

Name: _____

Date: _____

Period: _____

SL Topic 10 Organic Chemistry - Guided Notes

Slide 3: Essential Ideas

- **10.1:** Organic chemistry focuses on the chemistry of compounds _____ carbon.
- **10.2:** Structure, bonding, and chemical reactions involving functional group _____ are key strands in organic chemistry.

Slide 4: 10.1 Understandings

- A _____ series is a series of compounds of the same family, with the same general formula, which differ from each other by a common structural unit.
- Structural formulas can be _____ in full and condensed format.
- Structural isomers are compounds with the same molecular formula but different _____ of atoms.
- _____ groups are the reactive parts of molecules.
- Saturated compounds contain single bonds only and _____ compounds contain double or triple bonds.
- Benzene is an aromatic, _____ hydrocarbon.

Slide 5: 10.1 Applications and Skills

- _____ of the trends in boiling points of members of a homologous series.
- _____ between empirical, molecular, and structural formulas.
- Identification of different classes: alkenes, alkynes, _____, alcohols, ethers, aldehydes, ketones, esters, carboxylic acids, amines, amides, nitriles, and arenes.
- _____ of typical functional groups in molecules, e.g. phenyl, hydroxyl, carbonyl, carboxyl, carboxamide, aldehyde, ester, ether, amine, nitrile, alkyl, alkenyl, and alkynyl.
- _____ of 3D models (real or virtual) of organic molecules.
- Application of IUPAC rules in the _____ of straight-chain and branched-chain isomers.
- Identification of primary, secondary, and tertiary carbon atoms in _____ and alcohols and primary, secondary, and tertiary nitrogen atoms in amines.
- _____ of the structure of benzene using physical and chemical evidence.

Slide 6: 10.1: Fundamentals of Organic Chemistry

Slide 7: Organic Chemistry

- There are a few **inorganic** compounds that contain carbon: **carbon and its oxides and _____**.
- Most compounds _____ carbon are organic compounds.
- These _____ contain chains or rings of carbon atoms.
- Nearly all organic compounds contain _____-bonded hydrogen.
- **The study of carbon-_____ compounds and their properties.**

Slide 8: Catenation

- One of the main reasons for the vast number of organic _____.

- Carbon is able to form 4 covalent bonds (remember, carbon has 4 valence _____).
- Total number of organic compounds is so large that it is _____ to estimate (at least 10 million).
- Number is increasing as new materials are _____ (organic molecules can be synthesized outside of living things - discovered by Wöhler in 1828 when he synthesized urea).
- Each organic compound is unique in structure and _____.
- **Carbon's _____ to link to itself to form chains and rings**

Slide 9: Hydrocarbons

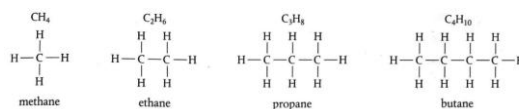
- The **simplest** class of organic _____.
- _____ are compounds formed from carbon and hydrogen.
- Can be classified as **saturated** or _____.
- _____ **only single carbon-carbon bonds**
- _____ **either double or triple carbon-carbon bonds**

Slide 10: Homologous Series

- Way to classify the millions of organic _____ that exist.
- **Main features of _____ series:**
- _____ members differ by a $-\text{CH}_2-$ group
- Members of a series be _____ by presence of **functional groups**
- Members of a series can be _____ by the same general formula.
- Members of a series show a gradation in their physical _____.
- Members of a series have similar chemical _____.
- **'Families' of organic _____**
- **a group of atoms that has similar chemical _____ in various compounds**

Slide 11: Successive members differ by a $-\text{CH}_2-$ group

- **Alkanes:** _____ series with only single-bonded carbon and hydrogen atoms
- _____ (unbranched, saturated _____)

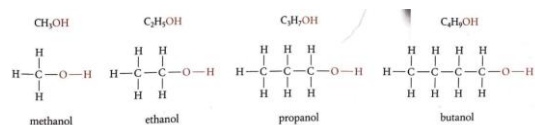


Slide 12: You Try!

- **Draw the Structures of Pentane, Hexane, and Heptane**

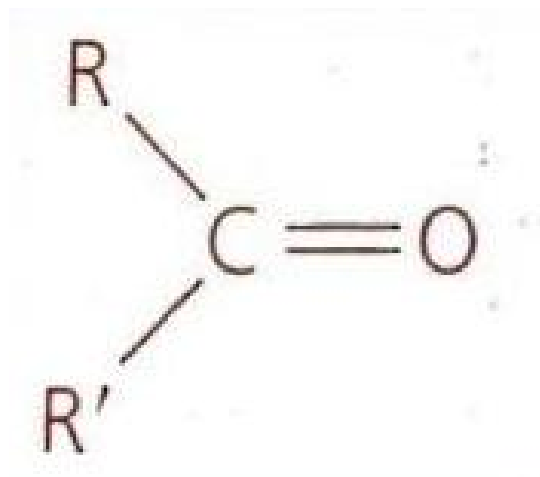
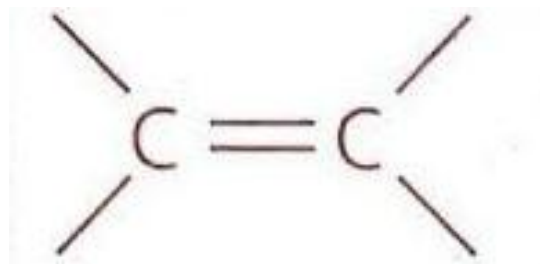
Slide 13: Members characterized by functional groups

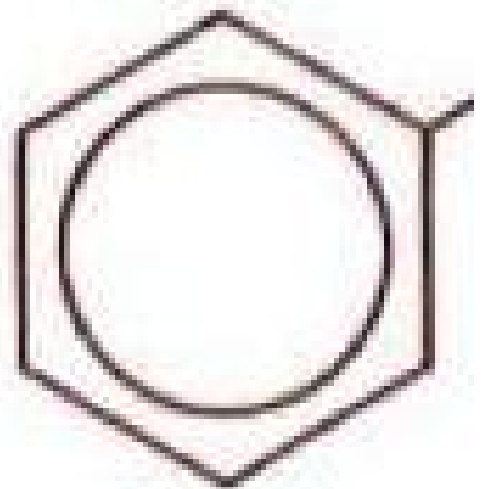
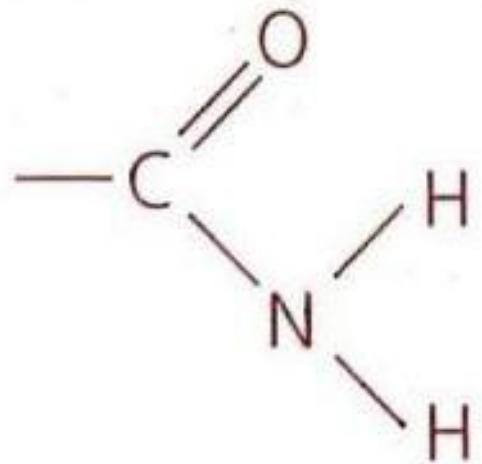
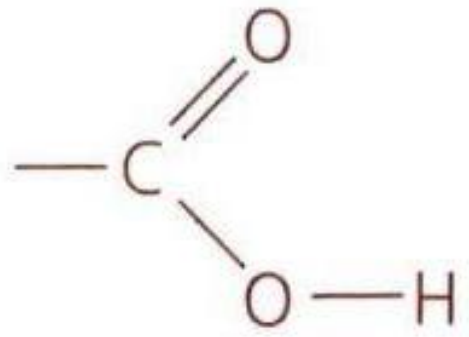
- Homologous series can be characterized by presence of particular functional groups
- Reflected in general formula of the series
- Suffix of compound name indicates specific functional groups
- Example: **alcohols** contain the **hydroxyl (--OH)** functional group



