Chapter 18: Organic Chemistry

Organic chemistry is a branch of chemistry that focuses on compounds that contain carbon

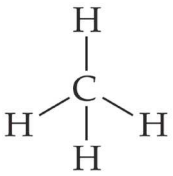
(Exceptions: CO, CO_2, CO_3^{2-}, and CN^-)

- Even though organic compounds only contain a few elements (mainly C, H, O, N, S, and P), the unique ways carbon atoms can attach together to form molecules leads to millions of different organic compounds.
- Life as we know it is because of organic chemistry.

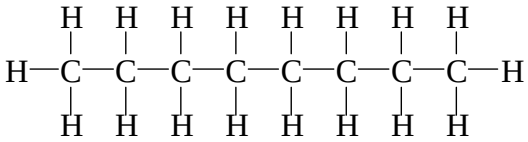
What's So Special About Carbon?

Carbon atoms can do some unique things that other atoms cannot do.

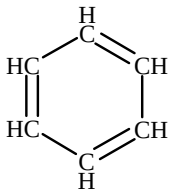
- Carbon can bond to as many as four other atoms.



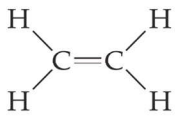
- Bonds to carbon are very strong and nonreactive.
- Carbon atoms can attach together in long chains.



- Carbon atoms can attach together to form rings.



- Carbon atoms can form single, double, or triple bonds.



Hydrocarbons

Hydrocarbons are organic compounds containing only carbon and hydrogen

Two types of hydrocarbons:

1) Saturated - contains only C—C single bonds
2) Unsaturated - contains one or more C=C double bonds, C≡C triple bonds and/or rings

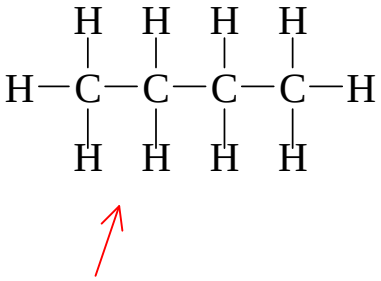
Alkanes

Saturated hydrocarbons with only C—C single bonds

- Can have straight-chain and branched-chain forms with the general formula C_nH_{2n+2}

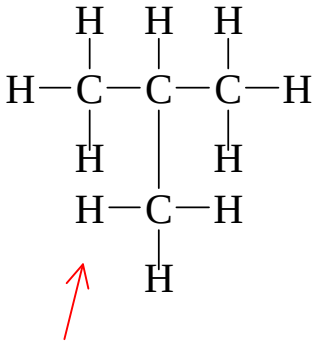
Ex.

Straight-chain alkane



Structural formula of butane
Molecular formula = C_4H_{10}

Branched-chain alkane

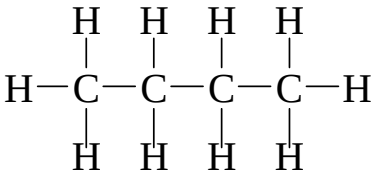


Structural formula of 3-methylpropane
Molecular formula = C_4H_{10}

The two alkanes above are **STRUCTURAL ISOMERS** - they have the same molecular formula but different structural formulas. (Connectivity is different)

Alkanes

Can also write **<u>condensed structural formulas</u>** for alkanes

	Butane	Butane
Ex.	<u>Structural formula</u>	<u>Condensed structural formula</u>
		$CH_3CH_2CH_2CH_3$ or $CH_3(CH_2)_2CH_3$

<u>Series of Straight-Chain Alkanes 1 through 10 Carbons</u>

Molecular <u>Formula</u>	Condensed <u>Formula</u>	**(reminder: C_nH_{2n+2})** <u>Name</u>
CH_4	CH_4	methane
C_2H_6	CH_3CH_3	ethane
C_3H_8	$CH_3CH_2CH_3$	propane
C_4H_{10}	$CH_3(CH_2)_2CH_3$	_____
C_5H_{12}	$CH_3(CH_2)\ CH_3$	_____
C H	$CH_3(CH_2)\ CH_3$	_____
C H	$CH_3(CH_2)\ CH_3$	_____
C H	$CH_3(CH_2)\ CH_3$	_____
C H	$CH_3(CH_2)\ CH_3$	_____
C H	$CH_3(CH_2)\ CH_3$	_____

