Unit 13: Organic Chemistry

Ms. Johnson

Honors Chemistry

Unit Learning Objectives: By the end of the unit students will be able to…

(1) Name and draw hydrocarbons including alkanes, cycloalkanes, alkenes, cycloalkenes, and alkynes.
(2) Name and draw structural isomers for hydrocarbons.
(3) Name and draw stereoisomers for alkenes.
(4) Name and draw molecules with functional groups including alkyl halides, alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, amines, and amides.
(5) Give examples of applications of molecules with different functional groups.

Monday	Tuesday	Wednesday	Thursday	Friday
May 16 Organic Chemistry Activity **Work on Final Review**	**17** alkanes Naming →	**18** alkenes →	**19** Benzene and alkynes →	**20** Functional groups →
23 Esterification and Amino Acid Formation	**24** **Lab**: Ester Synthesis	**25** Review	**26** **Unit 13 Test** **HW packet Due**	**27** **Lab Final:** Investigation of a chemical Reaction
30 **Lab Final:** Investigation of a chemical Reaction	**31** **Lab Final:** Investigation of a chemical Reaction	**June 1** **Final Review** Practice Free Response Test	**2** **Final Review** Practice Multiple Choice Test ** After school Review Session**	**3** **Free Response Final** ** All Late work Due**
6 **AM Final** **Period 1 Final** **Period 2 Final**	**7** **AM Final** **Period 3 Final** **Period 4 Final**	**8** **Period 5 Final** **Period 6 Final**	**9** Last Day of School	**10** **Have a wonderful SUMMER!** 

Organic Chemistry

Organic Chemistry is _____.

I. Hydrocarbons

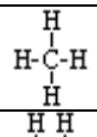
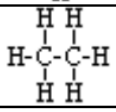
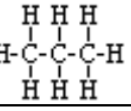
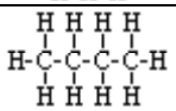
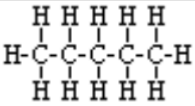
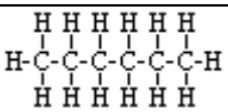
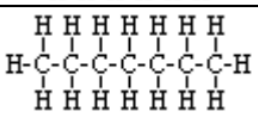
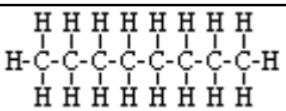
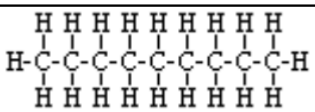
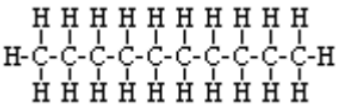
– contain only _____and _____

(1) Alkanes

– contain only **single** bonds

– called "saturated" hydrocarbons (contain maximum number of hydrogens for each carbon)

Unbranched Alkanes

Formula	Name	Structural Drawing	Lewis Structure
CH_4	Methane	CH_4	
C_2H_6	Ethane	CH_3CH_3	
C_3H_8	Propane	$CH_3CH_2CH_3$	
C_4H_{10}	Butane	$CH_3CH_2CH_2CH_3$	
C_5H_{12}	Pentane	$CH_3CH_2CH_2CH_2CH_3$	
C_6H_{14}	Hexane	$CH_3CH_2CH_2CH_2CH_2CH_3$	
C_7H_{16}	Heptane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	
C_8H_{18}	Octane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	
C_9H_{20}	Nonane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	
$C_{10}H_{22}$	Decane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	

Alkanes are called "saturated" hydrocarbons since they contain the maximum number of hydrogen atoms for each.

General Formula for Alkanes: C_nH_{2n+2}

Ex. An alkane has 15 carbon atoms, how many hydrogen atoms does it have? What is the chemical formula?

Branched Alkanes

– branched alkanes have alkyl groups attached to the main chain

– **main chain:** _____Also called the _____**.**

– alkyl group: alkane missing one hydrogen so that it can bond to the main chain.

Common Alkyl Groups

Name	Drawing
Methyl	**CH_3–**
Ethyl	**CH_3CH_2–**
Propyl	**$CH_3CH_2CH_2$–**
Butyl	**$CH_3CH_2CH_2CH_2$–**

Naming Alkanes

(1) Identify the main chain.