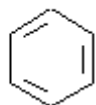
Slide 14: Note: amines are groups with nitrogen atoms that contain a lone pair - the R groups do not have to be hydrogen

- **R:** _____ of part of a hydrocarbon (aka **alkyl** group) whose exact details are not necessary to show.
- : represents a
- **benzene** ring, C₆H₆
- These are known as **aromatic** _____

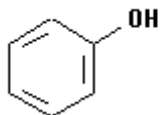




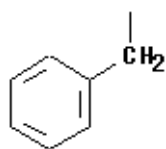
Slide 15: A note on phenyl groups



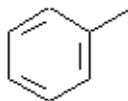
benzene
 C_6H_6



phenol
 C_6H_5OH



benzyl (group)
 $C_6H_5CH_2^-$



phenyl (group)
 $C_6H_5^-$

Slide 16: Functional Group Activity

- Identify all of the _____ groups on each card.

Slide 17: Members represented by same general formula

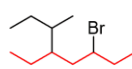
- Members of the same homologous series are _____ by the same general formulas

Slide 18: Naming Alkanes

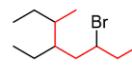
- Notice that even though the isopropyl group is at position 5, it is still placed before the methyl group at position 2 since the substituents are placed _____.

Slide 19: Naming Halogenoalkanes

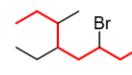
- Find the _____. Here, we have three substituents – two alkyl groups and a halide:
- Find the parent chain. The longest _____ chain consists of eight carbons, so the parent chain is octane:



7 carbons
Incorrect



7 carbons
Incorrect



8 carbons
Correct

Slide 20: Naming Halogenoalkanes

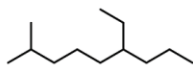
- Number the parent chain giving the lowest possible numbers to the _____. If there is a tie for the first locant, compare the second and then the third locants.

Slide 21: Naming Alkenes

Slide 22: Naming Alkenes

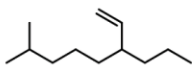
Alkane and Alkene Nomenclature

Alkane

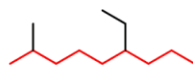


vs

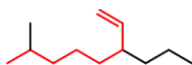
Alkene



1. Identify the parent chain

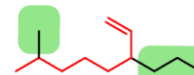
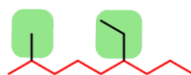


longest carbon chain

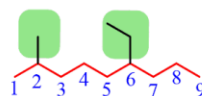


longest carbon chain
containing C=C bond

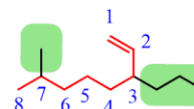
2. Identify the substituents



3. Number the parent chain.

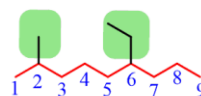


Substituents-smallest locants

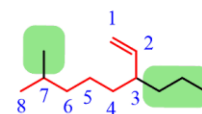


c=c gets smallest locant

4. Place the substituents alphabetically



6-ethyl-2-methylnonane



7-methyl-3-propyloct-1-ene
or
7-methyl-3-propyl-1-octene

Slide 23: Naming Alkynes

Slide 24: Naming Alcohols

Slide 25: Naming Alcohols

Slide 30: Naming Amines

Slide 31: Naming Esters

Slide 32: The substituents are numbered based on the position of the COOR group and placed in alphabetical order:

Slide 36: Naming Nitriles

Slide 37: Naming Arenes

- If the _____ is an alkyl chain with more carbon atoms than benzene, then benzene can be treated as a substituent. The ring, in this case, is called a **phenyl** group just like the methyl, ethyl, etc. The phenyl group is often abbreviated as "Ph".

Slide 38: Naming Arenes

Slide 41: If a higher priority group is present, then the nitrile is considered as a substituent indicated with the prefix "cyano". It is placed alphabetically just like any other substituent:

Slide 43: The halogen and ether can only be substituents with the corresponding prefixes. The “chloro” prefix will go before “methoxy” simply because of the alphabetical order.

- Between the **acid and the alcohol**, the former gets a priority and _____, the **parent chain takes a suffix “oic acid”** and the **alcohol takes a prefix “hydroxy”**:

Slide 44: Members show gradation in physical properties

- _____ members of a homologous series have longer carbon chains.
- Compounds with longer carbon chains have _____ boiling points.
- due to increased _____ dipoles and stronger London dispersion forces between molecules.
- Density and viscosity also increase with _____ carbon number.

Slide 45: Members have similar chemical properties

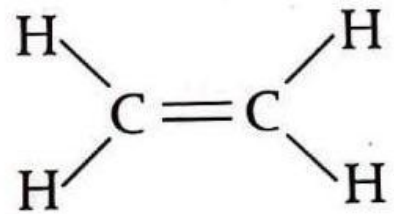
- Members of the same homologous series have the same functional groups, therefore have similar chemical reactivities
- Knowing reactions of functional groups allows the predictions of the properties of all members of a series.
- Examples:
- alcohols can be oxidized to form organic acids
- —COOH functional group of carboxylic acids gives acidic properties to these compounds.

Slide 46: Structural Formulas

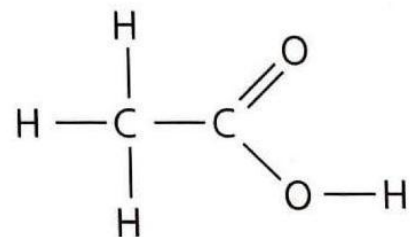
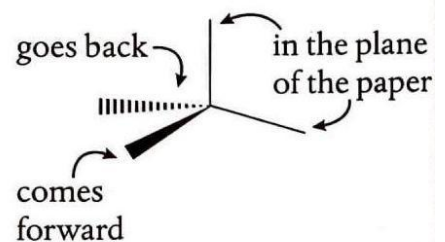
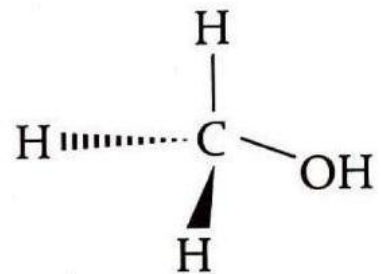
- **Structural formula**
- **Full _____ formula**
- **Condensed _____ formula**
- _____ formula
- _____ of a molecule showing how atoms are bonded to each other
- shows every bond and atom (_____ using 90°, 120°, and 180° bond angles)

