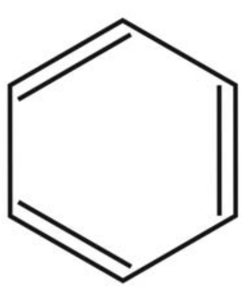
Grade 12 Chemistry

Organic Chemistry

Class 2

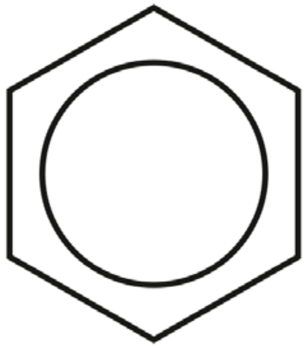
Aromatic Hydrocarbons

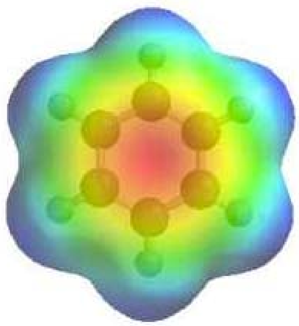
- Benzene was discovered in 1826
- Benzene is C_6H_6 but scientists could not determine the structure of benzene based on the known properties of benzene



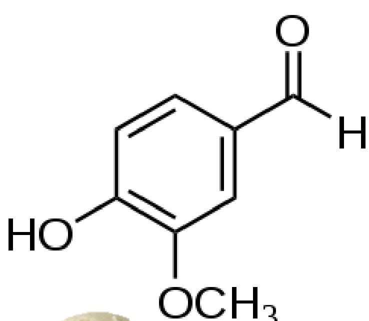
Benzene
- 3 double bonds
- 3 single bonds

… not exactly

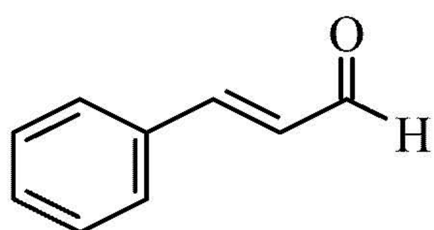




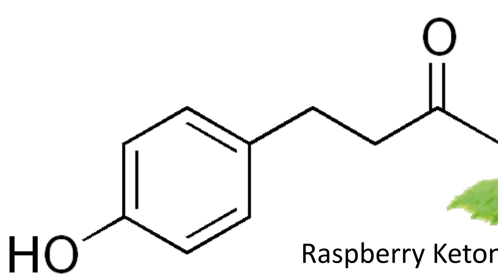
- Benzene is cyclic
- Electrons that form the double bonds are spread out and shared over the whole molecule
- Benzene has 6 identical bonds, each one half-way between a single and a double bond
- This type of electron sharing = aromatic



Vanillin



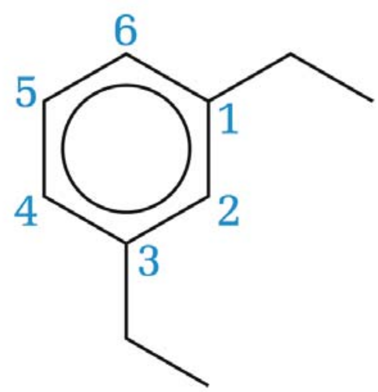
Cinnamaldehyde



Raspberry Ketone

Naming Aromatic Compounds

- Similar to naming cycloalkanes except the parent name is benzene



1,3-diethylbenzene

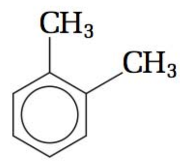
Priority Naming

Highest priority	$—OH$
	$—NH_2$
	$—F$, $—Cl$, $—Br$, $—I$
	$—CH_2CH_2CH_3$
	$—CH_2CH_3$
Lowest priority	$—CH_3$

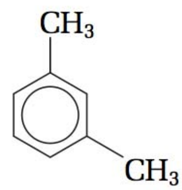
- If an organic compound as more than one alkyl group, number the main chain so that the most important branches have the lowest possible position number

Ortho-, Meta-, Para- Naming

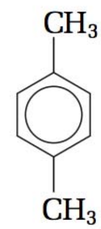
- Only used when a benzene ring has two branches



1,2-dimethylbenzene
ortho-dimethylbenzene
(common name:
ortho-xylene)



