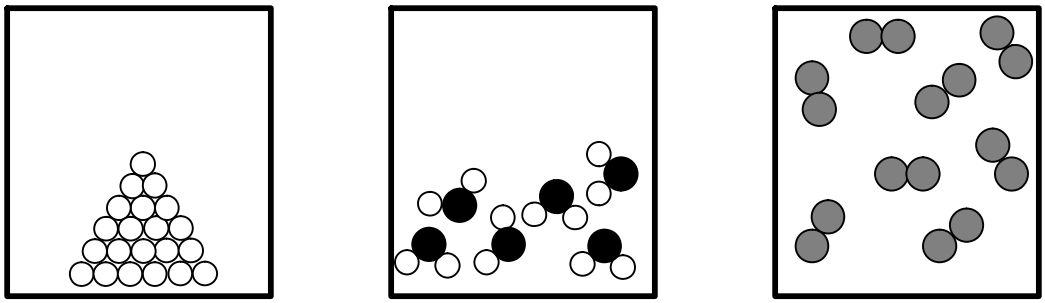
# Intermolecular Forces

The interactions BETWEEN molecules

## Model 1



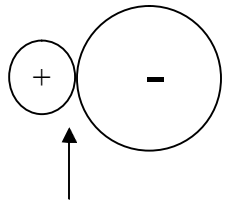
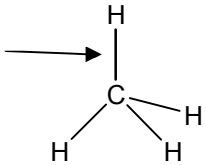
Q1. Label the diagrams above according to which physical state is represented: gas, solid, or liquid.

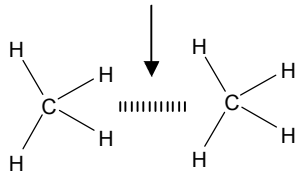
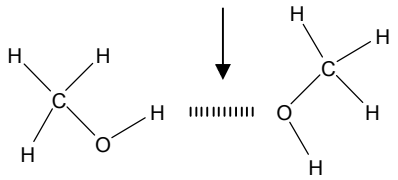
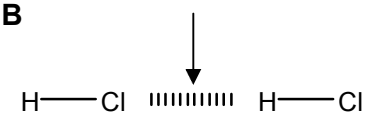
Q2. In which physical state(s) are the attractions between the individual particles (atoms or molecules) stronger?

Q3. In which physical state is the attraction between the individual particles (atoms or molecules) weakest?

**This activity will be based on the attractions *between* particles (ions, atoms, molecules). These attractions are called "Intermolecular forces", or "Non-covalent interactions."**

## Table 1: Types of bonds and their approximate energies

| Diagram of the bond (Two groups, A and B) | Type of bond | Approximate bond energy, kJ/mol |
|---|---|---|
| **Group A**   | Ionic | 800 |
| **Group A**   | Covalent | 400 |

| | | |
|---|---|---|
| **Group B**  | London dispersion force | 10 |
| **Group B**  | Hydrogen bond | 40 |
| **Group B**  | Dipole-Dipole Interaction | 25 |

Q4. Intermolecular forces are non-covalent interactions between molecules. Which group consists **only** of intermolecular forces, Group A or B?

Q5. List the bonds (Group A) and types of interactions (Group B) in order of increasing strength.

Q6. Which are stronger, Group A bonds or Group B bonds?

Q7. When you are boiling water, which bonds do you think are breaking:

a) covalent bonds between oxygen and hydrogen atoms, or

b) intermolecular forces between water molecules

Melting points (mp) and boiling points (bp) are usually good indicators of how strong the intermolecular forces are that exist within a substance.

## Table 2: Selected boiling points

| Molecule | bp (ºC) |
|---|---|
| $CH_4$ | -161 |
| $C_2H_6$ | -88 |
| HCl | -80 |
| HF | 20 |
| $H_2O$ | 100 |

Q8. Assign each molecule in Table 2 above as either polar or nonpolar.

Q9. Complete the following:

The more polar the molecule, the _____ (higher or lower) its bp.

Q10. Complete the following:

The more polar the molecule, the _____ (stronger or weaker) its intermolecular forces.

Q11. Which do you predict will have a higher bp, $CO_2$ or CO? Explain.

## Table 3: Selected physical properties data

| Molecule | bp (ºC) | mp (ºC) |
|---|---|---|
| $F_2$ | -188 | -220 |
| $Cl_2$ | -34 | 172 |
| $Br_2$ | 59 | 266 |
| $I_2$ | 184 | 387 |

Q12. a)Assign each molecule above as solid, liquid, or gas at room temperature (25ºC).

b) Based on your answer to Part a, which element in Table 3 must have the strongest intermolecular forces?

