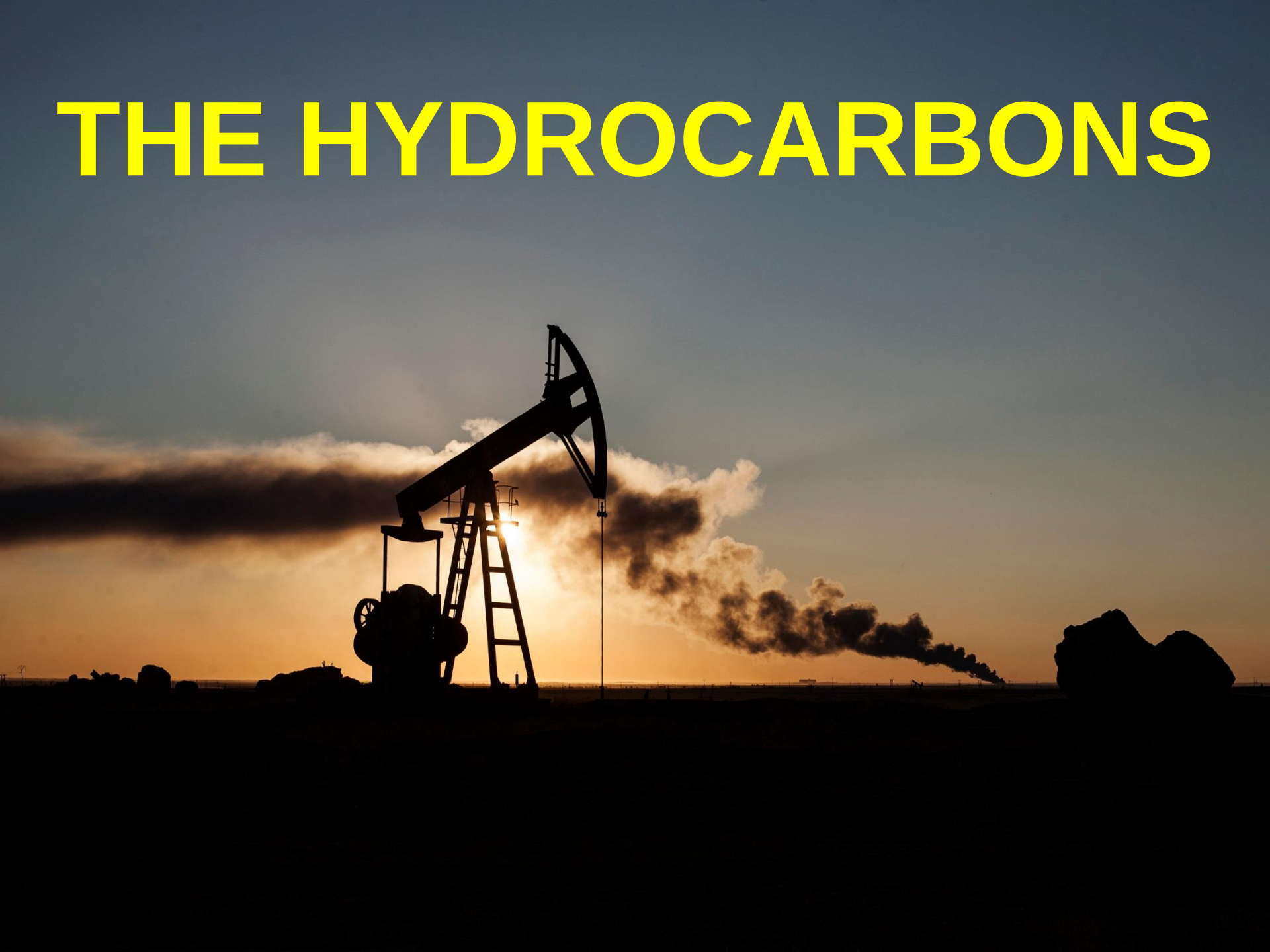
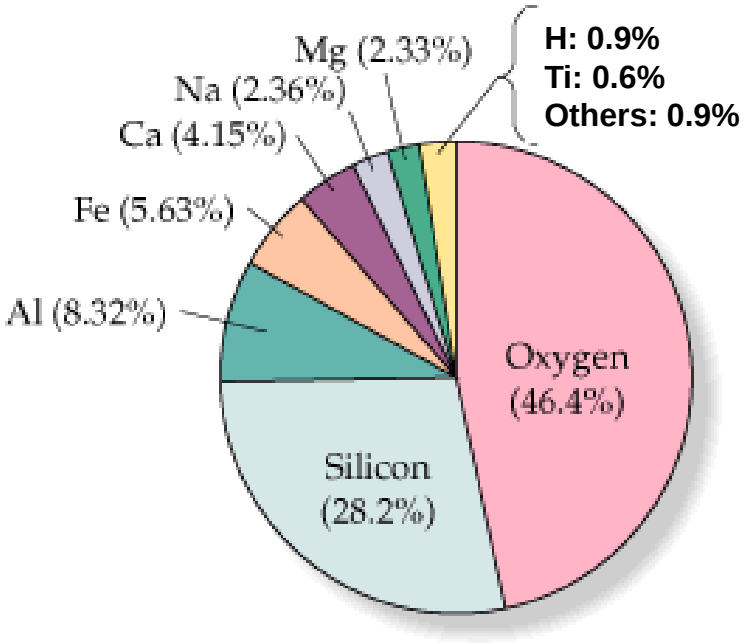
THE HYDROCARBONS



Organic Compounds

Organic Compounds

Chemistry of Carbon (H, O, N, S, Halogens, and P).



C one of the 116 elements

Organic Compounds

Obtained by:

- Isolation from nature (animal and plant)
  (extract-isolate-purify)
- Synthesis in lab

Organic compounds: 10 million

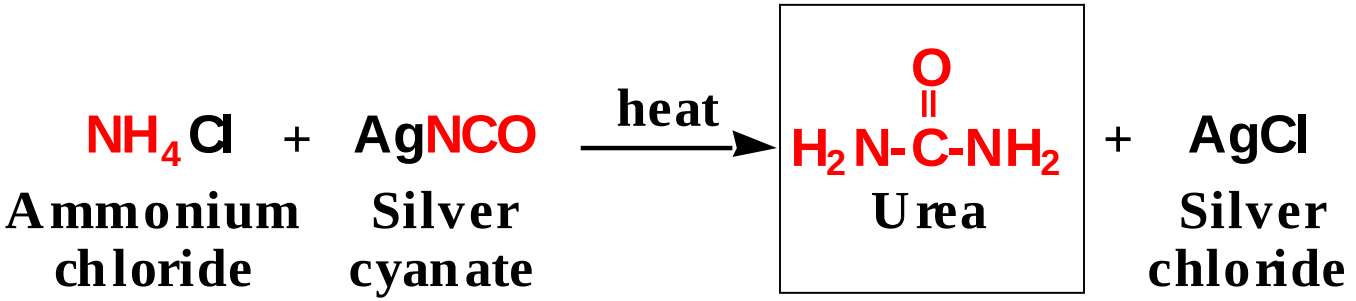
Inorganic compound: 1.7 million

Compounds in living systems are organic: Biochemistry

Organic Compounds

First organic compound that is synthesized in lab.

Friedrich Wöhler (1828)



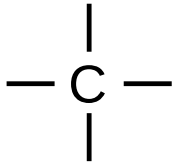
Organic Compounds

Typical organic compounds:

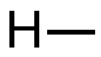
- Contain carbon
- Have covalent bonds
- Have low melting points
- Have low boiling points
- Are flammable (all burn)
- Are soluble in nonpolar solvents
- May be gases, liquids or solids

C_3H_8
Propane

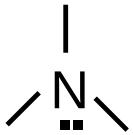
- Carbon: normally forms four covalent bonds and has no unshared pairs of electrons.



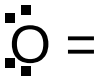
- Hydrogen: forms one covalent bond and no unshared pairs of electrons.



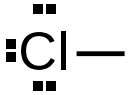
- Nitrogen: normally forms three covalent bonds and has one unshared pair of electrons.



- Oxygen: normally forms two covalent bonds and has two unshared pairs of electrons.



- Halogen: normally forms one covalent bond and has three unshared pairs of electrons.



