Summary of IUPAC Nomenclature of Organic Compounds

Introduction

The purpose of the IUPAC system of nomenclature is to establish an international standard of naming compounds to facilitate communication. The goal of the system is to give each structure a unique and unambiguous name, and to correlate each name with a unique and unambiguous structure.

I. Fundamental Principle

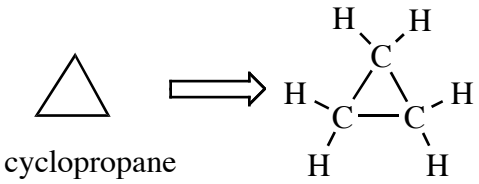
IUPAC nomenclature is based on naming a molecule's longest chain of carbons connected by single bonds, whether in a continuous chain or in a ring. All deviations, either multiple bonds or atoms other than carbon and hydrogen, are indicated by prefixes or suffixes according to a specific set of priorities.

II. Alkanes and Cycloalkanes (also called "aliphatic" compounds)

Alkanes are the family of saturated hydrocarbons, that is, molecules containing carbon and hydrogen connected by single bonds only. These molecules can be in continuous chains (called linear or acyclic), or in rings (called cyclic or alicyclic). The names of alkanes and cycloalkanes are the root names of organic compounds. Beginning with the five-carbon alkane, the number of carbons in the chain is indicated by the Greek or Latin prefix. Rings are designated by the prefix "cyclo". (In the geometrical symbols for rings, each apex represents a carbon with the number of hydrogens required to fill its valence.)

C_1	CH_4	methane
C_2	CH_3CH_3	ethane
C_3	$CH_3CH_2CH_3$	propane
C_4	$CH_3[CH_2]_2CH_3$	butane
C_5	$CH_3[CH_2]_3CH_3$	pentane
C_6	$CH_3[CH_2]_4CH_3$	hexane
C_7	$CH_3[CH_2]_5CH_3$	heptane
C_8	$CH_3[CH_2]_6CH_3$	octane
C_9	$CH_3[CH_2]_7CH_3$	nonane
C_{10}	$CH_3[CH_2]_8CH_3$	decane
C_{11}	$CH_3[CH_2]_9CH_3$	undecane

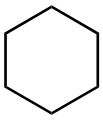
C_{12}	$CH_3[CH_2]_{10}CH_3$	dodecane
C_{13}	$CH_3[CH_2]_{11}CH_3$	tridecane
C_{14}	$CH_3[CH_2]_{12}CH_3$	tetradecane
C_{20}	$CH_3[CH_2]_{18}CH_3$	icosane
C_{21}	$CH_3[CH_2]_{19}CH_3$	henicosane
C_{22}	$CH_3[CH_2]_{20}CH_3$	docosane
C_{23}	$CH_3[CH_2]_{21}CH_3$	tricosane
C_{30}	$CH_3[CH_2]_{28}CH_3$	triacontane
C_{31}	$CH_3[CH_2]_{29}CH_3$	hentriacontane
C_{40}	$CH_3[CH_2]_{38}CH_3$	tetracontane
C_{50}	$CH_3[CH_2]_{48}CH_3$	pentacontane



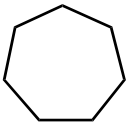
cyclopropane

cyclobutane

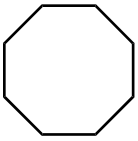
cyclopentane



cyclohexane



cycloheptane



cyclooctane

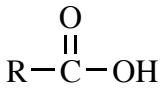
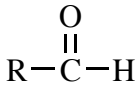
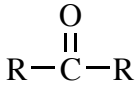
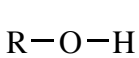
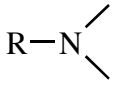
The IUPAC system of nomenclature is undergoing many changes, most notably in the placement of position numbers. The new system places the position number close to the functional group designation; however, you should be able to use and recognize names in either the old or the new style. Ask your instructor which system to use.

III. Nomenclature of Molecules Containing Substituents and Functional Groups

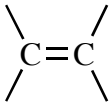
A. Priorities of Substituents and Functional Groups

LISTED HERE FROM HIGHEST TO LOWEST PRIORITY, except that the substituents within Group C have equivalent priority.

