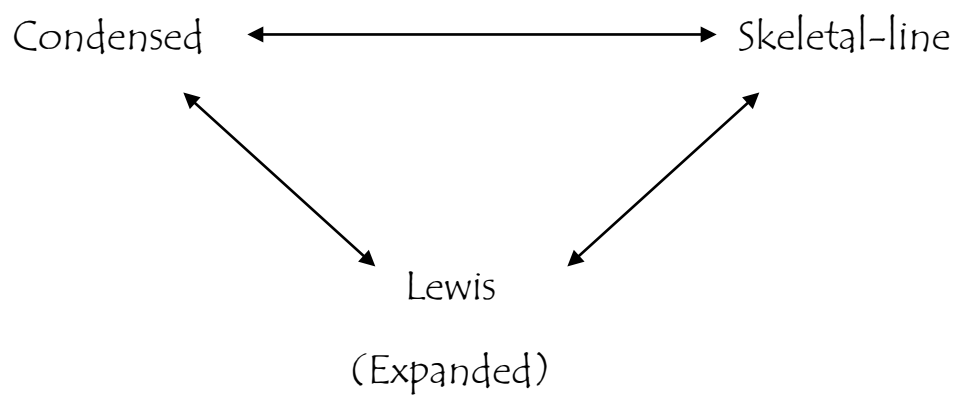


# Hydrocarbons Part 1: Structural Formulas

## Structural Formulas for Organic Molecules



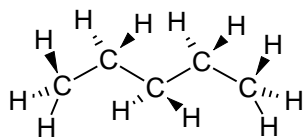
# Neutral Bonding Patterns for Organic Compounds

