SAM Teachers Guide
Intermolecular Attractions

Overview

This activity focuses on the attractive forces between molecules. Both London Dispersion and dipole-dipole intermolecular attractions are discussed. Polarity and surface area are shown to be defining factors for the strength of intermolecular attractions. Students observe the effect of these factors on the properties of materials.

Learning Objectives

Students will be able to:

- Describe the difference between the kinds of molecules attracted via London Dispersion attractions and dipole-dipole attractions.
- Indicate which type of intermolecular attraction is generally stronger.
- Describe two factors that affect the strength of intermolecular attractions.
- Determine which substance would have the highest boiling point based upon its molecular structure.
- Explain why oil and water don't mix.

Possible Student Pre/Misconceptions

- Water and oil repel each other.
- Heating a substance weakens its intermolecular attractions.
- Hydrogen bonds are the covalent bonds between hydrogen and oxygen within a water molecule.

Models to Highlight and Possible Discussion Questions

After completion of Day 1 of the activity:

Models to Highlight:

- Page 2 – Dipole-Dipole and London Dispersion Attractions
    - o Discuss how you can tell that polar (dipole-dipole) attractions are stronger than non-polar (London Dispersion).
- Page 3 – Intermolecular Attractions
    - o **Boiling model**: Boiling in this model is represented as molecules separating from each other. Emphasize how it takes more heat energy for molecules to overcome the attractions between polar molecules.
    - o **Solubility model**: Point out how oil and water attract, but water attracts to itself better than to oil. Discuss this in light of student misconceptions.

- o Link to other SAM activities: **Phase Change**. Emphasize how boiling point is impacted by the attraction between molecules.
  - o Link to other SAM activities**: Solubility.** Emphasize how different strengths of attracts allow for variations in solubility.
- Page 4 – Connecting to Real Molecules
  - o Be sure to emphasize that molecules can be more or less polar by having *multiple regions* of polarity. Molecules of similar size but different polarity will have varying overall attractions. Emphasize that molecules that are more polar have stronger attractions.
- Page 5 – London Dispersion Attractions
  Molecules with larger surface area can form more "contacts" than smaller molecules, but the shape of the molecule can affect how much of the surface can form London Dispersion attractions.

Possible Discussion Questions:
- Have students list some properties that are affected by intermolecular attractions (e.g., boiling point, viscosity, solubility).
- Explain what happens as a substance boils. (Watch out for answers that indicate intermolecular attraction gets weaker.)
- **Demonstration/Laboratory Ideas:** Create three tubes with liquids of varying viscosity. Place steel ball in tube and watch it fall through the liquid. Use magnet to repeat. See some suggested liquids and models of their polarity here:
  http://chemsite.lsrhs.net/ChemicalBonds/viscosity_demo.html
- Predict what the properties are (more or less polar, larger molecules with more or less surface area) for the liquids in the tubes and explain.

**After completion of Day 2 of the activity:**
Models to Highlight:
- Page 6 – Gaseous Water
  - o Be sure to emphasize that the hydrogen bond is represented as the dotted line between water molecules, not the covalent bond between oxygen and hydrogen within the water molecule itself.
  - o Link to other SAM activities: **Chemical Bonding**. Discuss how unequal sharing of electrons will lead to attraction between atoms and different types of chemical bonds.
- Page 7 – Hydrogen Bonds in DNA
  - o Link to other SAM activities: **DNA to Proteins**. Use model of DNA's hydrogen bonds to start discussion of how biological molecules are affected by atomic interactions.

- Page 8 – Antibody-Antigen Interactions
  - Point to similarities between the new biological context and the models students have been using on the previous pages. Use the antibody design as a way to bring both charge and surface area together.
  - Link to other SAM activities: **Electrostatics**. Emphasize the impact of charge in the antibody/antigen interactions. This is an opportunity to review Coulomb's Law: like charges repel and unlike charges attract.

Possible Discussion Questions:
- Why do we need different antibodies for each kind of disease? Why can't we just have one antibody that sticks to all "bad" molecules?
- Why does water seem to "climb" up the sides of a glass or even a paper towel dipped into water?
- What would it be like if there were no intermolecular attractions at all?

