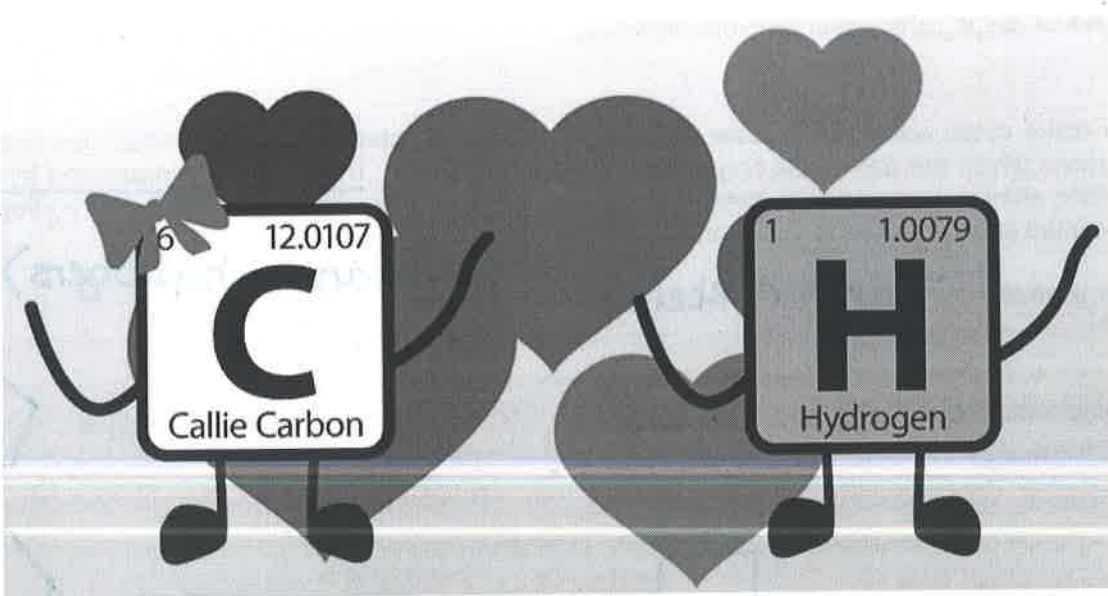
# Chemistry 11

## Organic Chemistry

# Book 2




**Name:**__________________________ **Block:**__________

@ room temp. short chains - $C_1 \rightarrow C_4$ = gases
$C_5 \rightarrow$ long = liquids
very long e.g. $C_{16}H_{34}$+ = waxes/paraffins (solids)

## THE PROPERTIES OF ALKANES

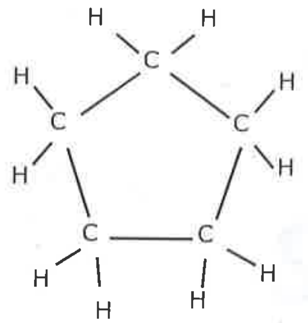
- Alkanes are very unreactive because C–C and C–H bonds are strong and not easily broken.
- Methane, ethane, propane and butane are gases at room temperature (butane is easily liquified under pressure). Pentane and longer chains are liquids.
- Very long chains ($C_{16}H_{34}$ and longer) are solids and are commonly called WAXES or PARAFFINS.

### Cycloalkanes

Carbon atoms may bond to each other and form a cyclic structure called a ring, like the one in the diagram below. The hormones testosterone and progesterone are examples of compounds that contain ring structures.

Consider the molecule shown in Figure 8.1.4(a).
This compound has the formula $C_5H_{10}$.
Alkanes have the general formula $C_nH_{(2n+2)}$.
What is the **general formula** for a cycloalkane like the one in the diagram below? $C_nH_{(2 \cdot n)}$

(a)



$C_5H_{10}$

(b)

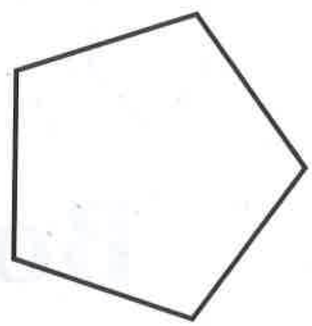
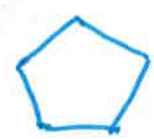


**Figure 8.1.4** *(a) $C_5H_{10}$; (b) the carbon skeleton formula for $C_5H_{10}$*

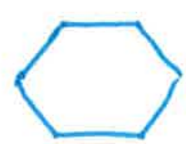
To make cyclic compounds easier to draw, a shorthand notation is used in which the hydrogens and carbons which are part of the ring are not represented at all. The rings are represented by lines, and a carbon atom is assumed to be present at each angle in the ring. The proper number of hydrogen atoms is assumed to be attached to each carbon.