You NEED TO KNOW the formulas and names of the straight-chain alkanes above

Isomers and Alkane Properties

- As the number of carbon atoms increases, the greater the number of possible isomers

Carbon content	Molecular formula	Possible isomers
4	C_4H_{10}	2
5	C_5H_{12}	3
6	C_6H_{14}	5
7	C_7H_{16}	9
8	C_8H_{18}	18
9	C_9H_{20}	35
10	$C_{10}H_{22}$	75

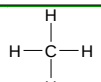
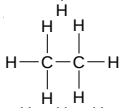
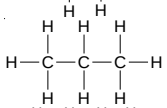
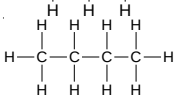
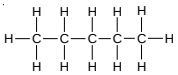
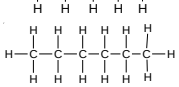
Draw the structural formulas of three structural isomers that have the molecular formula C_5H_{12}.

Hint: Draw the carbon skeletons of the 3 isomers first, then add the bonds to hydrogen.

Alkanes are nonpolar compounds - they are not miscible with water (a polar compound)

Important Reaction of Alkanes: COMBUSTION

As the number of carbon atoms increases in alkanes, the melting point, boiling point, and density increases.

Name	Structural formula	Condensed formula	Boiling point
Methane		CH_4	-162 °C
Ethane		CH_3CH_3	-89 °C
Propane		$CH_3CH_2CH_3$	-42 °C
Butane		$CH_3CH_2CH_2CH_3$	0 °C
Pentane		$CH_3CH_2CH_2CH_2CH_3$	36 °C
Hexane		$CH_3CH_2CH_2CH_2CH_2CH_3$	69 °C

Alkyl Groups

We will soon learn how to name branched-chain alkanes. In order to do so, you need to know the names of the **common alkyl groups**.

- The names of the straight-chain alkyl groups are *derived from the name of the corresponding alkane*.
- Branched alkyl groups that have 4 carbons or less have the names shown below.

TABLE 18.4 Common Alkyl Groups

Condensed Structural Formula	Name
$-CH_3$	methyl
$-CH_2CH_3$	ethyl
$-CH_2CH_2CH_3$	propyl
$-CH_2CH_2CH_2CH_3$	butyl
$-CH(CH_3)_2$	isopropyl
$-CH_2CH(CH_3)_2$	isobutyl
$-CH(CH_3)CH_2CH_3$	*sec*-butyl
$-C(CH_3)_3$	*tert*-butyl

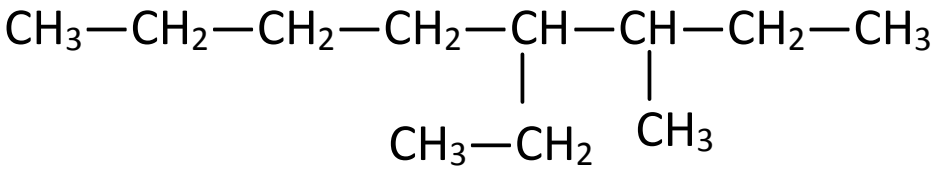
YOU NEED TO KNOW ALL THE ALKYL GROUP NAMES ABOVE

Nomenclature of Branched-Chain Alkanes

We will name branched-chain alkanes using the **IUPAC** Rules

- IUPAC - stands for the **I**nternational **U**nion of **P**ure and **A**pplied **C**hemistry - established rules for systematic nomenclature of chemical compounds

Ex.

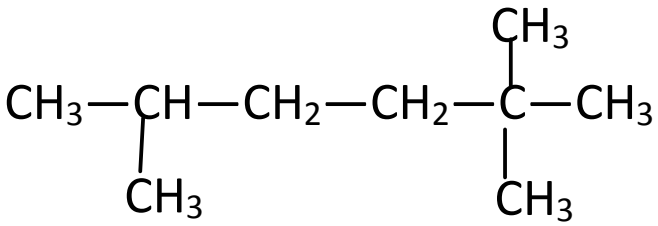


1. Select the longest carbon chain and name it as the normal straight-chain alkane (this is the "parent chain")
2. Number the parent chain starting at the end of the chain nearest the first alkyl substituent.
3. Use the numbers obtained by the application of rule #2 to designate the locations of the alkyl substituent groups. **Name the alkyl groups.**
4. List alkyl groups alphabetically, along with the location number, before the parent chain name (i.e. **e**thyl before **m**ethyl).
5. When two alkyl groups are present on the **same** carbon, use the number twice (or 3 times, if 3 groups).
6. When two or more alkyl groups are identical, use the prefixes di, tri, tetra, etc.. (These prefixes are NOT used when alphabetizing).

