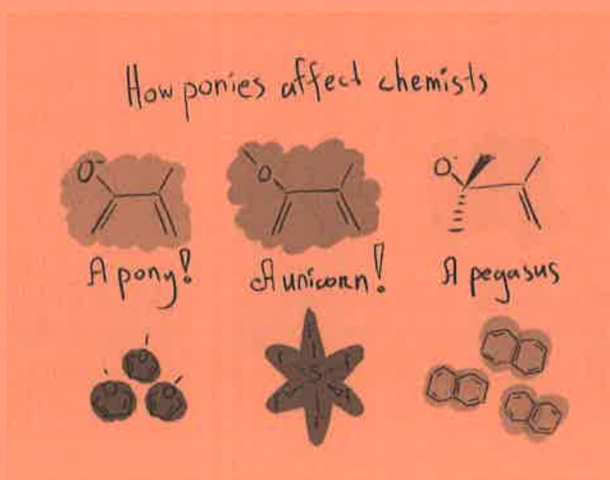
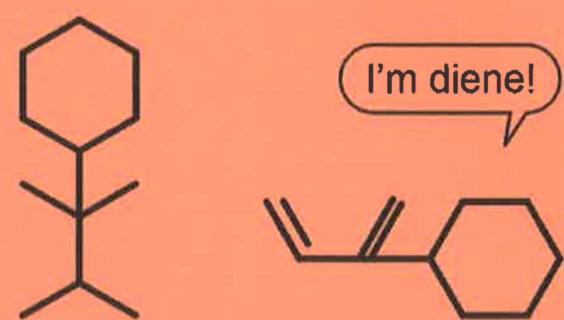
Chemistry 11

Organic Chemistry



Are you feeling like a happy Organic Chemistry Pony fully of rainbows, sunshine and joy?

...Or are you more like this guy?
(don't worry...this is the last booklet)



Before Organic Exam

After Organic Exam

Book 3

Name: Teacher Key **Block:**________

Functional Group Overview

R = represents the hydrocarbon chain

Class of Compound	Functional Group	General Formula	Example
halocarbon	–F –Cl –Br –I (–X)	R–X	CH_3Cl chloromethane
alcohol	–OH	R–OH	$CH_3CH_2CH_2OH$ 1-propanol
ether	–O–	R–O–R' ("oxy")	$CH_3OCH_2CH_3$ methoxyethane (R, R')
aldehyde	$-C(=O)-H$	$R-C(=O)-H$	$CH_3CH_2C(=O)H$ propanal
ketone	$-C(=O)-$	$R-C(=O)-R'$	$CH_3C(=O)CH_3$ propanone ← KetONE
carboxylic acid	$-C(=O)-OH$	$R-C(=O)-OH$	$CH_3CH_2C(=O)OH$ propanoic acid
ester	$-C(=O)-O-$	$R-C(=O)-OR'$	$CH_3C(=O)OCH_3$ methylethanoate
amine	$-NH_2$	$R-NH_2$	$CH_3CH_2CH_2NH_2$ propanamine
amide	$-C(=O)-NH_2$	$R-C(=O)-NH_2$	$CH_3CH_2C(=O)NH_2$ propanamide

R' = second hydrocarbon chain

Functional Groups

Earlier in this chapter, you learned about organic compounds containing carbon and hydrogen atoms. The number of isomers possible for large hydrocarbons is enormous. Now imagine how many more isomers would be possible if we included atoms of oxygen, nitrogen, sulphur, or other elements!

In Books 1 & 2, you learned about the structures of alkenes, alkynes, and aromatic hydrocarbons, such as benzene. Groups of organic compounds like these are called Functional groups.

A functional group is an atom, group of atoms, or organization of bonds in an organic molecule that react in a characteristic manner.

Organic compounds with the same functional group react in a similar manner

Functional groups are identified by the placement of certain atoms (or groups of atoms) ie: more than 1. in a molecule.

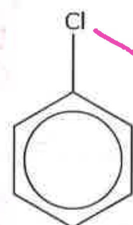
NEW SHORTHAND:

Chemists use a shorthand to represent carbon and hydrogen atoms that are **not part** of the functional group itself.

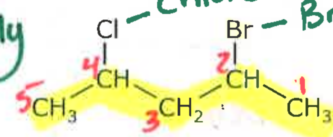
We use the symbol R' to represent the hydrocarbon fragment of the organic molecule NOT involved. in the functional group.

R' (called "r prime") may be used for a different hydrocarbon fragment in the same molecule.

Figure 8.2.1 *Examples of alkyl halides*



(a) chlorobenzene



2-bromo-4chloropentane

*name branches alphabetically

Alkyl Halides: R-X (where X = F, Cl, I, or Br)

Organic compounds containing halogens are called alkyl halides.