1,3-dimethylbenzene
meta-dimethylbenzene
(common name:
meta-xylene)



1,4-dimethylbenzene
para-dimethylbenzene
(common name:
para-xylene)

Checkpoint

Draw the following structural diagrams:

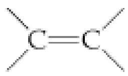
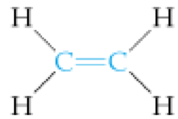
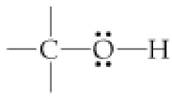
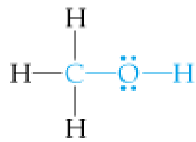
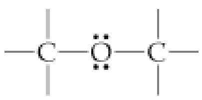
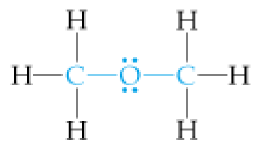
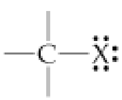
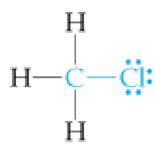
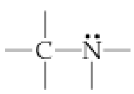
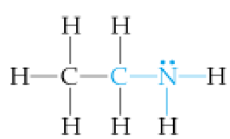
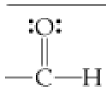
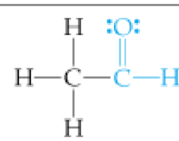
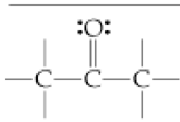
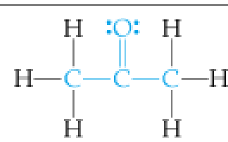
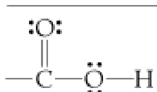
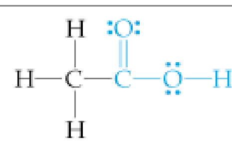
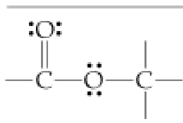
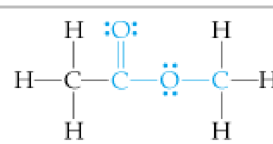
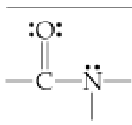
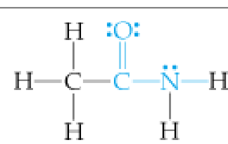
a) 2-ethyl-1,4-dimethylbenzene
b) Para-chlorofluorobenzene
c) 2-phenylbut-2-ene

Functional Groups

- Functional Groups – an atom or group of atoms within a molecule that has a characteristic chemical behavior and physical properties
- **The chemistry of an organic molecule, regardless of size and complexity, is largely determined by the functional groups it contains**

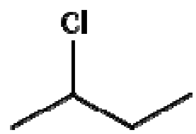
- Physical properties are determined by intermolecular forces
  - Hydrogen Bonding – strong interaction between H and O, N, F
  - Dipole-dipole interactions – interaction between polar molecules due to the attraction of partial charges
  - London Dispersion – interaction between all covalent molecules; strengthen as the size of the molecule increases

TABLE 25.4 Common Functional Groups in Organic Compounds

Functional Group	Type of Compound	Suffix or Prefix	Example	Systematic Name (common name)
	Alkene	*ene*		Ethene (Ethylene)
—C≡C—	Alkyne	*-yne*	H—C≡C—H	Ethyne (Acetylene)
	Alcohol	*-ol*		Methanol (Methyl alcohol)
	Ether	*ether*		Dimethyl ether
 (X = halogen)	Haloalkane	*halo-*		Chloromethane (Methyl chloride)
	Amine	*-amine*		Ethylamine
	Aldehyde	*-al*		Ethanal (Acetaldehyde)
	Ketone	*-one*		Propanone (Acetone)
	Carboxylic acid	*-oic acid*		Ethanoic acid (Acetic acid)
	Ester	*-oate*		Methyl ethanoate (Methyl acetate)
	Amide	*-amide*		Ethanamide (Acetamide)

Haloalkanes (Alkyl Halides)

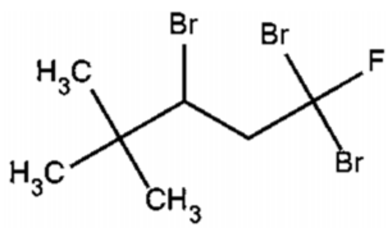
- Alkanes with halogens (F, Cl, Br, I) are named using prefixes: *fluoro-, chloro-, bromo-, iodo-*



2-chlorobutane

Draw: 2,2-dibromo-3-iodo-4-methylhexane

Name:



Alcohols

- An **alcohol** is an organic compound that contains the R-OH functional group.
- Depending on the position of the hydroxyl group, an alcohol can be *primary*, *secondary*, or *tertiary*.