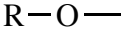
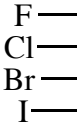
Group A—Functional Groups Named By Prefix Or Suffix

Functional Group	Structure	Prefix	Suffix
Carboxylic Acid		carboxy-	-oic acid (-carboxylic acid)
Aldehyde		oxo- (formyl)	-al (carbaldehyde)
Ketone		oxo-	-one
Alcohol		hydroxy-	-ol
Amine		amino-	-amine

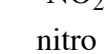
Group B—Functional Groups Named By Suffix Only

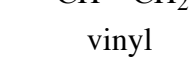
Functional Group	Structure	Prefix	Suffix
Alkene		--------	-ene
Alkyne		--------	-yne

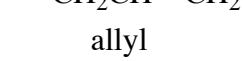
Group C—Substituent Groups Named By Prefix Only

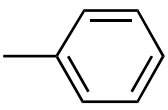
Substituent	Structure	Prefix	Suffix
Alkyl (see next page)		alkyl-	--------
Alkoxy		alkoxy-	--------
Halogen		fluoro- chloro- bromo- iodo-	-------- -------- -------- --------

Miscellaneous substituents and their prefixes

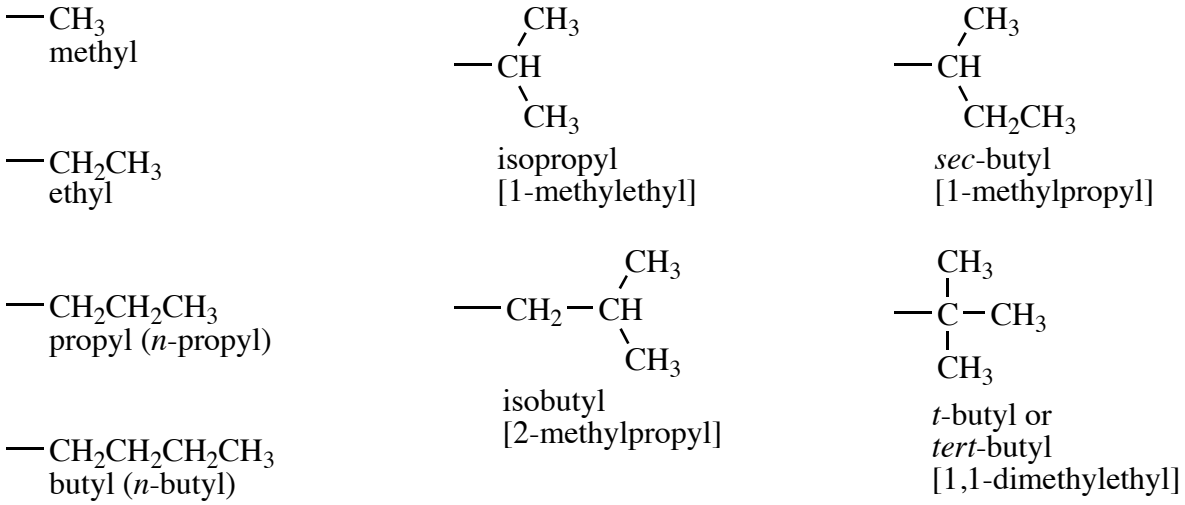

nitro


vinyl


allyl


phenyl

Common alkyl groups—replace "ane" ending of alkane name with "yl". Alternate names for complex substituents are given in brackets.



B. Naming Substituted Alkanes and Cycloalkanes—Group C Substituents Only

Organic compounds containing substituents from Group C are named following this sequence of steps, as indicated on the examples below:

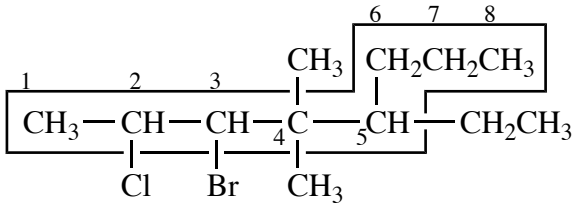
•Step 1. Find the longest continuous carbon chain. Determine the root name for this parent chain. In cyclic compounds, the ring is usually considered the parent chain, unless it is attached to a longer chain of carbons; indicate a ring with the prefix "cyclo" before the root name. (When there are two longest chains of equal length, use the chain with the greater number of substituents.)