## Periodic Table of the Elements

|                    |                    |  |                    |                    |                    |                    |                    |                     |                    |                    |                    |                     |                    |                    |                    |                    |                     |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
|--------------------|--------------------|--|--------------------|--------------------|--------------------|--------------------|--------------------|---------------------|--------------------|--------------------|--------------------|---------------------|--------------------|--------------------|--------------------|--------------------|---------------------|----------------------|--------------------|-------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|--------------------|--------------------|
| 1<br>Group<br>IA   |                    |  |                    |                    |                    |                    |                    |                     |                    |                    |                    | 13<br>Group<br>IIIA |                    | 14<br>Group<br>IVA | 15<br>Group<br>VA  | 16<br>Group<br>VIA | 17<br>Group<br>VIIA | 18<br>Group<br>VIIIA |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 1<br>H<br>1.01     | 2<br>Group<br>IIA  |  |                    |                    |                    |                    |                    |                     |                    |                    |                    | 5<br>B<br>10.81     | 6<br>C<br>12.01    | 7<br>N<br>14.01    | 8<br>O<br>16.00    | 9<br>F<br>19.00    | 10<br>Ne<br>20.18   |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 3<br>Li<br>6.94    | 4<br>Be<br>9.01    |  |                    |                    |                    |                    |                    |                     |                    |                    |                    | 13<br>Al<br>26.98   | 14<br>Si<br>28.09  | 15<br>P<br>30.97   | 16<br>S<br>32.06   | 17<br>Cl<br>35.45  | 18<br>Ar<br>39.95   |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 11<br>Na<br>22.99  | 12<br>Mg<br>24.30  | 3<br>Group<br>IIIB   | 4<br>Group<br>IVB  | 5<br>Group<br>VB   | 6<br>Group<br>VIB  | 7<br>Group<br>VIIB | 8<br>Group         | 9<br>Group<br>VIIIB | 10<br>Group        | 11<br>Group<br>IB  | 12<br>Group<br>IIB |                     |                    |                    |                    |                    |                     |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 19<br>K<br>39.10   | 20<br>Ca<br>40.08  | 21<br>Sc<br>44.96  | 22<br>Ti<br>47.87  | 23<br>V<br>50.94   | 24<br>Cr<br>52.00  | 25<br>Mn<br>54.94  | 26<br>Fe<br>55.84  | 27<br>Co<br>58.93   | 28<br>Ni<br>58.69  | 29<br>Cu<br>63.55  | 30<br>Zn<br>65.39  | 31<br>Ga<br>69.72   | 32<br>Ge<br>72.64  | 33<br>As<br>74.92  | 34<br>Se<br>78.96  | 35<br>Br<br>79.90  | 36<br>Kr<br>83.80   |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 37<br>Rb<br>85.47  | 38<br>Sr<br>87.62  | 39<br>Y<br>88.91   | 40<br>Zr<br>91.22  | 41<br>Nb<br>92.91  | 42<br>Mo<br>95.94  | 43<br>Tc<br>98     | 44<br>Ru<br>101.07 | 45<br>Rh<br>102.91  | 46<br>Pd<br>106.42 | 47<br>Ag<br>107.87 | 48<br>Cd<br>112.41 | 49<br>In<br>114.82  | 50<br>Sn<br>118.71 | 51<br>Sb<br>121.76 | 52<br>Te<br>127.60 | 53<br>I<br>126.90  | 54<br>Xe<br>131.29  |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 55<br>Cs<br>132.91 | 56<br>Ba<br>137.33 | 57<br>La<br>138.91   | 72<br>Hf<br>178.49 | 73<br>Ta<br>180.95 | 74<br>W<br>183.84  | 75<br>Re<br>186.21 | 76<br>Os<br>190.23 | 77<br>Ir<br>192.22  | 78<br>Pt<br>195.08 | 79<br>Au<br>196.97 | 80<br>Hg<br>200.59 | 81<br>Tl<br>204.38  | 82<br>Pb<br>207.2  | 83<br>Bi<br>208.98 | 84<br>Po<br>(209)  | 85<br>At<br>(210)  | 86<br>Rn<br>(222)   |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 87<br>Fr<br>(223)  | 88<br>Ra<br>(226)  | 89<br>Ac<br>(227)  | 104<br>Rf<br>(261) | 105<br>Db<br>(262) | 106<br>Sg<br>(266) | 107<br>Bh<br>(264) | 108<br>Hs<br>(268) | 109<br>Mt<br>(268)  | 110<br>-<br>(271)  | 111<br>-<br>(272)  | 112<br>-<br>(277)  | 114<br>-<br>(289)   |                    | 116<br>-<br>(289)  |                    | 118<br>-<br>(293)  |                     |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
|                    |                    | <table border="1"> <tr> <td>58<br/>Ce<br/>140.12</td> <td>59<br/>Pr<br/>140.91</td> <td>60<br/>Nd<br/>144.24</td> <td>61<br/>Pm<br/>(145)</td> <td>62<br/>Sm<br/>150.36</td> <td>63<br/>Eu<br/>151.96</td> <td>64<br/>Gd<br/>157.25</td> <td>65<br/>Tb<br/>158.93</td> <td>66<br/>Dy<br/>162.50</td> <td>67<br/>Ho<br/>164.93</td> <td>68<br/>Er<br/>167.26</td> <td>69<br/>Tm<br/>168.93</td> <td>70<br/>Yb<br/>173.04</td> <td>71<br/>Lu<br/>174.97</td> </tr> <tr> <td>90<br/>Th<br/>232.04</td> <td>91<br/>Pa<br/>231.04</td> <td>92<br/>U<br/>238.03</td> <td>93<br/>Np<br/>(237)</td> <td>94<br/>Pu<br/>(242)</td> <td>95<br/>Am<br/>(243)</td> <td>96<br/>Cm<br/>(248)</td> <td>97<br/>Bk<br/>(247)</td> <td>98<br/>Cf<br/>(251)</td> <td>99<br/>Es<br/>(252)</td> <td>100<br/>Fm<br/>(257)</td> <td>101<br/>Md<br/>(260)</td> <td>102<br/>No<br/>(259)</td> <td>103<br/>Lr<br/>(262)</td> </tr> </table> |                    |                    |                    |                    |                    |                     |                    |                    |                    |                     |                    |                    |                    |                    | 58<br>Ce<br>140.12  | 59<br>Pr<br>140.91   | 60<br>Nd<br>144.24 | 61<br>Pm<br>(145) | 62<br>Sm<br>150.36 | 63<br>Eu<br>151.96 | 64<br>Gd<br>157.25 | 65<br>Tb<br>158.93 | 66<br>Dy<br>162.50 | 67<br>Ho<br>164.93 | 68<br>Er<br>167.26 | 69<br>Tm<br>168.93 | 70<br>Yb<br>173.04 | 71<br>Lu<br>174.97 | 90<br>Th<br>232.04 | 91<br>Pa<br>231.04 | 92<br>U<br>238.03 | 93<br>Np<br>(237) | 94<br>Pu<br>(242) | 95<br>Am<br>(243) | 96<br>Cm<br>(248) | 97<br>Bk<br>(247) | 98<br>Cf<br>(251) | 99<br>Es<br>(252) | 100<br>Fm<br>(257) | 101<br>Md<br>(260) | 102<br>No<br>(259) | 103<br>Lr<br>(262) |
| 58<br>Ce<br>140.12 | 59<br>Pr<br>140.91 | 60<br>Nd<br>144.24   | 61<br>Pm<br>(145)  | 62<br>Sm<br>150.36 | 63<br>Eu<br>151.96 | 64<br>Gd<br>157.25 | 65<br>Tb<br>158.93 | 66<br>Dy<br>162.50  | 67<br>Ho<br>164.93 | 68<br>Er<br>167.26 | 69<br>Tm<br>168.93 | 70<br>Yb<br>173.04  | 71<br>Lu<br>174.97 |                    |                    |                    |                     |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |
| 90<br>Th<br>232.04 | 91<br>Pa<br>231.04 | 92<br>U<br>238.03  | 93<br>Np<br>(237)  | 94<br>Pu<br>(242)  | 95<br>Am<br>(243)  | 96<br>Cm<br>(248)  | 97<br>Bk<br>(247)  | 98<br>Cf<br>(251)   | 99<br>Es<br>(252)  | 100<br>Fm<br>(257) | 101<br>Md<br>(260) | 102<br>No<br>(259)  | 103<br>Lr<br>(262) |                    |                    |                    |                     |                      |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |                    |