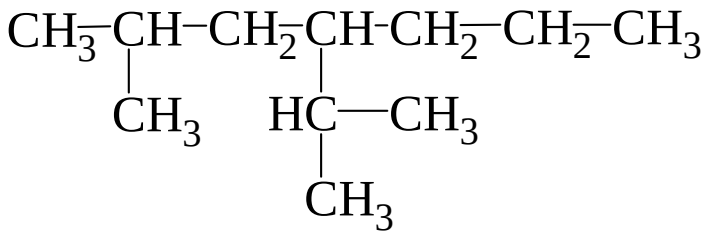
Nomenclature of Branched-Chain Alkanes

Give the IUPAC name of the following branched-chain alkanes:

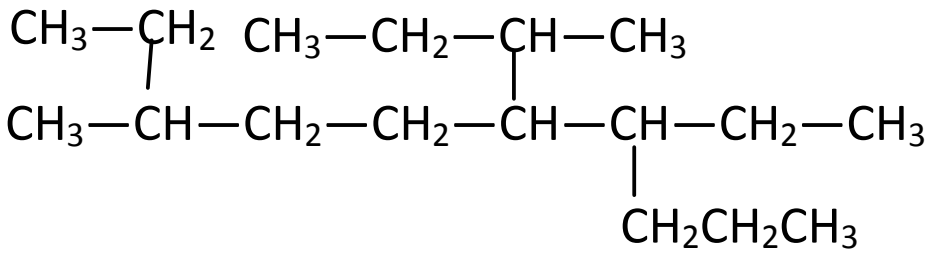
a)



b)



c)

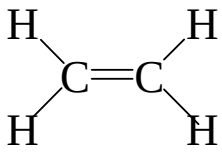


Draw the condensed structural formula for the following alkanes:

3-ethyl-2,3-dimethylhexane 5-*tert*-butyl-3,4,6-trimethylnonane

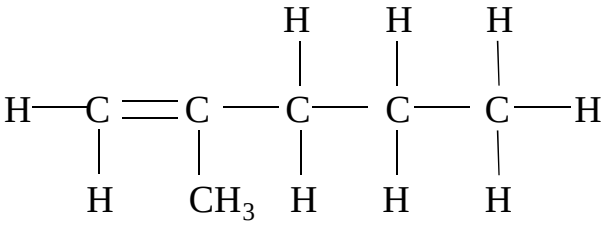
Alkene Nomenclature

Alkenes - hydrocarbons that contain carbon-carbon double bonds



← Simplest alkene: Ethene

Ex.



IUPAC Nomenclature of Alkenes

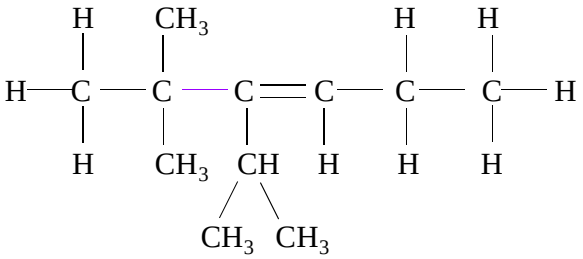
1) Find the longest carbon chain **containing the double bond** - this is the parent chain. Name the parent chain like an alkane, but drop the 'ane' ending and add 'ene'.

2) Number the parent chain <u>starting from the end closer to the double bond</u> and designate the location of the first carbon in the double bond as a number in front of the parent chain.

3) Name alkyl groups that branch off the parent chain just like in alkanes.

