



Classifying Hydrocarbons

- alkanes- single C-C bonds, if all C's have H's attached, molecules are called **saturated** hydrocarbons *max # C-H*
- alkenes- have one or more C=C **double** bonds
- alkynes- have one or more C≡C **triple** bonds
- alkenes & alkynes are called **unsaturated** hydrocarbons because they have **fewer** than the maximum possible number of H atoms
- can form either a straight chain or a **cyclic** (ring) structure
- hydrocarbons which are attached to the main structure are called **alkyl** groups and are named according to the number of carbons

Table 2 Alkanes and Related Alkyl Groups

Prefix	IUPAC name	Formula	Alkyl group	Alkyl formula
meth-	methane	CH _{4(g)}	methyl-	-CH ₃
eth-	ethane	C ₂ H _{6(g)}	ethyl-	-C ₂ H ₅
prop-	propane	C ₃ H _{8(g)}	propyl-	-C ₃ H ₇
but-	butane	C ₄ H _{10(g)}	butyl-	-C ₄ H ₉
pent-	pentane	C ₅ H _{12(l)}	pentyl-	-C ₅ H ₁₁
hex-	hexane	C ₆ H _{14(l)}	hexyl-	-C ₆ H ₁₃
hept-	heptane	C ₇ H _{16(l)}	heptyl-	-C ₇ H ₁₅
oct-	octane	C ₈ H _{18(l)}	octyl-	-C ₈ H ₁₇
non-	nonane	C ₉ H _{20(l)}	nonyl-	-C ₉ H ₁₉
dec-	decane	C ₁₀ H _{22(l)}	decyl-	-C ₁₀ H ₂₁

- a 4th group are the **aromatic** hydrocarbons which have a unique ring structure
- simplest is **benzene** and all others are derivatives of benzene

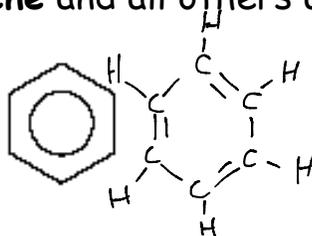


Figure 2

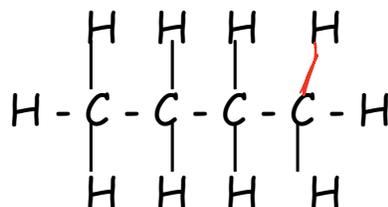
Benzene, C₆H₆, is colourless, flammable, toxic, and carcinogenic, and has a pleasant odour. Its melting point is 5.5°C and its boiling point 80.1°C. It is widely used in the manufacture of plastics, dyes, synthetic rubber, and drugs.

Drawing Hydrocarbons

Four types of diagrams can be used to represent the structure of a hydrocarbon: e.g. butane

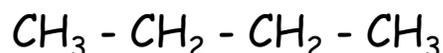
1) Complete Structural Diagram

Shows all the atoms in a structure and the way they are bonded together.



2) Condensed Structural Diagram

Shows the bonds between carbon atoms, not the bonds between carbon and hydrogen atoms.



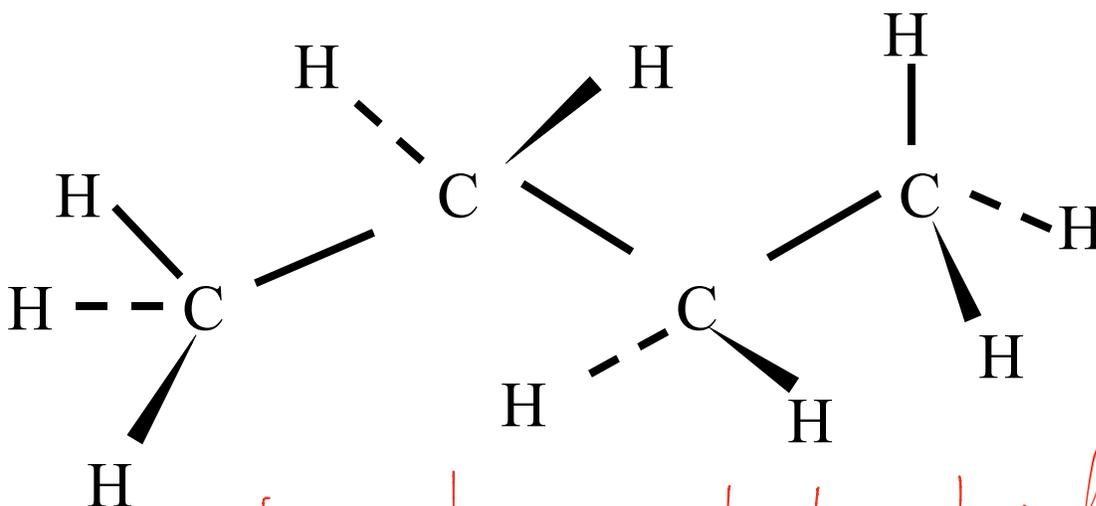
3) Line Structure Diagram

The end of each line, and the points at which the lines meet represent carbon atoms.



4) Three-Dimensional Structural Diagrams

Wedges are used to give the impression that an atom or group is coming out of the page. Dashed lines indicate an atom being pushed into the page.



main shape tetrahedral
109.5°

SUMMARY

Naming Branched Alkanes

- Step 1** Identify the longest carbon chain; note that structural diagrams can be deceiving—the longest chain may travel through one or more “branches” in the diagram.
- Step 2** Number the carbon atoms, starting with the end that is closest to the branch(es).
- Step 3** Name each branch and identify its location on the parent chain by the number of the carbon at the point of attachment. Note that the name with the lowest numerals for the branches is preferred. (This may require restarting your count from the other end of the longest chain.)
- Step 4** Write the complete IUPAC name, following this format: (number of location)-(branch name)(parent chain).
- Step 5** When more than one branch is present, the branches are listed either in alphabetical order or in order of complexity; in this book, we will follow the alphabetical order.
- Note:** When naming cyclic hydrocarbons, the carbon atoms that form the ring structure form the parent chain; the prefix *cyclo-* is added to the parent hydrocarbon name, and the naming of substituted groups is the same as for noncyclic compounds.

Note: When naming propyl & butyl groups we have to consider how these groups attach onto the parent chain
i.e. when an alkyl group has 3 or more C atoms the group can attach either at an end C atom or at a middle C atom (see Fig.4 & 5)

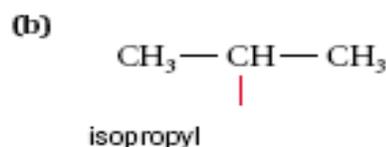
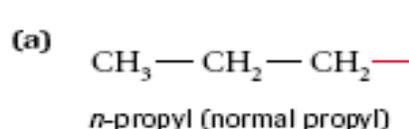


Figure 4
Two isomers of the propyl group. The coloured bond indicates where the group is attached to the larger molecule.

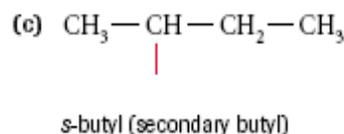
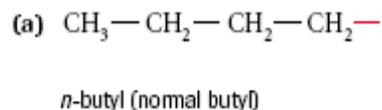
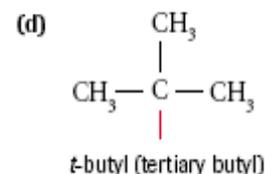
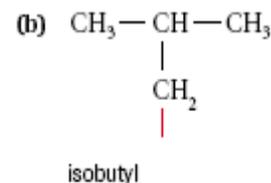


Figure 5
Four isomers of the butyl group



Physical Properties	Chemical Properties
<p>← (—C—C—C—C—C)</p> <ul style="list-style-type: none"> • Relatively low mp and bp that ↑ as length of molecule ↑ . • Branched chains have a ↓ bp than a straight chain of same length. • Molecules are non-polar and attracted by dispersion forces • Insoluble in water (non-polar). 	<ul style="list-style-type: none"> • Relatively low reactivity but will undergo: <ol style="list-style-type: none"> combustion reactions. substitution reactions. (e.g. sub. H for a halogen) cracking reactions which produce smaller chained alkanes.

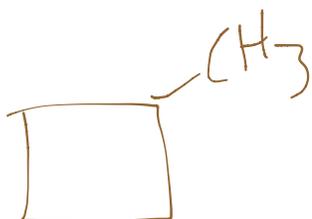
Cycloalkanes are isomers of **alkenes** (C_nH_{2n}). They occur when two ends of a hydrocarbon chain are joined together with the removal of two H atoms.

e.g. cyclohexane

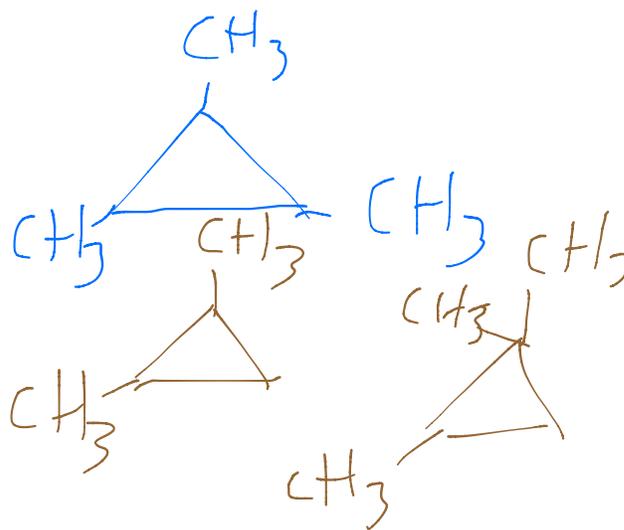


Draw condensed structural formulas for the following:

a) methylcyclobutane



b) 1,2,3-trimethyl cyclopropane



Alkenes (unsaturated hydrocarbons)

Aliphatic hydrocarbons with molecules containing at least 1 carbon to carbon **double** bond with an open (non-cyclic) structure.

