Unit 12
Organic Chemistry
Do Now: True or false?

1. Electrochemical cells generate electricity.
2. Electrons flow from left to right in a battery.
3. Redox reactions happen in both batteries and electrolytic cells.
The study of carbon, hydrogen, oxygen and nitrogen containing compounds
THE HYDROCARBONS

- Characteristics
  - contain only carbon and hydrogen
  - non-polar molecules
  - low boiling point - decompose easily
  - insoluble in water (most)
  - slow reactivity
  - non-electrolytes (poor ionization)
NOMENCLATURE in Ref. Tables

- The number of carbon atoms is determined by the root part of the name

  - meth 1 carbon
  - eth 2 carbon
  - prop 3 carbon
  - but 4 carbon
  - pent 5 carbon
  - hex 6 carbon
  - hept 7 carbon
  - oct 8 carbon
The Alkanes

- Characteristics
  - saturated hydrocarbons (single bonds only)
  - homologous series (follow same pattern)
  - fewer # of carbons - lower boiling points
  - follow same general formula - $C_nH_{2n+2}$
  - end in -ane
The Alkanes - Saturated hydrocarbons

Methane
\[
\begin{align*}
\text{H} & \quad \text{C} \quad \text{H} \\
\text{H} & \quad \text{H} \\
\end{align*}
\]

\[\text{CH}_4\]

Ethane
\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \quad \text{H} \\
\text{H} & \quad \text{H} \\
\end{align*}
\]

\[\text{C}_2\text{H}_6\]

Propane
\[
\begin{align*}
\text{H} & \quad \text{H} \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{H} \\
\text{H} & \quad \text{H} \quad \text{H} \quad \text{H} \\
\end{align*}
\]

\[\text{C}_3\text{H}_8\]
QOD: What are isomers?

Do Now: What prefix is used if there are three carbons in a carbohydrate?
Naming

1- find longest chain of C atoms and name it
2- name attached group
3- indicate the *address* of the attached group with number
Isomers - molecule has the *SAME* chemical formula, but *DIFFERENT* structural formula

Butane is the first hydrocarbon to exhibit isomerism.

n- Butane

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\]

\[\text{C}_4\text{H}_{10}\]

2-methyl propane (isobutane)

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\]

\[\text{C}_4\text{H}_{10}\]
n-pentane

\[
\begin{align*}
&H \quad H \quad H \quad H \quad H \quad H \\
&H - C - C - C - C - C - H \\
&H \quad H \quad H \quad H \quad H \quad H \\
&H \quad C \quad H \\
&H \quad H \quad H \quad H \quad H \quad H
\end{align*}
\]

\[C_5H_{12}\]

2-methylbutane (isopentane)

\[
\begin{align*}
&H \\
&H - C - H \\
&H \quad H \quad H \quad H \quad H \quad H \\
&H - C - C - C - C - H \\
&H \quad H \quad H \quad H \quad H \quad H
\end{align*}
\]

\[C_5H_{12}\]

2,2-dimethylpropane (neopentane)

\[
\begin{align*}
&H \\
&H - C - H \\
&H \quad H \quad H \quad H \quad H \quad H \\
&H - C - C - C - C - H \\
&H \quad H \quad H \quad H \quad H \quad H \\
&H - C - H \\
&H \quad H
\end{align*}
\]

\[C_5H_{12}\]
What elements will you find in a hydrocarbon molecule?

Draw a methane and an ethane molecule.
QOD: How do we define and name alkenes?

Do Now: Draw the structural formula for pentane and write the condensed formula.

How many isomers can you come up with for pentane? Try as many as you can.
n-hexane
\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \]
\[ \text{C}_6\text{H}_{14} \]

n-heptane
\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \]
\[ \text{C}_7\text{H}_{16} \]

n-octane
\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \]
\[ \text{C}_8\text{H}_{18} \]
The Alkenes - Unsaturated hydrocarbons

• Characteristics
  – unsaturated hydrocarbons (have at least 1 double bond)
  – homologous series (follow same pattern)
  – fewer # of carbons - lower boiling points
  – follow same general formula - \( C_nH_{2n} \)
  – end in \_ene
The Alkenes

- Ethene - $C_2H_4$

- Propene - $C_3H_6$
Isomers - compounds with the same chemical formula but differing shapes (structural formulae)

• 1-Butene

• 2-Butene
The Alkynes - Unsaturated hydrocarbons

- Characteristics
  - unsaturated hydrocarbons (have at least 1 triple bond)
  - homologous series (follow same pattern)
  - fewer # of carbons - lower boiling points
  - follow same general formula - $C_nH_{2n-2}$
  - end in -yne
Alkynes - $C_nH_{2n-2}$

- Ethylene

- Propyne

- 1-Butyne

- 2-Butyne
Exit Question

Draw and name the following hydrocarbon:

\[ \text{CH}_3\text{CHCHCHCH(CH}_3\text{)CH}_3 \]

What type of hydrocarbon is it?

