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Alkanes:

They are saturated hydrocarbons (they have only carbon-carbon single bonds). The molecular formula of this group is C_nH_{2n+2} (n is the number of carbon atoms).

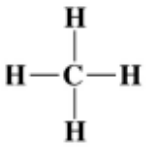
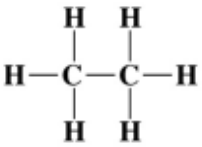
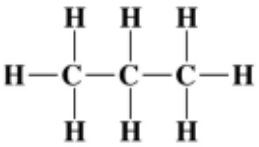
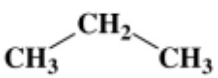
Naming the unbranched alkanes:

The IUPAC name for an alkane consists of two parts: 1. A prefix that shows the number of carbon atoms (meth-, eth-, prop-, but-, pent-, hex-, hept-, oct-, non- and dec-). 2. The suffix "**-ane**".

CH_4 **Methane** C_2H_6 **Ethane** C_3H_8 **Propane** C_4H_{10} **Butane**

Note: we can represent the formula of an organic compound by the molecular formula or by the structural formula. Structural formulas can be represented by three ways: **Expanded (Complete) structural formula**, **Condense structural formula**, and **Line-angle formula**:

Table 16.3 Writing Structural Formulas for Some Alkanes

Alkane	Methane	Ethane	Propane
Molecular formula	CH_4	C_2H_6	C_3H_8
Structural formulas			
Expanded			
Condensed	CH_4	$CH_3—CH_3$	$CH_3—CH_2—CH_3$ or 

Expanded (complete) structural formula: to represent this model, the carbon atom is shown attached to the hydrogen atoms (we show all connections).

Condensed structural formula: to represent this model, the hydrogen atoms are grouped with their carbon atom. The number of hydrogen atoms is written as subscript.

CH_3-CH_2-CH_2-CH_2-CH_3 or CH_3-$(CH_2)_3$-CH_3

Line-angle formula: is a form of the structural formula. A line represents a carbon-carbon bond and a vertex represents a carbon atom. A line ending in space represents a $-CH_3$ group.

CH_3-CH_2-CH_3 Propane

CH_3-CH_2-CH_2-CH_2-CH_3 Pentane

Substituent groups: they are the branches in organic compounds. A substituent group derived from an alkane by removal of a hydrogen atom is called an **alkyl group (R-)**. Alkyl groups are named by dropping the "-ane" from the name of the parent alkane and add the suffix "**-yl**".

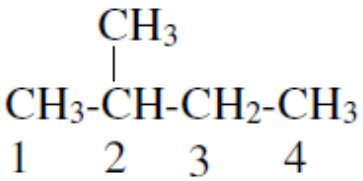
CH_3- Methyl C_2H_5- Ethyl C_3H_7- Propyl

Note: some substituents derived from other elements or other spices than alkanes:

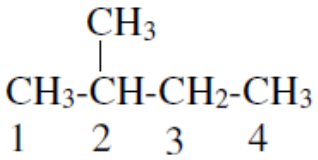
-F Fluoro -Cl Chloro -OH Hydroxyl $-NO_2$ Nitro

Naming branch alkanes:

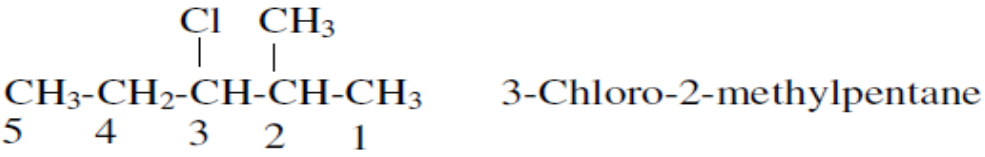
1. Write the alkane name of the longest continuous chain of carbon atoms (parent chain or root chain).
2. Number carbon atoms starting from the end nearest substituent.
3. Give the location and name of each substituent (alphabetical order) as a prefix to the alkane name (main chain). Use a hyphen to connect the number to the name.



In this example, the longest chain is Butane. We number carbon atoms starting from the end nearest substituent (left to right). The location of subtituent is 2 and its name is methyl. Therefore, the complete name of this compound is 2-Methylbutane.



Constitutional isomers: compounds with the same molecular formula but a different connectivity of their atoms (different structural formulas).



