



eScience Labs

LLC

Lab Manual Physical Science





Physical Science

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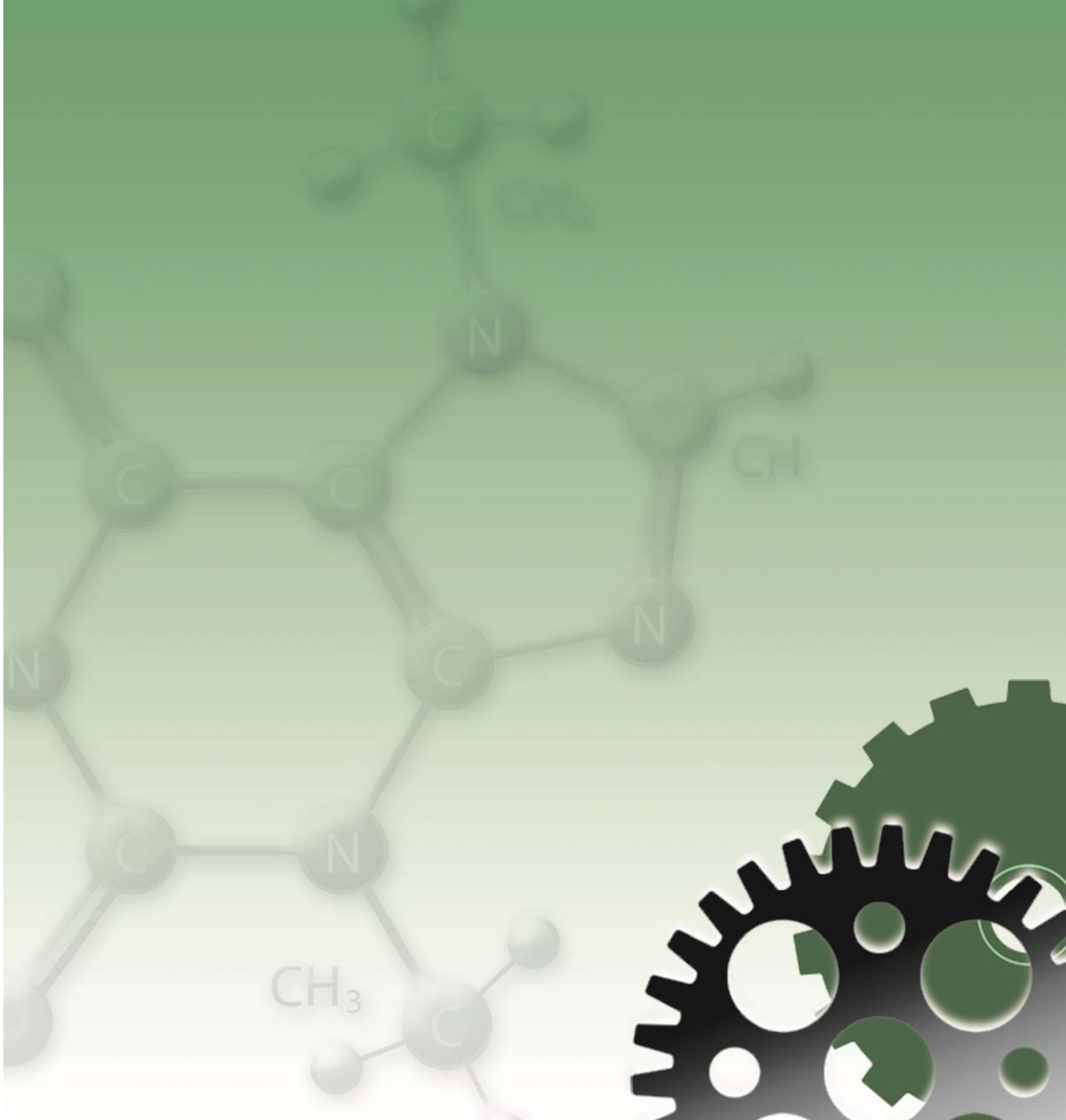
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Lab 5: Molecular Models



Concepts to explore:

- Understand why molecules have a particular shape
- Determine the shapes of molecules using the VSEPR model

Introduction

Why can't you play basketball with a football?

The obvious answer is because a football isn't the right shape. A football can't be dribbled and would be very difficult to shoot. On the other hand, a fairly large spherical ball can be easily dribbled and is needed to successfully play basketball. The shape of a molecule is also extremely important in how it can be used. Just like sports need objects of a particular shape, certain reactions or applications need molecules of a particular shape.

The shapes of the different objects used in sports can be described in a few words. For example, an arrow can be described as straight or linear, a hockey puck as a flat disc, a football as oblong, and a basketball as spherical. Molecules also have definite shapes that can be described in a few words. A few molecular shape examples are linear, bent, trigonal planar, pyramidal, and tetrahedral. Some of these words might already give you an idea of how such molecules are shaped.

