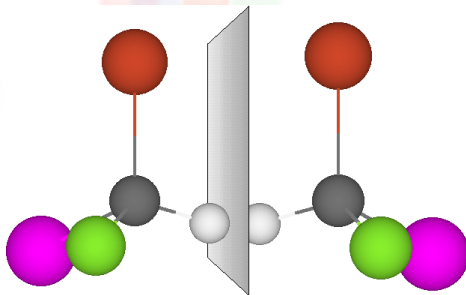
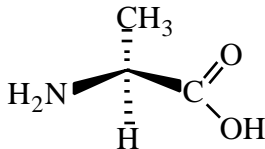
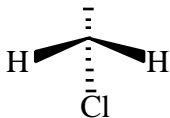
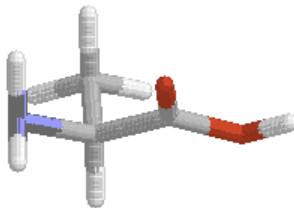
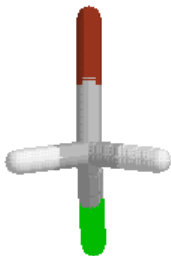


Stereochemistry

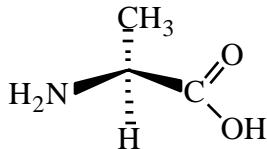
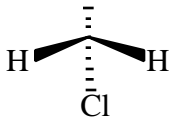
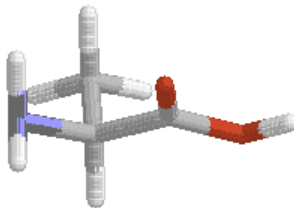
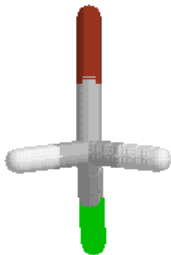


© 2000, Paul R. Young
University of Illinois at Chicago, All Rights Reserved

...or represented by converting condensed structures into three dimensional representations using dashed lines and “wedges”.

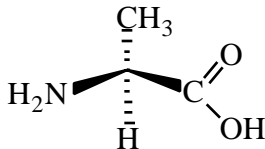
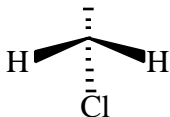
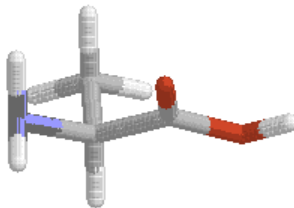
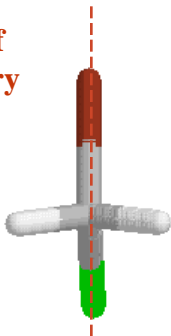


It is important to be able to visualize this stereochemistry in order to test molecules for **internal planes of symmetry**.



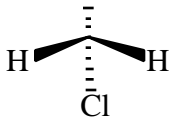
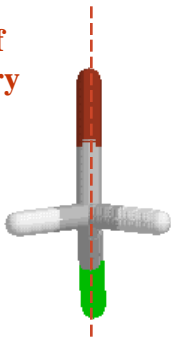
It is important to be able to visualize this stereochemistry in order to test molecules for **internal planes of symmetry**.

Plane of Symmetry

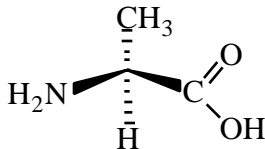
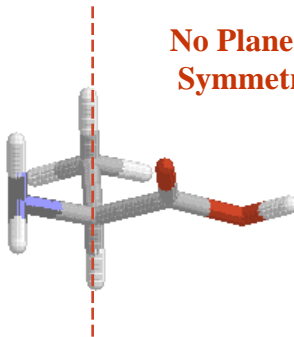


It is important to be able to visualize this stereochemistry in order to test molecules for **internal planes of symmetry**.

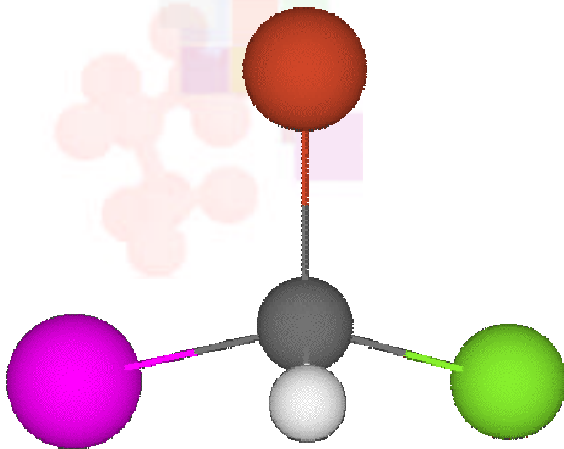
Plane of Symmetry



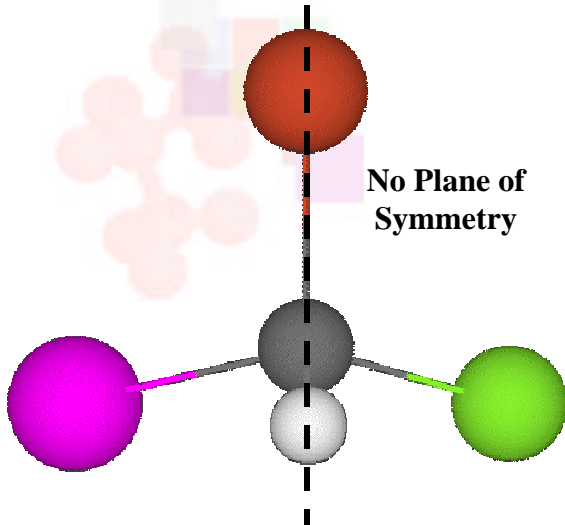
No Plane of Symmetry



One consequence of tetrahedral geometry is an internal asymmetry which occurs whenever there are **four different substituents arranged around a tetrahedral center...**

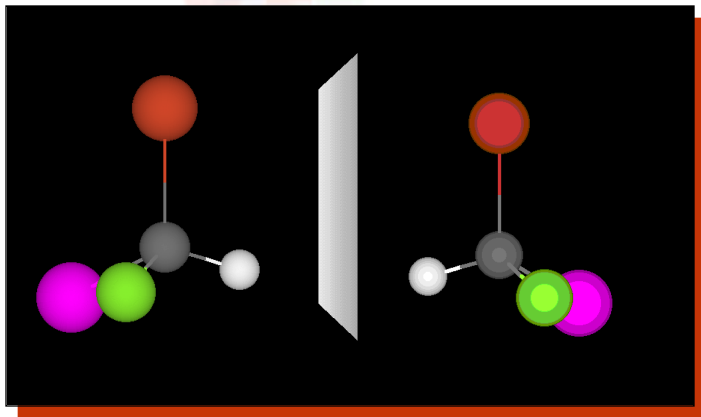


One consequence of tetrahedral geometry is an internal **asymmetry** which occurs whenever there are **four different substituents arranged around a tetrahedral center...**

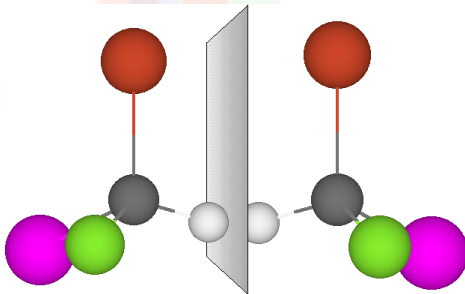


The net effect of this asymmetry is to generate a molecule which is **not superimposable on its mirror image**.

Mirror Plane

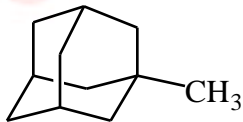
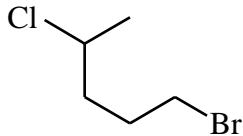
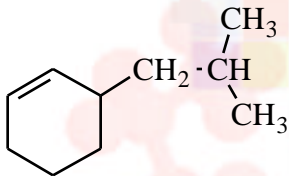


A carbon which is attached to **four different substituents** is called a **chiral carbon**...and a pair of **non-superimposable mirror images** are called **enantiomers**.

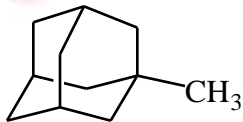
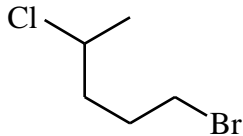
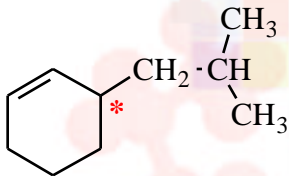


...a pair of **enantiomers**

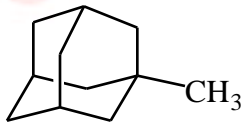
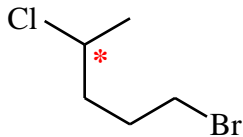
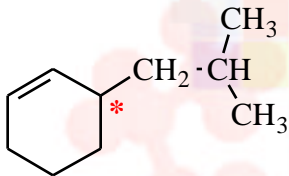
For each of the molecules shown below, indicate each of the chiral centers with an asterisk (*)



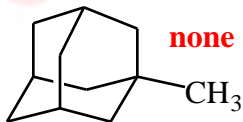
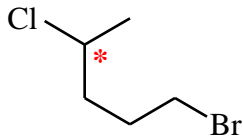
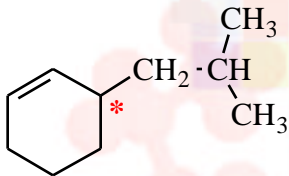
For each of the molecules shown below, indicate each of the chiral centers with an asterisk (*)



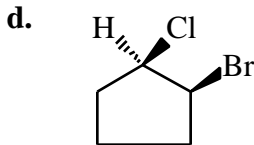
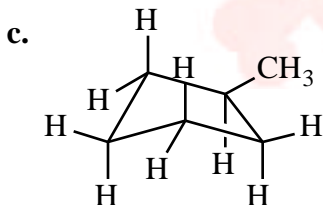
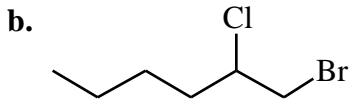
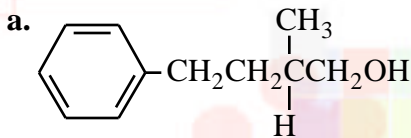
For each of the molecules shown below, indicate each of the chiral centers with an asterisk (*)

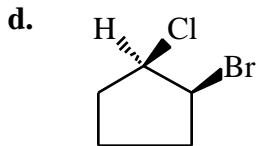
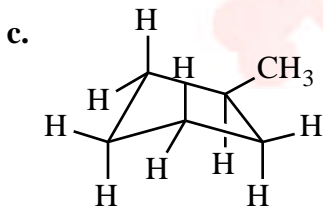
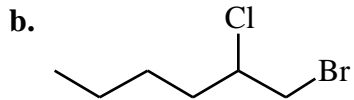
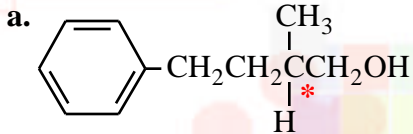


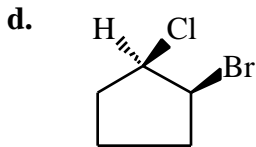
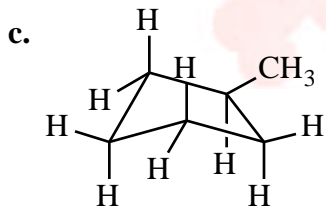
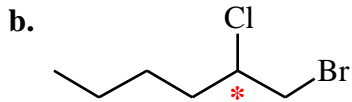
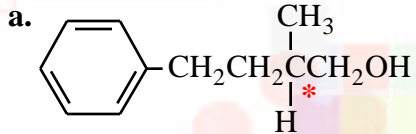
For each of the molecules shown below, indicate each of the chiral centers with an asterisk (*)

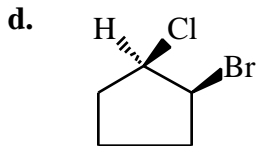
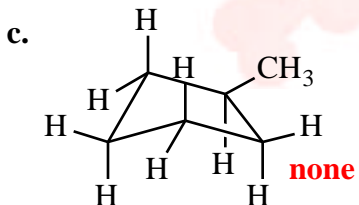
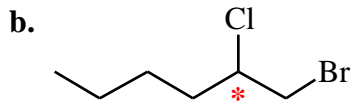
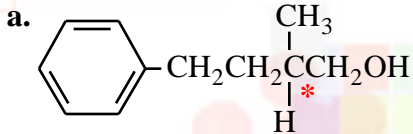


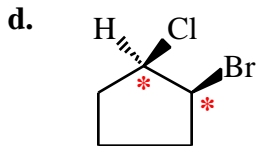
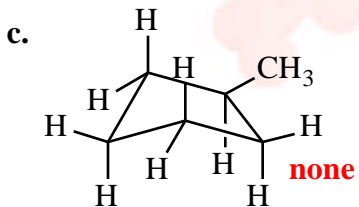
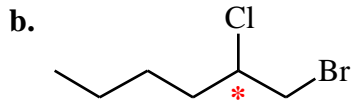
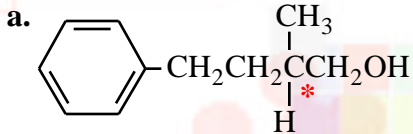
For each of the molecules shown below, indicate each of the chiral centers with an asterisk (*)







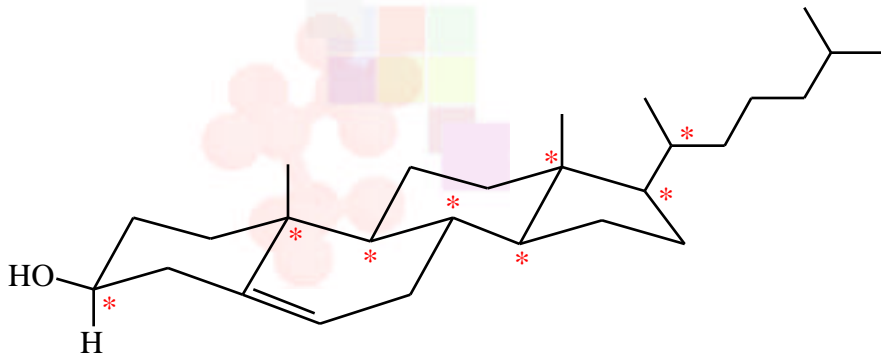




For each of the molecules shown below, indicate each of the chiral centers with an asterisk (*)

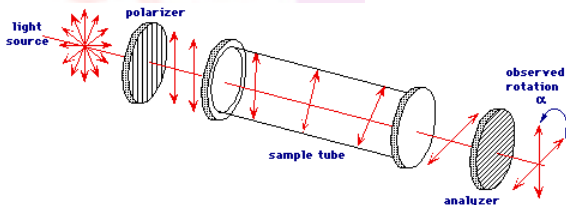


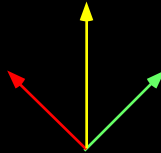
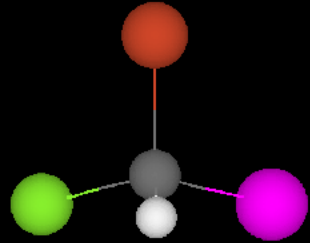
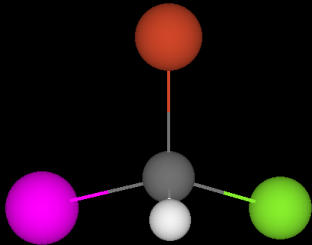
For each of the molecules shown below, indicate each of the chiral centers with an asterisk (*)



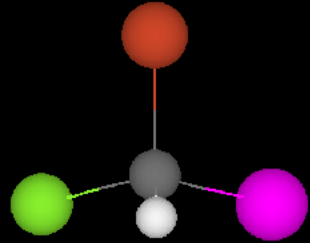
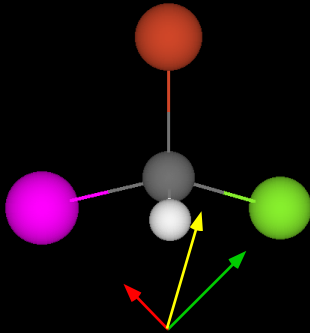
Eight Chiral Centers $\equiv 2^8$ Stereoisomers

Enantiomers are identical in every physical and chemical property (except in their interactions with other chiral molecules) except for the fact that they rotate the plane of plane polarized light in opposite directions, and hence chiral compounds are often termed “optically active”.