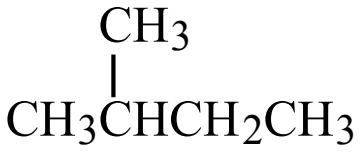
(2) Number each carbon on the main chain. Begin at the end closest to the first alkyl group. If both ends are equally close to an alkyl group, begin numbering at the end closest to the longer alkyl group *or* at the end closest to the second alkyl group.

(3) Assign a number to each alkyl group based on the carbon number the alkyl group attaches to on the main chain. Name the alkyl groups in alphabetical order. If there is more than one of an alkyl group, use prefixes (ie. di, tri, tetra) to indicate how many of the alkyl groups there are. (Note: prefixes DO NOT affect alphabetization for the alkyl groups).

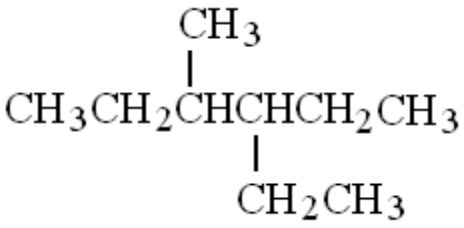
(4) Name the main chain based on the number of carbon atoms it contains.

Name the following alkanes

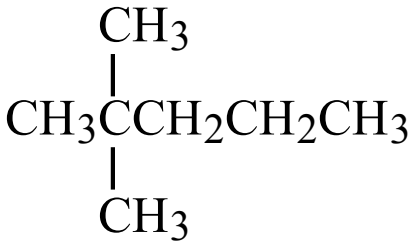
ex.



ex.



ex.



Drawing Alkanes

(1) Draw the main chain and number the carbons.

(2) Add the alkyl groups at the correct number on the main chain. Be sure the alkyl group attaches through a carbon that can bond. The alkyl groups may be drawn above or below the main chain.

(3) Fill in the missing hydrogen atoms so that each carbon has four bonds. A carbon is bonded to any carbon it is adjacent to and any alkyl group that is attached to it.

Draw the following alkanes

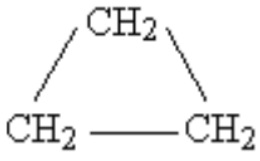
ex. 3–Ethyl–5–methylheptane

ex. 4,5–Diethyl–4–propylnonane

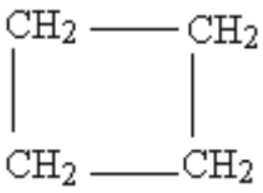
(2) Cycloalkanes

– the main chain forms a "circle". The cycloalkane is named for the number of carbons in the "circle" with the prefix "cyclo"

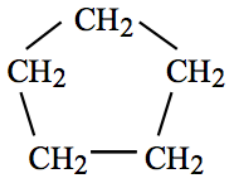
Cyclopropane



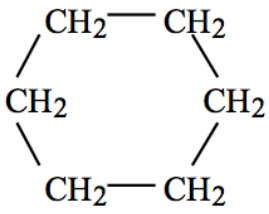
Cyclobutane



Cyclopentane



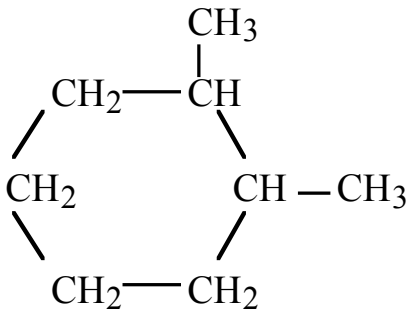
Cyclohexane



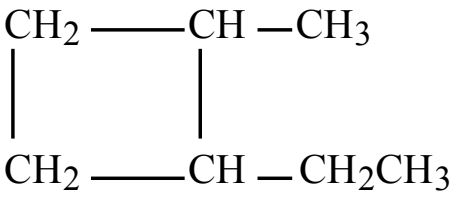
The cycloalkane is numbered so that the alkyl groups have the lowest numbers possible and so that the longer alkyl group is preferentially given a lower number.

