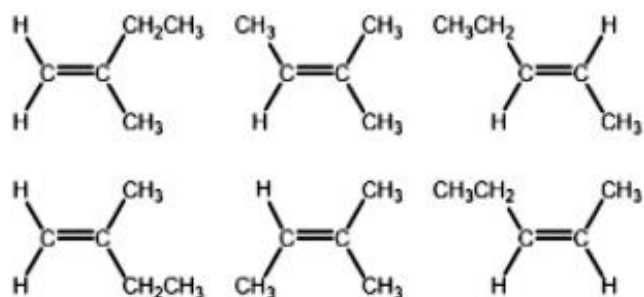
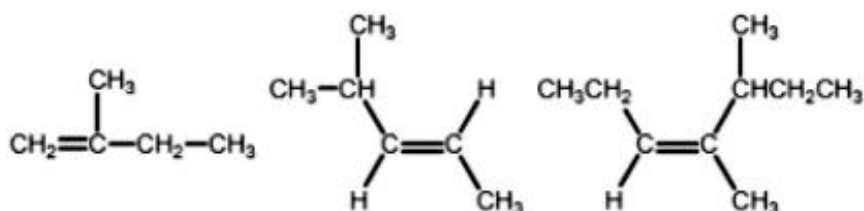


3. Which of the following molecules are structural isomers of each other, which are geometric isomers of each other, and which are the same molecule?



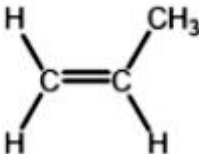
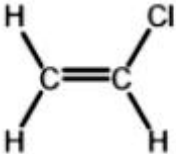
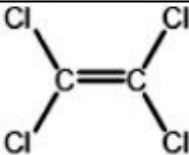
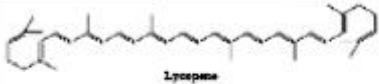
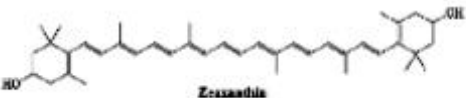
4. provide IUPAC names for the following molecules:

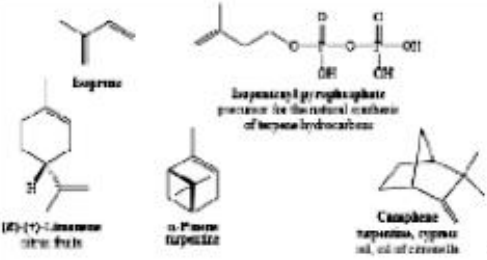
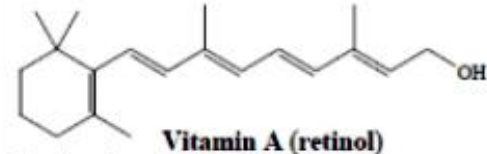


5. Draw structural formulas for the following molecules:
- cis-2-pentene
 - trans-3-methyl-3-hexene

Some Important Alkenes

Name	Structure	Uses
Ethylene (ethene)		<p>Used in the manufacture of the plastic polyethylene.</p> <p>The release of ethylene stimulates the beginning of the ripening process in many plants; some plants can be picked while unripe (when they are less fragile), and exposed to ethylene gas to cause ripening once they reach</p>

		their destination
Propylene (propene)		Produced in the cracking of petroleum; used in the manufacture of the plastic polypropylene.
Vinyl chloride (chloroethene)		A carcinogenic gas manufactured from ethylene; used in the manufacture of the plastic polyvinyl chloride (PVC).
Tetrachloroethylene		Better known as perchloroethylene ("Perc"); a non- flammable organic solvent, widely used in dry cleaning; it is also used as an industrial solvent, degreaser, and paint remover.
		A red pigment found in tomatoes, watermelon, guava, papaya, pink grapefruit, apricots, and rosehips; lycopene is a good antioxidant, and is more readily absorbed from cooked tomatoes and tomato paste, especially if the foods contain fat.
		Zeaxanthin: A yellow pigment found in corn, egg yolk, orange juice, mangoes; also contributes to the yellowish color of animal fats. It is also found in the macula region of the retina (macula lutea, "yellow spot"), where it filters out some blue

		and UV light, acting like internal sunglasses; macular degeneration is the most common cause of blindness in the elderly
Terpenes and Essential Oils	 <p>isoprene</p> <p>(E)-(+)-limonene citrus fruits</p> <p>α-Pinene turpentine</p> <p>isopentenyl pyrophosphate precursor for the natural synthesis of terpene hydrocarbons</p> <p>Camphene turpentine, cymene oil of rosemary</p>	<p>Terpenes and Essential Oils Terpenes are a diverse group of molecules which are biologically synthesized from isoprene units. They are found in many plants, and often have distinctive flavors and aromas. They are often components of essential oils, so named because they have a characteristic “essence” or fragrance. Many of these molecules are components of common foods and perfumes. (Lycopene and its related compounds are also terpenes.)</p>
	 <p>Vitamin A (retinol)</p>	<p>A fat-soluble vitamin; a metabolic product of carotene, found in liver, egg yolks, butter, and milk. It combines with the protein opsin to form rhodopsin, the primary light-gathering pigment in vertebrate retinas; also involved in cell growth and maintenance of healthy skin tissue.</p>

Physical and Chemical Properties of Alkenes

Physical Properties of Alkenes

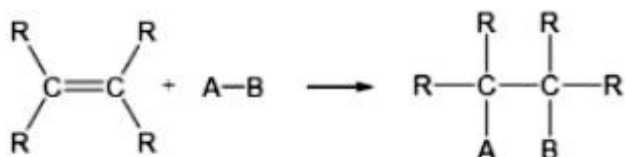
Many of the physical properties of alkenes are similar to those of alkanes.

- Alkenes are nonpolar compounds.
- They are insoluble in water.
- They are soluble in nonpolar solvents.
- They are less dense than water.
- Range of physical states: ≤ 4 C's — gases — 5 - 17 C's — liquids — ≥ 18 C's — solids •

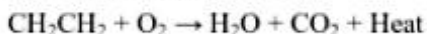
The chemical properties of alkenes

These are completely different from those of alkanes.

1. **Addition Reaction:** Most reactions of alkenes can be classified as addition reactions, in which both parts of a reactant are added to the carbon-carbon double bond:

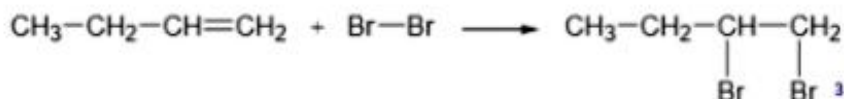
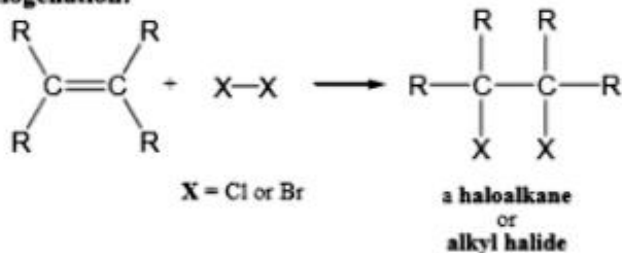


- a) **Combustion:** Just like all hydrocarbons alkenes burn in the presence of oxygen to give CO_2 water and Energy



- b) **Halogenation of Alkenes**

In a halogenation reaction, an alkene reacts with a halogen molecule to form an alkylhalide (haloalkane). Eg., An alkene reacts with molecular bromine (Br_2) or chlorine (Cl_2) to form an alkyl halide (or haloalkane).