Is it saturated or unsaturated? Why?
Draw and name the following hydrocarbon:

$CH_3CH_2CH(CH(CH_3)CH_3$
Write the combustion reaction of ethane.
Do Now: Draw 3,4 - dimethyl 2-heptene.
Reactions of the Alkanes

1. Combustion
Alkane + Oxygen $\rightarrow$ Carbon dioxide + Water

Ex.
CH$_4$(g) + 2 O$_2$(g) $\rightarrow$ CO$_2$ (g) + 2 H$_2$O (g)

2. Halogen Substitution
One hydrogen from a saturated hydrocarbon is replaced by a halogen atom forming a halogen substituted hydrocarbon.

Ex.
C$_2$H$_6$ + Cl$_2$ $\rightarrow$ C$_2$H$_5$Cl + HCl
Two products are always produced.
Reactions of the Alkenes

1. **Combustion**
   Alkene + Oxygen $\rightarrow$ Carbon dioxide + Water

2. **Addition**
   A. **Hydrogen (hydrogenation)** - breaks double bond, adds two hydrogen atoms
      Alkene + Hydrogen $\rightarrow$ Alkane
      $\text{C}_3\text{H}_6 + \text{H}_2 \rightarrow \text{C}_3\text{H}_8$
   B. **Halogen (halogenation)** - breaks double bond, adds two halogen atom
      Alkene + Halogen $\rightarrow$ Halogen substituted hydrocarbon
      $\text{C}_3\text{H}_6 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_6\text{Cl}_2$
Activity

With your partner, build an alkane, an alkene and an alkyne from your sheet.
QOD: What are the functional groups?

Do Now: Draw the structural formula for $\text{CH}_3\text{CH(CH}_3\text{)}\text{CHCHCH}_3$ and name it.

What group of hydrocarbons does this molecule belong?

Is it saturated or unsaturated? Why?
Reactions of the Alkynes

1. Combustion
Alkyne + Oxygen → Carbon dioxide + Water

2. Addition
A. Hydrogen (hydrogenation) - breaks triple bond, adds four hydrogen atoms
Alkyne + 2 Hydrogen → Alkane
\[ C_2H_2 + 2 H_2 \rightarrow C_2H_6 \]

B. Halogen (halogenation) - breaks triple bond, adds four halogen atoms
Alkyne + 2 Halogen → Halogen substituted hydrocarbon
\[ C_2H_2 + 2 Cl_2 \rightarrow C_2H_2Cl_4 \]
The Functional Groups

• The Alcohols - Characteristics
  – Functional Group: -OH  hydroxyl group
  – General Formula: R-OH (R stands for a radical - methyl, ethyl propyl, etc.)
  – Soluble in water (less than 5 C atoms)
  – Non-electrolyte: 0% ionization
  – Name ends in - ol
Monohydroxy Alcohols

Methanol

\[
\begin{align*}
\text{H} & \quad \text{C} \quad \text{O} \quad \text{H} \\
\text{H} & \quad & \\
\end{align*}
\]

\[\text{CH}_3\text{OH}\]

Ethanol

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \quad \text{O} \quad \text{H} \\
\text{H} & \quad & \quad \text{H} \\
\end{align*}
\]

\[\text{C}_2\text{H}_5\text{OH}\]

Produced by Fermentation

Glucose \[\xrightarrow{\text{zymase}}\] Carbon dioxide + Ethanol

\[\text{C}_6\text{H}_{12}\text{O}_6 \quad \xrightarrow{}\quad \text{CO}_2 + \text{C}_2\text{H}_5\text{OH}\]
1-propanol
\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{OH} \quad \text{C}_3\text{H}_7\text{OH} \]

The above is a primary alcohol

2-propanol (isopropyl alcohol)
\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{H} \quad \text{C}_3\text{H}_7\text{OH} \]

The above is a secondary alcohol.
The -OH is attached to a C atom which is attached to two others.