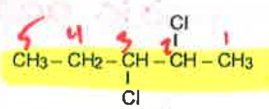
They are named using the same rules you learned before, except that the halogen atom is named as a branch group.

It is treated the same way as an alkyl group was in branched alkanes, alkenes and alkynes.

The prefixes to use for each element are:

F = fluoro Cl = chloro Br = bromo I = iodo

Problem 9. Name the halogenated compounds below.

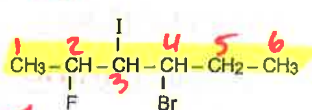
a. 

2,3-dichloropentane

b. 

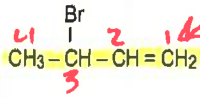
difloromethane (no numbers needed...only 1 place they can be)

order them by ABC's

c. 

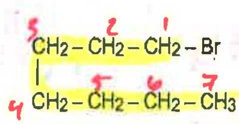
4-bromo-2-floro-3-iodohexane

number to get lowest combo for branches.

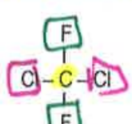
d. 

number based on double bond.

3-bromo-1-butene

e. 

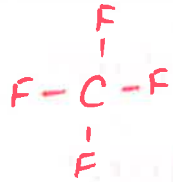
1-bromoheptane

f. 

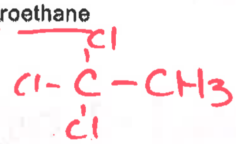
dichlorodifloromethane

Problem 10. Write condensed structural formulas (such as those shown above) for the following.

a. tetrafluoromethane 4 F 1C

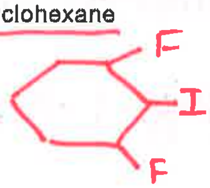


b. 1,1,1–trichloroethane 3Cl



c. chlorocyclopentane

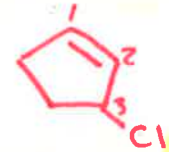
d. 1,3–difluoro–2–iodocyclohexane



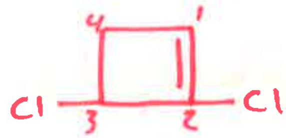
e. 3,4–dibromo–6–methyl–1–heptyne

$CH \equiv C-CH(Br)-CH(Br)-CH_2-CH(CH_3)-CH_3$

f. 3–chlorocyclopentene



g. 2,3–dichlorocyclobutene



Alcohols: R-OH

Organic compounds containing a hydroxyl (–OH) –OH) group attached to a carbon atom are called alcohols

Do not confuse a hydroxyl group with a hydroxide ion. (OH^-) basic

Compounds with a hydroxide ion are bases and are ionic.

Alcohols are covalent compounds that do not readily release the –OH group.

1. The parent chain must contain an atom attached to the –OH group. Number the carbon atoms in the parent chain such that the –OH group is given the lowest number.
2. The name of the parent chain ends with "–ol" instead of "–e."
3. Name and identify positions of the branches as usual.

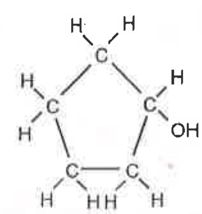
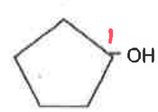
Study the examples shown *(right)*.

Note that the number indicating the position of the -OH group is not used if the chain is shorter than 3 carbons.

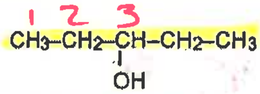
Why is that? b/c there is only 1 place for the -OH group to attach.

Also you see that the -OH group is not included in the names of cyclic alcohols either.

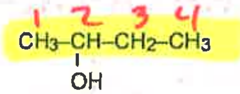
Why not? The "-OH" is always named as position 1

Name	*Formula*	*Condensed Structural Formula*
methanol	CH_3OH	CH_3-OH
ethanol	CH_3CH_2OH	CH_3-CH_2-OH
1–propanol	$CH_3CH_2CH_2OH$	$CH_3-CH_2-CH_2-OH$
2–propanol	$CH_3CHOHCH_3$	$CH_3-CH(OH)-CH_3$
cyclopentanol		

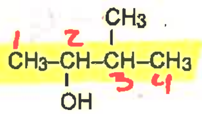
Problem 1. Name the alcohols given below.

a. 

3-pentanol

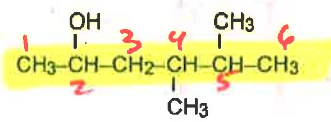
b. 

2-butanol

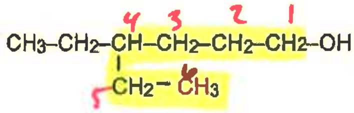
c. 

*name -OH first as lowest #

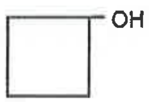
3-methyl-2-butanol

d. 