Functional groups

An atom or group of atoms within a molecule that shows a characteristic set of predictable physical and chemical properties.

- A way to classify organic compounds into families.
- They determine the chemical and physical properties of a compound.
- They undergo the same types of chemical reactions.
- A way to name organic compounds.

Hydrocarbons

Large family of organic compounds

Composed of only carbon and hydrogen

Saturated hydrocarbons

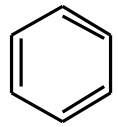
Alkanes

C - C

Unsaturated hydrocarbons

Alkenes, Alkynes & Aromatics

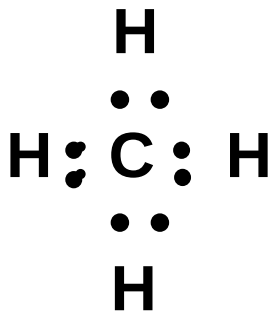
C = C C ≡ C

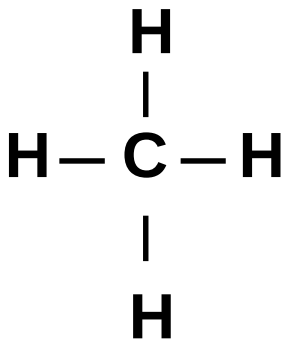


Carbon

- Carbon has four valence electrons; hydrogen has one.

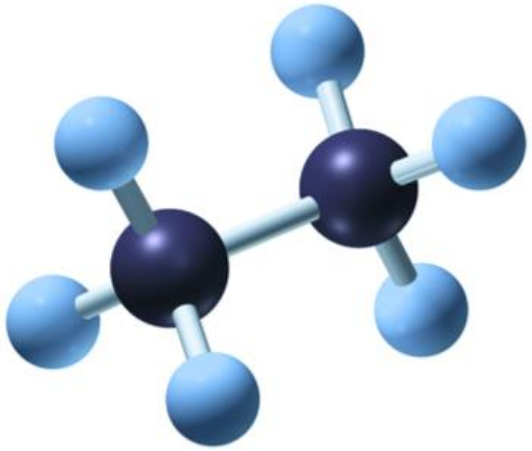
- To obtain an octet, carbon forms four bonds.





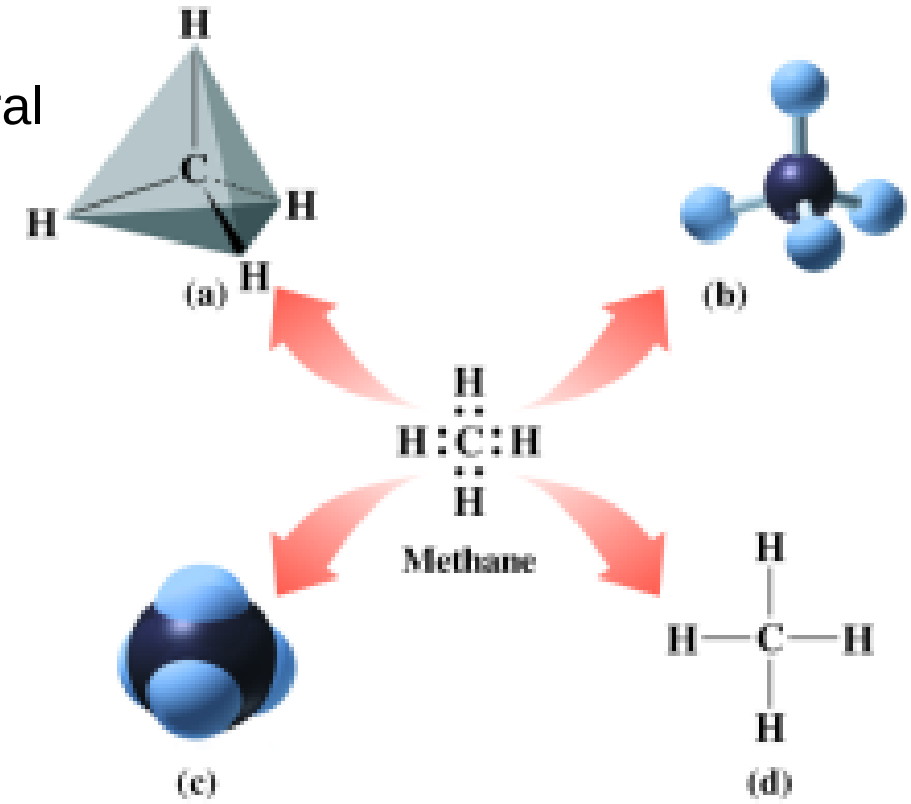
CH_4 , methane

Alkanes



Methane

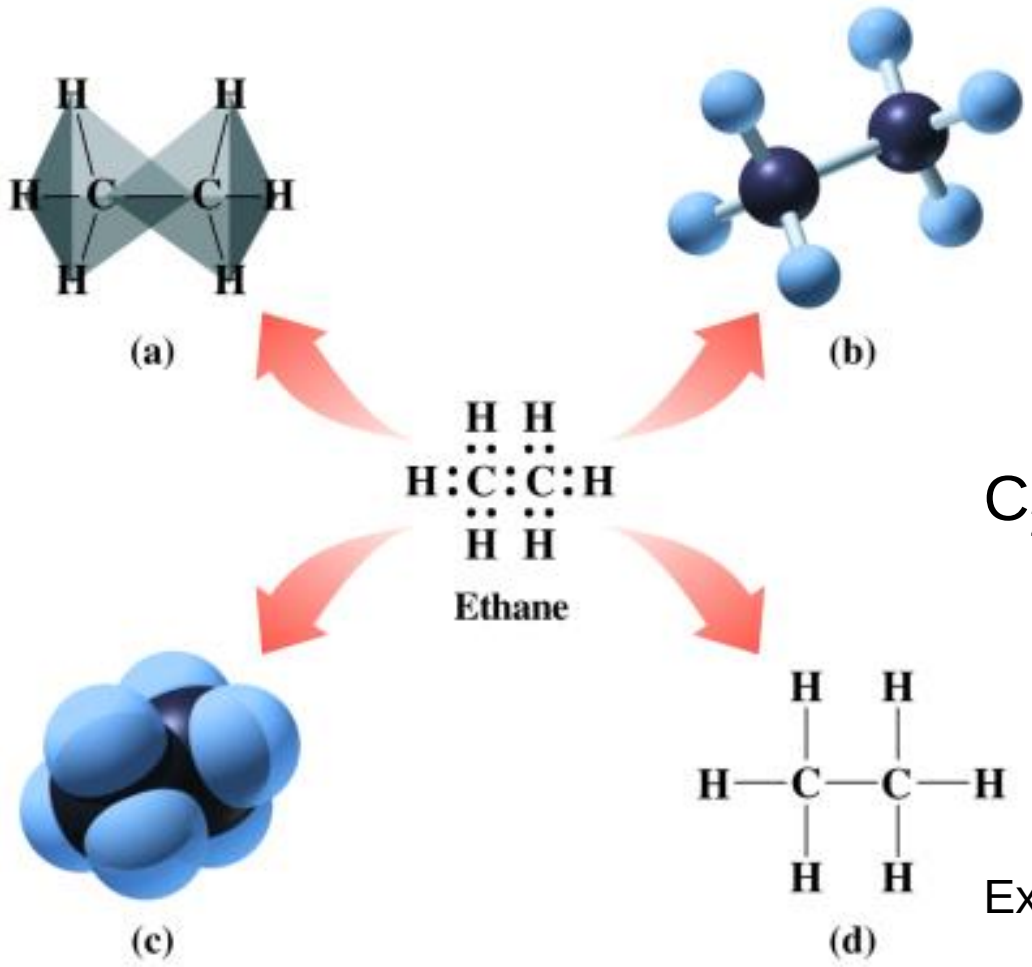
Tetrahedral



Expanded structural formula:
showing each bond line.