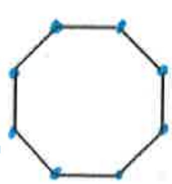
For example: "carbon skeleton" (don't draw hydrogens)

cyclopropane = $C_3H_6$ = 

cyclopentane = $C_5H_{10}$ = 

cyclobutane = $C_4H_8$ = 

cyclohexane = $C_6H_{12}$ = 

Name this compound → 

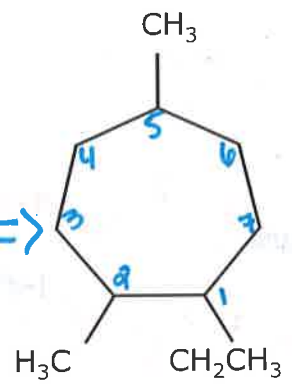
C ↗

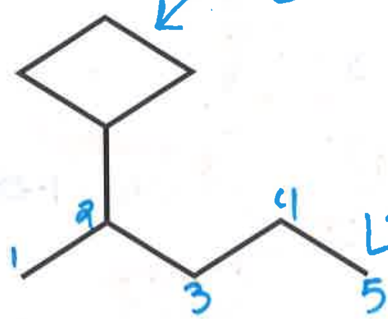
(4) cyclooctane
↳ yes... 2 "O"

**Rules for Naming:**
When naming an alkane that contains a ring structure, the same rules apply as for a chain alkane.

1. The ring that contains the greater number of carbon atoms is the parent. chain. The prefix "cyclo" is placed before the parent chain name.
2. The carbon atoms in the parent ring are numbered either clockwise or counterclockwise so that the lowest numbers are used to identify the placement of the branches (alkyl groups)
3. If the ring structure is **not** the longest continuous chain... ...then the ring is named as a branch with the prefix "cyclo" and ends in "yl."

ring is parent chain =>



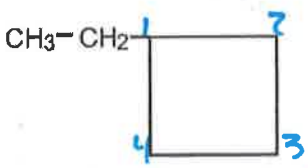

(a) 1-ethyl-2,5-dimethylcycloheptane (b) 2-cyclobutylpentane

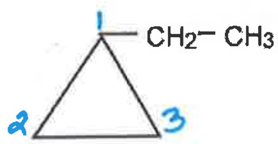
* numbers are used to describe multiple branches.

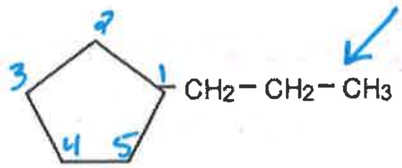
**Figure 8.1.5** *Example of alkanes that contain ring structures*

*if there is only 1 branch.... we name it without the number.

**Problem 8.** Name the cyclic molecules below.



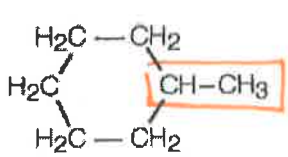

a. ethylcyclobutane b. ethylcyclopropane c. propylcyclopentane

## SUBSTITUTED CYCLOALKANES

Rules for naming!

**RULE:** Substituted cycloalkanes follow the same rules as straight–chain alkanes, except that
- a ***single*** substituent does not use a number to indicate the position of attachment (all carbons in the cycloalkyl group are identical).
- if there is more than one substituent, the first substituent is assumed to be at the "1" position and the remaining substituents are numbered either clockwise or anticlockwise so as to have the lowest set of overall values.

***EXAMPLE:***

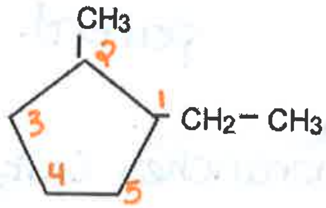



= methylcyclohexane ✓

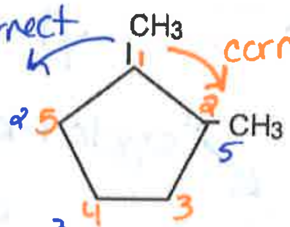
NOT 1-methylcyclohexane

remember that we name alphabetically

**Examples of Branched Cycloalkanes:**



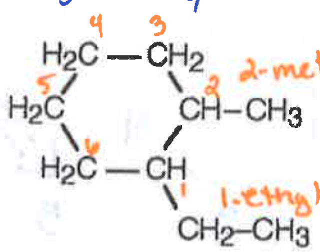

← This is called 1-ethyl-2-methylcyclopentane




← This is called 1,2-dimethylcyclopentane

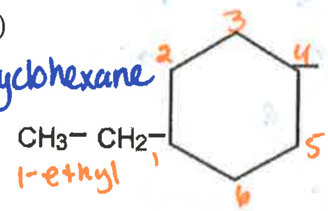
(It is NOT called 1,5-dimethylcyclopentane)

A)



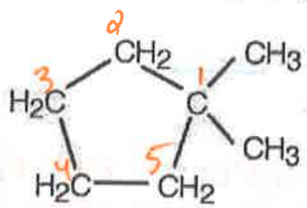

= 1-ethyl-2-methylcyclohexane

C)



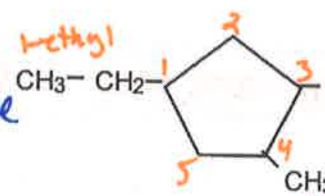

1-ethyl-4-methylcyclohexane

B)



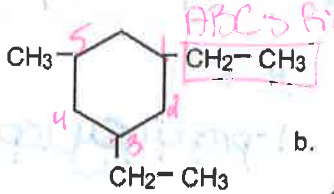

= 1,1-dimethylcyclopentane

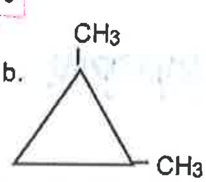
D)

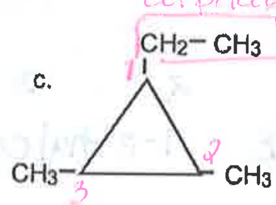


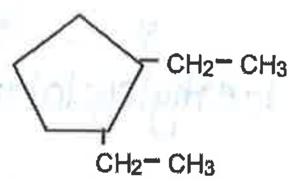

1-ethyl-3,4-dimethylcyclopentane

HW **Problem 9.** Name the cyclic alkanes shown below:

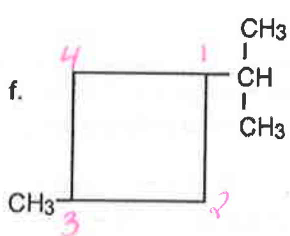
a. 