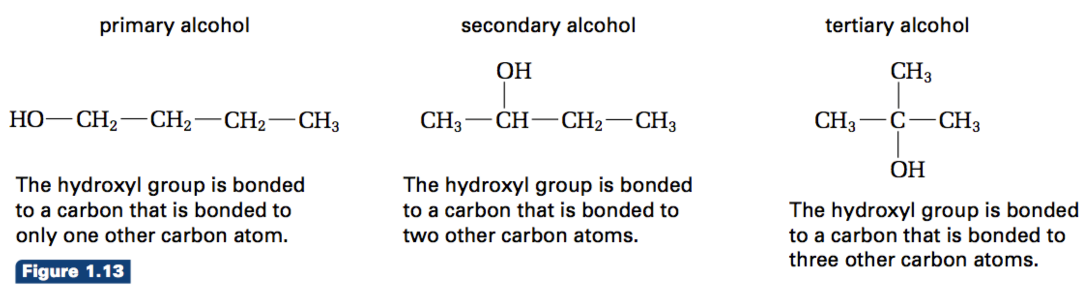
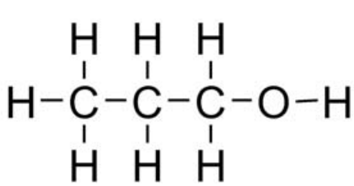


Table 1.6 Physical Properties of Alcohols

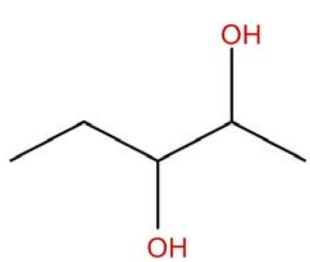
Polarity of functional group	The O—H bond is very polar. As the number of carbon atoms in an alcohol becomes larger, the alkyl group's non-polar nature becomes more important than the polar O—H bond. Therefore small alcohols are more polar than alcohols with large hydrocarbon portions.
Hydrogen bonding	Alcohols experience hydrogen bonding with other alcohol molecules and with water.
Solubility in water	The capacity of alcohols for hydrogen bonding makes them extremely soluble in water. Methanol and ethanol are *miscible* (infinitely soluble) with water. The solubility of an alcohol decreases as the number of carbon atoms increases.
Melting and boiling points	Due to the strength of the hydrogen bonding, most alcohols have higher melting and boiling points than alkanes with the same number of carbon atoms. Most alcohols are liquids at room temperature.

Naming Alcohols

1) Follows the same rules as naming alkanes. Replace the –*e* on the alkane to an –*ol*
   – Ex: Ethane → Ethanol; Butane → Butanol
2) When numbering, give the alcohol the lowest number possible.



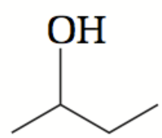
propanol

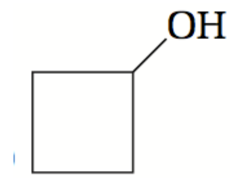


Pentane-2,3-diol

Checkpoint

Name the following and classify as primary, secondary or tertiary:



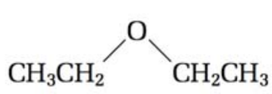


Draw the following:

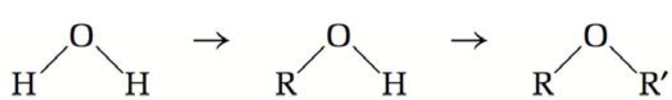
a) 3-ethyl-4-methyl-1-octanol
b) 2,4-dimethyl-1-cyclopentanol
c) Butane-2,2-diol

Ethers

- R-O-R’ pattern where R and R’ are hydrocarbons
- Common used in anesthetics
- Alcohols and ethers can be considered derivatives of water



ethoxyethane
(common name:
diethyl ether)



water alcohol ether

Table 1.7 Physical Properties of Ethers

Polarity of functional group	The bent shape around the oxygen atom in an ether means that the two C—O dipoles do not counteract each other. Because a C—O bond is less polar than an O—H bond, an ether is less polar than an alcohol.
Hydrogen bonding	Because there is no O—H bond in an ether, hydrogen bonding does not occur between ether molecules. Ethers can accept hydrogen bonding from water molecules.
Solubility in water	Ethers are usually soluble in water. The solubility of an ether decreases as the size of the alkyl groups increases.
Melting and boiling points	The boiling points of ethers are much lower than the boiling points of alcohols with the same number of carbon atoms.

