

MODULE: Intermolecular Forces (IMF) and Acid Base Reactions

LESSON 1: Intermolecular Forces

STANDARD (S) & INDICATOR (S):

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.

OBJECTIVE (S): Students will be able to:

1. Rank molecules in order of increasing IMF strength.
2. Draw the interactions of multiple molecules of a compound.
3. Determine the type of intermolecular forces between the molecules of each solvent using their molecular structures

INTRODUCTION:

All molecules have London dispersion forces (Van der Waals) due to the movement of electrons. As electrons move around the nucleus, they aren't always distributed evenly, causing somewhat of a charge distribution. Slightly positive sides of a molecule are attracted to the slightly negative sides of another molecule. This is the weakest intermolecular force.

Dipole-dipole forces occur between molecules that are polar. In polar molecules the electrons are unevenly distributed because some elements are more electronegative than others. The partial negative side of one molecule is attracted to the partial positive side of another molecule. This type of force is stronger than London dispersion forces because polar molecules have a permanent uneven distribution of electrons.

Hydrogen bonding is a misnomer, as it is also an intermolecular force and not a bond. It is the strongest intermolecular force. It is a special kind of dipole-dipole interaction that occurs when a hydrogen atom is bonded to fluorine, oxygen, or nitrogen. (Remember it by: hydrogen bonding is FON). Because hydrogen doesn't hold its electrons closely, it has a partial positive and fluorine; oxygen or nitrogen is partially negative. The oppositely charged sides of the molecules are attracted to one another.

MATERIALS:

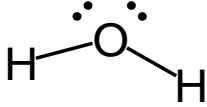
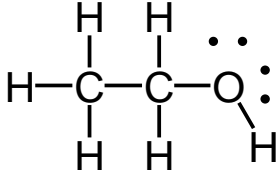
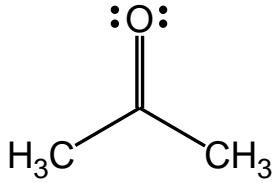
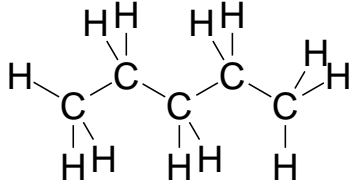
- Water
- Ethanol
- Acetone
- Pentane
- Pennies

BACKGROUND INFORMATION:

1. Student knows the difference between ionic and covalent bonding.
2. Student can determine if a molecule is polar or not.
3. Student knows the various intermolecular forces and their strengths

CLASSROOM ACTIVITY DESCRIPTION (LABORATORY/EXERCISES/PROBLEMS) including detailed procedures:

1. Workings in pairs determine the number of drops a penny can hold for each of the 4 solvents (water, ethanol, acetone, pentane). Insert your data in the table below.
2. On the table above you can circle, triangle, and/or box (\circ , Δ , \square) the locations on the solvent molecules that the intermolecular forces will act.
3. Share your data with the rest of the class. Insert your data in the table below.

	Structural Diagram	London Dispersion Forces (O)	Dipole-Dipole (Δ)	Hydrogen Bonding (\square)	# of Drops on Penny
Water H_2O					
Ethanol CH_3CH_2O H					
Acetone CH_3COC H_3					
Pentane C_5H_{12}					

ANSWER THE FOLLOWING QUESTIONS:

- Which type of IMF is predominant in water? Why?
- Which type of IMF is predominant in pentane? Why?
- Which type of IMF is predominant in acetone? Why?
- Place the solvents (liquids) in order of increasing IMF. Explain your reasoning.
- Did your data support your answer to number 4?
- Determine which solvent can hold more drops on the penny, and using intermolecular forces concept and molecular formula and structure explain why.

7. On page 6 draw how 4 molecules of water would interact. Do the same for ethanol and acetone. Please attach your papers to your lab before you hand it in.