Halogenation:

The addition reaction with bromine is a useful qualitative test for the presence of double bonds. A solution of bromine in carbon tetrachloride is red, whereas alkenes and bromoalkanes are usually colorless.

As the bromine adds to the double bond, the red color disappears, a result providing a simple test for the presence of double bonds.



A solution of bromine in carbon tetrachloride is red.

Solutions of alkenes and bromoalkanes are usually colorless.

As the bromine adds to the double bond, the red color disappears, a result providing a simple test for the presence of double bonds.

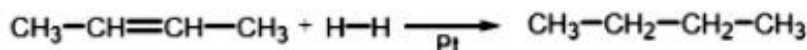
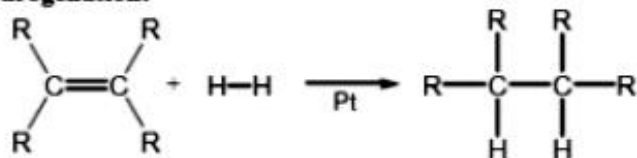
c) Hydrogenation of Alkenes

In a hydrogenation reaction, is an addition reaction in which a hydrogen atom is added to each carbon of the double bond, converting the alkene into an alkane.

The reaction only takes place in the presence of a metal catalyst (usually Pt).

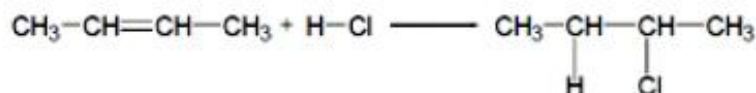
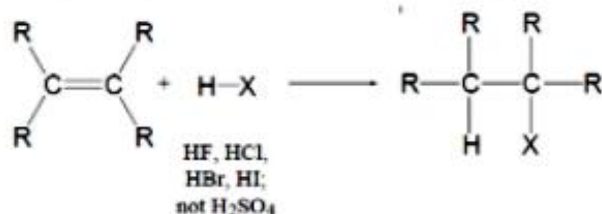
This same process is used to produce hydrogenated vegetable oils such as margarine.

Hydrogenation:

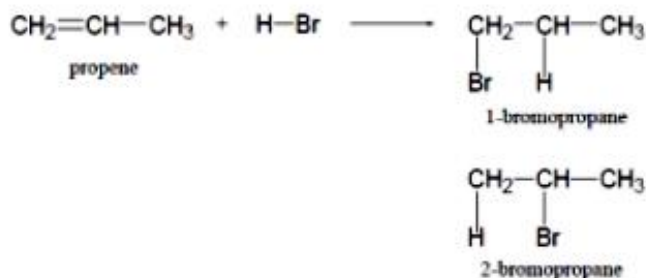


d) Addition of Acids

Acids (HF, HCl, HBr, and HI) can add to a double bond to produce an alkyl halide.



If the alkene is unsymmetrical, there are two possible products in this kind of reaction:

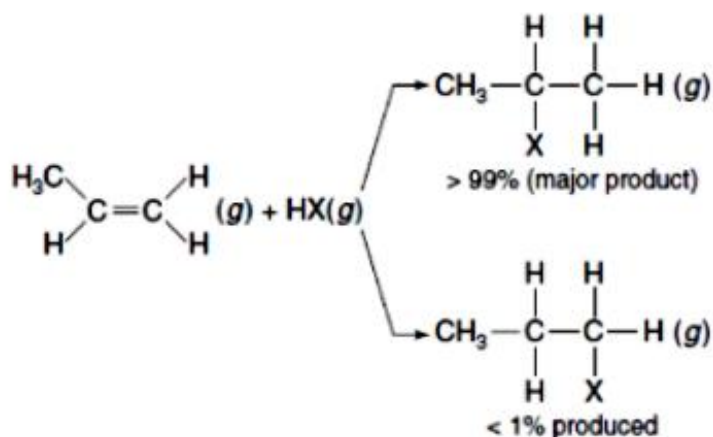


The **major product** of the reaction is predicted using *Markonikov's Rule*:

Markonikov's Rule (Vladimir Markonikov, 1869): when a molecule of the form H-X adds to a double bond, the hydrogen becomes attached to the carbon atom that is already bonded to the most hydrogen atoms. ("The rich get richer")

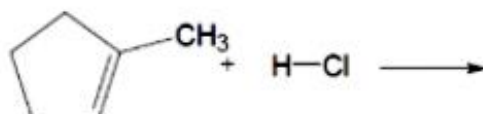
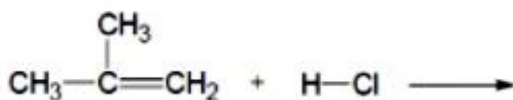
In the example above 1-bromopropane will be the major product.

Addition of a hydrogen halide, HX, where X is a halogen:



Exercise:

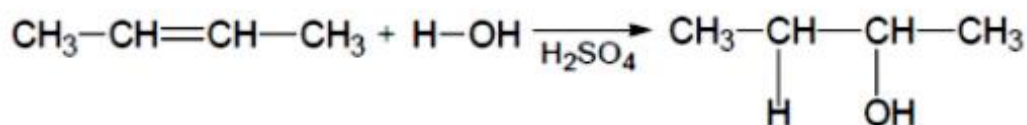
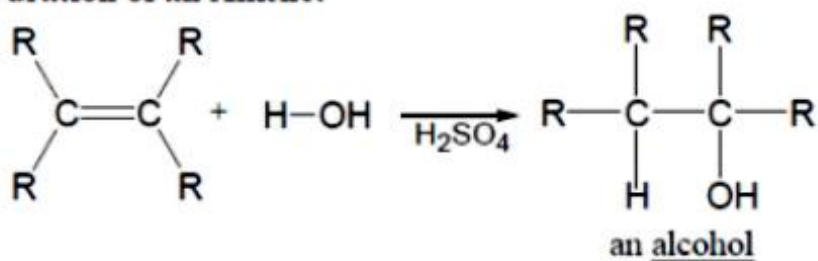
Complete the following reactions and indicate the major product in each case.



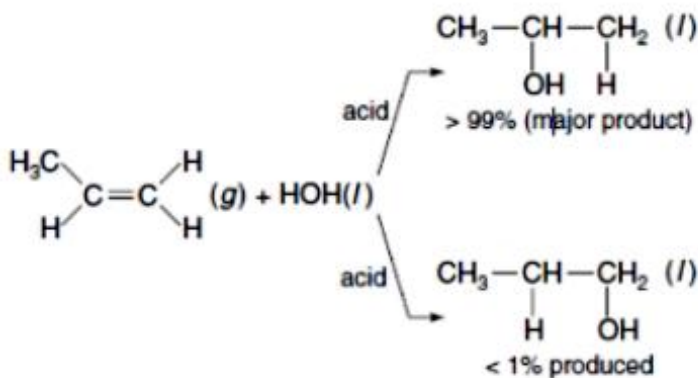
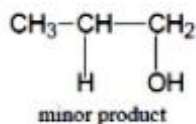
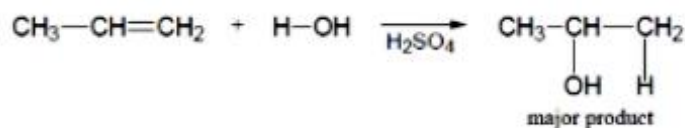
e) Hydration of Alkenes

In a **hydration** reaction, the elements of water are added to an alkene, producing an **alcohol** as the product in the presence of a strong acid catalyst (usually H₂SO₄)

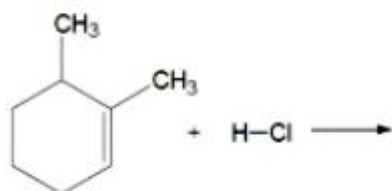
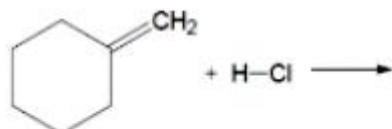
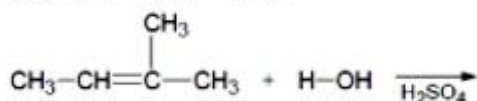
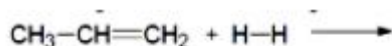
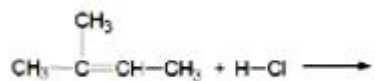
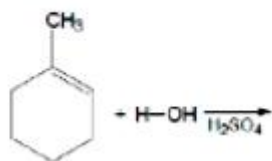
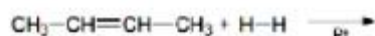
Hydration of an Alkene:



This reaction also follows Markonikov's rule if the alkene is unsymmetrical.