## Skeletal Line Structures

Carbon atoms can form long chains with branches. The tetrahedral electron geometry results in the carbon atoms forming a zigzag shape. Skeletal-line drawings show the carbon skeleton at the end of each line and at each corner.



### Guidelines for Writing Skeletal-Line Structures

Rule 1: All carbon-carbon single bonds are shown as a single line

Rule 2: Double bonds are shown as two parallel lines  
Triple bonds are shown as three parallel lines

Rule 3: The chemical symbol of carbon, C, is omitted. The presence of a carbon atom is implied wherever two lines join and at the end of a line. A continuous carbon chain is represented as a zigzag arrangement of lines.

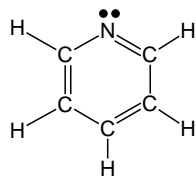
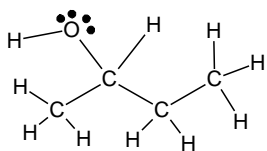
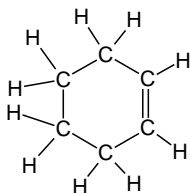
Rule 4: Heteroatoms are atoms other than carbon or hydrogen and must be written.

Rule 5: Hydrogen atoms must be drawn on heteroatoms and the carbons of aldehyde groups.

Note: Since carbon atoms ALWAYS have 4 bonds, you can determine the number of H atoms bonded to a particular carbon atom by counting the number of bonds and subtracting this value from 4.

### Practice

#### Lewis Structure

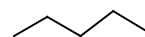
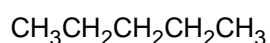
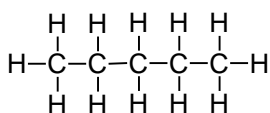


#### Skeletal-line Structure

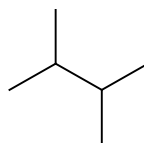
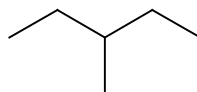
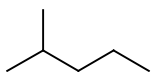
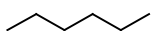
## Condensed Structures

Because the carbon atoms form the backbone of the skeleton, it is also common to omit the bonds and only show the atoms. Double and triple bonds are often still shown.

The following three structures ALL represent the same compound:



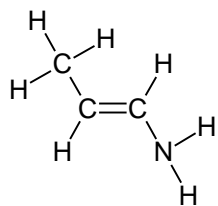
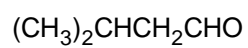
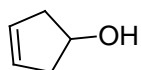
Write the condensed structures for the 5 structural isomers of  $\text{C}_6\text{H}_{14}$ .



Here are "4 different ways" to describe an organic compound:

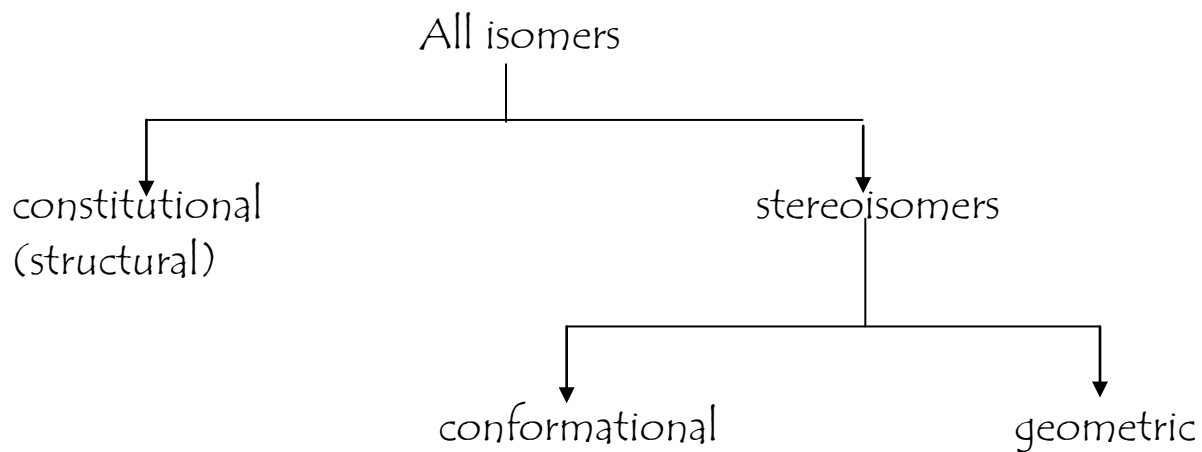
Molecular Formula vs Lewis Structure vs Bond-Line vs Condensed

Draw these compounds the "other 3 ways" & add the lone pair electrons.



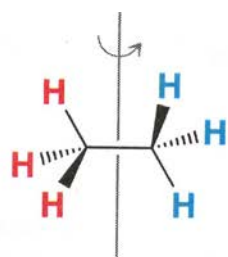
## Hydrocarbons Part 2: Recognizing Isomers

### Recognizing Isomers

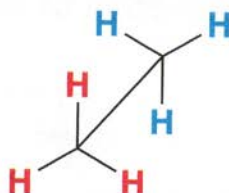


# Conformers

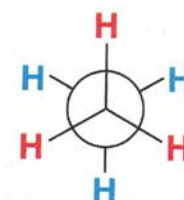
Perspective Formulas, Sawhorses, and Newman Projections  
3 different ways to show conformations



Wedge and dash

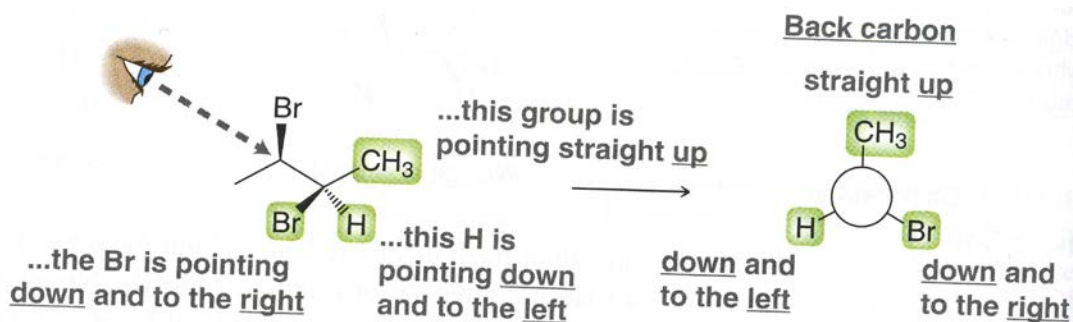
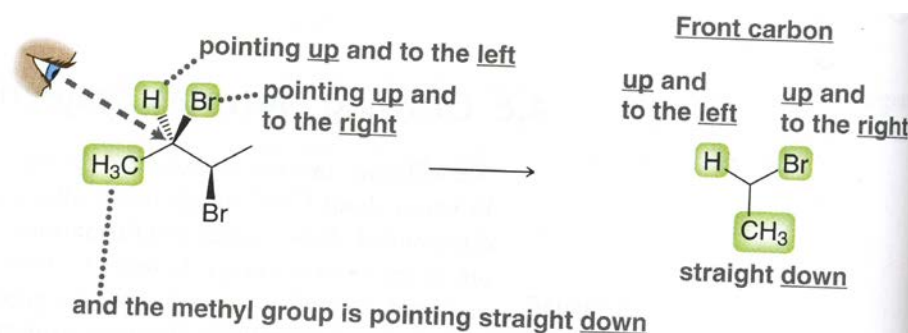
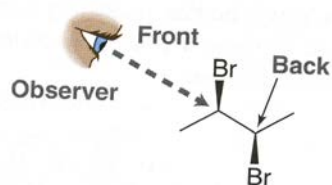


Sawhorse



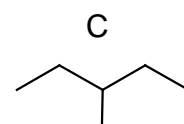
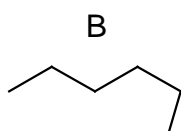
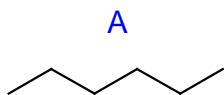
Newman projection

Converting the perspective formula for 2,3-dibromobutane into a Newman Projection along the C2-C3 axis.



