**Objectives**

12. Recognize exceptions to the octet rule.
13. Recognize common polyatomic ions.
15. Understand how bond dipoles are dictated by electronegativity.
16. Understand what determines the 3-d shape around an atom in a molecule.
17. Be able to determine if a molecule has a molecular dipole moment.
18. Understand how molecular dipole moments affects the properties of compounds.

**Electron Dot Diagrams**

- Ammonia: NH₃
- Carbon Dioxide: CO₂
- Ozone: O₃
- Ethylene: C₂H₄
Exceptions to the Octet Rule

- Incomplete Octets – BeH₂, BF₃
  - \( \text{H} \equiv \text{Be} \equiv \text{H} \)

- Odd-Electron Molecules – NO₂
  - radicals

- Expanded Octets – SF₆
  - Able to expand into d orbitals
  - Only 3rd period and below!

Polyatomic Ions

- Groups of covalently bound atoms that have a charge are polyatomic ions
  - How/why could they have gotten a charge?
  - Polyatomic cation: \( \text{NH}_4^+ \) – ammonium
  - Polyatomic anions: not all have –ide ending
    - \( \text{OH}^- \) hydroxide
    - \( \text{SO}_4^{2-} \) sulfate
    - \( \text{NO}_3^- \) nitrate
    - \( \text{PO}_4^{3-} \) phosphate
    - \( \text{CO}_3^{2-} \) carbonate
    - \( \text{CN}^- \) cyanide

Know the formulas, names, and charges of these ions.

Polyatomic Ions

- As other ions, polyatomic ions will form ionic compounds.
- The compounds may be with monoatomic ions or with other polyatomic ions.
- What force holds the compounds together?

- When writing the formula, the polyatomic ion is put in parentheses if it has a subscript, with the subscript on the outside.
- These compounds are named as other ionic compounds. Cation anion.
Some ionic compounds (with polyatomic ions)

<table>
<thead>
<tr>
<th>TUMS</th>
<th>Calcium carbonate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epsom salts</td>
<td>Magnesium sulfate</td>
</tr>
<tr>
<td>Baking soda</td>
<td>Sodium bicarbonate</td>
</tr>
<tr>
<td>Bleach</td>
<td>Sodium hypochlorite</td>
</tr>
<tr>
<td>Smelling salts</td>
<td>ammonium carbonate</td>
</tr>
<tr>
<td>Milk of magnesia</td>
<td>Magnesium hydroxide</td>
</tr>
</tbody>
</table>

A little review of ionic and covalent compounds

- Label the compounds below as ionic or covalent
- FeS
- Li₂P
- SiCl₄
- Ni₃
- NH₄Cl
Electronegativity

- Electronegativity – the ability for atoms to attract electrons.

Which elements have the most attraction for electrons?
Which have the least?

Ionic bonds – formed between atom with large differences in electronegativity
- Results in complete electron transfer

Covalent compounds – can there be an electronegativity difference?

Electronegativity and covalent bonds

- Look at the electronegativity differences for the bonds
  - H—H
  - H—Cl
  - H—O
  - H—C

Which atoms are going to hold the electrons more tightly?
Bonds with an electronegativity difference (greater than 0.4) are called polar.
The separation of charge is called a dipole.
Note: just because a compound contains a dipole, does not mean the molecule is polar.
A look back at boron trifluoride

- Now we can understand a little better why the molecule doesn’t contain a double bond.
- Fluorine does not want to give two more electrons to boron.

Electronegativity differences in bonding partners

Difference = 0
Pure covalent bond

0 < Difference < 1.7
Polar Covalent bond

Difference ≥ 1.7
Ionic bond

Polarity in Molecules

Indicate polar bonds in the molecules.
Do these bonds indicate whether the molecule is polar?
Molecular Shape

- To determine if a molecule has a dipole moment, we must know its 3-D shape.
- We can use basic ideas of bonding to estimate shapes.
- What are bonds made of?
- What will be important about their arrangement?
- VSEPR theory

The VSEPR Model

- Valence Shell Electron Pair Repulsion (VSEPR) can predict the 3-dimensional geometry of a molecule based on the repulsion of electron pairs, both bonding and nonbonding.
- Electron pairs repel each other, so get as far apart in 3-D space as possible.
- Use electron dot diagrams to look at the regions of electrons around a central atom.

