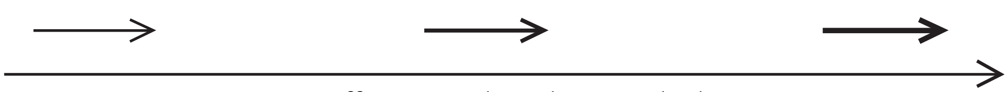
5. In Model 1, the shaded circle in each atom indicates the core of the atom—the nucleus and the nonvalence electrons. Discuss with your group how a **core charge** could be calculated for each of the atoms in Model 1 and write the result in the Model 1 table.

STOP

Read This!

The valence electrons in an atom are influenced not only by the attractive power of the nucleus but also by the repulsive power of neighboring and core electrons. The shielding effect of the core electrons reduces the attractive power of the nucleus. The pulling force that a valence electron actually feels, the **effective nuclear charge (Z*)**, is much less than the nuclear charge because of this **shielding effect** of core electrons. Although the effective nuclear charge is difficult to calculate directly due to complex quantum effects within the atom, it is approximately equal to the core charge of an atom.

6. Use arrows like those below to illustrate the relative strength of the effective nuclear charge on the valence electrons in the atoms of Model 1.



Increasing effective nuclear charge = thicker arrow

7. According to Model 1, what happens to the effective nuclear charge of atoms as you move from left to right on the periodic table?

8. Explain the trend as you move across a row of the periodic table for each of the following atomic properties using your understanding of effective nuclear charge.

   a. Atomic radius

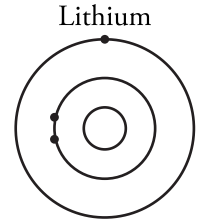
   b. Ionization energy

   c. Electronegativity

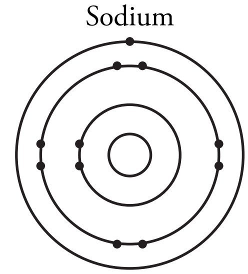
Model 2 – The Alkali Metals

	Atomic Number	Core Charge	Atomic Radius	1st Ionization Energy	Electro-negativity
Lithium			152 pm	520 kJ/mole	0.91
Sodium			186 pm	496 kJ/mole	0.87
Potassium			227 pm	419 kJ/mole	0.73

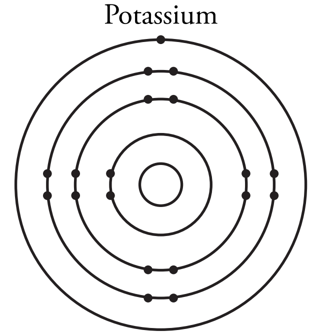
Lithium



Sodium



Potassium



9. Describe the relationship of the three elements in Model 2 with regards to their relative positions on the periodic table.

10. Draw a circle and lightly shade the area representing the core of each atom in Model 2.

11. Refer to a periodic table to complete the table in Model 2.

12. According to Model 2, what happens to the effective nuclear charge of atoms as you move from the top to the bottom of a column on the periodic table?

13. Is effective nuclear charge a factor in how periodic properties change within a column of the periodic table? If no, propose another factor that would influence the attractive forces between the nucleus and valence electrons in an atom.

14. Use arrows like those in Model 1 to illustrate the relative strength of attraction between the nucleus and the valence electrons in the atoms of Model 2.

15. Explain the trend as you move down a column of the periodic table for each of the following atomic properties using your understanding of effective nuclear charge and any other factors that might govern periodic trends.

