

The Attraction of Molecules: Relating the Shapes to Properties of Molecules

Learning Objectives

- Characterize molecules based on their three dimensional shape using VSEPR theory
- Predict the polarity of molecules
- Using experimental observations develop the connection between the molecular shape and polarity to the physical properties like boiling point, melting point, and response to a charge

Background

For this week's lab you will want to read the following sections in your textbook as preparation. The pre-lab questions will test your understanding of this material. If you need more information after reading the textbook, there are also some links to YouTube videos throughout the background section that covers the material.

- Chapter 6 sections 6.4-6.6

In today's lab we will examine the attractive forces that hold groups of molecules together and explore the relationship between the strength of those forces, the shape of the molecule, and the distribution of the electrons throughout the molecule.

As you have gathered from your reading, molecules exist in three dimensions. The different shapes that the molecules take on are classified using valence shell electron pair repulsion theory or VSEPR. VSEPR is used to classify the arrangement of the atoms around a central atom. The electron geometry treats lone pairs and bonds the same and there are five classifications of electron geometries. The molecular geometry distinguishes between lone pairs and bonds and so each of the five electronic geometries are broken down into subcategories. These geometries are summarized in Tables 6.2 and 6.3 in your textbook. Check out a video explaining molecular geometries and VSEPR: https://www.youtube.com/watch?v=uoNF7c_n92M

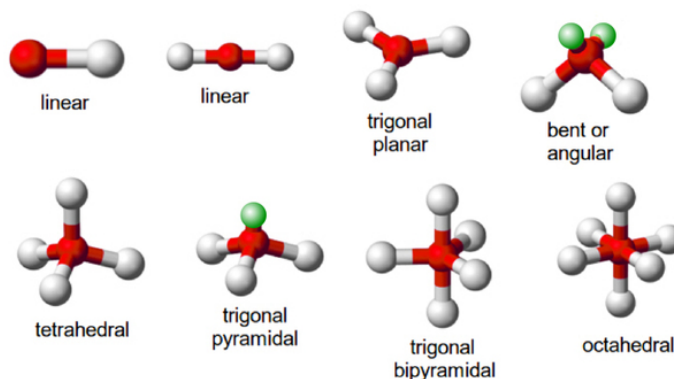


Figure 1: Some different geometries that molecules can have

One property that is determined using the molecular geometry as determined by VSEPR is the polarity of the molecule. A molecule's polarity is a description of how the electrons are distributed within the molecule. If all of the electrons are distributed evenly, then the molecule is said to be non-polar where as if one of the atoms has an excess of electron density, then the molecule is classified as polar. To predict a molecule's polarity, you begin by assigning the bond polarity. When a more electronegative atom is bonded to a less electronegative atom, the bond is polar with the bond

dipole moment pointing towards the more electronegative atom. This is showing that the more electronegative atom contains more electron density than the less electronegative atom (it is stealing the electrons or not sharing fairly). The bond dipole moments add throughout the molecule to create an overall dipole moment that determines the polarity of the molecule. Check out a video explaining this with pictures: <https://www.youtube.com/watch?v=2RfI5xr42o0>

In a sample of molecules there are many, many individual molecules (moles of them in fact). Based on the electron distribution within these molecules, you can predict how they will be attracted to each other (or how “sticky” they are). There are three main types of attractive forces that exist in a sample of molecules: Dispersion forces, Dipole-Dipole forces, and Hydrogen bonding. Check out a video explaining the difference between these three types of attractive forces: https://www.youtube.com/watch?v=S8QsLUO_tgQ

When a sample is in the liquid phase, the molecules are close together and can interact with each other. In the gas phase, the molecules are separated by large distances and do not interact with each other. For the molecules to transition from the liquid phase to a gas phase (evaporation) enough energy must be added so that the attractive forces between the molecules can be broken. This transfer of energy from the surroundings to the molecules to break those attractive forces is why sweating cools our body and prevents us from overheating.