Molecular formula CH_4

Ethane



C_2H_6 Molecular formula

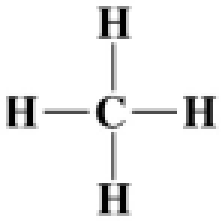
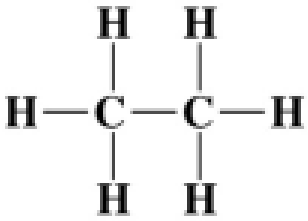
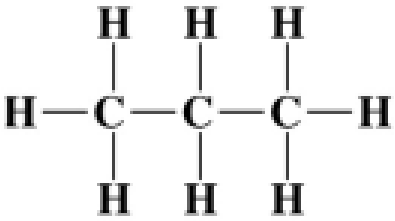
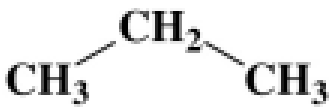
Expanded structural formula

$CH_3 – CH_3$

Condensed structural formula: with each carbon atom and its attached hydrogen atoms.

Alkanes

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 

C_nH_{2n+2}

n: number of carbon atoms

Naming of Alkanes

Table 16.2 IUPAC Names for the First Ten Continuous-Chain Alkanes

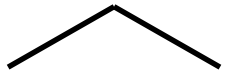
Number of Carbon Atoms	Prefix	Name	Molecular Formula	Condensed Structural Formula
1	Meth	Methane	CH_4	CH_4
2	Eth	Ethane	C_2H_6	$CH_3—CH_3$
3	Prop	Propane	C_3H_8	$CH_3—CH_2—CH_3$
4	But	Butane	C_4H_{10}	$CH_3—CH_2—CH_2—CH_3$
5	Pent	Pentane	C_5H_{12}	$CH_3—CH_2—CH_2—CH_2—CH_3$
6	Hex	Hexane	C_6H_{14}	$CH_3—CH_2—CH_2—CH_2—CH_2—CH_3$
7	Hept	Heptane	C_7H_{16}	$CH_3—CH_2—CH_2—CH_2—CH_2—CH_2—CH_3$
8	Oct	Octane	C_8H_{18}	$CH_3—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_3$
9	Non	Nonane	C_9H_{20}	$CH_3—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_3$
10	Dec	Decane	$C_{10}H_{22}$	$CH_3—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_3$

Prefix + ane

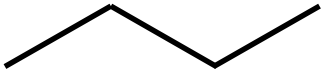
C_nH_{2n+2}

Line-angle Formula

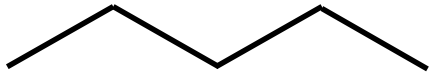
Propane $CH_3\text{-}CH_2\text{-}CH_3$



Butane $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$



Pentane $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$



Naming Substituents

In the IUPAC system:

- Removing a H from an alkane is called **alkyl group.**

  -ane ⟶ **-yl**

- Halogen atoms are named as **halo**.

  -ine ⟶ **-O**

Table 16.5 Names and Formulas of Some Common Substituents

Substituent	Name
$CH_3—$	methyl
$CH_3—CH_2—$	ethyl
$CH_3—CH_2—CH_2—$	propyl
F—, Cl—, Br—, I—	fluoro, chloro, bromo, iodo

-OH	Hydroxyl
$-NO_2$	Nitro

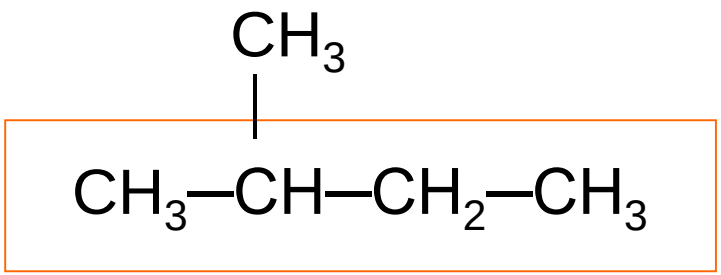
Guide to Naming Alkanes

STEP 1
Write the alkane name of the longest continuous chain of carbon atoms.

STEP 2
Number the carbon atoms starting from the end nearest a substituent.

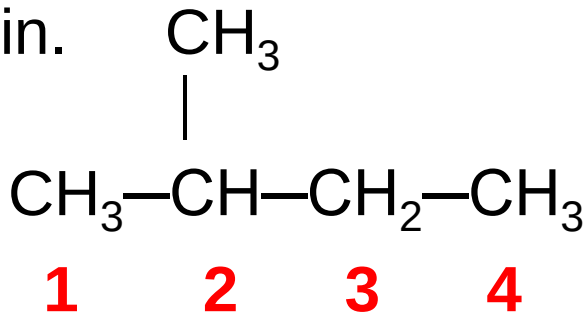
STEP 3
Give the location and name of each substituent (alphabetical order) as a prefix to the name of the main chain.

Give the name of:



STEP 1 Longest chain is butane.

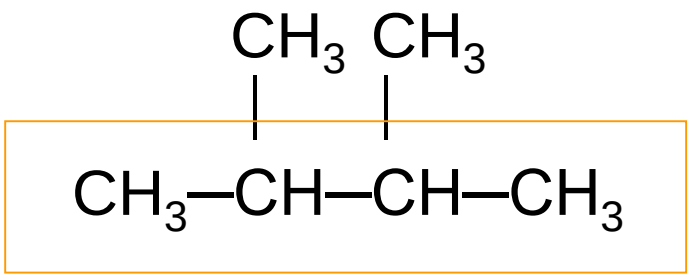
STEP 2 Number chain.



STEP 3 Locate substituents and name.

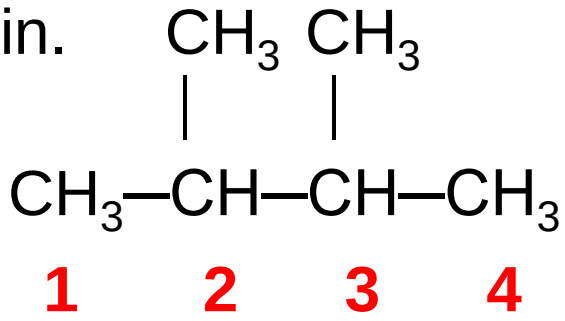
2-Methylbutane

Give the name of:



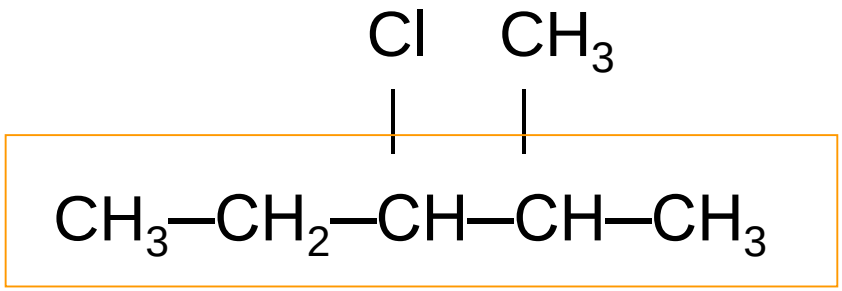
STEP 1 Longest chain is butane.

STEP 2 Number chain.



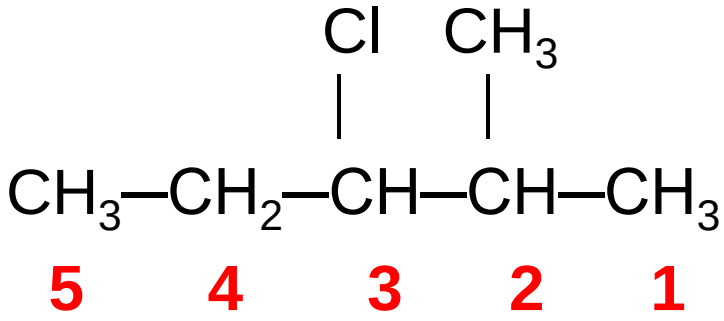
STEP 3 Locate substituents and name.

2,3-dimethylbutane



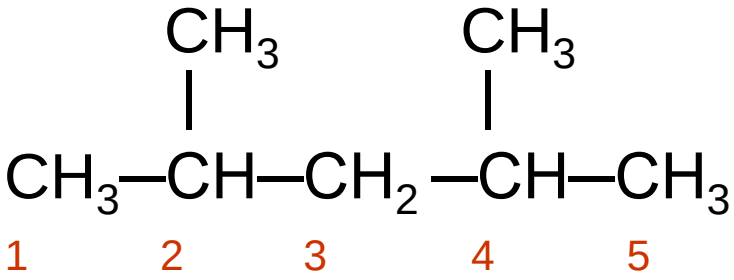
STEP 1 Longest chain is pentane.