HOMEWORK PROBLEMS:

- Determine the intermolecular forces available between each of the listed substances (mark yes or no in each cell).
- Think about intermolecular forces and intramolecular forces. Which are stronger? Why?

Substance	Polar or Nonpolar	London Dispersion Forces	Dipole-Dipole Forces	Hydrogen Bonding
$\text{H}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{F}}}$				
$\begin{array}{ccccc} & \text{H} & \text{H} & \text{H} & \\ & & & & \\ \text{H} & -\text{C} & -\text{C} & -\text{C} & -\text{H} \\ & & & & \\ & \text{H} & \text{H} & \text{H} & \end{array}$				
$\begin{array}{c} \text{H} \\ \diagdown \\ \text{C} = \overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{O}}} \\ \diagup \\ \text{H} \end{array}$				
$\begin{array}{c} \cdot\cdot \\ \\ \text{H}-\text{N}-\text{H} \\ \\ \text{H} \end{array}$				

Grading Rubric:

Class participation (5 points)

Team work (5 points)

Correct answer with scientific analysis (15 points)

Questions # 7 (5 points)

Total Grade = 30 points

REFERENCES: <http://sites.jmu.edu/chemdemo>

MODULE: Intermolecular Forces (IMF) and Acid Base Reactions

LESSON 1: Acids and Bases

STANDARD (S) & INDICATOR (S):

5-PS1-3. Make observations and measurements to identify materials based on their properties.

OBJECTIVE (S):

 Students will be able to:

1. Explain what an indicator is and its role in acidic and basic solutions.
2. Explain the difference between pH and pOH.
3. Examine how the pH scale works and what it signifies using the result of part two of this activity.
4. Calculate pH and pOH from concentrations of acids and bases respectively and vice versa.
5. Create a pH scale for an indicator

INTRODUCTION:

Acids and bases are important in numerous chemical processes that occur around us, from industrial to biological processes, from the laboratory to the environment. According to Arrhenius definition, acids are compounds that produce H^+ (Hydrogen ion) in water and bases are compounds that produce OH^- (Hydroxide ion) in water. The strength of acidity and basicity depends on the amount of hydrogen ions and hydroxide ions produced. To qualitatively determine if a solution is acidic or basic, indicators are used. An indicator is a large organic molecule that works somewhat like a "color dye". Whereas most dyes do not change color with the amount of acid or base present, there are many molecules, known as **acid - base indicators**, which do respond to a change in the hydrogen ion concentration. Most of the indicators are themselves weak acids.

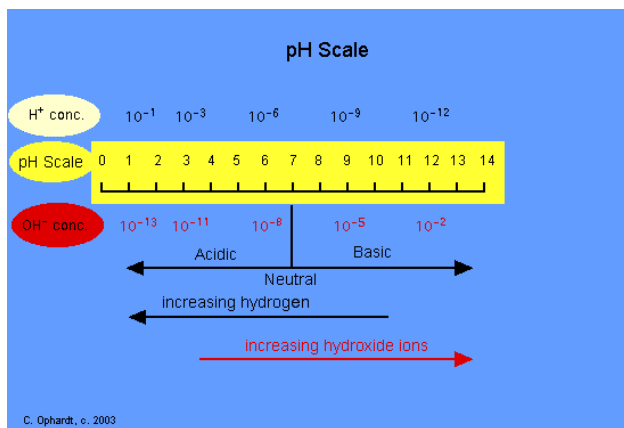
To measure or calculate strength of acidity in a solution quantitatively, a mathematical function known as pH (power of hydrogen) is used. To calculate the pH of an aqueous solution you need to know the concentration of the hydronium ions in moles per liter (Molarity). The pH is then calculated using the expression:

$$pH = -\log [H_3O^+].$$

Example: Find the pH of a 0.0025 M HCl solution. The HCl is a strong acid and is 100% ionized in water. The hydronium ion concentration is 0.0025 M. Thus:

$$pH = -\log (0.0025) = -(-2.60) = 2.60$$

The pH scale ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic. A pH greater than 7 is basic.