Naming Ethers

IUPAC Name

1) Choose the longest alkyl group as the parent alkane.
2) Treat the second alkyl group as an alkoxy group by changing from *–yl* to *–oxy*
3) Put the two together: Alkoxy alkane

Common Name

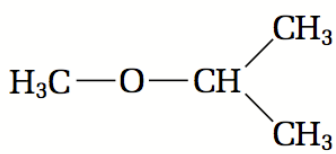
1) List the alkyl groups attached to the oxygen atom in alphabetical order
2) Add ether to the end of both alkyl groups

Checkpoint

Give the IUPAC name and the common name for the following:

(a) $H_3C—O—CH_3$

(c) $CH_3—CH_2—CH_2—CH_2—O—CH_3$

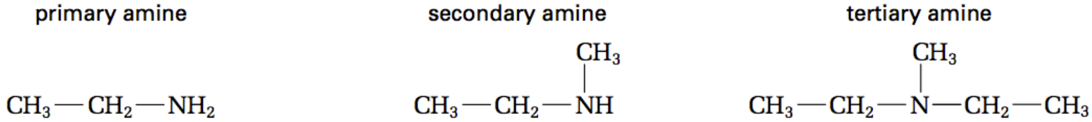
(b) 

Draw: 3-ethoxy-4-methylheptane

Amines

- R-NR'$_2$, where N is the nitrogen atom and R refers to the alkyl group
- Depending on how many alkyl groups are attached to the N, you can have *primary, secondary* and *tertiary* amines

primary amine | secondary amine | tertiary amine



A primary amine has one alkyl group and two hydrogen atoms attached to the nitrogen.

A secondary amine has two alkyl groups and one hydrogen atom attached to the nitrogen.

A tertiary amine has three alkyl groups attached to the nitrogen atom.

Figure 1.16

Naming Amines

- **Amines** – Name the longest hydrocarbon chain and change the *–e* on the alkane to *–amine*

$CH_3—CH_2—NH_2$
ethanamine

$$\begin{array}{c} NH_2 \\ | \\ CH_3—CH—CH_3 \end{array}$$
2-propanamine

- For secondary or tertiary amine, the longest alkane chain is numbered; each alkyl group bonded to the N atom is named as a *N-alkyl* group

$$\begin{array}{ccccccccc} CH_3 & — & CH_2 & — & CH_2 & — & NH & — & CH_3 \\ 3 & & 2 & & 1 & & & & \end{array}$$
N-Methyl-1-propanamine

$$\begin{array}{ccccccc} & & HN—CH_3 & & & & \\ & & | & & & & \\ CH_3 & — & CH & — & CH_2 & — & CH_3 \\ 1 & & 2 & & 3 & & 4 \end{array}$$
N-Methyl-2-butanamine

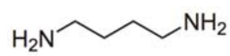
Table 1.8 Physical Properties of Amines

Polarity of functional group	C—N and N—H bonds are polar. Thus, amines are usually polar.
Hydrogen bonding	The presence of one or more N—H bonds allows hydrogen bonding to take place.
Solubility in water	Because of hydrogen bonding, amines with low molecular masses (four or less carbon atoms) are completely miscible with water. The solubility of an amine decreases as the number of carbon atoms increases.
Melting and boiling points	The boiling points of primary and secondary amines (which contain N—H bonds) are higher than the boiling points of tertiary amines (which do not contain an N—H bond). The higher boiling points are due to hydrogen bonding between amine molecules.