Name the following Cycloalkanes

ex.



ex.



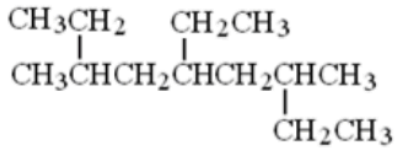
Draw the following Cycloalkanes

ex. 4–Methyl–1,3–dipropylcyclopentane

1,2,3–Trimethylcyclopropane

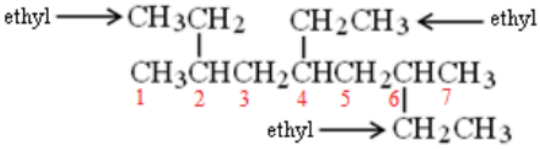
Identifying the Main Chain

Name the following alkane:



Recall, the main chain is the **LONGEST** chain of carbon atoms in a molecule. When drawn, the main chain can be shown bent (i.e. it does not need to be shown straight across in the drawing). When numbering, always look for the highest possible number of carbons in a row. Number the carbons from the end closest to the first alkyl group. If both ends are equally close to an alkyl group, begin numbering at the end closest to the longer alkyl group and then at the end closest to the second alkyl group.

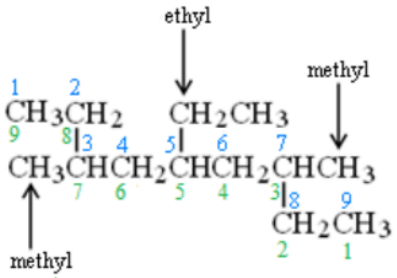
X WRONG



X 2, 4, 6–triethylheptane

The longest chain of carbons in this alkane is NOT seven, so this is not the correct way to number the carbons and name the molecule.

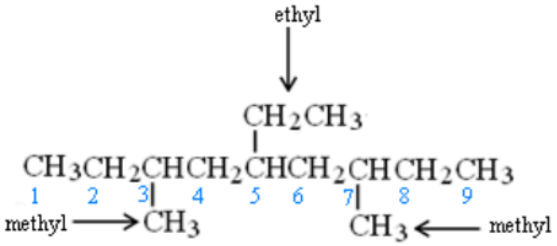
√ RIGHT



√ 5–ethyl–3,7–dimethylnonane

The main chain can be numbered starting from the top left or bottom right, since both ends are equally close to the alkyl groups. There are nine carbons in the main chain. The carbon atoms that are not numbered at the end of the part of the molecule that is drawn straight are alkyl groups (i.e. methyl groups). A 5 is written before the ethyl because it attaches at carbon 5. A 3 and an 7 are written for the methyl groups because they attach at carbons 3 and 7. There are two methyl groups, so the prefix "di" is used. The ethyl is named before the methyl because it comes first alphabetically. The main chain has nine carbon atoms, so the name of the main chain is nonane.

Note: The above molecule could also have been drawn as follows, showing the main chain drawn straight across:



(3) Alkenes and cycloalkenes

- -contain **double bonds** between carbon atoms
- General Formula for Alkenes: C_nH_{2n}
- Alkenes are called "unsaturated" hydrocarbons since they contain fewer hydrogen atoms for each atom of carbon. (ie an alkane with 15 carbon atoms has 32 hydrogen atoms and an alkene with 15 carbon atoms has 30 hydrogen atoms)

Naming Alkenes

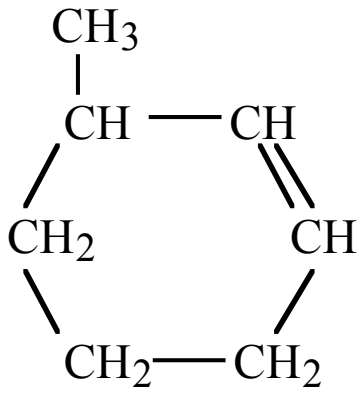
(1) Identify the main chain containing the double bond.
(2) Number each carbon on the main chain so that the carbon number of the double bond is the lowest. The double bond takes priority over alkyl groups. For cycloalkenes, the double bond is always numbered such that it is placed between carbons 1 and 2.
(3) Assign a number to each alkyl group and name the alkyl groups in alphabetical order. If there is more than one of an alkyl group, use prefixes (ie. di, tri, tetra) to indicate the number.
(4) Name the main chain based on the number of carbons it contains and change the ending to "ene". Indicated the position of the double bond with the carbon number the double bond comes after. (For cycloalkenes, the number 1 is not written in the name)