Give the IUPAC name of:

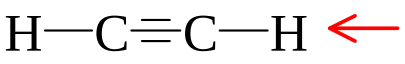
(Note: the alkyl groups should have the lowest numbers possible)



Draw 2-methyl-4-octene

Alkynes

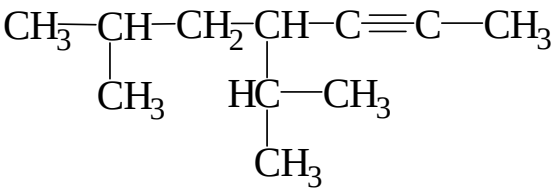
Alkynes - hydrocarbons that contain carbon-carbon triple bonds



← Simplest alkyne: Ethyne

Name alkynes just like alkenes, except the parent chain 'ane' ending changes to 'yne'.

Name the alkyne:

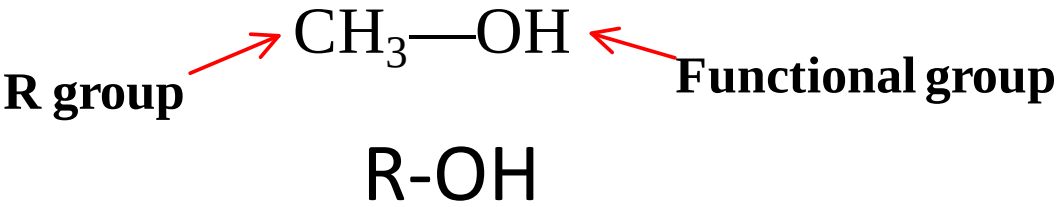


We will not cover Sections **18.9** and **18.10**: Hydrocarbon Reactions and Aromatic Hydrocarbons- **you don't need to know the material in these sections.**

Functional Groups

A functional group is a group of atoms that exhibit a characteristic influence on the properties of the molecule.

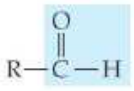
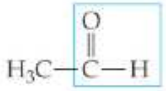
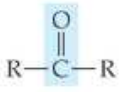
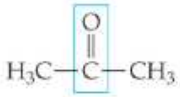
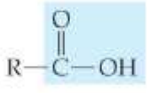
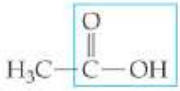
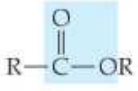
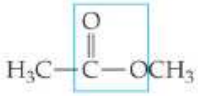
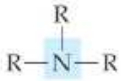
- In general, the reactions that a compound will undergo are *determined by what functional groups it has*.
- Since many times the identity of the hydrocarbon chain is irrelevant to the reactions, it is indicated by the general symbol **R**.



R-OH

Functional Groups

TABLE 18.7 Functional Groups

Family	General Formula	Condensed General Formula	Example	Name
alcohols	R—OH	ROH	CH_3CH_2—OH	ethanol (ethyl alcohol)
ethers	R—O—R	ROR	CH_3—O—CH_3	dimethyl ether
aldehydes		RCHO		ethanal (acetaldehyde)
ketones		RCOR		propanone (acetone)
carboxylic acids		RCOOH		acetic acid
esters		RCOOR		methyl acetate
amines		R_3N		ethyl amine

You need to be able to recognize and know the names of all the functional groups above **except the amines**.

Alcohols

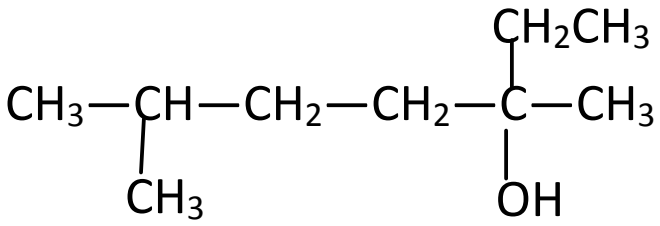
General Formula: R-OH where R = an alkyl group

Common Alcohols:

- Ethanol (Ethyl alcohol) = CH_3CH_2OH
  - Grain alcohol; made from fermentation of sugars
  - In alcoholic beverages and is a gas additive
- 2-Propanol (Isopropyl alcohol) = $(CH_3)_2CHOH$
  - Rubbing alcohol; Poisonous
- Methanol (Methyl alcohol)= CH_3OH
  - Wood alcohol; Poisonous (can cause blindness)

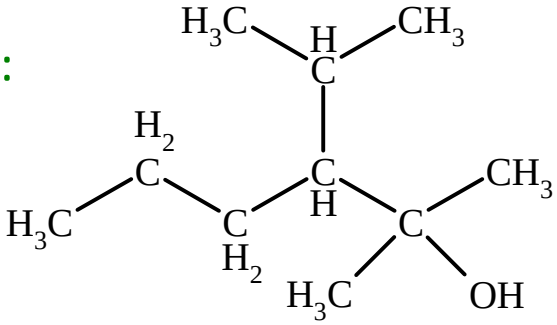
Nomenclature of Alcohols (IUPAC)

Ex.



