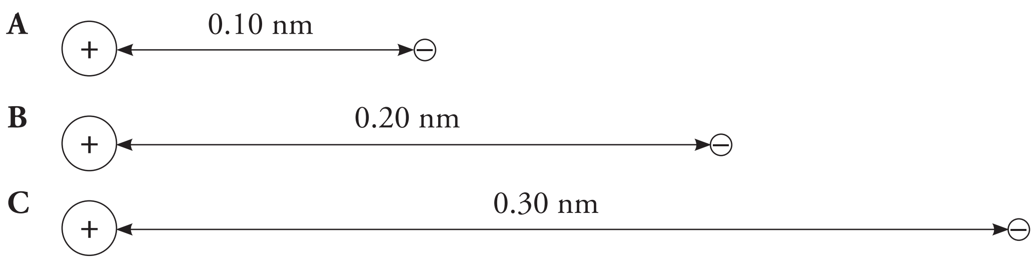
Coulombic Attraction

What variables will affect the force of attraction between charged particles?

Why?

Coulombic attraction is the attraction between oppositely charged particles. For example, the protons in the nucleus of an atom have attraction for the electrons surrounding the nucleus. This is because the protons are positive and the electrons are negative. The attractive force can be weak or strong. In this activity, you will explore the strength of attraction between protons and electrons in various atomic structures.

Model 1 – Distance and Attractive Force



	Force of Attraction (Newtons)
A	2.30×10^{-8}
B	0.58×10^{-8}
C	0.26×10^{-8}

1. What subatomic particles do these symbols represent in Model 1?

   (+) ⊖

   Proton. *Electron.*

2. Would you expect to observe attraction or repulsion between the subatomic particles in Model 1?

   Attraction.

3. Consider the data in Model 1.

   a. What are the independent and dependent variables in the data?

   Independent—distance between particles. Dependent—attractive force.

   b. Write a complete sentence that describes the observed relationship between the independent and dependent variables in Model 1.

   As the distance between the protons and electrons increases, the force of attraction decreases.

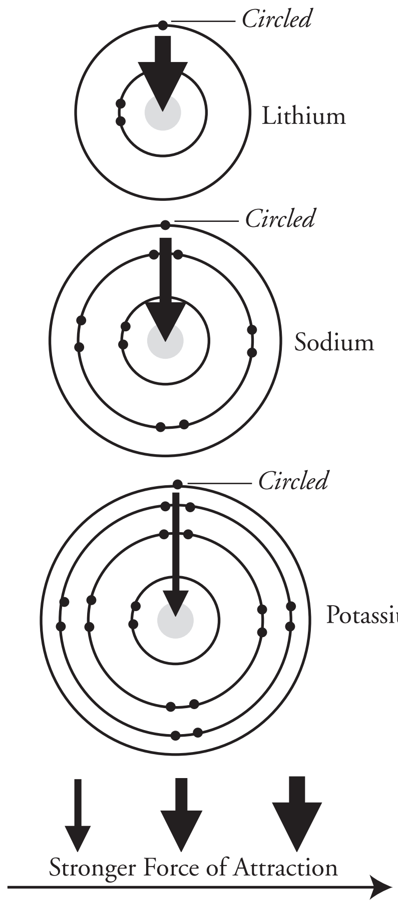
4. If the distance between a proton and electron is 0.50 nm, would you expect the force of attraction to be greater than or less than 0.26×10^{-8} N?

   Less than.

5. If two protons are 0.10 nm away from one electron, would you expect the force of attraction to be greater than or less than 2.30×10^{-8} N?

   Greater than.

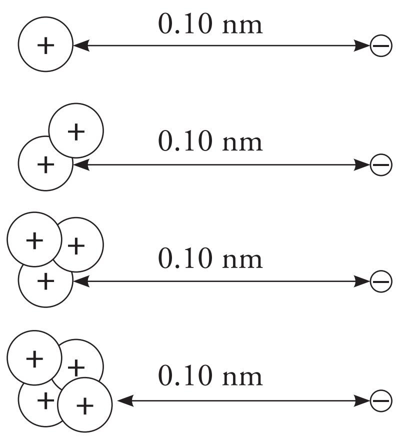
Model 2 – The Alkali Metals



6. Consider the diagrams in Model 2.
   a. What do the arrows represent?
   Attractive force between the protons in the nucleus and the electrons.
   b. How does the thickness of the arrows relate to the property given in part *a*?
   The thicker the arrow, the stronger the attraction.
7. Using a periodic table, locate the elements whose atoms are diagrammed in Model 2. Are the elements in the same column or the same row?
   They are all in the same column or family of the periodic table.
8. Circle the outermost electron in each of the diagrams in Model 2.
   a. As you move from the smallest atom to the largest atom in Model 2, how does the distance between the outermost electron and the nucleus change?
   The outermost electron is further away in the larger atom.
   b. As you move from the smallest atom to the largest atom in Model 2, how does the attractive force between the outermost electron and the nucleus change?
   The attractive force between the electron and the nucleus gets weaker as the atom gets larger.
   c. Are your answers to parts *a* and *b* consistent with the information in Model 1?
   Yes, the attractive force should get weaker as the distance increases.