•Step 2. Number the chain in the direction such that the position number of the first substituent is the smaller number. If the first substituents have the same number, then number so that the second substituent has the smaller number, *etc*.

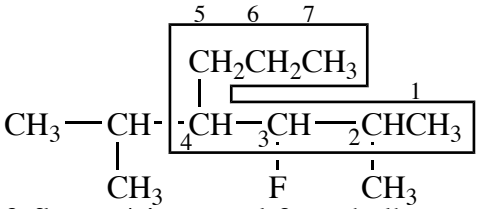
•Step 3. Determine the name and position number of each substituent. (A substituent on a nitrogen is designated with an "*N*" instead of a number; see Section **III**.D.1. below.)

•Step 4. Indicate the number of identical groups by the prefixes di, tri, tetra, *etc*.

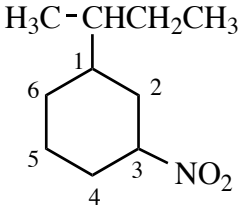
•Step 5. Place the position numbers and names of the substituent groups, in alphabetical order, before the root name. In alphabetizing, ignore prefixes like *sec*-, *tert*-, di, tri, *etc*., but include iso and cyclo. Always include a position number for each substituent, regardless of redundancies.



3-bromo-2-chloro-5-ethyl-4,4-dimethyloctane



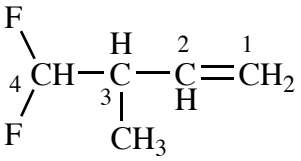
3-fluoro-4-isopropyl-2-methylheptane



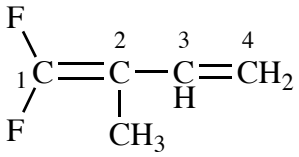
1-*sec*-butyl-3-nitrocyclohexane
(numbering determined by the alphabetical order of substituents, "b" comes before "n")

C. Naming Molecules Containing Functional Groups from Group B—Suffix Only

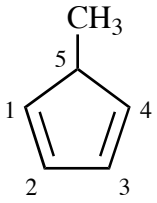
1. Alkenes—Follow the same steps as for alkanes, except:
a. Number the chain of carbons *that includes the C=C* so that the C=C has the lower position number, since it has a higher priority than any substituents;
b. Change "ane" to "ene" and assign a position number to the first carbon of the C=C; place the position number just before the name of functional group(s);
c. Designate geometrical isomers with a *cis,trans* or *E,Z* prefix.



4,4-difluoro-3-methylbut-1-ene

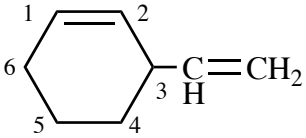


1,1-difluoro-2-methyl-buta-1,3-diene



5-methylcyclopenta-1,3-diene

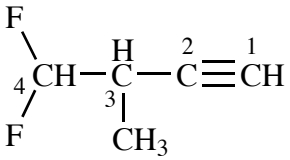
Special case: When the chain cannot include an alkene, a substituent name is used. See Section **V**.A.2.a.



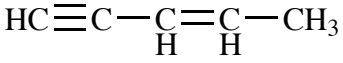
3-vinylcyclohex-1-ene

Numbering must be on EITHER a ring OR a chain, but not both.

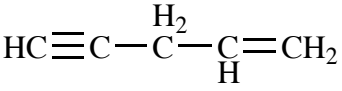
2. Alkynes—Follow the same steps as for alkanes, except:
a. Number the chain of carbons *that includes the C≡C* so that the alkyne has the lower position number;
b. Change "ane" to "yne" and assign a position number to the first carbon of the C≡C; place the position number just before the name of functional group(s).
Note: The Group B functional groups (alkene and alkyne) are considered to have equal priority: in a molecule with both an ene and an yne, whichever is closer to the end of the chain determines the direction of numbering. In the case where each would have the same position number, the alkene takes the lower number. In the name, "ene" comes before "yne" because of alphabetization.



