Lewis Dot Structures and Molecular Geometries

Dr. Walker
What will you know? What will you do?

- (3c) · Lewis dot diagrams are used to represent valence electrons in an element. Structural formulas show the arrangements of atoms and bonds in a molecule and are represented by Lewis dot structures.
- Draw Lewis dot diagrams to represent valence electrons in elements and draw Lewis dot structures to show covalent bonding.
- Use valence shell electron pair repulsion (VSEPR) model to draw and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal).
- Polar bonds form between elements with very different electronegativities. Non-polar bonds form between elements with similar electronegativities.
- Polar molecules result when electrons are distributed unequally.
- Recognize polar molecules and non-polar molecules.
- (6a) · Draw Lewis dot structures, identify geometries, and describe polarities of the following molecules: CH₄, C₂H₆, C₂H₄, C₂H₂, CH₃CH₂OH, CH₂O, C₆H₆, CH₃COOH.
Lewis Dot Structures

• Created by Gilbert Lewis in 1916

• Shows **structural formulas** for compounds
  – Arrangement of atoms and bonds within a compound

```
  H
 /   \
H—C—H Structural formula for
   \   
    H

Methane, CH₄
```
Lewis Dot Structures

- Uses valence electrons
- One dot = one valence electron
- One dash = a covalent bond = two electrons
# Lewis Dot Structures

![Lewis Elements](http://www.roymech.co.uk/images14/lewis_elements.gif)
Practice

• How many dots will the following elements contain?
  – Fluorine
  – Boron
  – Carbon
Practice

• How many dots will the following elements contain?
  – Fluorine
    • 7
  – Boron
    • 3
  – Carbon
    • 4

• Equal to number of valence electrons
  – For main groups, equal to last number of group number
Lewis Structures

• Lewis structures show how valence electrons are arranged among atoms in a molecule.

• Lewis structures reflect the idea that stability of a compound relates to the octet rule

• Shared electrons pairs are covalent bonds and can be represented by two dots (:) or by a single line ( - )
HONC, HONC..

• The HONC Rule
  – **Hydrogen** (and **Halogen**s) form one covalent bond
  – **Oxygen** (and sulfur) form two covalent bonds
    • One double bond, or two single bonds
  – **Nitrogen** (and phosphorus) form three covalent bonds
    • One triple bond, or three single bonds, or one double bond and one single bond
  – **Carbon** (and silicon) form four covalent bonds.
    • Two double bonds, or four single bonds, or one triple and one single, or one double and two singles
Lewis Dot Structures - Compounds

• Make the atom wanting the most bonds the central atom (if more than 2 total atoms)

• Draw proper number of dots (= valence electrons around each atom).

• Join atoms on the outside with the central atom using electron pairs, obeying the HONC rule

• Make sure every atom has a full valence shell (2 e\textsuperscript{-} for H, 8 for everything else)
  – Boron the only exception we’ll cover, he gets 6 valence electrons
Additional Note on Octet Rule

- Atoms in the third row and below can disobey the octet rule at various times. We will not cover those structures in this course. (DE anyone?)
  - This is for a simplification of material with a degree of honesty.
Examples – On Board

- $\text{H}_2\text{O}$
- $\text{NH}_3$
- $\text{BH}_3$
- $\text{CCl}_4$
- $\text{CO}_2$
- HCN
- Diatomics
Examples

$\text{H--O--H}$

$\text{H--N--H}$

$\text{H--B--H}$

Ammonia

$\text{O==C==O}$

$\text{H--C==N}$

$\text{O==O}$

$\text{N==N}$
Carbon Based Molecules

- With multiple carbon compounds, connect carbons together
- Arrange other elements around carbon, fill octets
Carbon Based Molecules

- Practice (on board)
  - $C_2H_6$
  - $C_2H_4$
  - $C_2H_5OH$
  - Formaldehyde ($CH_2O$)
Carbon Based Molecules

Ethane

Ethene

Ethyne

Ethanol

Formaldehyde
Carbon Based Molecules

Benzene

Acetic Acid
Molecular Geometry

• Based on Valence Shell Electron Pair Repulsion (VSEPR) theory

• Electron pairs around a central atom arrange themselves so they can be as far apart as possible from each other.
Molecular Geometry

• You will be responsible for five molecular shapes
• Compounds take a three-dimensional shape based on:
  – Number of atoms attached
  – Number of unbonded electrons present
• These are general rules for binary compounds
  – There are always exceptions!!! (including organics)
Linear

- Carbon is central atom
- Surrounded by two oxygen atoms
- No unbonded electrons on carbon
- Look for AX2 geometry
  - Central atom is group 14
• Oxygen is central atom
  – Central atom is typically group 16.
• Surrounded by two atoms (H or halogen)
• Two unbonded electron pairs on oxygen, push hydrogens out of the plane
Bent vs. Linear
What’s The Difference?