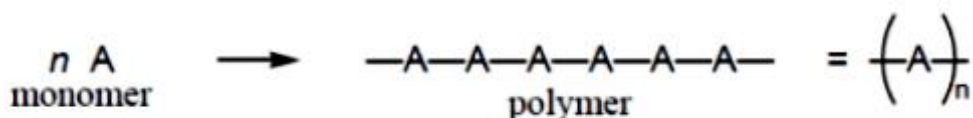


Exercise: Complete the following reactions:



f) Polymerization: Polymerization is the process of binding a number of molecules which contain a small number of Carbon atoms (Monomer) to form one molecule of a large number of Carbon atoms (Polymer).

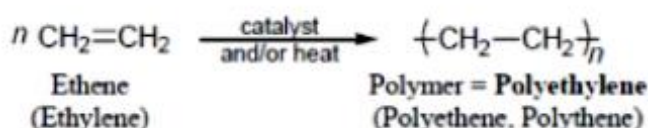
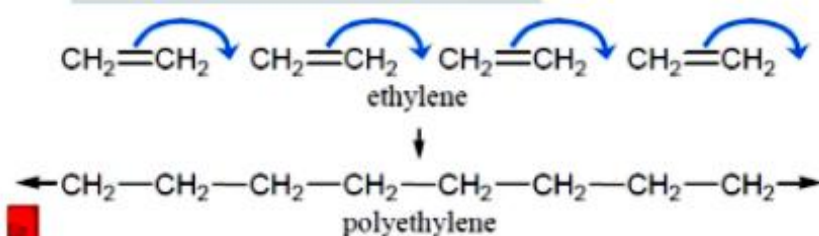
Monomers are small, single molecules, such as hydrocarbons and amino acids which combine together chemically to form long chains or large 3D molecules..



In **addition polymers**, every atom in the reacting molecules becomes incorporated into the resulting polymer molecule.

In most addition polymers, the monomer contains a double bond.

i. Manufacture of polyethene



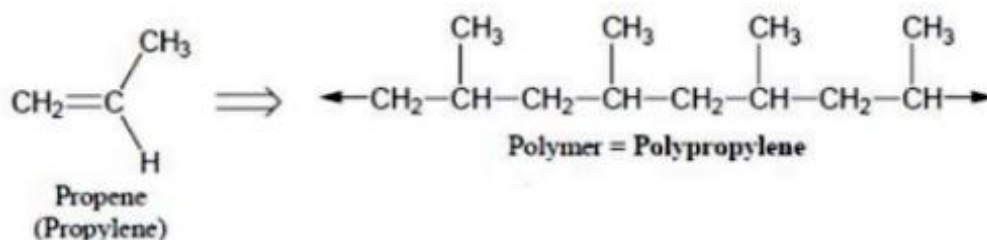
$n = 10,000 - 30,000$ = low-density polyethylenes (LDPE)

$n = 10,000 - 50,000$ = high-density polyethylenes (HDPE)

$n = \text{up to } 200,000$ = ultrahigh-molecular-weight polyethylenes (UHMWPEs)

Polyethylene is useful in food storage containers, plastic wraps and films, garbage bags, insulation for electrical wiring, squeeze bottles, etc.

ii. Manufacture of polypropene from propene or propylene



Polypropylene (PP) forms a more orderly polymer than polyethylene, and is much harder, and is stable at higher temperatures (which make it possible to use in sterilizable storage containers). It is used in fibers, indoor-outdoor carpets, bottles, artificial turf, etc.

ALKYNES

Alkynes: an unsaturated hydrocarbon that contains one or more carbon-carbon triple bonds. The molecular formula of this group is $\text{C}_n\text{H}_{2n-2}$ for one triple bond in the structure (n is the number of carbon atoms).

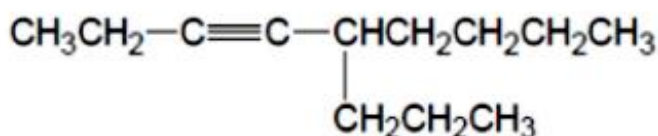
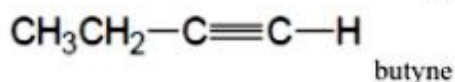
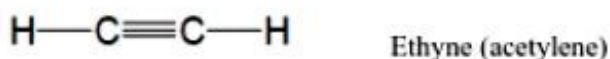
Alkynes have less hydrogen atoms than alkanes and alkenes.

Nomenclature of alkynes

The nomenclature system for alkynes is identical to that of alkenes, except the suffix **-yne** is used to indicate the triple bond.

The suffix *-yne* is used to indicate an alkyne.

Examples:

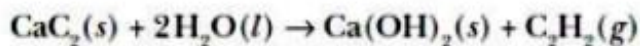


Acetylene is a colorless gas, which is produced primarily from petroleum.

It is used in oxyacetylene torches, which produce relatively high temperatures.

Acetylene also is used as the starting material for a number of plastics.

Acetylene can also be produced by the reaction of calcium carbide and water described by

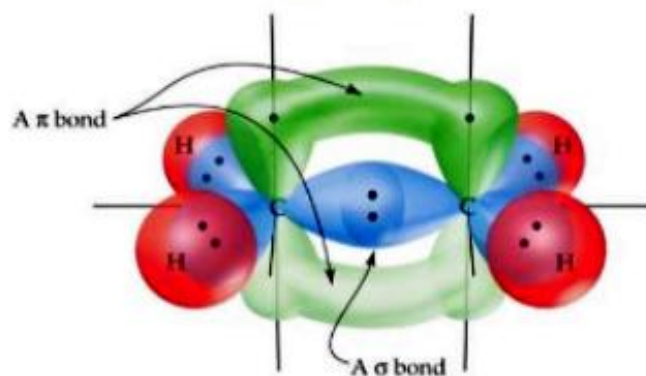


Bonding in Acetylene

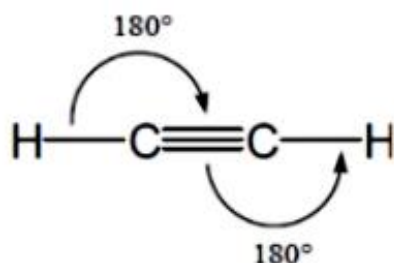
- When two *sp*-hybridized carbons are next to each other, three orbital overlaps take place:
 - *end-on-end overlap* of the *sp* orbitals to make a **σ -bond**.
 - *side-to-side overlap* of both sets of unhybridized *p* orbitals to make **two π -bonds**.

Because of the π -bonds, free rotation is not possible around carbon-carbon triple bonds.