The simplest alkene is **ethene** $C_2H_4(g)$

SUMMARY

Naming Alkenes and Alkynes

- Step 1.** The parent chain must be an alkene or alkyne, and thus must contain the multiple bond.
- Step 2.** When numbering the C atoms in the parent chain, begin with the end closest to the multiple bond.
- Step 3.** The location of the multiple bond is indicated by the number of the C atom that begins the multiple bond; for example, if a double bond is between the second and third C atoms of a pentene, it is named 2-pentene.
- Step 4.** The presence and location of multiple double bonds or triple bonds is indicated by the prefixes *di-*, *tri-*, etc.; for example, an octene with double bonds at the second, fourth, and sixth C atoms is named 2,4,6-octatriene.

All have the general formula C_nH_{2n} ($n = C$ atoms)

1. Draw expanded structural formulas for the following:

a) 3-methyl-1-pentene

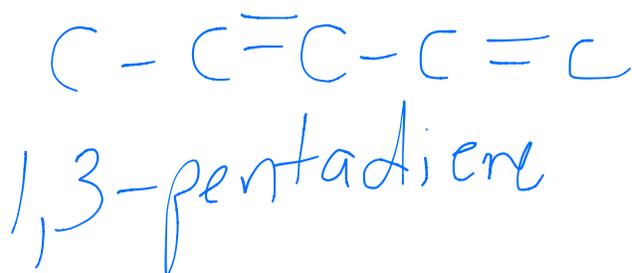
b) 2-methyl-1,3-pentadiene



2. Draw the following as expanded formulas and correct the following names:

a) 2,4-pentadiene

b) 3-chloro-1,3-butadiene



Physical Properties	Chemical Properties
<ul style="list-style-type: none"> • Bp usually less than a similar sized alkane • Insoluble in water (non-polar). 	<ul style="list-style-type: none"> • Reactive, undergoing the following reactions: <ol style="list-style-type: none"> i) combustion . ii) addition (e.g. add a halogen or H atom. iii) polymerization. • Can be prepared by dehydration from an alcohol.

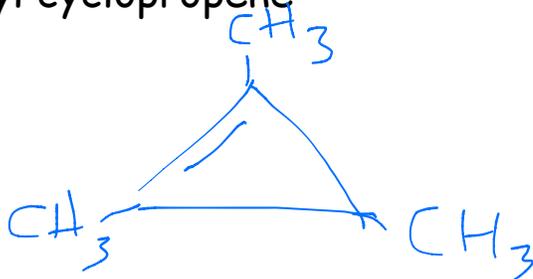
Cycloalkenes are isomers of **alkynes** (C_nH_{2n-2})

e.g. Cyclohexene



Draw condensed structural formulas for the following:

a) 1,2,3-trimethyl cyclopropene



b) 1,1-dicyclopropyl-2-methyl-1-propene

Alkynes (unsaturated hydrocarbons)

Aliphatic hydrocarbons with molecules containing at least 1 carbon to carbon **triple** bond with an open (non-cyclic) structure.

The simplest alkyne is **ethyne** $C_2H_2(g)$



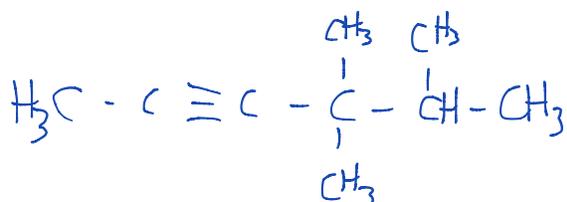
All have the general formula C_nH_{2n-2} ($n = C$ atoms)

Alkynes have chemical and physical properties very similar to alkenes.

1. Draw expanded structural formulas for the following:

a) 3-methyl-1-pentyne

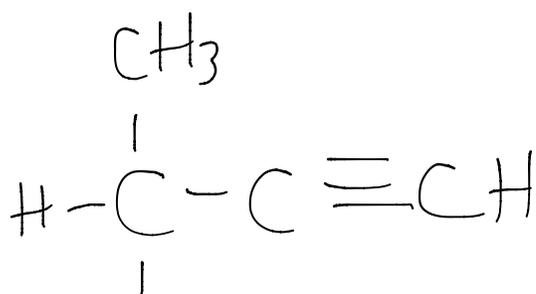
b) 4,4,5-trimethyl-2-hexyne



2. Draw the following and correct the following names:

a) 3,3-dimethyl-1-propyne

b) 2,2-diethyl-4-nonyne



CH_3 3-methyl-1-butyne

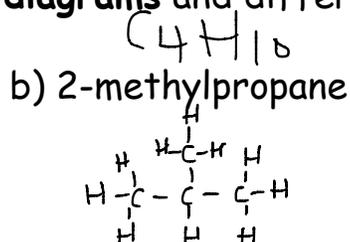
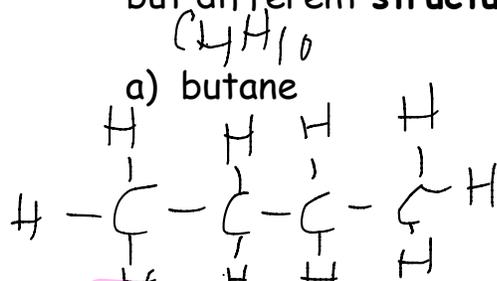
Isomers

*Molecules that have the same molecular formula but are arranged differently.

There are two main types of isomers:

i) Structural (Constitutional) Isomers

Structural isomers are chemicals with the same molecular formula but different **structural diagrams** and different names e.g.

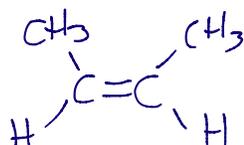


ii) Geometric (Stereoisomers) Isomers

Molecules that have the same molecular formula, bonded the same way but arranged differently in space.

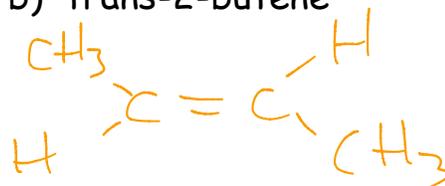
Diastereomers differ in structure only by the position of groups attached on either side of a carbon carbon **double bond** e.g.

a) cis-2-butene



both groups are on the **SAME** side of the structure

b) trans-2-butene

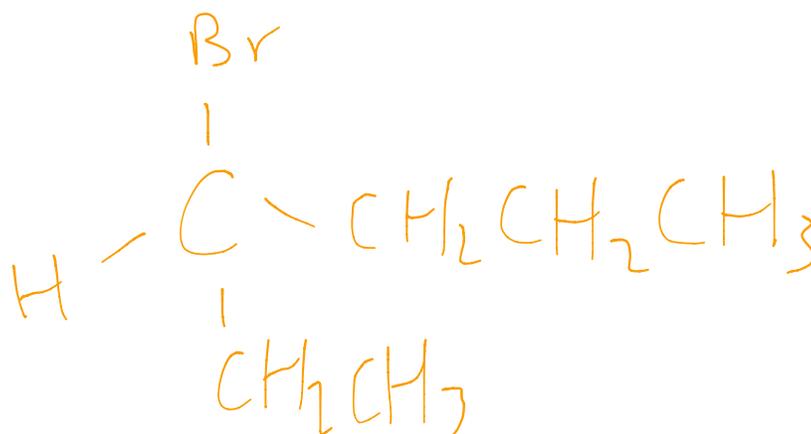


both groups are on the **OPPOSITE** side of molecular structure

Enantiomers

Stereoisomers in which molecules are mirror images of each other

a) bromo-chloro-fluoro-methane (**chiral** = **optically active**)



Chemical Reactions of Hydrocarbons

1) Chemical Reactions of Alkanes

- alkanes because of their C-C bonds are relatively **unreactive** due to their being **difficult** to break
- they do participate in **combustion** reactions, making them useful as fuels

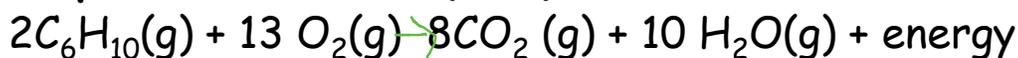
i) Cracking

large alkane + hydrogen gas → smaller alkane

ii) Reforming

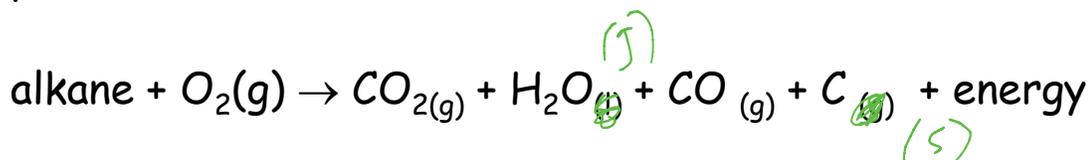
small alkane → larger alkane (or more branched) + hydrogen gas

iii) Complete Combustion (fast)



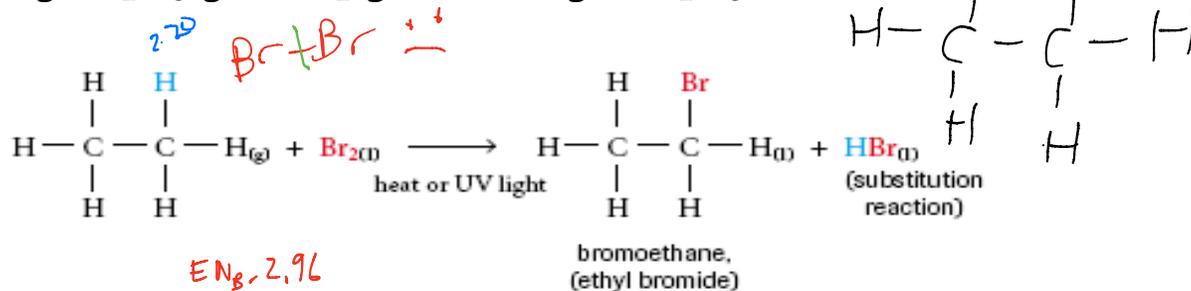
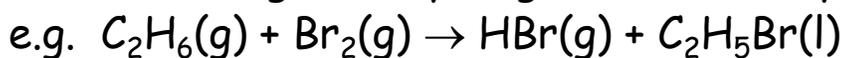
iv) Incomplete ~~Complete~~ Combustion (slow)

produces carbon and carbon monoxide



v) Substitution Reaction (slow)

Alkane + halogen → hydrogen halide + alkylhalide

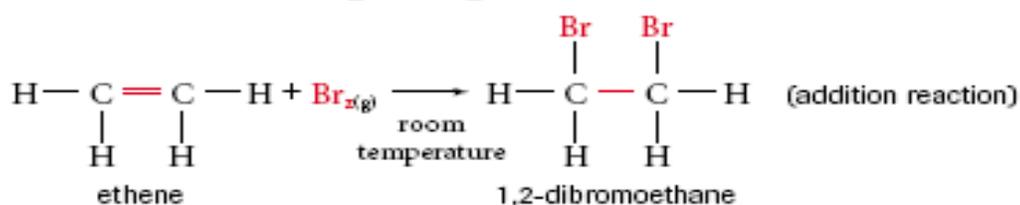


Adding more Br₂ can lead to substitution of another H atom.