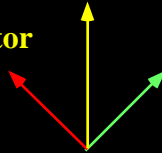




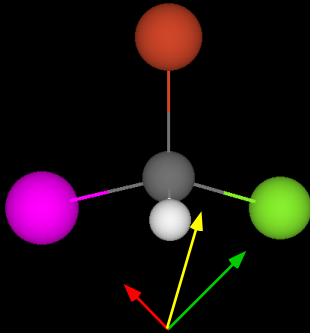
**Plane Polarized Light Can Be Described as
Identical Magnetic & Electric
Vectors; Resultant is Vertical Plane**



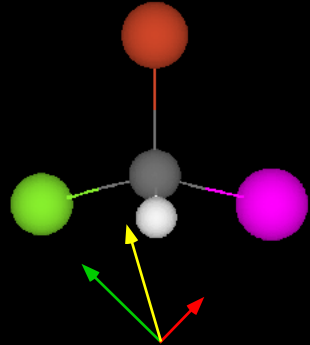
**Magnetic or Electric
Component Absorbed
Differently; Resultant Vector
is Displaced**



**Plane Polarized Light Can Be Described as
Identical Magnetic & Electric
Vectors; Resultant is Vertical Plane**

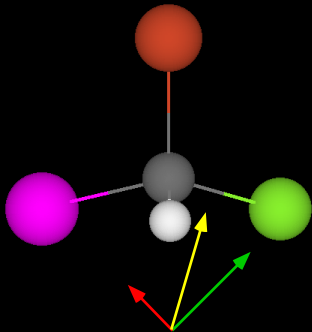


**Magnetic or Electric
Component Absorbed
Differently; Resultant Vector
is Displaced**

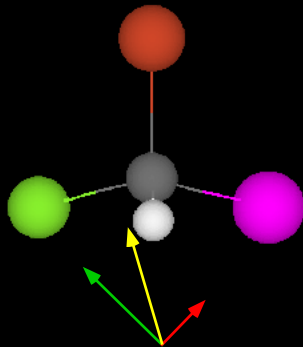


**Magnetic or Electric
Component Absorbed
Differently; Resultant Vector
is Displaced**

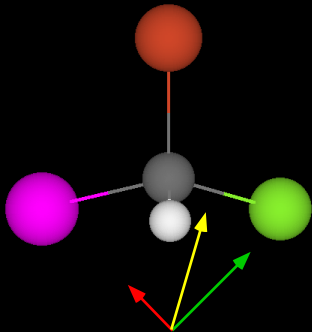
**Plane Polarized Light Can Be Described as
Identical Magnetic & Electric
Vectors; Resultant is Vertical Plane**



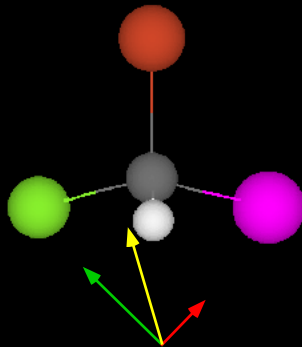
A solution containing one enantiomer will therefore rotate polarized light one direction...



...and the other enantiomer will rotate polarized light in the opposite direction.



A solution containing one enantiomer will therefore rotate polarized light one direction...



...and the other enantiomer will rotate polarized light in the opposite direction.

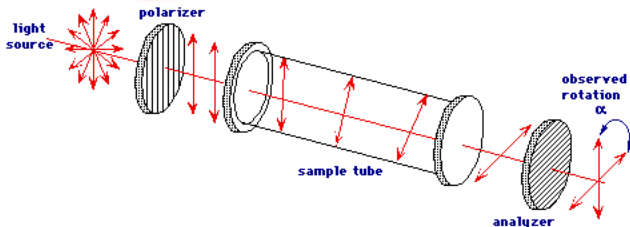
A solution containing equal concentrations of both will therefore have no effect on plane polarized light. A mixture of equal concentrations of two enantiomers is called a Racemic Mixture.

Specific Rotation, $[\alpha]$

$$[\alpha]_D = \frac{\text{Observed Rotation (degrees)}}{\text{Path length } l, (\text{dm}) \times \text{Concentration } C, (\text{g/mL})} = \frac{\alpha}{l \times C}$$

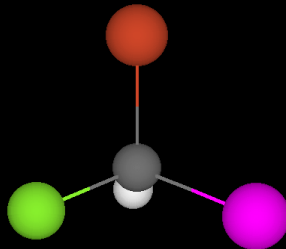
The **Specific Rotation** is equal to the observed rotation (α) divided by the the pathlength of the cell (l) in **dm**, multiplied by the concentration (C) in **g/mL**

The subscript **D** refers to the wavelength of light used (**the sodium “D-line”**)



Assigning Absolute Configuration

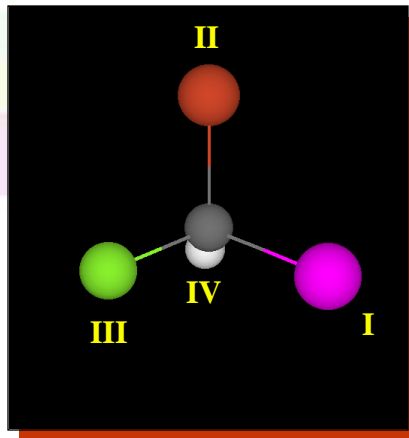
The direction in which an optically active molecule rotates light is *specific* for a given molecule, but is **not related to the absolute orientation of groups in that molecule around the chiral center.**



[α] could be either + or -

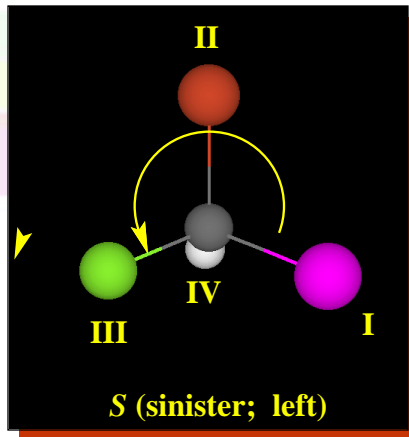
Assigning Absolute Configuration

In order to signify the **absolute configuration**, a system of nomenclature has been established in which groups around the chiral center are assigned “**priorities**”. **The lowest priority group is placed towards the back**, and the direction (**clockwise or counterclockwise**) of a line connecting the remaining groups is determined.



Assigning Absolute Configuration

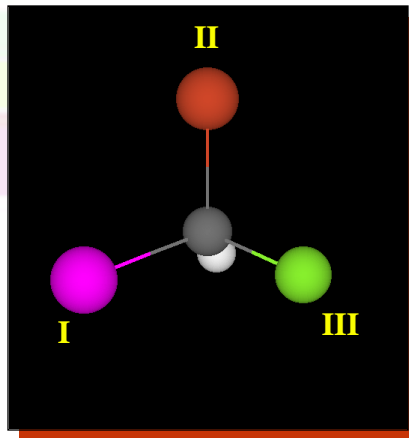
In order to signify the **absolute configuration**, a system of nomenclature has been established in which groups around the chiral center are assigned “**priorities**”. The **lowest priority group is placed towards the back**, and the direction (**clockwise or counterclockwise**) of a line connecting the remaining groups is determined.



Counterclockwise is denoted S

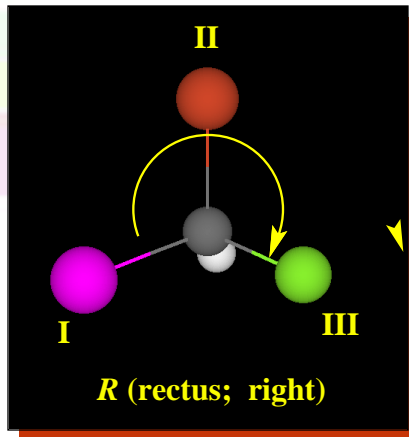
Assigning Absolute Configuration

In order to signify the **absolute configuration**, a system of nomenclature has been established in which groups around the chiral center are assigned “**priorities**”. **The lowest priority group is placed towards the back**, and the direction (**clockwise or counterclockwise**) of a line connecting the remaining groups is determined.



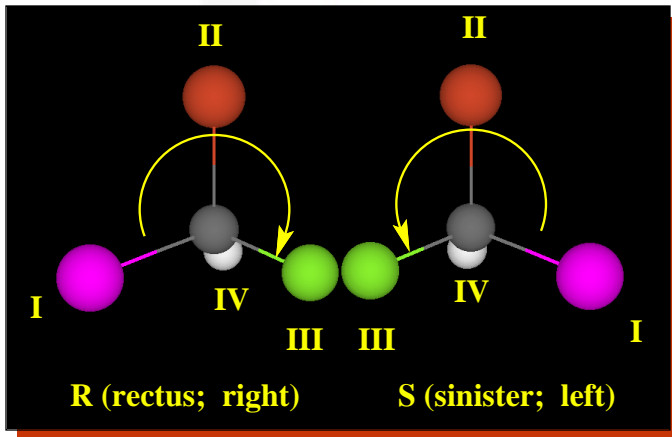
Assigning Absolute Configuration

In order to signify the **absolute configuration**, a system of nomenclature has been established in which groups around the chiral center are assigned “**priorities**”. The **lowest priority group is placed towards the back**, and the direction (**clockwise or counterclockwise**) of a line connecting the remaining groups is determined.



Clockwise is denoted R

Assigning Absolute Configuration



Recall the Cahn-Ingold-Prelog Rules for *E-Z* Designation

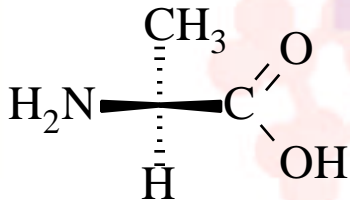
1. Rank atoms directly attached to the alkene according to **atomic number**.
2. If there is a “tie” at any substituent, **look at the second, third, etc., until a difference is found**.
3. **Multiple bonds count as multiples** of that same atom.
4. If the highest priority groups are on the **same side** of the double bond, the molecule is **Z**; if the highest priority groups are on **opposite sides**, the molecule is **E**.

The Cahn-Ingold-Prelog Rules for *R-S* Designation

1. Rank atoms directly attached to the **chiral center** according to **atomic number**.
2. If there is a “tie” at any substituent, **look at the second, third, etc., until a difference is found**.
3. **Multiple bonds bonds as multiples** of that same atom.
4. Rotate the **lowest priority group to the back**; if a line connecting the three highest priority groups **in descending order** goes **clockwise**, the molecule is ***R***; if the connecting line proceeds **counterclockwise**, the molecule is ***S***.

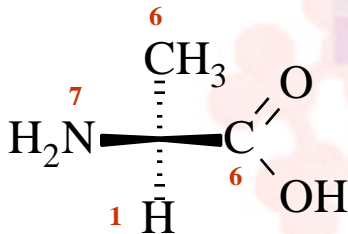
Determine the absolute configuration of the molecule shown below.

First, assign priorities...

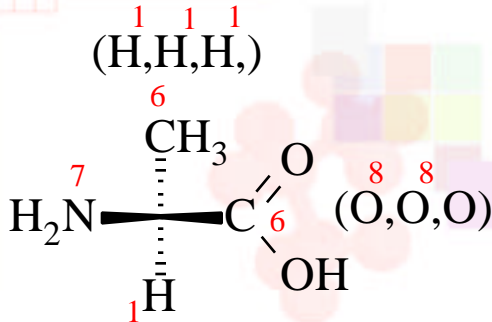


Determine the absolute configuration of the molecule shown below.

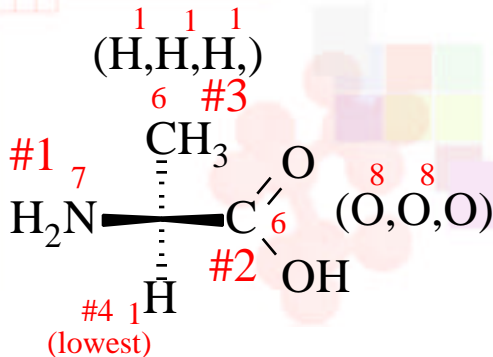
First, assign priorities...



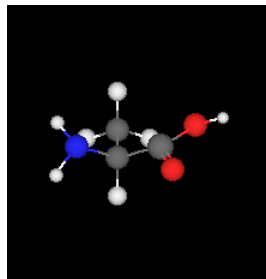
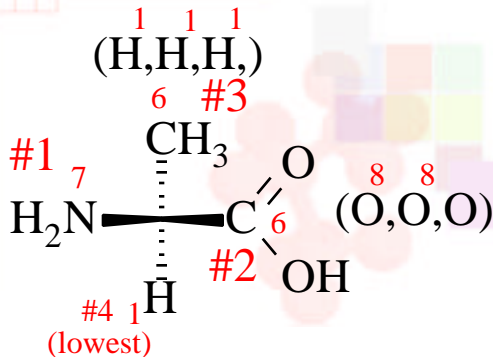
The carbons are a “tie”, therefore look at what is attached and rank the groups.