1. Count the number of carbon atoms on the <u>longest chain to which the OH group is attached</u>. Give this the name of the parent alkane, but drop the 'e' ending and add 'ol'
2. Number the parent chain <u>starting from the end closer to the hydroxy (OH) group</u> and *designate the location of the hydroxy group in **front** of the parent alcohol name.*
3. Name substituents that branch off the alcohol parent chain just like in alkanes.

Name the alcohol:



Write the structure of 4,4-dimethyl-6-isobutyl -3-decanol

Ethers

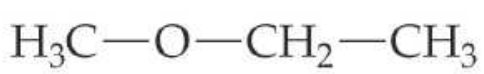
General Formula: R-O-R' where R,R' = alkyl groups

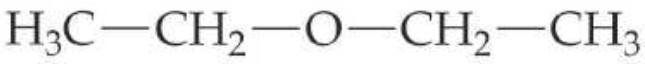
(Note: can also have aromatic rings bonded to ether oxygen)

We will only name simple ethers using the **common** nomenclature:

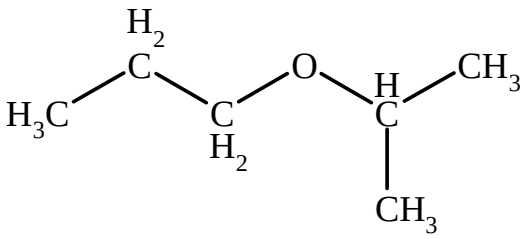
- Name both alkyl groups attached to the oxygen and add the name 'ether' to the end
- Alphabetize alkyl group names. If have two of the same alkyl groups, use the prefix 'di'

Give the common name of the following ethers:

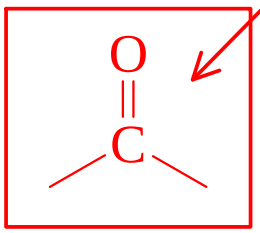




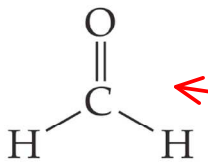
Aldehydes and Ketones



Both contain the **carbonyl** group



Aldehydes = at least 1 side H

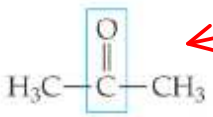


simplest aldehyde

methanal

(formaldehyde)

Ketones = both sides R groups



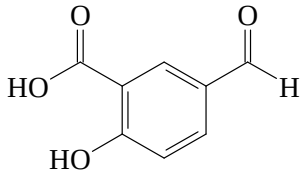
simplest ketone

2-propanone

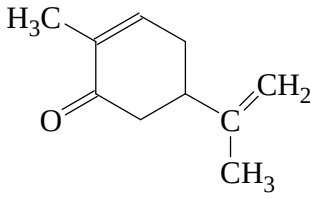
(acetone)

Aldehydes and Ketones

Many aldehydes and ketones have pleasant tastes and aromas.



Vanillin (in vanilla)



Carvone (spearmint flavor)

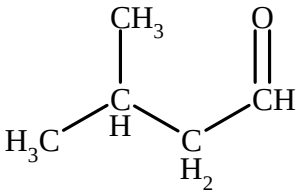
IUPAC Nomenclature of Aldehydes

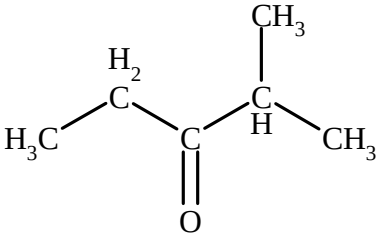
Find the longest carbon chain that contains the carbonyl group. Drop the 'e' ending from the parent chain name and add the 'al' ending. Substituents named same as in alkanes. (C of CHO group always carbon 1 - position is not indicated in the name).