    a. Atomic radius

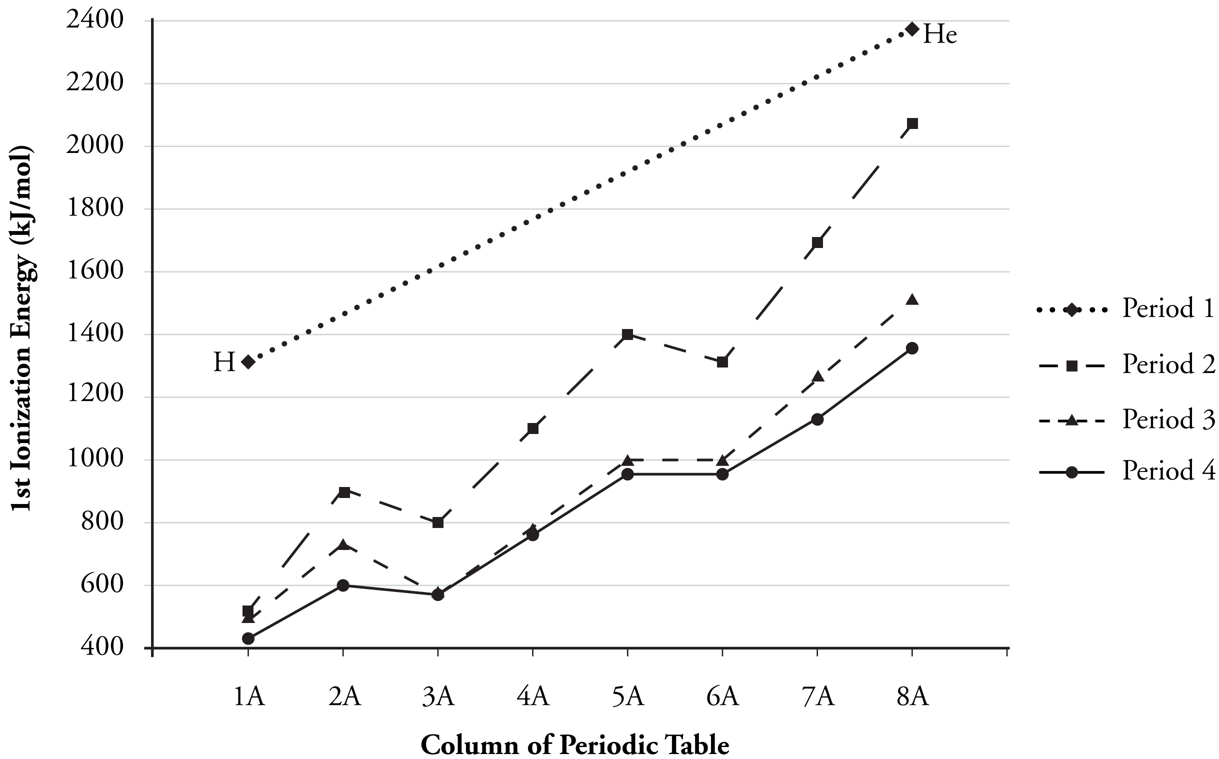
    b. Ionization energy

    c. Electronegativity

16. Answer the question posed in the *Why?* box at the start of this activity: "If more protons in the nucleus pull electrons in tighter, then why don't atoms get smaller when going down a column?"

Extension Questions

Model 3 – Ionization Energies



17. Refer to the graph in Model 3.

    a. What property of atoms does the graph illustrate?

    b. There are four lines on the graph. What do the lines represent?

    c. Two elements, hydrogen and helium, have been labeled on the graph. Label the remaining elements on the graph. You should finish with krypton.

18. How does the graph in Model 3 illustrate the periodic trend for ionization energy as you move across a row of the periodic table?

19. How does the graph in Model 3 illustrate the periodic trend for ionization energy as you move down a column of the periodic table?

20. Are either of the trends you described in Questions 18 and 19 perfect? If not, where are the "blips" or discrepancies in the trends? Do they always occur in the same place?

21. Consider the elements represented in Model 3 and how their discrepancies may relate to electron configuration. At what points would discrepancies occur? Explain.

22. Consider everything you know about the attractive and repulsive forces in the atom and propose an explanation for the discrepancies you see in Model 3.

23. Explain why aluminum and gallium have almost identical 1st ionization energies even though they are in different periods. (Based on the spacing of the other lines, gallium should be much lower.)