- Both have a similar formula (AX$_2$)
- Look at the central atom
  - If the element is group 14, it is linear
  - If the element is group 16, it is bent
- Look for presence or absence of unbonded electrons

Unbonded electrons on oxygen

Bent

No unbonded electrons on carbon

Linear
Trigonal Pyramidal

- Nitrogen surrounded by three hydrogen atoms (or halogens)
- One pair of unbonded electrons, push hydrogens out of plane
Basic 2 dimensional and 3 dimensional shapes of molecules

**Trigonal Pyramidal**

- 3 atoms bonded to the central atom
- One set of lone pairs
- Example molecule: \( \text{NH}_3 \)

**2 dimensional sketch:**
- The way students tend to draw it:

**3 dimensional sketch:**
- The way it can be drawn to show the effect of lone pairs:

http://edtech2.boisestate.edu/melissagetz/images/trig_pyr_top.jpg
• Boron is central atom surrounded by three fluorine atoms (or H or other halogen)
• Boron can defy octet rule, happy with six electrons
• No unbonded electrons on boron, fluorine atoms stay within a single plane
Planar vs. Pyramidal

- Both have similar formula (AX$_3$)

- Look at the central atom
  - If it has unbonded electrons, it will be trigonal pyramidal
  - If it doesn’t have unbonded electrons (only boron!), it will be trigonal planar

No unbonded Electrons on boron
**Tetrahedral**

- AX$_4$ formula
- Carbon (or silicon) surrounded by four hydrogens (or halogens)
- Only shape we’re concerned with four surrounding atoms

http://www.elmhurst.edu/~chm/vchembook/204tetrahedral.html
<table>
<thead>
<tr>
<th>Molecular Geometry</th>
<th>Diagram</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear $(AX_2)$</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>2 outside atoms 0 lone pairs</td>
<td>$\text{CO}_2$</td>
</tr>
<tr>
<td>Bent $(AX_2)$</td>
<td><img src="image2.png" alt="Diagram" /></td>
<td>2 outside atoms 2 lone pairs</td>
<td>$\text{H}_2\text{O}$</td>
</tr>
<tr>
<td>trigonal planar $(AX_3, A = \text{boron})$</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td>3 outside atoms 0 lone pairs</td>
<td>$\text{BF}_3$</td>
</tr>
<tr>
<td>Tetrahedral $(AX_4)$</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td>4 outside atoms 0 lone pairs</td>
<td>$\text{CH}_4$</td>
</tr>
<tr>
<td>trigonal pyramidal $(AX_3)$</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td>3 outside atoms 1 lone pair</td>
<td>$\text{NH}_3$</td>
</tr>
</tbody>
</table>
Polarity

– Bond Polarity

• Difference in electronegativity between two atoms in a chemical bond
• Unequal sharing of electrons between elements
Bond Polarity

- **Ionic**
  - Elements on opposite sides of periodic table (metal + nonmetal)
  - Examples
    - NaCl, LiF, ZnCl

- **Polar Covalent** (unequal sharing)
  - Two elements on right side (both nonmetals) of periodic table
  - C-O, S-O, P-Br

- **Nonpolar covalent** (equal sharing)
  - Two of the same element on the right side of the periodic table
  - H-H, Cl-Cl, O=O
Molecular Polarities

- Polar molecules occur when electrons **are NOT distributed equally**
- Look for symmetry within molecule
  - Only one line of symmetry – Polar molecule
- Polar shapes
  - Trigonal pyramidal
  - Bent
- These rules will apply regardless of the number of atoms on the molecule with these shapes
Molecular Polarities

• Nonpolar molecules occur when electrons are distributed equally
• Look for symmetry within molecule
  – More than one line of symmetry – Nonpolar molecule
• Nonpolar shapes
  – Linear
  – Trigonal Planar
  – Tetrahedral
• These are just guidelines for binary compounds (two elements). Compounds with multiple elements and organics do not apply to these rules.
Polar molecules have asymmetric (without symmetry) electron distributions. Draw an arrowhead on the side with the higher EN. This is the Dipole Moment. The side with higher EN has a greater pull on the electrons, so is charged $\delta^{-}$. The other side is charged $\delta^{+}$. You have completed a polar molecule!

\[
\begin{align*}
\text{Structural Formula} & \quad \text{Lines of symmetry: either side of the line is a mirror image} \quad \text{Look up the ENs of the atoms on the ends of the line of symmetry} \\
H - Cl & \quad H - Cl \\
H - O & \quad H - O \\
\end{align*}
\]

NONPOLAR MOLECULES have two or more lines of symmetry. The electronegativities along these lines of symmetry are equal, so there is an equal pull on electrons from all sides of the molecule. There is no dipole moment. The molecule has symmetrical electron distribution.

\[
\begin{align*}
\text{H - Cl} & \quad \text{H - Cl} \\
\text{H - O} & \quad \text{H - O} \\
\text{H - H} & \quad \text{Cl - Cl} \\
\text{N - N} & \quad \text{O - O} \\
\text{H - C - H} & \quad \text{H - C - H} \\
\end{align*}
\]
Skills to Master

• Drawing Lewis dot structures from a given molecular formula
• Assigning a shape based on a molecular formula (or Lewis dot structure)
• Determine whether a bond is polar or nonpolar
• Determine whether a molecule is polar or nonpolar based on formula (or Lewis dot structure)
Terms To Know

- Lewis Dot Structure
- Structural formula
- Linear
- Bent
- Trigonal pyramidal
- Trigonal planar
- Tetrahedral
- Polarity
- Electronegativity (review)
- Polar
- Polar covalent
- Nonpolar
- Nonpolar covalent