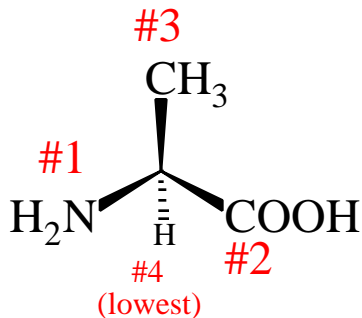
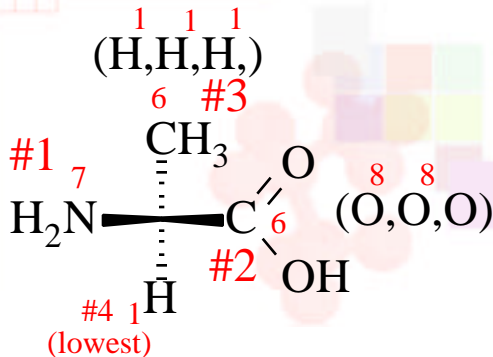
Next, tip the molecule towards you to place the lowest priority group (the hydrogen) towards the back...



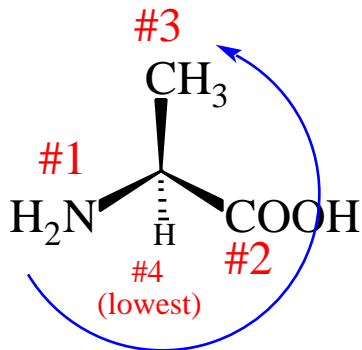
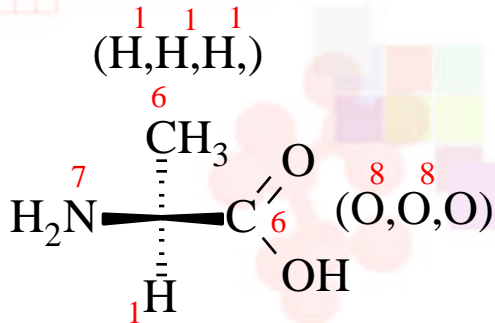
Next, tip the molecule towards you to place the lowest priority group (the hydrogen) towards the back...

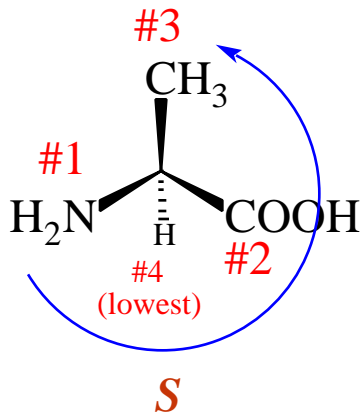
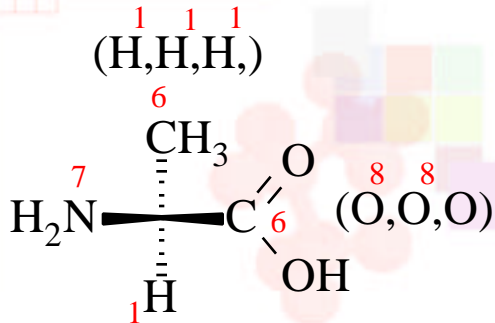


Next, tip the molecule towards you to place the lowest priority group (the hydrogen) towards the back...

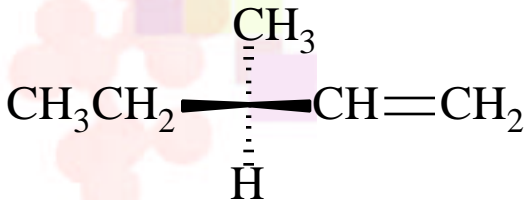


...then connect the groups in descending order and determine configuration.

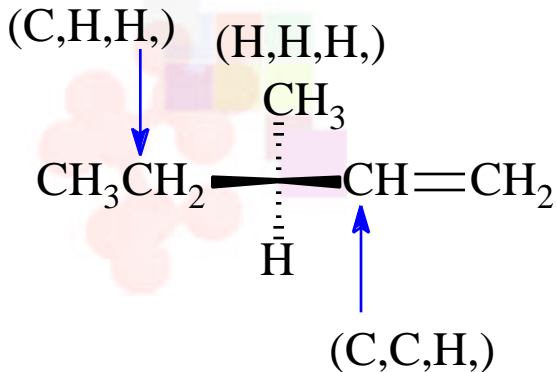




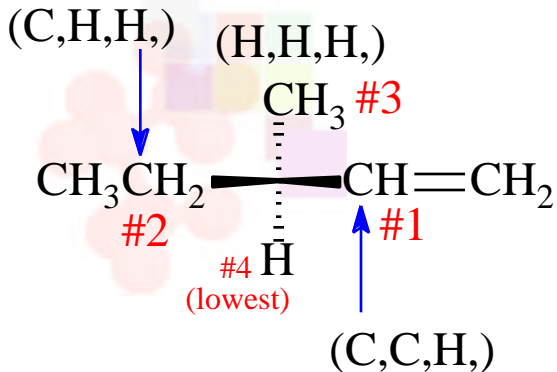
Determine the absolute configuration of the molecule shown below.



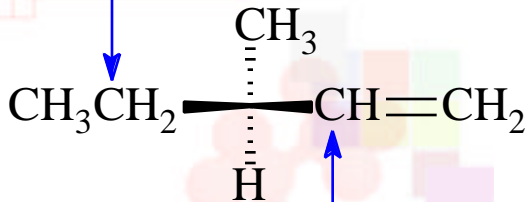
Determine the absolute configuration of the molecule shown below.



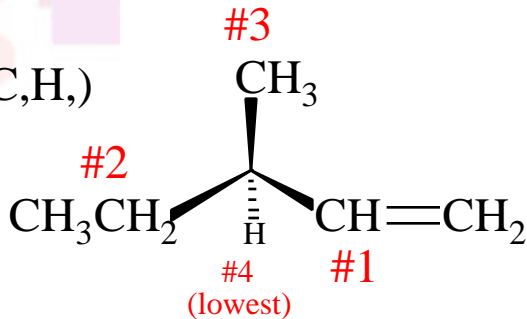
Determine the absolute configuration of the molecule shown below.



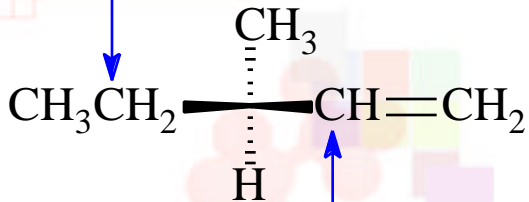
(C,H,H) (H,H,H)



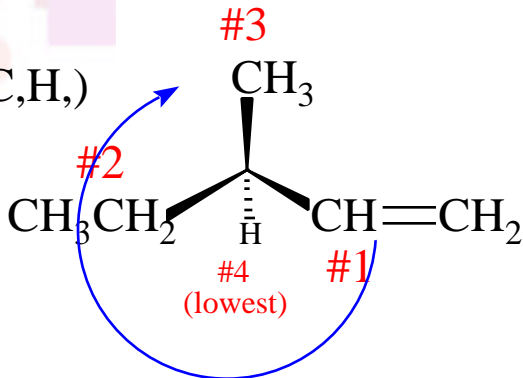
(C,C,H)



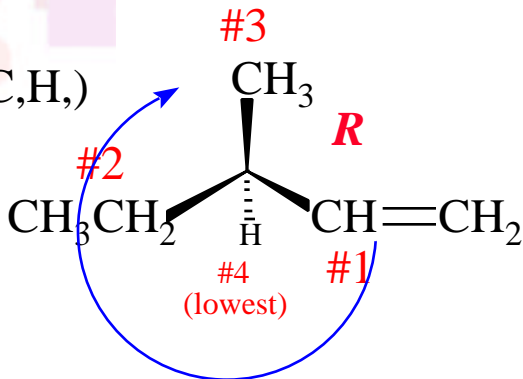
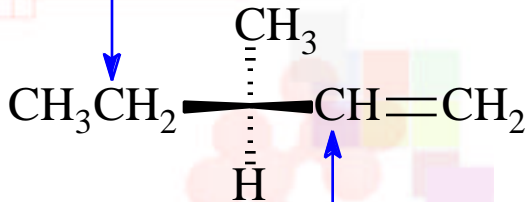
(C,H,H,) (H,H,H,)



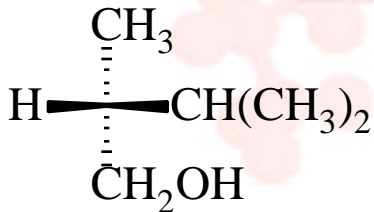
(C,C,H,)



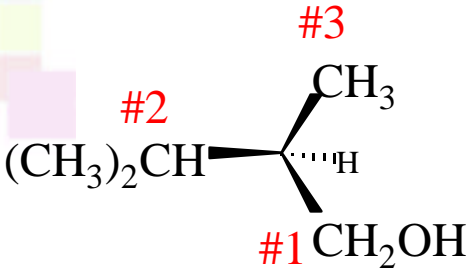
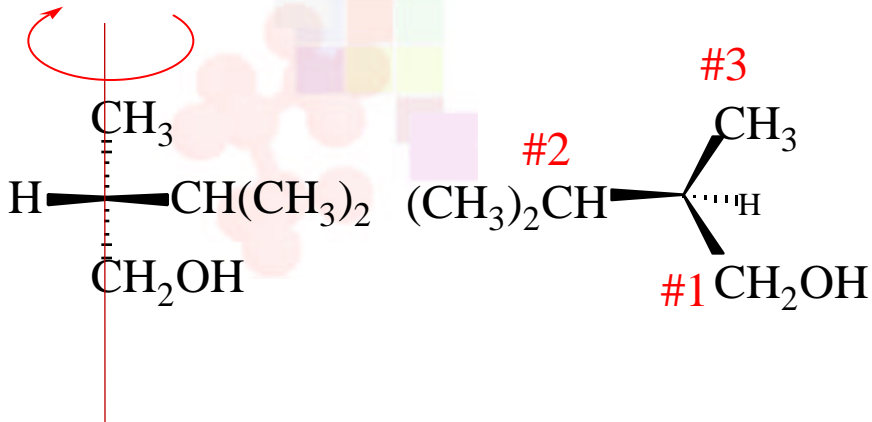
(C,H,H,) (H,H,H,)

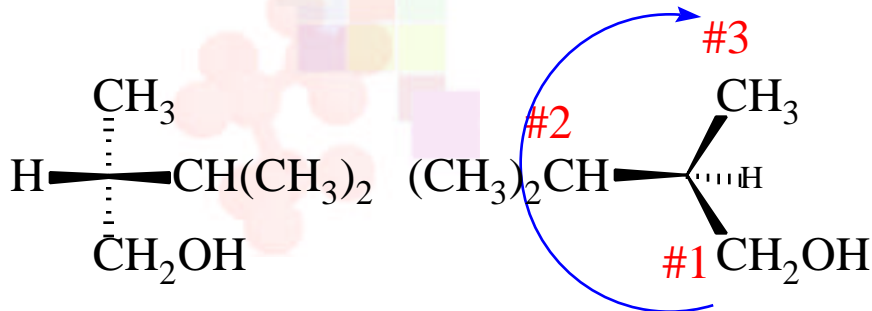


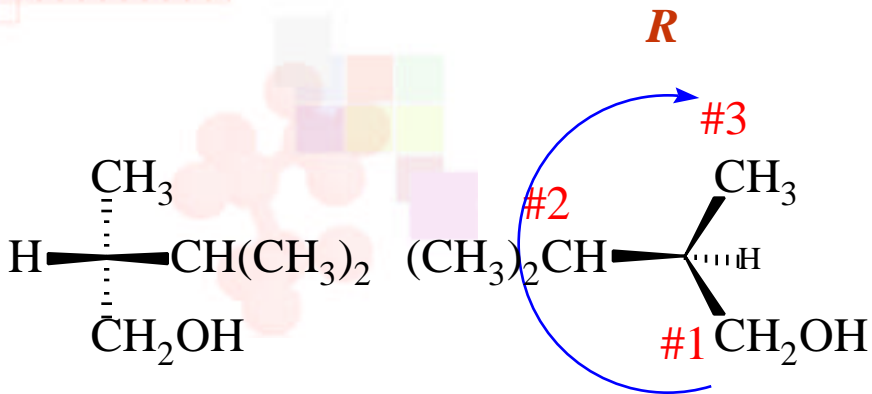
Determine the absolute configuration of the molecule shown below.



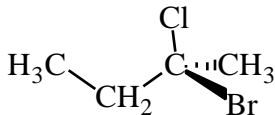
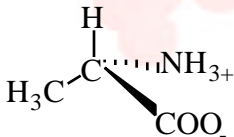
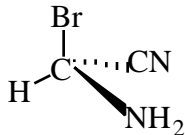
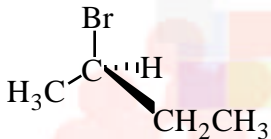
Determine the absolute configuration of the molecule shown below.



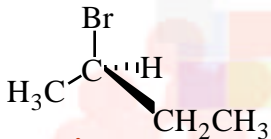




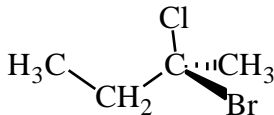
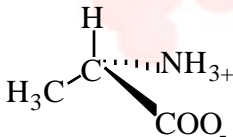
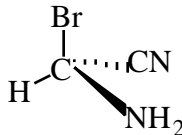
Determine the absolute configuration of the molecules shown below.

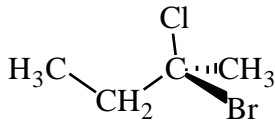
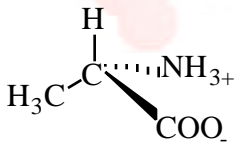
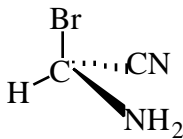
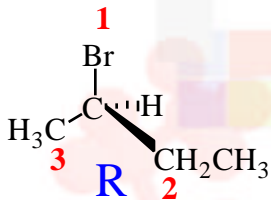


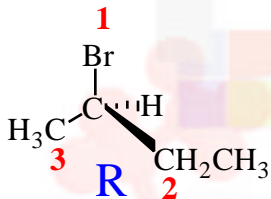
Determine the absolute configuration of the molecules shown below.



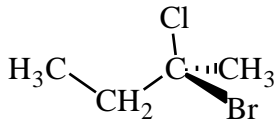
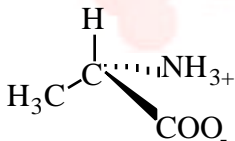
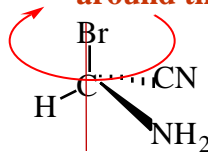
The hydrogen is pointing back...

