

Chemistry 500: Chemistry in Modern Living

Topic 3: The Chemistry of Global Warming

Molecular Structures and Moles

Chemistry in Context, 2nd Edition: Chapter 3, Pages 73-110

Chemistry in Context, 3rd Edition: Chapter 3, Pages 93-136

Outline Notes by Dr. Allen D. Hunter, YSU Department of Chemistry, ©2000.

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3A The Greenhouse Effect

- What is a gardening greenhouse?
 - A heater and a cover (glass or plastic cover)
 - Hand Drawing!

- Earth as a greenhouse
 - The atmosphere acts as a cover
 - Lets light in but does not let heat out
 - Graphics from Text: Figure 3.2, the Earth's Greenhouse
 - Venus has an actual average temperature of 450 °C vs. 100 °C if no greenhouse effect
 - Earth has an actual average temperature of 15 °C vs. -18 °C if no green house effect

- Greenhouse Gasses
 - CO₂, H₂O, CFCs, etc.

3B Changes in CO₂ Over Time

- Graphics from Text: Figure 3.1, Atmospheric CO₂ changes over the last 160,000 years
 - Note: the correlation between temperatures and [CO₂]
 - Note: the waxing and waning of the Ice Ages
 - How measured?

- Graphics from Text: Figure 3.3, Mona Loa [CO₂]
 - Note: The seasonal variations and longer term trends in [CO₂]

- Graphics from Text: Figure 3.4 in 2nd Edition and 3.5 in 3rd Edition, Average measured temperature changes at the earth's surface
 - How measured?

- Graphics from Text: Figure 3.4 in the 3rd Edition, predicted trends in CO₂ emissions

➤ How estimated?

➤ Dynamic Balance of CO₂

➤ Photosynthesis



➤ Respiration

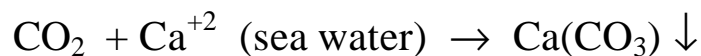


➤ Longer term processes

➤ Biomass

➤ Fossil Fuels

➤ Carbonate Minerals (e.g., Calcium Carbonate)



➤ Graphics from Text: Figure 3.8 in 2nd Edition and 3.9 in 3rd Edition, the Carbon Cycle

3C Molecules: How They Shape Up

➤ How do we know molecular shapes?

Experimental Observations of Shapes



Measurements of Bond Lengths and Bond Angles



Correlations with Bonding Theories



Predictions of Shapes for New Molecules

- Observed Molecular Shapes
 - General Features of Structures

 - Complex 3D Shapes
 - 109.5°, 120°, and 180° Bond Angles
 - correlated with the number of groups around an atom