- omits assumed bonds and groups atoms together; contains minimum _____ needed to describe the molecule
- shows relative _____ of atoms and groups around carbon in 3-D
- Molecular formula
- actual number of atoms of each element present in a _____
- ethanoic acid

ethene, C_2H_4



methanol, CH_3OH



CH_3COOH

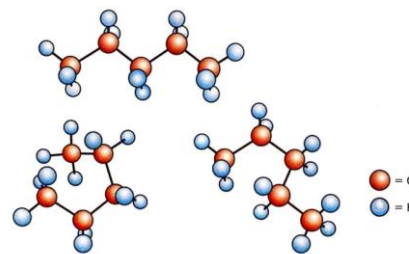
$C_2H_4O_2$

Slide 47: Nomenclature

- IUPAC system: set of rules to name _____
- enables _____ across international boundaries
- **Rule 1:** The stem of the _____ name is based on the longest straight chain of carbon atoms
- **Rule 2:** The _____ group determines the suffix of the compound name
- **Rule 3:** The prefix of the _____ name is based on the side chains (other function groups).
- naming organic _____

Slide 48: Rule 1: Identify the longest straight chain of carbon atoms

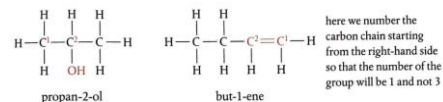
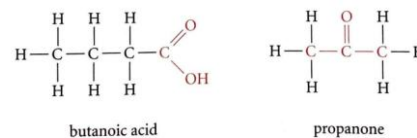
- Gives stem of _____ name
- 'straight chain' means _____/unbranched carbon chains
- does not mean 180° angles
- molecule may appear _____ based on the way it is depicted on paper, but is, in fact, continuous
- straight chain may include the carbon of the _____ group (e.g. carboxylic acids, esters, amids, etc.)
- **Different _____ of pentane (C₅H₁₂)**



Number of carbon atoms in longest chain	Stem in IUPAC name	Example of compound
1	meth-	CH ₄ , methane
2	eth-	C ₂ H ₆ , ethane
3	prop-	C ₃ H ₈ , propane
4	but-	C ₄ H ₁₀ , butane
5	pent-	C ₅ H ₁₂ , pentane
6	hex-	C ₆ H ₁₄ , hexane

Slide 49: *The longest carbon chain can include the functional group

- Rule 2: Identify the _____ group
- The suffix is dependent on the _____ group
- —ane is the suffix for the **parent alkane**
- If a functional group is present, it replaces the —ane with the _____ suffix
- the position of a _____ group is indicated by a number between dashes inserted before the functional group suffix
- the number is the carbon atom to which the _____ group is attached
- the straight chain _____ starts at the end that is closest to where branching occurs
- ***The _____ groups can only be in one position here, so numbers aren't necessary**



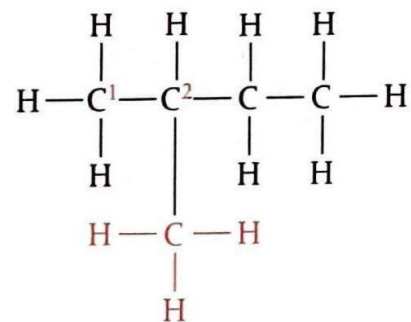
Slide 50: *The functional group is the site of reactivity in the molecule (it is NOT the same as the class of molecule)

Class	Functional group	Name of functional group	Suffix in IUPAC name	Example of compound	General formula
alkane			-ane	C ₂ H ₆ , ethane	C _n H _{2n+2}
alkene		alkenyl	-ene	H ₂ C=CH ₂ , ethene	C _n H _{2n}
alkyne		alkynyl	-yne	HC≡CH, ethyne	C _n H _{2n-2}
alcohol	-OH	hydroxyl	-anol	C ₂ H ₅ OH, ethanol	C _n H _{2n+1} OH
ether	R-O-R'	ether	-oxyalkane	H ₃ C-O-C ₂ H ₅ , methoxyethane	R-O-R'
aldehyde		aldehyde (carbonyl)	-anal	C ₂ H ₅ CHO, propanal	R-CHO
ketone		carbonyl	-anone	CH ₃ COCH ₃ , propanone	R-CO-R'
carboxylic acid		carboxyl	-anoic acid	C ₂ H ₅ COOH, propanoic acid	C _n H _{2n+1} COOH
ester*		ester	-anoate	C ₂ H ₅ COOCH ₃ , methyl propanoate	R-COO-R'
amide		carboxamide	-anamide	C ₂ H ₅ CONH ₂ , propanamide	
amine	-NH ₂	amine	-anamine	C ₂ H ₅ NH ₂ , ethanamine	
nitrile	-C≡N	nitrile	-anenitrile	C ₂ H ₅ CN, propanenitrile	
arene		phenyl	-benzene	C ₆ H ₅ CH ₃ , methyl benzene	

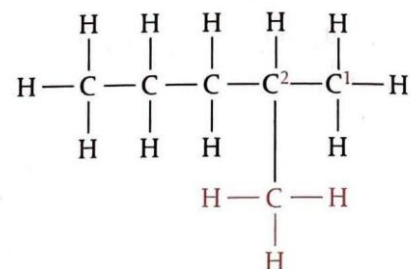
Slide 51: Rule 3: Identify the side chains

- Side chains (aka _____) are functional groups other than the one used for the suffix
- If there are two or more functional groups in a molecule, the _____ will be the **prefix** (e.g. **amino acid**).
- Sometimes -NH₂ can be both a prefix and a suffix (if it is the only _____ group, it will be the suffix; if there are 2 or more functional groups it will be the prefix).
- The position of the _____ is indicated by a number then a dash in front of the compound name to show the carbon atom to which it is attached (number the longest carbon chain of carbon atoms sequentially starting at the end closest to the branching).

Class	Functional group	Name of functional group	Prefix in IUPAC name	Example of compound
alkane			methyl, ethyl, propyl, etc.	CH ₃ CH ₂ CH ₂ CH ₃ , 2-methylbutane CH ₃ (CH ₂) ₃ , 3-ethylpentane CH ₃ (CH ₂) ₃ , 4-propylheptane
haloalkane	-F, -Cl, -Br, -I	halogeno	fluoro, chloro, bromo, iodo	C ₂ H ₅ Cl, chloroethane CH ₂ CH ₂ Br, 2-bromopropane
amine	-NH ₂	amine	amino	CH ₂ (NH ₂)COOH, 2-aminoethanoic acid



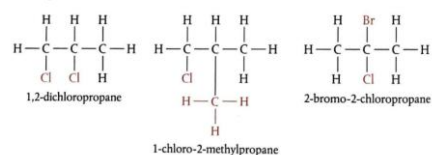
2-methylbutane



2-methylpentane

Slide 52: Rule 3 continued

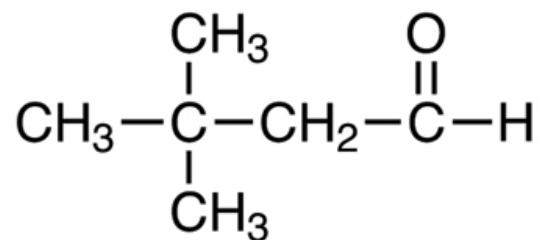
- If there is more than one of the same type of _____ group, use commas between the numbers and prefixes di-, tri-, or tetra- before the name.
- List the _____ in order of the number of the carbon atom to which they are attached.
- if more than one group is on the same atom, they are put in _____ order.