Q13. Assign each molecule above as polar or non-polar.

Q14. Is there a relationship between polarity and bp here, as there was in Table 2?

Q15. What is the relationship between molecular weight and boiling point?

Q16. Complete the following:

As the molar mass of a compound increases, the strength of its intermolecular forces _____ (increases or decreases).

## Table 4: Selected boiling points

| Element | bp (ºC) | Compound | bp (ºC) |
|---|---|---|---|
| He | -269 | $CH_4$ | -161 |
| Ne | -246 | $C_2H_6$ | -88 |
| Ar | -186 | $C_3H_8$ | -42 |
| Kr | -152 | $C_4H_{10}$ | 0 |

Q17. Does the statement you completed in the previous question agree also with the data presented in Table 4 above?

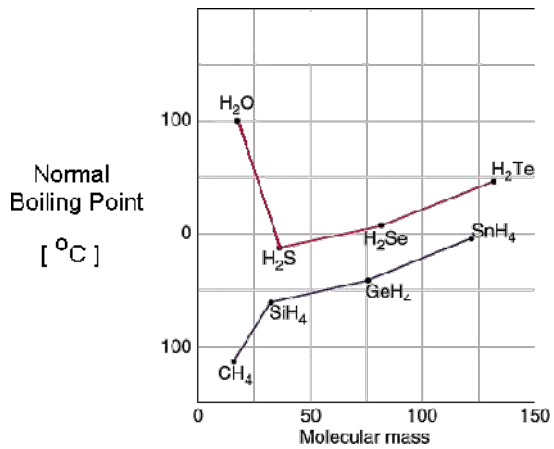
Q18. According to Graph 1 (at right):

a) In which substance are there stronger intermolecular forces, $SnH_4$, or $CH_4$?

b) How can you tell based on the graph?

c) Explain based on what you have learned so far why your choice should have stronger intermolecular forces.
(Hint: Think about polarity and/or molar mass)
Use one or two complete sentences.

**Graph 1: Selected boiling points vs. molar mass**



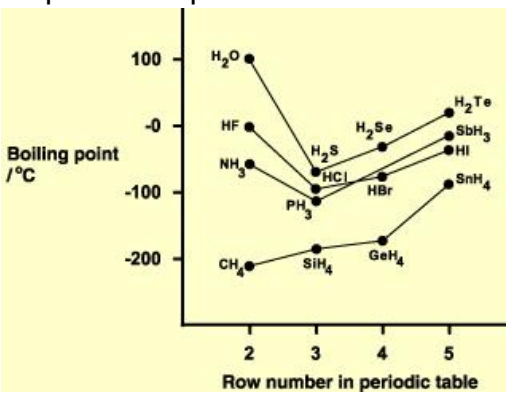

Q19. The bottom line in Graph 1 shows one trend, and the top line in Graph 1 shows a very different trend.

a) Which has stronger intermolecular forces, $H_2S$ or $H_2O$?

b) Explain why. (Mostly due to polarity OR molar mass?) Use one or two complete sentences.

Q20. We see similar trends with other compounds.

Graph 2: Selected boiling points vs. period




a) Which three compounds deviate from the linear relationship that seems to be present between bp and row number (in Graph 2)?

b) This indicates that the three compounds listed in part a have _____ (stronger or weaker) intermolecular forces than expected.

c) Besides H, which other elements are in these three compounds?

d) Complete the following:

| |
|---|
| Compounds containing a hydrogen atom bonded to the elements<br><br>_____, ____, and _____ form very strong intermolecular forces.<br><br>**These forces are called hydrogen bonds.** |

e) Are hydrogen bonds the same as covalent bonds between H and another element? (See Table 1).

If not, are hydrogen bonds stronger than covalent bonds? (See Table 1).

Q21. Compare the boiling points of $NH_3$ and $SbH_3$ in Graph 2.

a) Which is more polar, $NH_3$ or $SbH_3$?

b) Which can hydrogen bond, $NH_3$ or $SbH_3$?

c) Based on polarity and hydrogen bonding, which do you expect should have the stronger intermolecular forces?

d) Which is shown in Graph 2 to have stronger intermolecular forces?

e) Provide an explanation.

## Exercises

This activity is based on sections 9.6 on non-covalent interactions (intermolecular forces). Refer to these sections for additional reading. I also recommend the in-chapter exercises and problem boxes in Sec. 9.6 (p. 409-418) and Questions for Review and Thought (Chapter 9: # 54-62 (bold).

Answer key to this activity will be posted online.