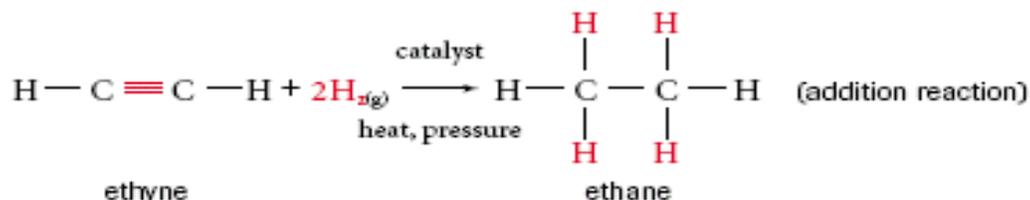
2) Chemical Reactions of Alkenes/Alkynes

- both exhibit **greater** reactivity than alkanes i.e. if reacted with Br₂ the reaction will be fast and will occur at room temperature
- both undergo a characteristic reaction called an **addition reaction**, where atoms are **added** to the molecule with no loss of H atoms
- addition reactions can involve halogens, H, hydrogen halides, and water, given the right conditions.

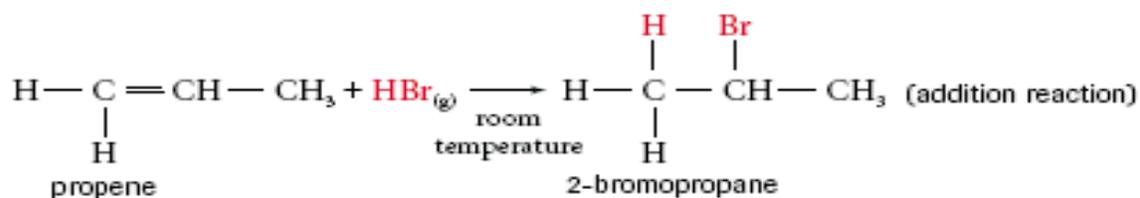
Halogenation (with Br₂ or Cl₂)



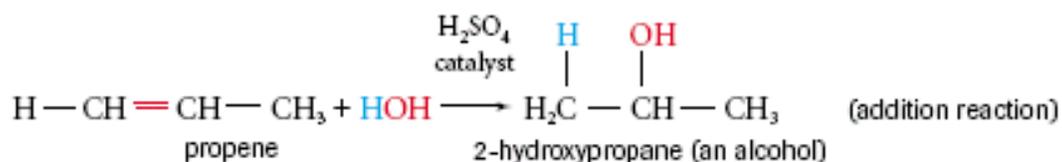
Hydrogenation (with H₂)



Hydrohalogenation (with hydrogen halides)



Hydration (with H₂O)



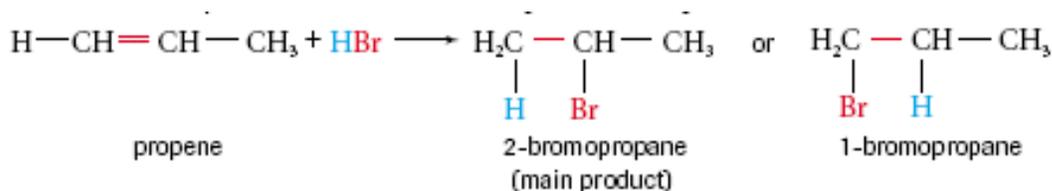
➤ common prefixes for functional groups include;

Table 2 Prefixes for Functional Groups

Functional group	Prefix
-F	fluoro
-Cl	chloro
-Br	bromo
-I	iodo
-OH	hydroxy
-NO ₂	nitro
-NH ₂	amino

➤ when molecules consisting of 2 identical atoms (H₂) are added to a double bond **only 1** possible product is formed, i.e a H atom gets added to each side of the double bond

➤ but when molecules of a **non-identical** atom is added, **2** different products may form e.g.

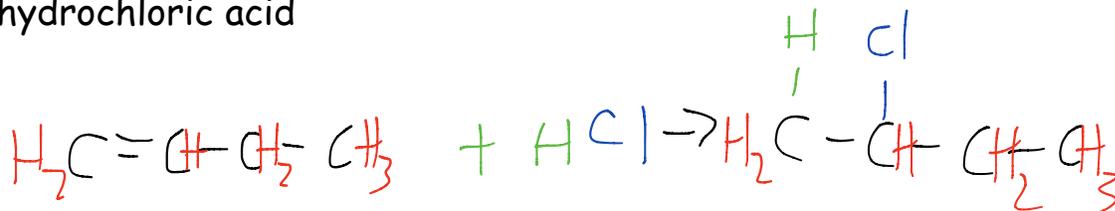


➤ experiments have shown that only one main product is formed which leads us to Markovnikov's Rule..."the rich get richer"

Markovnikov's Rule

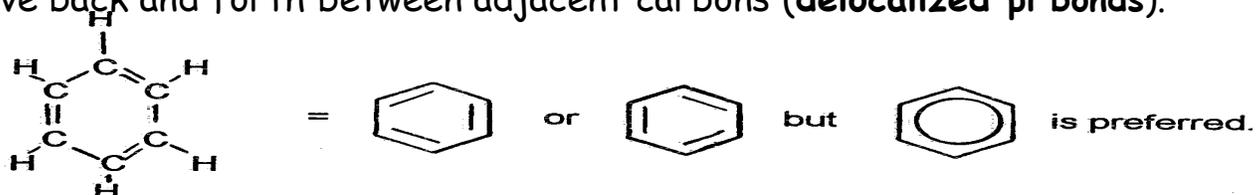
When a hydrogen halide or water is added to an alkene or alkyne, the hydrogen atom bonds to the carbon atom within the double bond that *already has more hydrogen atoms*. This rule may be remembered simply as "the rich get richer."

1. Draw the major product for the reaction between 1-butene and hydrochloric acid



Aromatic Hydrocarbons

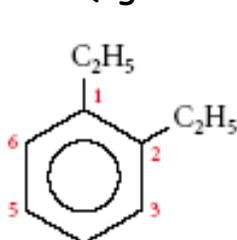
Benzene is a 6 C ring in which **alternating** carbon bonds **resonate** or move back and forth between adjacent carbons (**delocalized pi bonds**).



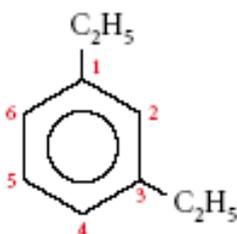
➤ benzene ring usually considered to be the parent chain and attached alkyl groups are the branches

➤ if a methyl group is attached, the molecule is called methylbenzene and we don't need to assign a number

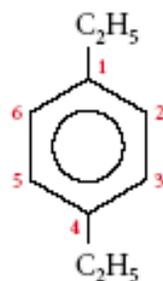
➤ when we have 2 or more alkyl groups attached we need to use numbers (again numbering so that we have the lowest numbers)



ortho-diethylbenzene
(a) 1,2-diethylbenzene



(b) 1,3-diethylbenzene



(c) 1,4-diethylbenzene

Note: a) also known as **ortho-** or o-diethylbenzene

b) also known as **meta-** or m-diethylenebenzene

c) also known as **para-** or p-diethylenebenzene

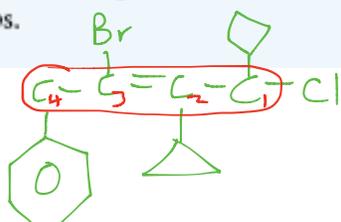
➤ when an aromatic molecule is too difficult to name sometimes we would consider the benzene ring as the attached branch and not the parent molecule

➤ when the benzene ring is the attached branch it is called a **phenyl** group e.g. 2-phenylbutane or s-butylbenzene

SUMMARY

Naming Aromatic Hydrocarbons

1. If an alkyl group is attached to a benzene ring, the compound is named as an alkylbenzene. Alternatively, the benzene ring may be considered as a branch of a large molecule; in this case, the benzene ring is called a phenyl group.
2. If more than one alkyl group is attached to a benzene ring, the groups are numbered using the lowest numbers possible, starting with one of the added groups.