Draw the Newman projection for  $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$  along the C2-C3 axis.

What are the relationships between compounds A, B and C?





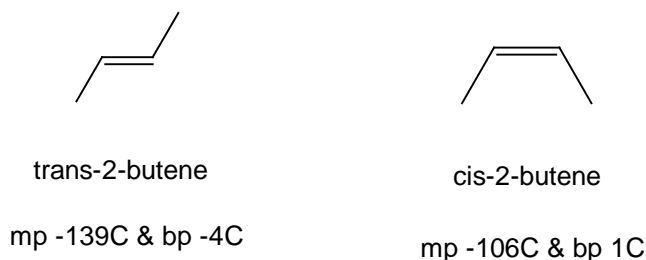
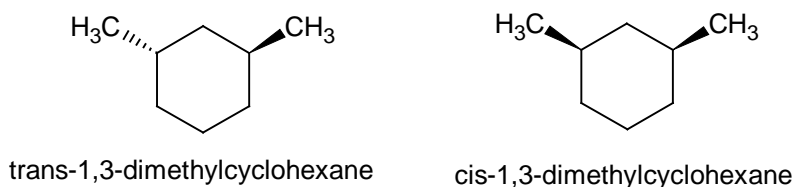
## Structural (Constitutional) Isomers

compounds with the SAME chemical formula, but  
DIFFERENT connectivity of atoms

Draw the 5 structural isomers with the molecular formula  $C_6H_{14}$  using skeletal-line structures.

Geometric Isomers: compounds with the same connectivity between atoms, yet different spatial arrangements.

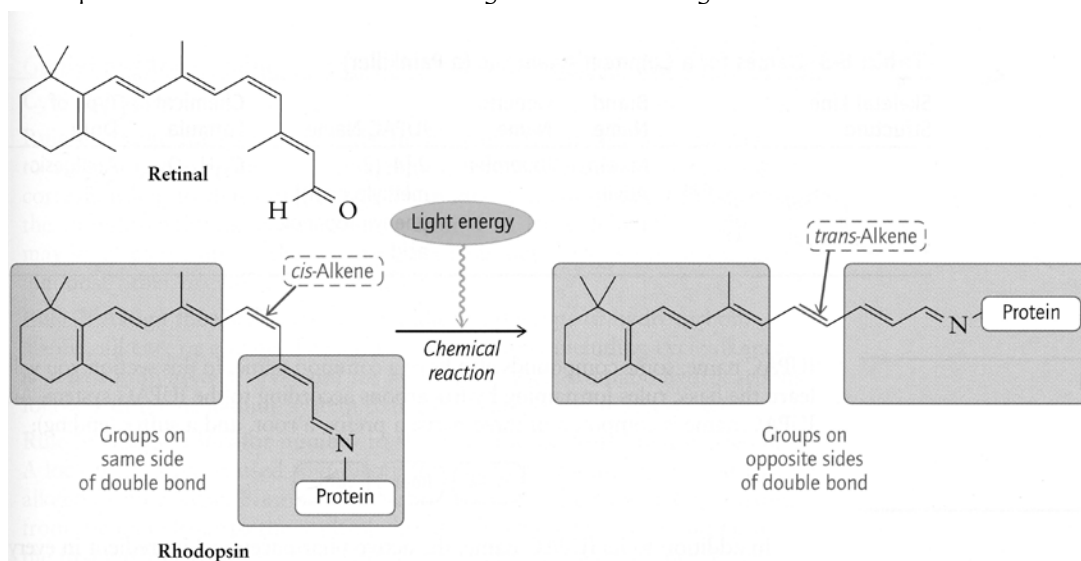
Cis & trans isomers can NOT inter-convert. They are unique cpds.