Bonding in Ethylene



Since each carbon in the double bond is linear in space, the entire acetylene molecule is a **linear** molecule.

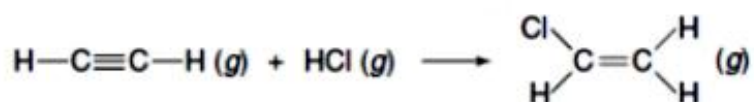


Besides the combustion reaction that all hydrocarbons undergo, acetylene and other alkynes undergo the same type of addition reactions as alkenes do.

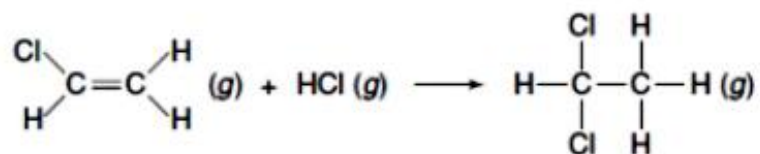
For example, let's consider the product when $\text{HCl}(g)$ reacts with $\text{C}_2\text{H}_2(g)$.

The reaction can be broken down into two steps.

The first step is

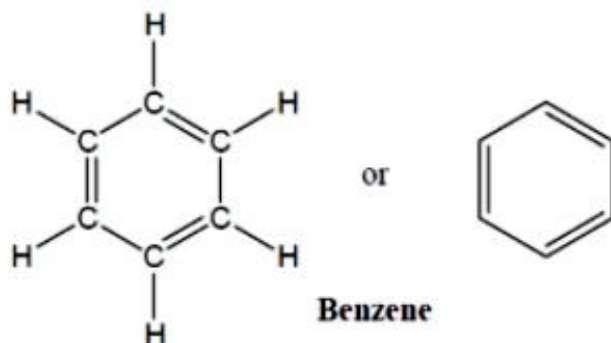


The second step is



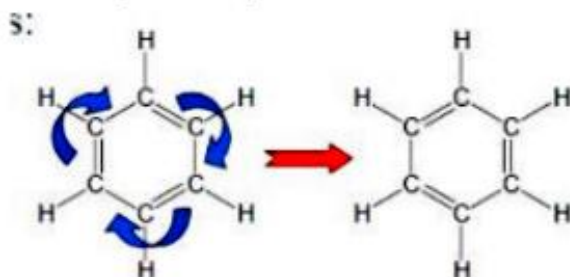
AROMATIC COMPOUNDS

- **Aromatic compounds** are those that contain the **benzene ring** (C_6H_6) or its structural relatives.
- **Aliphatic compounds** do not contain benzene rings.



The Structure of Benzene

- Although the formula indicates the presence of double bonds, benzene does not undergo the typical alkene reactions.
- The ring structure of benzene was proposed by August Kekulé in 1865; he suggested that the double bonds switch positions to give two equivalent.



The Resonance Structures of Benzene

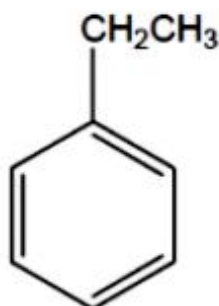
In reality, the double bonds and single bonds in benzene do not change position.

The two Kekulé structures for benzene are **resonance structures**, meaning that each individual structure is fictitious.

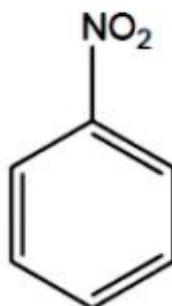
The benzene ring is sometimes represented as a hexagon with a circle inside, which emphasizes that all of the positions on the benzene ring are equivalent.

Nomenclature of Benzene Derivatives

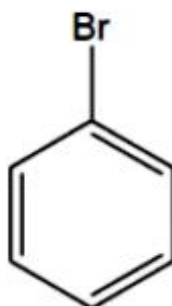
• **Rule 1.** When a single hydrogen of the benzene ring is replaced, the compound can be named as a derivative of benzene



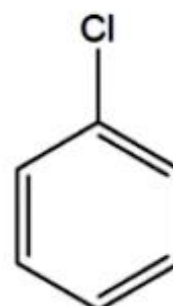
ethylbenzene



nitrobenzene

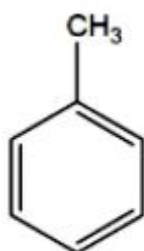


bromobenzene

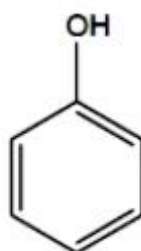


chlorobenzene

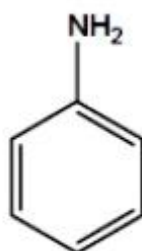
Rule 2. A number of benzene derivatives are known by their common (trivial) names rather than by their formal IUPAC names.



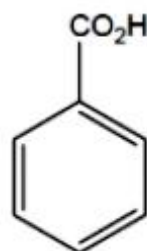
toluene



phenol

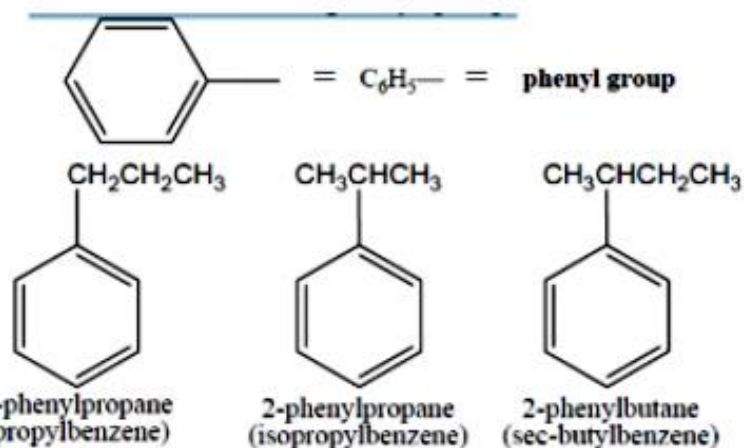


aniline

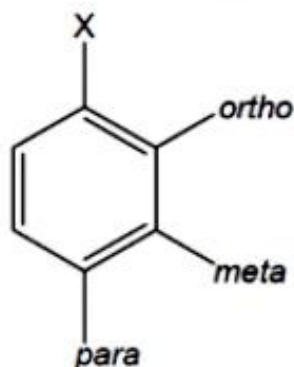


benzoic acid

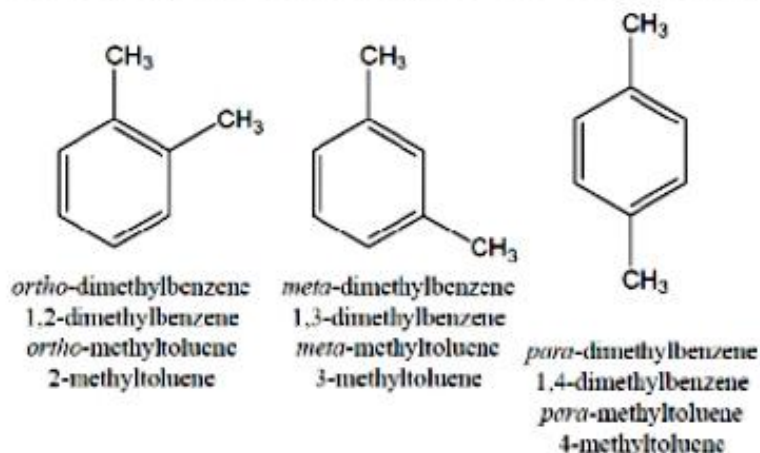
Rule 3. Compounds formed by replacing a hydrogen of benzene with a more complex hydrocarbon group can be named by naming the benzene ring as the substituent, called the **phenyl group**.