Linear

- Linear molecules have a bond angle of 180 degrees.
- The possible bonds that can have linear geometry:
  - Two atoms (example HCl)
    - any number of lone pairs
  - Three atoms (example CO₂)
    - No lone pairs
Trigonal Planar

- Trigonal planar molecules have bond angles of exactly 120 degrees
- There is only one way to have a trigonal planar molecule
  - Three atoms bonded to the central atom with no lone pairs (example BCl₃)

Tetrahedral

- Tetrahedral molecules have bond angles of 109.5 degrees
- They are formed by having four bonds on a central atom with no lone pairs (example CH₄)

Geometry vs. Shape

- Look at what happens if there are lone pairs:
  - Lone pairs are accounted for when determining electron geometry, but since there are no atoms in those positions, the "visible" shape of the molecule changes.
  - Predict the geometry and shapes for water and ammonia:
  - How many regions of electrons are around the central atom?

http://www.molecules.org/VSEPR_table.html
Trigonal Pyramidal

- Trigonal Pyramidal atoms have a bond angle of 107 degrees
- Found in molecules with three bonds and one lone pair (ex. NH₃)
- What is the difference between trigonal pyramidal and trigonal planar?

Bent

- Bent molecules have a bond angle of less than 180 degrees
- Two atoms bonded to the central atom with two lone pairs (example H₂O) 105°

Electron Geometry vs. Shape (molecular geometry)

- The shape of a molecule describes how we view the atom arrangement, so lone pairs are not seen. The lone pairs must be counted though since the lone pair electrons take part in repulsion with the bonding electrons.
- Remember, both bonding and nonbonding electrons are valence electrons and are in the outer shell of atoms. (That means they are the available electrons for bonding, even if they are already in bonds.)
Summary of shapes

<table>
<thead>
<tr>
<th># of electron groups (around central atom)</th>
<th>Electron Pair Geometry</th>
<th>Molecular Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Linear</td>
<td>linear</td>
</tr>
<tr>
<td>3</td>
<td>Trigonal planar</td>
<td>Bent, trigonal planar</td>
</tr>
<tr>
<td>4</td>
<td>Tetrahedral</td>
<td>Bent, pyramidal, tetrahedral</td>
</tr>
</tbody>
</table>

Example with lone pairs

- Look at sulfur dioxide
  - How many regions of electrons are around S?
  - What is the electron geometry?
  - What is the molecular geometry?
  - How is it different from water?

Some space to practice drawing

Those tetrahedral structures require 3-D skills but are not too difficult:

All lines come from the central point (atom)
1. Draw one bond as a vertical line and a second bond diagonally downward from it.
2. Draw a wedge diagonally down opposite the first diagonal line.
3. Draw a dashed line still pointing diagonally down, but above the wedged line.
Molecular polarity

- The shape of a molecule affects the presence of a molecular dipole.
- Not all polar bonds result in polar molecules.
- Bond dipoles that cancel result in a nonpolar molecule.
- Bond dipoles that do not cancel result in a net dipole and a polar molecule.

Molecular Dipoles

- Look again at the methane, water, and ammonia molecules from earlier. From the shapes, determine if they have a molecular dipole moment.

Water Polarity
Ammonia Polarity

Molecular polarity

Molecular polarity: properties

- We describe the atoms in polar molecules as having partial charges.
- The partial charges affect properties of the molecules.
- What will those charges do when two polar molecules come together?
Hydrogen bonding and surface tension

Ionic and covalent compounds form to satisfy the octet rule, although there are some exceptions. Ionic bonds are held by electrostatic attraction between cations and anions (monoatomic or polyatomic). Covalent bonds are held by shared electrons in overlapping orbitals to form molecules. They usually form between nonmetals.

Atoms form bonds according to their placement in the periodic table. Electrons (bonding and nonbonding) arrange around atoms as far apart as possible to give a molecule its shape. Some atoms pull electrons more strongly than others, so bonds are made polar (dipoles). Assymetrically arranged polar bonds can result in polar molecules (molecular dipole).

Dipoles in molecules create partial positive and negative charges that allow electrostatic interactions between molecules.

Review Chapter 5!

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