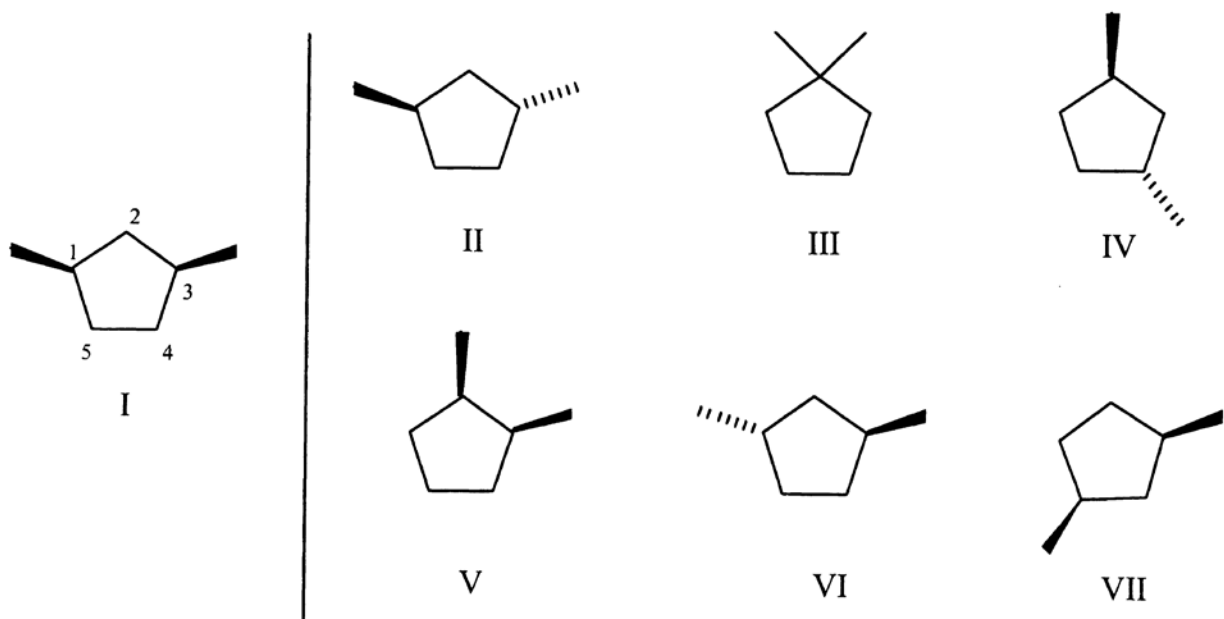
## Cis-trans Isomers in Biochemistry

Isomerization reaction: a chemical reaction that converts one structural isomer or geometric isomer into another

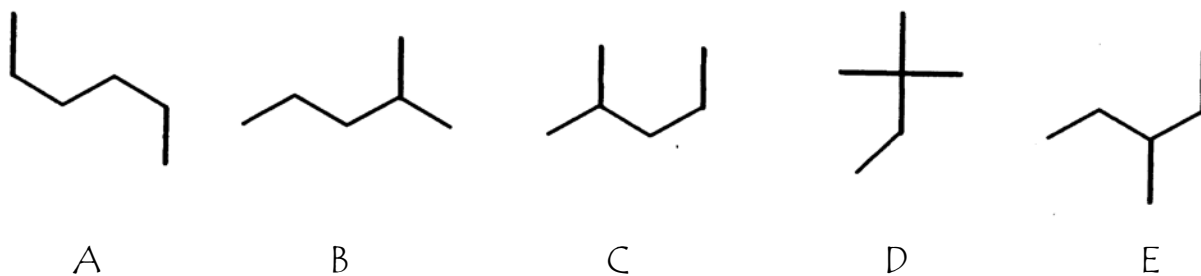
The retina of the eye contains 2 types of photoreceptors: rods and cones. The rods contain a polyene known as retinal which is part of a larger protein known as rhodopsin. Light induces one of the cis- double bonds to undergo isomerization reaction to a trans double bond causing the entire molecule to change shape which initiates a nerve impulse that travels along the optic nerve to the brain resulting in a visual image.



1. a) What are the relationships between Cpđ I and other Cpđs II to VII – identical (I), structural isomers (SI), or geometric isomers (GI)?
- b) Label all geometric isomers as cis or trans.

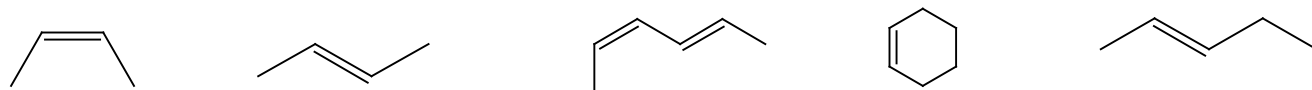


2. Use the following compounds to answer the questions below.



- a) Which compounds are structural isomers?
- b) Which compounds are conformers?