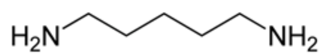
“Eau de Death”

- Chemist, Dr. Raychelle Burks from Nebraska designs a perfume with notes of rotting flesh
- Features 3 chemical compounds:

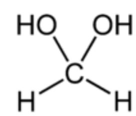
Putrescine



Cadaverine



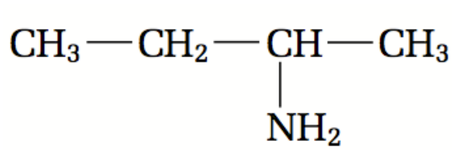
Methanethiol

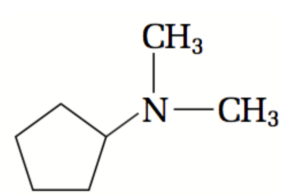


- Purpose: To act as a zombie-repellant

Checkpoint

Name the following and classify as primary, secondary or tertiary





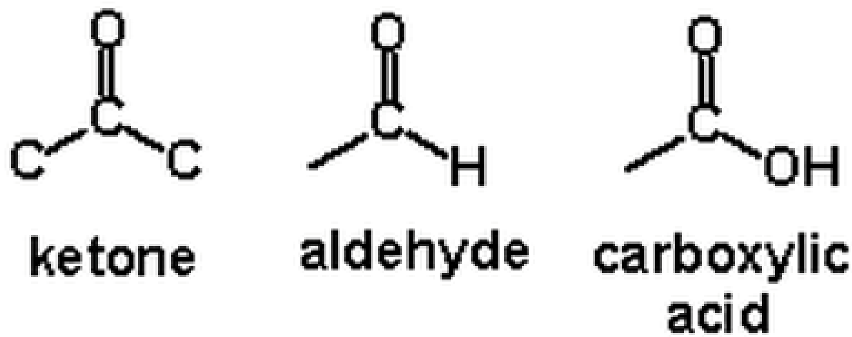
Draw a condensed structural diagram for:

a) N-methyl-1-butanamine

b) N,N-diethyl-3-heptanamine

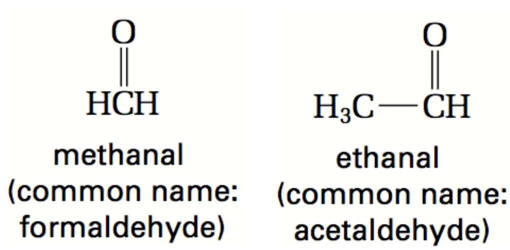
Carbonyl Groups

- A carbonyl group is a carbon double-bonded to an oxygen; C=O



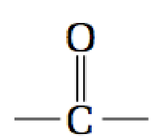
Aldehydes and Ketones

- Aldehydes: R-CHO



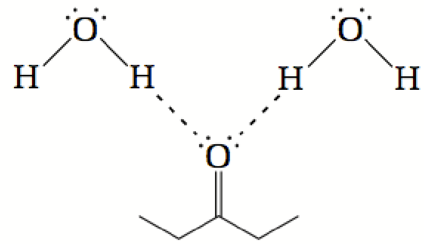
- Name the parent alkane. Give the aldehyde group position #1. Replace *–e* with *–al.* Ex: Butane → Butanal

- Ketones: R-CO-R'



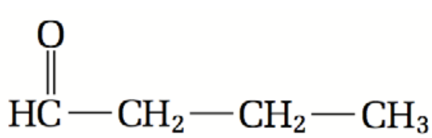
- Name the parent alkane. Give priority to the carbonyl group and replace *–e* with *–one.* Ex: Butane → Butanone

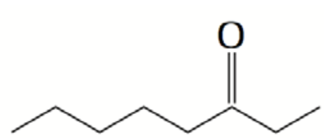
Table 1.9 Physical Properties of Aldehydes and Ketones

Polarity of functional group	The C=O bond is polar, so aldehydes and ketones are usually polar.
Hydrogen bonding	Hydrogen bonding cannot occur between molecules of these compounds, since there is no O—H bond. The oxygen atom, however, can accept hydrogen bonds from water, as shown here. 
Solubility in water	Aldehydes and ketones with low molecular masses are very soluble in water. Aldehydes and ketones with a large non-polar hydrocarbon part are less soluble in water.
Melting and boiling points	The boiling points of aldehydes and ketones are lower than the boiling points of the corresponding alcohols. They are higher than the boiling points of the corresponding alkanes.