Slide 53: Nomenclature Summary

- How would you name this compound according to IUPAC nomenclature?

Prefix	Stem	Suffix
position, number and name of substituents		number of carbon atoms in longest chain		class of compound determined by functional group



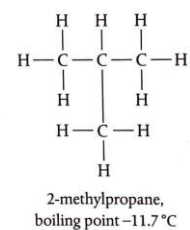
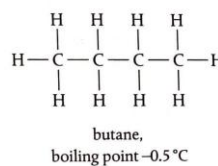
Slide 55: Let's Practice!

- Building and Naming Activity



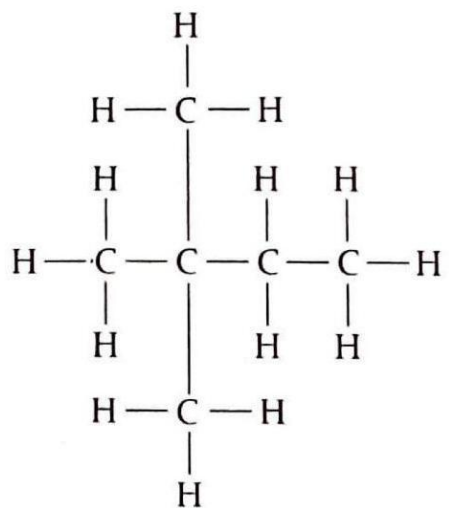
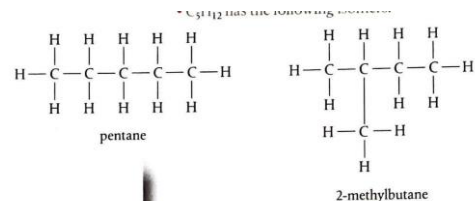
Slide 56: Structural Isomers

- _____ isomers are **distinct compounds** with **unique physical** and **chemical properties**
- Number of _____ isomers **increases** with **increasing size** of the molecule
- **Compounds having the same molecular formula but different _____ of atoms**

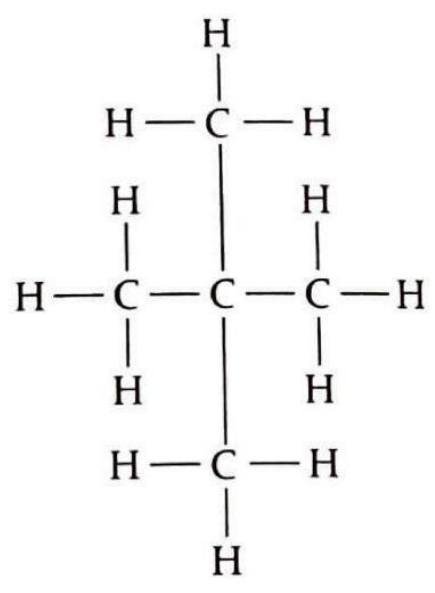


Slide 57: Structural isomers continued

- C_5H_{12} isomers
- C_6H_{14} isomers



2,2-dimethylbutane



2,2-dimethylpropane

Slide 59: Why are isomers important?

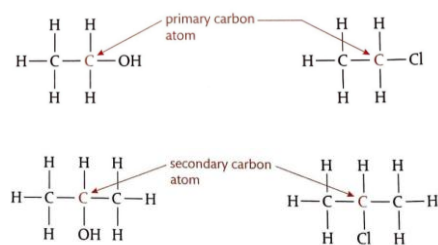
- Branched-chain isomers burn more smoothly in internal combustion engines compared to straight-chain isomers, which make the former 'better grade', a higher octane number, and more expensive
- important in biochemistry and drug industries
- Methoxymethane and ethanol are structural isomers (C_2H_6O), but have very different functions.
- methoxymethane is a gas used in aerosol propellants
- ethanol used in alcoholic beverages

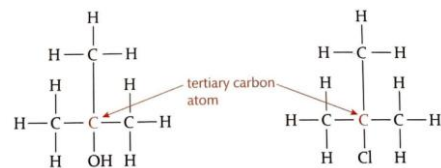
Slide 60: Let's Practice!

- **Structural Isomers Activity**
- Pick a formula from the bag.
- One partner draws an isomer of the compound and shows it to their partner.
- The other partner names the first isomer, then draws a second isomer of the same compound.
- The first partner names the second isomer.
- Repeat until structures of all formulas from the bag have been drawn.
- **Note: You can do this in groups of three as well, just have the third partner draw a third isomer.**

Slide 61: Primary, Secondary, and Tertiary Carbon Atoms

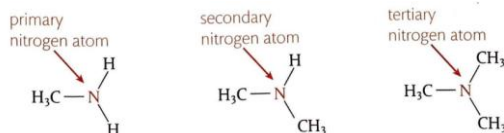
- The **activity** of a _____ group depends on its **position** in the carbon chain
- **Primary carbon atom:** attached to the _____ group and also to at least two hydrogen atoms
- **Secondary carbon atom:** attached to the _____ group and also to one hydrogen atom and two alkyl groups
- **Tertiary carbon atom:** attached to the _____ group and also to three alkyl groups





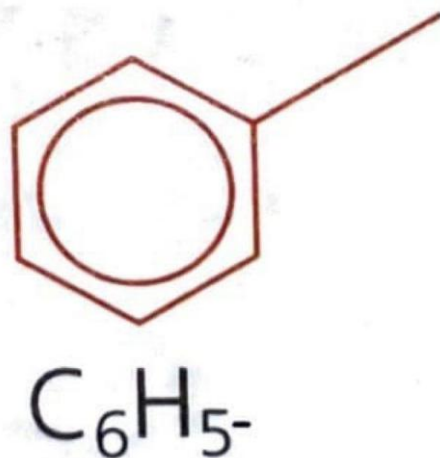
Slide 62: Primary, Secondary, and Tertiary Amines

- Similar to carbon atoms, labels of primary, _____, and tertiary nitrogen atoms can be assigned to amines.
- at least 2 _____ atoms
- 1 _____ atom and 2 alkyl groups
- 3 alkyl groups



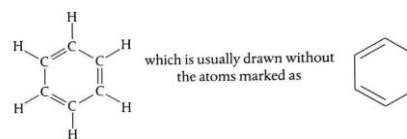
Slide 63: Arenes

- class of compounds derived from benzene; contain phenyl _____ group
- **Aromatics:** unsaturated _____ that have one or more planar rings; have properties distinct from other organic compounds
- **Aliphatics:** non-aromatic _____
- **Phenyl** _____ group
- **Benzene**
- C_6H_6



Slide 64: Benzene

- 1:1 ratio of carbon to _____
- high degree _____
- no isomers
- The first model (proposed by Kekulé) for benzene was suggested by Kekulé in 1865 which suggested the cyclic _____ of the carbons with alternating double bonds.
- This model explained some of the known _____ of benzene such as no isomers but it did not explain the low reactivity.
- Advances in _____ provided data to develop the current



model of the benzene structure.