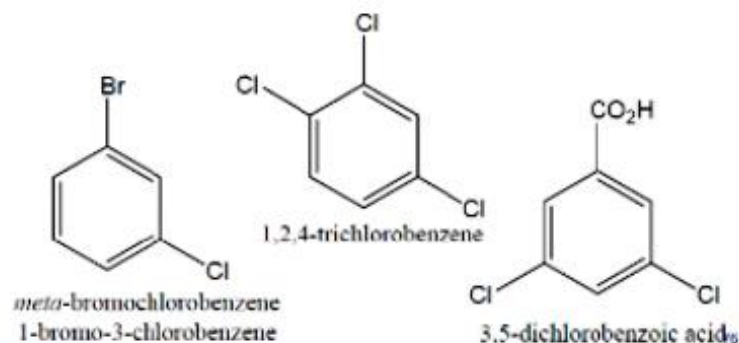
Rule 4. When two groups are attached to a benzene ring, three isomeric structures are possible:



In naming these compounds, either the ortho / meta / para prefixes may be used, or position numbers (begin numbering at the group which comes first in alphabetical order)

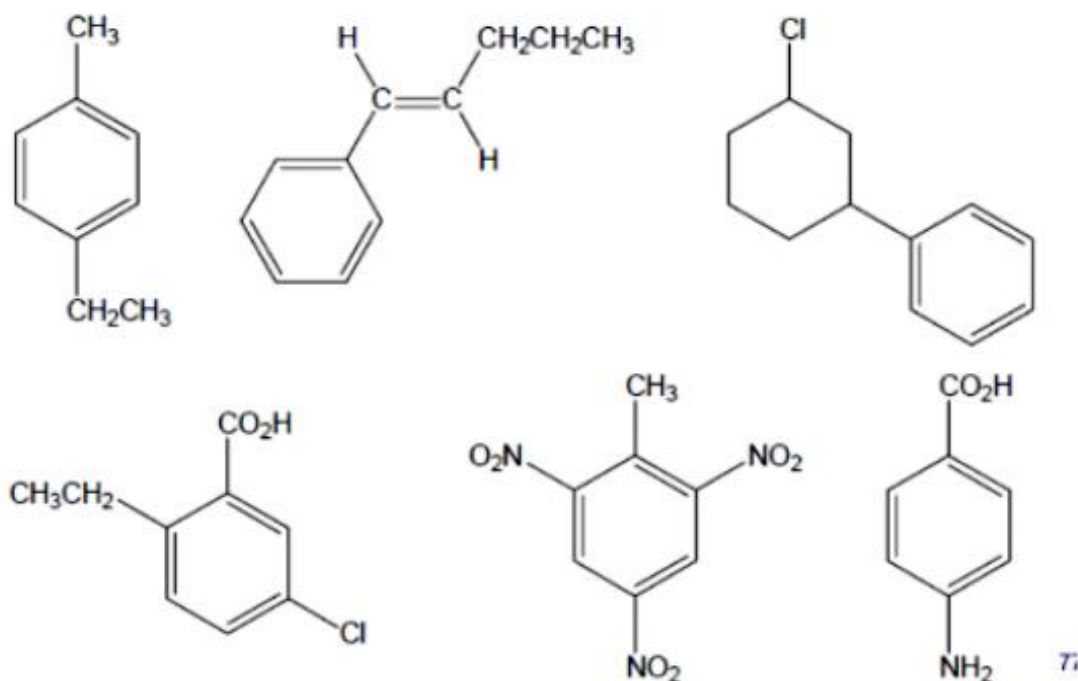


Rule 5. When two or more groups are attached to the benzene ring, their positions can be indicated by numbering the carbon atoms of the ring to obtain the lowest possible numbers for the attachment positions. Groups are arranged in alphabetical order.



Exercise:

1) Provide IUPAC names for the following molecules:



2) Draw structural formulas for the following molecules:

i. *meta*-ethyltoluene

- ii. 2,5-dibromobenzoic acid
- iii. *para*-nitrophenol
- iv. 3-phenylheptane
- v. Butylbenzene
- vi. 1,4,5-tribromobenzene (what's wrong with this name?)

Physical Properties of Aromatic Compounds

- i. Just like alkanes and alkenes, aromatic compounds are **nonpolar**,
- ii. They are **insoluble in water** (unless other substituents, such as OH groups, are present).
- iii. They are also usually less dense than water.
- iv. Many aromatic compounds are obtained from petroleum and coal tar.
- v. Benzene and toluene are commonly used as solvents, and are the starting materials for the synthesis of other useful organic compounds.
- vi. Some foods contain aromatic compounds, which can be synthesized by some plants. Some aromatic amino acids and vitamins are listed as *essential*, because we lack the ability to synthesize them, and must obtain them from our diet.

Chemical Properties of Aromatic Compounds

Aromatic compounds are chemically stable (unlike alkenes).

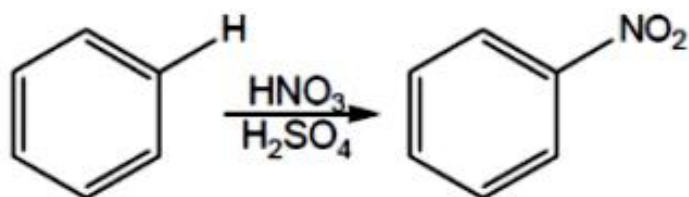
They do **NOT** undergo addition reaction reactions like alkenes.

They undergo substitution reactions in which a hydrogen is replaced by some other group such as nitrogen, alkyl group, amine, halogen, Oh etc..

- i. Nitration of benzene: substitution of a hydrogen on a benzene ring with a nitro group in the presence of sulphuric acid as a catalyst.

When we heat benzene or one of its derivatives with a mixture of concentrated nitric and sulphuric acids, a nitro (-NO₂) group replaces one of the hydrogen atoms bonded to the ring.

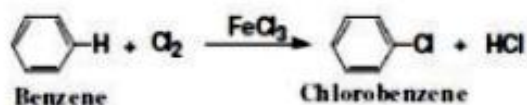
In this reaction, sulfuric acid is a catalyst and it is added to speed up the reaction.



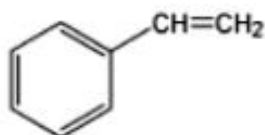
Benzene

nitrobenzene

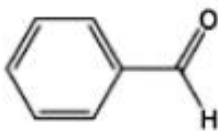
Halogenation: in the presence of an iron catalyst, chlorine reacts rapidly with benzene to give chlorobenzene and HCl.



