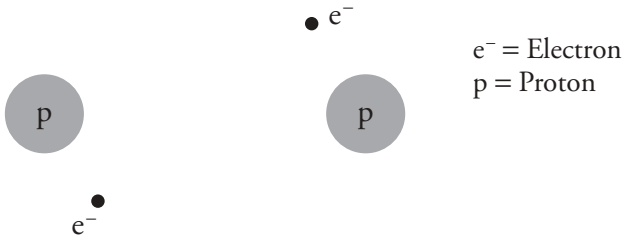
Properties of Covalent Bonds

What factors determine the length and strength of a covalent bond?

Why?

Many of the chemical and physical properties of a substance are determined by the strength and/or length of the bonds within that substance. It is fairly easy to find values for these properties in your textbook or on the Internet. It is even more helpful however to understand what makes a bond stronger or weaker than another bond. These trends in bond length and energy will be explored in this activity.

Model 1 – Attractive and Repulsive Forces

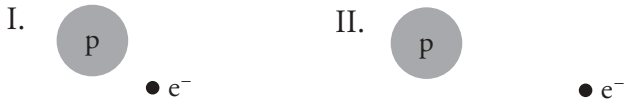


1. Two atoms are illustrated in Model 1 (not to scale). Identify the element to which the atoms belong.

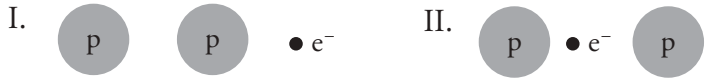
2. Consider the attractive and repulsive forces that would exist if the atoms in Model 1 were to approach each other by random motion.
   a. Draw a dashed line to represent any repulsive forces between similarly charged particles.
   b. Draw a solid line to represent any attractive forces between oppositely charged particles.

3. In order for a bond between atoms to be stable, how should the attractive forces compare to the repulsive forces?

4. Recall that the potential energy of the system is decreased when attractive forces are maximized.
   a. Which situation below would have the lowest potential energy? Justify your reasoning.



   b. Which situation below would have the lowest potential energy? Justify your reasoning.

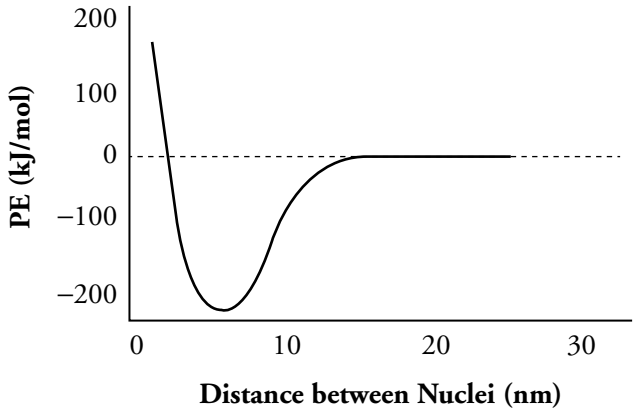


5. Draw a diagram similar to that in Model 1 showing where the electrons would be in relationship to the nuclei when the attractive forces in the system are maximized.

6. Draw a diagram similar to that in Model 1 showing where the nuclei would be when the repulsive forces in the system are maximized.

7. Attractive forces are written using negative potential energy values. Explain why this is reasonable in terms of the energy of the system of particles in Model 1.

Model 2 – A Bond Energy Curve



8. The graph in Model 2 shows the changes in potential energy of a two-atom system as the distance between nuclei changes.

   a. Consider the potential energy of the system when the atoms are more than 15 nm apart. Describe the system's potential energy in terms of attractive and repulsive forces.

   b. Consider the potential energy of the system when the atoms are less than 5 nm apart. Describe the system's potential energy in terms of attractive and repulsive forces.

9. Circle the place on the graph where the system of atoms is the most stable. Justify your reasoning.

Read This!

When atoms bond, they are not still. Bonds are more like frictionless springs that have been stretched and released. The atoms vibrate, getting closer and further apart rhythmically. Therefore, it is difficult to determine a "bond length" for a given system of atoms. It is possible, however, to determine the most stable distance between atoms. This is sometimes tabulated as the **average bond length** in chemistry textbooks. Keep in mind that the atoms likely vibrate at approximately that distance.