Note: Constitutional isomers are different compounds and have different physical and chemical properties.

Physical properties of alkanes:

1. They are nonpolar compounds (the electronegativity difference between carbon and hydrogen is 2.5-2.1 = 0.4).
2. They are insoluble in water (because water is polar) and they are soluble in nonpolar organic compounds.
3. They have the lower density than water (their densities is between 0.7 and 0.8 g/mL).
4. They have the low boiling points and the low melting points.
5. They can be gases (with 1 to 4 carbon atoms), liquids (with 5 to 17 carbon atoms), or solids (with 18 or more carbon atoms).

Chemical properties of alkanes: in general, they have a low reactivity (inert). Their most important reactions are combustion (reaction with oxygen) and halogenation (reaction with halogens).

Combustion: alkanes react with oxygen (they are oxidized). In this reaction, CO_2, H_2O, and energy (heat) are produced.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{energy (heat)}$$

1. $2C_2H_6 + 7O_2 \Rightarrow 4CO_2 + 6H_2O$

2. $C_3H_8 + 5O_2 \Rightarrow 3CO_2 + 4H_2O$

3. $2C_4H_{10} + 13O_2 \Rightarrow 8CO_2 + 10H_2O$

Halogenation: alkanes react with chlorine and bromine if we heat the mixture or if we expose the mixture to light (in the dark at room temperature, nothing happens).

$$CH_4 + Cl_2 \xrightarrow{\text{heat or light}} CH_3Cl + HCl$$

Chloromethane

If chlromethane is allowed to react with more chlorine:

$$CH_3Cl + Cl_2 \xrightarrow{\text{heat or light}} CH_2Cl_2 + HCl$$

Dichloromethane

$$CH_2Cl_2 + Cl_2 \xrightarrow{\text{heat or light}} CHCl_3 + HCl$$

Trichloromethane

$$CHCl_3 + Cl_2 \xrightarrow{\text{heat or light}} CCl_4 + HCl$$

Tetrachloromethane

Alkene: an unsaturated hydrocarbon that contains one or more carbon-carbon double bonds. The molecular formula of this group is C_nH_{2n} (n is

the number of carbon atoms). Alkenes have less hydrogen atoms than alkanes.

C_2H_4 $CH_2=CH_2$ C_3H_6 $CH_2=CH\text{-}CH_3$

Alkynes: an unsaturated hydrocarbon that contains one or more carbon-carbon triple bonds. The molecular formula of this group is C_nH_{2n-2} (n is the number of carbon atoms). Alkynes have less hydrogen atoms than alkanes and alkenes.

C_2H_2 $CH \equiv CH$ C_3H_4 $CH \equiv C\text{-}CH_3$

Naming unbranched alkenes and alkynes: we use the IUPAC system of naming for alkanes. For alkenes, we replace the suffix "-ane" of alkanes by "**-ene**". For alkynes, we replace the suffix "-ane" of alkanes by "**-yne**".

Alkane	Alkene	Alkyne
$H_3C—CH_3$	$H_2C=CH_2$	$HC\equiv CH$
Ethane	Ethene (ethylene)	Ethyne (acetylene)
$CH_3—CH_2—CH_3$	$CH_3—CH=CH_2$	$CH_3—C\equiv CH$
Propane	Propene (propylene)	Propyne

Naming branched alkenes and alkynes:

1. Name the longest carbon chain that contains the double or triple bond.
2. Number the carbon chain starting from the end nearest the double or triple bond.
3. Give the location and name of each substituent (alphabetical order) as a prefix to the alkene or alkyne name.

$CH_3\text{-}CH=CH\text{-}CH_3$ 2-butene

$C\equiv C\text{-}CH_2\text{-}CH_3$ 1-butyne

$CH_3\text{-}CH_2\text{-}C(CH_2\text{-}CH_3)=CH\text{-}CH_3$ 3-ethyl-2-pentene

PROBLEM 16◆

Give the systematic name for each of the following compounds:

a. $BrCH_2CH_2C{\equiv}CCH_3$

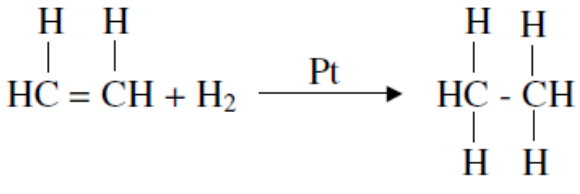
b. $CH_3CH_2\underset{\displaystyle Br}{\underset{|}{C}}H{-}C{\equiv}C{-}CH_2\underset{\displaystyle Cl}{\underset{|}{C}}HCH_3$