Name the following alkenes

$CH_2{=}CHCH_2CH_3$

$CH_3CH{=}CHCH_3$

$CH_3CHCH{=}CHCH_2CH_3$ (with CH_3 branch)



Drawing Alkenes

(1) Draw the main chain and number the carbons. Add the double bond at the indicated carbon of the main chain. For cycloalkanes, the double bond is always between carbons one and two.
(2) Add the alkyl groups at the correct number on the main chain.
(3) Fill in the missing hydrogen atoms (each carbon has four bonds). The double bond accounts for two bonds.

Draw the following alkenes

ex. 4–Methyl–2–pentene

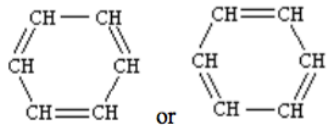
ex. 4–Ethyl–3,5–Dimethyl–2–hexene

ex. 3–methylcycloheptene

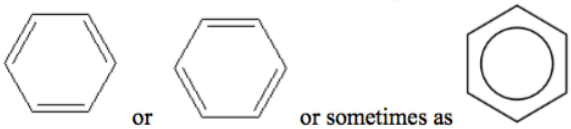
Benzene

There is an important cycloalkene called 1,3,5-cyclohexatriene with six carbon atoms in a ring with alternating single and double bonds. This molecule is commonly known as "benzene".

Benzene can be drawn as shown:



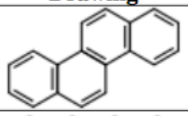
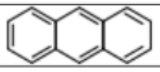
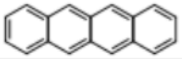
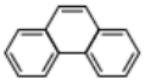
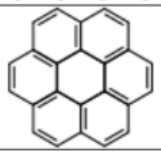
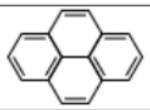
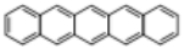
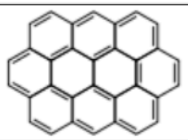
Benzene can also be shown in several simplified forms:



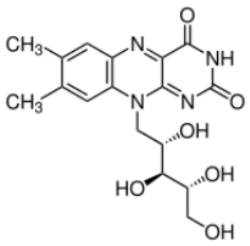
(Each vertex represents a carbon atom with the correct number of hydrogen atoms)

Benzene is a colourless, sweet smelling liquid that is highly flammable. Benzene is used in many industrial processes including the production of plastics, rubbers, lubricants, dyes, detergents, drugs, explosives, and pesticides. Benzene and compounds like benzene (with alternating single and double bonds) are collectively called "aromatics" (historically named for the observation that many had distinct fragrances). Aromatic compounds are very stable. Many aromatics are highly carcinogenic and have been linked to various forms of cancer.

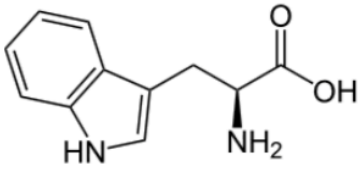
Examples of Aromatic Molecules

Name	Drawing	Name	Drawing
Naphthalene		Chrysene	
Anthracene		Tetracene	
Phenanthrene		Coronene	
Pyrene		Pentacene	
Corannulene		Ovalene	

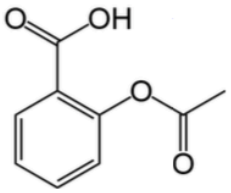
Compounds containing aromatic regions are found in many biomolecules (for example vitamins, proteins, and pharmaceuticals)



Vitamin B_2
(Rioflavin)



Tryptophan
(an amino acid)



Acetylsalicylic acid
(Apsirin)

