Chemistry 500: Chemistry in Modern Living

Topic 4: Energy, Chemistry, and Society

Thermodynamics, Kinetics, and Fossil Fuels

Chemistry in Context, 2nd Edition: Chapter 4, Pages 113-148

Chemistry in Context, 3rd Edition: Chapter 4, Pages 137-182

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

Outline

4A Heat, Temperature, and Energy

- Heat: at a chemical level can be thought of as atomic and molecular motion

- Temperature: a measure of the degree of heat in a substance, a scale

- Energy: the capacity to do work
  - Units of energy
    - A calorie, cal, is the amount of energy required to raise one gram of water 1 °C
    - A calorie also equals 4.184 joules (J, metric)
    - A Calorie (in food) is really 1,000 calories = 1 kcal

- Heat Capacity: a measure of the amount of heat energy that a substance can hold

- Discuss:
  - Fire walking
  - Oven burns

- First Law of Thermodynamics
  - Also called the law of conservation of energy
  - Energy can neither be created nor destroyed

4B Energy Consumption Patterns

- Graphics from Text: Figure 4.2 in the 2nd Edition and 4.3 in the 3rd Edition, Annual per capita energy consumption levels of selected countries

- Ask Students: Explain the origins of the observed differences in total energy consumption between different countries.
  - Group Activity

- Ask Students: Using these same factors, predict how the energy consumption in the valley has changed in the last 30 years.
  - Group Activity

- Graphics from Text: Figure 4.4, Annual US energy consumption from various sources.
  - Discuss the origins of the trends for:
    - Wood
    - Coal
    - Oil
    - Natural Gas
    - Nuclear Fission

- Graphics from Text: Figure 4.5 in Text, Sources of US vs. World Energy Consumption

- Ask Students: Why does the US pattern differ from other countries
  - Group Activity

4C Energy: Where From and How Much?

- Exothermic Reactions
  - Reactions that give off heat \

- Endothermic Reactions
  - Reaction that consume heat

- Examples

$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O + \text{Energy}$ (Exothermic)

$CO_2 + 2\,H_2O + \text{Energy} \rightarrow CH_4 + 2\,O_2$ (Endothermic)

- Example Calculation
  - Methane Oxidation produces approximately 800 kJ/mole
  - If one has 1 g of Methane, how much total heat will be produced

800 kJ/mole x 1 g / 16 g/mole = 50 kJ/g

- Where does this energy come from / go to?
  - Changes in Bond Energy

  - If the total of all the bond strengths in the products are stronger than the bonds in the starting material than the reaction will "want" to proceed and energy will be given off

  - If the total of all the bond strengths in the products are weaker than the bonds in the starting material than the reaction will not "want" to proceed and energy will be consumed

- Bond Strengths
  - Graphics from Text: Table 4.1 in the Text, Table of Bond Energies
    - Practice reading the values off of the table for different bond types
  - General Trends
    - Single Bonds are Weaker than Double Bonds which are Weaker than Triple Bonds

4D Activation Energy

- Graphics from Text: Figure 4.9 in 2nd Edition and 4.10 in 3rd Edition, Energy - Reaction Pathway Diagram

- Analogy with Mountain Passes and Valleys

- Energy of Activation
  - The energy required by the reagents before the reaction can proceed
  - A barrier that must be surmounted to go from starting materials to product

- Net Energy Change of Reaction
  - The net energy given off or consumed by a reaction

- For a reaction to occur quickly, need the correct collision energy, collision orientation, and number of collisions

- Exothermic Reaction Pathway Diagram

- Thermoneutral Reaction Pathway Diagram

- Endothermic Reaction Pathway Diagram

4E The Nature of a Flame (Optional Topic 4.1)

- Discussion of what a candle flame looks like

- What burns: Solids, Liquids, and/or Gasses?

- Diagram: Fuel, Charred Fuel, Pyrolysis Zone, Transport Zone, Combustion Zone
  - Role of Free Radicals in combustion
  - Nature of Fuel Molecules

- How to make something fireproof
  - Slow Pyrolysis, Slow Combustion, Remove Heat
  - Fireproofing strategies
  - Halons and fire extinguishers

- Ask Students: What is it that actually kills people in fires?
  - Group Activity

- What is Flashover?

4F King Coal

- What is the structure of coal?
  - Organic
  - Mineral / Inorganic
  - Scale Effects

- How was Coal Formed?
  - Plants
  - Anaerobic Decomposition
  - Heat and Pressure

- Rank of Coal

Peat

⇓

Brown Coal

⇓

Sub-bituminous Coal

⇓

Bituminous Coal

⇓

Anthracite Coal

- Due to differences in age and heating history
- Changes of elemental composition with time
- Changes in appearance
- Typical Formula: $C_{135}H_{96}O_9NS$, Extremely Variable

- Graphics from Text: Table 4.2 from Text, Classification, Composition, and Fuel Values of various North American coals

- Sulfur content of coal
  - Organic Sulfur
  - Inorganic Sulfur
  - US regional trends in Sulfur content
  - Clean Coal Desulfurization Initiative
  - Combustion

$$\text{Coal (S)} + \text{Oxygen} \Rightarrow CO_2 + H_20 + \text{Energy} + SO_2 / SO_3$$

- Coal Mining
  - Underground mining
  - Open pit mining
  - Pollution (air, water, radiation)
  - Safety (100,000 deaths in US since 1900)

4G Refining Petroleum

- Water Distillation diagram

- The process of moonshining
  - Corn mash, fermentation, distillation

- Petroleum Distillation
  - Graphics from Text: Figure 4.11 from 2nd Edition and 4.12 from 3rd Edition, Diagram of a distillation tower

  - Fractions Obtained
    - Gasoline (C5 to C12), Pavement (C20 or greater), etc.
    - Relationships to boiling point / volatility
    - Relative values of fractions as a function of molecular weight
    - "Oil Shortages" as "fraction shortages"
    - Relative compositions of different oils

- Improving the Yield, Cracking
  - Graphics from Text: Figure 4.13 in 3rd Edition, typical yields from a barrel of petroleum
  - Synthetic process to break complex molecules into smaller / simpler ones that have a higher value

$$C_{16}H_{34} \Rightarrow C_8H_{18} + C_8H_{16} + \text{etc.}$$

- "Synthetic Oils"
  - Costs of production vs. importing oil
  - Capital costs high
  - Cracking, Hydrogenation, Reforming, …
  - Heavy Oil
    - Steam / Surfactant Injection
  - Shale Oil in Colorado
  - Tar Sands in Alberta
    - $10 - 15 a barrel production cost
    - Environmental costs

4H Alcohol Fuels

- Fuels
  - Grains, harvest residues, garbage, etc.

- Fermentation to give Ethanol

$$\text{Sugar } (C_6H_{12}O_6) + \text{Yeast} \Rightarrow 2\ C_2H_5OH + 2\ CO_2$$

- Concentration
  - Byproducts

- Distillation
  - Gives 95% ethanol
  - Energy cost
  - Reverse osmosis

- Gasohol = Gasoline + Ethanol + Blending Agent (MTBE)

4I Electricity from Heat

- Graphics from Text: Figure 4.13 in 2nd Edition and 4.16 in 3rd Edition, Diagram of any heat powered plant for electricity generation

- Graphics from Text: Figure 4.14 from 2nd Edition and 4.17 from 3rd Edition, Conversions of types of energy in power plants

Potential Energy (Chemical Bonds)

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Heat Energy

⇓

Mechanical Energy

⇓

Electrical Energy

- Energy lost at each stage

Index of Vocabulary and Major Topics