Experimenting with Shapes and Attractive Forces

Your Experimental Mission, If You Choose to Accept

You will work to determine the relationship between the shape, polarity, and physical properties of a molecules. This lab will walk you through determining the shape, the polarity, and collecting data about a variety of molecules and you will use that data to make conclusions about the relationships that exist between these properties.

Your Experimental Toolbox

This varies by station. Look within each station to determine what tools you have.

Station 1: Shapes, Polarity, and Solubility

One way to test if a molecule is polar or non-polar is to see how it mixes with other solvents. Use the following to predict the polarity of the provided molecules and then test your prediction by determining its miscibility. You do not need large amounts of the solvents to be able to determine their miscibility.

Molecules:

Water – H_2O

Methanol – CH_3OH

Acetone – $(\text{CH}_3)_2\text{CO}$

Hexanes – C_6H_{14}

Dichloromethane – CH_2Cl_2

1. Complete the following table to determine the miscibility of the molecules. Record “yes” if the two molecules are miscible and “no” if they are not.

	H_2O	CH_3OH	$(\text{CH}_3)_2\text{CO}$	C_6H_{14}	CH_2Cl_2
H_2O	---				
CH_3OH		--			
$(\text{CH}_3)_2\text{CO}$			--		
C_6H_{14}				--	
CH_2Cl_2					--

2. What patterns do you notice between the polarity of molecules and their miscibility? Support your answer with evidence.

3. Using this information, explain what you believe “like dissolves like” means in the context of polarity and miscibility.

Station 2: Shapes and Evaporation

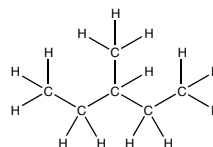
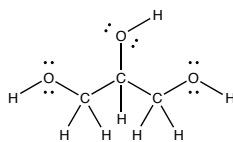
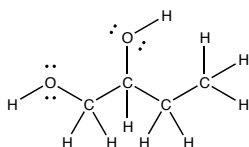
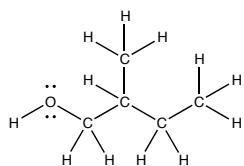
In this part of the experiment you want to determine which of the five molecules: acetone ($\text{CH}_3\text{CO}_2\text{H}$), methanol (CH_3OH), hexanes (C_6H_{14}), dichloromethane (CH_2Cl_2), and water (H_2O) evaporates the fastest. To determine the rate of evaporation, wrap a piece of filter paper around the end of a thermometer and submerge it into the solution of choice. After you have an initial temperature reading, remove the thermometer and position it so that the solution can evaporate from the filter paper. Record the temperature every 30 seconds until the temperature stabilizes (approximately 9 minutes).

- ## 1. Data from the experiment

[illegible]

2. Explain the relationship between the intermolecular forces (attractive forces) and the rate of evaporation.

3. Predict the order of the rate of evaporation for the following molecules. #1 will have the fastest rate of evaporation and #4 will have the slowest rate of evaporation. Explain your reasoning in 2-4 sentences.



Station 3: Testing Polarity

At this station you will predict and test your hypothesis about the polarity of molecules. To test the polarity you will statically charge saran wrap with a towel. Then measure the amount of deflection that the static charge causes to a stream of the liquid dispensed from a burette.

1. Complete the following table to predict the polarity of the given molecules.

Molecule	Electron Geometry	Molecular Geometry	Polarity
H ₂ O			
CH ₃ OH			
(CH ₃) ₂ CO			
Hexanes			
CH ₂ Cl ₂			

- Rank the molecules in order of increasing deflection caused by the statically charged rod.
- In 2-3 sentences explain how the shape of the molecule is related to the amount of deflection caused by the statically charged rod.

Station 4: Shapes and Physical Properties

Below is a series of molecules with data about their physical properties (boiling point, viscosity, vapor pressure, molecular weight, etc.). Use this data to answer questions about the molecules.