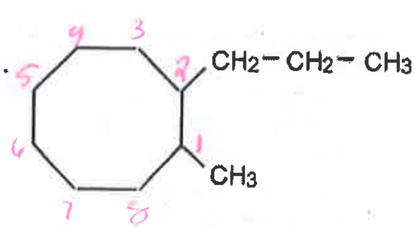

b. 


c. 


d. 


e. 


f. 


g. 


a. 1,3-diethyl-5-methylcyclohexane

b. 1,2-dimethylcyclopropane

c. 1-ethyl-2,3-dimethylcyclopropane

d. 1,2-diethylcyclopentane

e. 1,3,5-trimethylcyclohexane

f. 1-(iso)propyl-3-methylcyclobutane

g. 1-methyl-2-propylcyclooctane

**Problem 10:** Sketch the following compounds *(complete this question on a seperate page)* (see attached answer key)

(a) 1,2–dimethylcyclobutane
(b) 1,1,2–trimethylcyclopropane
(c) 1,3–dipropylcyclopentane
(d) propylcyclopropane
(e) 1,3–diethyl–2,2–dimethylcyclooctane
(f) 1,2,4–triethylcycloheptane

## Alkenes

Alkenes are hydrocarbons containing double bonds.
They are unsaturated. This means that the double bond is a reactive site where other atoms could attach to the carbon skeleton.
They have the general formula $C_nH_{(2n)}$
As you saw above, cycloalkanes have the same *general formula* as alkenes.
Molecules with this general formula contain either one alkane ring or one double bond.
(which is why naming is so important.)

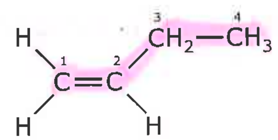
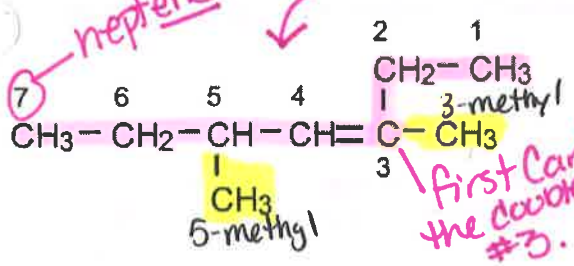


**Figure 8.1.6** *An example of an alkene: 1-butene*

The rules for naming alkenes are the same as for alkanes except that an alkene's parent chain name ends in "ene." See Figure 8.1.6 for an example.

- The **parent chain** must contain the double bond.
- The position of the **double bond** is indicated in the name by stating the **number of the carbon atom** in the parent chain that the double bond follows.
- The parent chain carbon atoms are numbered starting at the end closest. to the double bond.

Name this example: "3,5-dimethyl-3-heptene."




A number is not used to locate the double bond in chains which are shorter than four carbons. Two examples are below.

$CH_2{=}CH_2$ ← This is called ethene, not 1-ethene

$CH_3{-}CH{=}CH_2$ ← This is called propene, not 1-propene

$CH_2{=}CH{-}CH_3$

Why is it that these two molecules do not require the use of the number? (7) There is only 1 possible location for the double bond. ∴ no need to number.

**Problem 10.** Name the alkenes below. After you have located the longest chain containing the double bond, be sure to number the chain so that the double bond gets the lowest possible number.

a. $CH_3{-}CH_2{-}CH{=}CH_2$ — 1-butene

b. $CH_3{-}CH{=}CH{-}CH_3$ — 2-butene

c. $CH_3{-}CH_2{-}CH{=}CH{-}CH_3$ — 2-pentene

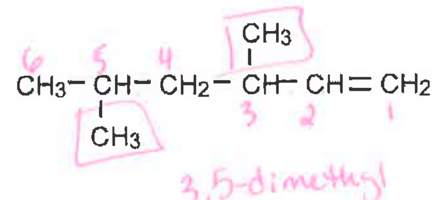
d. $CH_3{-}CH_2{-}CH{=}CH{-}CH_2{-}CH_3$ — 3-hexene

e. $CH_2{=}CH_2$ — ethene

f. $CH_3{-}CH{=}CH_2$ — propene

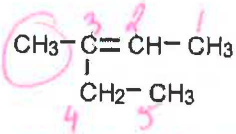
(*remember rule from above.)

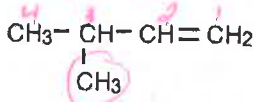
g.

