Chemistry 1506: Allied Health Chemistry 2

Section 2: Alkenes, Alkynes, and Aromatic Compounds

Hydrocarbons with Multiple Bonds

Outline

Section 2.1 Introduction and Nomenclature of Alkenes

- Ethene = (Ethylene), $CH_2=CH_2$

- IUPAC Rules
  - Start numbering from the end that gives the double bond the lowest number.
  - Indicate position of double bond(s) by numbers.
  - Use the ene ending
  - Indicated number of double bonds by prefixes (ene, diene, triene, tetraene, etc.)

  - Examples

- Geometric Isomers
  - No free rotation (π-bonds)
    - Experimental observations
  - cis isomers vs. trans isomers
  - Examples

Section 2.2 π-Bonds

- Bonding: sp^2 hybridization for 3 σ-bonds to the three atoms bonded to each carbon
- p_z orbital for π-bond
- Typical C=C bond distance (i.e., 1.34 Å) and thus shorter than the C-C distance (i.e., 1.54 Å)
- slightly shorter C-H distance than alkanes

Section 2.3 Physical Properties

- Almost identical to Alkanes of same MW
  - Van der Waals forces
- Slightly higher Mp and Bp
- Smell (turpentine like)
- Density
- Solubility

Section 2.4 Chemical Properties: Addition Reactions

- Addition reaction (generic)
  - π-bonds weaker than σ-bonds

- Hydrogenation: Addition of H_2 or D_2 (Pt catalyst)

- Addition of Cl_2 or Br_2 (X_2)

- Addition of HX ((HF) HCl, HBr (HI))
  - Halide Influences
  - Markovnikov Addition

- Addition of Water (Hydration)
  - H^+ Catalyst
  - Markovnikov

Section 2.5 Addition Polymers

- Definition of Addition Polymers
  - No loss of mass
  - Rapid chain growth
  - π-bond opening
  - "Generic" Synthesis Reaction
    - typical monomers are CH_2=CH-R

- Role of Catalysts
  - Speed reaction but aren't themselves consumed
  - Highly reactive species

- Reversibility of Reactions
  - Polymerization under low temperatures/high pressures
    - i.e., monomer (liquids or gasses) -> polymer (solids)
  - Depolymerizations (unraveling) at high temperatures
    - i.e., polymer -> monomer
- Molecular Weights and Molecular Weight Distributions
  - High average Molecular Weights
  - Distributions rather than discrete weights
- Linear Chains vs. Branched Chains

- Examples
  - Polyethylene, PE, Synthesis
    - $CH_2=CH_2$, R = H

  - Poly(vinyl chloride), PVC, Synthesis
    - $CH_2=CH\text{-}Cl$, R = Cl

- Polypropylene, PP, Synthesis
  - CH_2=CH-CH_3, R = CH_3

- Polystyrene, PS, Synthesis
  - CH_2=CH-C_6H_5, R = C_6H_5

- Poly(methyl methacrylate), PMMA, Synthesis
  - CH_2=C(CH_3)(CO_2CH_3)

- Teflon Synthesis
  - $CF_2=CF_2$

- Rubber (Polyisoprene) Synthesis
  - $CH_2=CH-CH=CH_2$

Section 2.6 Alkynes

- Carbon-Carbon Triple Bonds
  - sp hybridized
  - Very Short C≡C Bond distance (i.e., 1.20 Å), much shorter than the C=C distance (i.e., 1.34 Å) and the C-C distance (i.e., 1.54 Å)
  - Bonding: 1 σ-bond and 2 π-bonds (p_x and p_y)
  - slightly shorter C-H distance than alkanes or even alkanes
  - Ethyne = Acetylene, H-C≡C-H

- Physical Properties
  - Almost identical to Alkanes/Alkenes of same MW
    - Van der Waals forces
  - Slightly higher Mp and Bp
  - Density
  - Solubility

- Nomenclature
  - yne ending
  - yne > ene in priority of naming
  - Examples

- Alkyne Reactions
  - Generic Reaction
    - Very like Alkenes
    - Normally Double Addition

  - Hydrogenation: Addition of H_2 or D_2 (Pt catalyst)

  - Addition of X_2 (Cl_2 or Br_2)

- Addition of HX (most commonly HCl and HBr)
  - Markovnikov Addition

- Addition of H_2O (H^+ catalyst)
  - Markovnikov Addition
  - Secondary elimination of water from diol
    - gives carbonyl group (aldehyde or ketone)

Section 2.7 Aromatic Hydrocarbons

- Sources
  - Coal Tar
    - Coke production
    - Direct separation
    - Start of industrial chemistry
  - Petroleum
    - multiple processing steps
  - Uses
    - Octane enhancers in gasoline
    - Plastics
    - Pigments/Dyes
    - Pharmaceuticals
  - Aromatic: Properties, Reactivity, C/H Ratios (cf. Alkane/Alkenes/Alkynes)

- Substitution Reactions not Addition Reactions (i.e., not like alkenes)

- Bonding / Resonance Stabilization

- Nomenclature
  - IUPAC Names
    - Halobenzenes (X = F, Cl, Br, I)
    - Nitrobenzene (Z = NO_2)
    - Alkylbenzenes (phenylalkanes)

- Common Names (IUPAC)
  - Phenol (Z = OH)
  - Aniline (Z = NH_2)
  - Toluene (Z = CH_3, methylbenzene)
  - Benzoic Acid (Z = CO_2H)

- Multiply Substituted Arenes
  - Numbering Ring Positions
  - Ortho, Meta, Para, Ipso
- As Side Chains (phenyl groups)

Section 2.8 Amino Acids having Simple Aromatic Side Chains

- Generic AA = $H_2N\text{-}CHR\text{-}CO_2H$

- Phenyl Alanine (non-polar)
  - R = $CH_2C_6H_5$
  - PKU

Section 2.9 Aromatic Reactions

- Substitution Reactions
  - Require catalyst
  - "Generic"
  - Z^+ Electrophiles

- Nitration ($Z = NO_2$, HNO_3/H_2SO_4, TNT)

- Sulfonation (Z = SO_3H, H_2SO_4/SO_3)

- Halogenation (X = Cl or Br, Cl_2/Fe or Br_2/Fe)

Section 2.10 Fused Ring Aromatics

- Polycyclic Aromatic Hydrocarbons, PAHs
- Toxicity
- Naphthalene ($C_{10}H_8$)

- Anthracene ($C_{14}H_{10}$)

- Phenanthrene ($C_{14}H_{10}$)

Section 2.11 Heterocyclics (Not covered in detail)

- Replace C-H by Heteroatom Groups such as: N, O, S, etc.

- Important in Biomolecules

- Pyridine (C_5H_5N)

Index of Topics and Vocabulary