Lecture 8: Organic Geochemistry

Topic outline:

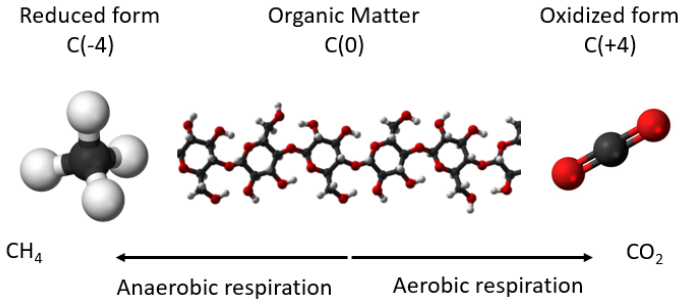
1. What is an organic compound?
2. Chemical bonds and chemical structures
3. Major categories of organic compounds
4. Important organic functional groups
5. Chemistry of organic matter in the environment
6. Techniques used to analyze organic matter

1. What is an organic compound?

Organic compound: A compound containing the element C bonded to the element H (excludes carbonate species)

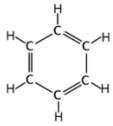
2. Chemical bonds and chemical structures

a. Carbon is the building block of organic matter
b. Forms four covalent bonds with H or other atoms (e.g., CH_4 to CR_4), where R = something other than H (usually C or O)
c. Organic compounds decompose to form CO_2 (aerobic respiration) or $CO_2 + CH_4$ (anaerobic respiration)



3. Major categories of organic compounds

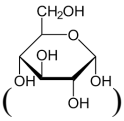
- Aliphatic – straight, branched, or cyclic chains of hydrocarbons
  - *Alkanes* (saturated): single bonds (branched or unbranched)
  - *Alkenes* (unsaturated): contain at least one double bond ($R_2C=CR_2$)
- Aromatic - Contain at least one cyclic ring with alternating double bonds (benzene); delocalized electrons



- Heterocyclic compounds
  - A ring that contains a heteroatom (typically N or O) that is not C

What happens when we burn organic molecules?

- $CH_2O + O_2 \rightarrow CO_2 + H_2O$
- Energy is released as C-H bonds are broken
- Oxygen from the air combines with C to form CO_2
- Eventually all the organic material is converted to CO_2 (assuming no byproducts)

Example of aerobic respiration: glucose oxidation (

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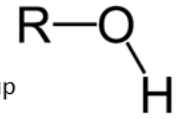
$C_6H_{12}O_6 + 6\ O_2 \rightarrow$ (intermediate compounds) $\rightarrow 6\ CO_2 + 6\ H_2O$ + energy

What are the redox pairs in this reaction?

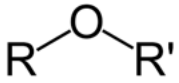
4. Organic functional groups

- Functional groups are specific groups (moieties) of atoms or bonds within molecules that are responsible for the chemical reactions of those molecules.

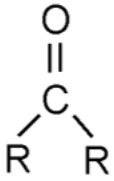
Alcohol
Hydroxyl (OH) group



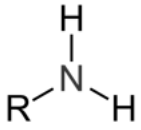
Ether
O bonded to two C atoms



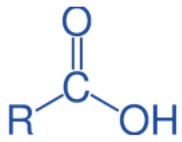
Carbonyl
C double bonded to the O atom



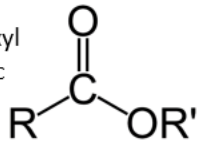
Amines
N atom bonded to one or more C-H groups



Carboxyl
C doubled bonded to O and single bonded to a hydroxyl group



Ester
Replaces H in carboxyl with another organic group



Phenols
Hydroxyl group bonded to a benzene ring

Carboxylic acids are organic molecules that contain carboxyl groups; example, acetic acid (CH_3COOH)

$CH_3COOH \leftrightarrow CH_3COO^- + H^+$

5. Where does natural organic matter come from?

Common terms used to describe organic matter in the environment:

- Natural organic matter (NOM) – naturally occurring in the environment
- Soil organic matter (SOM) – decomposing remains of plants, animals, and microbial byproducts contained in soils; typically a large pool relative to DOM
- Soil organic carbon (SOC) – the C contained in SOM
- Dissolved organic matter (DOM) – organic molecules that are soluble in water
- Dissolved organic carbon (DOC) – the C contained in water-soluble organic molecules
- Particulate Organic Matter (POM) - pieces of organic material > 0.45 μm; also POC
- Total Organic Carbon – all of the carbon contained in organic molecules in an unfiltered sample

Challenges for remediating organic pollutants:

a. Dispersion – movement of pollutants through the subsurface
b. Adsorption – binding of pollutants to organic and mineral surfaces

Polar compounds

- adsorb to surface charges on clay minerals and oxides

Nonpolar compounds

- Partition out of water; strongly adsorb to nonpolar phases in the subsurface; e.g., solid organic matter coatings on minerals
- ***Adsorption*** of nonpolar compounds follows distribution coefficient (K_d):
  $K_d = C_{ads}/C_{soln}$
  - The distribution coefficient for an organic molecule depends on its hydrophobicity, affinity for natural organic matter, and abundance of natural organic matter

6. Techniques to analyze natural organic matter

- TOC analyzers
- Loss-on-ignition
- Spec**tro**scopy