<http://www.elmhurst.edu/~chm/vchembook/184ph.html>

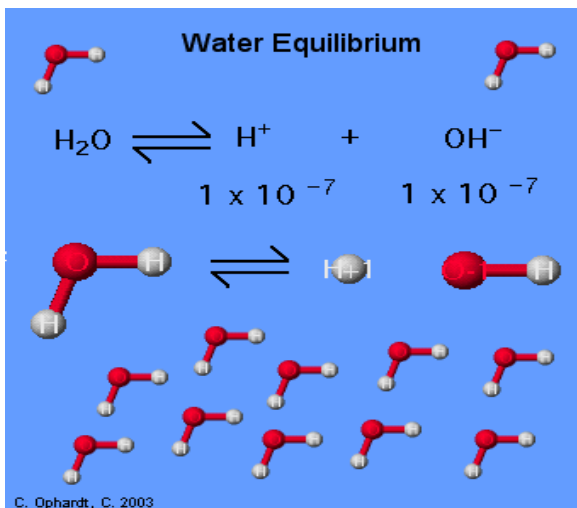
To calculate the pOH of a solution, which determines the strength of basicity of a solution, you need to

know the concentration of the hydroxide ions in moles per liter (Molarity). The pOH is then calculated using the expression:

$$\text{pOH} = -\log [\text{OH}^-]$$

Example: What is the pOH of a solution that has a hydroxide ion concentration of $4.82 \times 10^{-5} \text{ M}$?

$$\text{pOH} = -\log [4.82 \times 10^{-5}] = -(-4.32) = 4.32$$



<http://www.elmhurst.edu/~chm/vchembook/184ph.html>

Water dissociates into H^+ ion or H_3O^+ ion and OH^- ion as depicted in the figure above where the concentration of hydrogen ions are equal to hydroxide ions.

$$[\text{H}^+] = [\text{OH}^-] = 1 \times 10^{-7}$$

$$\begin{aligned} \text{pOH} &= -\log [\text{OH}^-] = -\log [1 \times 10^{-7}] = 7 \\ \text{pH} &= -\log [\text{H}_3\text{O}^+] = -\log [1 \times 10^{-7}] = 7 \end{aligned}$$

Therefore pH and pOH of a water solution at 25°C are related by the following equation.

$$\text{pH} + \text{pOH} = 14$$

If either the pH or the pOH of a solution is determined using a pH electrode, the other can be quickly calculated.

Example: A solution has a pOH of 11.76. What is the pH of this solution?

$$\text{pH} = 14 - \text{pOH} = 14 - 11.76 = 2.24$$

Calculating the Hydronium Ion Concentration from pH

The hydronium ion concentration can be found from the pH by the reverse of the mathematical operation employed to find the pH.

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} \text{ or } [\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH})$$

Example: What is the hydronium ion concentration in a solution that has a pH of 8.34?

$$\begin{aligned} 8.34 &= -\log [\text{H}_3\text{O}^+] \\ -8.34 &= \log [\text{H}_3\text{O}^+] \\ [\text{H}_3\text{O}^+] &= 10^{-8.34} = 4.57 \times 10^{-9} \text{ M} \end{aligned}$$

On a calculator, calculate $10^{-8.34}$, or "inverse" log (- 8.34).

Calculating the Hydroxide Ion Concentration from pOH

The hydroxide ion concentration can be found from the pOH by the reverse mathematical operation employed to find the pOH.

$$[\text{OH}^-] = 10^{-\text{pOH}} \text{ or } [\text{OH}^-] = \text{antilog} (-\text{pOH})$$

Example: What is the hydroxide ion concentration in a solution that has a pOH of 5.70?

$$5.70 = -\log [\text{OH}^-] \quad -5.70 = \log [\text{OH}^-] \quad [\text{OH}^-] = 10^{-5.70} = 2.00 \times 10^{-6} \text{ M}$$

On a calculator calculate $10^{-5.70}$, or "inverse" log (- 5.70).

