

Activity 25: The Attractive Forces

Learning Objectives

Part 1 *Recognize trends between boiling and melting points and the attractive forces present*

Recognize molecules that can form hydrogen bonds with themselves or with water

Draw hydrogen bonds between molecules

Recognize that the physical properties of viscosity and surface tension are also affected by attractive forces present

Part 2 *Characterize and identify the attractive forces present between molecules*

Part 3 *Use the attractive forces found in a molecule to predict its solubility in water*

Draw a fatty acid micelle in cartoon representation

Estimated Completion Time

Part 1—45 Minutes; Part 2—30 Minutes;
Part 3—60 Minutes

Instructor Information

Part 1. This is the first exposure to attractive forces between condensed phases of matter. I prefer the term *attractive force* rather than *intermolecular forces* because ionic and ion–dipole forces are also introduced here. At first, students will be uncomfortable not knowing the definitions of the attractive forces shown. However, the activity can be completed by observing the trends in Table 1 and reading the extra information provided in the questions. Question 10 of Part 1 is a demonstration of surface tension which can be used if time permits.

Part 2. This activity defines the attractive forces reinforcing their nature.

Part 3. The attractive forces are now applied to solubility. The predictions made here should be noted to be on a continuum of highly soluble to not highly soluble. Fatty acids are introduced in the questioning to extend the concept and introduce amphiphiles.

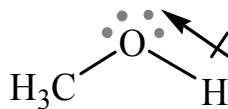
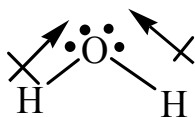
ANSWERS TO QUESTIONS

Part 1. Attractive Forces and Physical Properties

- a. $\sim 20\text{ }^{\circ}\text{C}$ b. Liquid c. Above d. Below
- Higher
- Solid
- Gases: methane; liquids: 2,3-Dimethylbutane, hexane, chloroform, acetone, methanol, water, ethylene glycol, and glycerol.
-

| Phase of Matter at Room Temperature | Boiling Point vs. Room Temperature | Melting Point vs. Room Temperature |
|-------------------------------------|------------------------------------|------------------------------------|
| Solid | Above | Above |
| Liquid | Above | Below |
| Gas | Below | Below |

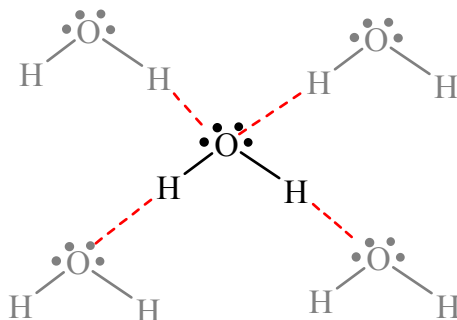
- a. Strongest: Ionic; Weakest: London b. Hexane, 2,3-dimethylbutane, and methane
- a. Both have the molecular formula C_6H_{14} .
b. Students should recognize that their overall shape is different.
c. For alkanes with the same molecular formula, the more branched the molecule, the lower the boiling point. The longer the chain, the higher the boiling point.
- a. Water
b. Water—hydrogen bonding; methanol—hydrogen bonding; methane—London forces
c.



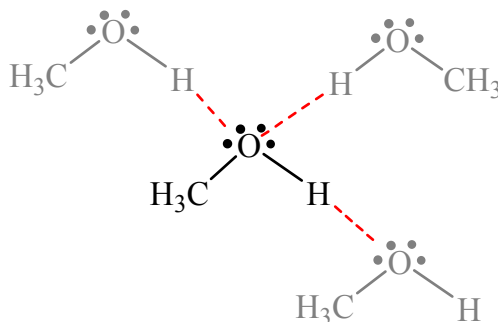
d. From letter c, they could say that the more polar the molecule is, the higher its boiling point.

e. i. 2; 1 ii. 2; 2 iii. 4; 3

iv.



v.



vi. Both water and methanol have hydrogen bonding as their strongest attractive force. One water molecule can make up to four hydrogen bonds with neighboring water molecules, whereas one methanol molecule can only make up to three hydrogen bonds with neighboring methanol molecules. Because there are more hydrogen bonds per molecule possible in water, the amount of energy needed to send a single water molecule into the gas phase is greater than that of methanol. That is, breaking four hydrogen bonds (water) takes more energy than breaking three (methanol).