STEP 2 Number chain from end nearest substituent.

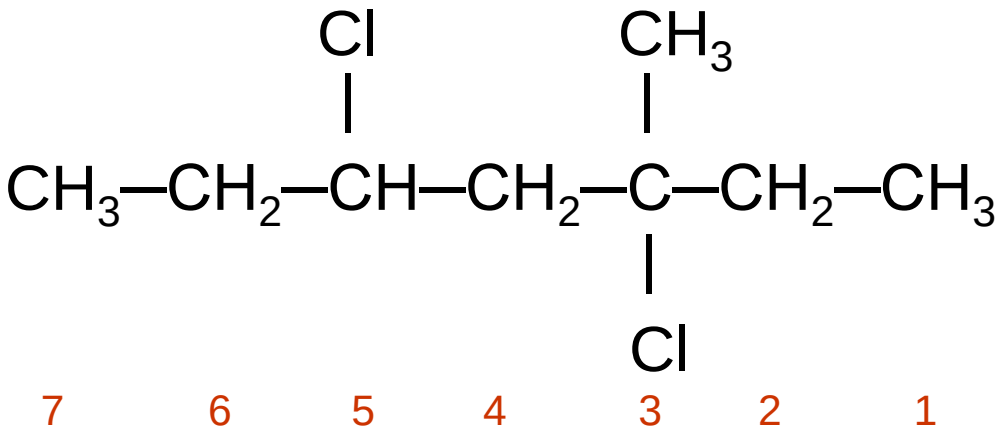


STEP 3 Locate substituents and name alphabetically.

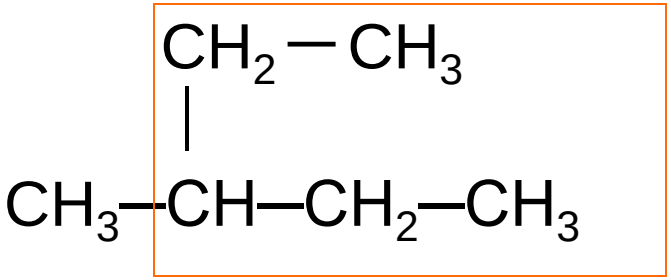
3-Chloro-2-methylpentane



2,4-dimethylpentane

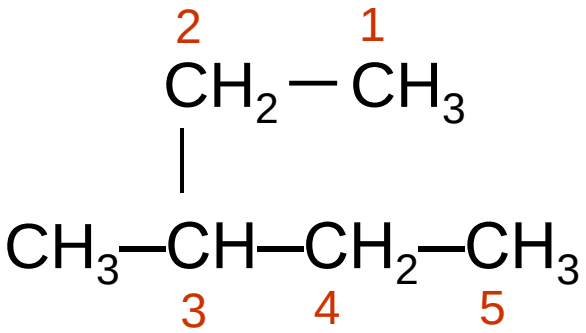


3,5-dichloro-3-methylheptane



STEP 1 Longest chain has 5 carbon atoms (Pentane).

STEP 2 Number chain from end nearest substituent.



STEP 3 Locate substituent and name.

3-Methylpentane

Constitutional (Structural) Isomers

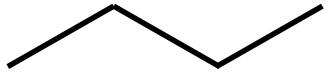
- Have the same molecular formula.

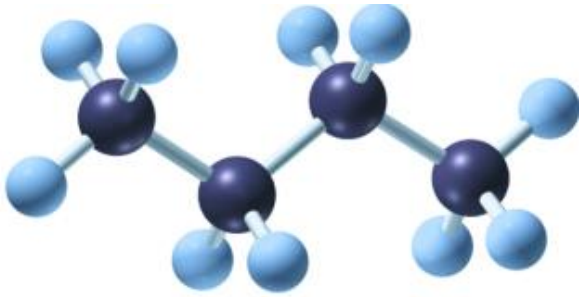
- Have different atom arrangements (different structural formula).

Butane

C_4H_{10}

$CH_3CH_2CH_2CH_3$

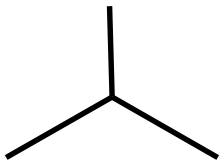


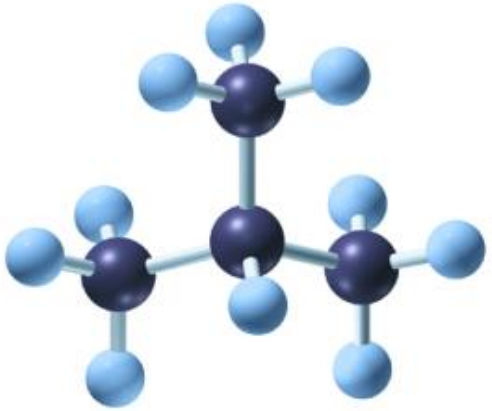


2-Methylpropane

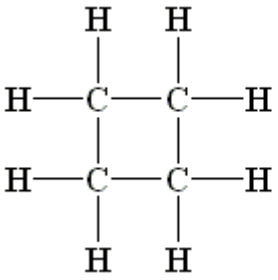
C_4H_{10}

CH_3CHCH_3 (with CH_3 above the central CH)





Cyclic Hydrocarbon - Cycloalkane



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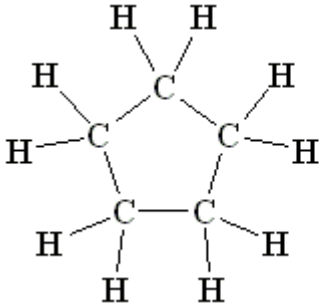
Cyclobutane



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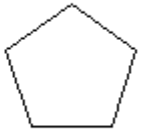
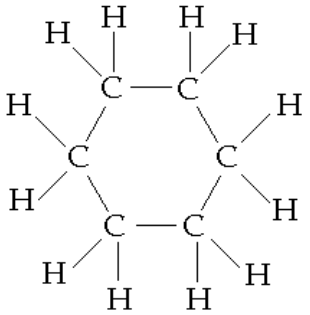


Cyclopentane



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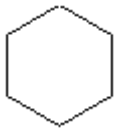


Cyclohexane

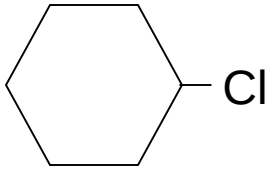
Naming of Cycloalkanes

Prefix “cyclo-” + the name of the open-chain alkane

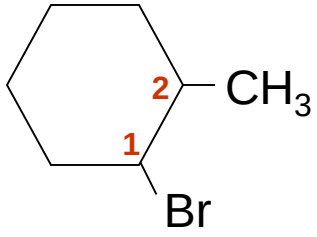
Substituents:

- One substituent: no location number

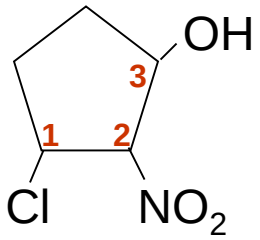
- Two or more substituents: number the ring beginning with the substituent of lower alphabetical order.



