SAM Teachers Guide
Chemical Bonds

Overview

Students discover that the type of bond formed — ionic, non-polar covalent, or polar covalent — depends on the electronegativity of the two atoms that are bonded together. First, students experiment with how orbital shapes are affected by other charges and atoms. Then they explore the role of electronegativity in bond formation. Students observe the very disparate electronegativities in ionic bonds, the somewhat disparate electronegativities of polar covalent bonds, and the similar electronegativities of non-polar covalent bonds. Finally, they observe how a molecular surface becomes polarized when polar covalent bonds are part of a larger molecule.

Learning Objectives

Students will be able to:

- Explain how negatively charged electrons may interact with other charged particles. (That is, opposite charges attract and like charges repel.)
- Explore how a covalent bond is formed between two atoms.
- Explain the term electronegativity and how it plays a role in the formation of chemical bonds: polar covalent, non-polar covalent, and ionic.
- Determine how a dipole is related to the electronegativity of a molecule.
- Predict atomic bonding patterns based on an understanding of electronegativity.

Possible Student Pre/Misconceptions

- The structure of an atom follows the Bohr model with electrons orbiting around a nucleus on a set path, like planets around the sun.
- Bonds are tangible, physical structures.
- Orbitals are flat, not a three-dimensional region of space where electrons are likely to be found.
- Bonds must be either ionic or covalent there are no weak interactions.
- Covalent bonds are always weaker than ionic bonds.

Models to Highlight and Possible Discussion Questions

After completion of Part 1 of the activity:

Models to Highlight:

- Page 2 – Orbital Distortions
    - Highlight that by charging the walls or using the point charge, the same principle emerges: Like charges repel, opposite charges attract. Distance between the two atoms plays a role in these attractive or repulsive forces.

- Link to other SAM activities: **Electrostatics**. Use this opportunity to review Coulomb's Law.
- Page 3 – Visualizing Covalent Bonds
    - Emphasize how a covalent bond is not a physical thing.
- Page 4 – Pictures of Charge Distribution
    - Use pictures to highlight the definition of electronegativity and the difference in meaning between electrons being shared evenly (no surface coloration) and electrons being shared unevenly (blue = partial negative charge; red = partial positive charge).
    - Link to other SAM activities: **Intermolecular Attractions**. Review the concept of uneven sharing of electrons (polarity) and how this might impact chemical bonding.
- Page 5 – Electronegativity Values
    - Highlight the electronegativity numbers in the boxes. Make connections between being more or less electronegativity and where the electrons spend their time.

Possible Discussion Questions:

- What causes atoms to attract one another? Why is that attraction is not always "even"?
- **Demonstration/Laboratory Ideas:**
    - Have students build molecular models and discuss the types of bonds using calculations of electronegativity differences.
    - Use bar magnets to review poles and polarity; also review how opposites attract and like charges repel.
    - Heating reactions (such as copper sulfate) to show bond breaking and bond formation.

After completion of Part 2 of the activity:

Models to Highlight:

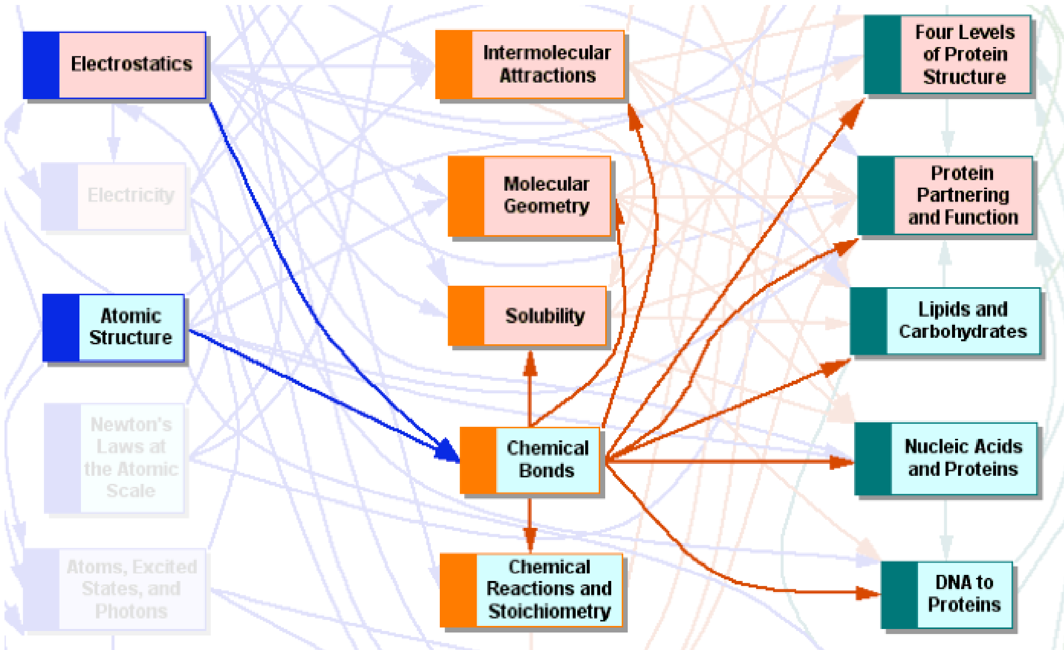
- Page 6 – Electronegativity Difference
    - Use the model to review that the difference in electronegativity determines the type of bond (ionic, non-polar covalent, or covalent) that will be formed. Non-polar covalent bond means equal sharing, covalent is unequal distribution, while ionic bonds are so unequal it is like an electron transferred.
- Page 8 – Predicting Bonds From Electronegativity
    - Highlight the difference between polar and non-polar covalent bonds.
- Page 9 – Extending Predictions to Larger Molecules

- Highlight that bonds are one part of much larger molecules and the type of bond formed affects how part(s) of the molecule will behave. This is the case with proteins. Although students have not yet been exposed to protein biology, they can use what they know about the chemistry of the bond to predict how the molecule might behave.
- Link to other SAM activities: **Four levels of Protein Structure** and **Molecular Geometry**. Use this opportunity to preview the importance of chemical bonds in biological molecules. In addition, review how the three-dimensional structure of a molecule is important and influenced by the distribution of electrons.

Possible Discussion Questions:

- What is the relationship between differences in electronegativity and the type of bond formed?
- What is the difference in how electrons are shared in the three types of bonds addressed in this activity?
- What can you infer about how the location of two different elements on the Periodic Table relates to the type of bond created?
    - What kinds of bonds are likely formed between a metal and non-metal? Two non-metals?
- Can there be more than one type of bond in a molecule? Why?

Connections to Other SAM Activities



This activity focuses on electronegativity as a way to describe how well electrons are shared between atoms. Electrons can be shared perfectly evenly (non-polar covalent bonds), very unevenly (ionic bonds), or somewhat unevenly (polar covalent bonds). This lesson is supported by the **Electrostatics** activity, where students learn about the attraction of positive and negative charges. In the **Atomic Structure** activity, students explore the model of the atom as a core of positive charge (the nucleus) and a haze of negative charge (the electron cloud) and apply this understanding of the electron cloud to the interactions that form chemical bonds.

The **Chemical Bonds** activity supports **Intermolecular Attractions**. The polar nature of bonds is what allows for attraction between molecules. Even non-polar molecules can be attracted to one another because of slight or intermittent inequalities of how electrons are distributed. This background also supports students' ability to make predictions about electron repulsion and three-dimensional structure of molecules addressed in **Molecular Geometry**. To understand **Solubility**, students learn that it is the attractive forces between molecules that allow for solutes to dissolve. **Chemical Reactions and Stoichiometry** explores how reactions progress by the making and breaking of chemical bonds. Finally, **Four Levels of Protein Structure**, **Protein Partnering and Function** , **Lipids and Carbohydrates, Nucleic Acids and Proteins,** and **DNA to Proteins** all rely on understanding of chemical bonds. In addition, in **Lipids and Carbohydrates** students can differentiate between when there are intermolecular interactions, such as in a membrane versus when there are chemical bonds present, such as within a phospholipid.

Activity Answer Guide

Page 1:

1. Which answer best describes electrons when they surround the nucleus of an atom?
(c)

Page 2:

1. Describe why charging walls changes the shape of the orbital.

When the wall is negatively charged, the electrons (also negatively charged) remain close to the nucleus. When the wall is positively charged, the electrons are attracted to the wall and the orbital distorts in that direction.

2. Does the distance between charges have any effect on the shape of the orbital? Support your answer with observations.

The distance has an effect on whether or not the shape of the orbital changes. When the positive charge is close to the electron cloud, it changes shape and elongates toward the charge due to its attraction. When the distance between the positive charge and the electron cloud is increased, the orbital is not as affected and the orbital shape remains the same.