STOP

Model 3 – Number of Protons and Attractive Force



	Force of Attraction (Newtons)
A	2.30×10^{-8}
D	4.60×10^{-8}
E	6.90×10^{-8}
F	9.20×10^{-8}

9. Consider the data in Model 3.
   a. What are the independent and dependent variables in the data?

   Independent—number of protons. Dependent—attractive force.

   b. Write a complete sentence that describes the relationship between the independent and dependent variables in Model 3.

   As more protons are added, the attractive force on the electron increases.

10. What would be the attractive force on a single electron if five protons were in the nucleus of an atom? Show mathematical work to support your answer.

    $5(2.3 \times 10^{-8}\ N) = 11.5 \times 10^{-8}\ N$

11. Imagine that a second electron were placed to the left of a nucleus containing two protons (Model 3, set D). Predict the force of attraction on both the original electron and the second electron. Explain your prediction with a complete sentence.

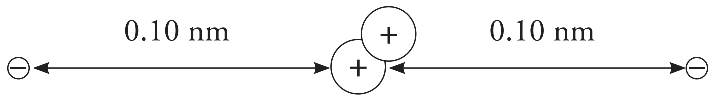
    Answers will vary.

    Some students will predict that the attractive force will be 4.6×10^{-8} N on each electron, explaining that the force will be felt equally by both electrons.

    Others might predict the attractive force will be 2.3×10^{-8} N on each electron, thinking that the same force will essentially be divided in half.

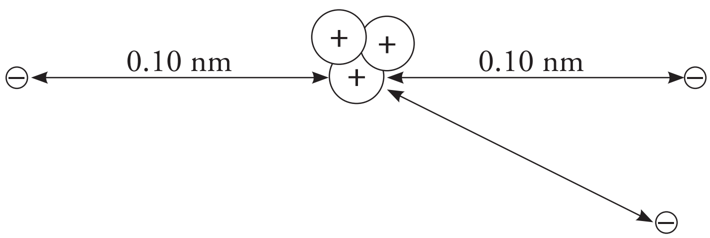
Read This!

The attractive and repulsive forces in an atom are rather complex. An electron is attracted to the protons in the nucleus, but it is also repelled by the other electrons in the atom. It is important to note however that the attractive force of the nucleus is NOT divided up among the electrons in the atom. Each electron gets approximately the full attractive force of the nucleus (minus the repulsive effects of other electrons). Compare the diagram below to set D in Model 3. Notice the similarity in attractive force.



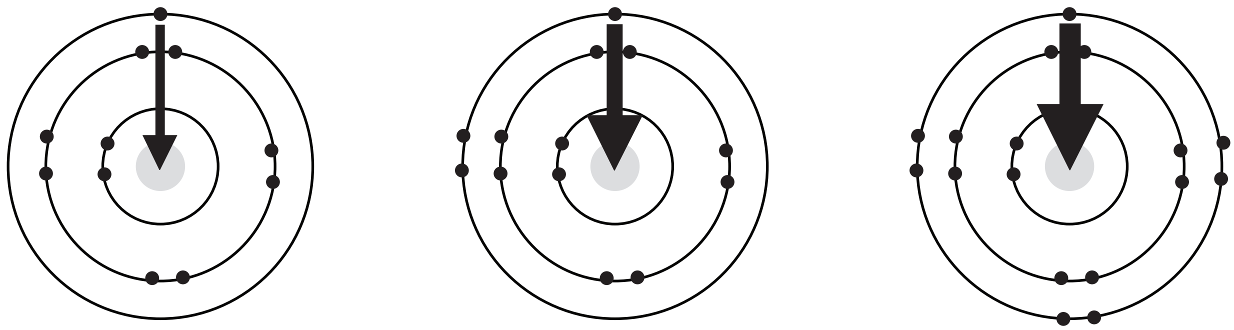
approx. 4.60×10^{-8}
(on each electron)

12. What is the approximate attractive force on each electron below?



Approximately 6.90×10^{-8} N on each electron.

Model 4 – Period 3 Elements



Sodium Aluminum Chlorine

13. Using the periodic table, locate the elements whose atoms are diagrammed in Model 4. Are the elements in the same column or the same row?

    They are all in the same period or row of the periodic table.

14. Circle the outermost electron(s) in each of the atoms in Model 4.

    All of the electrons in the third "shell" should be circled.

15. Which of the three atoms diagrammed in Model 4 has the strongest attraction for its outermost electron(s)?

    Chlorine—it has the thickest arrow.

16. Consider the information in Model 4.

    a. As you move from the smallest atom to the largest atom, does the distance between the outermost electron(s) and the nucleus change significantly?

    The distance does not change significantly.

    b. Can the differences in the attractive force shown by the arrows be explained by a change in the distance between the electron(s) and the nucleus?

