Lecture #3

Environmentally Responsible Design and Manufacturing

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Revisiting Concerns

- **While environmental challenges are often global in nature, let's view things from a U.S. perspective...**
- **What makes a company competitive??**
- **Taylor & history (Ind. Rev., Wage Incentive Plans, Apollo program, Quality)**
- **Japan -- no energy resources -- impact on products**
- **Northern Europe -- diminishing landfills**
- **Sutherland's theory: "real or artificial challenges drive technological change"**

Global Benchmarking

Government Activities—Relative Competitiveness*

Activity	Japan	U.S.	Europe
Take-back legislation	**	*	****
Landfill bans	**	*	***
Material bans	*	*	**
LCA tool and database development	***	**	****
Recycling infrastructure	**	*	***
Economic incentives	**	*	***
Regulate by medium	*	**	*
Cooperative/joint efforts with industry	**	*	****
Financial and legal liability	*	****	*

*Number of asterisks indicate comparative strength, and are intended to be indicative of level of effort and emphasis as much as actual level of success.

Global Benchmarking

Industrial Activities—Relative Competitiveness

Activity	Japan	U.S.	Europe
ISO 14000 certification	****	*	***
Water conservation	**	***	*
Energy conservation/CO2 emissions	****	**	**
Decreased releases to air and water	*	***	**
Post Industrial solid waste reduction/recycling	****	**	***
Post-consumer recycling	**	*	****
Material and energy inventories	***	*	**
Alternative material development	**	*	***
Supply chain involvement	**	*	**
EBM as a business strategy	****	**	***
Life-cycle activities	**	**	**

Global Benchmarking

Research and Development Activities—Relative Competitiveness

Activity	Japan	U.S.	Europe
Relevant Basic Research (> 5 years out)			
Polymers	**	***	**
Electronics	**	***	*
Metals	***	*	**
Automotive/Transportation	**	*	***
Systems	**	*	***
Applied R&D (< 5 years out)			
Polymers	*	***	**
Electronics	***	**	**
Metals	***	*	**
Automotive/Transportation	***	*	***
Systems	**	*	***

Course Philosophy

- **Abandoning industrial activity -- not an option!**
- **We must improve the products and processes we develop -- less environmental impact.**
- **Our challenge: identify environmental improvement opportunities that are "win-win" -- benefit the environment AND reduce cost, improve performance, etc.**

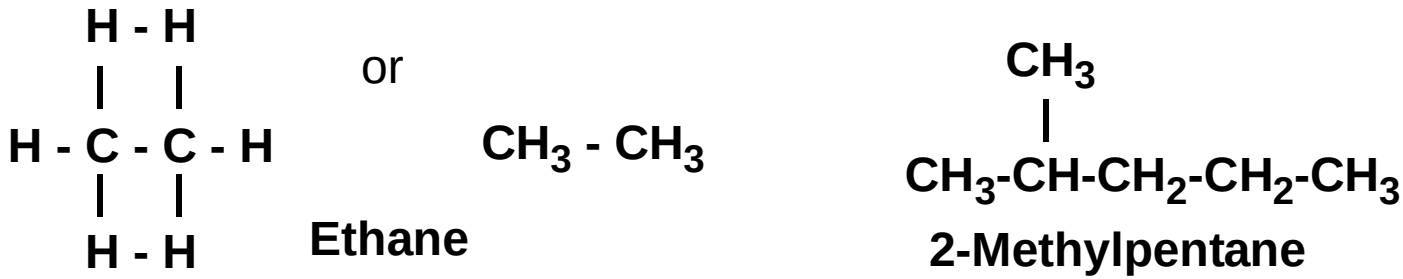
Emissions and Impacts

- **Organic Chemicals**
- **Metals and Inorganic Materials**
- **Contaminant Transport / Transformation**
- **Air Pollution**

Organic Chemicals

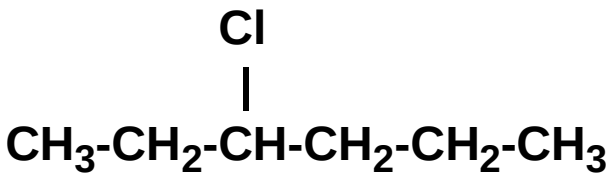
- **Aliphatic Compounds**
  Straight or branched chains of carbon atoms or rings with single bonds between the carbons