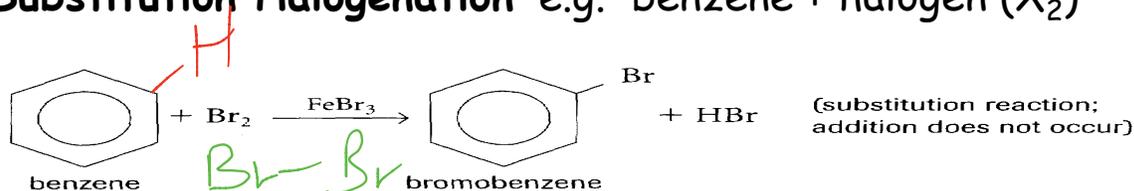
4-phenyl-1-cyclopropylbutane

3-bromo-1-cyclobutyl-1-chloro-2-butene

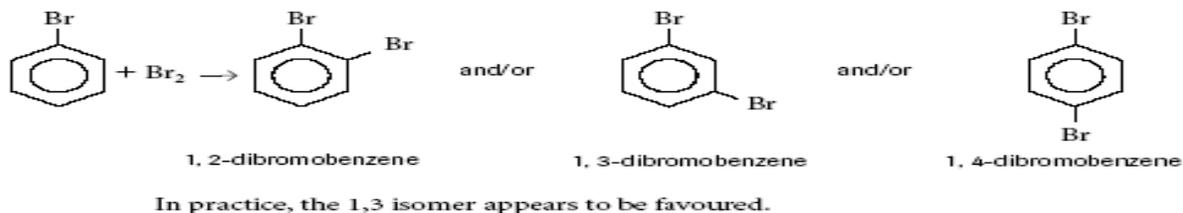
Chemical Reactions of Aromatics

- although aromatic hydrocarbons are unsaturated, they do **not** undergo addition reactions **except** under **extreme** conditions
- they do undergo **substitution** reactions and in fact the H atoms are more easily replaced than in alkanes
- the reactivity of aromatic hydrocarbons are in between the alkanes & alkenes
- Examples:

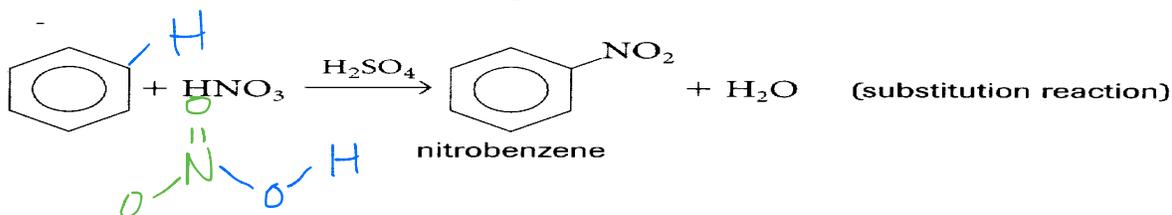
i) Substitution Halogenation e.g. benzene + halogen (X₂)



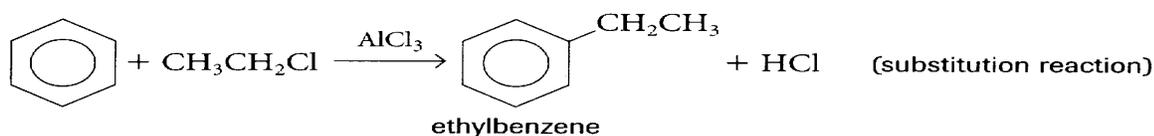
- in reaction (i) further reaction of bromobenzene with Br₂ results in substitution of another Br₂, resulting in 3 possible isomers of dibromobenzene



ii) Substitution Nitration e.g. benzene + nitric acid (HNO₃)



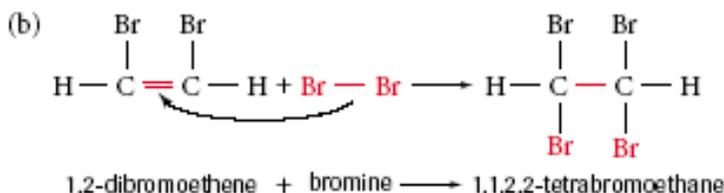
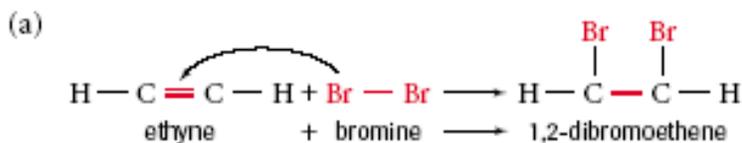
iii) Substitution Alkylation e.g. benzene + alkyl halide



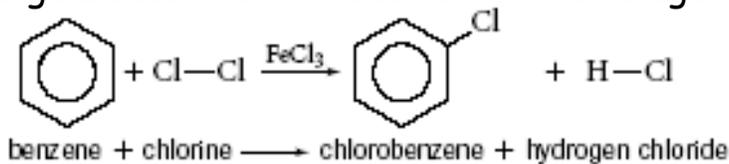
Preparing Organic Halides

➤ can be produced by halogenation reactions

- haloalkane
- alkyl halides

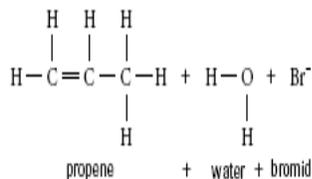
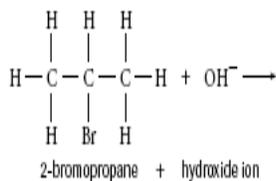


➤ similarly, if we wanted to produce a halide of a benzene ring, we would arrange a substitution reaction with a halogen



Preparing Alkenes from Alkyl Halides: Elimination Reactions

➤ alkyl halides can eliminate a H atom and a halogen atom from adjacent C atoms resulting in the formation of a double bond and therefore an alkene in an **elimination** reaction



SUMMARY

Organic Halides

Functional group: R-X

Preparation:

- alkenes and alkynes → organic halides
addition reactions with halogens or hydrogen halides
- alkanes and aromatics → organic halides
substitution reactions with halogens or hydrogen halides

Pathway to other groups:

- alkyl halides → alkenes
elimination reactions, removing hydrogen and halide ions

SUMMARY

Reactions of Hydrocarbons

- All hydrocarbons undergo combustion reactions with oxygen to produce carbon dioxide and water.

Alkanes

- Primarily undergo **substitution** reactions, with heat or UV light:
 - with halogens or hydrogen halides: halogenation
 - with nitric acid

Alkenes and Alkynes

- Primarily undergo **addition** reactions:
 - with H_2 : hydrogenation
 - with halogens or hydrogen halides: halogenation
 - with water: hydration

Aromatics

- Primarily undergo **substitution** reactions:
 - with X_2 : halogenation, $\text{C}_6\text{H}_5\text{-X}$
 - with HNO_3 : nitration, $\text{C}_6\text{H}_5\text{-NO}_2$
 - with RX : alkylation, $\text{C}_6\text{H}_5\text{-R}$
- Do *not* undergo addition reactions.

Functional Groups

➤ are used to identify compounds but also to explain properties like solubility, melting & boiling points, etc.

➤ there are many different functional groups but they contain one of 3 main components

i.e.

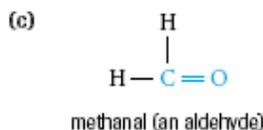
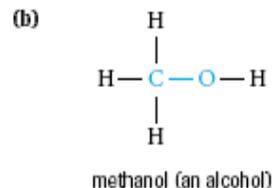
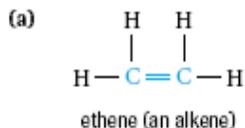
Figure 2

Examples of the three main components of functional groups:

(a) A double bond between two carbon atoms

(b) A single bond between carbon and a more electronegative atom (e.g., oxygen)

(c) A double bond between carbon and oxygen



Chapter 1

Carbon-Carbon Bonds

➤ C-C single bonds are strong covalent bonds and are **not** very reactive

➤ C=C and C≡C are more reactive and their 2nd and 3rd bonds are more **easily** broken

➤ this allows these parts of a compound to be the **sites** where reactions occur

Single Bonds Between C & more Electronegative Bonds

➤ where there is an unequal attraction of the electrons the bond is **polar** e.g. between C and a more electronegative atom

➤ the C atom becomes more **+ve** and the O, N or halogen atom is more **-ve**

➤ an increase in **polarity** increases **intermolecular forces** which in turn increases the melting & boiling points

➤ O-H and N-H bonds form bonds with special properties and they can form **H-bonds** with other OH groups, they increase intermolecular attractions but also enables these molecules to **dissolve** in polar solutes & solvents

➤ "like dissolves like"

polar solute dissolves in polar solvent
non-polar " " non-polar solvent

Double Bonded Carbon & Oxygen

➤ this double covalent bond has 4 electrons being shared with ALL 4 electrons being more strongly attracted to the O atom

➤ this bond is **very** polar with an accompanying increase in melting & boiling points and increased solubility in polar solvents



SUMMARY

Three Main Components of Functional Groups

Multiple bonds between C atoms

$-C=C-$ Unlike single $C-C$ bonds, double and triple bonds allow atoms to be added to the chain.
 $-C\equiv C-$

C atom bonded to a more electronegative atom (O, N, halogen)

$C-O$ Unequal sharing of electrons results in polar bonds, increasing intermolecular attraction, and raising boiling and melting points.
 $C-N$
 $C-Cl, C-Br, C-F$

$C-OH$ or These groups enable hydrogen bonding, increasing solubility in polar substances.
 $C-NH-$

C atom double-bonded to an O atom

$C=O$ The resulting polar bond increases boiling point and melting point.

Alcohols R-OH

Consists of a "hydroxyl group" (OH) attached to a carbon atom.