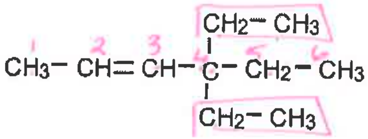



3,5-dimethyl-1-hexene

(lowest # for double bond)

h.  3-methyl-2-pentene

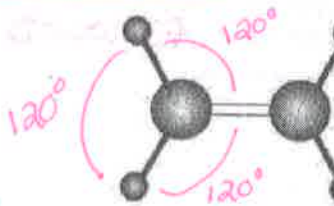
i.  3-methyl-1-butene

j.  4,4-diethyl-2-hexene

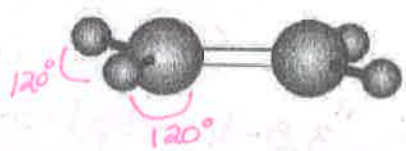
## THE GEOMETRY OF ALKENES AND ALKYNES

In alkanes, each carbon atom is bonded to four other atoms in a tetrahedral shape. The resulting structure is very flexible as a result of atoms being able to rotate freely around the axis of each single bond.

Alkenes have a geometry in which the three atoms connected to each carbon lie flat, arranged 120° from each other in a plane.

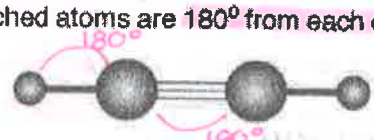



which looks like this from the side:




triple bond

Alkynes have a geometry in which the two atoms attached to the central carbon lie in a straight line, such that the attached atoms are 180° from each other.



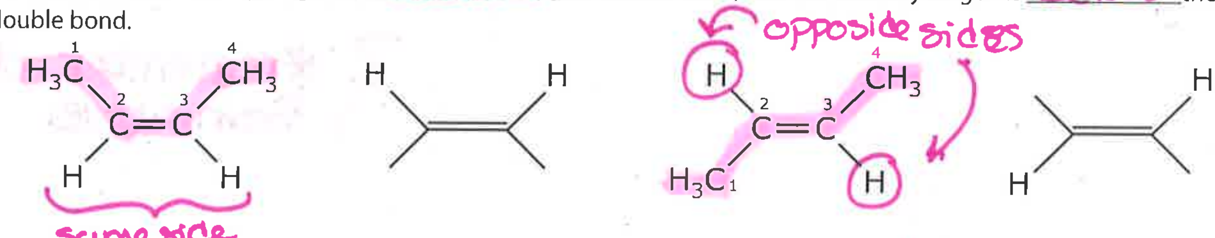

Whereas alkanes have flexible structures, alkenes have very rigid structures. The double bonds effectively "lock" the structure to prevent the attached atoms from "twisting" around the double bond.

### Geometric Isomers

In some cases, the groups attached to the double-bonded carbon atoms provide for a new type of isomerism, as shown in Figure 8.1.7. Geometric **isomers** are alkenes that have the same structure, but the orientation of the groups across the double bond are different.

Geometric isomers are also called cis - trans **isomers.**

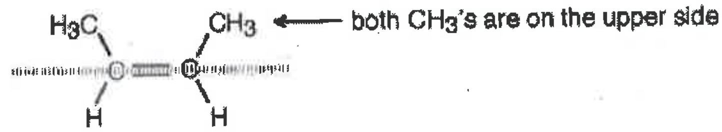
For example, ***cis*-2-butene** has two hydrogen atoms bonded to the double-bonded carbon atoms on the SAME side of the double bond. Both hydrogen atoms are below the double bond. trans-2-butene has the groups bonded to the double-bonded carbon atoms on opposite sides of the double bond. One hydrogen is above the double bond, and the other hydrogen is below the double bond.



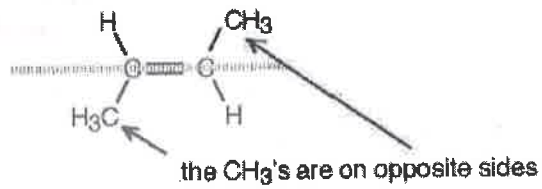

cis-2-butene　　　　trans-2-butene

**Figure 8.1.7** *Examples of cis-trans isomers*

**Note:** In a "**CIS**" isomer, the two groups are on the **SAME SIDE** of the double bond.




In a "**TRANS**" isomer, the two groups are "**TRANSVERSE**" to each other (that is, on opposite sides of the double bond).



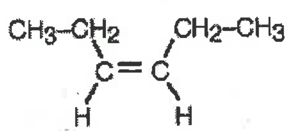

HW!

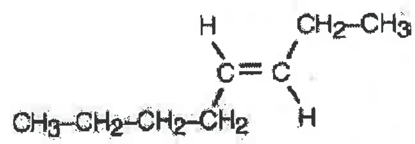
***EXERCISES:***

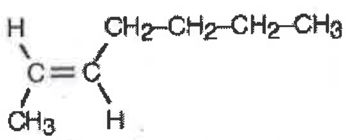
26. Draw the actual shape of the following molecules using condensed structures.
    (a) trans–2–hexene (b) 3–hexyne (c) cis–3–octene (d) trans–4–decene (e) 2–butyne (f) 4–methyl–cis–2–pentene

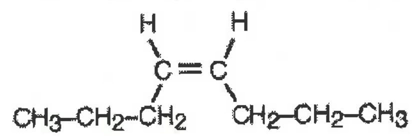
27. Which of the following molecules can exhibit cis–trans isomerism?
    (a) 1–butene (b) 3–hexene (c) 4–heptyne (d) 2–octene (e) 3–ethyl–3–hexene (f) 2,5–dimethyloctane

28. Name the following as "cis" or "trans" isomers.

(a) 


(b) 


(c) 


(d) 


Chemistry 11

# Cis-Trans Isomerization Worksheet

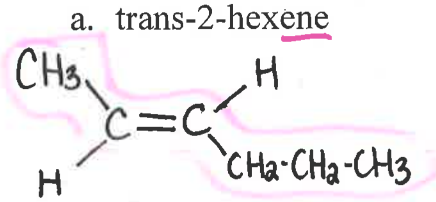
Complete the following questions on a separate piece of paper.

