Activity: Comparing Attractive Forces

FOR THE TEACHER

Summary
In this activity, students will use a simulation to investigate different types of intermolecular forces (London dispersion and dipole-dipole). In the analysis that follows the activity, they will relate IMFs (including hydrogen bonding) to physical properties (boiling point and solubility).

Grade Level
High School

AP Chemistry Curriculum Framework
This activity supports the following units, topics and learning objectives:

- **Unit 2: Molecular and Ionic Compound Structure and Properties**
  - **Topic 2.1:** Types of Chemical Bonds
    - **SAP-3.A:** Explain the relationship between the type of bonding and the properties of the elements participating in the bond.
  - **Topic 2.7:** VSEPR and Bond Hybridization
    - **SAP-4.C:** Based on the relationship between Lewis diagrams, VSEPR theory, bond orders, and bond polarities:
      a. Explain structural properties of molecules.
      b. Explain electron properties of molecules.

- **Unit 3: Intermolecular Forces and Properties**
  - **Topic 3.1:** Intermolecular Forces
    - **SAP-5.A:** Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when:
      a. The molecules are of the same chemical species.
      b. The molecules are of two different chemical species.
  - **Topic 3.8:** Representations of Solutions
    - **SPQ-3.B:** Using particulate models for mixtures:
      a. Represent interactions between components.
      b. Represent concentrations of components.
  - **Topic 3.10:** Solubility
    - **SPQ-3.C:** Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.

- **Unit 4: Chemical Reactions**
  - **Topic 4.1:** Introduction for Reactions
    - **TRA-1.A:** Identify evidence of chemical and physical changes in matter.

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

- Better understand the relative strengths of intermolecular forces.
- Relate intermolecular forces to physical properties.
Chemistry Topics
This activity supports students’ understanding of
- Intermolecular forces
- Physical properties

Time
Teacher Preparation: 10 minutes
Lesson: 30 minutes

Materials
- Computer with internet connection

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

Teacher Notes
- This lesson is most effective if students have some prior knowledge about the following:
  - Intermolecular forces (IMFs)
  - Electronegativity
  - Polarity
  - How physical properties relate to IMFs
- To introduce the general concept of dipole-dipole forces vs. London dispersion forces, you can use the Molecular Workbench simulation called Comparing Dipole-Dipole to London Dispersion.
- To further investigate hydrogen bonding, you can use the Molecular Workbench simulation called Hydrogen Bonds: A Special Type of Attraction.
FOR THE STUDENT

Lesson

Intermolecular Forces

Background
Compounds interact with each other differently depending on their polarity. These interactions are called intermolecular forces (IMFs), and physical properties of compounds can be inferred by the type of IMFs. In this activity, you will have the opportunity to “feel” the strength of different intermolecular forces with the help of a computer simulation, and then you will consider what that means about some of the compounds’ physical properties. Remember, the IMFs are hydrogen bonds, dipole-dipole interactions, induced dipole attraction, and London dispersion forces.

Procedure
2. From the dropdown menu “select a pair of molecules” choose “pull apart Br₂ and Br₂.”
3. Predict how difficult it will be to pull apart the two molecules in the data table.
4. Using the green star, move one Br₂ away from the other. Comment on how easy or difficult this was in the data table.
5. From the dropdown menu, choose “pull apart H₂ and H₂.”
6. Predict how difficult it will be to pull apart the two molecules in the data table.
7. Using the green star, move one H₂ away from the other. Comment on how easy or difficult this was in the data table.
8. From the dropdown menu, choose “pull apart HBr and HBr.”
9. Predict how difficult it will be to pull apart the two molecules in the data table.
10. Using the green star, move one HBr away from the other. Comment on how easy or difficult this was in the data table.
11. From the dropdown menu, choose “pull apart Br₂ and HBr.”
12. Predict how difficult it will be to pull apart the two molecules in the data table.
13. Using the green star, move Br₂ away from HBr. Comment on how easy or difficult this was in the data table.
14. In the last two columns, determine whether the molecules are polar or nonpolar and identify the type of intermolecular forces the molecules exhibit.

Data

<table>
<thead>
<tr>
<th>Molecules</th>
<th>Predict</th>
<th>Actual</th>
<th>Polar/nonpolar?</th>
<th>IMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Br₂ &amp; Br₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂ &amp; H₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HBr &amp; HBr</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Br₂ &amp; HBr</td>
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</tr>
</tbody>
</table>

Analysis
1. Explain why you classified the intermolecular forces the way you did for each pair of molecules taking into account polarity.
   a. Br₂ & Br₂
   b. H₂ & H₂
   c. HBr & HBr
   d. Br₂ & HBr
2. If you had samples of HBr(aq) and Br₂(l) in real life and you mixed them together, would you expect them to mix or separate into two layers? Explain.
3. If HF was used in the simulation instead of HBr, how easy or difficult would it be to separate the molecules? What kind of polarity and IMFs would the molecules experience? Complete the following data table with your predictions:

<table>
<thead>
<tr>
<th>Molecules</th>
<th>Predict</th>
<th>Polar/nonpolar</th>
<th>IMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Br₂ &amp; Br₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HF &amp; HF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Br₂ &amp; HF</td>
<td></td>
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</tr>
</tbody>
</table>

Explain your IMF classifications, taking into account polarity.

4. How would you expect HF’s boiling point to compare to HBr? Explain. You can use the Molecular Workbench simulation [Boiling Point](http://bit.ly/1xEty5j) to help you.

5. If F₂ was used in the simulation instead of Br₂, how easy or difficult would it be to separate the molecules? What kind of polarity and IMFs would the molecules experience? Complete the following data table with your predictions:

<table>
<thead>
<tr>
<th>Molecules</th>
<th>Predict</th>
<th>Polar/nonpolar</th>
<th>IMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₂ &amp; F₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HBr &amp; HBr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F₂ &amp; HBr</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Explain your IMF classifications, taking into account polarity.

6. How would you expect F₂’s boiling point to compare to Br₂? Explain.
7. How would you expect HBr’s boiling point to compare to Br₂? Explain.
8. Consider the familiar compound water (H₂O). How would water’s boiling point compare to HBr and HF? Explain.
9. Look up the boiling points of H₂O, Br₂, F₂, HBr, and HF. Were your predictions correct? Explain.
10. Of the two original compounds you investigated in the simulation (HBr and Br₂), which would be soluble in water? Explain.
11. Rank the vapor pressures of water, HBr, and HF from lowest to highest. Explain.

**Conclusion**

When considering physical properties, are IMFs the only factor to consider? Explain.