Alkynes

- Contain triple bonds between carbon atoms
- General formula for alkynes: C_nH_{2n-2}

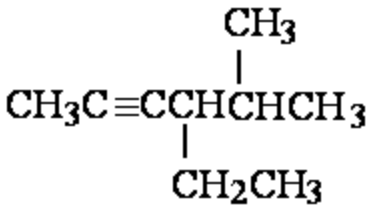
Naming Alkynes

(1) Identify the main chain containing the triple bond.
(2) Number each carbon on the main chain so that the carbon number of the triple bond is the lowest. The triple bond takes priority over alkyl groups.
(3) Assign a number to each alkyl group and name the alkyl groups in alphabetical order. If there is more than one of an alkyl group, use prefixes (ie. di, tri, tetra) to indicate the number.
(4) Name the main chain based on the number of carbons it contains and change the ending to "yne". Indicate the position of the triple bond with the carbon number the triple bond comes after.

Name the following alkynes

ex.
$CH{\equiv}CCH_2CH_3$

ex.



Drawing Alkynes

(1) Draw the main chain and number the carbons. Add the triple bond at the indicated carbon of the main chain.
(2) Add the alkyl groups at the correct number on the main chain.
(3) Fill in the missing hydrogen atoms (each carbon has four bonds). The triple bond accounts for three bonds.

Draw the following alkynes

ex. 3,5–Dimethyl–1–heptyne

ex. 4–Ethyl–5–methyl–2–nonyne

Structural Isomers

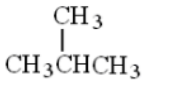
Structural Isomers are different molecules having the same molecular formula, but with a different arrangement of atoms.

ex. C_4H_{10} has two structural isomers:

butane

$CH_3CH_2CH_2CH_3$

2–methylpropane

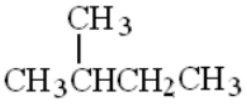


ex. C_5H_{12} has three structural isomers:

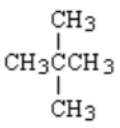
pentane

$CH_3CH_2CH_2CH_2CH_3$

2–methylbutane

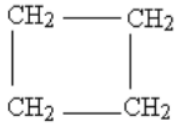
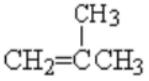
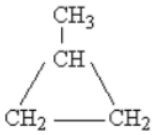


2,2–dimethylpropane



Structural isomers can draw for all types of hydrocarbons (alkanes, alkenes, and alkynes) as well as other types of organic compounds.

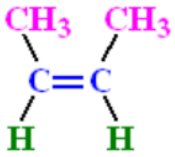
ex. C_4H_8 has five structural isomers

cyclobutane	2-methyl-1-propene	1-butene	2-butene	1-methylcyclopropane
		$CH_2{=}CHCH_2CH_3$	$CH_3CH{=}CHCH_3$	

Stereoisomers
The carbon atoms connected by a double bond in an alkene are fixed meaning that the atoms surrounding them are stationary. Different orientations of alkyl groups relative to a double bond are called stereoisomers. Stereoisomers are only displayed for ALKENES.

ex. Consider 2-butene:

$CH_3CH{=}CHCH_3$



cis-2-butene
or (Z)-2-butene

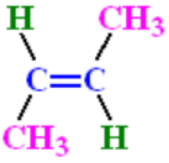
Here the hydrogen atoms are on the same side of the molecule.
The molecule is named with a "cis" or a "Z"

Can also be drawn as shown below:

trans-2-butene
or (E)-2-butene

Here the hydrogen atoms are on opposites sides of the molecule.
The molecule is named with a "trans" or an "E"