9. Yes. The stronger and more numerous the attractive forces, the higher the boiling and melting points of the substance.

10. a. Honey
- b. Both sugars and water contain OH bonds and can hydrogen bond. However a molecule of fructose or glucose can form many more hydrogen bonds than a molecule of water (4), which gives honey a higher viscosity.
- c. When the soap is added to the water, the hydrogen bonding network of the water molecules is disrupted and the surface tension lessens.

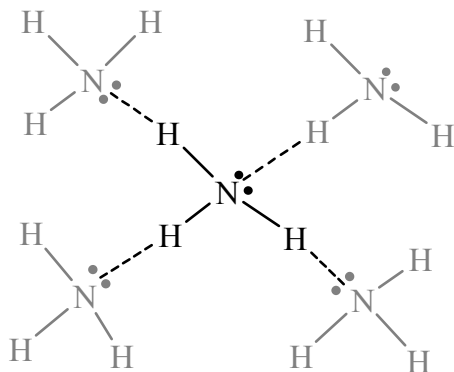
Activity 25: Skill Development—Attractive Forces and Physical Properties

1. a. CH_3OH b. *n*-butane c. CH_3OH
2. Highest: 1-butanol; lowest: *n*-butane. The molecule with the strongest attractive forces between molecules will have the highest boiling point. 1-butanol can H-bond (strongest attractive force present), while *n*-butane only has London forces present (weakest attractive force). Diethylether (first molecule) is polar but cannot H-bond to itself, so its boiling point is predicted to be between the other two.
3. Methanol (BP = 65°C) contains the attractive force H-bonding which is the strongest force present in the three molecules shown. Methane is nonpolar and contains only the weak London force. Fluoromethane is polar and possesses a dipole–dipole interaction having intermediate strength.
4. Aminomethane (BP = -6°C) contains the attractive force H-bonding which is the strongest force present in the three molecules shown. Ethane is nonpolar and contains only the weak London force. Chloromethane is polar and possesses a dipole–dipole interaction having intermediate strength.

Part 2. Characterizing the Attractive Forces

1. Ionic; London force
2. All the attractions are between oppositely charged areas of compounds.
3. According to the table, a formal +/– attraction is stronger.
4. The London force

5. The London force
6. One NH_3 can make up to four H-bonds to neighboring ammonia molecules



7. a. London force b. hydrogen bonding c. dipole–dipole
d. hydrogen bonding

Activity 25: Skill Development— Characterizing the Attractive Forces

1. a. CH_4 . The strongest attractive force in H_2O is hydrogen bonding, in CH_4 it is the London force.
b. CO_2 . CO_2 is a nonpolar molecule, so its strongest attractive force is the London force. The strongest attractive force in NH_3 is hydrogen bonding.
c. Acetone (molecule on left). Acetone only has dipole–dipole forces, while acetic acid can H-bond.
d. CH_3COOH . In theory, if the solution was only acetic acid molecules, it would not have any ion–dipole forces and would have hydrogen bonding as its strongest attractive force. Acetate ions would form ion–dipole attractions that are stronger than hydrogen bonds.
2. a. $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$. The strongest attractive force in methanol is hydrogen bonding, and the strongest attractive force in the molecule shown (diethyl ether) is dipole–dipole.
b. $\text{N}(\text{CH}_3)_3$. The strongest attractive force in CH_3NH_2 is hydrogen bonding, and the strongest attractive force in $\text{N}(\text{CH}_3)_3$ is dipole–dipole.