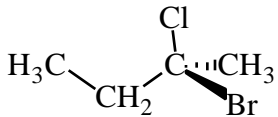
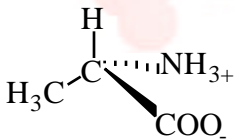
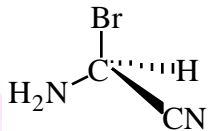
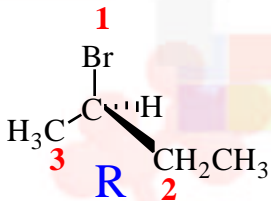


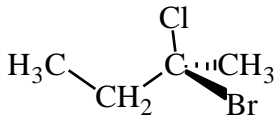
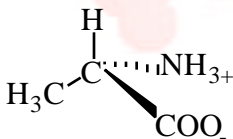
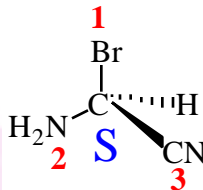
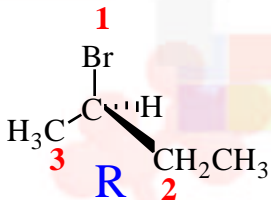


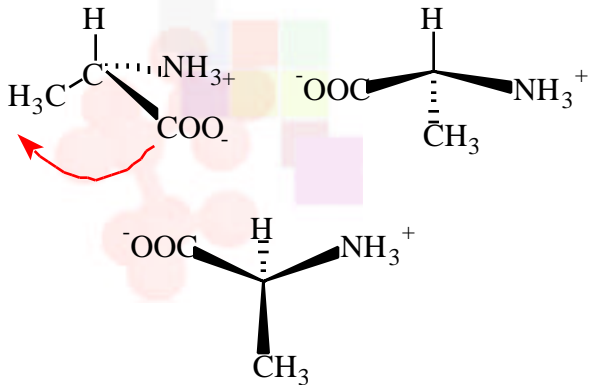


The hydrogen is *not*
 pointing back, but
 we can rotate
 around the C-Br
 axis.

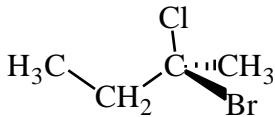
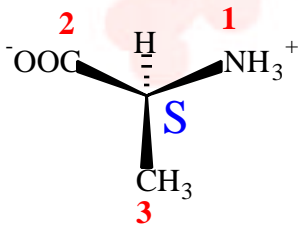
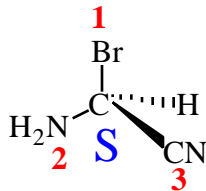
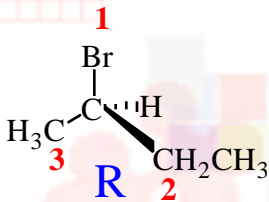


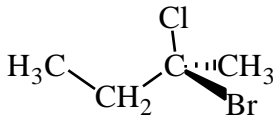
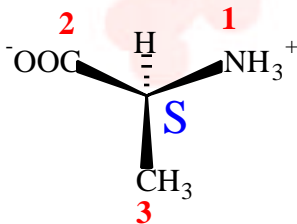
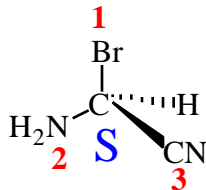
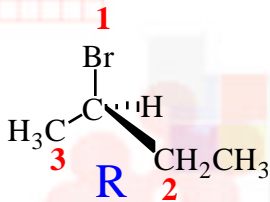




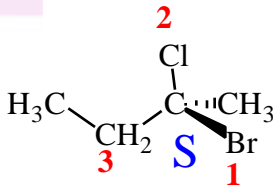
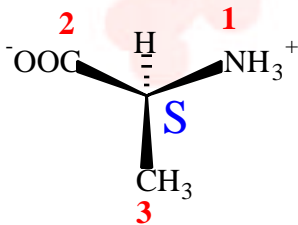
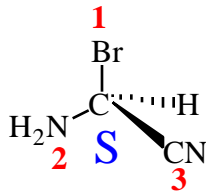
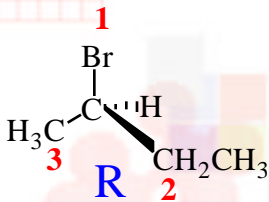


We can easily do this by first rotating around the C-H axis, and then tipping backwards.

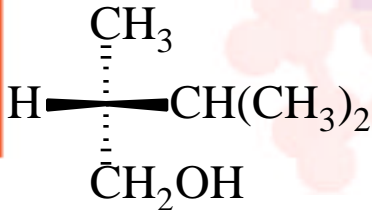




The methyl group is the lowest priority, and it is in the correct position.

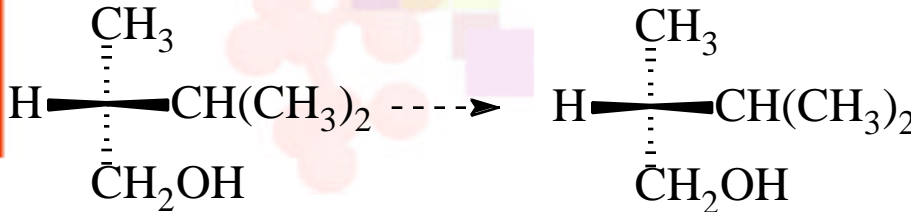


Conversion of 3-D Structure to a *Fischer Projection* (Jones, page 1236)



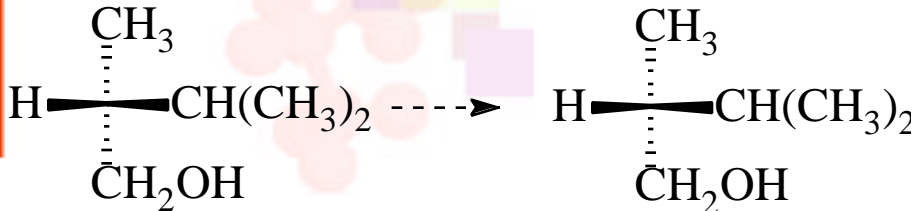
These types of manipulations can be simplified somewhat, by using a 2-D projection of the molecule instead of the 3-D rendering. The 2-D drawing we will construct is commonly called a **Fischer Projection**.

Conversion of 3-D Structure to a *Fischer Projection* (Jones, page 1236)



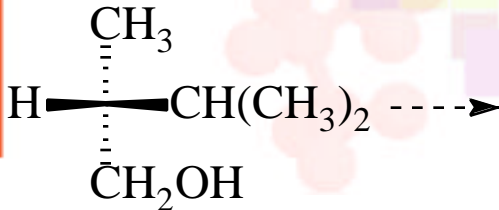
To generate a Fischer Projection,
draw your molecule so that the **two**
horizontal bonds are coming out
towards you, and then...

Conversion of 3-D Structure to a *Fischer Projection* (Jones, page 1236)

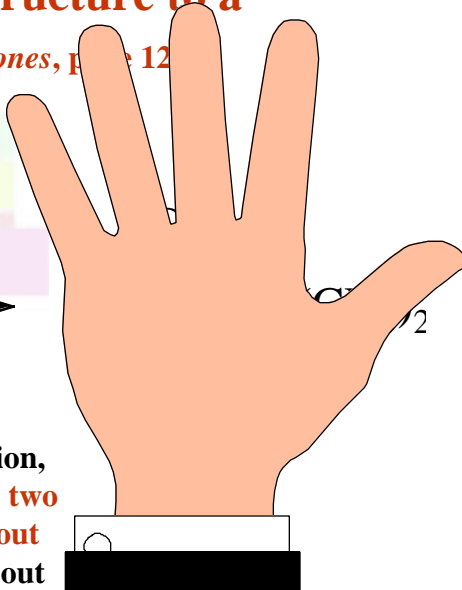


To generate a Fischer Projection, draw your molecule so that the **two horizontal bonds are coming out towards you**, and then flatten out the molecule.

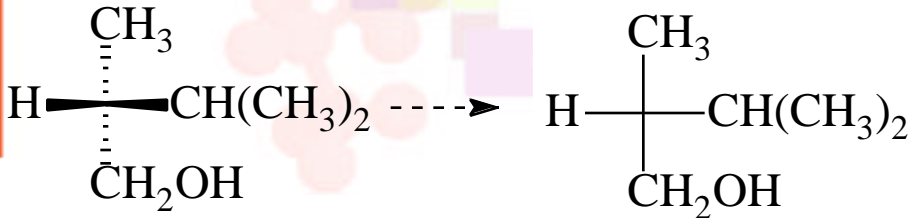
Conversion of 3-D Structure to a *Fischer Projection* (Jones, Page 12)



To generate a Fischer Projection, draw your molecule so that the **two horizontal bonds are coming out towards you**, and then flatten out the molecule.

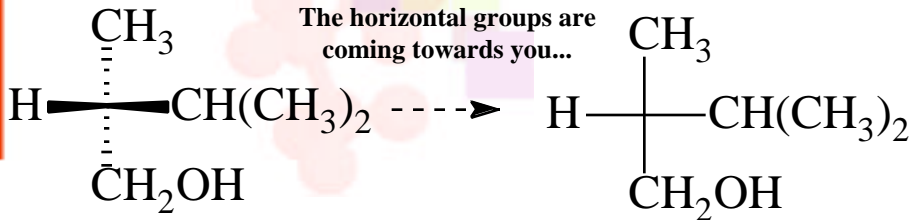


Conversion of 3-D Structure to a *Fischer Projection* (Jones, page 1236)



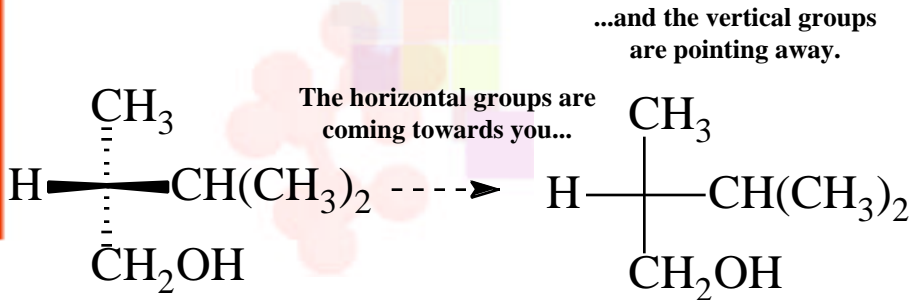
The result is a drawing with **no central carbon** and with **simple intersecting lines**. A drawing like this **implies absolute stereochemistry** and should be regarded as a shorthand way to draw stereocenters.

Conversion of 3-D Structure to a *Fischer Projection* (Jones, page 1236)



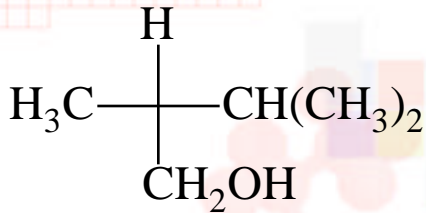
The result is a drawing with **no central carbon** and with **simple intersecting lines**. A drawing like this **implies absolute stereochemistry** and should be regarded as a shorthand way to draw stereocenters.

Conversion of 3-D Structure to a *Fischer Projection* (Jones, page 1236)

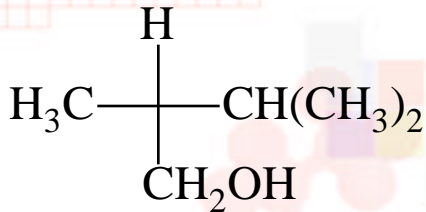


The result is a drawing with **no central carbon** and with **simple intersecting lines**. A drawing like this **implies absolute stereochemistry** and should be regarded as a shorthand way to draw stereocenters.

Conversion from a Fischer Projection...

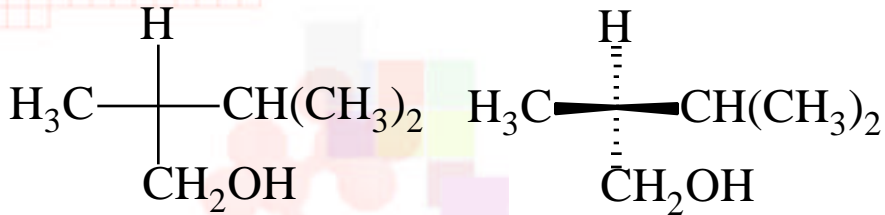


Conversion from a Fischer Projection...

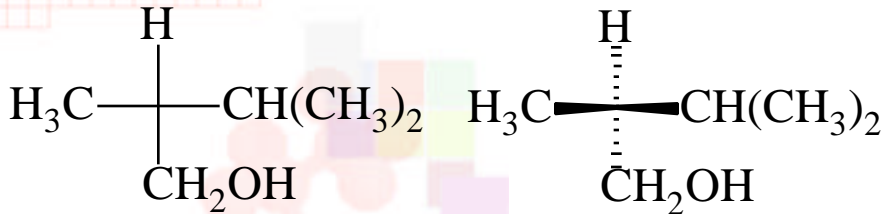


Simply redraw the structure, showing the implied stereochemistry.

Conversion from a Fischer Projection...

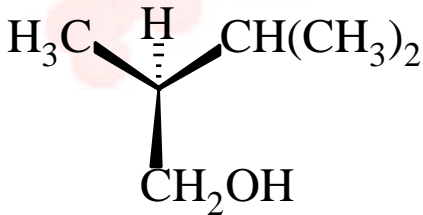
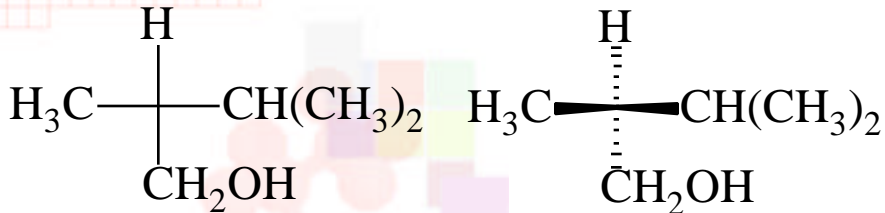


Conversion from a Fischer Projection...

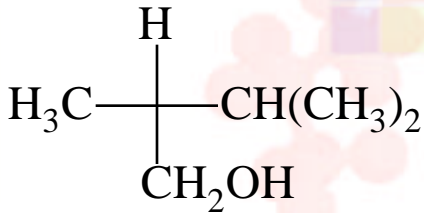


This drawing can be manipulated as we have done before.

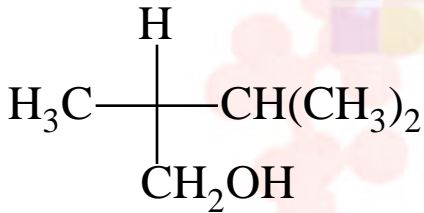
Conversion from a Fischer Projection...