Chlorocyclohexane



1-Bromo-2-methylcyclohexane



1-Chloro-3-hydroxyl-2-nitrocyclopentane

Physical Properties of Alkanes

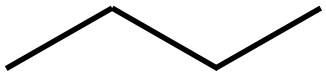
- Nonpolar
- Insoluble in water.
- Lower density than water.
- Low boiling and melting points.
- Gases with 1-4 carbon atoms.
  (methane, propane, butane)
- Liquids with 5-17 carbon atoms.
  (kerosene, diesel, and jet fuels)
- Solids with 18 or more carbon atoms.
  (wax, paraffin, Vaseline)

Boiling & melting points of Alkanes

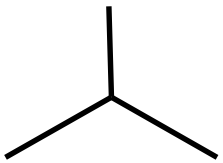
Number of carbon atoms ↑ ⇨ bp & mp ↑

Number of branches ↑ ⇨ bp & mp ↓

$CH_3CH_2CH_2CH_3$

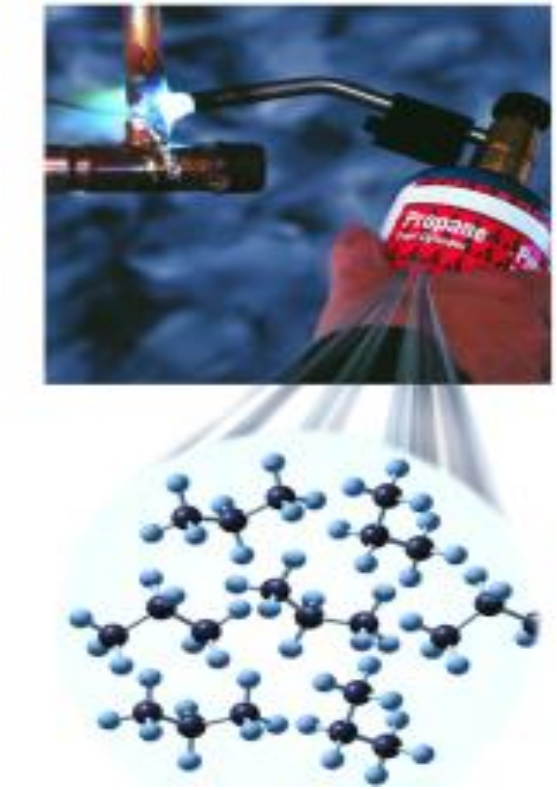


$$\begin{array}{c} CH_3 \\ | \\ CH_3CHCH_3 \end{array}$$



Chemical reactions of Alkanes

Low reactivity



1- Combustion:

- Alkanes react with oxygen.
- CO_2, H_2O, and energy are produced.
- Alkane + O_2 $\longrightarrow$ CO_2 + H_2O + heat

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ + energy

Chemical reactions of Alkanes

Low reactivity

2- Halogenation:

Alkanes react with Halogens. Substitution Reaction

$CH_4 + Cl_2 \xrightarrow[\text{Heat or light}]{} CH_3Cl + HCl$ Chloromethane

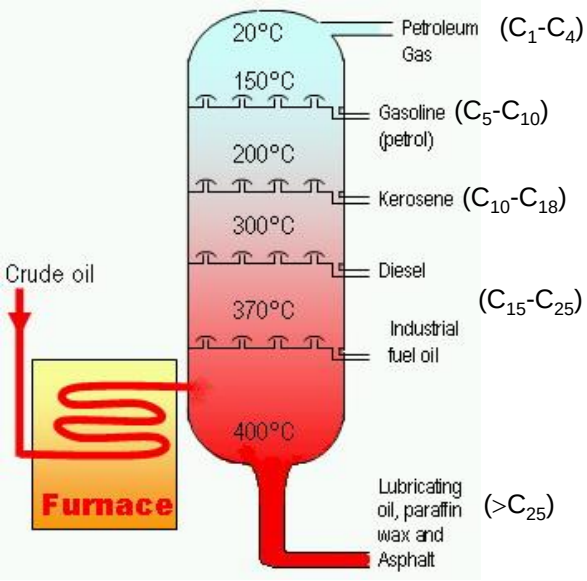
$CH_3Cl + Cl_2 \xrightarrow[\text{Heat or light}]{} CH_2Cl_2 + HCl$ Dichloromethane

$CH_2Cl_2 + Cl_2 \xrightarrow[\text{Heat or light}]{} CHCl_3 + HCl$ Trichloromethane

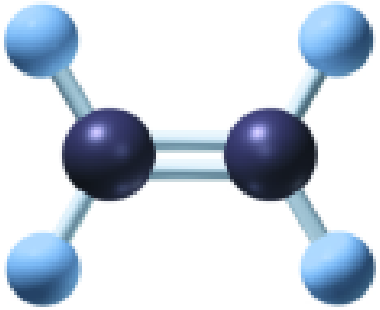
$CHCl_3 + Cl_2 \xrightarrow[\text{Heat or light}]{} CCl_4 + HCl$ Tetrachloromethane

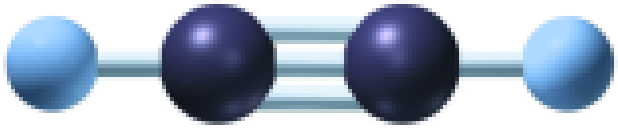
Sources of Alkanes

- Natural gas
  - 90 to 95 percent methane.
  - 5 to 10 percent ethane, and
  - a mixture of other low-boiling alkanes, chiefly propane, butane, and 2-methylpropane.
- Petroleum
  - A thick liquid mixture of thousands of compounds, most of them hydrocarbons, formed from the decomposition of marine plants and animals.



Alkenes and Alkyens





Alkenes and Alkynes

Saturated compounds (alkanes):
Have the maximum number of hydrogen atoms attached to each carbon atom.

Unsaturated compounds:
Have fewer hydrogen atoms attached to the carbon chain than alkanes.

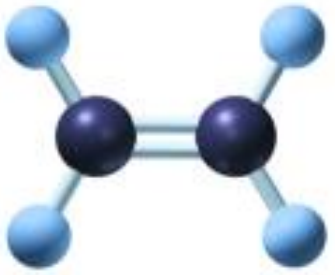
- Containing double bond are alkenes.

C_nH_{2n}

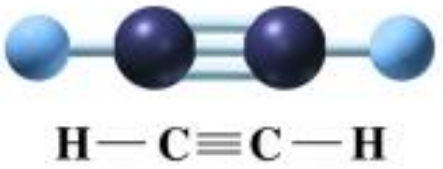
- Containing triple bonds are alkynes.

C_nH_{2n-2}

Ethene



Ethyne



Naming Alkenes & Alkynes

Using the IUPAC alkane names:

Alkene names change the end to -ene.

Alkyne names change the end to -yne

Comparison of Names for Alkanes, Alkenes, and Alkynes

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

Guide to Naming Alkenes and Alkynes

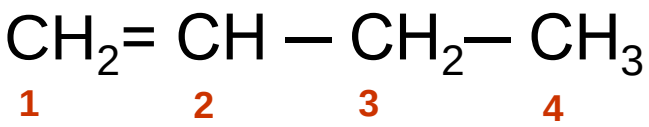
STEP 1
Name of the longest carbon chain with a double or triple bond.

STEP 2
Number the carbon atoms starting from the end nearest a double or triple bond.

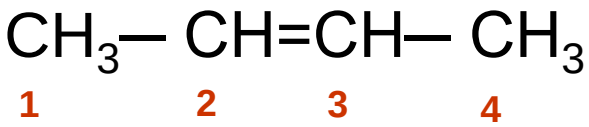
→ Give the location for double and triple bond

STEP 3
Give the location and name of each substituent (alphabetical order) as a prefix to the name of the main chain.