- c. $\text{CH}_3\text{CH}_2\text{CH}_3$. The strongest attractive force in $\text{H}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_3$ is dipole–dipole, and the strongest attractive force in $\text{CH}_3\text{CH}_2\text{CH}_3$ is the London force.
- d. CH_3OH . The strongest attractive force in the first molecule is ionic, and the strongest attractive force in CH_3OH is hydrogen bonding.

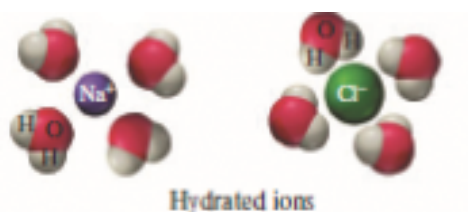
3. The London force
4. The dipole found in the London force exists only temporarily. The dipole of a dipole–dipole attraction is permanent and therefore stronger.
5. Yes, a water molecule can H-bond to acetone.
6. No. Even though CO_2 has polar bonds, its dipole is only temporary, and therefore a H-bond cannot form between water and CO_2 . (This could be a very complex answer for the inquisitive student.)

Part 3. Attractive Forces and Solubility

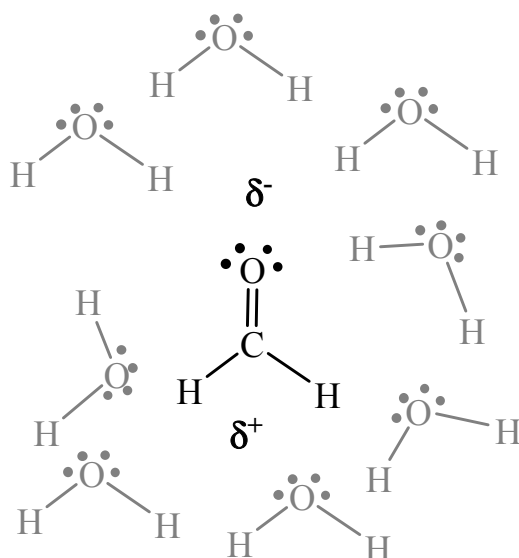
1. Students will likely be sure that NaCl and sucrose dissolve in water and that vegetable oil does not. There will be some debate over whether soap dissolves in water. This is okay at this point.
2. Water is a polar covalent compound.
3. The polarity. The compounds that dissolve in water are either ionic (have a formal charge) or polar.
4.
 - a. mainly polar, yes
 - b. mainly polar, yes
 - c. Ionic, yes
 - d. Nonpolar hydrocarbon, no
 - e. Mainly nonpolar, no

(Discussion of the answers to this question provides an opportunity to bring up the idea of partial solubility.)

5. Cations are surrounded by the negative dipole of water molecules; anions are surrounded by the positive dipoles of water molecules. See the accompanying figure.

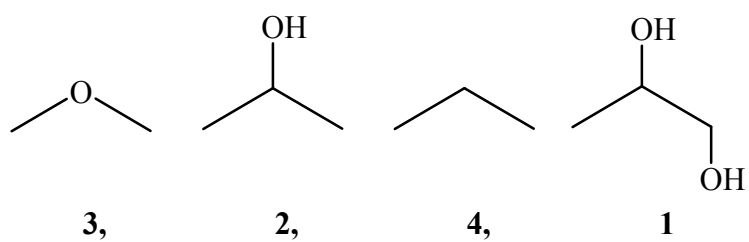


6. The partially positive side (δ^+) of the formaldehyde is surrounded by the positive dipoles of water, and the partially negative side (δ^-) of the formaldehyde is surrounded by the negative dipoles of water. An example is shown.