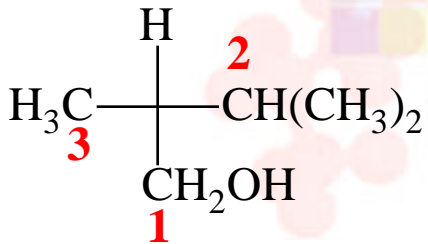
Determine the absolute configuration of the following molecule:

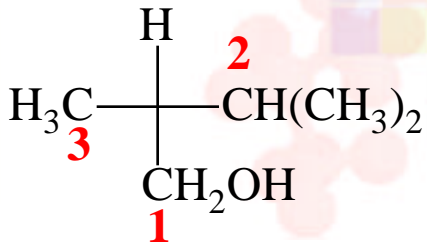


Determine the absolute configuration of the following molecule:

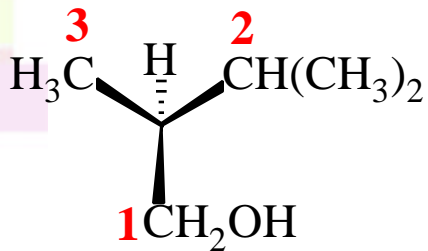
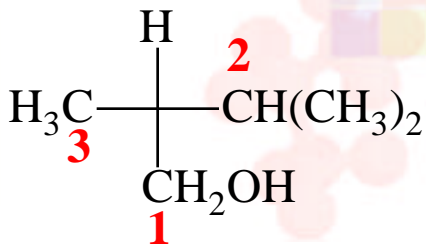


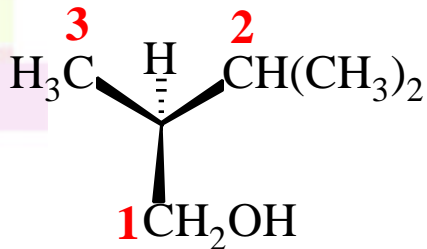
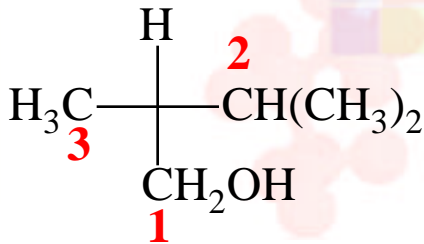
First, rank the atoms...



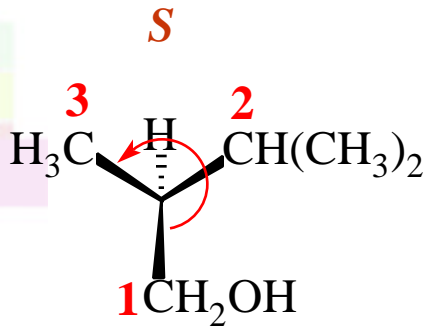
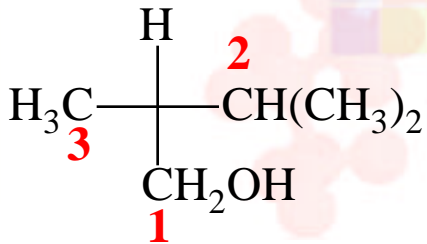


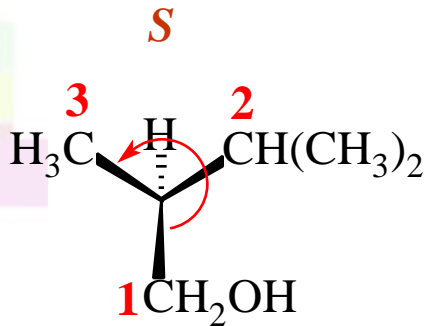
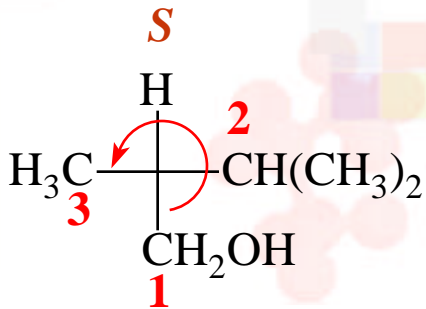
...then redraw the structure as a 3-D drawing.

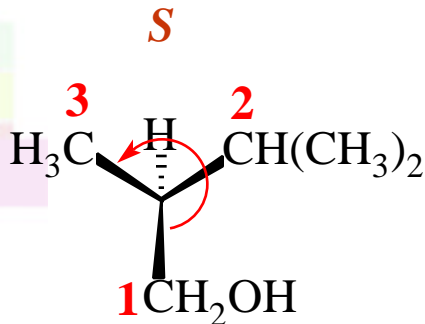
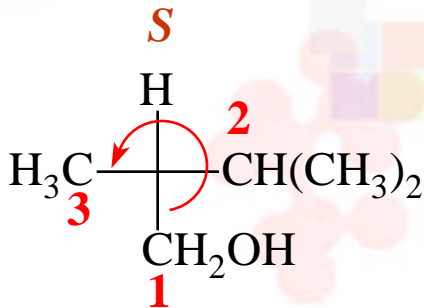




Determine the stereochemistry.

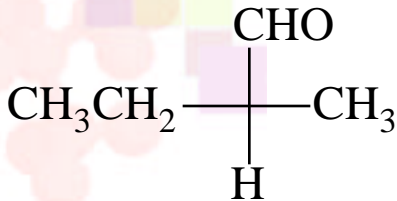




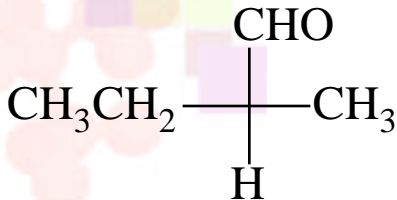


... whenever the lowest priority group is on the **bottom or the top**, you can assign priorities and determine the configuration **directly from the Fischer projection**.

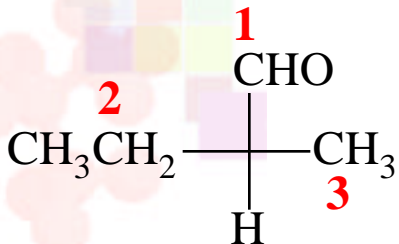
Determine the absolute configuration of the following molecule:

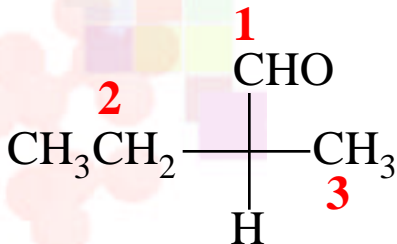


Determine the absolute configuration of the following molecule:

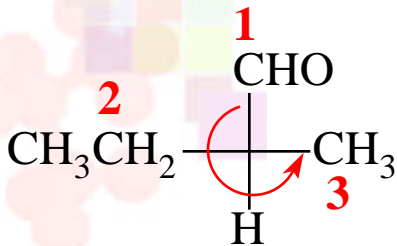


Rank the atoms...



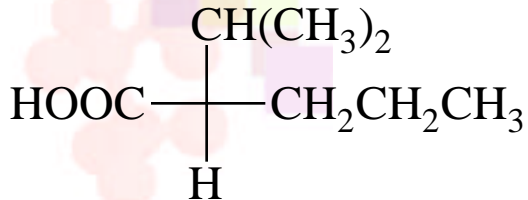


...assign the stereochemistry.

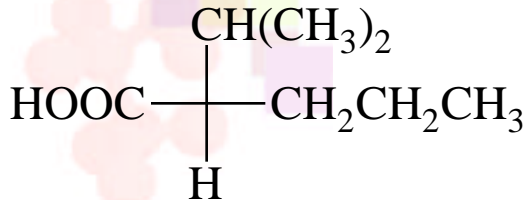


S

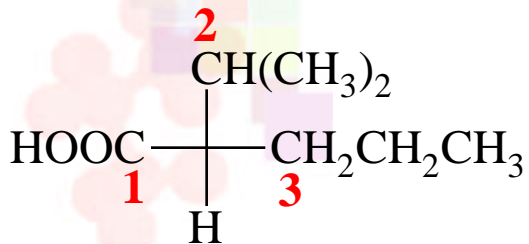
Determine the absolute configuration of the following molecule:

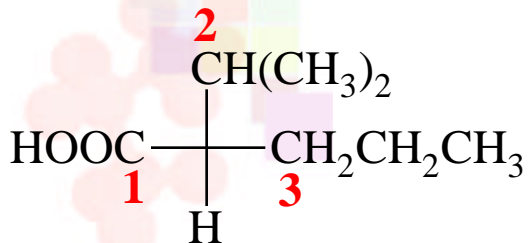


Determine the absolute configuration of the following molecule:

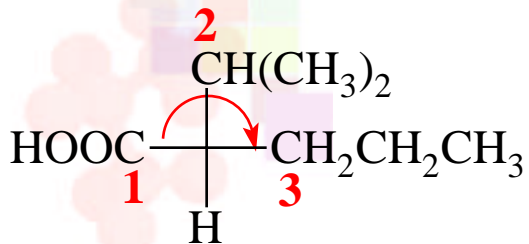


Rank the atoms...



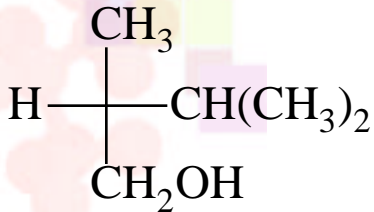


...assign the stereochemistry.

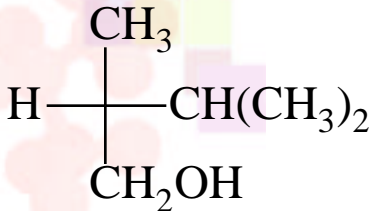


R

Determine the absolute configuration of the following molecule:

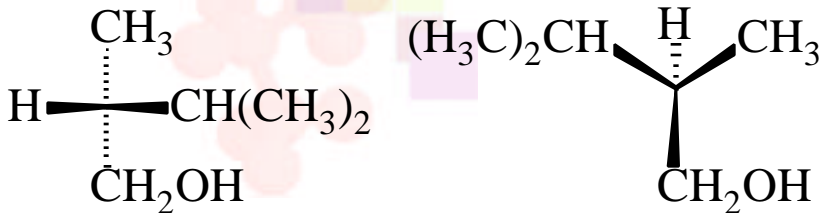


Determine the absolute configuration of the following molecule:

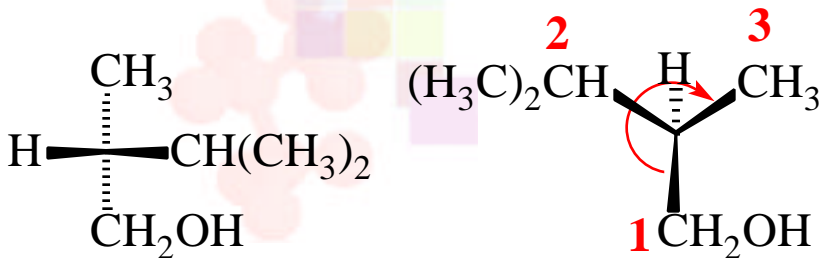


There is a problem here since the lowest priority group is not on the bottom or the top.

By converting to a 3-D structure, and then manipulating, we can assign the stereochemistry in the traditional way...

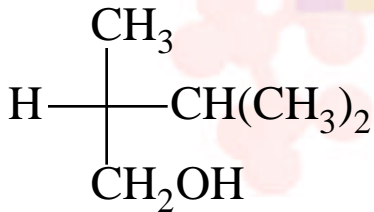


By converting to a 3-D structure, and then manipulating, we can assign the stereochemistry in the traditional way...

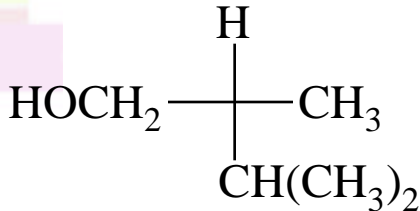
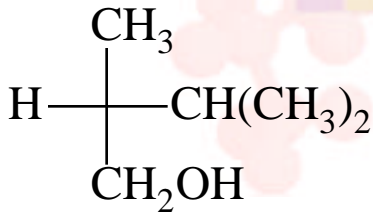


R

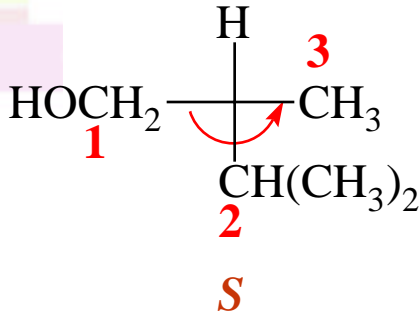
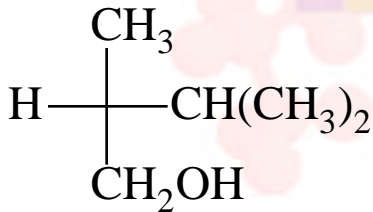
...but what would happen if you simply **rotated** the Fischer projection?



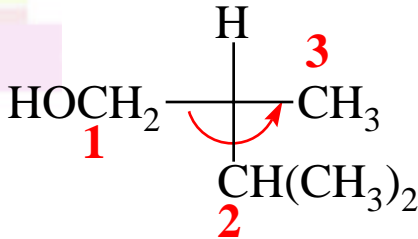
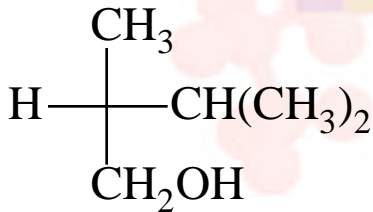
...but what would happen if you simply **rotated**
the Fischer projection?



...but what would happen if you simply **rotated** the structure?



...but what would happen if you simply **rotated** the structure?



But we know that the original molecule was **R** configuration.

S



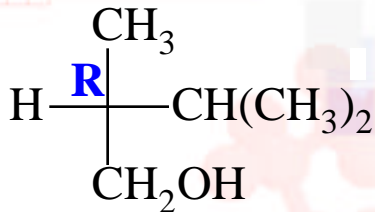
Rules for Manipulating Fischer Projections

1. **Never** rotate the molecule 90° , this generates an **enantiomeric** structure
- 

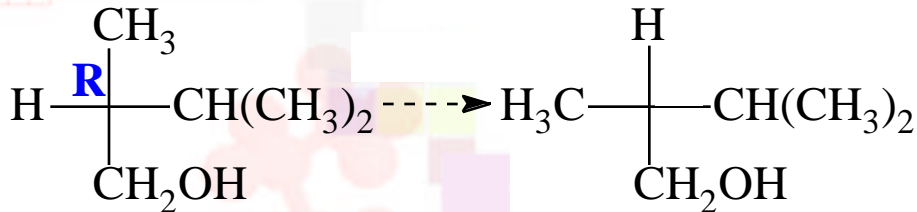
Rules for Manipulating Fischer Projections

1. **Never** rotate the molecule 90° , this generates an **enantiomeric** structure.