But how do you know the shape of a particular molecule since you can't see it? Fortunately a model has been developed that helps us predict the shapes of molecules. It is called the **VSEPR** model. VSEPR stands for valence-shell electron-pair repulsion.

When you play a team sport one of the first things you need to decide is who is going to be the captain. When using the VSEPR model a central atom has to first be decided. This is usually the atom in the molecule with the most bonds. A single bond counts as one bond, a double bond counts as two bonds, etc. For example, the carbon atom in methane, CH_4 , is the central

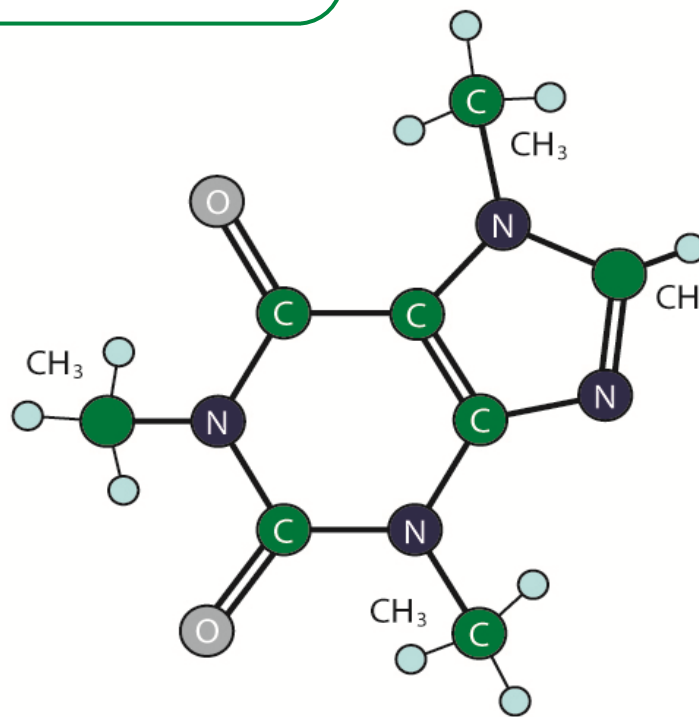


Figure 1: Molecular structure of a caffeine molecule. Can you identify instances where atoms act as the central atom of their grouping?

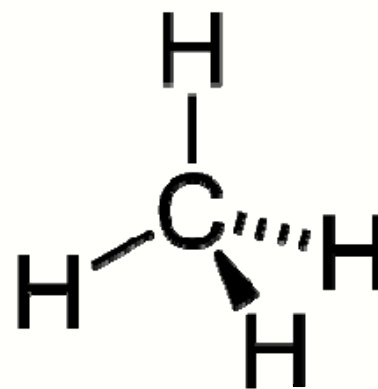


Figure 2: Molecular model for methane, CH_4 . Note the four regions of electron density—one for each single bond to the central carbon atom

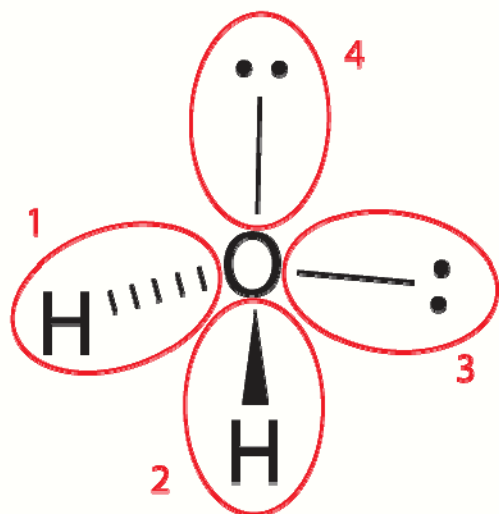


Figure 3: Regions of electron density for a water molecule (H_2O).

atom since it has 4 bonds and each hydrogen atom has just one bond. In water, H_2O , the oxygen has two bonds so it is chosen as the central atom. In carbon dioxide, CO_2 , the carbon has 2 double bonds or 4 total bonds so it is chosen as the central atom. In the case where two atoms have the same number of bonds, one can be chosen. For example, the oxygen atoms in hydrogen peroxide, HOOH , each have 2 bonds to them whereas the hydrogen atoms each have only one bond. In this case either one of the oxygen atoms can be depicted as the central atom.

After the central atom is decided, the number of regions of electron density around it is determined. This is a region that generally describes the location of negative charge due to surrounding electrons. A single, double, or triple bond **or** a pair of unshared electrons counts as one region of electron density. The carbon in methane, CH_4 ,

has four single bonds so it has four regions of electron density. However, the number of regions can be different than the number of bonds: in H_2O , the oxygen molecule has two single bonds and two pairs of unshared electrons—resulting in four regions of electron density.