4,4-difluoro-3-methylbut-1-yne



pent-3-en-1-yne
("yne" closer to end of chain)



pent-1-en-4-yne
("ene" and "yne" have equal priority unless they have the same position number, when "ene" takes the lower number)

(Notes: 1. An "e" is dropped if the letter following it is a vowel: "pent-3-en-1-yne" , not "pent-3-ene-1-yne". 2. An "a" is added if inclusion of di, tri, *etc*., would put two consonants together: "buta-1,3-diene", not "but-1,3-diene".)

D. Naming Molecules Containing Functional Groups from Group A—Prefix or Suffix

In naming molecules containing one or more of the functional groups in Group A, the group of highest priority is indicated by suffix; the others are indicated by prefix, with priority equivalent to any other substituents. The table in Section **III**.A. defines the priorities; they are discussed on the following pages in order of increasing priority.

Now that the functional groups and substituents from Groups A, B, and C have been described, a modified set of steps for naming organic compounds can be applied to all simple structures:

•Step 1. Find the highest priority functional group. Determine and name the longest continuous carbon chain that includes this group.

•Step 2. Number the chain so that the highest priority functional group is assigned the lower number. (The number "1" is often omitted when there is no confusion about where the group must be. Aldehydes and carboxylic acids must be at the first carbon of a chain, so a "1" is rarely used with those functional groups.)

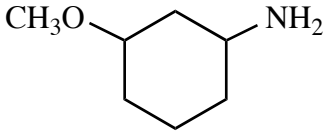
•Step 3. If the carbon chain includes multiple bonds (Group B), replace "ane" with "ene" for an alkene or "yne" for an alkyne. Designate the position of the multiple bond with the number of the first carbon of the multiple bond.

•Step 4. If the molecule includes Group A functional groups, replace the last "e" with the suffix of the highest priority functional group, and include its position number just before the name of the highest priority functional group.

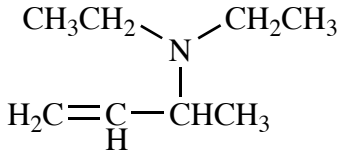
•Step 5. Indicate all Group C substituents, and Group A functional groups of lower priority, with a prefix. Place the prefixes, with appropriate position numbers, in alphabetical order before the root name.

1. Amines: prefix: amino-; suffix: -amine—substituents on nitrogen denoted by "*N*"

propan-1-amine

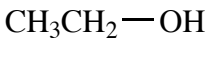


3-methoxycyclohexan-1-amine
("1" is optional in this case)

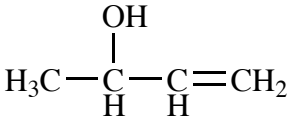


N,*N*-diethylbut-3-en-2-amine

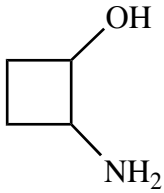
2. Alcohols: prefix: hydroxy-; suffix: -ol



ethanol

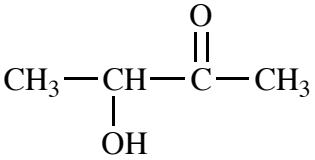


but-3-en-2-ol

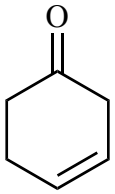


2-aminocyclobutan-1-ol
("1" is optional in this case)

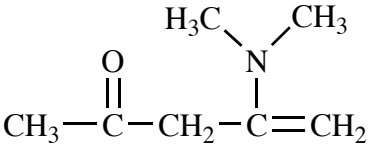
3. Ketones: prefix: oxo-; suffix: -one (pronounced "own")



3-hydroxybutan-2-one



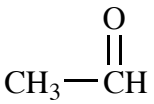
cyclohex-3-en-1-one
("1" is optional in this case)



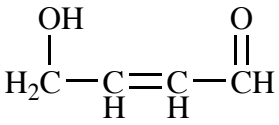
4-(*N*,*N*-dimethylamino)pent-4-en-2-one

4. Aldehydes: prefix: oxo-, or formyl- (O=CH-); suffix: -al (abbreviation: —CHO)
An aldehyde can only be on carbon 1, so the "1" is generally omitted from the name.

