Carbon Chemistry

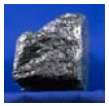
Prentice Hall *Physical Science* –
Chapter 9

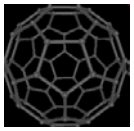
Introduction

- What do you know about organic chemistry?
- Organic compounds:
  - Contain C and H
  - May contain some other elements, such as O and N
- What kind of bonds does carbon make?
  - Covalent
- How many bonds can carbon make?
  - 4 single covalent
  - 1 double and 2 single
  - 2 double
  - 1 triple and 1 single

Forms of Carbon

- Three main forms of Pure Carbon
  - Diamond
    - Network solid (all atoms linked by covalent bonds)
    - Rigid, compact and strong
  - Graphite
    - Carbon atoms arranged in widely spaced layers
    - Soft and slippery
  - Fullerenes
    - Large hollow spheres/cages of carbon (like a soccer ball)





Saturated Hydrocarbons

- ***Hydrocarbon***: organic compound containing ONLY C and H
- ***Saturated hydrocarbon***: all bonds in compound are single covalent bonds
- Also called ***alkanes***
  - Names of alkanes end in *–ane*
  - Naming and properties depend on # of C atoms and arrangement

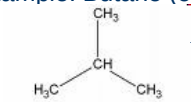
Saturated Hydrocarbons (cont'd)

- Straight chains
  - Carbon atoms arranged in a line
  - Naming depends on # of C atoms

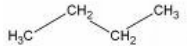
# of C atoms	Name of Compound
1	Methane
2	Ethane
3	Propane
4	Butane
5	Pentane
6	Hexane
7	Heptane
8	Octane
9	Nonane
10	Decane

Saturated Hydrocarbons (cont'd)

- Branched Chains
  - Carbon atoms arranged in branches
  - ***Isomers***: compounds with same molecular formula but different structures
  - Example: Butane (or n-Butane) and Isobutane



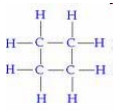
→ Isobutane (branched): C_4H_{10}



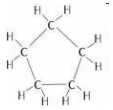
→ n-Butane (straight-chain): C_4H_{10}

Saturated Hydrocarbons (cont'd)

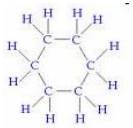
- Rings
  - Carbon atoms linked in a circle, or ring
  - AKA cyclic alkanes
  - Most have 5 or 6 carbon atoms



Cyclobutane
C_4H_8



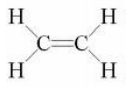
Cyclopentane
C_5H_{10}

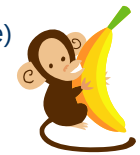


Cyclohexane
C_6H_{12}

Unsaturated Hydrocarbons

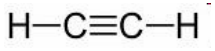
- ***Unsaturated Hydrocarbon***: contains one or more double or triple bonds
- Alkenes
  - Have one or more double bonds
  - Naming: end in *–ene* suffix
  - Example: Ethene (also known as Ethylene) (makes fruit ripen)





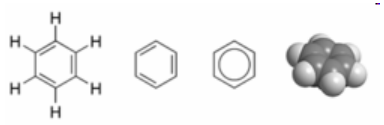
Unsaturated Hydrocarbons (cont'd)

- Alkynes
  - Have one or more triple bonds
  - Naming: end in *–yne* suffix
  - Example: Ethyne (also known as acetylene) (used in welding torches)
  - MOST REACTIVE HYDROCARBON COMPOUNDS



Unsaturated Hydrocarbons (cont'd)

- Aromatic Hydrocarbons
  - Contain ring structures where the valence e^- are shared by all carbon atoms
  - Represented by alternating single- and double-bonds
  - Example: Benzene

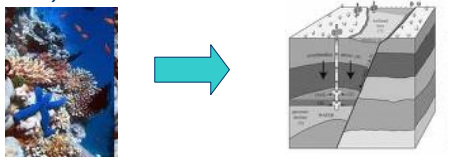


Fossil Fuels

- Mixtures of hydrocarbons that formed from remains of plants or animals
- Coal
  - Formed from plants
  - Mainly a mixture of aromatic hydrocarbons (high ratio of C to H – produces a lot of soot when burned)

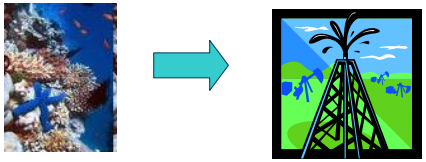
Fossil Fuels (cont'd)