 - 1.2 – 1.55 Å Bond Distances (C-H ≈ 1 Å)
 - Correlated with Bond Order

- Structural Correlations with Properties

➤ VSEPR, Valence Shell Electron Pair Repulsion Theory

➤ Molecular shapes \Rightarrow Bond Angles

➤ Each “thing” is an attached atom or a lone pair

➤ Four things \Rightarrow Tetrahedral, td, 109.5°

➤ Three things \Rightarrow Trigonal planar, 120°

➤ Two things \Rightarrow Linear, 180°

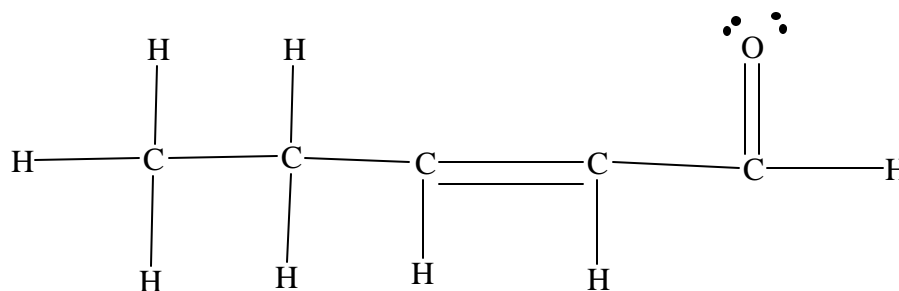
➤ Bond Distances

➤ Single Bonds \Rightarrow Long Distances

➤ Double Bonds \Rightarrow Medium Distances

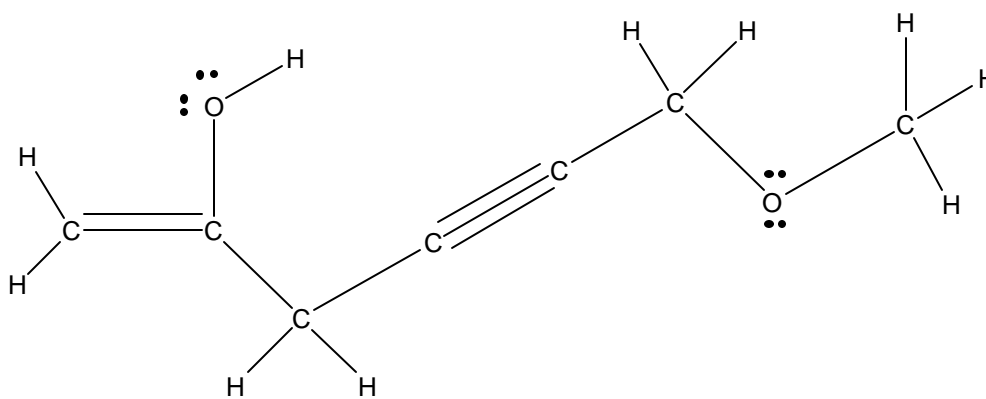
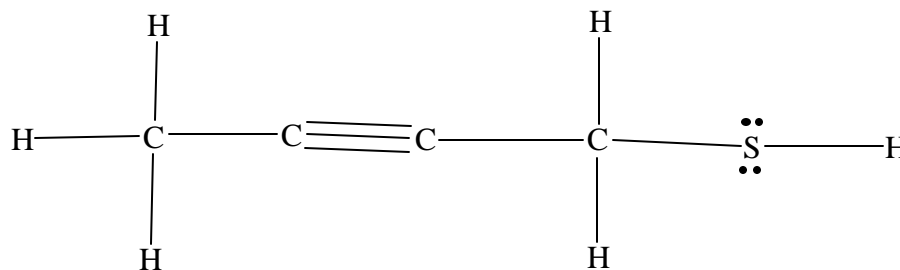
➤ Triple Bonds \Rightarrow Short Distances

➤ Example



➤ Ask Students: Predict the bond lengths and angles in the following molecules

➤ Group Activity



3D Vibrating Molecules

- The atoms in molecules never sit still with respect to one another
- They constantly vibrate as if held together by springs
- Once they start vibrating, the rate of vibration (i.e., its frequency) doesn't change
- Each molecules can only vibrate at certain specific frequencies

- When a molecule is hit by a photon of light having the same energy as the energy difference between two vibration, the vibration rate will “jump up”
- If a vibration rate slows down to a new rate, then a photon having the energy difference will be given off

- Vibration Frequencies and Molecular Structures
 - Stronger bonds vibrate at higher frequencies
 - Weaker bonds vibrate at lower frequencies
 - Heavier atoms vibrate a lower frequencies
 - Lighter atoms vibrate a higher frequencies
- Molecular structure effects the number and energy of vibrations
- The balance of these trends produces molecular spectra
 - No two of these are identical

- The more complex the molecular structure, the greater the number of vibrations that will occur
- In the Infra-Red (IR) region of the electromagnetic spectrum
- Graphics from Text: Figure 3.5 in 2nd Edition and 3.6 in 3rd Edition, IR Spectrum of CO₂
 - CO₂ has a simple structure and therefore a simple spectrum
- Graphics from Text: Figure 3.6 in 2nd Edition and 3.7 in 3rd Edition, IR Spectrum of H₂O
 - H₂O has a more complex structure and therefore a more complex spectrum
- Graphics from Text: Figure 3.7 in 2nd Edition and 3.8 in 3rd Edition, Molecular responses to various types of electromagnetic energy