Page 3:

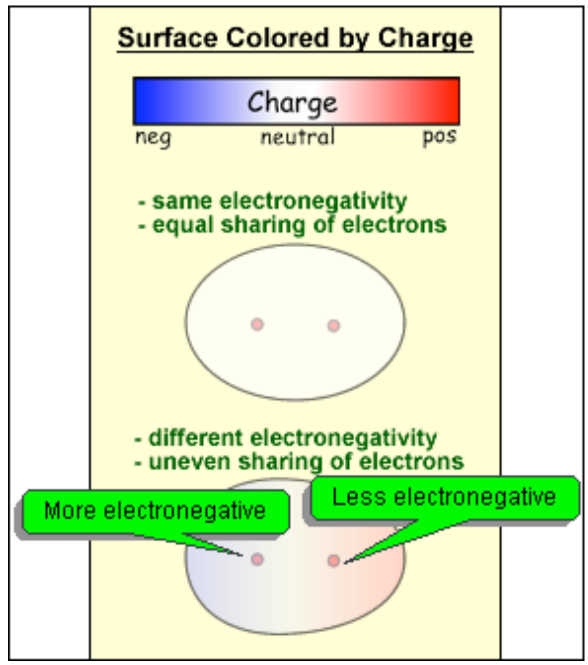
1. Select "Use Another Hydrogen Atom" and drag it around. Which best describes what you see? (c)

2. A covalent bond is formed when the electrons from two different atoms are considered to be "shared" between the nuclei. Move the two hydrogen atoms close together and explain how this can be a representation of a covalent bond.

A covalent bond is not a physical structure or connection, but rather a sharing of electrons between two or more atoms. This is seen as the electron orbitals appear to merge and become one orbital around both nuclei.

Page 4:

1. Place your annotated molecule here, showing which part is slightly positive and which part is slightly negative:



Sample snapshot: The left side of this molecule is slightly negative (blue) while the right side of this molecule is slightly positive (red). This means that the atom on the left is more electronegative. It is better than the atom on the right at attracting electrons.

Page 5:

1. Try setting one atom to have a slightly higher electronegativity than the other. Where do the electrons end up? (a)

2. When the electrons end up shifted toward the nucleus of one of the atoms, that causes the surface of the molecule around that atom to be: (b)

3. Explain your answers to the two multiple-choice questions. Be sure to use the term "electronegativity" correctly in your answer.

If an atom has higher electronegativity than the atom to which it is bonded, then the sharing of electrons will be uneven between them. The one with the higher electronegativity will attract the electrons more, so they will end up closer to that atom, and bring some extra negative charge with them. This causes the surface of the molecule near that atom to be more negative than around the other atom.

Page 6:

1. If you want to make a non-polar covalent bond, the difference in electronegativities between the atoms should be: (c)

2. If you want to make an ionic bond, the difference in electronegativities between the atoms should be: (a)

3. If you want to make a polar covalent bond, the difference in electronegativities between the atoms should be: (b)

4. What is the approximate numeric difference in electronegativity that divides non-polar from polar? All answers within the 0.4 to 0.8 range are acceptable

5. What is the approximate numeric difference in electronegativity that divides polar from ionic? (All answers within the 1.9 to 2.3 range are acceptable.

Page 7:

1. What kind of bond is formed between sodium (Na) and chlorine (Cl)? (c)

2. What kind of bond is formed between hydrogen (H) and oxygen (O)? (b)

3. What kind of bond is formed between carbon (C) and carbon (C)? (a)

4. Experiment with choosing various pairs of elements from different areas of the periodic table to see what kind of bonds are formed. What patterns do you see?

If atoms are chosen that are in the same area of the periodic table, they tend to form non-polar or polar covalent bonds. If they are from opposite sides, they tend to be polar covalent or ionic.