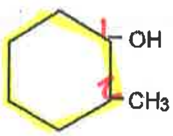
4,5-dimethyl-2-hexanol

e. 

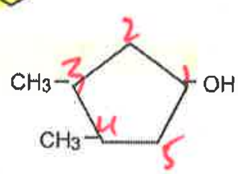
4-ethyl-1-hexanol

f. 

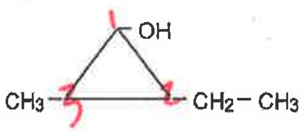
cyclobutanol

g. 

2-methylcyclohexanol

h. 

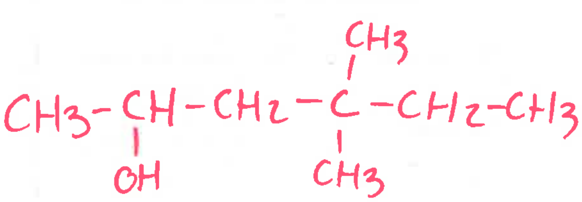
3,4-dimethylcyclopentanol

i. 

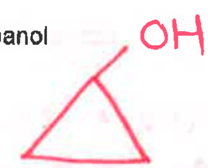
2-ethyl-3-methylcyclopropanol

Problem 2. Draw the condensed structural formulas for the following.

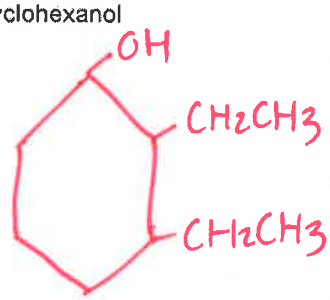
a. 4,4–dimethyl–2–hexanol



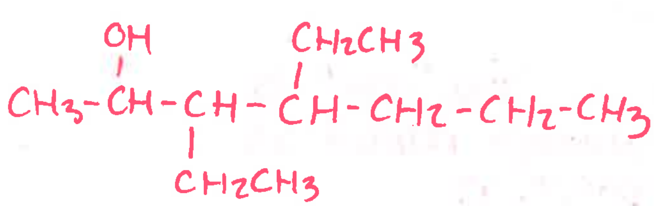
b. cyclopropanol

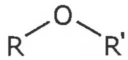


c. 2,3–diethylcyclohexanol



d. 3,4–diethyl–2–heptanol

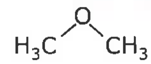
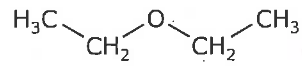
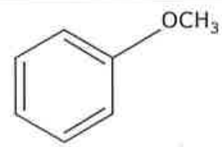




Ethers

Ethers are organic compounds in which 2 hydrocarbon fragments are attached by an oxygen atom.

Table 8.2.2 *Examples of Ethers and Their Applications*

Ether Name	Application	Structure
Methoxymethane (commonly called dimethyl ether)	aerosol spray propellant	
Ethoxyethane (commonly called diethyl ether)	early anesthetic	
Methoxybenzene (commonly called methylphenyl ether)	anise (licorice) flavoring	

Ethers are compounds which contain an oxygen atom bonded to two carbon atoms within the carbon chain. The functional group is the C–O–C arrangement found within the chain. When you look at an ether molecule, you will see an alkyl group on each side of the oxygen. For example, CH_3–CH_2–O–CH_3 has an ethyl group on the left of the oxygen atom and a methyl group on the right. The "common name" for this molecule is *methyl ethyl ether*. Although common names are still frequently used for ethers, we will stick to our "game plan" and use the IUPAC system.

Parent compound is "ethyl"

CH_3–CH_2–O–CH_3

Functional group is "methoxy"

In the IUPAC system, the larger of the two alkyl groups attached to the oxygen is considered to be the parent compound. For the ether mentioned in the last paragraph above, the parent compound would be ethane. The smaller alkyl group and the oxygen atom are considered to be a substituent group on the parent compound. The –O–CH_3 group is the substituent and it is called "methoxy." So the name of that ether is methoxyethane. If the substituent had been CH_3–CH_2–O–, it would have been called "ethoxy." Collectively these functional groups of the ethers are known as *alkoxy groups*. Only one modified rule needs to be mentioned here regarding the nomenclature of ethers.

Additional Rule for the Nomenclature of Ethers:

RULE: For ethers with parent chains that contain 3 or more carbon atoms, a number is included to indicate the position of the alkoxy group.

Study the examples below.

CH_3–O–CH_3	CH_3–CH_2–O–CH_2–CH_3	CH_3–O–CH_2–CH_2–CH_3	CH_3–O–CH(CH_3)–CH_3
methoxymethane	ethoxyethane	1–methoxypropane	2–methoxypropane

• 2 methyl groups

• 2 ethyl groups

*when the chain is 3+ you must state the number where the "oxy" group joins.. BUT # goes first.