methanal;
formaldehyde



ethanal;
acetaldehyde

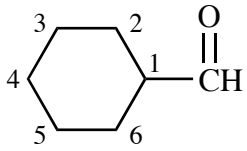


4-hydroxybut-2-enal

4-oxopentanal

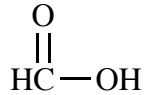
Summary of IUPAC Nomenclature, continued

Special case: When the chain cannot include the carbon of the aldehyde, the suffix "carbaldehyde" is used:

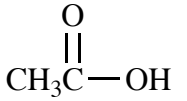


cyclohexanecarbaldehyde

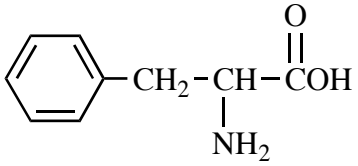
5. Carboxylic Acids: prefix: carboxy-; suffix: -oic acid (abbreviation: —COOH)
A carboxylic acid can only be on carbon 1, so the "1" is generally omitted from the name. (Note: Chemists traditionally use, and IUPAC accepts, the names "formic acid" and "acetic acid" in place of "methanoic acid" and "ethanoic acid".)



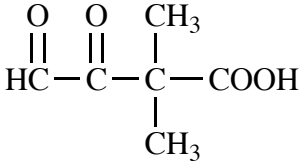
methanoic acid; formic acid



ethanoic acid; acetic acid

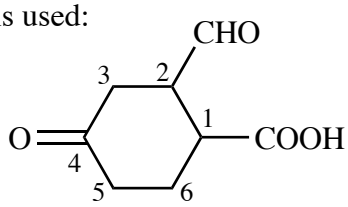


2-amino-3-phenylpropanoic acid



2,2-dimethyl-3,4-dioxobutanoic acid

Special case: When the chain numbering cannot include the carbon of the carboxylic acid, the suffix "carboxylic acid" is used:



2-formyl-4-oxocyclohexanecarboxylic acid ("formyl" is used to indicate an aldehyde as a substituent when its carbon cannot be in the chain numbering)

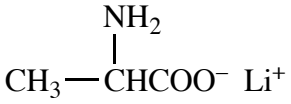
E. Naming Carboxylic Acid Derivatives

The six common groups derived from carboxylic acids are, in decreasing priority after carboxylic acids: salts, anhydrides, esters, acyl halides, amides, and nitriles.

1. Salts of Carboxylic Acids

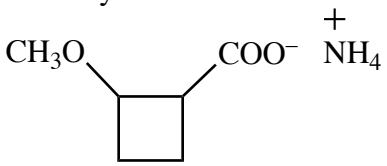
Salts are named with cation first, followed by the anion name of the carboxylic acid, where "**ic acid**" is replaced by "**ate**" :

acet**ic acid**	becomes	acet**ate**
butano**ic acid**	becomes	butano**ate**
cyclohexanecarboxyl**ic acid**	becomes	cyclohexanecarboxyl**ate**



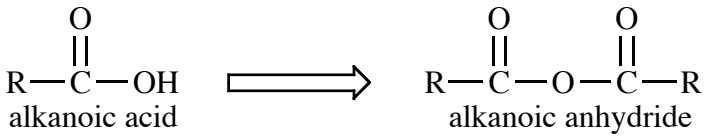
lithium 2-aminopropanoate

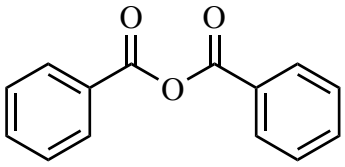
sodium chloroacetate



ammonium 2-methoxy-cyclobutanecarboxylate

2. Anhydrides: "oic acid" is replaced by "oic anhydride"

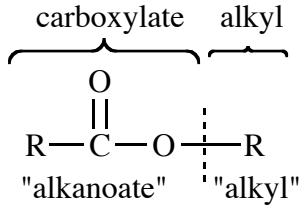




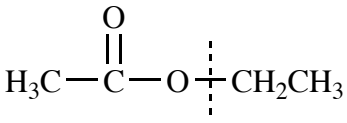
benzoic anhydride

3. Esters

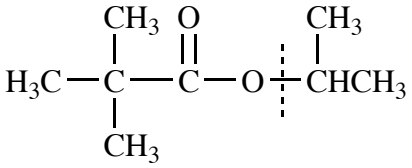
Esters are named as "organic salts" that is, the alkyl name comes first, followed by the name of the carboxylate anion. (common abbreviation: —COOR)