3E Weighing Substances

- One can determine the weight of individual molecules or collections of molecules
- Steps to calculate the Molecular Weight, MW, of the substance
 - 1st, find the atomic weight of each atom in the substance
 - 2nd, multiply the weight of each atom by the number of atoms of that type to give the total weight of each element
 - 3rd, add the total weights of all of the elements
 - 4th, this number is in AMU (Atomic Mass Units) for individual atoms and grams for moles of atoms
- Examples:
 - Calculate the MW of CO₂ ⇒ $12 + 2(16) = 44$
 - Calculate the MW of CH₂F₂ ⇒ $12 + 2(1) + 2(19) = 52$

- One can determine the Percent Composition of individual molecules and collections of molecules
- Steps to calculate Percent Composition
 - 1st, get the MW
 - 2nd, get the total weight of the element in that molecule
 - 3rd, divide the total weight of that element by the MW and multiply by 100 to get percentage
 - 4th, repeat for all elements
- Example:
 - Calculate the %C, %H, and %F of CH₂F₂ (remember MW = 52)
 - %C $\Rightarrow 12 / 52 \times 100 = 23.1\%$
 - %H $\Rightarrow 2 / 52 \times 100 = 3.8\%$
 - %F $\Rightarrow 38 / 52 \times 100 = 73.1\%$

- Ask Students: Calculate the MW and Elemental

Compositions of the following molecules

- Group Activity

- CS_2

➤ MW =

➤ %C =

➤ %S =

- $\text{C}_3\text{H}_2\text{F}_4$

➤ MW =

➤ %C =

➤ %H =

➤ %F =

3F Calculating with Moles

- Determining the number of moles of a substance you have
 - Steps:
 - Determine the Molecular Weight of the substance
 - Determine the Weight of the substance
 - Divide the two numbers, i.e., # Moles = Weight / MW

- Determining the number of grams of a substance you have
 - Steps:
 - Determine the Molecular Weight of the substance
 - Determine the number of moles of the substance
 - Divide the two numbers, i.e., Weight = # Moles x MW

- Examples (For each of the following, determine the number of moles or weight of the substance, as required):
 - For CH₂F₂ (MW = 52)

➤ Ask Students: For each of the following, determine the number of moles or weight of the substance, as required

➤ Group Activity

➤ CS₂ 20 g

➤ CS₂ 0.24 moles

➤ C₃H₂F₄ 11.5 g

➤ C₃H₂F₄ 11.6 moles

3G Humans and CO₂

➤ Ask Students: Estimate the number of tons of CO₂ produced by your car each year

➤ Group and Board Activity

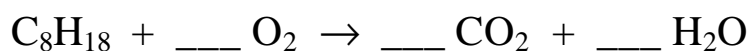
➤ Steps:

➤ Number of gallons of gas you add each week = ?

➤ Assume each gallon of gas weighs about 4 kg

➤ Assume that the formula for gasoline is C₈H₁₈ (i.e., pure Octane)

➤ Balance the reaction for combustion



➤ From the number of kg of Octane, calculate the number of moles of octane

➤ From the number of moles of Octane, calculate the number of moles of CO₂

➤ From the number of moles of CO₂, calculate its weight

- Given the number of cars in the world, one can easily see that we release a lot of CO₂

- Human effects on CO₂ balance
 - People release a total of about 6 - 7 billion tons per year
 - 5 billion tons from fossil fuels
 - 1 - 2 billion tons from deforestation

- CO₂ levels
 - 290 ppm before the Industrial Revolution
 - 360 ppm in 2000
 - net increase of 1.5 ppm per year

- of total CO₂ people release
 - one half is lost to Biosphere and Geosphere
 - this leaves about 3 billion tons added per year (i.e., 1.5 ppm or 740 billion metric tons)

3H Methane and Global Warming

- Remember: Methane has more peaks in its IR than does CO₂
 - It therefore is a stronger greenhouse gas (about 15 - 30 times)