- **Alkanes: all bonds between carbon atoms are single bonds (paraffins)**



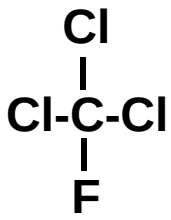
methane, ethane, propane, butane

replace one or more hydrogen atoms with other atoms: Halides (Cl^-, F^-, Br^-, I^-), Amines (NH_2), Amides [$CO(NH_2)$]



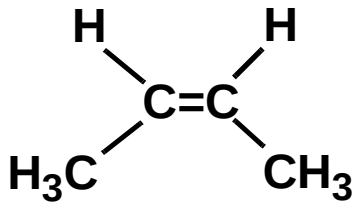
3-Chlorohexane

Chlorofluorocarbons (CFCs) an example, Trichlorofluoromethane or Freon 11



Freon 11

- **Alkenes: aliphatic compounds, double bond between two adjacent carbon atoms**



2-Butylene

- **Alkynes: Triple bond between two carbon atoms**

CH_3-C≡C-CH_2-CH_3 **2-Pentyne**

- **Organic acids: Usually have carboxylic acid group on end of molecule (--COOH). Molecule's name ends in -anoic. Methanoic acid.**

- **Esters: compounds formed by reaction of alcohols and organic acids. Of the form: R--COO--R' (where R and R' are organic groupings). Ethyl acetate**

- **Ethers: compounds formed by two alcohols.**
  Form: R--O--R'
  Diethyl ether: CH_3 - CH_2 - O - CH_2 - CH_3

- **Aldehydes & Ketones: Formaldehyde & Acetone**

- **Cyclic aliphatic compounds, e.g., cyclohexane**

- **Aromatic Compounds**
  Ring compounds with alternating single and double bonds between the ring carbons.
  Benzene is simplest
  Can add aromatics to aliphatics
  Other aromatics: Phenol, Toluene, & Styrene

  Polycyclic aromatic hydrocarbons - PAH (2 or more benzene rings fused together): e.g., Naphthalene

  Incomplete combustion produces many PAHs

  Chlorinated aromatic hydrocarbons - industrial applications
  Polychlorinated biphenyls (PCBs)

Metals & Inorganics

- **Arsenic -- not a true metal**
- **Cadmium**
- **Chromium**
- **Lead**
- **Mercury**
- **Cyanides**

Concentrations

$$\frac{1mg \text{ contaminant}}{10^6 mg \text{ media}} = 1.0ppm$$

$$\frac{1mg \text{ contaminant}}{10^3 mL \text{ solvent}} = 1.0mg/L$$

For water, 1kg = 1L.

$$\frac{mg}{L} = \frac{mg}{kg} = ppm$$

Transport Processes

- **Loading processes**
- **Dispersive processes**
- **Diffusional processes**
- **Reactive/transformation processes**
- **Solubility**
- **Volatilization**

Air Pollution

- **Carbon Monoxide**
- **Hydrocarbons (volatile organic compounds)**
- **Sulfur dioxide (SO_2)**
- **Particulates**
- **Nitrogen oxides (NO and NO_2)**
- **Carbon dioxide**
- **HAPs: Hazardous air pollutants**

Other Air Pollution Issues

- **Smog: Smoke + Fog, produced by a photochemical reaction -- interaction of nitrogen oxides & hydrocarbons under the influence of sunlight. Automobile exhaust.**
- **Acid Rain: Sulfur dioxide and nitrogen oxide emissions. Reactions for sulfuric and nitric acids. Effect is felt "downwind" from emission source.**
- **Global Warming: Biggest greenhouse gas - CO_2, efficient at absorbing infrared radiation. Other gases with GWP (global warming potential): methane, CFCs,**
- **Ozone depletion: Ozone (O_3) in stratosphere blocks harmful ultraviolet radiation. Some chemicals (CFCs) react with ozone & destroy it.**