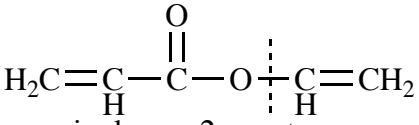
"alkyl alkanoate"



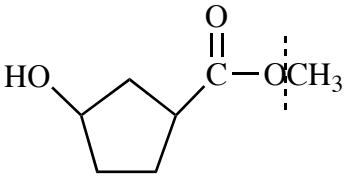
ethyl acetate



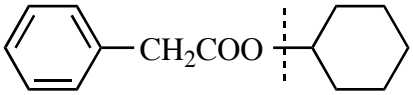
isopropyl 2,2-dimethylpropanoate



vinyl prop-2-enoate

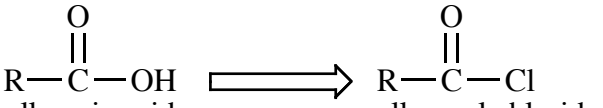


methyl 3-hydroxycyclo-pentanecarboxylate

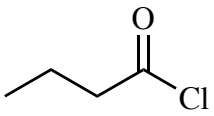


cyclohexyl 2-phenylacetate

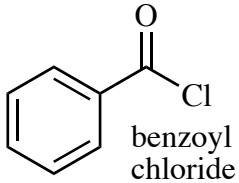
4. Acyl Halides: "oic acid" is replaced by "oyl halide"



alkanoic acid → alkanoyl chloride

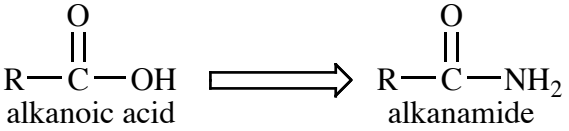


butanoyl chloride

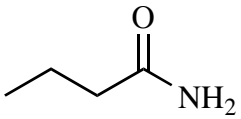


benzoyl chloride

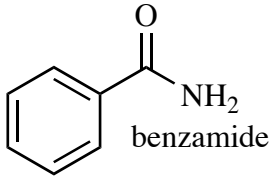
5. Amides: "oic acid" is replaced by "amide"



alkanoic acid → alkanamide



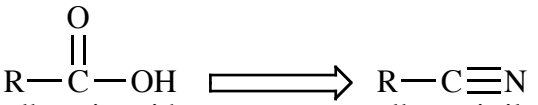
butanamide



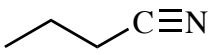
benzamide

Amides are notable for their role in biochemistry, i.e., the special amide bond between two amino acids is called a peptide bond.

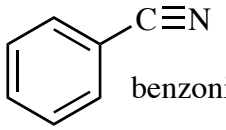
6. Nitriles: "oic acid" is replaced by "enitrile"



alkanoic acid → alkanenitrile



butanenitrile



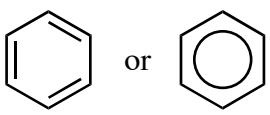
benzonitrile

(common spelling differs from IUPAC)

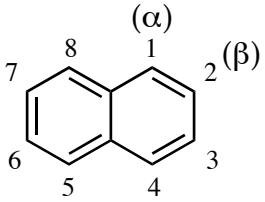
IV. Nomenclature of Aromatic Compounds

"Aromatic" compounds are those derived from benzene and similar ring systems. As with aliphatic nomenclature described above, the process is: determining the root name of the parent ring; determining priority, name, and position number of substituents; and assembling the name in alphabetical order. *Functional group priorities are the same in aliphatic and aromatic nomenclature*. See p. 2 for the list of priorities.