- 1, 3, 5-_____
- These are NOT the same
- It does not readily undergo addition reactions expected of _____ compounds.
- C_6H_6

Slide 65: All bonds between carbon atoms have equal length and electron density.

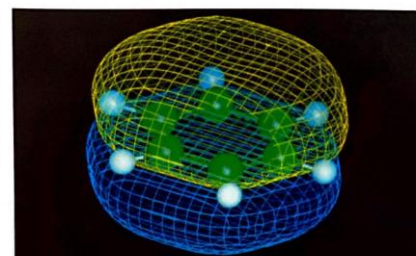
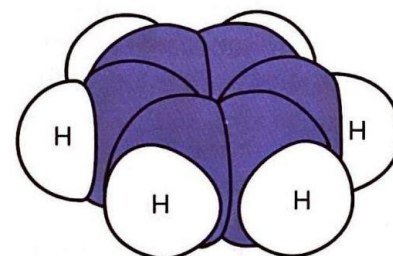
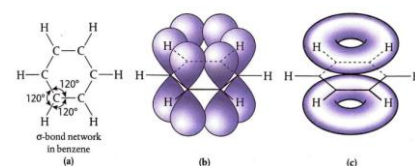
Each carbon atom is sp^2 hybridized and forms 3 σ bonds of 120° (planar structure)

One unhybridized p electron on each carbon atom is perpendicular to the plane of the ring.

Instead of pairing up, they are shared by all six carbon atoms

Causes the molecule to be very stable and have a low internal energy.

- Benzene
- Benzene is an important industrial solvent. It is used to synthesize dyes, drugs, and plastics. In the USA, petroleum contains up to 2% benzene (v/v). However, benzene is toxic and a known carcinogen, leading to aplastic anemia and leukemia with chronic exposure. Many countries have set exposure limits for benzene in water, food, and workplace _____.
- _____ πe^- cloud
- Graphical _____ of benzene



Slide 66: Benzene

- Benzene is depicted using a ring inside a hexagon (represents _____ electrons).

This model supports most observed properties of benzene.

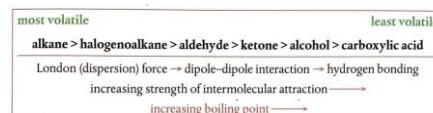
- This is _____, NOT benzene!
- This IS benzene!

Slide 67: Thoughts on models

- “The changing model of the structure of benzene has largely been a result of advances in technology and instrumentation. The Kekulé model seemed to explain many of the known properties of benzene at the time, but had to be reconsidered when quantitative data obtained through X-ray diffraction experimentation provided counter evidence, for example, on bond lengths. The progress of science sometimes demands a refinement or abandonment of a model as new data is obtained, and the acceptance of this is dependent on the objectivity and openness of scientists.”
- **As scientists, it is important to rely on models based on scientific evidence. However, what should scientists do if there is new evidence that disagrees with previous models?**

Slide 68: Volatility

- **Physical** _____ of compound affected by:
- _____ **skeleton** (carbon and hydrogen molecular frame); differs in size in members of same homologous series
- shorter straight chains = less London _____ forces = lower boiling points = more volatile
- More branching of hydrocarbon chains = less contact due to _____ from branched chains = less London dispersion forces = lower boiling points = more volatile
- _____ **groups**; differ between homologous series
- polar groups = more dipole-dipole forces = higher boiling points = less _____
- functional groups with hydrogen bonding = stronger _____ forces = higher boiling points = less volatile
- **how readily a liquid** _____ (more volatile = higher vapor pressures)



Slide 69: 10.2: Functional Group Chemistry

Slide 70: 10.2 Understandings

- **Alkanes:** have low reactivity and undergo free radical _____ reactions

- **Alkenes:** are more reactive than alkanes and undergo addition reactions. Bromine water can be used to _____ between alkenes and alkanes.
- _____: are more reactive than alkanes. They can undergo (nucleophilic) substitution reactions. A nucleophile is an electron-rich species containing a lone pair that it donates to an electron-deficient carbon.
- _____: addition polymers consist of a wide range of monomers and form the basis of the plastics industry.
- **Benzene:** does not readily undergo addition reactions but does undergo _____ substitution reactions.

Slide 71: 10.2 Applications and Skills

- **Alkanes:**
- Writing equations for the complete and incomplete combustion of _____.
- Explanation of the reaction of methane and ethane with halogens in terms of a free radical substitution mechanism involving _____ homolytic fission.
- **Alkenes:**
- Writing equations for the reactions of alkenes with hydrogen and halogens and of _____ alkenes with hydrogen halides and water.
- Outline the addition _____ of alkenes.
- _____ between the structure of the monomer to the polymer and repeating unit.
- **Alcohols:**
- Writing equations for the complete _____ of alcohols.
- Writing equations for the oxidation reactions of primary and secondary alcohols (using acidified potassium dichromate (VI) or potassium manganate (VII) as oxidizing agents). _____ of distillation and reflux in the isolation of the aldehyde and carboxylic acid products.
- **Halogenoalkanes:**
- Writing the equation for the substitution reactions of _____ with aqueous sodium hydroxide.

Slide 72: Alkane Chemistry

- _____ Formula: C_nH_{2n+2}
- Alkanes are saturated _____.
- _____ refer to compounds that contain hydrogen and carbon only.
- _____ means they contain all single carbon-carbon bonds.
- **Reactions:**
- Combustion
- _____ (halogenation)

Slide 73: Alkanes have low chemical reactivity

- _____ contain only C-C and C-H bonds.
- Both of these are **strong bonds** with bond enthalpies of 348 kJ/mol and 412 kJ/mol, _____.
- These _____ will only react in the presence of a **source of energy strong enough** to break these bonds.
- Most alkanes are **stable** under most conditions and can be **stored**, _____ and **compressed** safely.
- The C-C and C-H bonds are **non-polar** so they are not _____ to attack by most reactants.

Slide 74: Combustion of alkanes

- Alkanes are used as fuel because they **release** _____ **amounts of energy** when they are burned.

- When _____ are burned, they form **CO₂** and **H₂O**.
- These are very _____ reactions because large amounts of **energy are released** when the double bonds in CO₂ and the H₂O bonds are formed.
- Alkanes burn in the _____ of oxygen to form CO₂ and H₂O.
- $$\text{C}_3\text{H}_8 (\text{g}) + 5\text{O}_2 (\text{g}) \rightarrow 3\text{CO}_2 (\text{g}) + 4\text{H}_2\text{O} (\text{g}) \quad \Delta H = -2220 \text{ kJ/mol}$$
- The CO₂ produced in combustion reactions from the burning of fossil fuels is a Greenhouse gas which _____ to **global warming**.
- ***Forming bonds _____ energy**

Slide 75: Combustion of alkanes continued

- When the oxygen supply is limited, carbon _____ and water are produced.
- $$2\text{C}_3\text{H}_8 (\text{g}) + 7\text{O}_2 (\text{g}) \rightarrow 6\text{CO} (\text{g}) + 8\text{H}_2\text{O} (\text{g})$$
- Carbon monoxide is a toxin which reacts in the blood to prevent it from carrying oxygen. High traffic areas produce high volumes of CO. Adequate _____ is crucial to prevent carbon monoxide poisoning.

