

## **Chemistry 500: Chemistry in Modern Living**

### **Topic 4: Energy, Chemistry, and Society**

### **Thermodynamics, Kinetics, and Fossil Fuels**

Chemistry in Context, 2<sup>nd</sup> Edition: Chapter 4, Pages 113-148

Chemistry in Context, 3<sup>rd</sup> Edition: Chapter 4, Pages 137-182

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

## Outline

<b>4A</b>	<b>HEAT, TEMPERATURE, AND ENERGY .....</b>	<b>3</b>
<b>4B</b>	<b>ENERGY CONSUMPTION PATTERNS .....</b>	<b>5</b>
<b>4C</b>	<b>ENERGY: WHERE FROM AND HOW MUCH? .....</b>	<b>8</b>
<b>4D</b>	<b>ACTIVATION ENERGY.....</b>	<b>11</b>
<b>4E</b>	<b>THE NATURE OF A FLAME (OPTIONAL TOPIC 4.1).....</b>	<b>13</b>
<b>4F</b>	<b>KING COAL.....</b>	<b>15</b>
<b>4G</b>	<b>REFINING PETROLEUM.....</b>	<b>18</b>
<b>4H</b>	<b>ALCOHOL FUELS .....</b>	<b>21</b>
<b>4I</b>	<b>ELECTRICITY FROM HEAT.....</b>	<b>22</b>

## 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 2<sup>nd</sup> Edition and 4.3 in the 3<sup>rd</sup> 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?

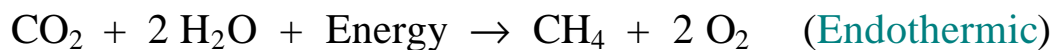
### ➤ Exothermic Reactions

- Reactions that give off heat \

### ➤ Endothermic Reactions

- Reaction that consume heat

### ➤ Examples



### ➤ Example Calculation

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

$$800 \text{ kJ/mole} \times 1 \text{ g} / 16 \text{ g/mole} = 50 \text{ kJ/g}$$



- 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 2<sup>nd</sup> Edition and 4.10 in 3<sup>rd</sup> 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

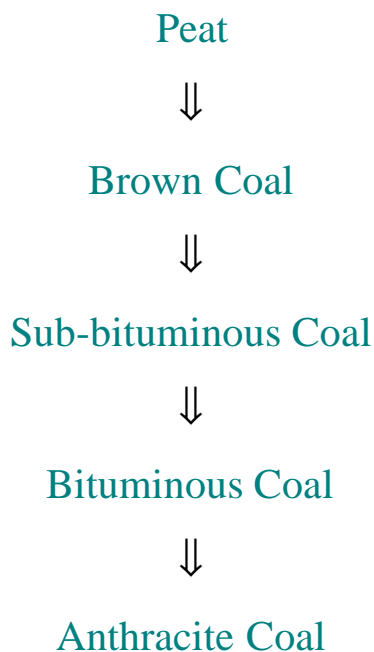
➤ How was Coal Formed?

➤ Plants

➤ Anaerobic Decomposition

➤ Heat and Pressure

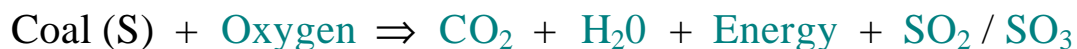
➤ Rank of Coal



- 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



- 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 2<sup>nd</sup> Edition and 4.12 from 3<sup>rd</sup> 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 3<sup>rd</sup> Edition, typical yields**  
from a barrel of petroleum

➤ Synthetic process to break complex molecules into smaller /  
simpler ones that have a higher value



- “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



- 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 2<sup>nd</sup> Edition and 4.16 in 3<sup>rd</sup> Edition, Diagram of any heat powered plant for electricity generation
- Graphics from Text: Figure 4.14 from 2<sup>nd</sup> Edition and 4.17 from 3<sup>rd</sup> Edition, Conversions of types of energy in power plants

Potential Energy (Chemical Bonds)