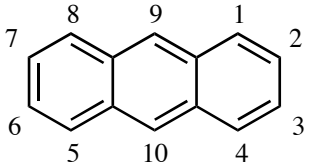
A. Common Parent Ring Systems



benzene



naphthalene

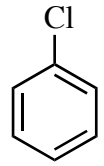


anthracene

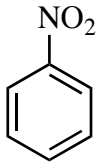
Summary of IUPAC Nomenclature, continued

B. Monosubstituted Benzenes

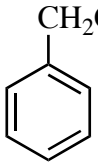
1. Most substituents keep their designation, followed by the word "benzene":



chlorobenzene

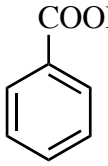


nitrobenzene

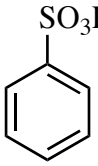


ethylbenzene

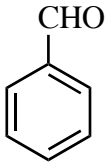
2. Some common substituents change the root name of the ring. IUPAC accepts these as root names, listed here in decreasing priority (same as Group A, p. 2):



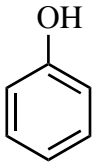
benzoic acid



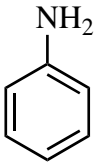
benzene-sulfonic acid



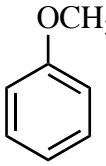
benzaldehyde



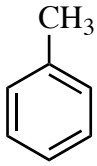
phenol



aniline



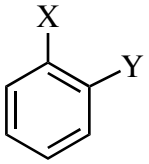
anisole

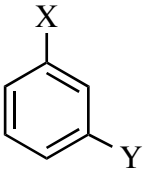


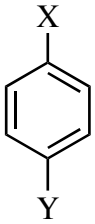
toluene

C. Disubstituted Benzenes

1. Designation of substitution—only three possibilities:

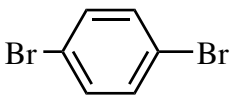




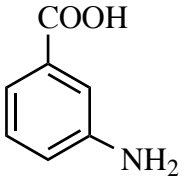


common:	*ortho-* *(o-)*	*meta-* *(m-)*	*para-* *(p-)*
IUPAC:	1,2-	1,3-	1,4-

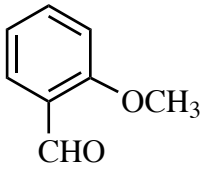
2. Naming disubstituted benzenes—Priorities from Group A, p. 2, determine root name and substituents



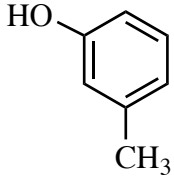
p-dibromobenzene
1,4-dibromobenzene



m-aminobenzoic acid
3-aminobenzoic acid

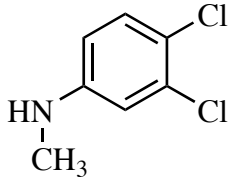


o-methoxybenzaldehyde
2-methoxybenzaldehyde

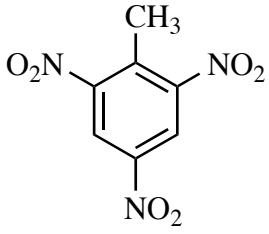


m-methylphenol
3-methylphenol

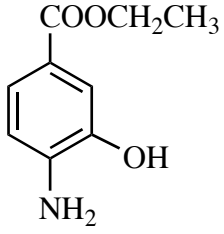
D. Polysubstituted Benzenes—must use numbers to indicate substituent position



3,4-dichloro-*N*-methylaniline



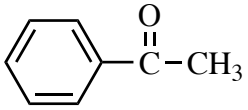
2,4,6-trinitrotoluene (TNT)



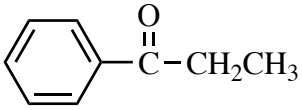
ethyl 4-amino-3-hydroxybenzoate

E. Aromatic Ketones

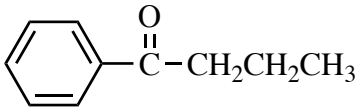
A special group of aromatic compounds are ketones where the carbonyl is attached to at least one benzene ring. Such compounds are named as "phenones", the prefix depending on the size and nature of the group on the other side of the carbonyl. These are the common examples:



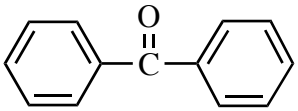
acetophenone



propiophenone



butyrophenone



benzophenone

In a companion document entitled Special Topics of IUPAC Nomenclature, three more advanced topics are discussed:

1. Nomenclature of Bicyclic Compounds
2. Replacement Nomenclature of Heteroatoms
3. Stereochemical Designations (R and S, E and Z, the Cahn-Ingold-Prelog system)