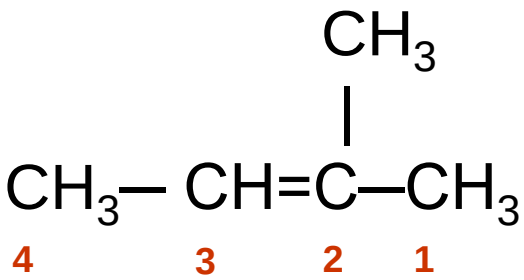
Naming Alkenes & Alkynes



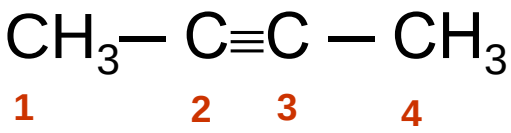
1-Butene



2-Butene

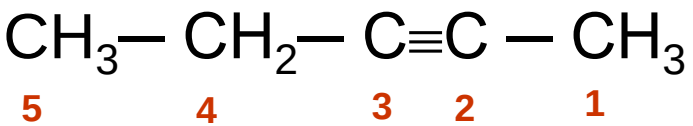


2-Methyl-2-butene

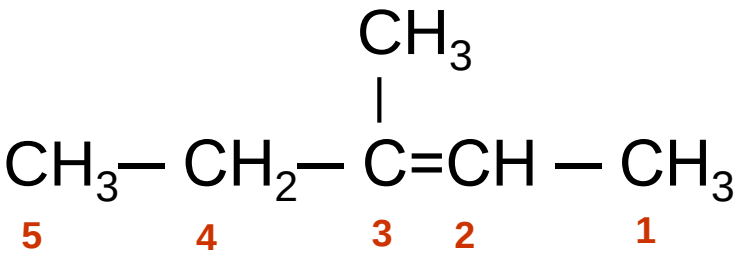


2-Butyne

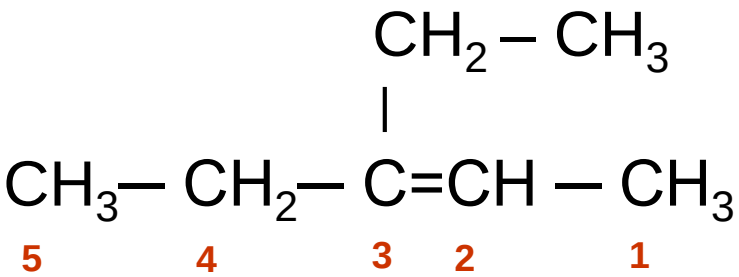
Naming Alkenes & Alkynes



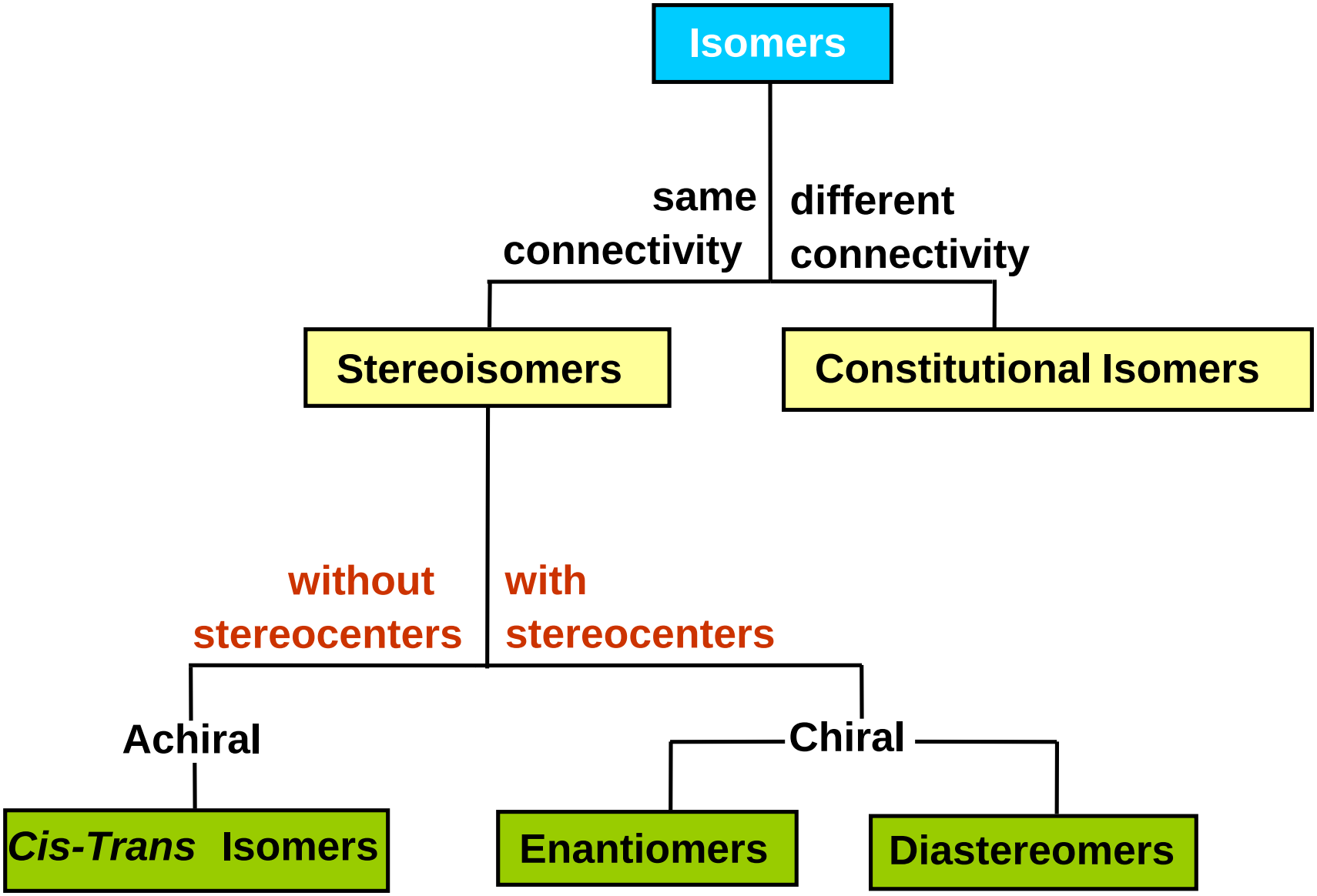
2-Pentyne



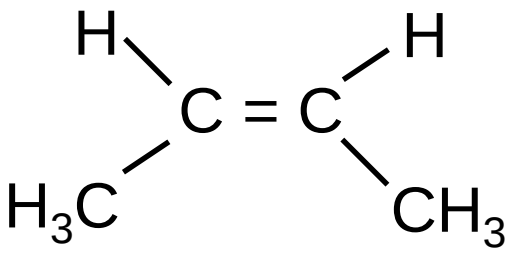
3-Methyl-2-pentene



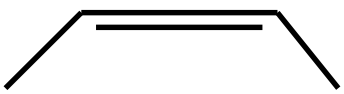
3-Ethyl-2-pentene


Isomers
same connectivity
different connectivity
Stereoisomers
Constitutional Isomers
without stereocenters
with stereocenters
Achiral
Chiral
Cis-Trans Isomers
Enantiomers
Diastereomers

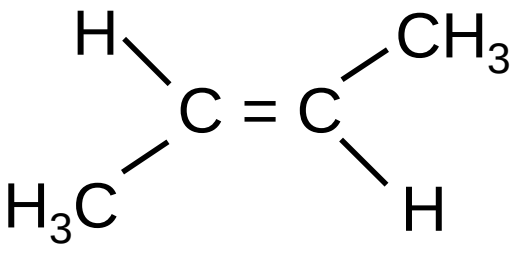
Cis & Trans Stereoisomers (Geometrical)



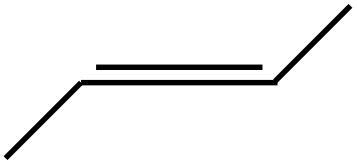
C_4H_8



cis-2-Butene



C_4H_8

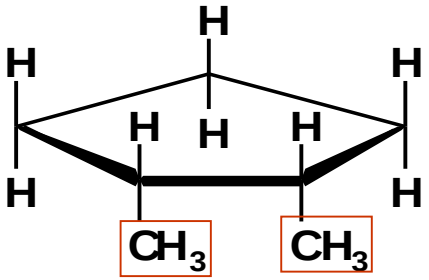


trans-2-Butene

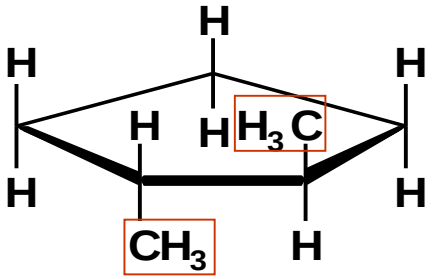
The same molecular formula and the same connectivity of their atoms but a different arrangement of their atoms in space.

mp & bp of cis < mp & bp of trans

Cis & Trans Stereoisomers (Geometrical)