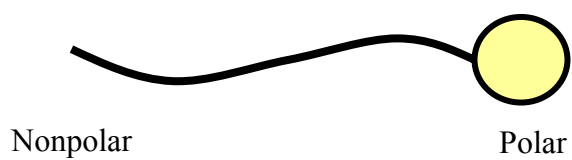


7. Pentolinium—likely soluble. Ionic charges are distributed across the molecule.
 Remeron—not likely soluble. Although there are a few polar nitrogen atoms, the bulk of the molecule is nonpolar.
 Methamphetamine—not likely soluble. There is one hydrogen bonding donor and acceptor, but the majority of the molecule is nonpolar.
 (The discussion of this question lends itself to question 4.)
8. The more numerous and alike the attractive forces of an organic molecule are to water, the more likely they are soluble in water. Alternatively, the more polar or ionic an organic molecule is, the more likely the molecule is to be soluble in water.

9.

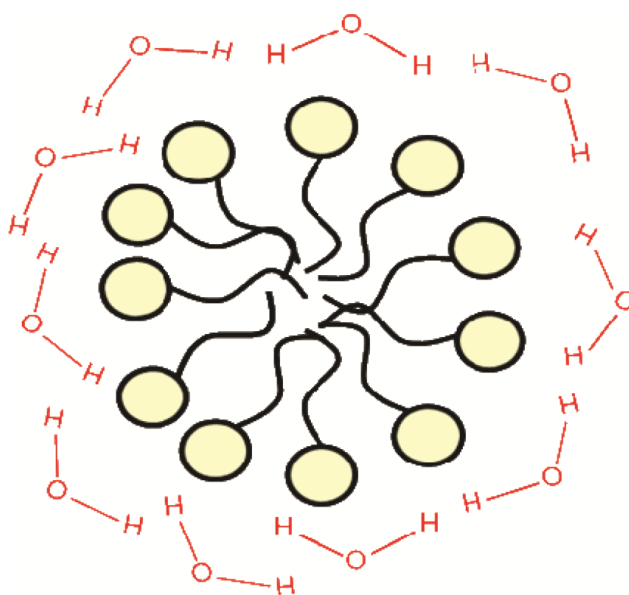


10. a.



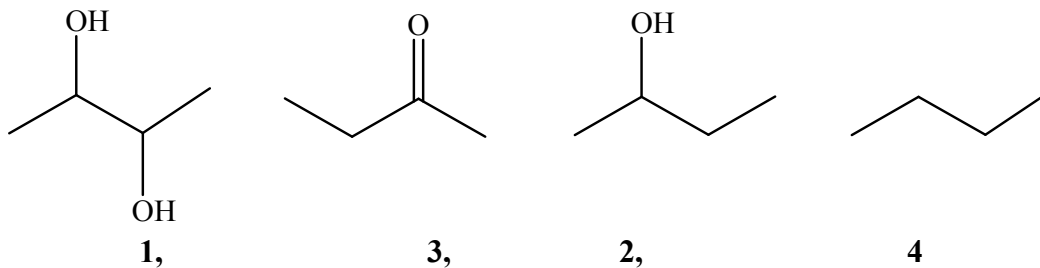
b. No

c.

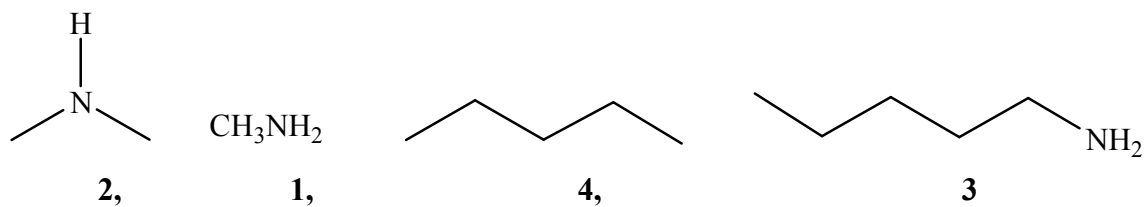


Activity 25: Skill Development— Attractive Forces and Solubility

1.



2.



3. a. c) form micelles b. b) be insoluble c. a) be soluble
d. c) form micelles e. b) be insoluble