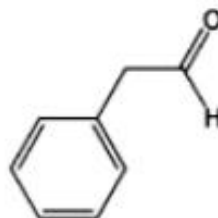
Some Important Aromatic Compounds



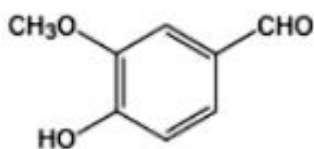
Styrene
Used to make polystyrene and styrofoam



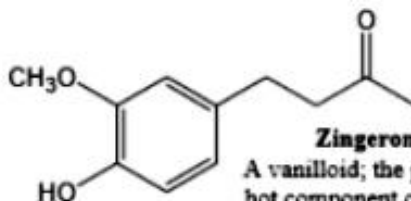
Benzaldehyde
Odor of almonds and cherries; also found in peach and apricot pits



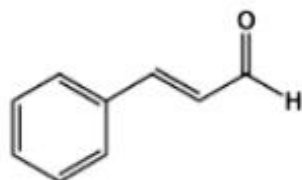
Hyacinthin
Floral scent found in hyacinth



Vanillin
Essential component of oil of vanilla; parent compound of the vanilloids

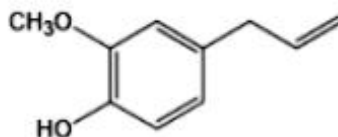


Zingerone
A vanilloid; the pungent, hot component of ginger



Cinnamaldehyde

Found in oil of cinnamon; has a *carminative* action (releases hydrogen sulfide, methane, and hydrogen from the intestine and stomach in one direction or the other)



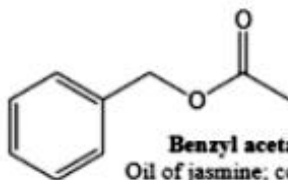
Eugenol

Found in oil of bay (bay leaves), oil of cloves, allspice (combines the flavors of cinnamon, nutmeg and cloves), carnations; shifting the location of the double bond produces isoeugenol, the odor of nutmeg



Anethole

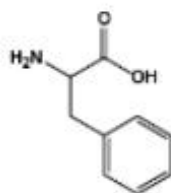
Oil of aniseed, fennel, tarragon



Benzyl acetate

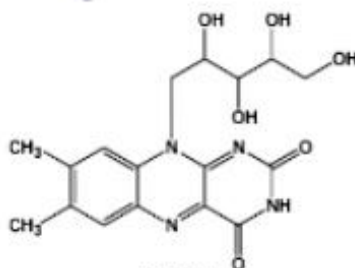
Oil of jasmine; common ingredient in perfumes

Aromatic rings in the diet



Phenylalanine

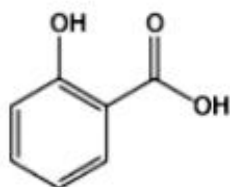
An essential amino acid; also found in *aspartame* (Nutra-Sweet)



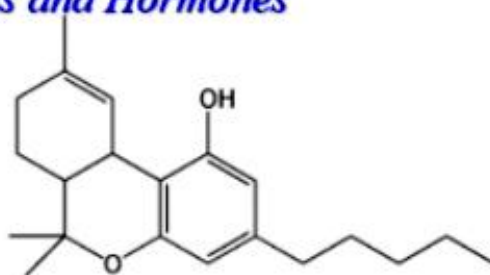
Riboflavin

Vitamin B₂; found in milk, meat, eggs, dark green vegetables, bread, beans, and peas; forms the coenzymes FMN and FAD, which are hydrogen transporters; deficiency results in dermatitis

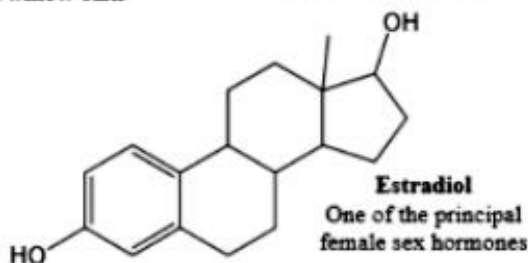
Drugs and Hormones



Salicylic acid
Analgesic, antipyretic, and
anti-inflammatory drug
found in willow bark



Tetrahydrocannabinol (THC)
Active component of cannabis

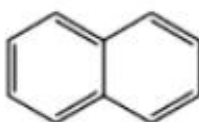


Estradiol
One of the principal
female sex hormones

8E

Polycyclic Aromatic Hydrocarbons (PAH)•

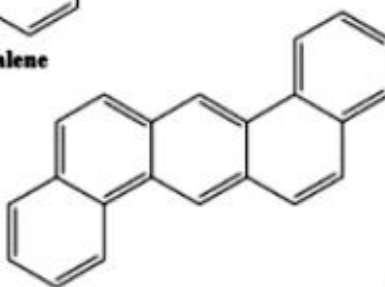
Polycyclic aromatic hydrocarbons consist of two or more benzene rings fused together; they produced when organic compounds are heated to high temperatures, and are present in tobacco smoke, car exhaust, and sometimes in heavily browned foods.



Naphthalene



Benzo[a]pyrene



Dibenz[a,h]anthracene

9

ALCOHOLS

The hydroxyl group (-OH) is found in the alcohol and phenol functional groups.

In alcohols, a hydroxyl group is connected to a carbon atom in an aliphatic compound.

R-O

The word “alcohol” comes from the Arabic term al kohl meaning “the fine powder.”

Originally, this referred to an antimony sulfide compound used for eye shadow, which was ground up to form a fine powder, but then later came to refer to any finely divided powder.

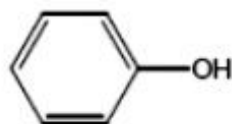
In the Middle Ages, this term came to mean the “essence” of anything.

When the Europeans took up alchemy in the Middle Ages, they referred to vapors from evaporating or boiling compounds as “spirits,” since they did not believe them to be material in the same sense that solids and liquids were.

Alchemists began referring to “spirits of wine,” and since an alcohol when it boils away seems to powder away to nothing, they also began to refer to “alcohol of wine” and then simply “alcohol”.

In phenols, -OH is connected to a benzene ring.

(The “parent” molecule of this class is also named phenol: PhOH or C₆H₅OH.)



a phenol

Some Common Alcohols

Methanol CH₃OH

methyl alcohol (wood alcohol) (“methy” = wine, “hule” = wood)

Found in wood smoke; contributes to the bouquet of new wine;

metabolized in the body to formaldehyde and formic acid, and can cause blindness or death (> 50 mL)

Ethanol CH₃CH₂OH

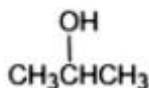
ethyl alcohol (grain alcohol)

The alcohol of alcoholic beverages; the fermentation of honey, grain, or fruit juices to yield beers and wines was probably the first chemical reaction to be discovered; metabolized in the body to produce acetaldehyde

1-propanol (n -propyl alcohol)



2-propanol (isopropyl alcohol)



Rubbing alcohol is 70% isopropyl alcohol and 30% water

Nomenclature of Alcohols and Phenols

Step 1. Name the longest chain to which the hydroxyl (-OH) group is attached.

The name for this chain is obtained by dropping the final -e from the name of the hydrocarbon parent name and adding the ending -ol.

Step 2. Number the longest chain to give the lowest possible number to the carbon bearing the hydroxyl group.

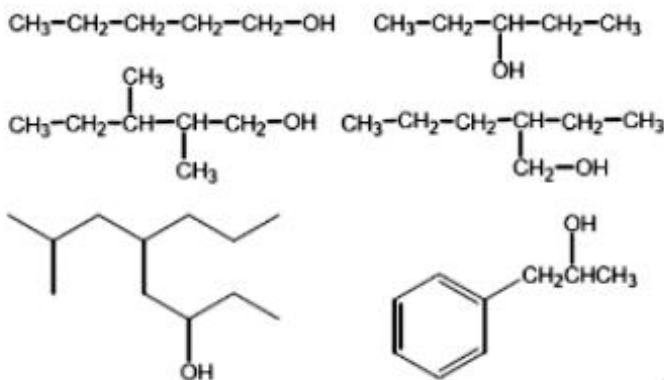
Step 3. Locate the position of the hydroxyl group by the number of the C to which it is attached.

Step 4. Locate and name any other substituents.

Step 5. Combine the name and location for other groups, the hydroxyl group location, and the longest chain into the final name.

Examples:

Provide acceptable IUPAC names for the following compounds.



Step 6. If there is more than one OH group, a counting prefix (di-, tri-, tetra-, etc.) is placed immediately in front of the suffix -ol (diol, triol, tetraol, etc.).