① Do all "ene"
1.a,c,d,f.
2.a,b,d,e
3.all.

HW!

1) Draw the actual shape of the following molecules using condensed structures:

a. trans-2-hexene




b. 3-hexyne

c. cis-3-octene

d. trans-4-decene

e. 2-butyne

f. 4-methyl-cis-2-pentene

2) Which of the following molecules can exhibit cis-trans isomerism?

a. 1-butene

b. 3-hexene

c. 4-heptyne

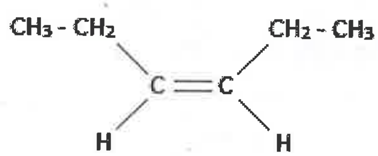
d. 2-octene

e. 3-ethyl-3-hexene

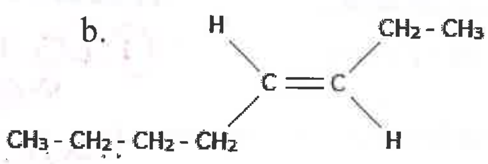
f. 2,5-dimthyloctane

3) Name the following as "cis" or "trans" isomers.

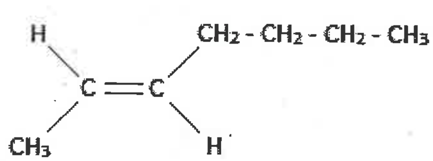
a.



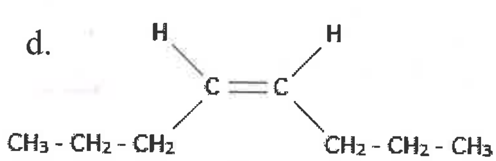

b.




c.

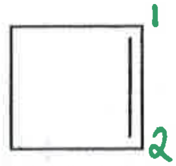



d.

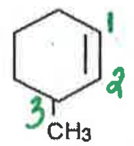


## SECTION 25.9 Naming Cycloalkenes

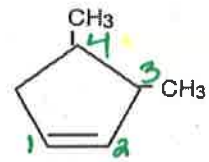
Cycloalkenes are named similarly to straight chained alkenes. The carbons in the ring that contain the double bond are always assigned the #1 and #2 positions, so numbers are used only to locate the positions of substitutents attached to the ring - not to locate the position of the double bond. The general formula for cyclic alkenes in $C_nH_{2n-2}$. Study the examples below.




cyclobutene




3-methylcyclohexene

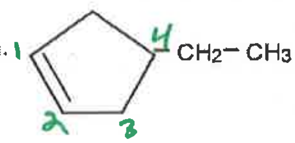



3,4-dimethylcyclopentene

*double bond C=C (1, 2) are assumed #1+#2 .... then number clockwise or counterclockwise so alkyl group has the lowest number.

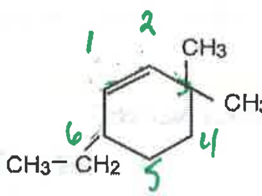
**Problem 11.** Name the following cycloalkenes.

a.




4-ethylcyclopentene

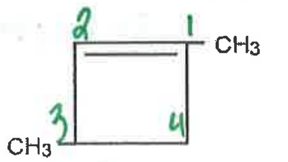
b.




lowest numbers.

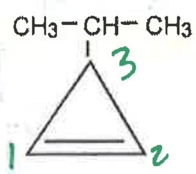
6-ethyl-3,3-dimethylcyclohexene

c.



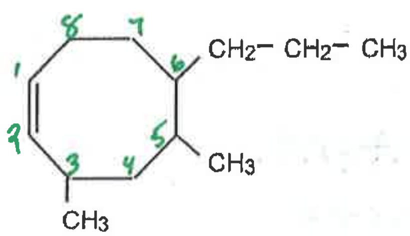

1,3-dimethylcyclobutene

d.



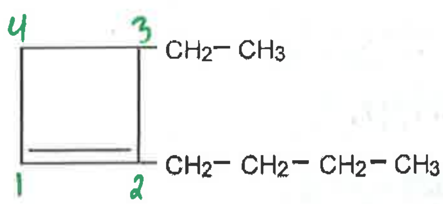

3-(iso)propylcyclopropene

e.




3,5-dimethyl-6-propylcyclooctene

f.




2-butyl-3-ethylcyclobutene

## Alkynes

Alkynes are hydrocarbons containing triple bonds. They are also unsaturated. They have the general formula $C_nH_{(2n-2)}$

The rules for naming alkynes are the **same as for alkanes** except the parent chain name ends in "yne" See Figure 8.1.8 for an example.