Connections to Other SAM Activities
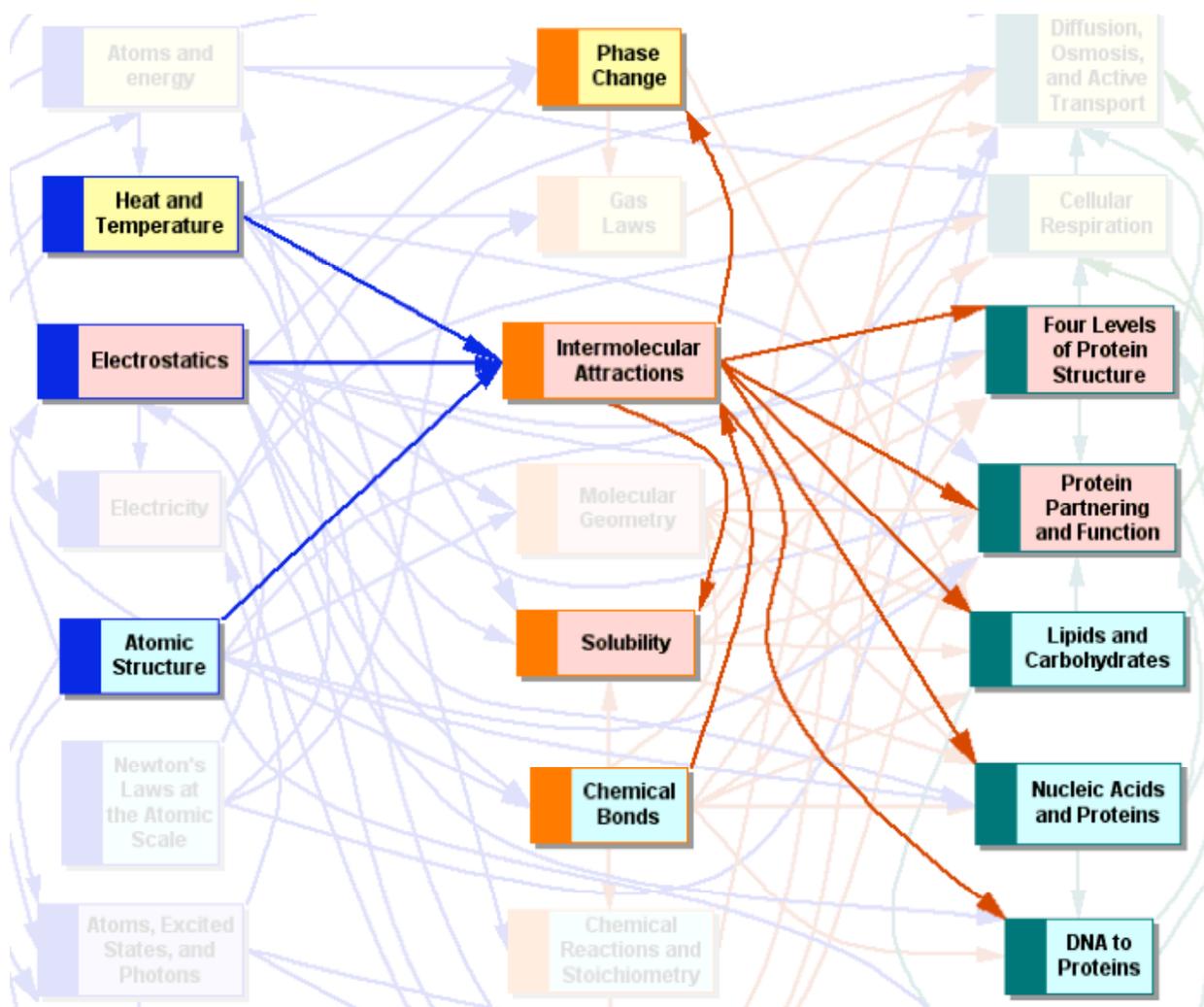
The **Intermolecular Attractions** activity highlights one of the fundamental principles of the molecular world: everything is "sticky." **Atomic Structure** sheds light on the source of charge, **Electrostatics** explores how oppositely charged things attract, and **Heat and Temperature** gives students a basis for understanding what happens when atoms and molecules are heated. Students explore the relationship of boiling point to intermolecular attractions in this activity. The **Chemical Bonds** activity helps explain why some molecules are polar or non-polar, the source of the intermolecular attractions.