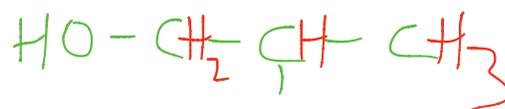
The rules:

- Name the longest carbon chain using the appropriate prefix (meth, eth, but, etc.)
- Add the suffix "ol" to the end of the name. Use diol, triol etc. if the chain has more than one hydroxyl groups.
- The OH group takes priority over alkyl side chains and double or triple bonds when numbering

1. Draw the following:

a) 3-methyl-1-butanol

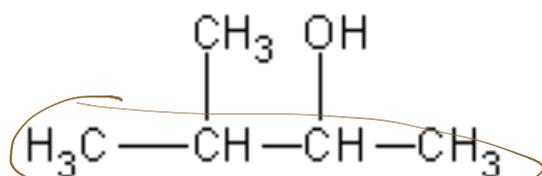
b) 1,2-propanediol



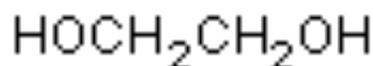
2. Name the following:

a)

b)



3-methyl-2-butanol

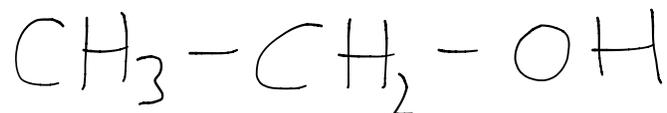


1,2-ethanediol

Classification of Alcohols

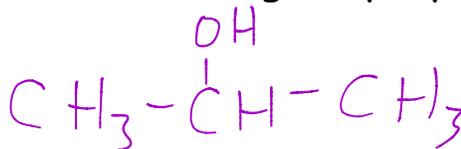
a) Primary Alcohols

The carbon to which the -OH is attached is in turn attached directly to one other carbon atom. e.g. ethanol



b) Secondary Alcohols

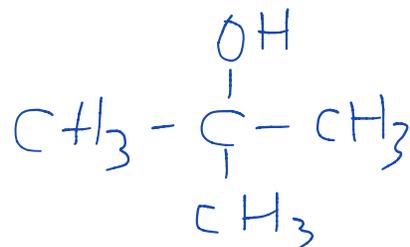
The carbon to which the -OH is attached is in turn attached directly to 2 other carbon atoms. e.g. 2-propanol



c) Tertiary Alcohols

The carbon to which the -OH is attached is in turn attached directly to 3 other carbon atoms.

e.g. 2-methyl-2-propanol



d) Polyhydroxy Alcohols

i) dihydroxy-contain 2 hydroxyl groups in the same molecule on different carbons.

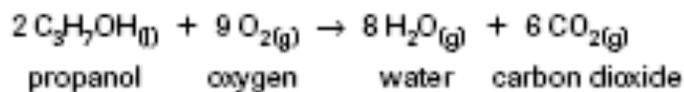
e.g. 1,2-ethanediol

ii) trihydroxy-contain 3 hydroxyl groups in the same molecule on different carbon atoms.

e.g. 1,2,3-propanetriol

Chemical Reactions of Alcohols

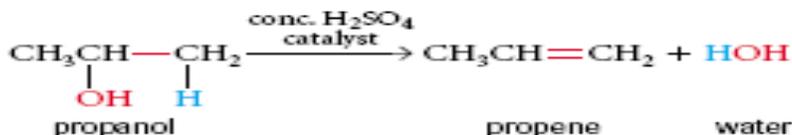
i) Combustion of alcohols e.g. alcohol + oxygen



ii) Substitution Hydrohalogenation e.g. alcohol + halogen acid (HX)



iii) Elimination e.g. alcohol (in the presence of H₂SO₄)



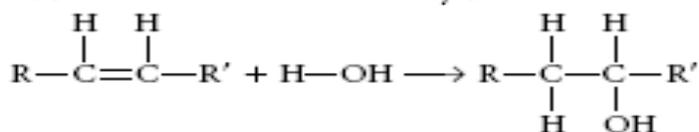
SUMMARY

Alcohols

Functional group: -OH, hydroxyl group

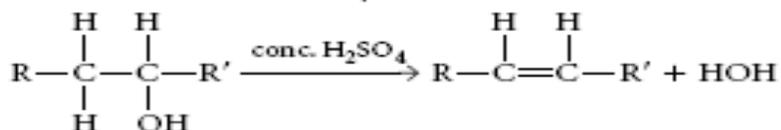
Preparation:

- alkenes → alcohols
addition reaction with water: hydration



Pathways to other groups:

- alcohols → alkenes
elimination reaction: dehydration



- alcohols → aldehydes → carboxylic acids (see Sections 1.6, 1.7)
controlled oxidation reaction

Aldehydes



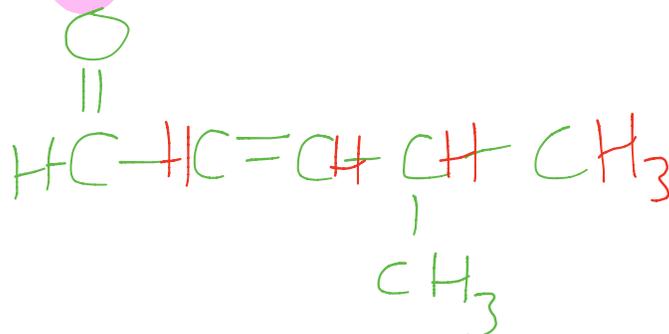
Consist of a "carbonyl group" attached to a hydrogen at the end of a hydrocarbon chain. The rules:

- Name the longest carbon chain using the appropriate prefix and add the suffix "al" to the end of the name.
- Always give the carbon atom of the carbonyl group position #1.

1. Draw the following:

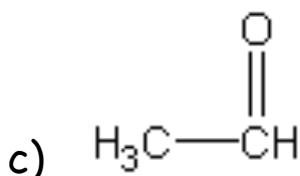
a) 2-methylpropanal

b) 4-methyl-2-pentenal

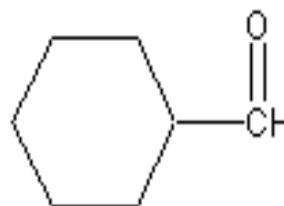


2. Name the following:

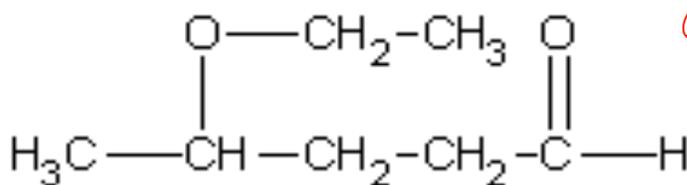
a)



b)



cyclohexylmethanal



Ketones $R-CO-R'$



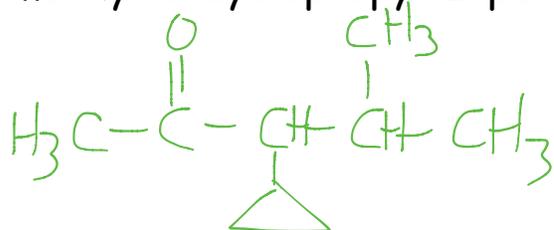
Contains a "carbonyl group" attached between 2 carbon atoms. The rules:

- Name the longest carbon chain with the carbonyl group using the appropriate prefix and add the suffix "one" to the end of the name.
- If the carbon chain is more than 4 carbons indicate the position number of the carbonyl group so that it has the lowest number.
- If there is more than one carbonyl group add the suffix dione (2) or trione (3)

1. Draw the following:

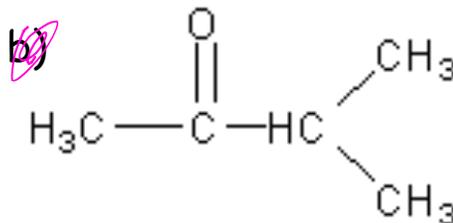
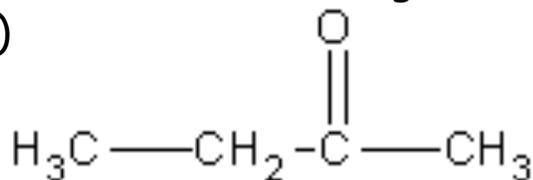
a) 4-methyl-2-pentanone

b) 4-methyl-3-cyclopropyl-2-pentanone



2. Name the following:

a)



3-methylbutanone

Properties of Aldehydes & Ketones

- aldehydes & ketones have lower boiling points than analogous alcohols and are **less** soluble in water as they don't have OH groups and **don't** participate in H bonding *dipole-dipole*
- **C=O** is a strongly polar group so that they are **both** more soluble in water than are hydrocarbons
- Are good solvents because they will mix with **both** polar and non-polar substances

Table 1 Boiling Points of Analogous Compounds

Compound	Structure	Boiling point (°C)
ethanol	CH ₃ CH ₂ OH	78
ethanal	CH ₃ CHO	21
1-propanol	CH ₃ CH ₂ CH ₂ OH	97
propanal	CH ₃ CH ₂ CHO	49
propanone	CH ₃ COCH ₃	56
1-butanol	CH ₃ CH ₂ CH ₂ CH ₂ OH	118
butanal	CH ₃ CH ₂ CH ₂ CHO	75
butanone	CH ₃ CH ₂ COCH ₃	80

Chemical Reactions of Aldehydes and Ketones

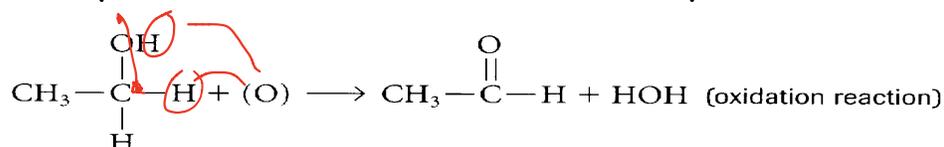
A) Preparing Aldehydes and Ketones

Aldehydes and ketones can be prepared by the controlled oxidation of alcohols.

In organic chemistry the term "oxidation" generally implies the **gain** of O atoms or the loss of H atoms. Another clue is when carbon atoms forms more bonds to O atoms or less bonds to H atoms.