Heat Energy



Mechanical Energy



Electrical Energy

- Energy lost at each stage

## Index of Vocabulary and Major Topics

**9**

95% ethanol..... 21

**A**

Activation Energy ..... 11

age..... 16

Alcohol Fuels ..... 21

Anaerobic Decomposition ..... 15

Anthracite Coal..... 16

Ask Students .....5, 6, 7, 14

**B**

Bituminous Coal..... 16

Blending Agent..... 21

boiling point ..... 18

Bond Energy ..... 9

bond strengths..... 9

Bond Strengths ..... 10

bond types..... 10

Brown Coal..... 16

Byproducts ..... 21

**C** $C_{16}H_{34}$  ..... 19 $C_2H_5OH$ ..... 21 $C_6H_{12}O_6$  ..... 21 $C_8H_{16}$  ..... 19 $C_8H_{18}$ ..... 19

cal ..... 3

calorie..... 3

Calorie..... 3

candle flame..... 13

Capital costs..... 20

 $CH_4$ ..... 8

Charred Fuel..... 13

Chemical Bonds..... 22

Classification..... 16

Clean Coal Desulfurization Initiative ..... 17

 $CO_2$ ..... 8, 17, 21

coal..... 15

Coal..... 6

Coal Mining..... 17

collision energy ..... 11

collision orientation ..... 11

Combustion ..... 13, 17

Combustion Zone..... 13

Composition..... 16

Concentration..... 21

conservation of energy ..... 4

Corn mash..... 18

Cracking..... 19, 20

**D**

deaths..... 17

distillation..... 18

Distillation..... 21

distillation tower..... 18

Double Bonds ..... 10

**E**

Electrical Energy ..... 22

Electricity from Heat ..... 22

electricity generation..... 22

elemental composition..... 16

Endothermic..... 8

Endothermic Reaction Pathway Diagram..... 12

Endothermic Reactions ..... 8

Energy ..... 3, 8, 17

Energy - Reaction Pathway Diagram..... 11

Energy Consumption Patterns..... 5

Energy of Activation..... 11

Energy: Where From and How Much..... 8

Environmental costs..... 20

Ethanol ..... 21

Exothermic ..... 8

Exothermic Reaction Pathway Diagram..... 12

Exothermic Reactions..... 8

**F**

fermentation..... 18

Fermentation..... 21

fire extinguishers..... 13

Fire walking..... 4

fireproof ..... 13

Fireproofing strategies..... 13

First Law of Thermodynamics..... 4

Flashover..... 14

Formula..... 16

fraction shortages..... 18

Fractions Obtained..... 18

Free Radicals..... 13

Fuel..... 13

Fuel Molecules ..... 13

Fuel Values..... 16

**G**

garbage..... 21

Gasohol ..... 21

Gasoline..... 18, 21

Gasses..... 13

Grains..... 21

Graphics from Text .....5, 6, 7, 10, 11, 16, 18, 19, 22

Group Activity.....5, 6, 7, 14

**H**

H <sub>2</sub> O.....	17
H <sub>2</sub> O.....	8
Halons .....	13
harvest residues .....	21
Heat.....	3, 13, 15
Heat Capacity .....	4
Heat Energy .....	22
Heat, Temperature, and Energy .....	3
heating history .....	16
Heavy Oil.....	20
Hydrogenation.....	20

**I**

Inorganic.....	15
Inorganic Sulfur.....	17

**J**

joules .....	3
--------------	---

**K**

King Coal.....	15
----------------	----

**L**

Liquids .....	13
---------------	----

**M**

Mechanical Energy .....	22
Methane .....	8
Mineral.....	15
moonshining.....	18
Mountain Passes .....	11
MTBE.....	21

**N**

Natural Gas.....	6
Net Energy Change of Reaction .....	11
Nuclear Fission.....	6

**O**

O <sub>2</sub> .....	8
Oil.....	6
Oil Shortages.....	18
Open pit mining.....	17
Optional Topic.....	13
Organic.....	15
Organic Sulfur.....	17
Oven burns .....	4
Oxidation .....	8
Oxygen.....	17

**P**

Peat .....	16
per capita energy consumption.....	5
Petroleum Distillation.....	18

Plants.....	15
Pollution.....	17
Potential Energy .....	22
power plants.....	22
Pyrolysis .....	13
Pyrolysis Zone.....	13

**R**

Rank of Coal.....	16
Refining Petroleum.....	18
Reforming.....	20
regional trends.....	17
Reverse osmosis .....	21

**S**

Safety .....	17
Shale Oil in Colorado.....	20
Single Bonds.....	10
SO <sub>2</sub> .....	17
SO <sub>3</sub> .....	17
Solids.....	13
Sub-bituminous Coal.....	16
Sugar.....	21
Sulfur content of coal.....	17
Surfactant.....	20
Synthetic Oils .....	20

**T**

Table of Bond Energies.....	10
Tar Sands in Alberta.....	20
Temperature.....	3
The Nature of a Flame.....	13
Thermoneutral Reaction Pathway Diagram.....	12
total energy consumption.....	5
Transport Zone.....	13
Triple Bonds.....	10

**U**

Underground mining.....	17
US energy consumption.....	6

**V**

volatility.....	18
-----------------	----

**W**

water.....	3
Water Distillation.....	18
Wood.....	6
World Energy Consumption.....	7

**Y**

Yeast.....	21
yields from a barrel of petroleum.....	19