Intermolecular Attractions helps explain the source of the attractive force, which must be overcome for a substance to go through a **Phase Change**. In addition, it explains the principle of "like dissolves like" as described in **Solubility** by describing that all things attract, but some do so better than others. Intermolecular attractions play a significant role in protein folding as discussed in **Four Levels of Protein Structure**, both in how

proteins interact with their environment (usually water) and in a stabilizing role within the folded protein. It's primarily intermolecular attractions and the unique surface shapes of molecules that allow for the connection between **Protein Partnering and Function.** The function of many macromolecules such as **Lipids and Carbohydrates** as well as **Nucleic Acids and Proteins** relies upon attractive forces between and within molecules. In **DNA to Proteins** the ability to make a protein (and always the same protein) is governed by the specificity of attractions between various molecules that read the DNA and link up the amino acids into a protein.

Activity Answer Guide

Page 1:

1. What is the difference between polar and non-polar molecules (Be sure to include more than the colors used to represent them in your response!**)?**

Polar substances have positive and negative parts, and non-polar substances don't. Polar substances have electrons that are shared unevenly, which causes the imbalance of charge.

2. Image showing intermolecular attractions:
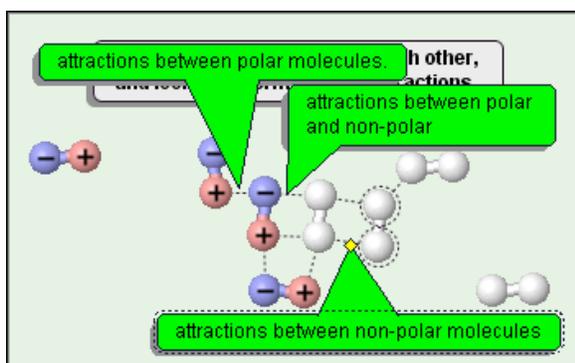
3. Which of the following formed intermolecular attractions: (b) (d) (e) (f)

Page 2:

1. What is the primary attraction between NON-POLAR molecules: (a)

2. What is the primary attraction between POLAR molecules: (b)

3. Which type of intermolecular attraction is stronger: (b)

Page 3:

1. Which liquid boiled first (i.e., had the lowest boiling point): (b)

2. Explain how intermolecular attractions affect the boiling point of a substance.

The stronger the intermolecular attractions the harder it is for something to boil, so the higher the boiling point must be.

3. Explain why polar and non-polar substances won't stay mixed with each other?

They all attract to each other, but the polar ones have a stronger attraction, so they stick to other polar molecules better than to the non-polar ones. This causes them not to mix well, just like oil and water.

Page 4:

1. Which molecule had the strongest attraction: (c)

2. Explain why polarity has an affect on the strength of attraction between molecules.

If something is more polar or has more areas of charge on it, then there are more places where it can form a dipole-dipole attraction to another molecule, especially another polar one like itself.

3. Which substance will have the highest boiling point: (c)

4. Explain your choice for highest boiling point:

It is the most polar and has the most places where it can attract to other 1,4,7-heptanetriol molecules. More attractions mean a stronger overall attraction, so it will be harder for them to separate and go into a gas phase.

Page 5:

1. Which molecule pairs had the strongest attraction (check all that apply): (b) (e)

2. Propane boils at -42°C, butane at 0°C, and pentane at 36°C. They are all straight molecules. Which one is the biggest? (c)

3. Small molecules did not attract well. However, only some of the large ones had a strong attraction. Describe how both size

and shape play a role in the strength of the London Dispersion attraction.

The larger the surface area that can come in contact with another molecule's surface, the greater the London Dispersion attraction will be.Large molecules have more surface area to come in contact with other molecules if in fact the shapes compliment each other. If the shapes do not match up well the number of points of attraction is greatly reduced and the strength of the London dispersion attractions is reduced..

Page 6:

1. Snapshot with annotations indicating hydrogen bonds:
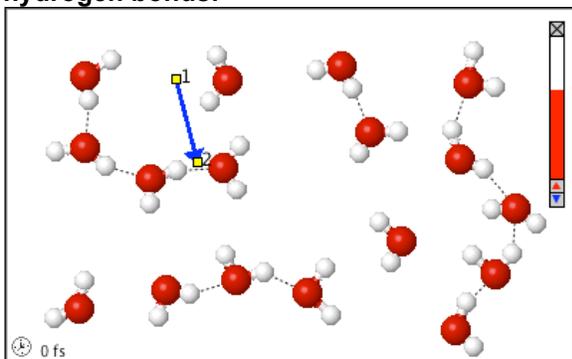
2. While not possible, imagine that water molecules had no attraction for each other at all. Would you most likely find water as a solid, liquid, or gas? Explain your reasoning.