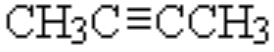
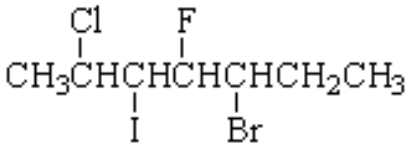
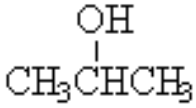
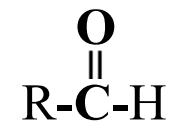
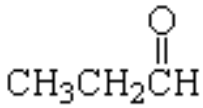
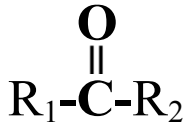
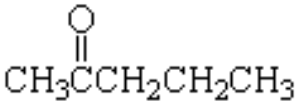
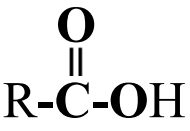
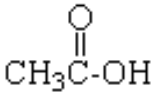
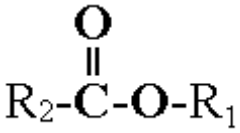
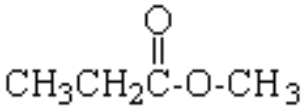
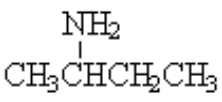
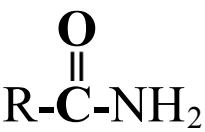
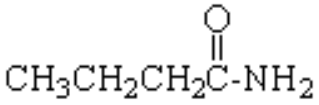
Can also be drawn as shown below:



ex. Draw and name the two stereoisomers of 3-nonene

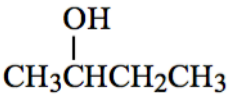
II. Functional Groups

Naming Organic Compounds with functional groups
(1) Identify the functional group.
(2) Number each carbon on the main chain containing the functional group so that the carbon number of the functional group is the lowest.
(3) Assign a number to each alkyl group and name the alkyl groups in alphabetical order. If there is more than one of an alkyl group, use prefixes (ie. di, tri, tetra) to indicate the number.
(4) Name the functional group with the appropriate ending.

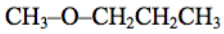
Functional Group	Structure	Ending	Example	Applications
Alkane	R-R **R= any alkyl group**	**"ane"**	**$CH_3CH_2CH_2CH_2CH_3$** Pentane	
Alkene	R=R	**"ene"**	**$CH_3CH{=}CHCH_2CH_2CH_3$** 2-hexane	
Alkyne	R≡R	**"yne"**	 2-butyne	
Alkyl Halide	R-X **X= F, Cl, Br, I** **fluoro, chloro, bromo, iodo**	**depends on main chain**	 5-bromo-2-chloro-4-fluoro-3-idoheptane	
Alcohol	R-OH	**"ol"**	 2-propanol	
Ether	R_1-**O**-R_2	**"ether"**	CH_3CH_2–O–$CH_2CH_2CH_3$ Ethyl propyl ether	
Aldehyde		**"al"**	 propanal	
Ketone		**"one"**	 2-pentanone	
Carboxylic Acid		**"oic acid"**	 ethanoic acid	
Ester		**"oate"**	 methyl propanoate	
Amine	R-NH_2 **NH_2 = amino**	**depends on main chain**	 2-aminobutane	
Amide		**"amide"**	 butanamide	

ex. Classify the functional group(s) for each molecule. Name/Draw the organic compound.

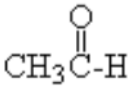
(1)



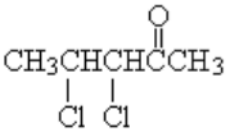
(2)



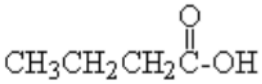
(3)



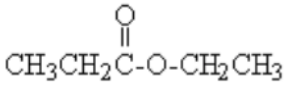
(4)



(5)



(6)



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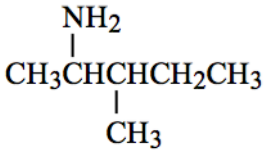

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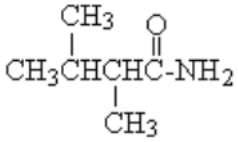