Problem 3. Name the following ethers:

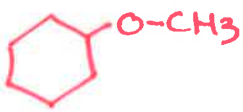
a. CH_3–O–CH_2–CH_2–CH_2–CH_3 — 1-methoxybutane

b. CH_3–CH_2–CH_2–O–CH_2–CH_2–CH_3 — 1-propoxypropane

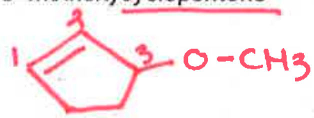
c. CH_3–CH_2–O–CH(–CH_3)–CH_2–CH_2–CH_3 — 2-ethoxypentane

Draw condensed structures for the following ethers:

d. methoxycyclohexane



e. 3–methoxycyclopentene (C=C always carbon 1 → 2)



f. 4–ethoxynonane

CH_3–CH_2–CH_2–CH(–O–CH_2CH_3)–CH_2–CH_2–CH_2–CH_2–CH_3

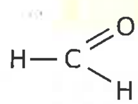
g. 2–isopropoxybutane

CH_3–CH(–O–CH(CH_3)–CH_3)–CH_2–CH_3

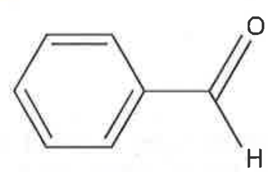
Aldehyde

R—C(=O)—H (Functional Group)

An **aldehyde** is an organic compound containing a carbonyl **at the** **END** of a carbon chain. A **carbonyl** group is a carbon atom double bonded to an oxygen atom. Aldehydes are used to produce dyes and organic acids. You may be familiar with formaldehyde, which is used as a biological preservative. Almond extract and some perfumes contain benzaldehyde.



(a) methanal (commonly called formaldehyde)



(b) benzaldehyde

Figure 8.2.2 *Examples of aldehydes*

C=O "carbonyl group"

Additional Rules for the Nomenclature of Aldehydes:

RULE 1: The longest continuous chain containing the aldehyde group is considered to be the parent compound.

RULE 2: The carbonyl carbon is part of the parent chain and is always considered to be in the #1 position. => R–C(=O)–H (carbon 1 always!)

RULE 3: The suffix "al" is added to the name of the parent compound to indicate that the compound is an aldehyde.

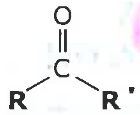
Note the examples of *aldehydes* shown below. You see that no number is needed to indicate the position of the functional group since it is always at position #1.

CH_3–CH_2–CH=O
propanal

CH_3–CH(CH_3)–CH_2–CH_2–CH=O
4–methylpentanal

H–C(=O)–CH_2–CH_2–CH_2–CH(CH_2–CH_3)–CH_2–CH_2–CH(CH_3)–CH_2–CH_3
5–ethyl–8–methyldecanal

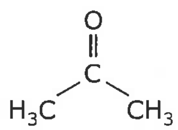
We name the branches "as normal"



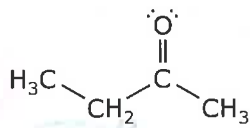
Ketone

A ketone is an organic compound also containing a [carbonyl] group, but unlike an aldehyde, the carbonyl group of a ketone is [NOT the end] of the carbon chain.

Nail polish remover is a ketone commonly called [acetone]. Ketones are used as solvents and to make polymers and pharmaceuticals. A **polymer** is a very large molecule that is produced by linking together many smaller molecules.



(a) propanone (commonly called acetone)



(b) 2-butanone (commonly called ethylmethylketone)

Figure 8.2.3 *Examples of ketones*

Would it be possible for a **ketone** to have a name: "3-methyl-1-hexanone" ?

[this means the carbonyl group is on the end (carbon #1) ... and that makes it an aldehyde.]

The nomenclature of ketones also requires a few rule modifications.

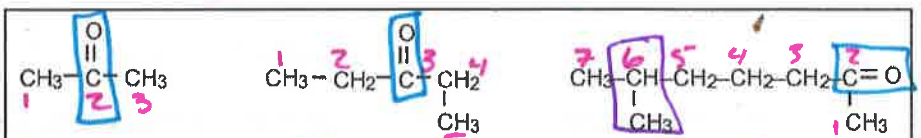
Additional Rules for the Nomenclature of Ketones:

RULE 1: The longest continuous chain containing the ketone group is considered to be the parent compound.

RULE 2: A number is included before the name of the parent compound to indicate the position of the ketone group. The chain is always numbered so that the carbonyl carbon has the lowest possible number.

RULE 3: The suffix "one" is added to the name of the parent compound to indicate that the compound is a ketone.