It would be a gas because you need the attractions to keep the molecules close together as they are in a liquid or solid.
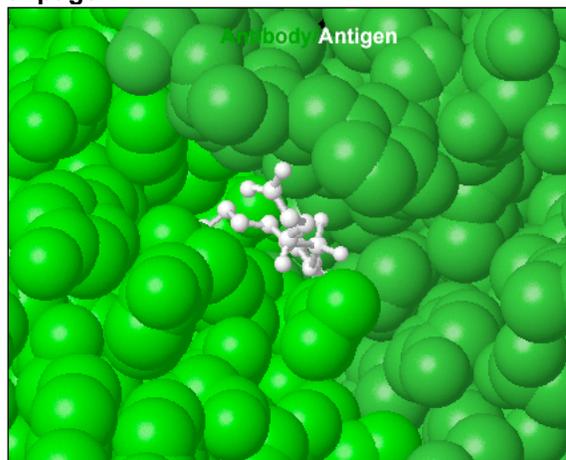
Page 7:

1. Which pair of bases is held together more strongly: C and G, or A and T? How do you know?
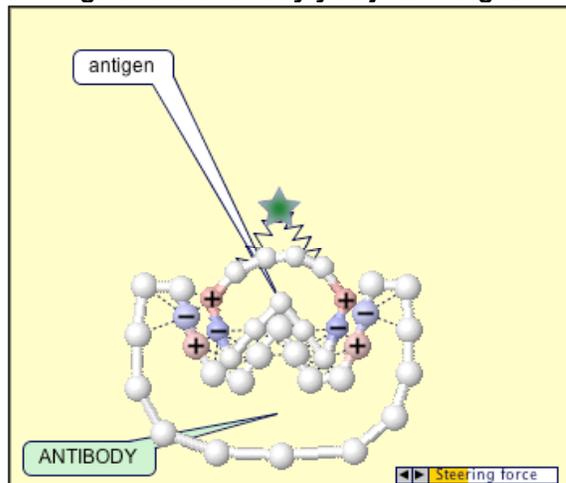
The C-G base pair is held together the strongest because they form three hydrogen bonds between them. A-T only forms two. More hydrogen bonds mean a greater overall attraction.

Page 8:
1. Image of the 3D antibody/antigen from top of page:

2. Image of the antibody you just designed:

Page 9:

1. Why do you think a gecko's feet stick much better to a wall than your fingers? Think about surface area, intermolecular attractions, and the rough surface (on a microscopic level) of a typical wall.

The gecko's toes have so many hair-like structures that a much larger surface area can come in contact with walls, so they stick better than our fingers can.

1. Which of the following is NOT an attractive force between molecules: (c)

2. Which factors affect the strength of the intermolecular attractions? (check all that apply) (b) (c) (d)

3. You have two substances: A and B. Both have molecules of similar size and shape. Substance A has molecules that attract with London Dispersion attraction, and substance B has molecules that attract with dipole-dipole attraction. Which one will have the higher boiling point? (b)

4. Explain why you chose Substance A or B.

If they are the same size, then the surface area should be the same. So, the surface area is not much of a factor, only the polarity. That means the London Dispersion attraction will be weaker than the dipole-dipole attraction, which is naturally stronger. Stronger attraction means a higher boiling point, so I chose substance B.

5. You have two substances, both of which have the same boiling point (or attraction between their molecules). The first substance is made from molecules that are small (just a few atoms bonded together), and the second substance is made from molecules that are larger (many atoms bonded together). How can it be possible for two such different molecules to yield substances with the same boiling point? Describe the kinds of intermolecular attractions that must be involved and any other properties of the molecules that could cause this result.

The small one must be polar and the large one must be non-polar. The larger surface area of the non-polar one means the overall London dispersion attraction might be similar in strength to the smaller polar molecule, which is primarily using dipole-dipole attraction.

SAM HOMEWORK QUESTIONS
Intermolecular Attractions

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

1. What is the difference between a polar and non-polar molecule with regard to how they share electrons?

2. There are two categories of intermolecular attractions: London Dispersion and dipole-dipole attractions. What types of molecules experience London Dispersion attractions? What types of molecules experience dipole-dipole attractions? (Hint: Refer to polar vs. non-polar molecules in your answer.)