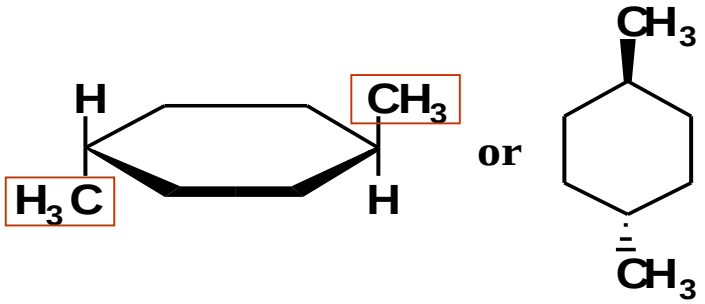


cis-1,2-Dimethyl-cyclopentane

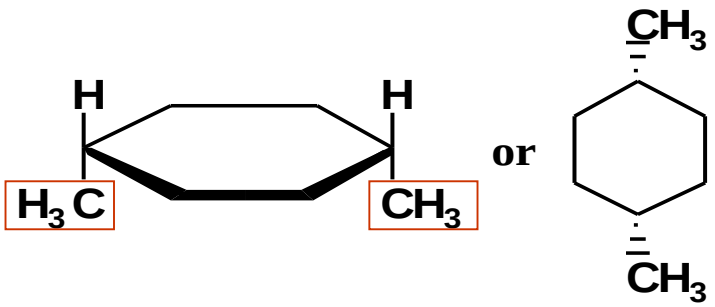


trans-1,2-Dimethyl-cyclopentane

Stereoisomers (Geometrical): Isomers that have the same molecular formulas and the same connectivity of their atoms but a different orientation of their atoms in space.



trans-1,4-Dimethylcyclohexane



cis-1,4-Dimethylcyclohexane

Chemical properties of Alkenes & Alkynes

More reactive than Alkanes

Addition of Hydrogen (Hydrogenation-Reduction)

Addition of Hydrogen Halides (Hydrohalogenation)

Addition of water (hydration)

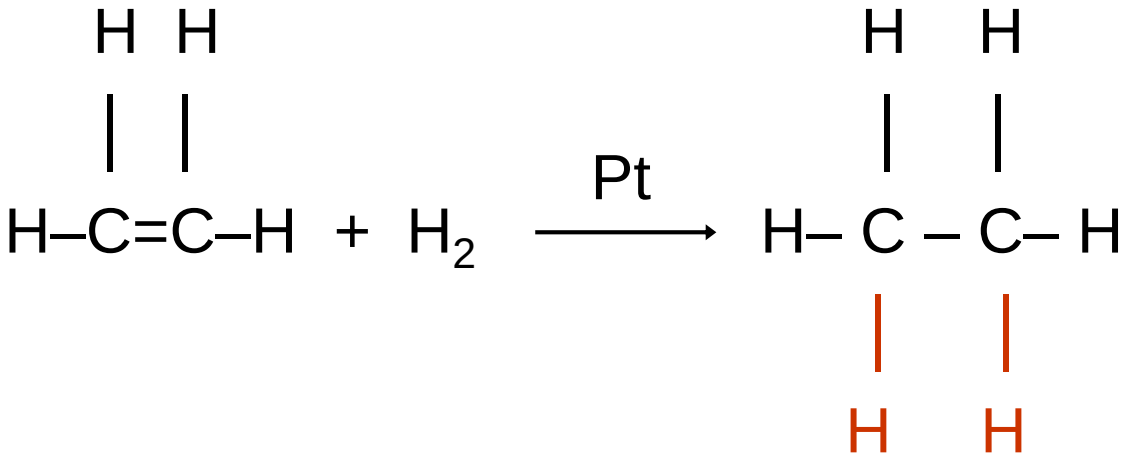
Addition of Bromine & Chlorine (Halogenation)

Chemical properties

More reactive than Alkanes

1. Hydrogenation (Reduction):

- A hydrogen atom adds to each carbon atom of a double bond.
- A catalyst such as platinum or palladium is used (Transition metals).

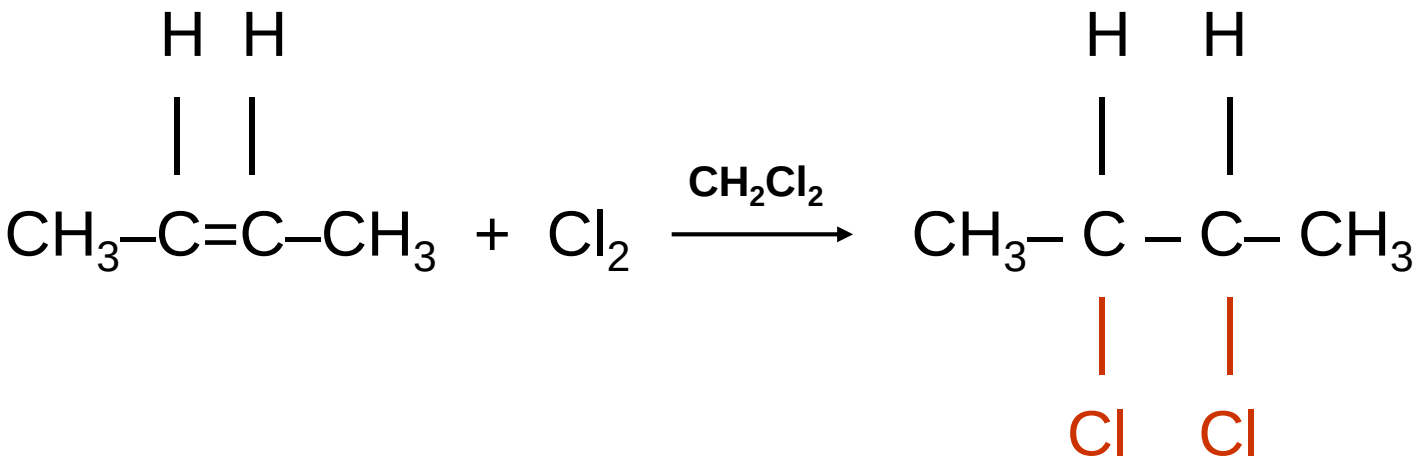


Chemical properties

More reactives than Alkanes

4. Halogenation:

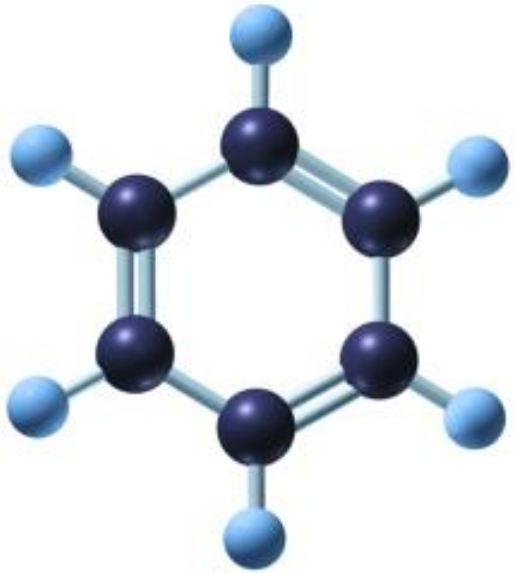
- A halogen atom adds to each carbon atom of a double bond.
- Usually by using an inert solvent like CH_2Cl_2.



2-Butene

2,3-dichlorobutane

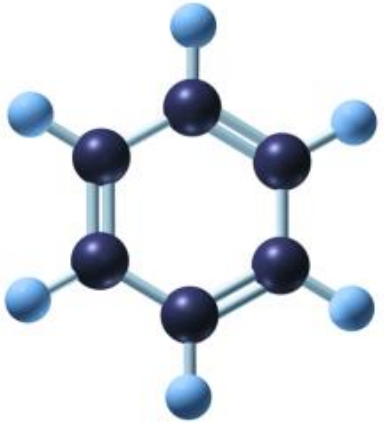
Aromatic Hydrocarbons



Benzene

Aromatic Compounds

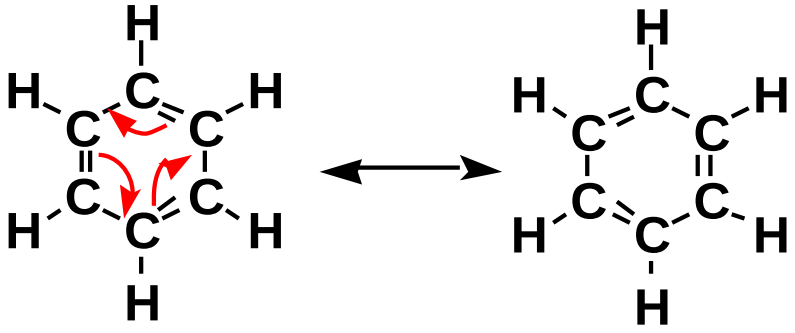
Aromatic compounds contain benzene ring.