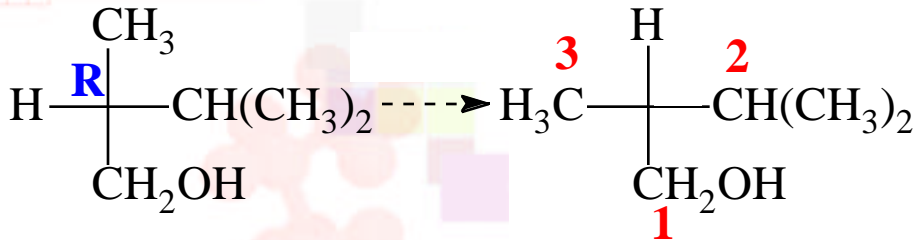
The fact that rearranging the positions of groups around the central atom in a Fischer projection can generate enantiomeric structures can be a useful tool in establishing the relationships between chiral molecules. This is often referred to as the “**exchange method**”.



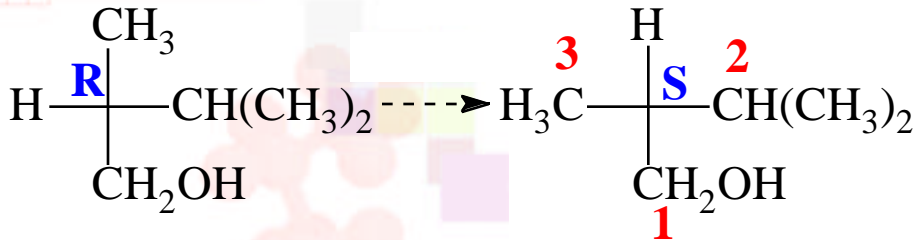
If we take the Fischer projection of our original molecule (*R* configuration) and simply “exchange” **any two groups**, we generate an **enantiomeric structure**.



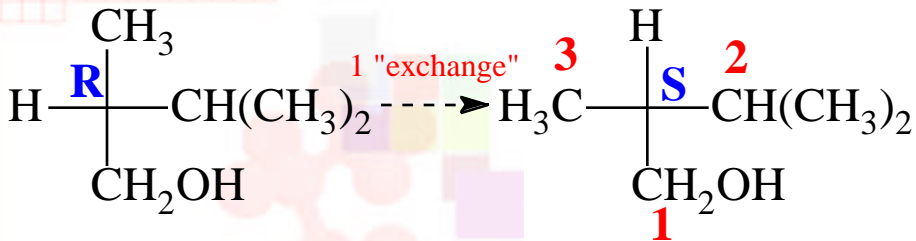
If we take the Fischer projection of our original molecule (*R* configuration) and simply “exchange” **any two groups**, we generate an **enantiomeric** structure.



If we take the Fischer projection of our original molecule (*R* configuration) and simply “exchange” **any two groups**, we generate an **enantiomeric** structure.

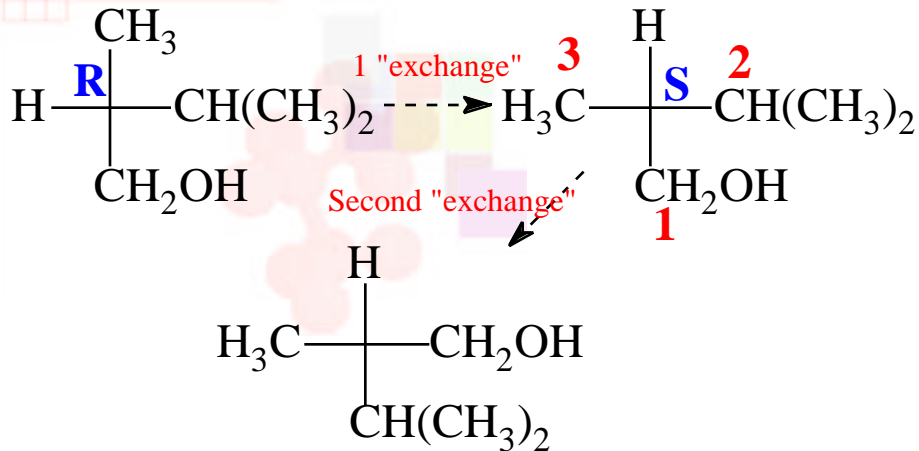


If we take the Fischer projection of our original molecule (*R* configuration) and simply “exchange” **any two groups**, we generate an **enantiomeric** structure.

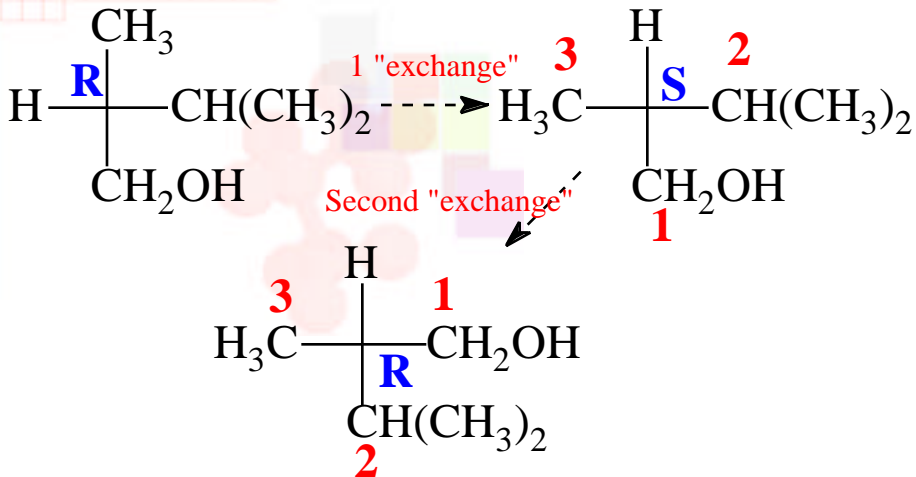


One “exchange” has generated the **enantiomer**.

Doing a second exchange...



Doing a second exchange...



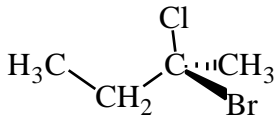
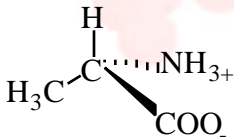
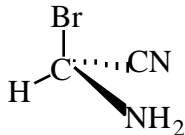
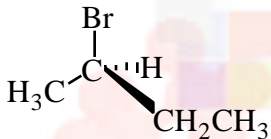
... regenerates the **original stereochemistry**.

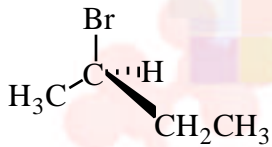
Rules for Manipulating Fischer Projections

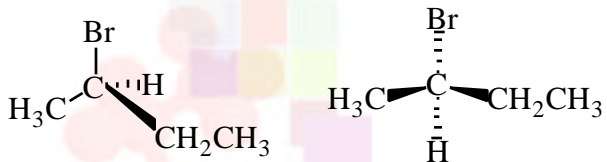
1. **Never** rotate the molecule 90° , this generates an **enantiomeric** structure
2. When you are “exchanging groups”, **one exchange generates an enantiomer**, the **second exchange regenerates the original stereochemistry**, three exchanges generates the enantiomer, etc.

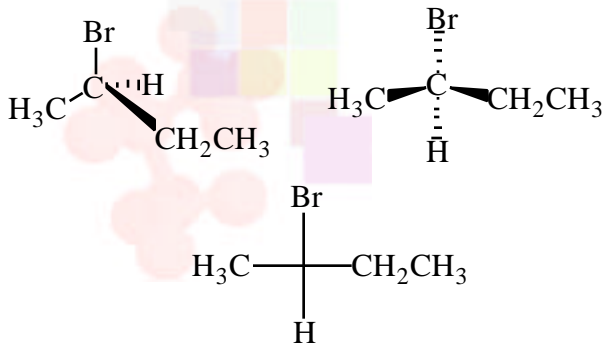
It is important to remember that the “exchange method” is simply bookkeeping, and is not meant to represent any chemical or physical changes in the molecules.

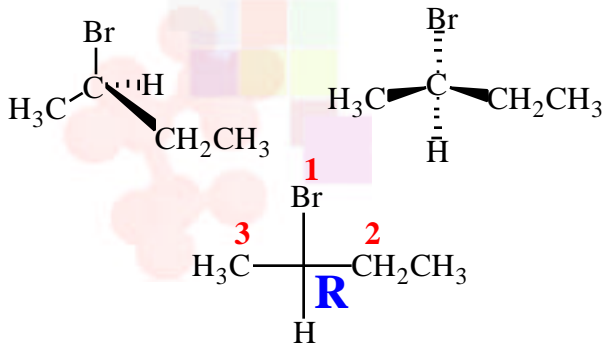
Convert the following into Fischer Projections
and determine if the stereochemistry is *R* or *S*.

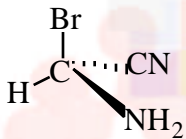


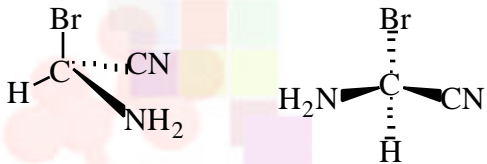


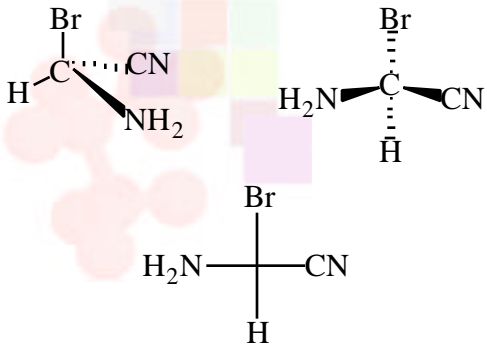


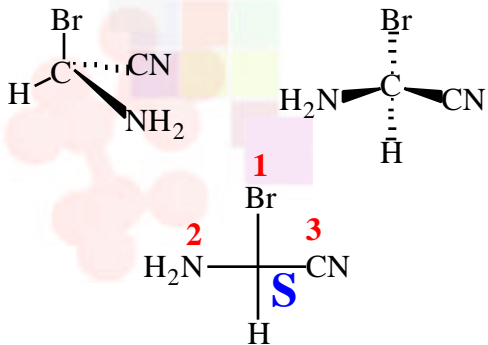


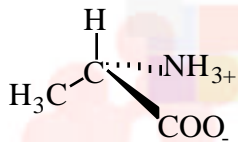


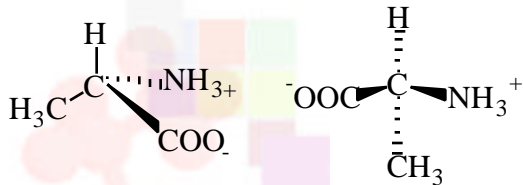


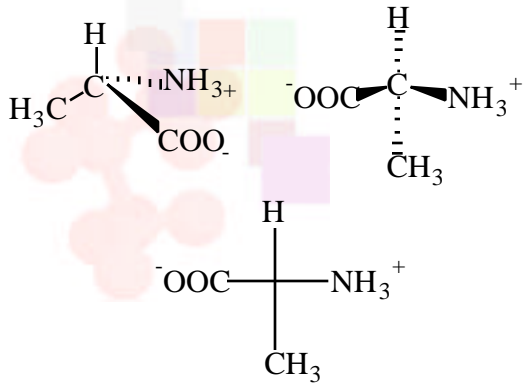


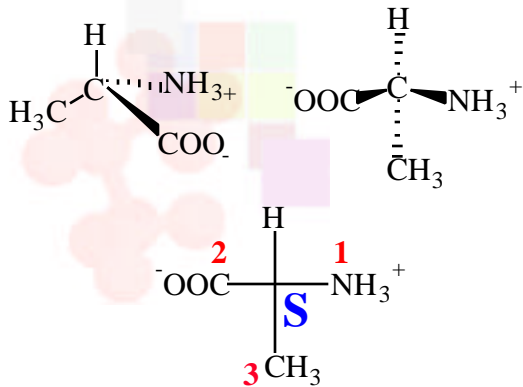


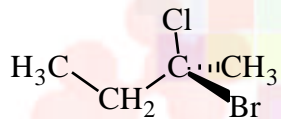


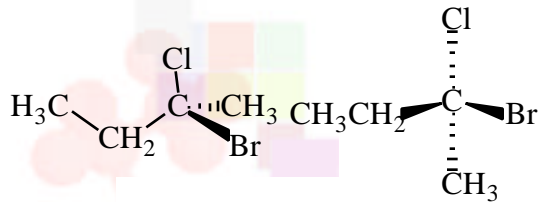


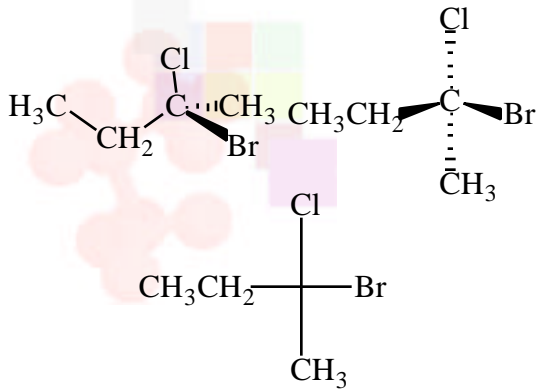


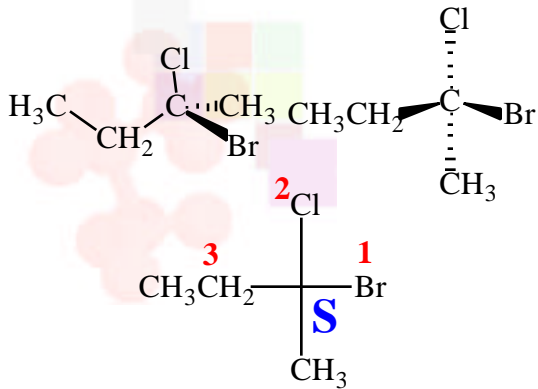




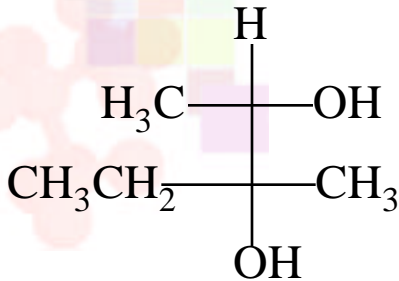




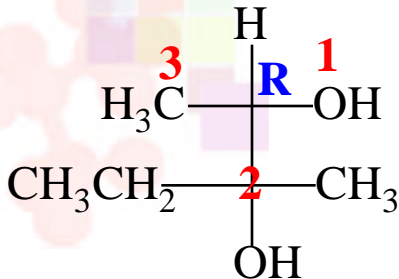




Determine the absolute configuration of **each** of the chiral centers in the molecule shown below:

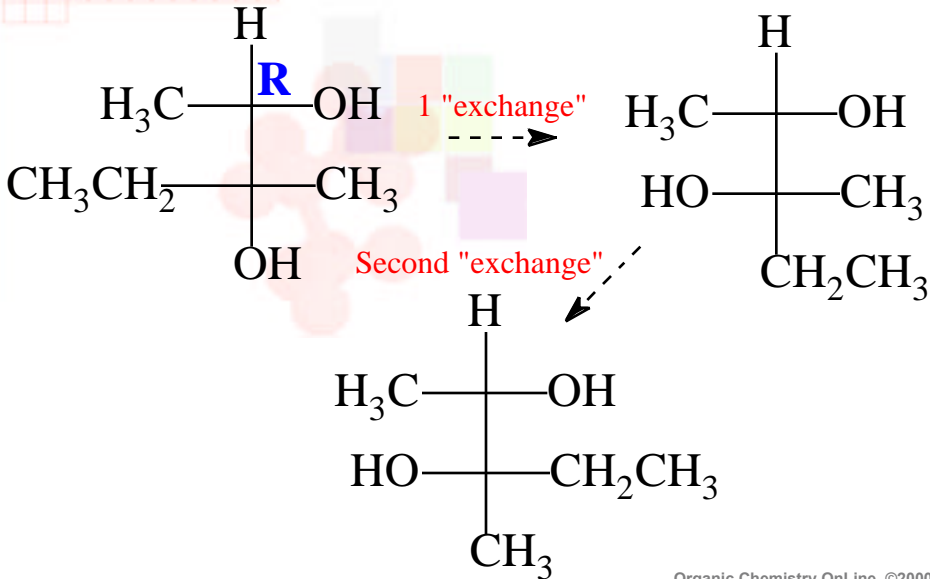


The top carbon has the lowest priority group on top...

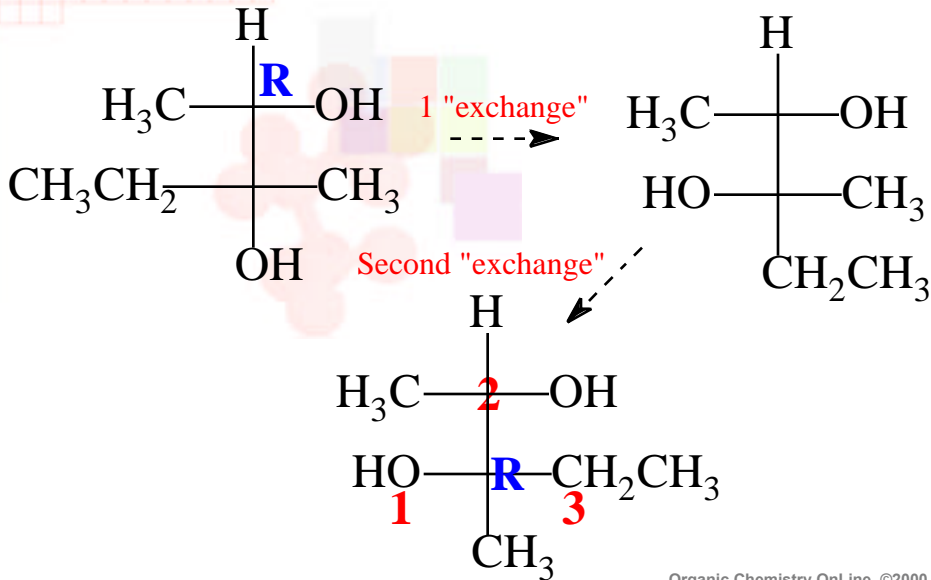


...but the lowest priority group on the bottom carbon is not in the correct position.

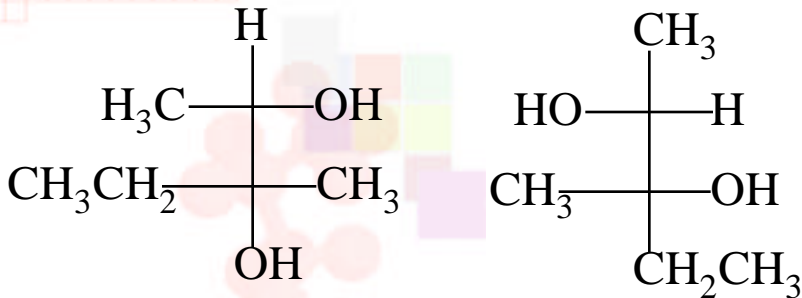
Therefore, we must make **two exchanges** to get the lowest priority group on the bottom carbon to the bottom of the projection.



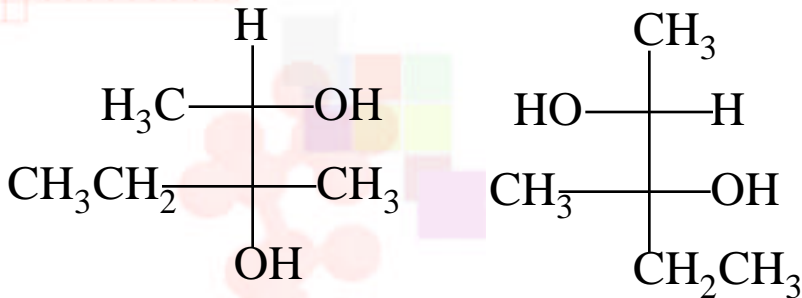
In this molecule, both the top and bottom carbons are **R** configuration.



What is the stereochemical relationship between the two molecules shown below?

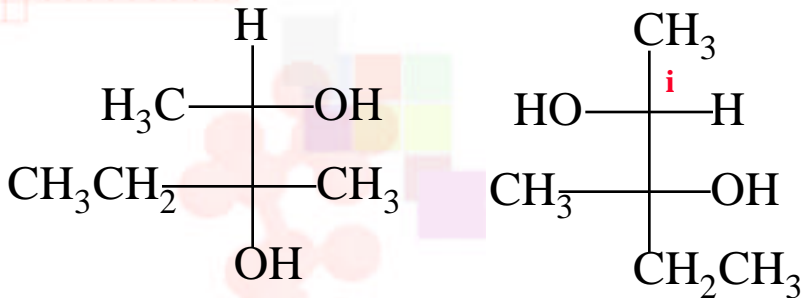


What is the stereochemical relationship between the two molecules shown below?



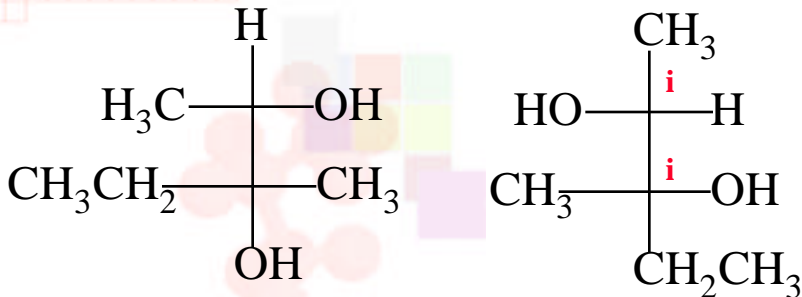
We proceed by selecting one molecule as **reference**, and **converting the second into the first by exchanging groups**, treating each chiral center separately.

What is the stereochemical relationship between the two molecules shown below?



1. **Top carbon: two exchanges** required (H:CH₃ then CH₃:OH), therefore they are **identical**

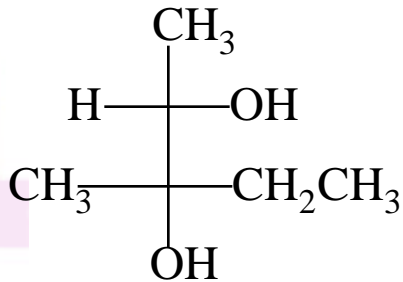
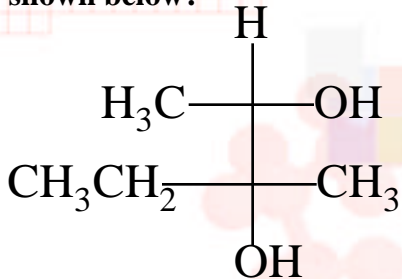
What is the stereochemical relationship between the two molecules shown below?



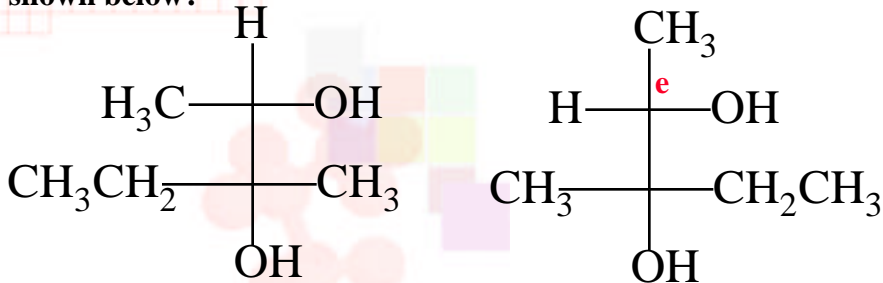
1. **Top carbon: two exchanges** required (H:CH₃ then CH₃:OH), therefore they are **identical**
2. **Bottom carbon: two exchanges** required (Ethyl:CH₃ then CH₃:OH), therefore they are **identical**

The molecules are **IDENTICAL**

What is the stereochemical relationship between the two molecules shown below?

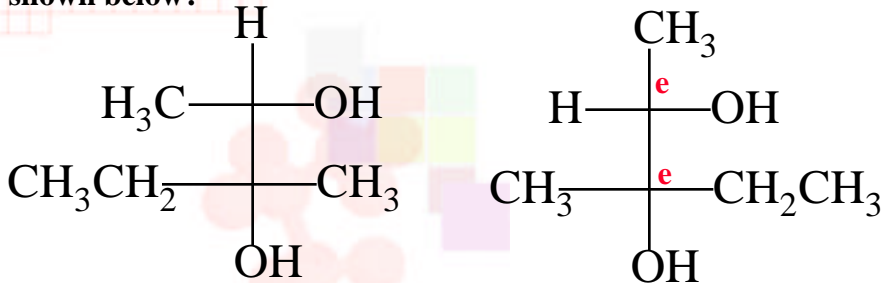


What is the stereochemical relationship between the two molecules shown below?



1. **Top carbon: one exchange** required (H:CH₃), therefore they are **enantiomeric**

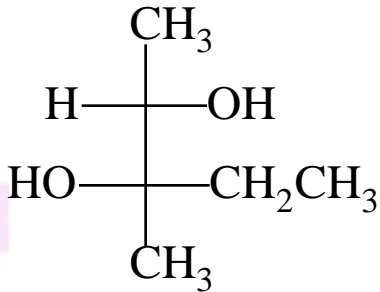
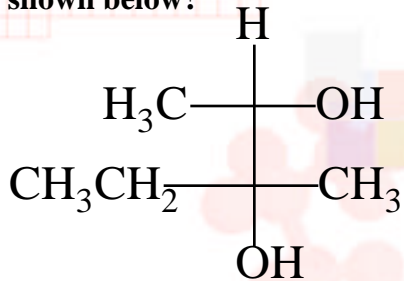
What is the stereochemical relationship between the two molecules shown below?



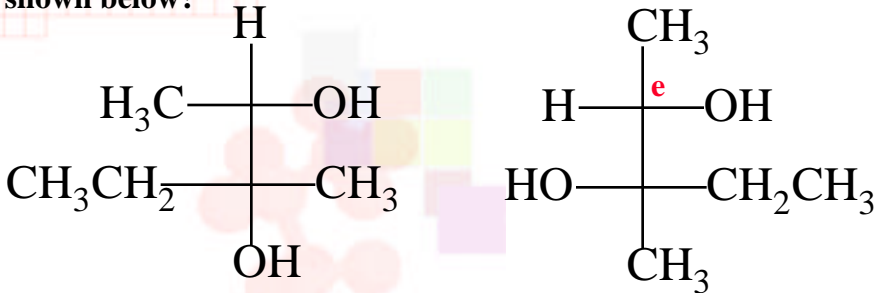
1. **Top carbon: one exchange** required (H:CH₃), therefore they are **enantiomeric**
2. **Bottom carbon: one exchange** required (Ethyl:CH₃), therefore they are **enantiomeric**

The molecules are **ENANTIOMERS**

What is the stereochemical relationship between the two molecules shown below?

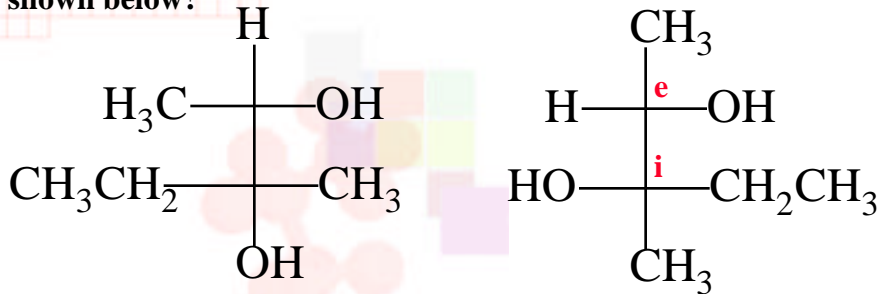


What is the stereochemical relationship between the two molecules shown below?



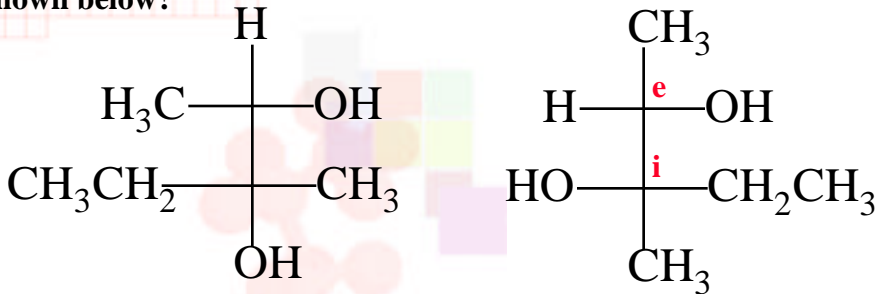
1. **Top carbon: one exchange** required (H:CH₃), therefore they are **enantiomeric**

What is the stereochemical relationship between the two molecules shown below?