The final "e" of the parent hydrocarbon is not dropped (e.g., 1,2-propanediol).

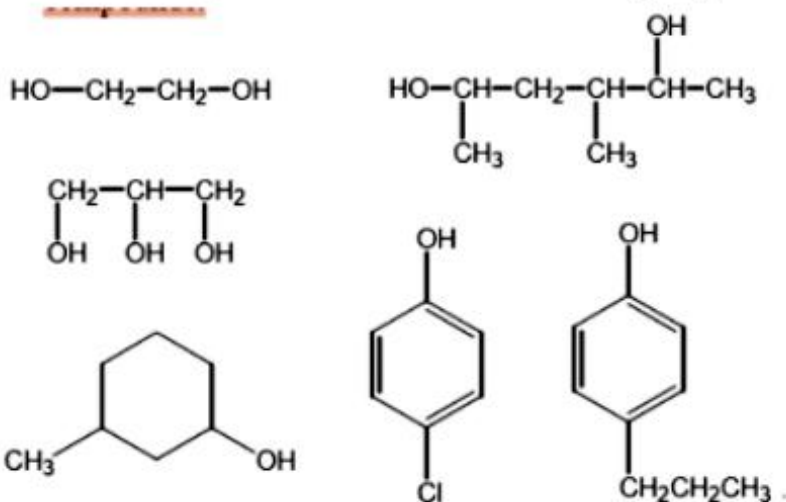
The position of each alcohol group is indicated by carbon number, separated by commas (e.g., 1,3- butanediol).

Step 7. For cyclic alcohols, the carbon bearing the OH is numbered as "1."

Phenols are named after the parent compound phenol; the C bearing the OH is numbered as "1."

Exercise:

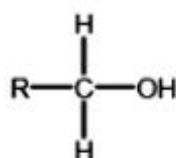
1. Provide acceptable IUPAC names for the following compounds:



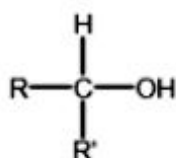
2. Draw structural formulas for the following molecules:
- 3-methyl-2-pentanol
 - 2,4,4,5-tetramethyl-2-heptanol
 - 1-ethyl-1-hexanol (what's wrong with this name?)
 - 3-ethylcyclopentanol
 - 3-ethylphenol
 - 3-methyl-2,4-pentanediol

Classification of Alcohols

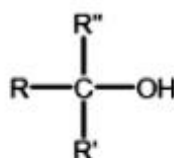
Alcohols are classified as primary (1°), secondary (2°), or tertiary (3°) according to how many carbon groups are attached to the carbon bearing the OH group:



Primary
1°



Secondary
2°



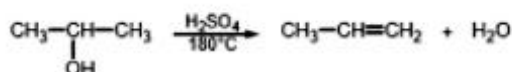
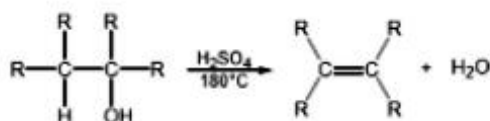
Tertiary
3°

Properties of Alcohols

i. Dehydration of Alcohols to Produce Alkenes

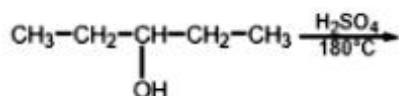
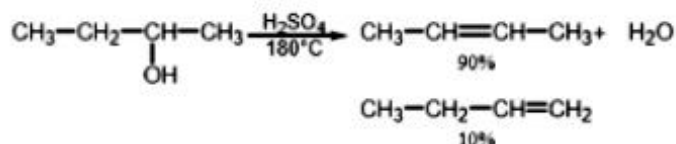
Heating alcohols in concentrated sulfuric acid (H_2SO_4) at 180°C removes the OH group and a H from an adjacent carbon to produce an alkene, with water as a by-product.

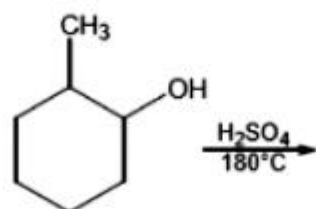
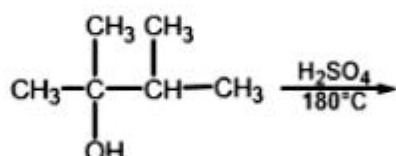
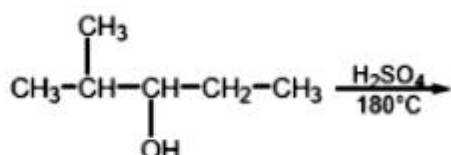
Since water is "removed" from the alcohol, this reaction is known as a dehydration reaction (or an elimination reaction):



If there is more than one possible product of a dehydration reaction, as for an unsymmetrical molecule, the major product can be predicted from Zaitsev's Rule.

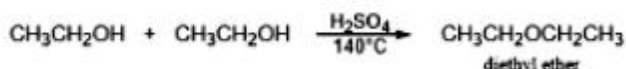
Zaitsev's Rule states that when an alkene is produced in an elimination reaction, the major product is the one with the more highly substituted double bond.





Dehydration of Alcohols to Produce Ethers

Heating alcohols (R-OH) in concentrated sulfuric acid (H₂SO₄) at 140°C removes a molecule of water from two alcohol molecules, causing the two "R" groups to become attached to an oxygen atom, forming an ether functional group:

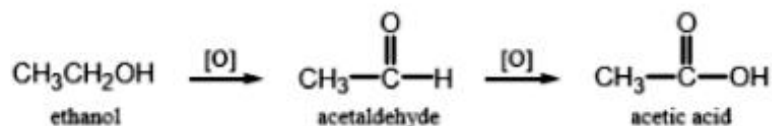
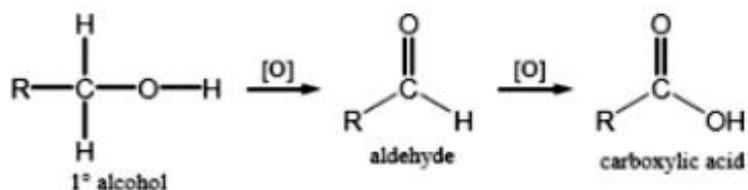


Oxidation of Alcohols to Carbonyl Compounds

An oxidation reaction occurs when a molecule loses electrons and this is usually manifested as an increase in the number of oxygen atoms or a decrease in the number of hydrogen atoms. Some common oxidizing agents include potassium permanganate (KMnO₄), chromic acid (H₂CrO₄), sodium dichromate (Na₂Cr₂O₇), and other Cr⁶⁺ salts.

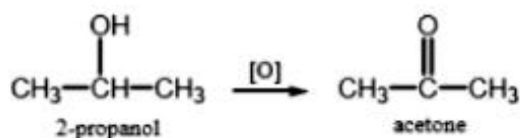
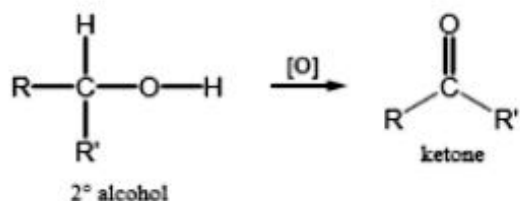
Alcohols can be oxidized by removing two H atoms from the molecule and the exact products of the reaction will depend on the type of alcohol.

- Primary alcohols are oxidized first to aldehydes, but the aldehydes are then usually oxidized into carboxylic acids.