1-butanol
\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{OH} \quad \text{C}_4\text{H}_9\text{OH} \]
2-butanol

\[
\begin{align*}
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{OH} & \quad \text{H} \\
\end{align*}
\]

\[\text{C}_4\text{H}_9\text{OH}\]

2-methyl-2-propanol (tertiary butanol)

\[
\begin{align*}
\text{H} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{OH} & \quad \text{H} \\
\end{align*}
\]

\[\text{C}_4\text{H}_9\text{OH}\]

Tertiary alcohol - the -OH is attached to a C atom which is attached to *three* others.
Alcohols - Diols

• Diols – these alcohols have 2 –OH groups
  – Example –
    1,2 Propanediol

• Triols – these alcohols have 3 –OH groups
  – Example - Glycerol
Ether

• Generally two hydrocarbons are joined together through a common bond to an oxygen
  \(-O-\)

Example – ethyl methyl ether
Aldehyde

- A hydrocarbon with a –COH group
- Example - ethanal
Ketones

• Generally two hydrocarbons are joined by a mutual bond to a –C=O group
• Example – 2-butanone
Organic Acids

• Generally hydrocarbons with a –COOH group are organic, or carboxylic acids (the acidic H is the one in the –COOH group)

• Example – pentanoic acid
Ester

• Generally 2 hydrocarbons that are joined by a mutual bond to a –COO– group
• These compounds often have characteristic tastes and odors (grapefruit, spearmint, banana, etc)
• Example – methyl ethanoate (the -oate ending is on the group where the C is bonded to 2 O’s
Amine

- Generally 3 hydrocarbons (or Hydrogens) are joined by mutual bonds to a Nitrogen
- This is one end of an amino acid (that is where they get their name)
- Example ethyl methylamine
Amide

- Generally 2 Hydrocarbons (or hydrogens) are joined by a mutual attraction to an amide group
- Example – Ethyl methanamide
Write the the hydrogenation reaction of ethene.
Activity

With your partner, draw the isomers on the worksheet. Then get a molecular kit and follow directions on the third page.

Before returning the kits, please organize the “atoms” nicely and make sure that nothing is missing from your kit.
QOD: What types of alcohols are there?

Do Now: Trial quiz

1. Write the halogenation reaction of 1 - Butene with Fluorine (F₂).

2. Draw the structural formula for CH₃CH(CH₃)CH₂CH₃ and name it.

3. Bonus: Which types of hydrocarbons are unsaturated?
Monohydroxy Alcohols

Methanol

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\text{H} & \\
\end{align*}
\]

\[\text{CH}_3\text{OH}\]

Ethanol

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\end{align*}
\]

\[\text{C}_2\text{H}_5\text{OH}\]

Produced by Fermentation

\[\text{Glucose} \xrightarrow{\text{zymase}} \text{Carbon dioxide} + \text{Ethanol}\]

\[\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow \text{CO}_2 + \text{C}_2\text{H}_5\text{OH}\]
1-propanol
\[
\begin{align*}
\text{C}_3\text{H}_7\text{OH} & \\
\text{H} & \text{C} & \text{C} & \text{C} & \text{OH} \\
\text{H} & \text{H} & \text{H} & \text{H}
\end{align*}
\]
The above is a primary alcohol.

2-propanol (isopropyl alcohol)
\[
\begin{align*}
\text{C}_3\text{H}_7\text{OH} & \\
\text{H} & \text{C} & \text{C} & \text{C} & \text{H} \\
\text{H} & \text{OH} & \text{H}
\end{align*}
\]
The above is a secondary alcohol.
The -OH is attached to a C atom which is attached to two others.

1-butanol
\[
\begin{align*}
\text{C}_4\text{H}_9\text{OH} & \\
\text{H} & \text{C} & \text{C} & \text{C} & \text{C} & \text{OH} \\
\text{H} & \text{H} & \text{H} & \text{H} & \text{H}
\end{align*}
\]
2-butanol

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{OH} & \quad \text{H} & \\
\end{align*}
\]

\[\text{C}_4\text{H}_9\text{OH}\]

2-methyl-2-propanol (tertiary butanol)

\[
\begin{align*}
\text{H} & \\
\text{H} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \\
\text{H} & \quad \text{OH} & \quad \text{H} & \\
\end{align*}
\]

\[\text{C}_4\text{H}_9\text{OH}\]

Tertiary alcohol - the -OH is attached to a C atom which is attached to three others.
Alcohols - Diols

• Diols – these alcohols have 2 –OH groups
  – Example –
    1,2 Propanediol

• Triols – these alcohols have 3 –OH groups
  – Example - Glycerol
The Benzene Series (Aromatic hydrocarbons)

The benzene series consists of molecules which are *cyclic* in nature. The general formula is $C_nH_{2n-6}$. 

Benzene

![Benzene molecular structure]

$C_6H_6$
Although it appears that the structure has alternating double and single bonds, the bonding involves *six identical* bonds. A *resonance* structure is used to show structural formula of benzene.

An abbreviated structural formula can be used in place of the above:
Toluene or Methylbenzene \( \text{C}_7\text{H}_8 \)

An abbreviated structural formula can be used in place of the above:

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]
QOD: How do we determine isomers?