- Natural gas
  - Formed from marine organisms
  - Mainly methane with some other light hydrocarbons (ethane, propane, butane and pentane)



Fossil Fuels (cont'd)

- Petroleum
  - Formed from marine organisms
  - AKA Crude Oil
  - Complex liquid mixture of hydrocarbons



Combustion of Fossil Fuels

- ***Combustion***: reaction with O_2
- Example: combustion of propane (C_3H_8):

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$

- Products of complete combustion:
  - CO_2
  - H_2O
- Some fossil fuels also contain sulfur and nitrogen, so their combustion releases sulfur dioxide and nitrogen oxides

Incomplete Combustion

- ***Incomplete combustion***: not enough O_2 available
- Example: incomplete combustion of propane

$$2C_3H_8 + 7O_2 \longrightarrow 6CO + 8H_2O$$

- Products of incomplete combustion:
  - CO (carbon monoxide – a toxic gas)
  - H_2O

Acid Rain

- Combustion of fossil fuels causes acidity of rain to increase
  - CO_2 forms carbonic acid
  - SO_2 forms sulfuric acid
  - Nitrogen oxides form nitric acid
- pH of acid rain can be as low as 2.7 (remember vinegar's pH?)
- Damages buildings and disrupts ecosystems

Substituted Hydrocarbons

- One or more hydrogen atom has been replaced by an atom or group of atoms
- The atom or group of atoms taking hydrogen's place is called the *functional group*
- See functional group chart on the back of the Molecule building lab handout (*note that dashes on the functional groups are where other bonds can be made with other atoms*)

Haloalkanes

- Functional Group = ***Halogen Atom*** (F, Cl, Br, I)
- Example: Chloromethane

  CH_3Cl
- Important refrigerants
- Chlorofluorocarbons (CFC's) have been banned because they deplete the ozone layer

Alcohols

- Functional Group = ***Hydroxyl*** (-OH)
- DO NOT confuse this with the hydroxide ion – they are DIFFERENT
- Examples:
  - Ethanol CH_3CH_2OH
  - Isopropanol → $CH_3\text{-}\underset{\displaystyle H}{\overset{\displaystyle OH}{\underset{|}{\overset{|}{C}}}}\text{-}CH_3$
- Synthsized by reaction between either
  - Haloalkane and a base
  - Alkene and water

Ethers

- Functional group = ***Ether*** (-C-O-C-)
- Examples:
  - Diethyl ether (or ethyl ethyl ether)
    - CH3CH2-O-CH2CH3
    - Used as an early anesthetic
  - Poly(ethylene glycol) (AKA PEG)
    - $HO\text{-}CH_2\text{-}(\text{-}CH_2\text{-}O\text{-}CH_2\text{-})_n\text{-}OH$
    - Polymer with the ether functional group used in many cosmetics and pharmaceuticals

Organic Acids (AKA Carboxylic Acids)

- Functional group – ***Carboxyl*** group (-COOH)

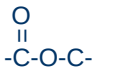
- Naming: end in –*oic* acid
- Examples:
  - Methanoic acid (AKA formic acid – think ant bites!)
  - Ethanoic acid (AKA acetic acid – in vinegar)

Organic Bases (AKA Amines)

- Functional group = ***Amino*** group ($-NH_2$)
- Example: Methylamine CH_3NH_2 (responsible for the smell of rotten fish)
- Play important role in protein synthesis (see section 9.3)

Esters

- Functional group: Ester (-COOC-)



- Formed from reaction between organic acids and alcohols
- Responsible for many food flavors and pleasant odors of flowers

Polymers

- ***Polymer***: large molecule formed when many smaller molecules are linked together by covalent bonds
- ***Monomer***: the smaller molecule that is linked together
- Classified as either
  - Natural polymers
  - Synthetic polymers

Synthetic Polymers

- Used for many applications
- Properties depend on
  - Number of monomers (or size)
  - Type of monomers
- Examples:
  - Rubber (tires, adhesives)
  - Nylon (fabrics for parachutes, windbreakers, ropes, etc…)
  - Polyethylene (plastic milk bottles, plastic wrap, toys)
  - Polycarbonate (optical lenses, CDs, fighter jet enclosures & other shatter-resistant glass applications)

Natural Polymers

- Large molecules produced by organisms
- Examples:
  - Starches (polymers of glucose)
  - Cellulose
  - Nucleic Acids (DNA, RNA)
  - Proteins (polymers of Amino Acids)