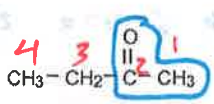
For example:

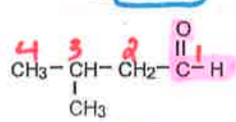


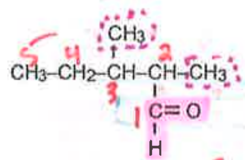
2-propanone | 3-pentanone | 6-methyl-2-heptanone

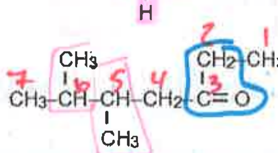
[Aldehyde + Keytone Q's.]

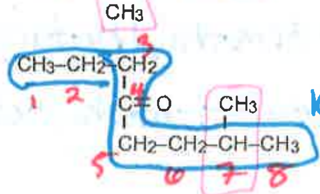
Problem 4. Name the molecules shown below.

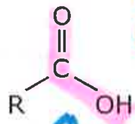
a.  [ketone] [2-butanone]

b.  [aldehyde] [3-methylbutanal]

c.  [aldehyde] [2,3-dimethylpentanal]

d.  [ketone] [5,6-dimethyl-3-heptanone]

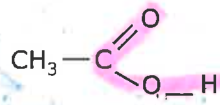
e.  [ketone] [7-methyl-4-octanone]



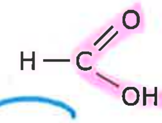
Carboxylic Acid

A carboxylic acid is an organic compound containing a carboxyl (–COOH) group.
These are sometimes called organic acids and are commonly found as food preservatives.
White vinegar is a 5% solution of ethanoic acid, commonly called acetic acid.
Methanoic acid (commonly called formic acid) is the compound responsible for the sting of bee or red ant bites.
Carboxylic acids usually have unpleasant odours.

Figure 8.2.4 *Examples of carboxylic acids*



(a) ethanoic acid
(commonly called acetic acid)



(b) methanoic acid
(commonly called formic acid)

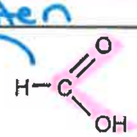
Additional Rules for the Nomenclature of Carboxylic Acids:

RULE 1: The longest continuous chain containing the carboxyl group is considered to be the parent compound.

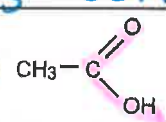
RULE 2: The carboxyl carbon is part of the parent chain and is always considered to be in the #1 position.

RULE 3: The suffix "oic" is added to the name of the parent compound, and the word "acid" is added to the name.

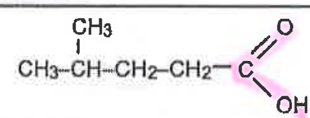
For example:



methanoic acid



ethanoic acid

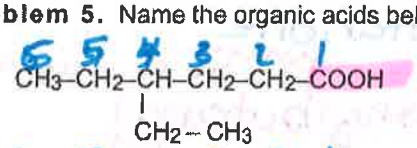


4–methylpentanoic acid

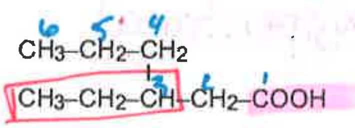
Acids also have common names. For example, ethanoic acid is also called *acetic acid* or "vinegar." We will work only with the IUPAC names.

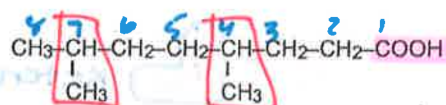
As you attempt to name the carboxylic acids, note that the carboxyl group is written in shorthand as –COOH in the condensed structural formulas.

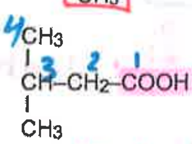
Problem 5. Name the organic acids below.

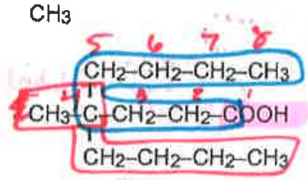
a. 

b. $CH_3–CH_2–CH_2–CH_2–CH_2–COOH$

c. 

d. 

e. 

f. 

a) 4-ethylhexanoic acid

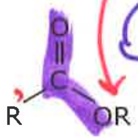
b) hexanoic acid

c) 3-ethylhexanoic acid

d) 4,7-dimethyloctanoic acid

e) 3-methylbutanoic acid

f) 4-butyl-4-methyloctanoic acid



Ester

An ester is an organic compound in which a **-COO-** – group connects **2** other hydrocarbon fragments. Many esters have strong **fruity** odors and are used in perfumes and flavorings. DNA and some plastics and explosives contain ester groups.