Do Now: Trial quiz

1. Write the halogen substitution of Hexane with chlorine.

2. Draw the structural formula for CH₃CH₂OCH₂CH₂CH₂CH₃ and name it.

3. Bonus: Why are alkanes saturated hydrocarbons?
Fermentation is a reaction in which living things (bacteria, yeast, humans) convert a sugar into alcohol and carbon dioxide.

\[
\text{Glucose} \xrightarrow{\text{zymase}} \text{Carbon dioxide} + \text{Ethanol}
\]

\[
\text{C}_6\text{H}_{12}\text{O}_6 \xrightarrow{} \text{CO}_2 + \text{C}_2\text{H}_5\text{OH}
\]
Glucose \rightarrow \text{Pyruvic acid} \rightarrow \text{NAD}^+ \rightarrow \text{NADH}

Pyruvic acid is metabolized by different organisms:

- **Propionibacterium**: Produces \( \text{CO}_2 \), propionic acid (Swiss cheese)
- **Aspergillus, Lactobacillus, Streptococcus**: Produces lactic acid (Cheddar cheese, yogurt, soy sauce)
- **Saccharomyces**: Produces \( \text{CO}_2 \), ethanol (Wine, beer)
- **Clostridium**: Produces acetone, isopropanol (Nail polish remover, rubbing alcohol)
- **Escherichia, Acetobacter**: Produces acetic acid (Vinegar)
• Esterification - the reaction of an organic acid and an alcohol yields an ester and water

\[
\text{Acid} + \text{Alcohol} \rightarrow \text{Ester} + \text{Water}
\]
Saponification

Saponification - hydrolysis of fat (complex esters) by bases to make soap and glycerol
Polymerization

Making large molecules or polymers from small molecules or monomers

- **Dehydration Polymerization** - monomers are joined together by -OH groups with the removal of water

- **Addition Polymerization** - double or single bonds are broken to link monomers together
Fig 1: The polymerisation of ethene into poly(ethene)
Which general formula represents the compound \( \text{CH}_3\text{CH}_2\text{CCH} \)?

(1) \( C_n\text{H}_n \)  
(2) \( C_n\text{H}_{2n} \)  
(3) \( C_n\text{H}_{2n-2} \)  
(4) \( C_n\text{H}_{2n+2} \)
Do Now: Per 4

1. Write the halogenation reaction of 1-Pentene with Chlorine ($Cl_2$).
2. Draw the structural formula for $CH_3CH(CH_3)CH_3$ and name it.
3. Bonus: Which type of hydrocarbons are saturated?
QOD: What are functional groups?

Do Now: Per 2

1. Write the halogen addition of Butyne with Fluorine (F₂).
2. Draw the structural formula for CH₃CCCH₂CH₃ and name it.
3. Draw 3 - methyl pentane
QOD: What are functional groups?

Do Now: Per 4

1. Write the hydrogenation of Propyne.

2. Draw the structural formula for \( \text{CH}_3\text{CCCH}_2\text{CH}_2\text{CH}_3 \) and name it.

3. Draw 2-methyl hexane
QOD: What are functional groups?

Do Now: Per 7

1. Write the halogenation of Pentyne with Iodine (I₂).
2. Draw the structural formula for CH₃CH₂CCCH₂CH₃ and name it.
3. Draw 2 - methyl butane
Do Now: Write the halogenation reaction of 1-Hexyne with Iodine.
QOD: What additional organic reactions are there?

Do Now: Pick one of the following molecules. Draw the structural formula and name the molecule.

\[ \text{CH}_3\text{CH}_2\text{CH(OH)CH}_2\text{CH}_3 \]

\[ \text{CH}_3\text{CH}_2\text{OCH}_3 \]
Fermentation

Fermentation is a reaction in which living things (bacteria, yeast, humans) convert a sugar into alcohol and carbon dioxide

Glucose $\xrightarrow{zymase}$ Carbon dioxide + Ethanol

$C_6H_{12}O_6 \rightarrow CO_2 + C_2H_5OH$
• Esterification - the reaction of an organic acid and an alcohol yields an ester and water
Saponification – hydrolysis of fat (complex esters) by bases to make soap and glycerol.
Polymerization

Making large molecules or polymers from small molecules or monomers

- **Dehydration Polymerization** - monomers are joined together by -OH groups with the removal of water

- **Addition Polymerization** - double or single bonds are broken to link monomers together
Fig 1: The polymerisation of ethene into poly(ethene)
QOD: What do I need to know about organic chemistry?

Do Now: What type of organic reaction is this? Name the product.
Green Book - Group Activity

In the Green Book, find these pages and complete the assignments:
Level 1: pg 100 Set 2 Questions 6 - 10
Level 2: pg 104 Set 1 Questions 1 - 16
Hydrocarbons
Level 3: pg 116 Set 1 Questions 1 - 14
Functional groups
1. What are the products of a fermentation reaction?

2. What do we need to add to form an ester?

3. What is soap made out of?