$\overset{5}{C}H_3\overset{4}{C}H_2\overset{3}{C}H\overset{2}{C}\equiv\overset{1}{C}H$ with $CH_3$ on C3

**Figure 8.1.8** *3-methyl-1-pentyne*

- The parent chain must contain the triple bond.
- The position of the triple bond is indicated in the name by stating the number of the carbon atom in the parent chain that the triple bond follows.
- The parent chain carbon atoms are numbered starting at the end closest to the triple bond.

**Additional Rules for the Nomenclature of Alkynes:** (extra).

RULE 1: The chain chosen as the parent chain must contain the carbon- carbon triple bond.

RULE 2: The parent chain must be numbered to give the carbon-carbon triple bond the lowest possible number.

RULE 3: The name of the alkyne must contain a number to indicate the position of the triple bond.

As was the case with the alkenes, no number is used to locate the triple bond if the parent chain is shorter than four carbons (because there is only 1 possible placement)

| $CH\equiv CH$ | $CH\equiv C-CH_3$ | $\overset{1}{C}H\equiv\overset{2}{C}-\overset{3}{C}H_2-\overset{4}{C}H_3$ | $\overset{1}{C}H_3-\overset{2}{C}\equiv\overset{3}{C}-\overset{4}{C}H_3$ |
|---|---|---|---|
| ethyne | propyne | 1-butyne | 2-butyne |

For the example at right, the correct name is 5-methyl-2-hexyne

$\overset{1}{C}H_3-\overset{2}{C}\equiv\overset{3}{C}-\overset{4}{C}H_2-\overset{5}{C}(CH_3)-\overset{6}{C}H_3$

5-methyl

**Problem 12.** Name the alkynes drawn below. Be sure to number the parent chain so as to give the triple bond the lowest possible number.

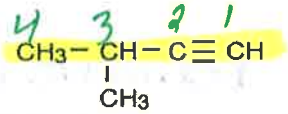
a. $\overset{1}{C}H\equiv\overset{2}{C}-\overset{3}{C}H_2-\overset{4}{C}H_2-\overset{5}{C}H_3$ 1-pentyne

b. $\overset{6}{C}H_3-\overset{5}{C}H_2-\overset{4}{C}H_2-\overset{3}{C}\equiv\overset{2}{C}-\overset{1}{C}H_3$ 2-hexyne

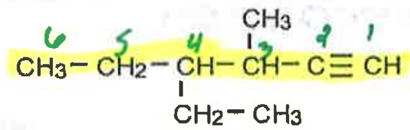
c. $\overset{5}{C}H_3-\overset{4}{C}H_2-\overset{3}{C}\equiv\overset{2}{C}-\overset{1}{C}H_3$ 2-pentyne

d. $\overset{5}{C}H_3-\overset{4}{C}H_2-\overset{3}{C}H_2-\overset{2}{C}\equiv\overset{1}{C}H$ 1-pentyne

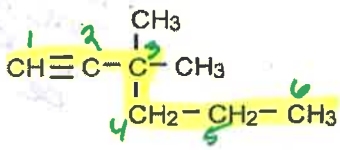
e. $\underset{1}{C}H_3-\underset{2}{C}\equiv\underset{3}{C}-\underset{4}{C}H_2-\underset{5}{C}H_2-\underset{6}{C}H_2-\underset{7}{C}H_3$ 2-heptyne

f. 

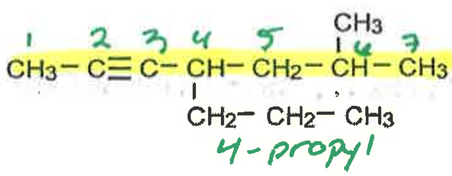
3-methyl-1-butyne

g. 

4-ethyl-3-methyl-1-hexyne

h. 

3,3-dimethyl-1-hexyne

i. 

6-methyl-4-propyl-2-heptyne

***EXERCISES:***

21. Look at the examples above (except for the cyclopentene) and decide on the general formula relating the ratio of carbons to hydrogens for each of the following.
    (a) an alkene (b) an alkyne
    Express your answer in a form similar to the expression $C_NH_{2N+2}$ which was found for alkanes.

22. Draw the condensed structure for the following.
    (a) 1–hexene (c) 3–decene (e) 2–octene
    (b) 4–nonyne (d) 2–heptyne (f) 1–octyne

(see attached answer key)

23. Name the following.
    (a) $CH_3-CH_2-CH=CH-CH_2-CH_3$
    (b) $CH_3-CH_2-CH_2-CH_2-CH_2-C\equiv CH$
    (c) $CH_3-CH_2-CH_2-C\equiv C-CH_2-CH_2-CH_2-CH_2-CH_3$
    (d) $CH_3-CH_2-CH=CH-CH_2-CH_2-CH_3$

24. Draw the condensed structure for each of the following.
    (a) 4–ethyl–3–methyl–2–hexene
    (b) 3–methyl–4–octyne
    (c) 1–ethyl–1–cyclononene
    (d) 3–ethyl–4–methyl–1–hexyne
    (e) dimethyl–2–butene
    (f) 3,6–dimethyl–1–cyclohexene
    (g) cyclopropyne
    (h) 1,3–dimethyl–1–cyclopentene