Oxidation Reactions

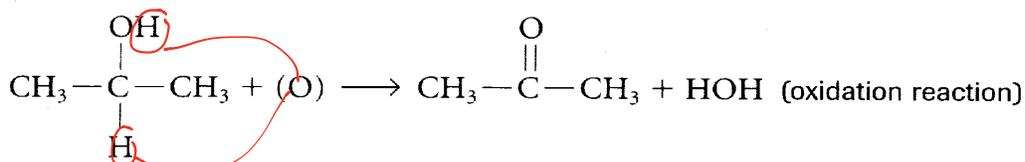
primary alcohol + oxidizer \rightarrow aldehyde



ethanol (1° alcohol)

ethanal

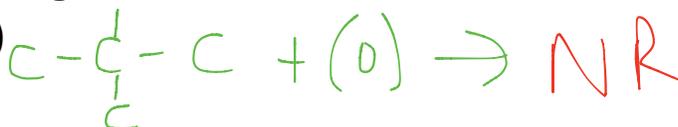
secondary alcohol + oxidizer \rightarrow ketone



2-propanol
(2° alcohol)

propanone

tertiary alcohol undergoes no reaction (no H atom available on central C atom)



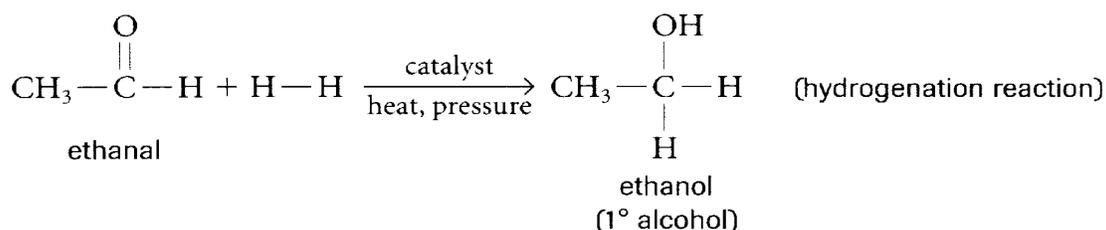
C) tertiary alcohol (oxidizer) \rightarrow no reaction (no H atom available on central C atom)

Arthur
3d!

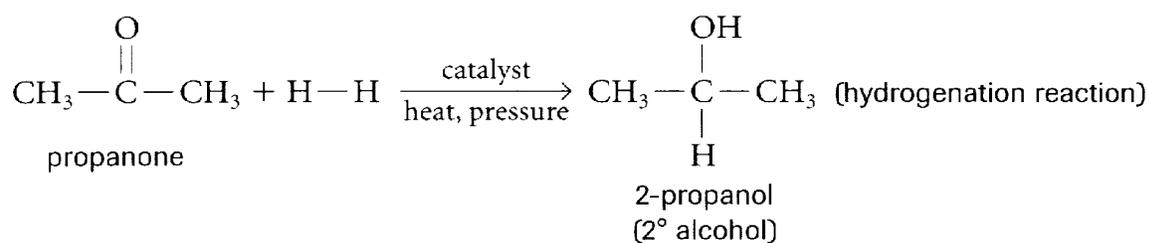
B) Other Reactions Involving Aldehydes and Ketones

Reduction (hydrogenation addition)

aldehydes + hydrogen → primary alcohol

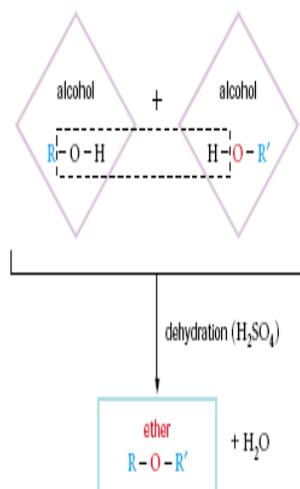


ketones + hydrogen → secondary alcohol



SUMMARY

Condensation Reactions of Alcohols to Ethers



SUMMARY

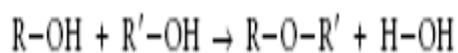
Ethers

Functional group: $\text{R}-\text{O}-\text{R}'$

Preparation:

• alcohols → ethers + water

Condensation reaction, eliminating H_2O ; dehydration



Carboxylic Acids R-COOH

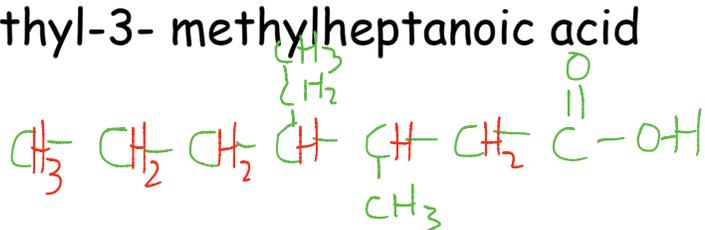


Contains a "carboxyl group" ($-\text{COOH}$) attached to the end of a hydrocarbon chain. The rules:

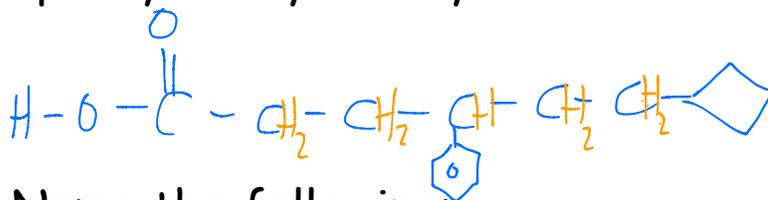
- Name according to longest carbon chain and add the suffix "oic acid".
- The carbon atom of the carboxyl group always given the position # 1.

1. Draw the following:

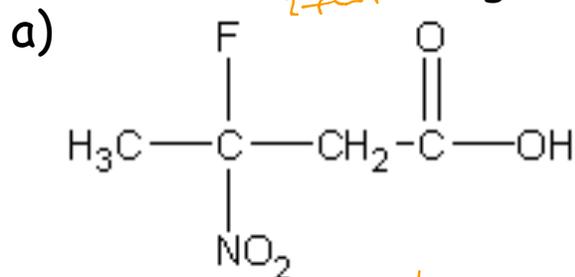
a) 4-ethyl-3-methylheptanoic acid



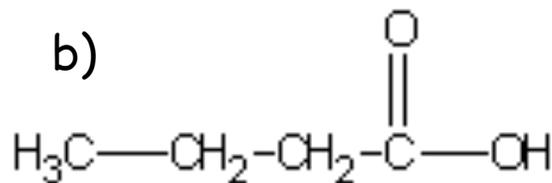
b) 4-phenyl-6-cyclobutylhexanoic acid



2. Name the following:



3-fluoro-3-nitrobutanoic acid



Properties of Carboxylic Acids & Esters

- organic acids have a carboxyl functional group -COOH and are called carboxylic acids
- like inorganic acids, carboxylic acids can react with OH containing compounds to form an organic "salt" called an **ester**
- Carboxylic Acids are generally **weak acids**, are found in citrus fruits, crab apples, rhubarb, and other foods known by their sour tangy taste
- carboxylic acids also have **distinct** odours that can be used in law enforcement
 - due to C=O and OH groups in carboxyl groups these molecules are **polar** and can form **hydrogen bonds** with each other and water molecules
- smaller acids have similar solubility to alcohols but larger ones are relatively **insoluble**
- carboxylic acids have the properties of acids and can react organic "bases" to form "salts"
- due to intermolecular attractions between the carboxyl functional groups the melting points are **higher** than their corresponding hydrocarbons

Table 1 Melting Points of Some Carboxylic Acids and Their Parent Alkanes

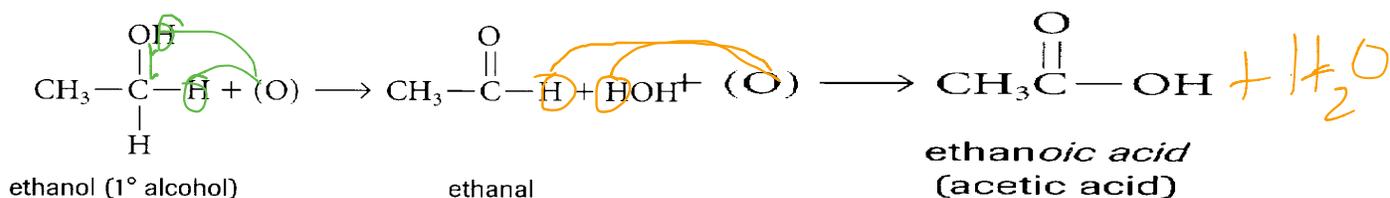
Number of C atoms	Number of COOH groups	Compound	Melting point (°C)
1	0	methane	-182
1	1	methanoic acid	8
2	0	ethane	-183
2	1	ethanoic acid	17
2	2	oxalic acid	189
4	0	butane	-138
4	1	<i>n</i> -butanoic acid	-8
4	2	tartaric acid	206
6	0	hexane	-95
6	1	hexanoic acid	13
6	3	citric acid	153

Chemical Reactions of Carboxylic Acids

A) Preparation of Carboxylic Acids

NOV 3 ☺

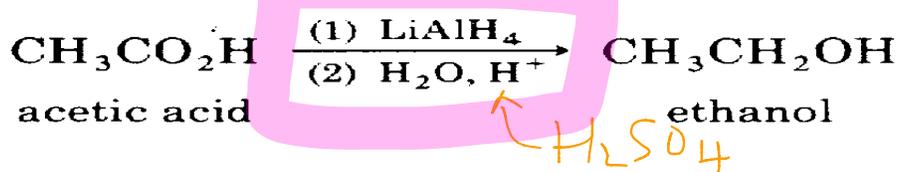
Oxidation Reactions



B) Other Reactions Involving Carboxylic Acids

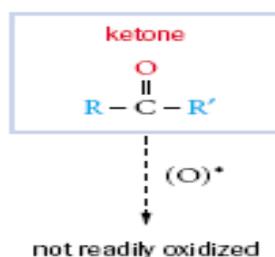
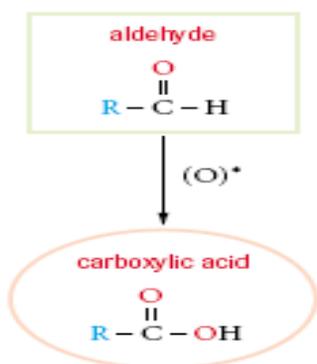
Reduction Reactions

- Carboxylic acids are **inert** to most common reducing agents (such as hydrogen plus a catalyst). LiAlH_4 is capable of reducing a carbonyl group directly to $-\text{CH}_2\text{OH}$.