    No, distance cannot explain the differences in attraction.

    c. On the diagrams in Model 4, write the number of protons located in the nucleus of each atom.

    Na—11 protons; Al—13 protons; Cl—17 protons

    d. Can the differences in attractive forces shown by the arrows in Model 4 be explained by a change in the number of protons in the nucleus? If yes, explain the relationship in Model 4.

    Yes, as the number of protons in the nucleus increases, the attractive force for the outermost electrons increases.

STOP

17. For each set of elements below, circle the element whose atoms will have a stronger attractive force between their outermost electron(s) and the nucleus.

    a. Ba and Ca *b.* Cr and Cu *c.* Ar and Xe

Extension Questions

18. Consider the atom diagrams in Model 2.

    a. On each diagram write the number of protons in the nucleus of the atom.

    Li – 3 *Na – 11* *K – 19*

    b. When comparing elements in the same column of the periodic table, which factor—distance to the nucleus or number of protons in the nucleus—seems to be the dominant factor for determining the attractive force between the outermost electron(s) and the nucleus? Explain.

    The distance seems to be the dominant factor; otherwise we would see an increase in the attractive force as you move from smaller to larger atoms down a column in the periodic table.

19. Consider the data presented in Models 1 and 3.

    a. Describe the mathematical relationship between the distance (d) and the attractive force (F) between protons and electrons.

    Force is inversely proportional to the distance squared between proton and electrons.

    $$F \propto \frac{1}{d^2}$$

    b. Describe the mathematical relationship between the number of protons in the nucleus (Z) and the attractive force (F) between the nucleus and electrons.

    Force is directly proportional to the nuclear charge Z.

    $$F \propto Z$$

Teacher Resources – Coulombic Attraction

Learning Objectives

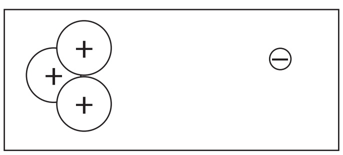
1. Rank sets of charged particles in order of increasing force of attraction by analyzing distances between particles and the total charges involved.
2. Predict the changes to the attractive force on the outermost electron in an atom as you move down or across the periodic table.

Prerequisites

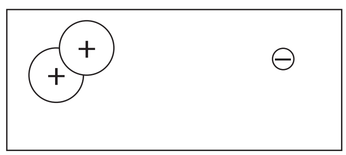
1. Students must know that opposite charges attract and same charges repel.
2. Students should be familiar with the terms "independent variable" and "dependent variable."
3. Students should have a basic understanding of atomic structure (number and location of electrons and protons) and be familiar with the Bohr model (shell model) of the atom.

Assessment Questions

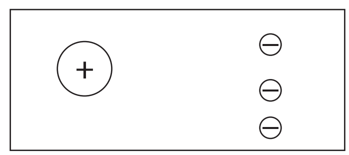
1. Rank the following sets of particles in order of INCREASING force of attraction on the electron.



Set A

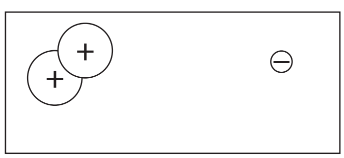


Set B



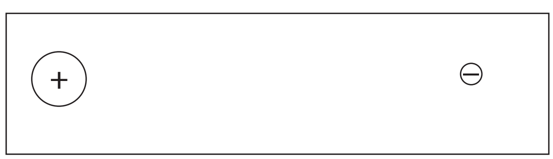
Set C

2. Rank the following sets of particles in order of INCREASING force of attraction on the electron.



Set A

Set B



Set C

3. Which of the sets of elements are NOT in order of INCREASING force of attraction on the outermost electron in atoms of that element?

   a. Ba < Sr < Ca

   b. Al < P < Cl

   c. F < Cl < Br

   d. Mo < Pd < Sn

Assessment Target Responses

1. *Set C < Set B < Set A*
2. *Set C < Set B < Set A*
3. *c.*

Teacher Tips

- The idea of "attractive force" is difficult for some students. To prepare students for this activity, it might be useful to give students some magnets to play with for a few minutes. What happens to the attractive force as the magnets move away from or toward each other? What happens to the attractive force when a stronger magnet is used? Although magnetic attraction and Coulombic attraction are actually quite different, this exercise may help students understand what is meant by attractive force.
- Students often think that attraction is based on a ratio of charges—for example +1/−1 will have the same attraction as +2/−2. The *Read This!* box on page 70 addresses this misconception.
- Although this activity does not address periodic trends specifically, it does lead directly to a discussion of atomic radius, electronegativity, metallic character, etc. This can be done in a traditional manner or by using the "Periodic Trends" POGIL activity.
- Students will need access to a periodic table for this activity. The colorful and teacher-developed Flinn Scientific Periodic Table is available as a two-sided hanging wall chart (Catalog No. AP9021), a one-sided roller-mounted chart (Catalog No. AP4530), and as an 11″ × 17″ fold-out notebook version (Catalog No. AP9020).