Slide 76: Combustion of alkanes continued

- In _____ when oxygen is extremely limited, carbon may be produced.
- $$\text{C}_3\text{H}_8 (\text{g}) + 2\text{O}_2 (\text{g}) \rightarrow 3\text{C} (\text{g}) + 4\text{H}_2\text{O} (\text{g})$$
- Unburned carbon particles have a direct negative impact on the respiratory system especially in highly polluted areas. These carbon _____ cause smog and are the source of **global dimming**.
- **Decrease in the amount of global direct _____ at Earth's surface**

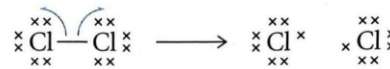
Slide 77: Substitution reactions of alkanes: halogenation

- $$\text{CH}_4 (\text{g}) + \text{Cl}_2 (\text{g}) \rightarrow \text{CH}_3\text{Cl} (\text{g}) + \text{HCl} (\text{g})$$
- $$\text{C}_2\text{H}_6 (\text{g}) + \text{Br}_2 (\text{g}) \rightarrow \text{C}_2\text{H}_5\text{Br} (\text{g}) + \text{HBr} (\text{g})$$
- **a substitution reaction where a halogen atom takes the place of a hydrogen in an alkane.**
- **Examples:**
- **Initiation**
- **Propagation**
- **Termination**
- **3 Stages:**
- **Halogen diatomic bond broken in the presence of UV light**
- **Reactions use and produce free radicals in chain reactions**
- **Free radicals removed by pairing with each other**



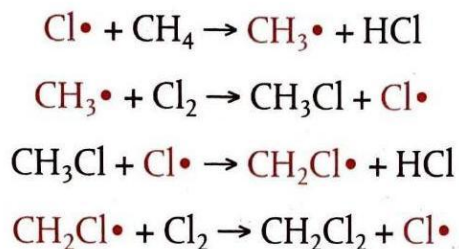
Slide 78: Initiation: Breaking of atomic bond by UV light

- Bond between 2 atoms is broken by UV light, _____ shared pair of e⁻ between the 2 atoms; produces 2 free radicals
- _____ Homolytic Fission
- Free _____ have an unpaired e⁻ they are very reactive but have no net charge
- 'fish-hooks' (single-sided, curly arrows) are used to show movement of single _____
- Free radicals will start a chain reaction that produces a mixture of products, including a _____
- The sequence of reaction steps is called the _____ reaction



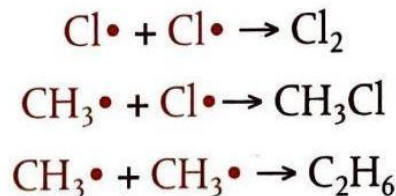
Slide 79: Chlorine radical reacts with methane. Through the reaction mechanism, dichloromethane is produced.

- _____: Free radicals are used and produced
- _____ occurs because the reactions both use and produce free radicals and allow the reaction to continue.



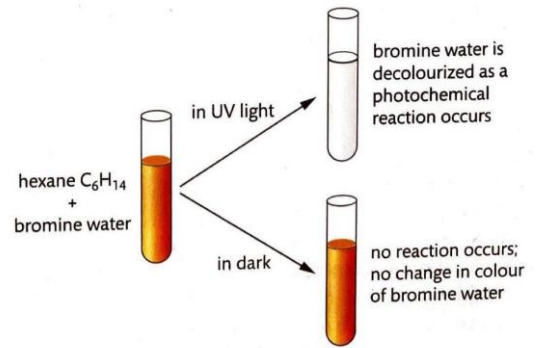
Slide 80: Termination: Removal of free radicals

- _____ reactions remove free radicals by causing them to react together and pair up electrons.
- There are many possible _____ steps.
- _____ mixture can contain many possible products.



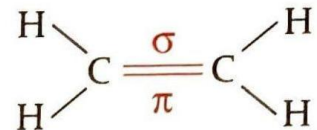
Slide 81: You Try! Example of halogenation rxn

- Write the reaction mechanism for the halogenation of hexane by bromine. Include initiation, propagation, and termination steps.



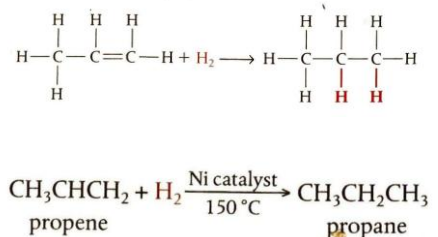
Slide 82: Alkenes

- _____ Formula: C_nH_{2n}
- Alkenes are **unsaturated** _____.
- _____ means they contain a double carbon-carbon bond.
- The double bond is made of one sigma bond and one pi bond.
- The carbon atoms are sp^2 _____ and have bond angles of 120 degrees.
- The π bond in alkenes is easily broken to create 2 new bonding _____ on the carbon atoms.
- **Reactions:**
- Addition to form _____ products
- hydrogen
- halogens
- hydrogen halides
- water



Slide 83: Alkenes: Addition of hydrogen

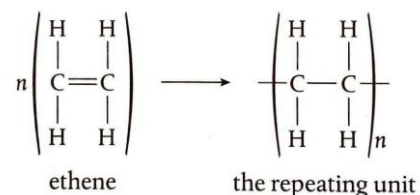
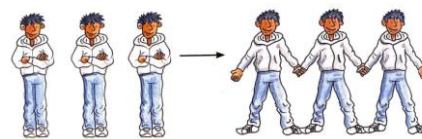
- Alkenes react with _____ to form alkanes in the presence of a nickel catalyst at about $150^\circ C$.
- **hydrogenation**
- _____ is used in the margarine industry to convert oils (unsaturated) into more saturated compounds with higher melting points.
- The double bond is broken to make room for the hydrogens. The _____ carbons are now saturated and contain no double



- Compounds containing the benzene ring are even more _____ (contain more double bonds) and burn with an even smokier flame.
- **Alkenes also readily undergo addition _____, whereas alkanes do not.**

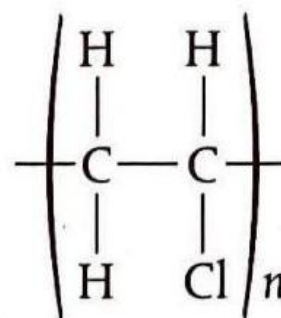
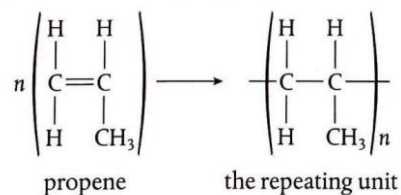
Slide 88: Polymerization of alkenes