3. Below is a snapshot of the water vapor molecules. First, draw in the partial charges that each polar water molecule will have. (Use + for partial positive and – for partial negative charges.) Then, draw in the hydrogen bonds that will exist because of the attraction between the water molecules. (Use ---- lines to show where the molecules will be attracted.)
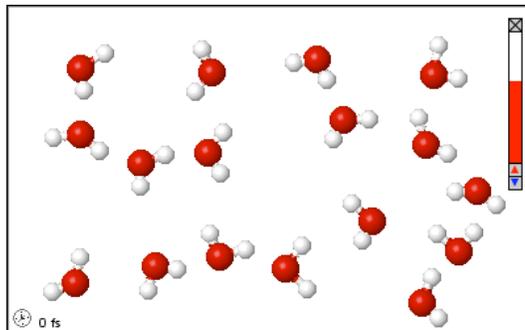
4. You have two substances: A and B. Both have molecules of similar size and shape. Substance A has molecules that attract with London Dispersion attraction, and substance B has molecules that attract with dipole-dipole attraction. Which one will have the lower boiling point? Explain your answer.

5. You have two substances: A and B. Both are attracted with London Dispersion attractions. Substance A is made of short linear molecules. Substance B is made of much longer, curved molecules that fit together tightly. Which substance will experience greater forces of attraction? What does the shape of the molecule have to do with attractive forces?

6. **Career connection:** The attractive force between molecules is based on electrostatic attraction (attraction between opposite charges). This is particularly important for nanoscale-sized devices or objects (sometimes made from single molecules). Research nanotechnology and find one way the electrostatic force is related to this.

SAM HOMEWORK QUESTIONS
## Intermolecular Attractions – With Suggested Answers for Teachers

1. What is the difference between a polar and non-polar molecule with regard to how they share electrons?
   Polar molecules do not share electrons evenly while non-polar molecules do.

2. There are two categories of intermolecular attractions: London Dispersion and dipole-dipole attractions. What types of molecules experience London Dispersion attractions? What types of molecules experience dipole-dipole attractions? (Hint: Refer to polar vs. non-polar molecules in your answer.)
   London Dispersion forces are experienced by non-polar molecules while dipole-dipole attractions are experienced by polar molecules.

3. Below is a snapshot of the water vapor molecules. First, draw in the partial charges that each polar water molecule will have. (Use + for partial positive and – for partial negative charges.) Then, draw in the hydrogen bonds that will exist because of the attraction between the water molecules. (Use ---- lines to show where the molecules will be attracted.)
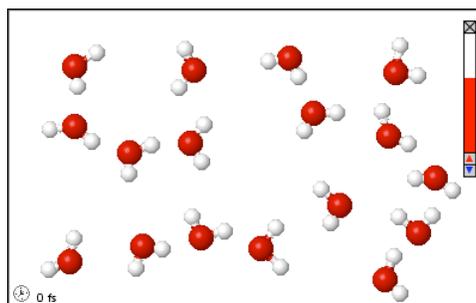
   -Red oxygen atoms are partially negative (-)
   -White hydrogen atoms are partially positive (+)
   -Hydrogen bonds should be shown from the partial negative end of one water molecule to the partial positive end of another with dashed lines.

4. You have two substances: A and B. Both have molecules of similar size and shape. Substance A has molecules that attract with London Dispersion attraction, and substance B has molecules that attract with dipole-dipole attraction. Which one will have the lower boiling point? Explain your answer.
   Substance A. The weaker London Dispersion attractions between the non-polar molecules are overcome more easily than the stronger dipole-dipole attractions between the polar molecules.

5. You have two substances: A and B. Both are attracted with London Dispersion attractions. Substance A is made of short linear molecules. Substance B is made of much longer, curved molecules that fit together tightly. Which substance will experience greater forces of attraction? What does the shape of the molecule have to do with attractive forces?
   Substance B will have a greater force of attraction between molecules. Because they are longer and curved, there are more available locations for attraction between atoms. The shape of the molecule influences the number of regions for attractions to occur and how well molecules can "fit" together.

7. **Career connection:** Nanotechnology is a rapidly developing field, so you will have to search for the latest online. One problem for developing molecular-sized devices is that most molecules carry at least some partial charge and everything tends to be "sticky" at the atomic level. Some people think this may prevent the promises of nanotech futurists from ever coming true. However, some devices may use this very property, such as molecule-sized sensors. http://pubs.acs.org/doi/abs/10.1021/jp910946v