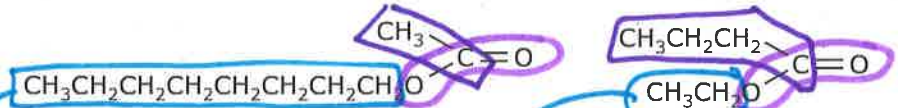
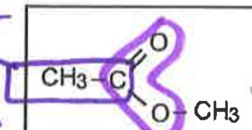


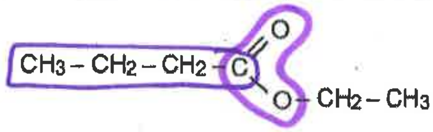
Figure 8.2.5 *Examples of esters*

(a) octyl ethanoate (orange flavouring) (b) ethyl butanoate (pineapple flavouring)

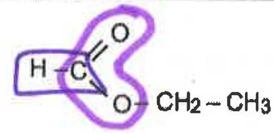
Esters are named by first naming the "R" group followed by the name of the acid portion. The suffix of the acid derivative is then changed from "–ic" to "–ate." For example, in the leftmost structure below, the parent acid is ethanoic acid. The "R" group is methyl, so the name of the ester is *methyl ethanoate*. In the center structure, the parent acid is butanoic, while the "R" group is ethyl, so the ester is named *ethyl butanoate*. Notice that the names of esters consist of two words, while the names of most of the previous types of compounds you have studied consisted of only one word.



methyl ethanoate



ethyl butanoate
(pineapples)



ethyl methanoate
(artificial rum flavor)

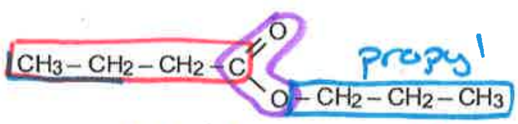
Additional Rules for the Nomenclature of Esters:

RULE 1: Determine the name of the "R" group.

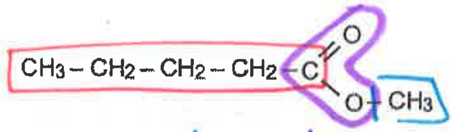
RULE 2: Place the name of the "R" group in front of the name of the parent acid, forming two words.

RULE 3: Determine the name of the parent acid, and change its suffix from "–ic" to "–ate." Drop the word "acid."

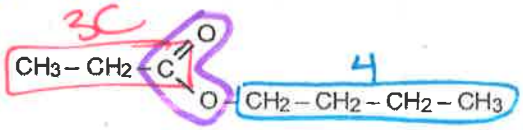
Problem 6. Name the esters below.

a. 

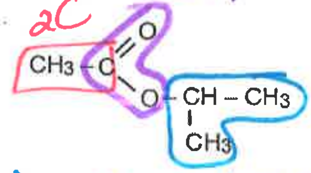
propyl butanoate

b. 

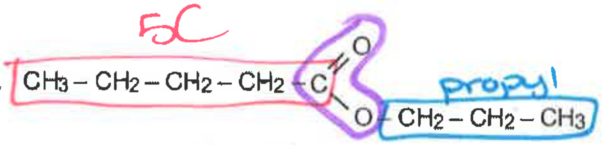
methyl pentanoate

c. 

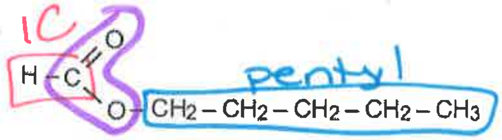
butyl propanoate

d. 

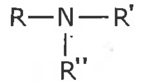
isopropyl ethanoate

e. 

propyl pentanoate

f. 

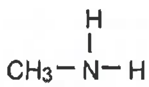
pentyl methanoate



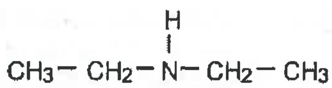
Amines: R-NH_2 or R-NH-R′ or as in the diagram to the left

Amines are organic compounds containing only ____________ bonds and ____________________ atoms attached to a carbon atom. Amines are used to produce dyes and drugs. For example, chlorpheniramine is used as an antihistamine. Ephedrine and phenylephrine are decongestants.

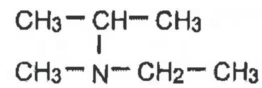
1. In *primary* amines one hydrogen atom in ammonia has been replaced by an alkyl group.
2. In *secondary* amines two hydrogen atoms in ammonia have been replaced by two alkyl groups.
3. In *tertiary* amines all three hydrogen atoms in ammonia have been replaced by three alkyl groups. Examine the examples below:



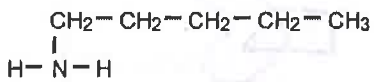
A Primary Amine



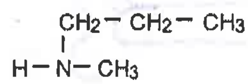
A Secondary Amine



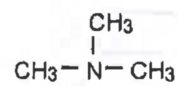
A Tertiary Amine



pentylamine (common)
1–aminopentane (IUPAC)
a primary amine



methylpropylamine
a secondary amine



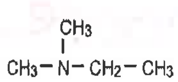
trimethylamine
a tertiary amine

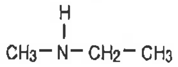
Additional Rules for the Nomenclature of Amines:

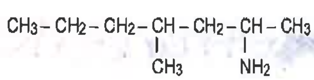
RULE 1: In primary amines only, the IUPAC system treats the NH_2 (amino) group as a substituent group on the parent chain.