IUPAC Nomenclature of Ketones

1. Find the longest carbon chain that contains the carbonyl group. Drop the 'e' ending from the parent alkane name and add the 'one' ending.
2. Number the parent chain starting at the end closer to the carbonyl group and designate the location of the carbonyl group as a number in front of the ketone parent name. (Substituents named same as in alkanes).

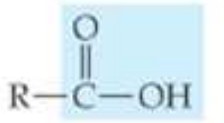
Give the IUPAC name of the following compounds:





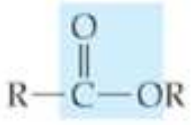
Carboxylic Acids and Esters

Carboxylic Acid General Formula RCOOH



(also RCO_2H)

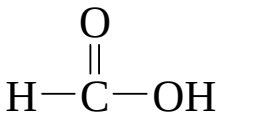
Ester General Formula RCOOR



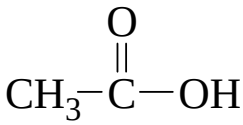
(also RCO_2R)

Sour tasting;weak acids

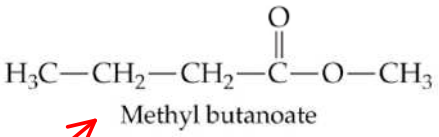
Usually pleasant odor and taste



Methanoic acid
(formic acid)
Insect bites & stings

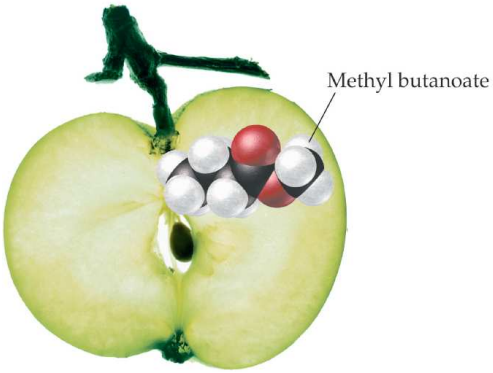


Ethan**oic acid**
(acetic acid)
In vinegar



Methyl butanoate

Ester partially responsible for the smell and taste of apples

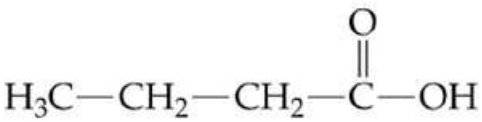


IUPAC Nomenclature of Carboxylic Acids

Select the longest chain containing the COOH group. Drop the 'e' ending from the parent alkane name and add 'oic acid'. (C of COOH group always carbon 1 - position is not indicated in the name)

Esters are made by reacting a carboxylic acid with an alcohol

Give the IUPAC name of the following carboxylic acid:



Nomenclature of Esters (IUPAC)

Esters can be made by reacting a carboxylic acid with an alcohol

$$R_aCOOH + HOR_b \Leftrightarrow R_aCOOR_b + HOH$$

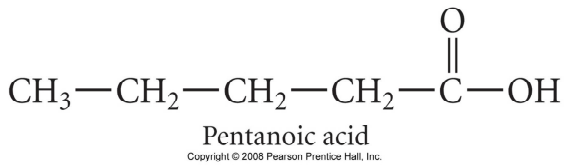
Carboxylic Acid Alcohol Ester Water

IUPAC Nomenclature of Esters

1. The names of esters are derived from the name of the carboxylic acid from which they are formed. Drop the 'ic acid' ending of the carboylic acid name and add the ending 'ate'. (This gives the ester base name).
2. The group attached to the oxygen of the ester is then named as an **alkyl group**. This group name is <u>placed in front of the ester base name</u>.

Example:

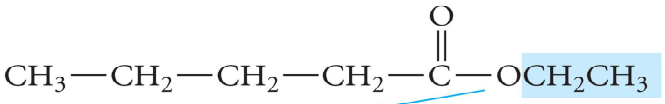
Carboxylic acid



Pentanoic acid

Drop 'ic acid' from carboxylic acid name

ESTER



Ethyl pentanoate

Add 'ate' ending to parent carboxylic acid name and then place the name of the alkyl group attached to the oxygen IN FRONT of the base name.

Give the IUPAC name of the following esters:

$CH_3CH_2CH_2CO_2CH_2CH_2CH_2CH_3$

$CH_3CO_2CH_2CH_2CH_3$

NOTE: We will not cover Sections 18.16 or 18.17 - you do not need to know the material in these sections.