3. Label the following double bonds as cis or trans if applicable.

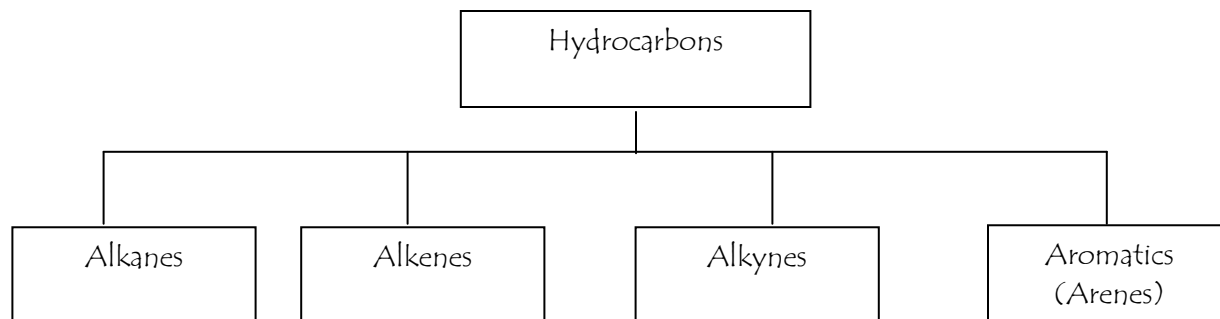


## Hydrocarbons Part 3: IUPAC Nomenclature

### Naming Hydrocarbons

IUPAC = International Union of Pure & Applied Chemistry

There are 4 types of hydrocarbons.



Alkanes are \_\_\_\_\_ hydrocarbons (aliphatic).

Alkenes, alkynes, and aromatics are \_\_\_\_\_ hydrocarbons

Names have 3 parts:

Straight chains are named using the root names from the homologous series.

Cycloalkanes are named using the same root names with the additional prefix "cyclo".

Alkane names end with the suffix "ane".

Alkene names end with the suffix "ene".

Alkynes end with the suffix "yne".

## Root Names – the Homologous Series

| # C's | Alkane Structure | Suffix name | Substituent name |
|-------|------------------|-------------|------------------|
| 1     |                  | methane     | methyl           |
| 2     |                  | ethane      | ethyl            |
| 3     |                  | propane     | propyl           |
| 4     |                  | butane      | butyl            |
| 5     |                  | pentane     | pentyl           |
| 6     |                  | hexane      | hexyl            |
| 7     |                  | heptane     | heptyl           |
| 8     |                  | octane      | octyl            |
| 9     |                  | nonane      | nonyl            |
| 10    |                  | decane      | decyl            |

-CH<sub>2</sub>-

-CH<sub>2</sub>CH<sub>2</sub>-

-CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>-

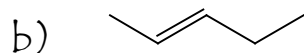
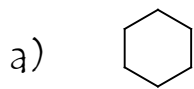
## Guidelines for Naming Straight-Chain Hydrocarbons and Cycloalkanes

- Rule 1: Assign the root by counting the carbon atoms in the chain.
- Rule 2: Assign the suffix.
- Rule 3: Assign a locator number to the root if a multiple-bond is present. The multiple-bond is ALWAYS assigned the lowest possible number.
- Rule 4: For cycloalkanes and alkenes, assign the cis or trans prefix if applicable.

Draw the skeletal-line structure for each of the following compounds.

- a) trans-2-hexene
- b) 3-octyne
- c) cyclopentane

Give the IUPAC name for the following compounds.



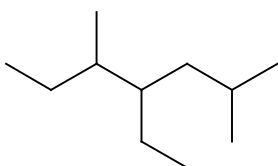
## Naming Branched-Chain Hydrocarbons

Main Chain: the longest continuous C-chain

Substituents: the carbon branches from the main chain (root)

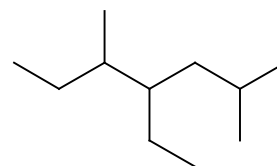
### Guidelines for Naming Branched-Chain Hydrocarbons

Rule 1: Find the longest continuous C-chain and assign the root name.



Rule 2: Assign the suffix based on the type of carbon-carbon bonds

Rule 3: Name each substituent.



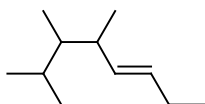
Rule 4: Assign a locator number to all substituents.  
Double & triple bonds are assigned the lowest possible number.  
If there are no C=C or C≡C bonds, then the main chain is numbered to give the first branch the lowest possible number.

Rule 5: Assemble the prefix name by listing the substituents in alphabetical order. Place the locator number in front of each substituent name separated by a hyphen.

If a substituent is repeated more than once along a chain, then insert an additional prefix di- (2), tri- (3), or tetra- (4) in front.

Rule 6: For cycloalkanes and alkenes, assign the cis or trans prefix if applicable.

Give the IUPAC for the following compound.