(9) 3-Ethyl-4-methylpentanoic acid

(10) 3-Methylheptanal

(11) 1-Fluoro-3-methyl-2-pentanol

(12) 2-Amino-1-iodo-3-methyloctane

(13) Dipropyl ether

(14) 4-Methyl-3-hexanone

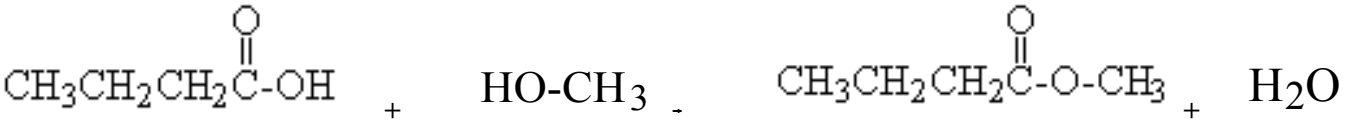
(15) 2-bromopropanamide

(16) Propyl pentanoate

Ester Condensation Reactions (Esterification or Ester Synthesis Reacation)
Esters can be produced from the reaction of a carboxylic acid with an alcohol. The "OH" from the carboxylic acid and the "H" from the alcohol combine together to make water. The remaining parts of each molecule join to produce an ester.

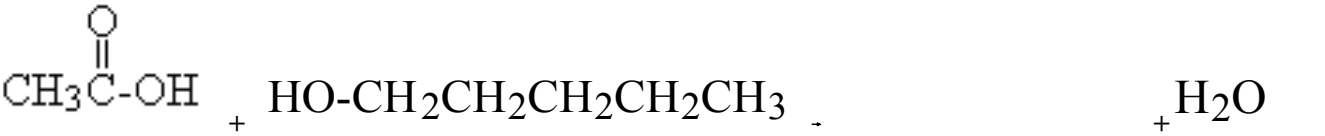
carboxylic acid + alcohol → ester + water

ex.



butanoic acid + methanol - methyl butanoate + water

ex. Complete the following ester synthesis reaction:

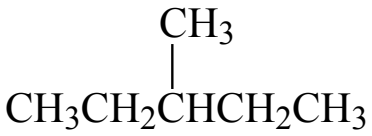


+ - + water

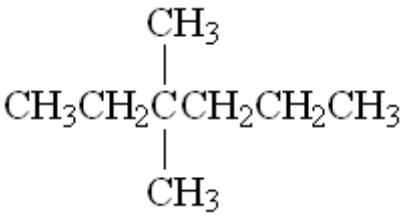
Review: Alkanes

(1) Name the compound.

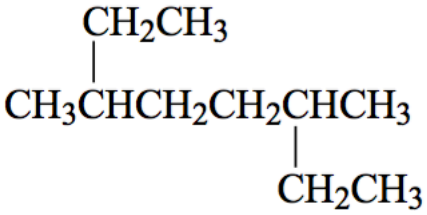
(a)



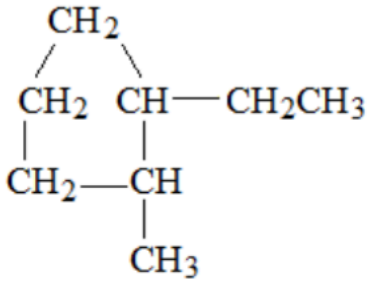
(b)



(c)



(d)



(2) Draw the compound.

(a) 3,5–Diethylheptane

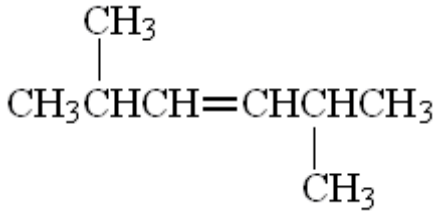
(b) 3–ethyl–2–methylnonane

(c) 1,3–dimethylcyclopropane

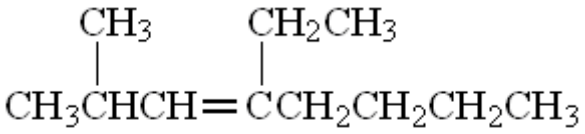
Review:

(1) Name the compound.

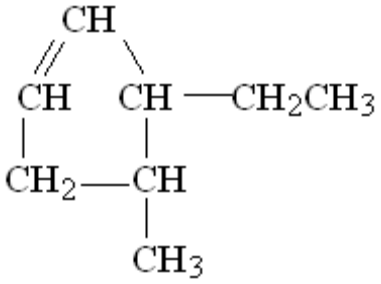
(a)



(b)



(c)



(2) Draw the compound.