MATERIALS:

1. Red cabbage
2. Knife
3. Cutting board
4. 600 mL beaker
5. 250 mL beaker
6. Hot plate
7. Cheesecloth
8. Funnel
9. Water
10. Small evaporating dishes
11. Solutions of varying pH (NaCl, Na₂CO₃, NaOH, HCl, borax, HC₂H₃O₂, baking soda)
12. Colored pencils or markers

BACKGROUND INFORMATION:

1. Student has had math experience with logarithms.
2. Student can graph on calculators and determine a line of best fit.

SAFETY:

1. The beaker on the hot plate will be very hot. Safety goggles should be worn at all times.
2. Cabbage doesn't have the most pleasant smell. The indicator can stain, so gloves and aprons are advised.

CLASSROOM ACTIVITY DESCRIPTION (LABORATORY/EXERCISES/PROBLEMS)

including detailed procedures:

Part 1- Indicator

1. Fill the 250mL beaker full of water and heat it on a hot plate.
2. Carefully Chop up some cabbage with the knife on the cutting board into small pieces, they don't have to be fine or even of uniform size, and place into the 600mL beaker.
3. Add the hot water to the large beaker, and allow soaking for a few minutes.
4. Place the cheesecloth into a funnel, and filter the liquid through the funnel into a bottle to keep. Discard the cabbage into the trash.
5. Obtain 7 x 20 mL test tubes and label them numerically according the table below.

Test Tube	Solution	pH (using pH meter)	Color with indicator	Acid (A) Base (B)
1	NaCl			
2	Na ₂ CO ₃			
3	NaOH,			
4	HCl,			
5	Borax			
6	HC ₂ H ₃ O			
7	Baking soda			

- Place 5 ml of each solution (NaCl, Na₂CO₃, NaOH, HCl, borax, HC₂H₃O₂, baking soda) into each designated test tube.
- Measure pH of each solution using a pH meter and record them in the table above.
- Determine if the solution is acidic or basic using the pH scale and record it in the table above using 'A' for Acid, and 'B' for Base.
- Add 1mL of the indicator (Red Cabbage Juice) to each test tube. Fill in each cell with the matching color pencil or marker to record the color in the table above and take a picture of all test tubes (attach to the lab).

Answer the following questions based on class discussion:

- Explain what pH is?
- Explain what pOH is and its relationship to pH.
- What is the role of indicators?

Part 2 – pH scale for Acids and Bases

Investigation Questions:

- What is pH? What does it measure?
- What do you notice about the scale?

Materials:

- Solutions:

1 M HCl
0.1 M HCl
0.01 M HCl
0.001 M HCl
0.0001 M HCl
0.00001 M HCl
0.000001 M HCl
0.000001 M NaOH
0.00001 M NaOH
0.0001 M NaOH
0.001 M NaOH
0.01 M NaOH
0.1 M NaOH
1 M NaOH

- Distilled water
- pH meters
- Beakers
- Graphing calculators

Directions:

1. Determine the pH of the solutions given.
2. Graph Concentration vs. pH, one graph for NaOH solutions and one graph for HCl solutions.
3. Analyze the graphs to explain the relationship observed.

PARAMETERS TO EVALUATE STUDENT WORK PRODUCTS:

1. Students draw a line graph of pH vs. concentration and use the graph to explain the relationship between pH scale and Hydrogen ion concentration.
2. Interpret the graph correlating pH scale to acidity and basicity.

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Contributors

Mina Armani, Union City High School, Union City, NJ, Primary Author

Howard Kimmel, Levelle Burr-Alexander, John Carpinelli - Center for pre-College Programs, NJIT.

Christopher d'Amrose, Dr. Rajesh Dave - C-SOPS, NJIT