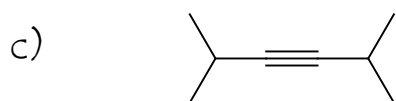
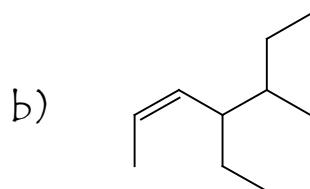
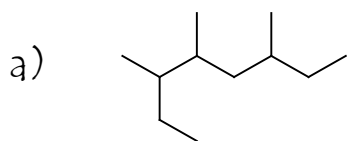


Draw the skeletal-line structure for each of the following compounds.

a) cis-4-ethyl-2-hexene

b) trans-1-ethyl-3-methylcyclohexane

Give the IUPAC name for the following compounds.





## Guidelines for Naming Substituted Benzenes

Rule 1: Assign the root name.

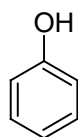
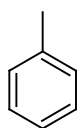
Rule 2: Name each substituent.

Rule 3: If there is more than one substituent present, then we number the benzene ring to give the 2<sup>nd</sup> substituent the lowest possible number. The first substituent is always given the number 1.

Rule 4: Assemble the prefix name by listing the substituents in alphabetical order. Place the locator number in front of each substituent name separated by a hyphen.

If a substituent is repeated more than once along a chain, then insert an additional prefix di- (2), tri- (3), or tetra- (4) in front.

Memorize the following common benzene derivatives.

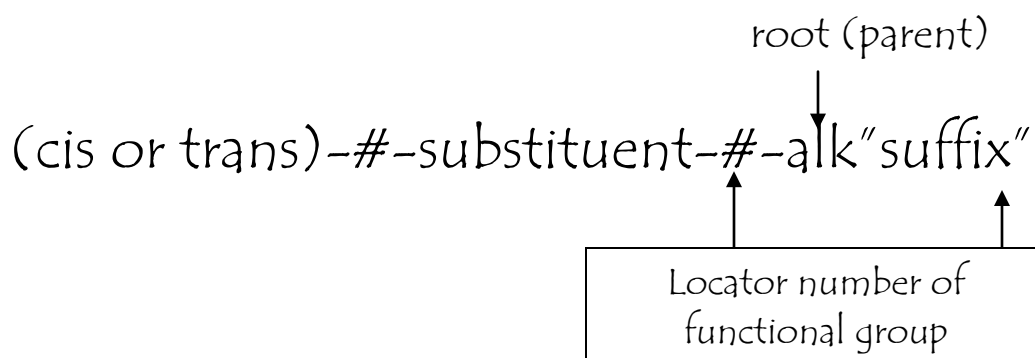
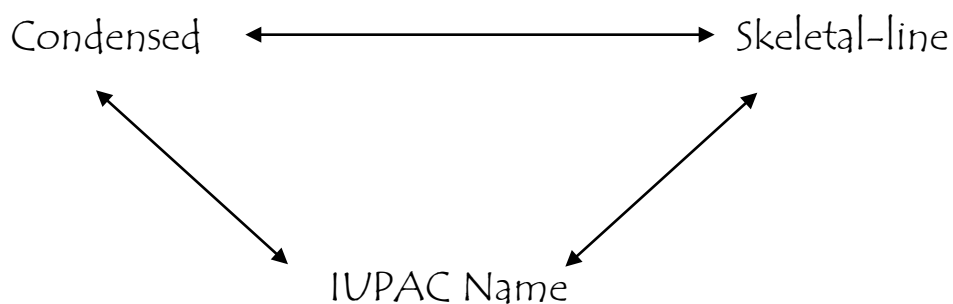


Draw the skeletal-line structure for 3-propylphenol.

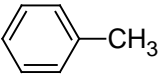
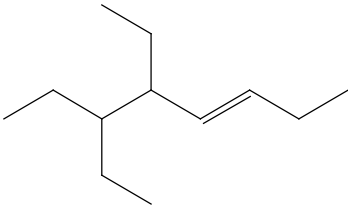
Give the IUPAC name for  $C_6H_5CH_2CH_2CH_2CH_3$ .

# Hydrocarbons Part 4: Structure & IUPAC Nomenclature Review

## Hydrocarbon Structure & Nomenclature Review



Complete the table.

| IUPAC Name                    | Skeletal-line Structure   | Condensed Structure  |
|-------------------------------|---|--|
| 4-ethyl-2-methyloctane        |   |  |
|                               |    |  |
|                               |   | $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$ |
| cis-6-ethyl-7-methyl-3-octene |   |  |
|                               |  |  |
|                               |   | $\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$            |