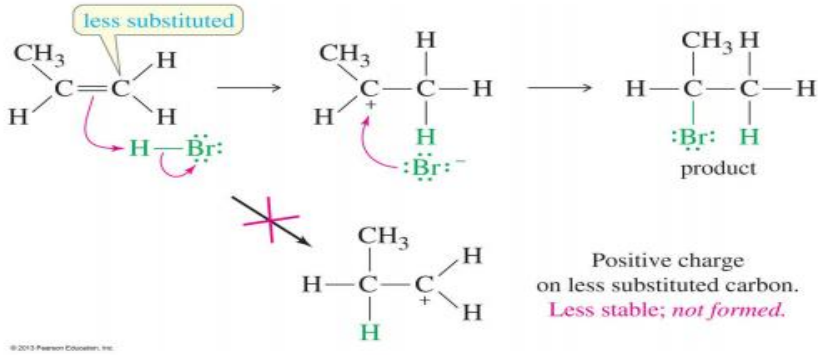
c. $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}HC{\equiv}CCH_2CH_3$

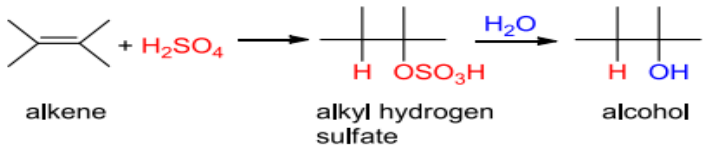
d. $CH_3CH_2\underset{\displaystyle CH_2CH_2CH_3}{\underset{|}{C}}HC{\equiv}CH$

Physical properties of alkenes and alkynes: their physical properties are similar to those of alkanes with the same carbon skeletons.

Chemical properties of alkenes and alkynes: these organic compounds are more reactive than alkanes. The most characteristic reaction of alkenes (alkynes) is **addition** to the carbon carbon double bond (triple bond): The double bond is broken and in its place single bonds form to two new atoms or groups of atoms. We can name four important chemical reactions for them: 1. Addition of hydrogen (**Hydrogenation or Reduction**). 2. Addition of hydrogen halides (**Hydrohalogenation**). 3. Addition of water (**Hydration**). 4. Addition of bromine and chlorine (**Halogenation**). **Hydrogenation or Reduction (addition of hydrogen):** A catalyst as platinum (Pt), nickel (Ni), or palladium (Pd) is added to speed up the reaction.



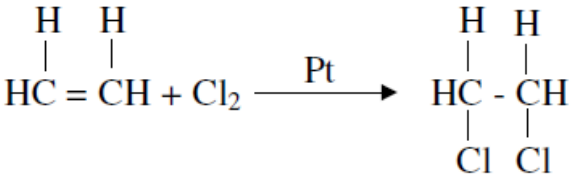




a. Give the major product of each of the following reactions:

1. $CH_3C(CH_3){=}CH_2 + HCl \longrightarrow$
2. $CH_3C(CH_3){=}CH_2 + HBr \longrightarrow$
3. $CH_3C(CH_3){=}CH_2 + H_2O \xrightarrow{HCl}$
4. $CH_3C(CH_3){=}CH_2 + CH_3OH \xrightarrow{HCl}$

Halogenation (addition of chlorine and bromine): chlorine and bromine react with alkenes (alkynes) at room temperature by addition of halogen atoms to the carbon atoms of the double bond (triple bond). We do not need any catalysts for this reaction (in general, we use an inert solvent, such as dichloromethane, CH_2CH_2).



Addition of a Hydrogen Halide to an Alkyne

PROBLEM 18◆

Give the major product of each of the following reactions:

a. $HC{\equiv}CCH_3 \xrightarrow{HBr}$

b. $HC{\equiv}CCH_3 \xrightarrow{excess\ HBr}$

c. $CH_3C{\equiv}CCH_3 \xrightarrow{excess\ HBr}$

d. $CH_3C{\equiv}CCH_2CH_3 \xrightarrow{excess\ HBr}$

Addition of Hydrogen to Alkynes