Activity: Examining the Strength of Intermolecular Forces of Attraction

FOR THE TEACHER

Summary
In this activity, students will be able to understand the strength of the attractions of the three intermolecular forces (IMFs) and use this information to help identify physical properties of molecules (such as melting point, boiling point or states of matter).

Grade Level
High School

NGSS Alignment
This activity will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-3**: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS3-2**: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
- **Scientific and Engineering Practices**:
  - Developing and Using Models
  - Analyzing and Interpreting Data

Objectives
By the end of this activity, students should be able to

- Determine the strongest IMF that exists in a sample of molecules.
- Identify the IMF between a set of molecules.
- Organize the IMFs from strongest to weakest between molecules.

Chemistry Topics
This activity supports students’ understanding of

- Intermolecular Forces
- Polarity
- Molecular Modeling
- Molecular Shapes
- States of Matter
- Chemical Properties (melting points/boiling points)

Time
**Teacher Preparation**: 30 minutes
**Lesson**: 30-45 minutes

Materials
- Tissue paper (something of similar strength)
- Cardboard or cardstock paper (manila folders could be used)
- Rulers/yard sticks
- Modeling kits
Safety

- No specific safety precautions need to be observed for this activity.

Teacher Notes

- This activity is best used after already introducing the concepts of molecular modeling, molecular shapes, polarity, and chemical bonding.
- Students should complete the pre-activity questions on the student handout first.
- Next a demonstration will occur in front of the class. 6 students are needed to participate in order to represent the molecules you will be using in the demonstration (these should be the same molecules used in the table for Prior Knowledge Question #2). Alternatively this could be completed as student-led small group activity (3-4 students) rather than in front of the class.
- Prior to the demonstration, the teacher will need to cut one strip of tissue paper and one strip of cardstock (1”-2” thick). It might be a good idea to cut extra pieces, just in case.
- Then you will need one ruler or yardstick for the demonstration.
- Prior to the activity, you should identify 3 molecules that have different IMFs. You may change these based on the level of your students. (Note that the molecules used in this activity/on student sheet are: London Dispersion Force: CH₄, Dipole-Dipole Force: HCl, Hydrogen Bonding: H₂O).
- As you are introducing the activity, have the students identify each molecule you have decided to use and the IMF that would act between those molecules in the sample.
- Now you will ask for 6 volunteers to represent the 6 molecules (2 of each) that you identified and that students have just determined the IMFs for.
- Have two of the students each represent one the molecules that have London Dispersion (example CH₄). Each student will hold an end of the tissue paper. The next two students will represent the molecules that have dipole-dipole forces (example HCl). Each student will hold an end of the cardboard. The final two students will represent the molecules that experience hydrogen bonding (example H₂O) and will hold an end of the yardstick.
- While the student representatives are in front of the class, engage the students in a discussion about heat/molecule movement/kinetic energy. The class should come to conclusion that molecules move faster as they gain kinetic energy. Apply this to the students representing the molecules, so that the students holding the end of the strips should begin to move.
- Important tip: Often the students will move in the same direction as a unit so it is good to ask the question: do molecules move independently? (Students should not move together, but separately causing the papers to move and eventually break in order of tissue paper, cardboard and ruler, (technically the ruler shouldn’t break).
- To demonstrate the varying strength of London Dispersion Forces, one piece of tissue paper could be used for the forces experienced between molecules of CH₄, while 8 pieces of tissue paper could be used for C₈H₁₈ molecules and 25 pieces for C₂₅H₅₂ molecules (other values can be substituted).
- This activity could be used as stepping stone for further discussions involving surface tension, viscosity, melting points, boiling points and reinforcement of LDFs increase with increasing molecular mass/number of electrons.
- Answer key for Student Worksheet available for download.
FOR THE STUDENT
Lesson
Excluding the Strength of Intermolecular Forces of Attraction

Background
Intermolecular forces are the attractions that hold different molecules together to form solids, liquids, and gases. They differ from chemical bonding (ionic and covalent) due to the energy needed to break the attraction between the molecules is less than the energy needed to break the bond between the atoms.

Prior Knowledge Questions
1. In your own words define Intermolecular Forces:

2. Complete the table below for molecules given.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Draw the structure</th>
<th>Name Shape (ex. Tetrahedral)</th>
<th>Polarity of molecule</th>
<th>Identify the strongest IMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (CH₄)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen chloride (HCl)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (H₂O)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Objective
How do we use intermolecular forces to determine which molecule will have a higher melting or boiling point?

Materials
- tissue paper (something of similar strength)
- cardboard or cardstock paper (manila folders)
- rulers/yard sticks
- modeling kits

Demonstration
- Your teacher will lead a demonstration that differentiates between the 3 IMFS.
Post Activity Questions
Directions:
Now we will continue to investigate intermolecular forces by visiting the simulation:
Comparing Attractive Forces (URL: https://teachchemistry.org/periodical/issues/november-2014/comparing-attractive-forces)

1. Click on top molecules H₂. By clicking on Star and dragging it to right, make some observations.
   a. Observe how difficult it is to pull the molecules apart:
   b. What intermolecular force holds the molecules together?

2. Let’s look at another molecule, click on molecules Br₂. By clicking on Star and dragging it to right, make some observations.
   a. Observe how difficult it is to pull the molecules apart:
   b. What intermolecular force holds the molecules together?

3. Click on molecules HBr. By clicking on Star and dragging it to right, make some observations.
   a. Observe how difficult it is to pull the molecules apart:
   b. What intermolecular force holds the molecules together?

4. Click on final set of molecules H₂ and HBr. By clicking on Star and dragging it to right, make observations.
   a. Observe how difficult it is to pull the molecules apart:
   b. What intermolecular force holds the molecules together?

5. What conclusions can you draw from what you saw from the demonstration and the simulation regarding intermolecular forces?

6. Explain which molecule (methane, hydrogen chloride or water) has the highest melting point.

Extension:
7. So we know that London Dispersion Forces increase with increasing molecular mass, how can we use the materials from the demonstration (tissue paper, cardboard and rulers) to show the increasing of the LDFs attraction. (Note: use CH₄, C₈H₁₈ and C₂₅H₅₂ as molecules in your explanation.)

8. Determine in the following pairs, which compound has the higher boiling point and explain why.
   a. H₂S or H₂O
   b. NH₃ or CH₃OH
   c. Br₂ or C₁₀H₂₂
9. Ethanol (C$_2$H$_5$OH) has a melting point of -114°C and octane (C$_8$H$_{18}$) has a melting point of -57°C, explain why.

10. Determine the IMFs for the following molecules:
    a. CCl$_4$
    b. HF
    c. CH$_3$NH$_2$
    d. SF$_2$
    e. Put the above molecules in order of increasing strength of IMFs.

11. Explore some common phenomena that are due to intermolecular forces. Present the information to your class. Ideas to explore: surface tension, viscosity, cohesion, adhesion, why substances are solid, liquids or gases at room temperature, why certain substances mix together and others do not.