SUMMARY

Oxidation of Aldehydes to Carboxylic Acids



* (O) indicates controlled oxidation with KMnO_4 or $\text{Cr}_2\text{O}_7^{2-}$, in H_2SO_4

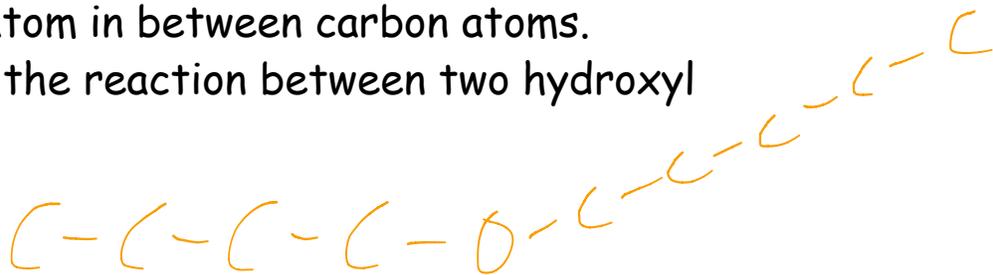
Ether Linkage

R-O-R

Contains an **oxygen** atom in between carbon atoms.

Can be formed from the reaction between two hydroxyl groups. The rules:

Common Name



- i) Groups attached to oxygen are named in alphabetical order.
- ii) Add the suffix "ether".

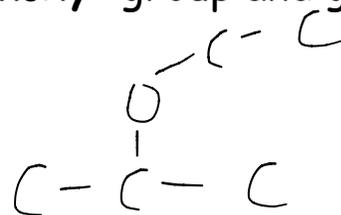
butyl pentyl ether

IUPAC Name

butoxy pentane

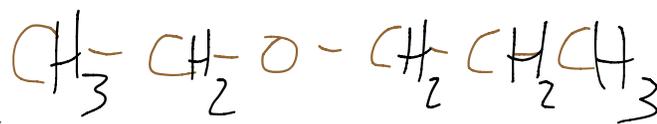
- i) Name according to longest alkyl group
- ii) Treat the second alkyl group as an "alkoxy" group and give it a position #.

1. Draw the following:



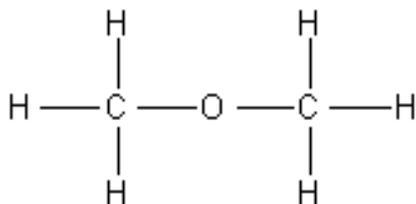
a) ethoxyethane
(diethyl ether)

b) 1-ethoxy propane
(ethyl-propyl ether)

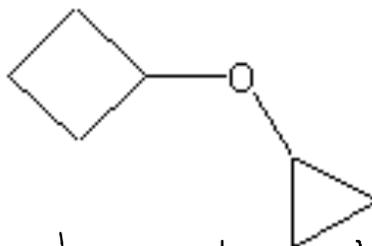


2. Name the following:

a)



b) 2 fm common
2 fm IUPAC



(C)
(I)

cyclobutyl cyclopropyl ether
cyclopropoxy cyclobutane

Properties of Ethers

- structure similar to **water** H-O-H and **alcohols** R-O-H only in ethers, structure is **R-O-R** (where R=alkyl groups)
- alkyl groups may be identical or different
- there are **no OH** bonds in ethers so they do not form hydrogen bonds *dipole-dipole*
- C-O bonds are **polar** and the **v-shape** of the C-O-C group make ether molecules **more** polar than hydrocarbons
- **intermolecular** attractions between ether molecules are **stronger** than hydrocarbons but weaker than those in alcohols, which is seen in Table 2 by looking at the boiling points

Table 2 Boiling Points of Analogous Compounds

Compound	Structure	Boiling point (°C)
ethane	CH ₃ -CH ₃	-89
methoxymethane (dimethyl ether)	CH ₃ -O-CH ₃	-23
ethanol	CH ₃ -CH ₂ -O-H	78.5
water	H-O-H	100

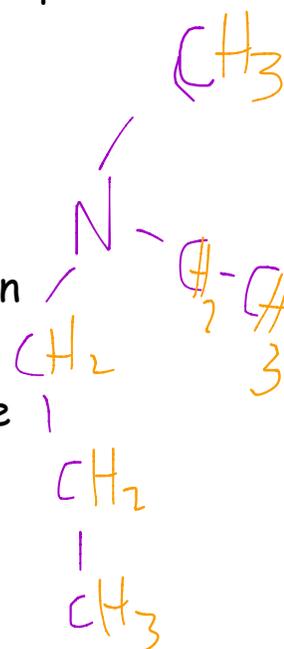
- ethers are good **solvents** for organic reactions because they mix readily with both polar and non-polar substances
- C-O bonds are polar so ethers can dissolve polar substances while their alkyl groups allow them to dissolve non-polar substances
- C-O bonds are **hard** to break, making ethers **unreactive** another property of a good solvent

Amines $R - NH_2$

Contains a amine group ($-NH_2$), a derivative of ammonia (NH_3) in which hydrogen has been replaced by a alkyl group

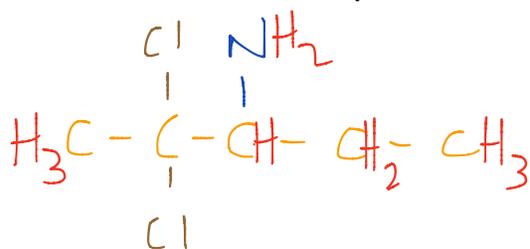
The rules:

- Name according to longest carbon chain attached to the nitrogen atom and add the suffix "amine"
- Name the other alkyl groups attached to the nitrogen atom. Use the letter "N" to locate the groups and "N,N-" to indicate that two identical alkyl groups are attached to the nitrogen atom.

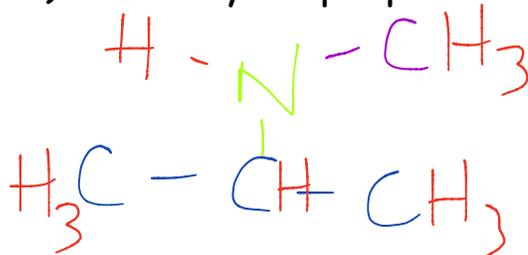


1. Draw the following:

a) 2,2-dichloro-3-pentanamine

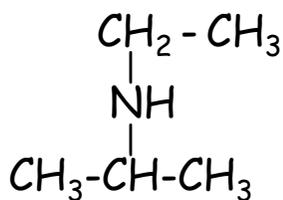


b) N-methyl-2-propanamine



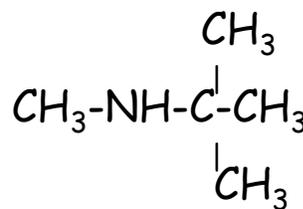
2. Name the following:

a)



N-ethyl-2-propanamine

b)



N-methyl-2-methyl-2-propanamine

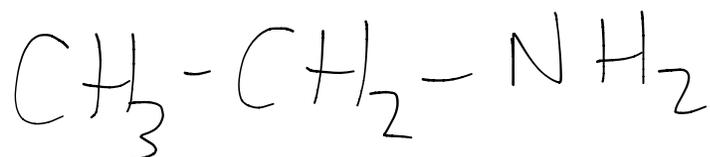
Classification of Amines

The meanings of the following terms are slightly different from alcohols

a) Primary Amines

Has **one** alkyl group and two hydrogen atoms attached to the nitrogen atom.

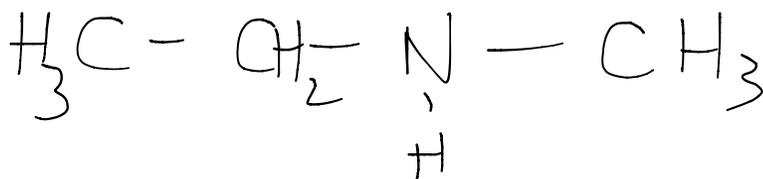
e.g. ethanamine



b) Secondary Amines

Has **two** alkyl groups and one hydrogen atom attached to the nitrogen atom.