If you have played with magnets, you probably know that when the same poles of magnets are brought together they repel each other. The VSEPR model is based on a similar concept. Valence electrons, shared or unshared, create a **negative region that repels the other negative regions**. For this reason, the regions of electron density are placed the same distance from the central atom, but as far away from each other as possible.

The last thing to be done is to describe the shape the atoms make. The unshared electrons influence the shape, but only the resulting shape of the atoms is described. Certain terminology is used for this. The shape is called the molecular geometry. Listed in Table 1 are some common molecular shapes and the words used to describe them.

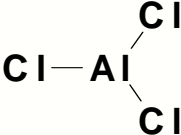
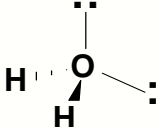
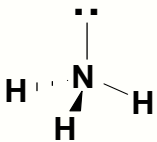
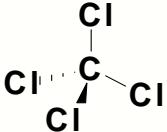
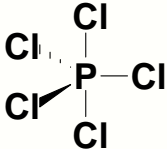
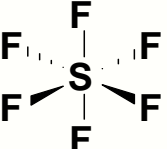
All of this can be summarized in 4 steps.

1. Determine the central atom.
2. Determine the regions of electron density around the central atom by adding the number of bonded atoms and the number of unshared electrons.
3. Place the regions the same distance away from the central atom and as far as possible away from each other.
4. Describe the shape only the atoms make.



Lab 5: Molecular Models

Table 1: Molecular Models

Example Atom (central atom is underlined)	Number of Bonds on Central Atom (multiple bonds count as 1)	Unshared electron pairs on central atom	Regions of Electron Density	Molecular Geometry	Structure
<u>C</u> O ₂	2	0	2	Linear	O=C=O
<u>Al</u> Cl ₃	3	0	3	Trigonal Planar	
H ₂ <u>O</u>	2	2	4	Bent	
<u>N</u> H ₃	3	1	4	Trigonal pyramidal	
<u>C</u> Cl ₄	4	0	4	Tetrahedral	
<u>P</u> Cl ₅	5	0	5	Trigonal bipyramidal	
<u>S</u> F ₆	6	0	6	Octahedral	



Pre-lab Questions

1. Identify the central atom and determine how many regions of electron density there are around the central atom in each of the following molecules:

Table 2: Pre-lab exercise

Molecule	Central Atom	# Regions of Electron Density
BeCl ₂		
BH ₃		
CBr ₄		

2. Explain why the shape of H₂O is bent and not linear.

Experiment: Molecular Structures

Materials

3 Bar magnets
Toothpicks
Modeling clay
Protractor

Procedure

Part 1: Magnets



1. Bring together the **same** poles of two bar magnets.
2. Observe and describe what happens.
3. Explore the linear shape of molecules by bringing the **same** poles as close together as you can in a straight line. Record your observations in the Data section.
4. Explore why a molecule makes a trigonal planar shape by placing the **same** pole of 3 bar magnets as the points of an equilateral triangle with the rest of the magnet behind them.
5. Slowly bring the same pole of the 3 magnets as close as it is possible **while maintaining the equilateral triangular appearance**. Now try to find another shape that will be as stable with all of the magnets at least as close as they were in the equilateral triangle position. Record your observations in Table 3.

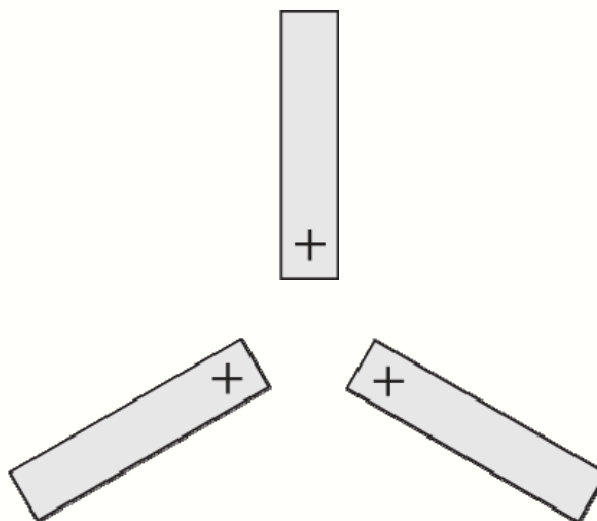


Figure 4: Magnet setup for experiment Procedure 1.

Data

Table 3: Observations for Procedure 1

Procedure Step	Observations
Step 1	
Step 2	
Step 3	



Table 4: Observations and data for Procedure 2

Molecular Shape	Observations	Bond Angle
Linear (2 atoms)		
Linear (3 atoms)		
Trigonal Planar		
Bent		
Trigonal Pyramidal		
Tetrahedral		
Trigonal Bipyramidal		
Octahedral		



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