## Aromatic Hydrocarbons

Benzene is a hydrocarbon with 6 carbon atoms in a ring. This structure is called a benzene ring. It has the molecular formula $C_6H_6$. The bonds between each carbon atom are slightly longer than a double bond, but slightly shorter than a single bond. The electrons in the benzene molecule are delocalized meaning that they are spread across more than one atom. In other words, there is more than one way to draw its Lewis structure. Equivalent Lewis structures are called resonance **structures.**

We can represent **benzene using the resonance structure** shown in Figure 8.1.9(a) and Figure 8.1.9(b) below

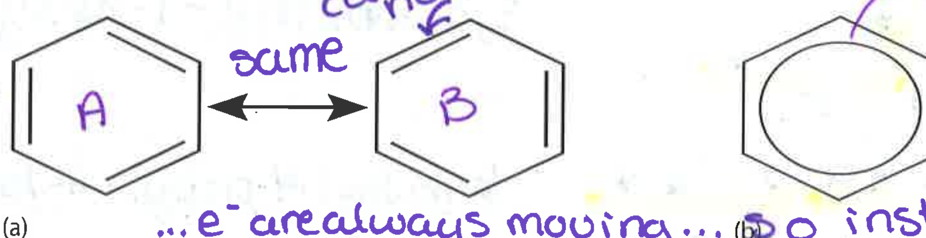



**Figure 8.1.9** *Examples of resonance structures for benzene*

**Benzene's resonance structures give it unusual stability; that is, it is highly resistant to chemical attack. Atoms attached to the benzene ring can be replaced, but only the strongest chemical attack (such as combustion) will affect the ring itself.**

The benzene ring, also known as an "aromatic ring", is present in a large number of molecules and many molecules contain two or more aromatic rings joined together.

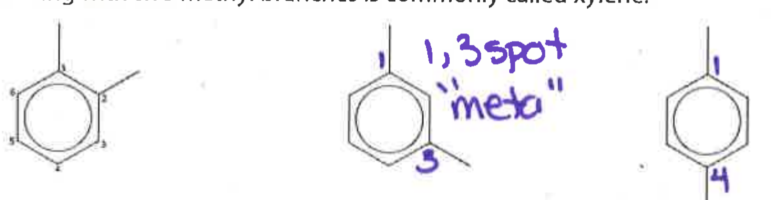
***Definition:*** An **AROMATIC MOLECULE** is a molecule containing one or more benzene rings.

The aromatic ring (benzene ring) is frequently shown as:  .

Aromatic hydrocarbons always contain at least one benzene ring.
When one of the hydrogen atoms in a benzene ring is replaced by another atom or group, we call it a monosubstituted benzene.
Monosubstituted benzenes are named by simply using the **name of the substituted group** as a prefix attached to "benzene."

If more than one hydrogen atom in a benzene has been replaced, we call it a polysubstituted benzene. For polysubstituted benzenes, branches are named and their "address" on the benzene ring is indicated in a similar way to that used for cycloalkanes. We label the first substituted carbon as 1 and proceed either clockwise or counterclockwise in such a way as to give the lowest combination of numbers of substituted carbons.

**For benzenes where only two branches exist on the ring, the three possible **1,2-, 1,3-, and 1,4- positions** can also be indicated using the **prefixes "ortho," "meta," and "para" respectively**. These prefixes describe how close the branches are to each other on the benzene ring (Figure 8.1.10). A benzene ring with one methyl branch is commonly called toluene. A benzene ring with two methyl branches is commonly called xylene.



1, 2-dimethylbenzene (*ortho*-xylene)    1, 3-dimethylbenzene (*meta*-xylene)    1, 4-dimethylbenzene (*para*-xylene)

**Figure 8.1.10** *Examples of prefixes used to describe the branches on a benzene ring*

**The naming of simple aromatic compounds formed by adding groups to a benzene ring is almost identical to the naming procedure used for other cyclic hydrocarbons. Two exercises on the next page allow you to apply what you know to naming aromatic compounds.**

The example molecules which follow do not have to be memorized; they are shown for your information.

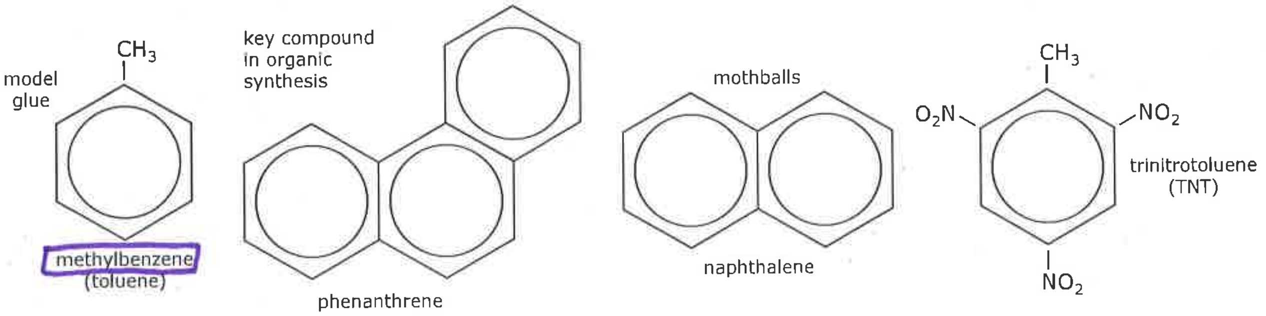


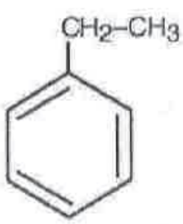

**Figure 8.1.12** *Examples of common aromatic compounds*

HW: ***EXERCISES:*** (Answers are "Hebden Textbook")