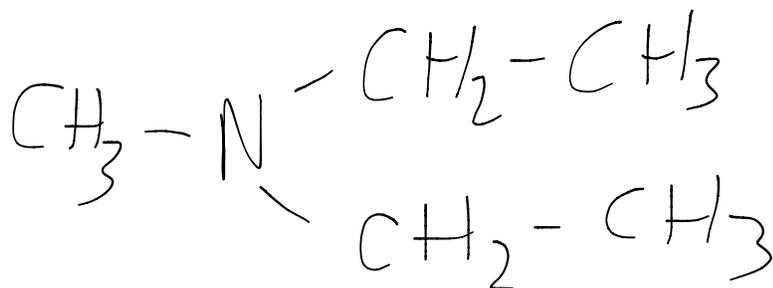
e.g. N-methyl ethanamine



c) Tertiary Amines

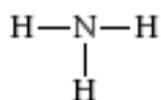
Has **three** alkyl groups attached to the nitrogen atom.

e.g. N-ethyl, N-methyl-ethanamine

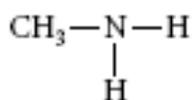


Properties of Amines

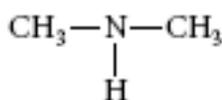
➤ amines have higher boiling points and melting points than hydrocarbons of the same size and smaller amines are soluble in water due to N-C and N-H both of which are polar



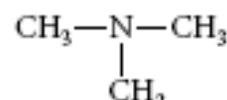
b.p. -33°C



b.p. -6°C



b.p. 8°C



b.p. 3°C

➤ when N-H bonds are present, hydrogen bonding **can** occur with water which explains the high solubility of amines in water

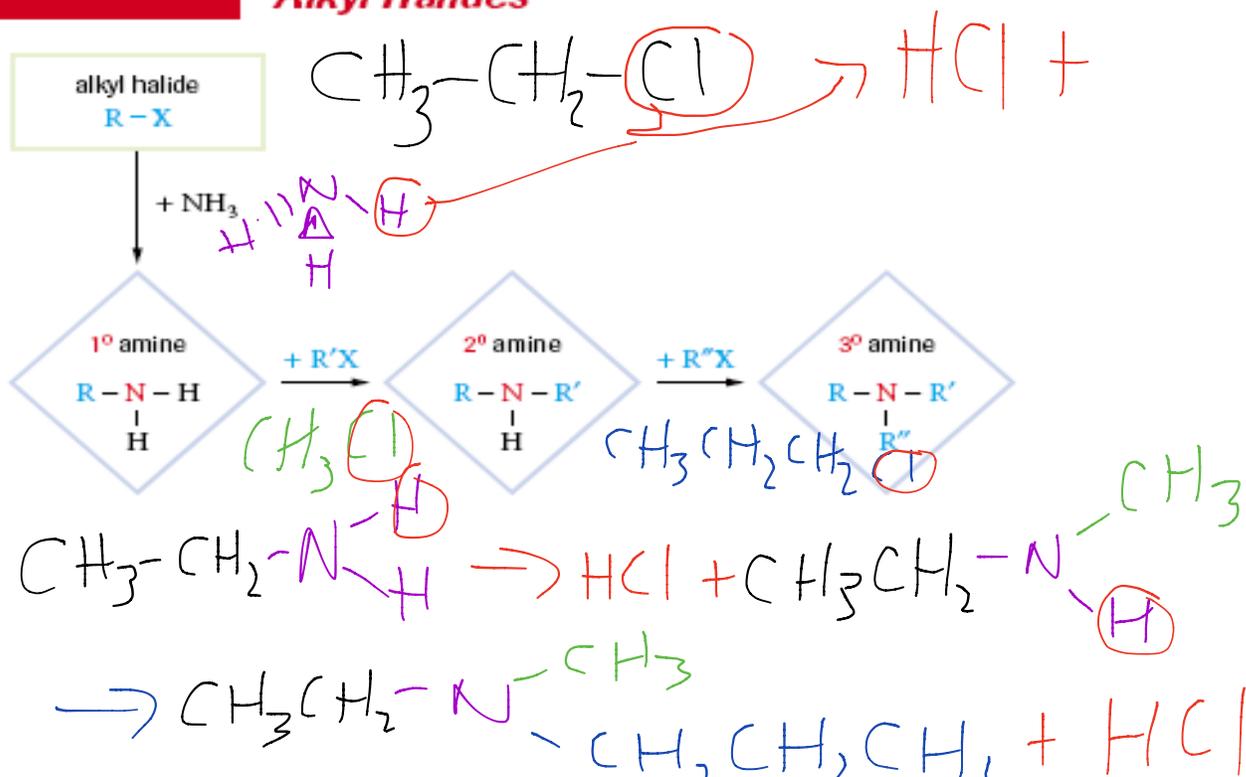
➤ N-H bonds are **less** polar than O-H so amines will boil at lower temperature

Table 2 Boiling Points of Analogous Hydrocarbons, Amines, and Alcohols

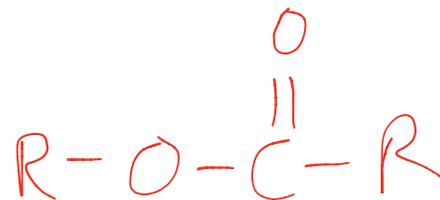
Hydrocarbon	b.p. ($^{\circ}\text{C}$)	Amine	b.p. ($^{\circ}\text{C}$)	Alcohol	b.p. ($^{\circ}\text{C}$)
CH_3CH_3	-89	CH_3NH_2	-6	CH_3OH	65
$\text{C}_2\text{H}_5\text{CH}_3$	-42	$\text{C}_2\text{H}_5\text{NH}_2$	16	$\text{C}_2\text{H}_5\text{OH}$	78
$\text{C}_3\text{H}_7\text{CH}_3$	-0.5	$\text{C}_3\text{H}_7\text{NH}_2$	48	$\text{C}_3\text{H}_7\text{OH}$	97
$\text{C}_4\text{H}_9\text{CH}_3$	36	$\text{C}_4\text{H}_9\text{NH}_2$	78	$\text{C}_4\text{H}_9\text{OH}$	117

SUMMARY

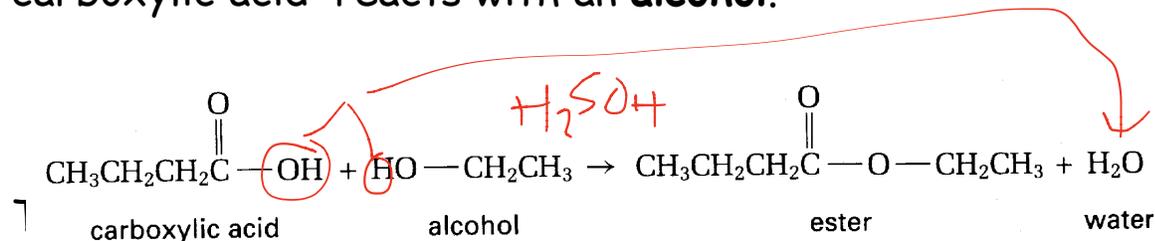
Synthesizing Amines from Alkyl Halides



Ester Linkage R-COOR'



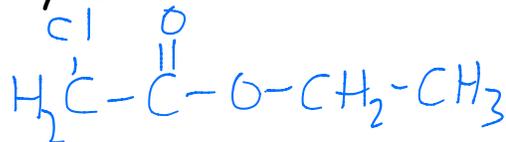
Contains a "carboxyl group" (---COOH) attached between carbon atoms. Can be formed when a carboxylic acid reacts with an **alcohol**.



- i) Name according to longest carbon chain containing the C=O and replace the "-oic acid" ending of the parent acid with "-oate". Write this second
- ii) Name the attached alkyl group first.

1. Draw the following:

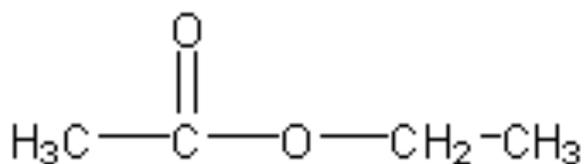
a) ethyl-2-chloroethanoate



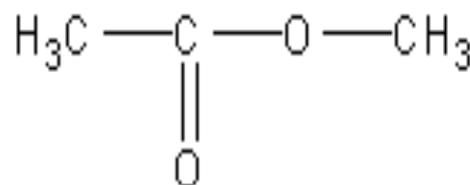
b) butyl ethanoate

2. Name the following:

a)



b)



Amide Linkage $R-CO-NR_2$



Formed when an amine reacts with a carboxylic acid.

The rules:

- i) Name according to longest carbon chain containing the $C=O$ and
replace the "-oic acid" ending of the parent acid with "-amide".

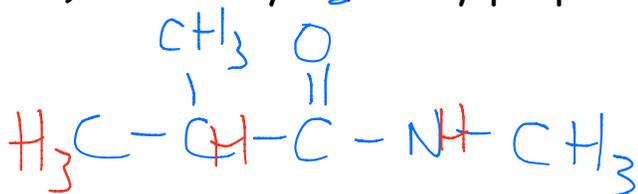
Write this second

- ii) If one alkyl group attached to N atom, add N- and location #.
If two alkyl groups, place in alphabetical order and add N- if different and N,N- if two groups are the same.

1. Draw the following:

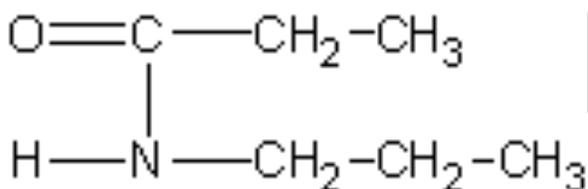
a) N-methyl-2-methylpropanamide

b) N-methylpropanamide

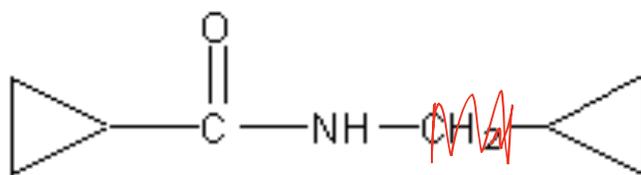


2. Name the following:

a)



b)



N-cyclopropyl
cyclopropylmethan
amide

Polymers

Polymer:

A long molecule formed from linking together many smaller repeating units called **monomers**.

Natural polymers include: starch, cotton wool etc.
e.g. starch

Synthetic polymers include: rayon, polystyrene, nylon
e.g. Polystyrene

Polymerization

1. Addition Polymerization

A reaction in which monomers with double bonds are joined together through multiple addition reactions. e.g. polyethene

2. Condensation Polymerization

ester

amide

A reaction in which monomers are joined together by the formation of ester or amide bonds and the release of water. Nylons or polyamides contain amide linkages and polyesters contain ester bonds e.g. Nylon-66