- Sources of Methane
 - Swamps (marsh gas)
 - Rice Paddies
 - Ruminant (cattle, sheep) flatulence (73 million tons per year)
 - Termites (about 0.5 tonnes of termites per person)
 - Natural Gas production leaks

- Clathrates
 - Methane ices
 - Arctic permafrost
 - Sea Beds
 - Fuels?
 - Non-linear effects

3I Where do we go from here: Climate Modeling and Future

Changes

- Climatic Modeling
 - Limits to its accuracy
 - Program limitations
 - Computer limitations
 - Science understanding limitations
 - Data limitations
 - What it does
 - General predictions
 - Average temperature changes
 - Changes in extreme temperatures
 - Rainfall changes
- Sources of political controversy, differential costs/benefits

Index of Vocabulary and Major Topics

<p><i>I</i></p> <p>[CO₂] 4</p> <p>I</p> <p>109.5° 7, 8</p> <p>120° 7</p> <p>180° 7</p> <p>A</p> <p>AMU 13</p> <p>Arctic permafrost 20</p> <p>Ask Students 9, 15, 17, 18</p> <p>atmosphere 3</p> <p>Atmospheric CO₂ changes over the last 160,000 years 4</p> <p>Atomic Mass Units 13</p> <p>atomic weight 13</p> <p>B</p> <p>Biomass 5</p> <p>Biosphere 19</p> <p>Bond Angles 6, 7, 8</p> <p>Bond Distances 7, 8</p> <p>Bond Lengths 6</p> <p>Bond Order 7</p> <p>C</p> <p>C₃H₂F₄ 15, 17</p> <p>C₆H₁₂O₆ 5</p> <p>C₈H₁₈ 18</p> <p>Ca(CO₃) 5</p> <p>Ca⁺² 5</p> <p>Calcium Carbonate 5</p> <p>Calculate the MW 13</p> <p>Calculating with Moles 16</p> <p>Carbon Cycle 5</p> <p>Carbonate Minerals 5</p> <p>cattle 20</p> <p>CFC 3</p> <p>CH₂F₂ 13, 14, 16</p> <p>Changes in CO₂ Over Time 4</p> <p>Clathrates 20</p> <p>Climatic Modeling 21</p> <p>CO₂ 3, 5, 12, 13, 18, 20</p> <p>CO₂ balance 19</p> <p>CO₂ levels 19</p> <p>combustion 18</p> <p>Complex 3D Shapes 7</p>	<p>Correlations with Bonding 6</p> <p>costs/benefits 21</p> <p>CS₂ 15, 17</p> <p>D</p> <p>Distances 8</p> <p>Double Bonds 8</p> <p>Dynamic Balance of CO₂ 5</p> <p>E</p> <p>Earth 3</p> <p>Earth's Greenhouse 3</p> <p>electromagnetic energy 12</p> <p>electromagnetic spectrum 12</p> <p>element 13</p> <p>Elemental Compositions 15</p> <p>energy difference 10</p> <p>Experimental Observations 6</p> <p>F</p> <p>flatulence 20</p> <p>Fossil Fuels 5</p> <p>frequencies 11</p> <p>frequency 10</p> <p>Fuels 20</p> <p>G</p> <p>gardening 3</p> <p>Geosphere 19</p> <p>Glucose 5</p> <p>gram 13, 16</p> <p>Graphics from Text 3, 4, 5, 12</p> <p>greenhouse 3</p> <p>greenhouse gas 20</p> <p>Greenhouse Gasses 3</p> <p>Group Activity 9, 15, 17</p> <p>Group and Board Activity 18</p> <p>H</p> <p>H₂O 3, 5, 12, 18</p> <p>Humans and CO₂ 18</p> <p>I</p> <p>Ice Ages 4</p> <p>individual atoms 13</p> <p>Industrial Revolution 19</p> <p>Infra-Red 12</p> <p>IR 12</p> <p>IR Spectrum of CO₂ 12</p>
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