Checkpoint

Name the following compounds:

(a) 

(b) 

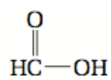
Draw a condensed structural diagram for:

a) 4-ethyl-3,5-dimethyloctanal

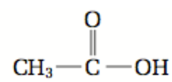
b) cyclohexanone

Carboxylic Acids

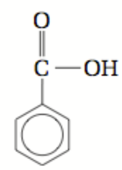
- R-COOH
- Polar compounds; undergo H-bonding
- Acidic because terminal H can be donated



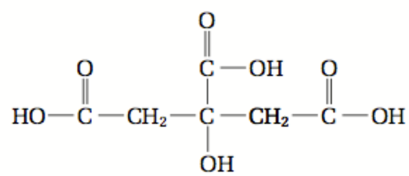
methanoic acid (common name: formic acid)



ethanoic acid (common name: acetic acid)

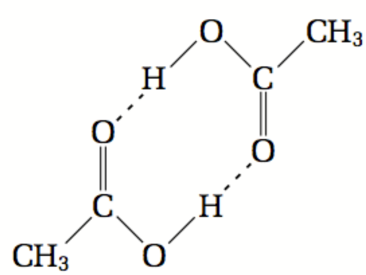


benzoic acid



citric acid

Table 1.12 Physical Properties of Carboxylic Acids

Polarity of functional group	Due to the presence of the polar O−H and C=O bonds, carboxylic acids are polar compounds.
Hydrogen bonding	The hydrogen bonding between carboxylic acid molecules is strong, as shown here: Hydrogen bonding also occurs between carboxylic acid molecules and water molecules. 
Solubility in water	Carboxylic acids with low molecular masses are very soluble in water. The first four simple carboxylic acids (methanoic acid, ethanoic acid, propanoic acid, and butanoic acid) are miscible with water. Like alcohols, ketones, and aldehydes, the solubility of carboxylic acids in water decreases as the number of carbon atoms increases.
Melting and boiling points	Because of the strong hydrogen bonds between molecules, the melting and boiling points of carboxylic acids are very high.

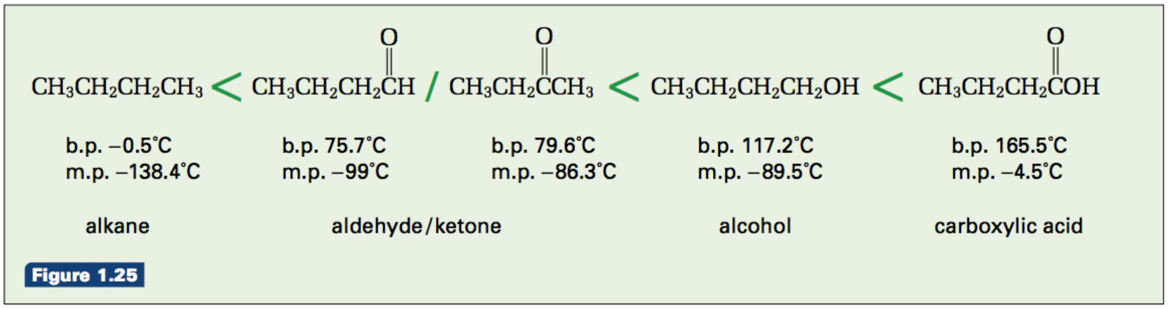


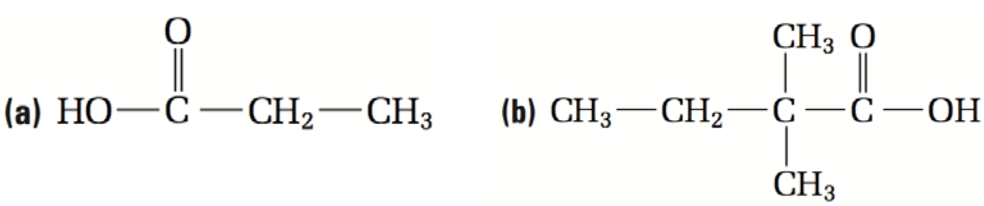
Figure 1.25

Naming Carboxylic Acids

- Name the parent alkane. Give the carboxylic acid group position #1. Replace *–e* with *–oic acid.* Ex: Butane → Butanoic Acid

Checkpoint

Name the following compounds:



Draw line structural diagrams for:

a) 3-propyloctanoic acid

b) 3,4-diethyl-2,3,5-trimethylheptanoic acid

Esters

- R-COOR' – a derivative of carboxylic acids
- Product of a carboxylic acid and a primary alcohol in a condensation reaction