1. **Top carbon: one exchange** required (H:CH₃), therefore they are **enantiomeric**
2. **Bottom carbon: two exchanges** required (Ethyl:CH₃ then Ethyl:OH), therefore they are **identical**

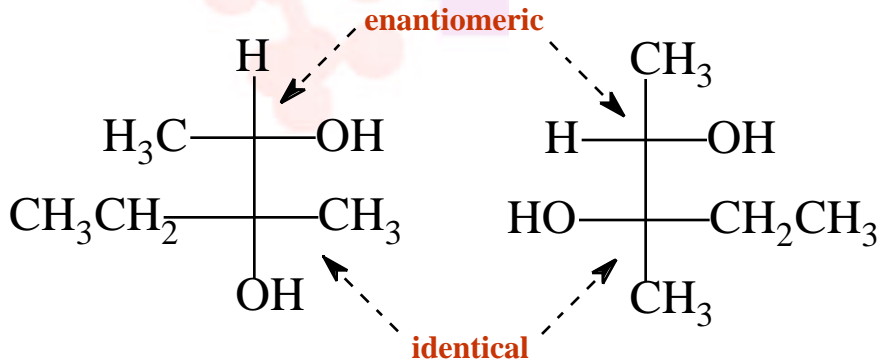
What is the stereochemical relationship between the two molecules shown below?



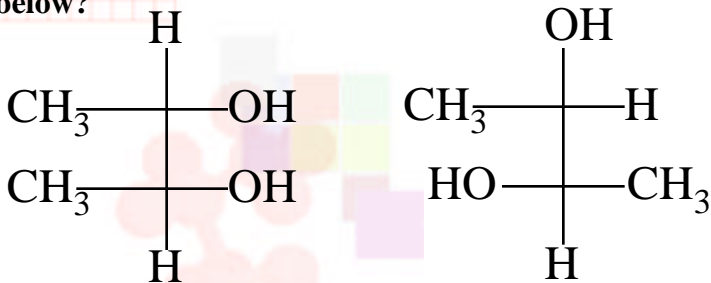
1. **Top carbon:** **one exchange** required (H:CH₃), therefore they are **enantiomeric**
2. **Bottom carbon:** **two exchanges** required (Ethyl:CH₃ then Ethyl:OH), therefore they are **identical**

The molecules are **DIASTEREOMERS**

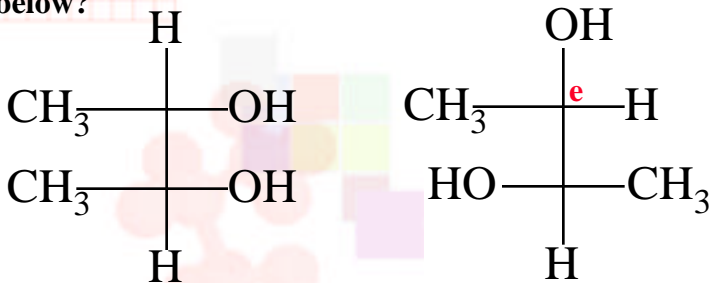
DIASTEREOMERS are stereoisomers which are not mirror images of each other. In general they are molecules in which one or more stereocenters are enantiomeric, and one or more are identical in configuration.



What is the stereochemical relationship between the two molecules shown below?

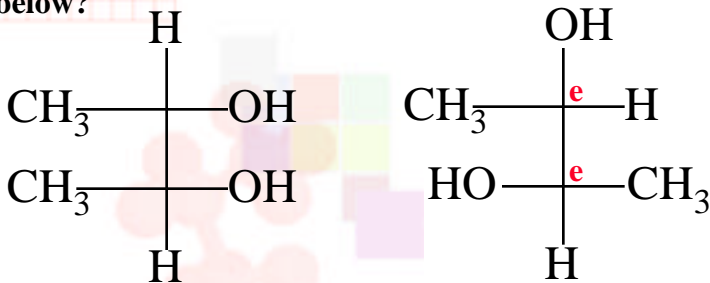


What is the stereochemical relationship between the two molecules shown below?



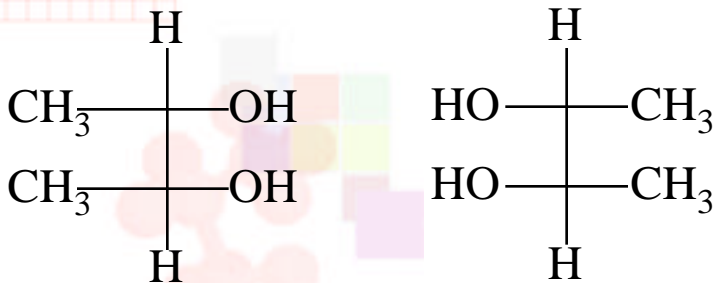
1. **Top carbon: one exchange** required (H:CH₃), therefore they are **enantiomeric**
2. **Bottom carbon: two exchanges** required (Ethyl:CH₃ then Ethyl:OH), therefore they are **identical**

What is the stereochemical relationship between the two molecules shown below?



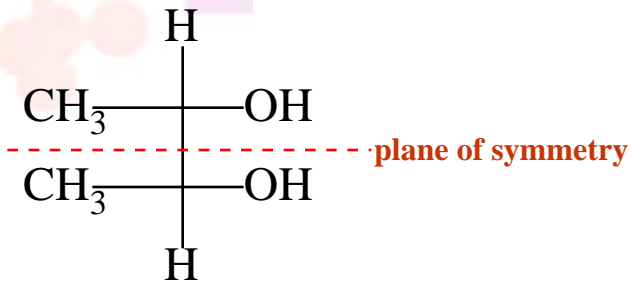
1. **Top carbon: one exchange** required (H:CH₃), therefore they are **enantiomeric**
2. **Bottom carbon: one exchange** required (H:CH₃), therefore they are **enantiomeric**

The molecules are **ENANTIOMERS**

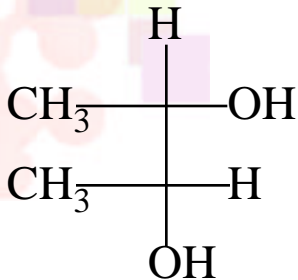


Two exchange on the structure on the right regenerate the same stereochemistry and clearly show the molecules to be mirror images.

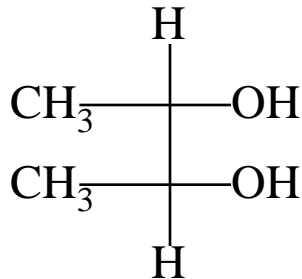
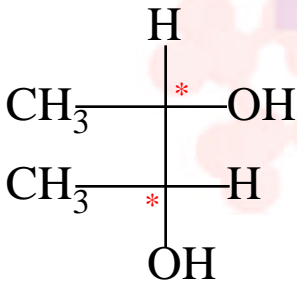
MESO COMPOUNDS are compounds which contain **chiral centers**, but the molecule as a whole is **achiral**. These molecules contain an *internal plane of symmetry*.



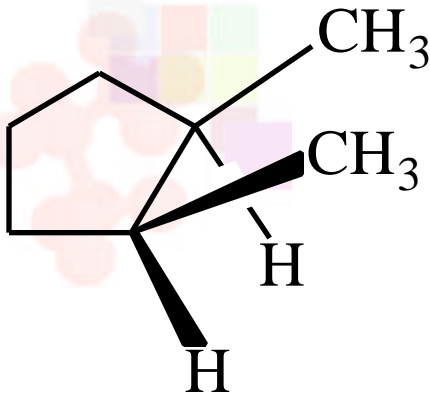
Indicate the chiral centers in the molecule below;
is the molecule itself chiral?

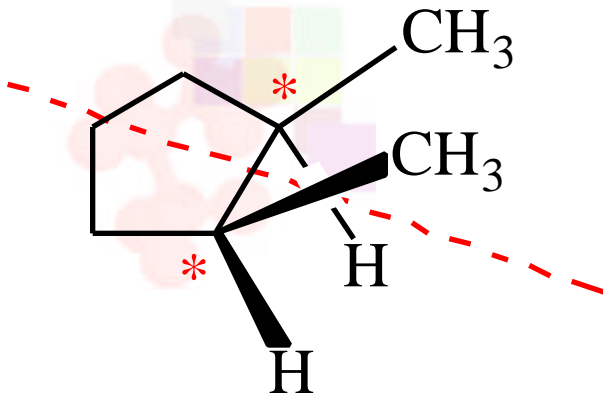


One exchange generates plane of symmetry.
therefore original compound is **not meso**



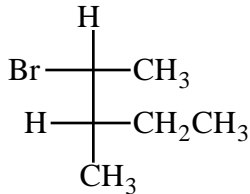
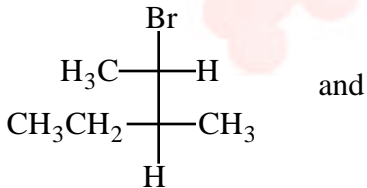
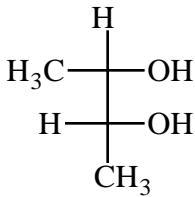
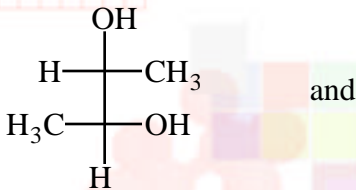
Indicate the chiral centers in the molecule below;
is the molecule itself chiral?

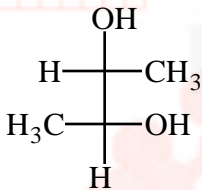




Meso

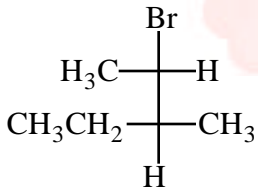
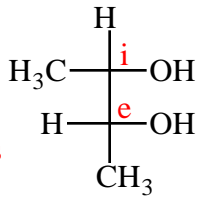
What is the stereochemical relationship between the sets of molecules shown below?



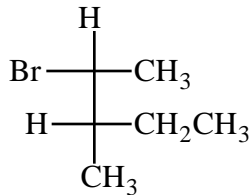


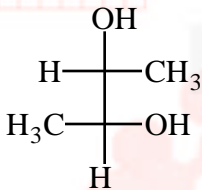
and

diastereomers

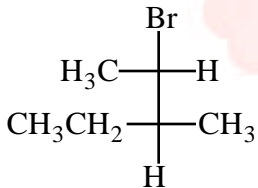
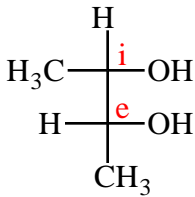


and

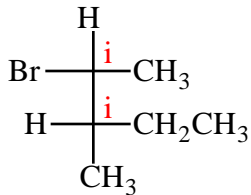




and
diastereomers

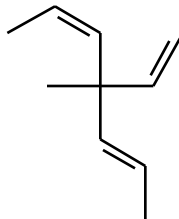
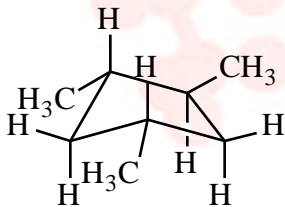


and
identical



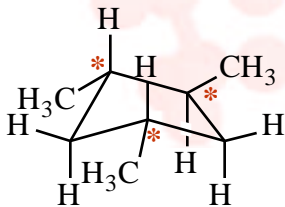
For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"

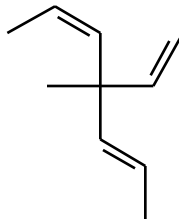


For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"

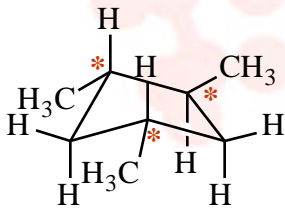


3

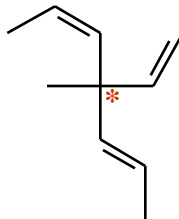


For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"



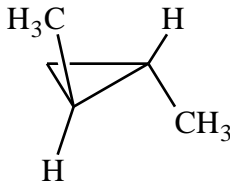
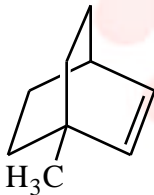
3



1

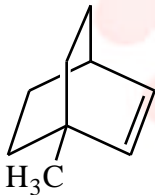
For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"

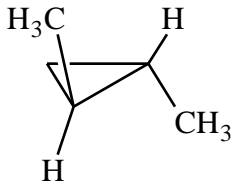


For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"

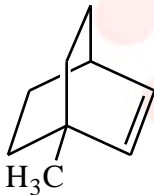


achiral

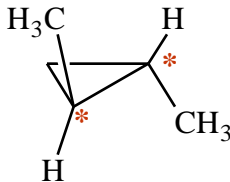


For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"



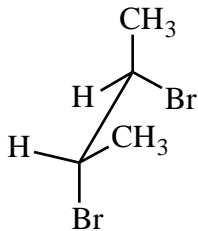
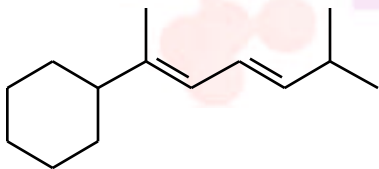
achiral



2

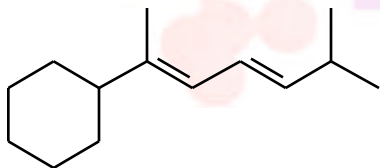
For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"

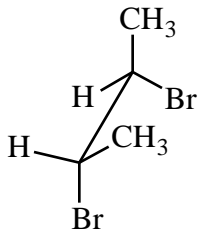


For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"

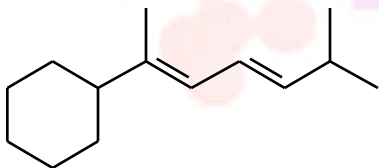


achiral

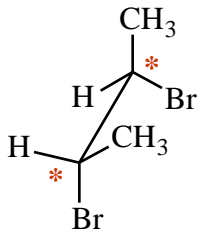


For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"

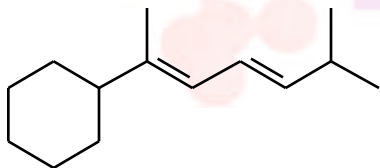


achiral

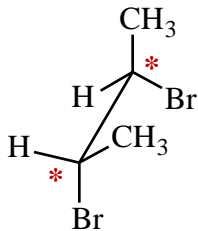


For each of the following molecules:

- if the molecule is chiral, indicate **total number of chiral centers**
- if the molecule contains no chiral centers, indicate "**achiral**"
- if the molecule is a **meso** compound, do not indicate the number of chiral centers, but indicate "**meso**"



achiral



meso

**How many chiral centers are there in these molecules?
Are the molecules chiral?**