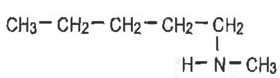
RULE 2: When using the common naming system, the names of the alkyl groups which are attached to the nitrogen atom are listed in alphabetical order and are attached to the suffix "amine" to form one word. Greek prefixes are used if specific alkyl groups occur more than once in a molecule. Name the amines below. Where two lines are present, give two names.

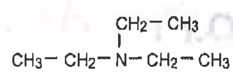
Problem 7. Name the amines below. Where two lines are present, give two names.

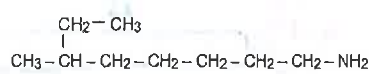
a.  ____________

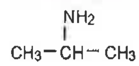
b.  ____________

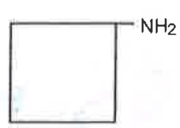
c.  ____________

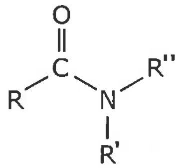
d.  ____________

e.  ____________

f.  ____________

g.  ____________

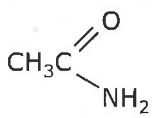
h.  ____________



Amides

Organic compounds containing a nitrogen atom bonded to a carbonyl group are called amides. Amides are found in plastics, rubber, inks, and cosmetics. Amides are also used to make nylon and Kevlar. The pain killer acetaminophen is an amide. An amide group links amino acids together in the peptide chains that make up proteins. You do not need to know how to name amides. Figure 8.2.7 shows two examples of amides.

(a) ethanamide (ethylamide)



(b) butanamide

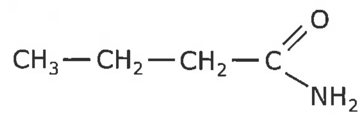
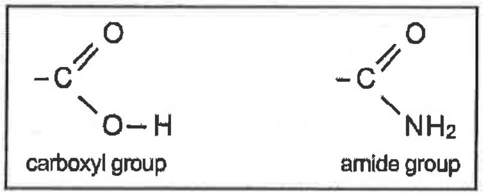
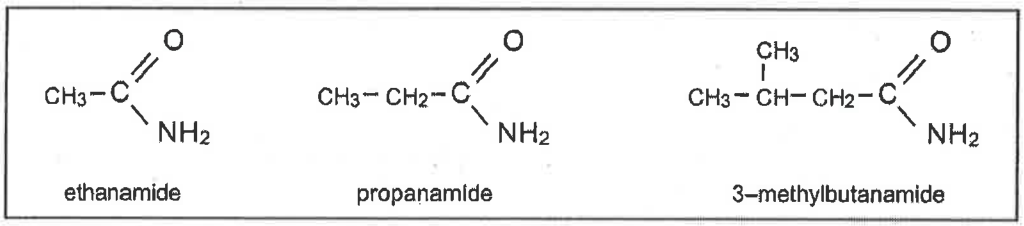


Figure 8.2.7 *Examples of amides*

You are already familiar with the carboxyl group which is the functional group of a carboxylic acid. If you replace the hydroxy group (–OH) in the carboxyl group with an amino group (–NH_2), you get the functional group of a class of organic compounds known as primary *amides.*



There are three classes of amides just as there were for amines, but we will consider only *primary* amides, and we will name them according to the IUPAC system. Amides are considered to be derivatives of carboxylic acids, which means they are formed from acids. Thus, the amides are named as derivatives of acids. To name an amide, simply identify the name of the organic acid from which the amide was derived, and change the "–oic" suffix in the acid's name to "–amide." The examples of amides shown below were derived from ethanoic, propanoic, and butanoic acids.



Additional Rules for the Nomenclature of Amides:

RULE 1: Identify the carboxylic acid from which the amide was derived and change the suffix of the acid name from "–oic" to "–amide," and drop the word acid.

RULE 2: Add the names of any alkyl groups to the name of the parent compound, forming one word.

Problem 8. Name the amides shown below. Note that the amide functional group is written in shorthand as $CONH_2$.

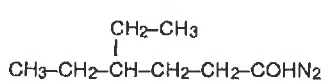
a. $HCONH_2$

____

b. CH_3–CH_2–CH_2–CH_2–$CONH_2$

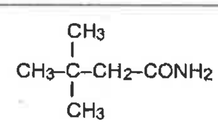
____

c.