- Alkenes readily undergo addition _____ by breaking their double bond.
- They can be joined _____ to produce long chains known as polymers.
- Chemical nature of the monomer will determine the _____ of the polymer.
- **Polymers _____ contain thousands of monomers. They are a major product of chemical industry. Many of our plastics are polymers of alkenes.**
- **Unit of _____ (the alkene used in the reaction)**
- **Monomer**
- _____ must break their double bonds in order to form a polymer.
- **poly(ethene)**

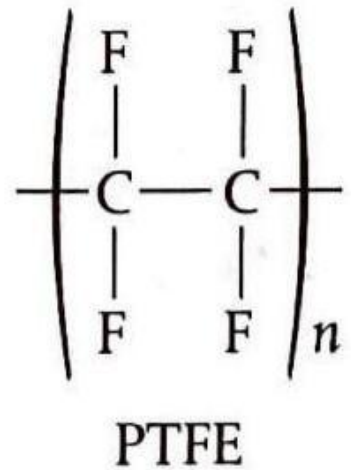


Slide 89: Polymerization rxns

- Propene polymerizes to form polypropene often called _____.
- It is used in the _____ of clothing.
- More _____ the production of thermal wear.
- _____ is known as PVC, poly vinyl chloride.
- It is one of the world's most _____ plastics.
- It is used in _____ materials, packaging, and electrical cable sheathing.
- Its _____ produces dioxins which are toxic and are linked to a variety of cancers.
- _____ is known as PTFE.
- It is often _____ as Teflon.

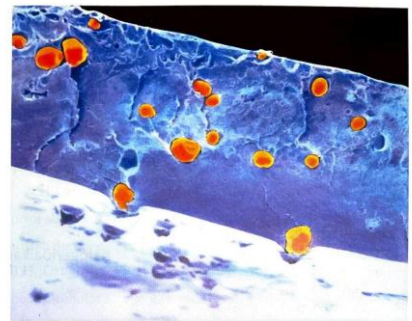


PVC



Slide 90: Disposal of Plastics

- Major global problem
- impermeable to water
- low reactivity
- often non-biodegradable
- remain in landfills for indefinite periods
- ~10% of plastics end up in the ocean (hazards to marine life)
- Measures to try to address the problem include
- more efficient recycling
- biodegradable plastics
- plastic-feeding microorganisms
- **Colored scanning electron micrograph of a section of a sheet of biodegradable plastic. Orange spheres are starch granules. After the plastic is buried, starch grains take up water to expand, breaking the plastic into small pieces. This increases the surface area bacteria have to digest the plastic.**



Slide 91: Let's Practice!

- Draw the repeating unit of polystyrene.
- Monomer: $\text{C}_6\text{H}_5\text{CHCH}_2$

Slide 92: Alkene Reaction Summary

Slide 93: Alcohols

- _____ Formula: $C_nH_{2n+1}OH$
- Alcohols contain the $-OH$ _____ group.
- The $-OH$ group is polar and increases the _____ in water when compared to alkanes of similar molar mass.
- **Reactions:**
- combustion
- oxidation
- esterification

Slide 94: Alcohols: Combustion

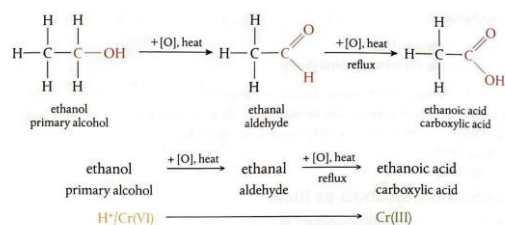
- _____ react with **oxygen** to produce **CO_2** and **H_2O** .
- These reactions **produce** _____ amounts of **energy**.
- The amount of **energy released increases** as we go **up a** _____ **series** because more CO_2 is produced.
- $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g) \quad \Delta H_c^\ominus = -726.1 \text{ kJ mol}^{-1}$
- $2C_5H_{11}OH(l) + 15O_2(g) \rightarrow 10CO_2(g) + 12H_2O(g) \quad \Delta H_c^\ominus = -3330.9 \text{ kJ mol}^{-1}$
- **Burning of methanol**
- **Burning of Pentanol**
- Like hydrocarbons, if there is **limited oxygen**, **CO** will be produced instead of CO_2 .
- **1:1 ratio** _____ : CO_2
- **1:5 ratio** _____ : CO_2
- **Increase in molar enthalpy of** _____

Slide 95: Alcohols: Oxidation

- _____ involves the **complete oxidation** of the entire alcohol molecule.
- It is possible to react alcohols with **acidified oxidizing agents** which _____ **oxidizes** the carbon atom attached to the $-OH$ group leaving the **carbon skeleton intact**.
- The most **commonly used oxidizing agent** is acidified **potassium** _____ (**VI**).
- The **Cr(VI)** is **bright orange** and _____ **to green** as it is reduced to **Cr(III)**.
- The oxidizing agent is _____ **by +[O]** over the **arrow** in equations.

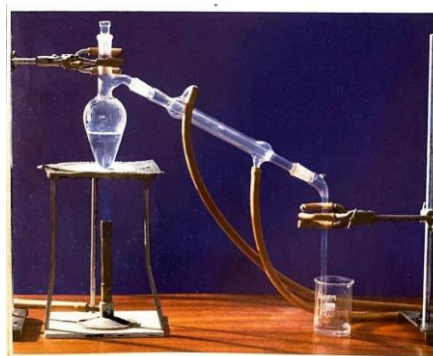
Slide 96: Oxidation of Primary Alcohols

- Primary _____ are oxidized in a 2 step process.
- The first step produces an aldehyde and the second step produces a _____ acid.



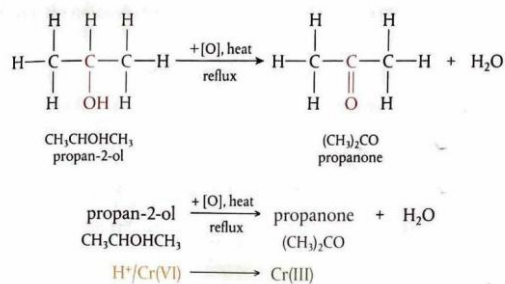
Slide 97: Separating components of alcohol oxidation

- _____ is used to separate liquids with different boiling points.
- Aldehydes have lower boiling points (no hydrogen bonding) than alcohols and carboxylic acids so can be separated through _____.
- The _____ acid can be separated from the reaction mixture by leaving the aldehyde in contact with the oxidizing agent for prolonged periods of time.
- Done using a **reflux** _____
- Collects and condenses vapors to enable volatile _____ to remain in reaction long enough for reaction to go to completion.**



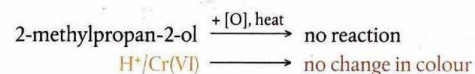
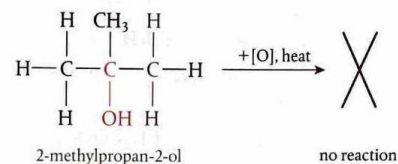
Slide 98: Oxidation of Secondary Alcohols

- _____ alcohols are oxidized to ketones, similar to oxidation of primary alcohols.