(a) 4, 5, 6–trimethyl–2–decene

(b) 3–methylcyclopropene

(c) 4,4–dimethyl–1–heptene

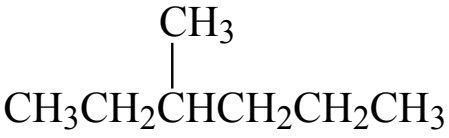
(4) Alkynes

– contain triple bonds

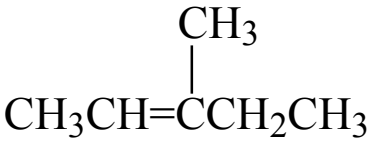
Review: Alkanes/Alkenes/Alkynes

(1) Name the compound.

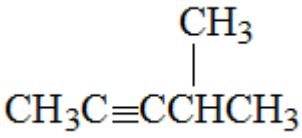
(a)



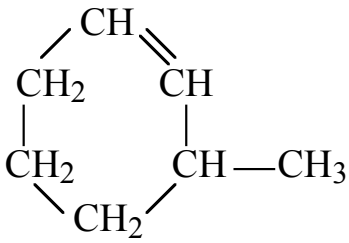
(b)



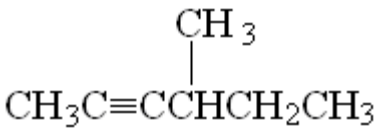
(c)



(d)



(e)



(2) Draw the compound.

(a) 2–methyl–3–heptyne

(b) 2–methyl–1–butene

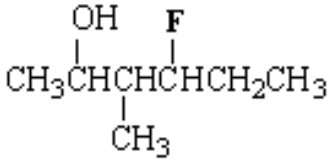
(c) 3,4–dimethylcyclopentene

(d) 3–ethyl–1–octyne

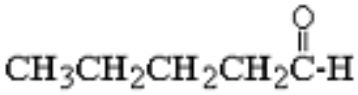
(e) 1,3–dimethylcyclooctane

Review: Organic Compounds

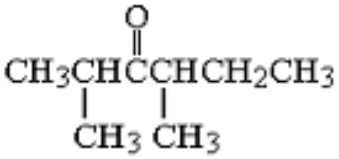
_____ **(a)**



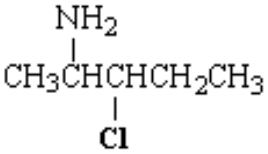
_____ **(b)**



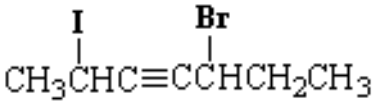
_____ **(c)**



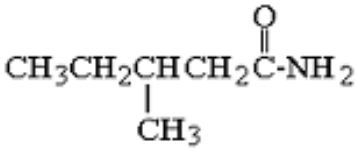
_____ **(d)**



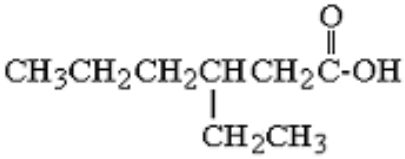
_____ **(e)**



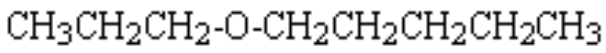
_____ **(f)**



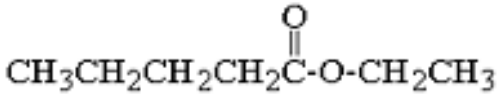
_____ **(g)**



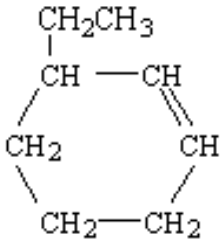
_____ **(h)**



_____ **(i)**



_____ **(j)**



(1) Pentyl propyl ether	**(6) 3–methylpentanamide**
(2) 4–fluoro–3–methyl–2–hexanol	**(7) 2,4–dimethyl–3–hexanone**
(3) pentanal	**(8) 2–amino–3–chloropentane**
(4) 3–ethylcyclohexene	**(9) 5–bromo–2–iodo–3–heptyne**
(5) 3–ethylhexanoic acid	**(10) ethyl pentanoate**