Name	Formula	Molecular Weight (g/mol)	# of Electrons	Boiling Point (°C)	Viscosity	Vapor Pressure (atm)
Propane	C ₃ H ₈	44.1	26	-42	---	9.23
Butane	C ₄ H ₁₀	58.12	34	-0.5	0.157	2.41
Pentane	C ₅ H ₁₂	72.15	42	36.1	0.214	0.672
Hexane	C ₆ H ₁₄	86.17	50	69	0.297	0.199
Decane	C ₁₀ H ₂₂	142.29	82	142	0.859	8.54 x 10 ⁻⁴
Acetone	C ₃ H ₆ O	58.08	32	56.2	0.316	0.303
2-butanone	C ₄ H ₈ O	72.11	40	79.6	0.400	0.119
2-pentanone	C ₅ H ₁₀ O	86.1	48	102	0.473	0.0466
2-hexanone	C ₆ H ₁₂ O	100	56	128	0.62	0.0153
2-decanone	C ₁₀ H ₂₀ O	156	88	210	---	---
1-propanol	C ₃ H ₈ O	60.1	34	97.4	1.95	0.0276
1-butanol	C ₄ H ₁₀ O	74.1	42	117	2.54	0.00921
1-pentanol	C ₅ H ₁₂ O	88.2	50	137	4.00	0.00289
1-hexanol	C ₆ H ₁₄ O	158	58	158	4.578	1.22 x 10 ⁻³
1-decanol	C ₁₀ H ₂₂ O	229	90	229	10.9	1.12 x 10 ⁻⁵

1. Complete the following table for each of the molecules. NOTE: These are organic molecules so the naming and the Lewis structure are a bit more complicated than you've seen before. Use the internet to help you determine and check the Lewis structure.

Name	Lewis Structure	Polar or Non-Polar	ALL Intermolecular Forces. Write the strongest force present.
Propane C_3H_8			
Butane C_4H_{10}			
Pentane C_5H_{12}			
Hexane C_6H_{14}			

Decane C ₁₀ H ₂₂			
Acetone C ₃ H ₆ O			
2-butanone C ₄ H ₈ O			
2-pentanone C ₅ H ₁₀ O			
2-hexanone C ₆ H ₁₂ O			
2-decanone C ₁₀ H ₂₀ O			

1-propanol $\text{C}_3\text{H}_8\text{O}$			
1-butanol $\text{C}_4\text{H}_{10}\text{O}$			
1-pentanol $\text{C}_5\text{H}_{12}\text{O}$			
1-hexanol $\text{C}_6\text{H}_{14}\text{O}$			
1-decanol $\text{C}_{10}\text{H}_{22}\text{O}$			

2. What is the relationship between the strength of the attractive forces between molecules and the boiling point? Provide an explanation for why you believe this trend exists.
3. What is the relationship between the strength of the attractive forces between molecules and its viscosity? Provide an explanation for why you believe this trend exists.
4. What is the relationship between the strength of the attractive forces between molecules and its vapor pressure? Provide an explanation for why you believe this trend exists.

- Pick a set of non-polar molecules that have differing numbers of electrons. What is the relationship between the strength of the attractive forces and the number of electrons in the molecule? Provide an explanation for why you believe this trend exists.
- Pick a set of non-polar molecules that have different length (differing numbers of atoms hooked together in a row). What is the relationship between the strength of the attractive forces and the length of the molecule? Provide an explanation for why you believe this trend exists.

7. Pick a set of non-polar molecules that have different amounts of branching. What is the relationship between the strength of the attractive forces and the amount of branching in the molecule? Provide an explanation for why you believe this trend exists.
8. Using what you've learned about the structure of organic molecules, their intermolecular forces, and their properties like boiling point, explain how fats and oils can both be triglycerides (same basic chemical structure), yet, fats are solids at room temperature and oils are liquids at room temperature. Your answer should include an explanation of the link between the structure of the molecule and the intermolecular forces present and the connection to physical properties like melting point.