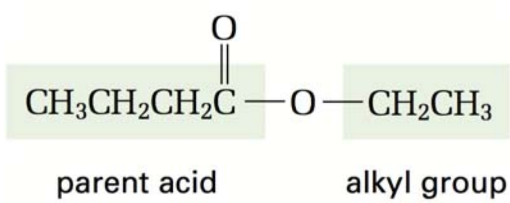
$$\underset{\text{carboxylic acid}}{CH_3CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}-OH} + \underset{\text{alcohol}}{HO-CH_2CH_3} \rightarrow \underset{\text{ester}}{CH_3CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_2CH_3} + \underset{\text{water}}{H_2O}$$

Table 1.13 Physical Properties of Esters

Polarity of functional group	Like carboxylic acids, esters are usually polar molecules.
Hydrogen bonding	Esters do not have an O–H bond. Therefore, they cannot form hydrogen bonds with other ester molecules.
Solubility in water	Esters can accept hydrogen bonds from water. Therefore, esters with very low molecular masses are soluble in water. Esters with carbon chains that are longer than three or four carbons are not soluble in water.
Melting and boiling points	Because esters cannot form hydrogen bonds, they have low boiling points. They are usually volatile liquids at room temperature.

Naming Esters

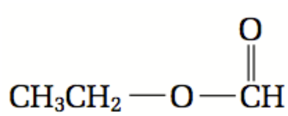
1. Identify the main part of the ester containing the C=O group. This is the parent chain.
2. Change the ending to *–oate*
3. The alkyl group after the O is named as normal
4. Put the names together in two words

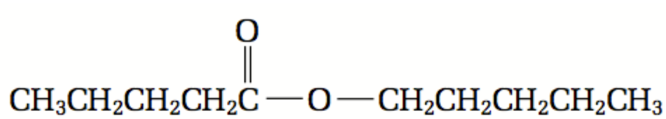


Ethyl butanoate

 Checkpoint 

Name the following compounds:





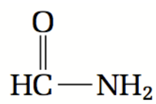
Draw condensed structural diagrams for:

a) Methyl pentanoate

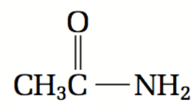
b) Ethyl 3,3-dimethylbutanoate

Amides

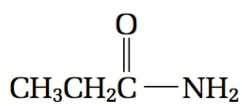
- R-CO-NR_2 – a derivative of carboxylic acids
- Product of a carboxylic acid with ammonia or an amine



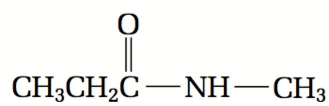
methanamide



ethanamide



propanamide



N-methylpropanamide

Table 1.14 Physical Properties of Amides

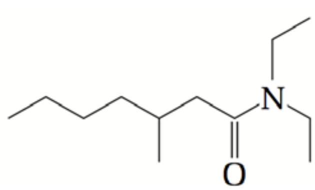
Polarity of functional group	Because the nitrogen atom attracts electrons more strongly than carbon or hydrogen atoms, the C−N and N−H bonds are polar. As a result, the physical properties of amides are similar to the physical properties of carboxylic acids.
Hydrogen bonding	Because primary amides have two N−H bonds, they have even stronger hydrogen bonds than carboxylic acids. Secondary amides also experience hydrogen bonding.
Solubility in water	Amides are soluble in water. Their solubility decreases as the non-polar hydrocarbon part of the molecule increases in size.
Melting and boiling points	Primary amides have much higher melting and boiling points than carboxylic acids. Many simple amides are solid at room temperature.

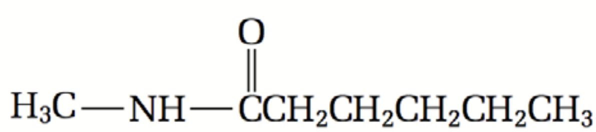
Naming Amides

- Identify the main part of the ester containing the C=O group. This is the parent acid.
- Change the ending to *–amide*
- Decide if primary, secondary or tertiary
  - – Primary: only hydrogens attached to the N
  - – Secondary: one alkyl group attached to the N; use the prefix N-
  - – Tertiary: two alkyl groups attached to the N; use the prefix N,N-

Checkpoint

Name the following compounds:





Draw line structural diagrams for:

a) N-ethyl-N-propylpropanamide

b) N-ethyl-2,4,6-trimethyldecanamide