Page 8:

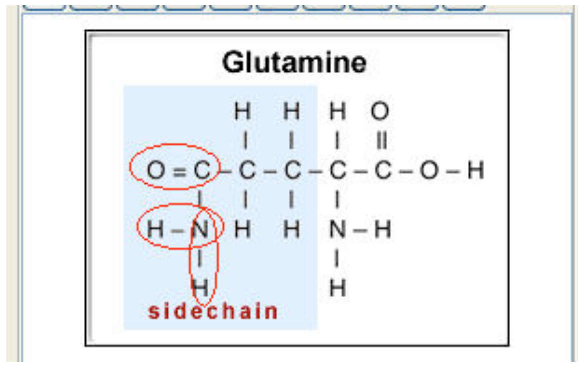
1. What kind of bond is formed between carbon (C) and oxygen (O)? (b)

2. What kind of bond is formed between hydrogen (H) and carbon (C)? (a)

3. What kind of bond is formed between nitrogen (N) and oxygen (O)? (a)

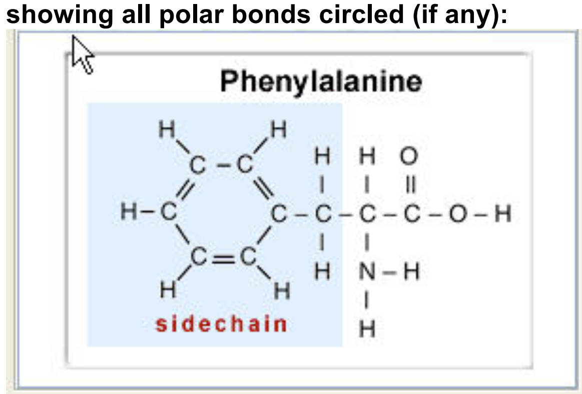
Page 9:

1. Place your image of glutamine here showing all polar bonds circled (if any):



Sample snapshot: When carbon bonds to itself, there is no difference in electronegativity, so the bond is non-polar covalent. The difference in electronegativity between C-H is 0.45, which makes it non-polar as well. Both N-H and C-O have electronegativities in the polar range (0.5 to 2.1.)

2. Place your image of phenylalanine here showing all polar bonds circled (if any):



Sample snapshot: The difference in electronegativity between C- H is 0.45, which makes it non-polar. There are no polar bonds in the side chain of the molecule.

3. Which amino acid would be good to use in the part of the protein that spans the cell

membrane? Non-polar amino acids work best inside of membranes. (b)

4. Explain why you made that choice.

Phenylalanine is a non-polar amino acid because all the bonds in the sidechain are non-polar covalent bonds. Because, non-polar amino acids work well inside membranes, having a protein with lots of non-polar amino acids as part of it will allow the protein to span the membrane.

Page 10:

1. Which of the following is NOT a chemical bond between atoms: (c)

2. In a non-polar covalent bond: (a)

3. Define electronegativity.

Electronegativity refers to the ability of an atom to attract electrons. This leads to the uneven sharing of electrons in chemical bonds.

4. In a polar covalent bond: (b)

5. Is water a polar molecule? Describe <u>in detail</u> how you know. Use the electronegativity table to the right to see values for various elements. Be sure to mention electronegativity, the meaning of polarity, the sharing of electrons, and the coloring of the water molecule seen in the diagram.

Yes, water is a polar molecule. The difference in electronegativities between the two elements is the absolute value of 2.1-3.44 or 1.34. This falls into the polar range as we learned in previous activities. That means the atoms do not share the electrons evenly. The oxygen is more electronegative and better at attracting electrons to spend time near it; that leaves both hydrogen atoms partially positive. This is shown in the diagram. The area around oxygen is blue (slightly negative) while the area around both hydrogen atoms is red (positive).

6. To make an ionic bond you would want to pick elements: (c)

SAM HOMEWORK QUESTIONS
Chemical Bonds

Directions: After completing the unit, answer the following questions to review.

1. Define an orbital in your own words.

2. What happens to electrons in the following three types of bonds:
   a) ionic —
   b) polar covalent —
   c) non-polar covalent —

3. You have learned by now that opposite charges attract and like charges repel. How does this principle affect atoms as they get close to each other?

4. Define the term electronegativity. How does an atom's electronegativity influence how it is able to chemically bond?

5. Differences in electronegativity influence bonding. Use the tables here to predict what type of bond would most likely form in the following situations. First, show your mathematical work, then select the type of bond formed.