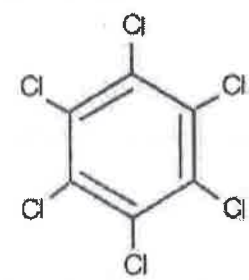
~~29.~~ (a) One resonance structure was drawn for naphthalene (above). Draw two other resonance structures.
(b) One resonance structure was drawn for anthracene (above). Draw three other resonance structures.

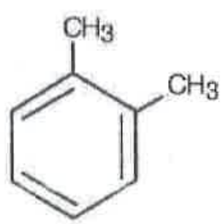
30. Draw the structures of the following compounds.
    - (a) 1,3,5–trimethylbenzene
    - (b) 1–bromo–4–chlorobenzene
    - (c) fluorobenzene
    - (d) 1,4–dibromo–2–methylbenzene
    - (e) 1,3–diethylbenzene
    - (f) hexylbenzene

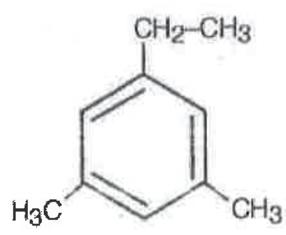
31. Name the following compounds.

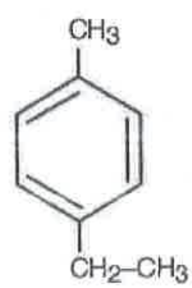
(a) 


(b) 


(c) 


(d) 


(e) 


(f) 

## SECTION 25.11 Review Problems

**Problem 13.** The names of the compounds listed below are NOT correct. Using the incorrect name, draw the structural formula in the work area. Then write the correct name of each compound on the line provided.

| *Incorrect Name* | *Correct Name* | *Work Area* |
|---|---|---|
| a. 4,4-dimethylhexane | ____________________ | |
| b. 2-n-propylpentane | ____________________ | |
| c. 1,1-diethylbutane | ____________________ | |
| d. 1,4-dimethylcyclobutane | ____________________ | |
| e. 3-methyl-2-butene | ____________________ | |
| f. 5-ethylcyclopentene | ____________________ | |
| g. 2-n-propyl-1-propene | ____________________ | |
| h. 2-isopropyl-3-heptene | ____________________ | |
| i. 2,2-dimethyl-3-butyne | ____________________ | |
| j. 5-octyne | ____________________ | |

**Problem 14.** Write condensed structural formulas for the following:

| *Name* | *Condensed Structural Formula* |
|---|---|
| a. 4-isopropyloctane | |
| b. 3,4-dimethyl-4-n-propylheptane | |
| c. 1,1-dimethylcyclobutane | |
| d. 3-ethyl-3-heptene | |
| e. 3-ethyl-2-methyl-1-hexene | |
| f. 3-octene | |
| g. 3,3-dimethyl-1-butyne | |
| h. 4,4-dimethyl-2-pentyne | |
| i. 3-n-butyl-2-ethylcyclohexene | |
| j. 3,4-diethyl-4,6-dimethylnonane | |

## *Nine Classes of Organic Compounds*

| Class of Compound | Functional Group | General Formula | Example |
|---|---|---|---|
| halocarbon | $-F$, $-Cl$, $-Br$, $-I$ | $R-X$ | $CH_3Cl$<br>chloromethane |
| alcohol | $-OH$ | $R-OH$ | $CH_3CH_2CH_2OH$<br>1-propanol |
| ether | $C-O-C$ | $R-O-R'$ | $CH_3OCH_2CH_3$<br>methoxyethane |
| aldehyde | $-\overset{O}{\overset{\|}{C}}-H$ | $R-\overset{O}{\overset{\|}{C}}-H$ | $CH_3CH_2\overset{O}{\overset{\|}{C}}H$<br>propanal |
| ketone | $C-\overset{O}{\overset{\|}{C}}-C$ | $R-\overset{O}{\overset{\|}{C}}-R'$ | $CH_3\overset{O}{\overset{\|}{C}}CH_3$<br>propanone |
| carboxylic acid | $-\overset{O}{\overset{\|}{C}}-OH$ | $R-\overset{O}{\overset{\|}{C}}-OH$ | $CH_3CH_2\overset{O}{\overset{\|}{C}}OH$<br>propanoic acid |
| ester | $-\overset{O}{\overset{\|}{C}}-O-C$ | $R-\overset{O}{\overset{\|}{C}}-OR'$ | $CH_3\overset{O}{\overset{\|}{C}}OCH_3$<br>methylethanoate |
| amine | $C-NH_2$ | $R-NH_2$ | $CH_3CH_2CH_2NH_2$<br>propanamine |
| amide | $-\overset{O}{\overset{\|}{C}}-NH_2$ | $R-\overset{O}{\overset{\|}{C}}-NH_2$ | $CH_3CH_2\overset{O}{\overset{\|}{C}}NH_2$<br>propanamide |