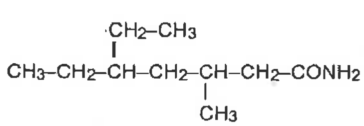
____

d.



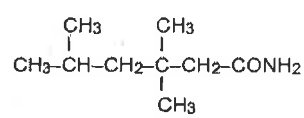
____

e.



____

f.

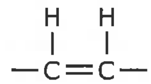
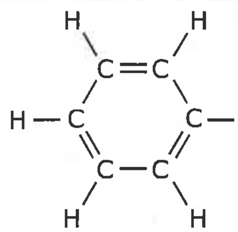
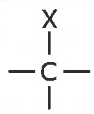
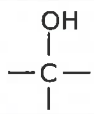
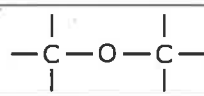
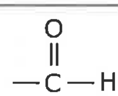
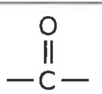
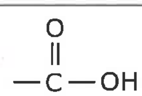
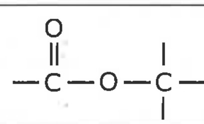
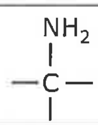
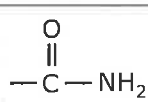


____

Functional Group Summary

Table 8.2.3 summarizes what you have learned about the functional groups described in this booklet.

Table 8.2.3 *Functional groups*

Functional Group	Classification of Organic Compound
	alkene
	alkyne
	aromatic hydrocarbon
	alkyl halide
	alcohol
	ether
	aldehyde
	ketone
	carboxylic acid
	ester
	amine
	amide

Activity: Recognizing Functional Groups

Question

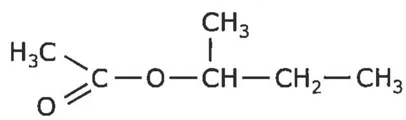
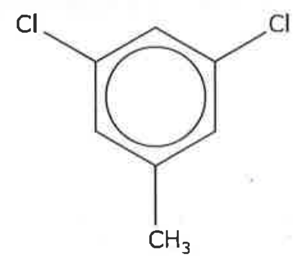
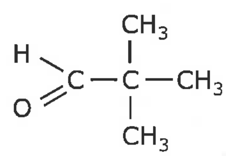
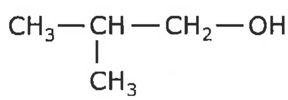
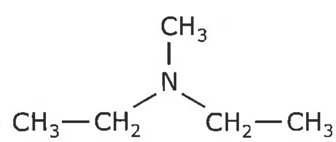
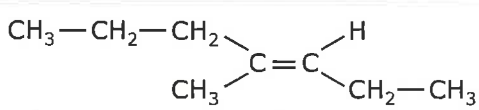
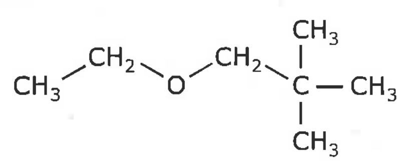
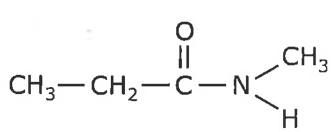
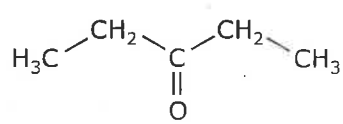
Can you classify an organic compound according to its functional group?

Background

The reactivity of an organic compound depends largely on the presence of its functional group. You can classify organic compounds by their functional group by carefully examining which groups of atoms are present on a molecule. You should be able to recognize the following types of functional groups in the following organic compounds: alkane, alkene, alkyne, cycloalkane, aromatic, alkyl halide, alcohol, ether, amine, amide, aldehyde, ketone, carboxylic acid, and ester.

Procedure

1. Work with a partner.
2. Copy the following structure diagrams onto a piece of paper.

1. 	2. 
3. $HC\equiv C-CH_3$	4. 
5. 	6. 
7. 	8. 
9. 	10. 

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3. Cut the paper into 10 squares and place each square face down on the table.

4. Take turns with your partner. Turn over one piece of paper, and state which functional groups are represented. Some examples may include more that one functional group. If your partner agrees, you get to keep that piece of paper. If your partner disagrees, place that piece of paper to the side.

Results and Discussion

1. Once you have completed all 10 squares, count how many questions you answered correctly. ______________

2. For questions where you disagreed, re-examine the question and try to come to an agreement about the functional group. If you cannot agree, ask a nearby pair of students.

3. You know how to name some of these compounds. List the names below of as many as you can and compare your answers to those of a nearby pair of students.