Electronegativity Difference

less than 0.5 = non-polar covalent
0.5 to 2.1 = polar covalent
more than 2.1 = ionic

Table of Pauling Electronegativity

H 2.1																
Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98
Na 0.93	Mg 1.31											Al 1.61	Si 1.9	P 2.19	S 2.58	Cl 3.16
K 0.82	Ca 1.0	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.9	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96
Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.6	Mo 2.16	Tc 1.9	Ru 2.2	Rh 2.28	Pd 2.2	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.1	I 2.66
Cs 0.79	Ba 0.89	La 1.1	Hf 1.3	Ta 1.5	W 2.36	Re 1.9	Os 2.2	Ir 2.2	Pt 2.28	Au 2.54	Hg 2.0	Tl 2.04	Pb 2.33	Bi 2.02	Po 2.0	At 2.2
Fr 0.7	Ra 0.89	Ac 1.1														

NOBLE GASES DON'T BOND

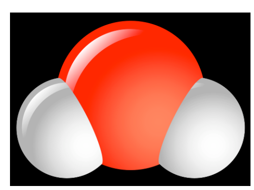
The first one is set up for you as a model.

a) H bonding to Cl: Absolute value of 2.1-3.16 = _______ so a(n)__________________ bond would form.

b) Na bonding to Cl:

c) C bonding to H:

6. To the right is a picture of a water molecule. Label the part(s) of the molecule you would expect to be partially positive and the part(s) of the molecule you would expect to be partially negative. Then, explain your reasoning.



7. **Career connection:** The computer has made entirely new fields of study possibly. There is now a field called "computational chemistry." What do computational chemists do and how does this relate to chemical bonds?

SAM HOMEWORK QUESTIONS
Chemical Bonds – With Suggested Answers for Teachers

1. Define an orbital in your own words. *An orbital is a region of space around the nucleus of an atom where electrons are likely to be found.*

2. What happens to electrons in the following three types of bonds:
   a. ionic — *electrons are lost or gained*
   b. polar covalent — *electrons are shared unevenly*
   c. non-polar covalent — *electrons are shared evenly*

3. You have learned by now that opposite charges attract and like charges repel. How does this principle affect atoms as they get close to each other? *As atoms get close, the electrons will repel each other while the electrons are also attracted to the positively charged nucleus of another atom.*

4. Define the term electronegativity. How does an atom's electronegativity influence how it is able to chemically bond? *Electronegativity refers to how well an atom attracts electrons from another atom. Differences in electronegativity cause atoms to be shared unevenly, or even transferred, in chemical bonds.*

5. Differences in electronegativity influence bonding. Use the tools below to predict what type of bond would most likely form in the following situations. First, show your mathematical work, then select the type of bond formed.

Electronegativity Difference

less than 0.5 = non-polar covalent
0.5 to 2.1 = polar covalent
more than 2.1 = ionic

a) H bonding to Cl: Absolute value of 2.1-3.16 = 1.06 so a polar covalent bond would form.

b) Na bonding to Cl: Absolute value of .93-3.16 = 2.23, ionic

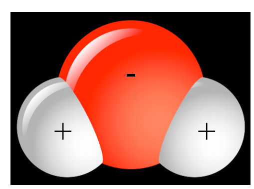
c) C bonding to H: Absolute value of 2.55-2.1 = 0.45, non-polar covalent

Table of Pauling Electronegativity

H 2.1																
Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98
Na 0.93	Mg 1.31											Al 1.61	Si 1.9	P 2.19	S 2.58	Cl 3.16
K 0.82	Ca 1.0	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.9	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96
Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.6	Mo 2.16	Tc 1.9	Ru 2.2	Rh 2.28	Pd 2.2	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.1	I 2.66
Cs 0.79	Ba 0.89	La 1.1	Hf 1.3	Ta 1.5	W 2.36	Re 1.9	Os 2.2	Ir 2.2	Pt 2.28	Au 2.54	Hg 2.0	Tl 2.04	Pb 2.33	Bi 2.02	Po 2.0	At 2.2
Fr 0.7	Ra 0.89	Ac 1.1														

NOBLE GASES DON'T BOND

6. To the right is a picture of a water molecule. Label the part(s) of the molecule you would expect to be partially positive and the part(s) of the molecule you would expect to be partially negative. Then, explain your reasoning. *Oxygen is more electronegative than hydrogen, so electrons would be more attracted to the oxygen atom, creating a partial negative charge on oxygen and a partial positive charge on the hydrogens. Polar covalent bonds are formed.*



7. **Career connection:** Computational chemists do chemistry with computer models. It is crucial for them to be able to calculate how and what kinds of bonds form between different types of atoms and molecules.