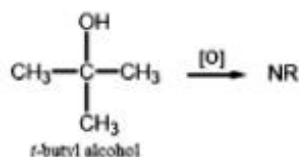
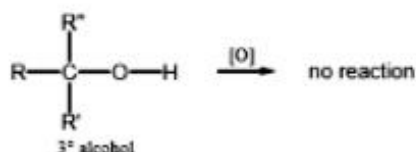


In the body, oxidation of ethanol to acetaldehyde takes place in the liver; the acetaldehyde is further oxidized to acetyl coenzyme A, which can be used to synthesize fat or eventually be oxidized to water and carbon dioxide.

- Secondary alcohols are oxidized to ketones, which cannot be oxidized any further:



- Tertiary alcohols, because there is by definition no hydrogen on the alcoholic carbon, cannot be oxidized:



Alcohols react with carboxylic acids in presence of conc H_2SO_4 (catalyst) to yield esters (sweet smelling compounds).



Ethanol pentanoic acid ethylpentanoate

Similarities between the properties of phenol and ethanol

- i. Phenol and ethanol are both hydroxy compounds as they both contain the $-\text{OH}$ group.
- ii. Both react with sodium metal producing hydrogen gas and the corresponding ethoxide or phenoxide.
- iii. Ethanol and water are miscible in all proportions. Phenol is only slightly soluble in water. If enough phenol is added, two liquid layers are produced.
- iv. Both do not react with sodium bicarbonate.

Differences between the properties of phenol and ethanol

- i. Phenol is a weak acid as it partially ionizes in water while ethanol is not.
- ii. Ethanol does not react with sodium hydroxide while phenol does.
- iii. Ethanol will not react with bromine water under normal conditions while phenol will decolorize bromine water and a white ppt forms.
- iv. Ethanol does not react with Iron(III)chloride solution while phenol reacts giving a purple-coloured product. This test is sometimes used to test for the presence of phenol.

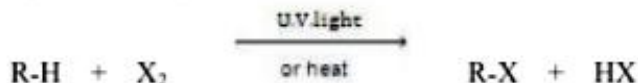
Aldehydes and ketones

Organic halogen compounds

The alkyl halides are a class of compounds with the general formula RX ; where R = alkyl group, X = halogens, F , Cl , Br and I

Methods of preparing monohalides and use chemical equations to illustrate each.

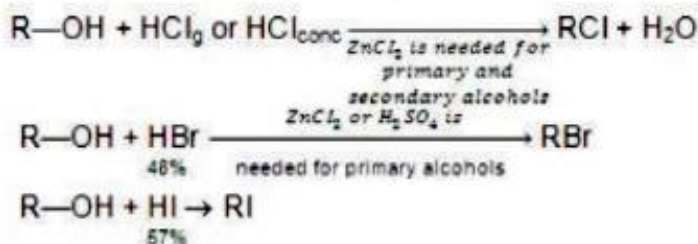
- i. By direct halogenations of alkanes: (See halogenations of alkanes)



- ii. By the addition of HX on alkenes:



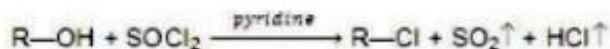
- iii. By reaction of alcohols and halogen acids:



- iv. By reaction of alcohols and phosphorus halides:



- v. By reaction of alcohols and thionyl chloride: or Darzen's method



Simple alkyl halides mostly those with only one halogen atom are named halo alkanes:

Thus:

chloromethane is CH_3Cl (methyl chloride),

bromoethane is CH_3CH_2Br (ethyl bromide),

2-iodopropane is CH_3CHICH_3 (isopropyl iodide)

1-bromo-5-chloro-2-iodohexane is $BrCH_2CHICH_2CH_2CHClCH_3$

3,4-dichloro-1-butene is

Note that the substituents are listed alphabetically using the lowest possible numbers just as for alkanes.

Physical properties of alkyl halides:

- Except for a few of the lower molecular weight members, the alkyl halides are colourless liquids that are heavier than water.
- boiling point increases with increasing molecular weight.
 CH_3Cl : -24°C ; $\text{C}_2\text{H}_5\text{Cl}$: 13°C ; $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$: 46°C ; CH_2Cl_2 : 40°C ;
 CH_3Br : 5°C ; $\text{C}_2\text{H}_5\text{Br}$: 38°C ; $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$: 71°C ;
 CHCl_3 : 61°C ; CH_3I : 42°C ; $\text{C}_2\text{H}_5\text{I}$: 72°C ; $\text{CH}_3\text{CH}_2\text{CH}_2\text{I}$: 102°C ; CCl_4 : 77°C .
- For isomers, just like for alkanes, chain branching results in a lower boiling point, e.g.:
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$: 77°C ; $\text{CH}_3\text{CH}_2\text{CHClCH}_3$: 69°C ; $(\text{CH}_3)_2\text{CHCH}_2\text{Cl}$: 69°C ;
 $(\text{CH}_3)_3\text{CCl}$: 51°C .
 $1^\circ \text{ halide} > 2^\circ \text{ halide} > 3^\circ \text{ halide}$ (for a given halide and alkyl group)

Chemical properties of alkyl halides

1. Alkyl iodides are the most reactive of the alkyl halides ($\text{RI} > \text{RBr} > \text{RCl} > \text{RF}$).

Generally alkyl fluorides are very inert (this is very useful in the case of teflon, the polymer of tetrafluoroethene $(-\text{CF}_2-\text{CF}_2-)_n$, whose chemical inertness makes it useful not only for lining frying pans but also in the construction of apparatus used in corrosive chemical reactions.

In fact polyfluorinated alkanes are both stable and able to dissolve oxygen and they can even be used as artificial blood.

2. Nucleophilic substitution

Halogens are much more electronegative (electron withdrawing) than carbon (electron repelling) and so the electron pair of the covalent bond is more associated with the halogen atom than the carbon atom.

This results in polarization making the carbon atom susceptible to attack by negatively charged species (nucleophiles) and readily undergoes substitution reactions (nucleophilic substitution).

A nucleophile is an electron-rich ion or molecule that reacts at a positive or positively polarised centre in a molecule.

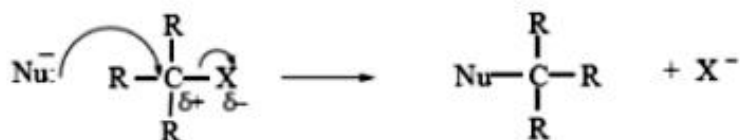
They can be represented as either a negatively charged ion or a neutral, electron rich molecule:

- Nu:⁻ e.g. hydroxide ion, HO⁻ or cyanide ion, CN⁻
- Nu: e.g. water, H₂O or ammonia, NH₃, each of which have a lone pair of electrons that constitute an electron-rich region.

A **nucleophilic substitution** reaction of an alkyl halide involves the replacement of the halogen atom by a suitable nucleophile.

A nucleophile is a "positive loving" species and will, itself, be negatively charged or electron rich. An electrophile is a "negative loving" species and will, itself, be positively charged or electron deficient.

The positive polarity at the carbon of the C-X bond attracts the electron-rich nucleophile. The general reaction is:



The carbon-halogen bond broken liberating a halide anion (the polarity helps) and forms a carbon-nucleophile bond.

In nucleophilic substitution, the group (or atom X in this case) that is displaced is called the leaving group.

The reaction is depicted in "arrow" notation above.

The double-headed arrows are used to indicate the movement of electrons and not the movement of atoms.

Some of the most commonly used strong nucleophiles are:

- HO⁻ (as NaOH in aqueous or organic solution)
- N≡C⁻ (as NaCN in aqueous or organic solution)
- H₂N⁻ (as NaNH₂ in liquid ammonia)
- R₃N: (as ammonia, R=H)