10. According to the graph in Model 2, what is the approximate average bond length for the system of atoms illustrated?

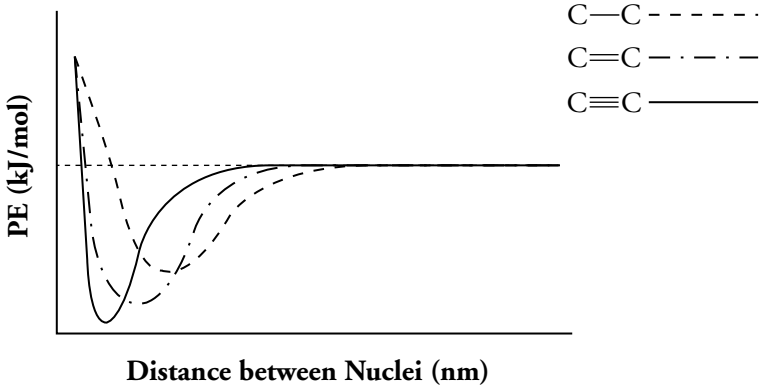
11. If the atoms in Model 2 were at their most stable bond length, how much energy would be needed to separate one mole of atom pairs completely?

12. According to Model 2, how much energy would be released when the two moles of atoms formed bonds to make one mole of bonded atom pairs?

13. Based on your answer in Question 12, how much energy would be released when one bond formed between two atoms?

STOP

Model 3 – Comparing Potential Energy Curves



14. Model 3 illustrates the potential energy curves for three different bonds. What three bonds are illustrated?

15. Which of the three bonds has the shortest average bond length?

16. Which of the three bonds has the smallest bond energy?

17. Compare the potential energy curves in Model 3. When a higher order bond forms between atoms, is the bond strengthened or weakened? Justify your reasoning.

18. Two oxygen atoms can form a single bond or a double bond between them. Complete the table below with either O—O or O═O in the far left column.

Bond	Average Bond Length (pm)	Average Bond Energy (kJ/mole)
	148	145
	121	498

Model 4 – The Effect of Atom Size

Bond	Average Bond Length (pm)	Average Bond Energy (kJ/mole)
Cl—Cl	199	243
Br—Br	228	193
I—I	267	151

19. How do the sizes of chlorine, bromine and iodine atoms compare?

20. Explain why the bond lengths vary for the three bonds shown in Model 4.

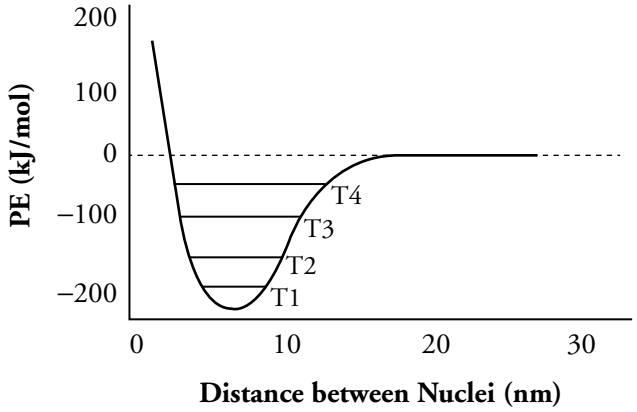
21. According to Model 4, how does the size of the atoms bonded affect the strength of the bond formed?

22. Predict which bond below would have the highest average bond energy. Justify your reasoning.

H—N H—O H—F

Extension Questions

Model 5 – Effect of Temperature



23. When the temperature of a substance increases, the bond vibrations get more extreme. Model 4 illustrates the minimum and maximum bond length during a vibration for four different temperatures. Which temperature is the highest temperature?

24. Explain why it is possible in most cases to break a covalent bond by increasing the temperature.

25. Use a ruler to find the midpoint of each temperature line in Model 5. Mark the midpoints with an X. What do these midpoints represent in terms of bond properties?

26. Explain why most substances exhibit thermal expansion—the volume of a sample increases when the temperature increases.