Benzene

Benzene has:

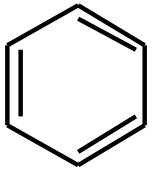
- 6 C atoms and 6 H atoms.
- Two possible ring structures.

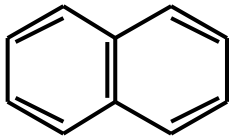


Resonance hybrid

Aromatic Compounds

Arene: A compound containing one or more benzene rings.

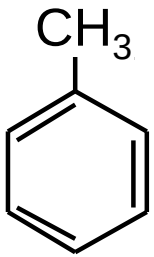




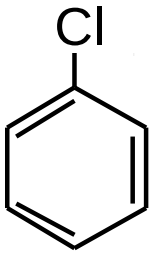
Naphthalene

Aromatic compounds are named:

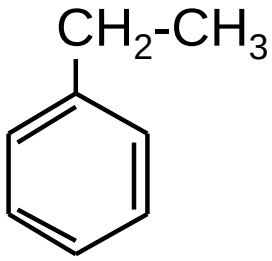
- With benzene as the parent chain.
- Name of substituent comes in front of the “benzene”.



methylbenzene



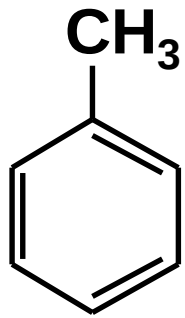
chlorobenzene



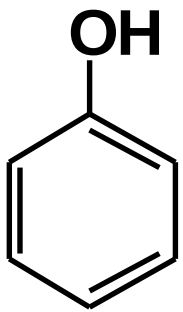
ethylbenzene

Naming of Aromatic Compounds

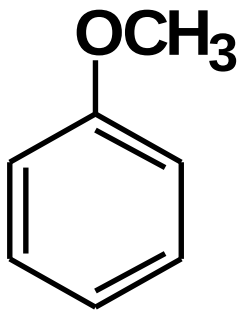
Some substituted benzenes have common names.



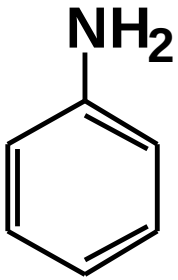
Toluene



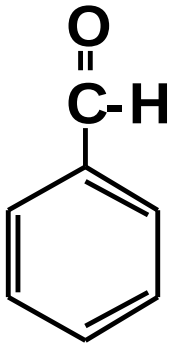
Phenol



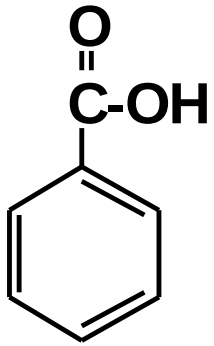
Anisole



Aniline



Benzaldehyde

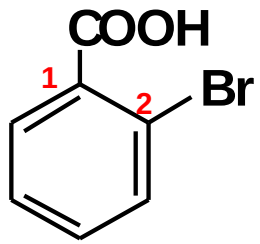


Benzoic acid

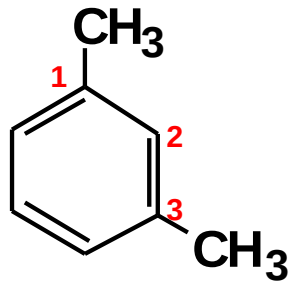
Naming of Aromatic Compounds

When two groups are attached to benzene, the ring is numbered to give the lower numbers to the substituents.

- Start numbering from a special name (if we have).
- If we do not have, number them to get the smallest set of numbers.
- List them by alphabetical order.

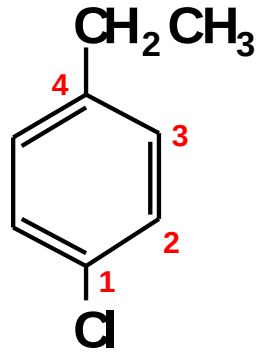


2-Bromobenzoic acid



3-methyltoluene

1,3-Dimethylbenzene

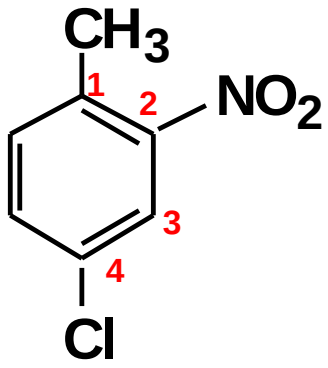


1-Chloro-4-ethylbenzene

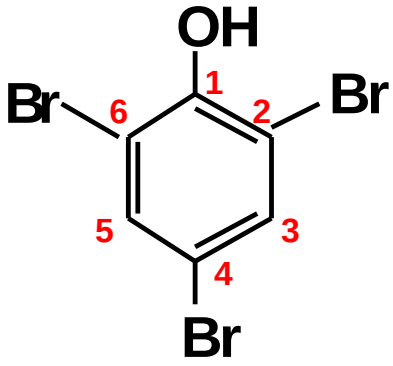
Naming of Aromatic Compounds

If we have three or more substituents:

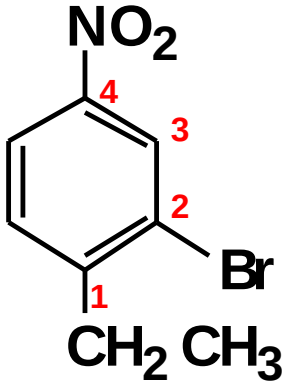
- Start numbering from a special name (if we have).
- If we do not have, number them to get the smallest set of numbers.
- List them by alphabetical order.



4-Chloro-2-nitrotoluene



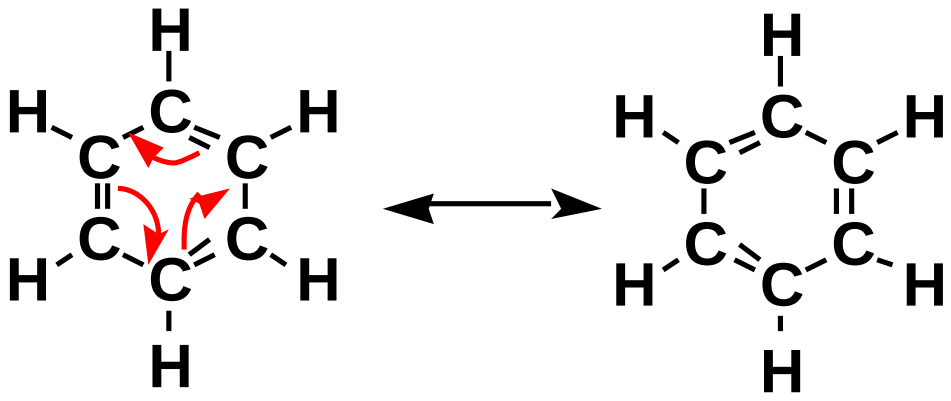
2,4,6-Tribromophenol



2-Bromo-1-ethyl-4-nitrobenzene

Chemical properties of benzene

Resonance: stable



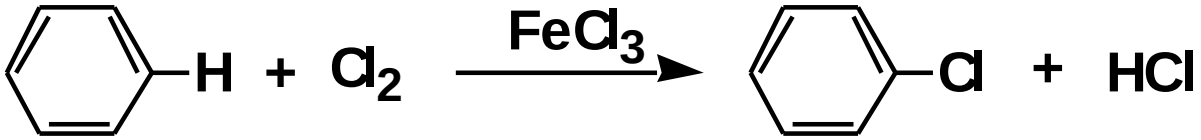
No addition reactions (almost unreactive)

Substitution Reactions

- Halogenation
- Nitration
- Sulfonation

Chemical properties of benzene

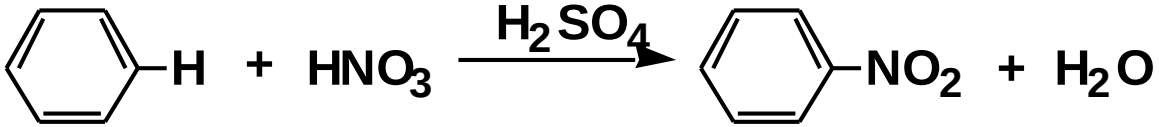
Halogenation



Benzene

Chlorobenzene

Nitration



Nitrobenzene