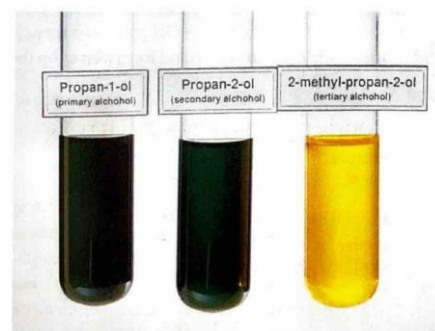
Slide 99: Oxidation of Tertiary Alcohols

- Tertiary alcohols do not readily oxidize under _____ conditions.



Slide 100: Summary of Alcohol Oxidation

- Oxidation with potassium _____ (VI) solution causes oxidation of primary and secondary, but not tertiary, alcohols.
- Orange Cr(VI) is _____ to green Cr(III).
- **carboxylic acid**
- **Ketone**
- **No rxn**

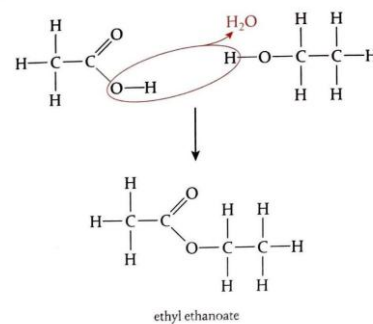


Summary of oxidation of alcohols

	Oxidation product	Colour change with acidified $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$
primary alcohol	aldehyde \rightarrow carboxylic acid	orange \rightarrow green
secondary alcohol	ketone	orange \rightarrow green
tertiary alcohol	not oxidized	no colour change

Slide 101: Alcohols: Esterification

- When one reactant contains a carboxylic acid group (-COOH) and the other reactant an alcohol group(OH-), they react together to form an ester.
- The name of the ester takes the name of the alkyl portion of the alcohol followed by the name of the acid salt.
- Conditions: Warm the mixture of alcohol and carboxylic acid in the presence concentrated sulfuric acid. The acid acts as a catalyst.
- **esterification**
- **ethanoic acid**
- **ethanol**
- **ethyl ethanoate**
- This is an example of a **condensation rxn**
- **2 molecules react to form a product, usually with the loss of H_2O , but can be HCl or NH_3**



- carboxylic acid + alcohol \rightleftharpoons ester + water
- ***This is an equilibrium rxn**

Slide 102: Esters

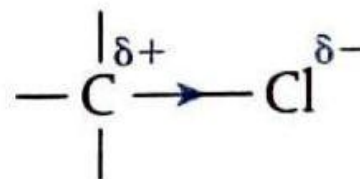
- Many esters have sweet, fruity smells and are used in food _____ and perfumes.
- Unlike the parent acid and alcohol, esters do not have a free -OH^- group so they cannot form _____ bonds.
- This makes them more _____ and less soluble in water.
- _____ occurring fats and oils are esters.
- _____ contain three ester links from a reaction between an alcohol with three -OH^- groups and three carboxylic acids known as fatty acids.

Slide 103: Halogenoalkanes

- _____ Formula: $\text{C}_n\text{H}_{2n+1}\text{X}$ (X=Halogen)
- _____ are saturated molecules that contain an atom of fluorine, chlorine, bromine or iodine bonded to the carbon skeleton of the molecule.
- Due to the presence of the halogen, they possess a polar bond unlike the non-polar alkanes (More polar = more likely to undergo _____ rxns).
- **Reactions:**
- _____ substitution

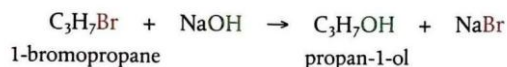
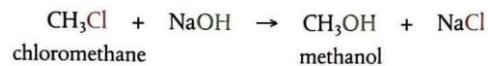
Slide 104: Halogenoalkanes: Nucleophilic Substitution

- The polarity in _____ is due to the halogen atom being **more electronegative** than carbon and therefore it exerts a **stronger pull on the shared electrons** in the carbon-halogen bond.
- The **halogen** gains a **partial negative charge** and the **carbon** gains a **partial positive charge** and is said to be electron _____.
- This **electron deficient carbon** defines much of the **reactivity** of the _____.
- _____ that are **electron rich and are very attracted to electron deficient atoms**
- **Nucleophile**
- _____ have a lone pair of electrons and may also carry a negative charge: H_2O , OH^- , NH_3 , CN^-



Slide 105: Halogenoalkanes: Nucleophilic Substitution

- The nucleophiles are attracted to the electron deficient carbon in the _____ which leads to a reaction where substitution of the halogen occurs.
- _____ **Substitution Rxns**

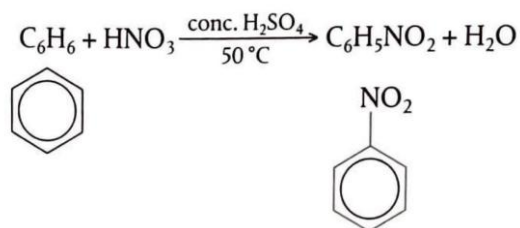
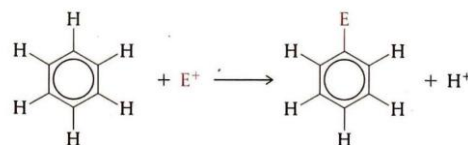
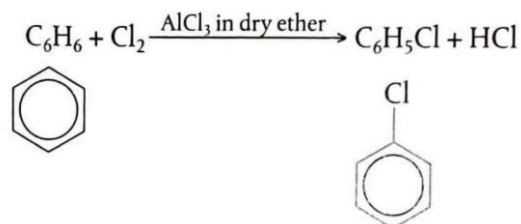


Slide 106: Benzene

- Addition rxns are not favored in benzene due to _____ of arene ring
- _____ rxns occur readily (one or more hydrogen atoms is replaced by an incoming group)
- _____ occurs in the delocalized e⁻ ring, but conserves the arene ring.
- Reactions:**
- _____ substitution

Slide 107: Benzene: Electrophilic Substitution

- _____ that are electron deficient (have a positive or partial positive charge)
- Electrophile**
- _____ (E⁺) are attracted to the electron-rich benzene ring to cause **electrophilic substitution reactions**
- _____ reacts with NO₂⁺
- Benzene reacts with _____**



Slide 108: Let's Practice!

- Write equations for
- the complete combustion of ethanol and propanol
- the esterification rxn between propanoic acid and butanol
- Predict the products of heating the following alcohols with acidified potassium dichromate (VI) solution, and the color changes that would be observed in the reaction mixture.
- butan-2-ol

- methanol (product collected by distillation immediately)
- 2-methylbutan-2-ol
- Explain what is meant by nucleophilic substitution, using the reaction between NaOH and chloroethane to illustrate your answer.
- Discuss why benzene, which is highly unsaturated, tends to undergo substitution reactions rather than addition reactions.