

Stereochemistry Tutorial: Drawing Enantiomers and Diastereomers

Definitions for vocabulary words can be found in the *Illustrated Glossary of Organic Chemistry*, available on the course web site.

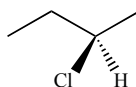
A. Discussion

For the same reasons as it is important to recognize and classify stereoisomers it is valuable to be able to draw enantiomers and diastereomers as well.

B. Drawing Enantiomers

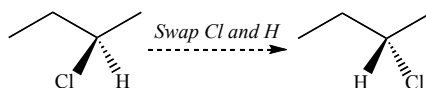
Recall that enantiomers are molecules that are nonsuperposable mirror images. Because these are mirror image molecules, and because stereoisomers can only have two absolute configurations, all the stereocenters of one enantiomer will be the mirror image of the other enantiomer. A mirror image stereocenter can be drawn by swapping two groups attached to the stereocenter, or by swapping the positions of the solid and broken wedges on the stereocenter. We can also draw the mirror image of the enantiomer using an imaginary mirror.

Example: Draw the enantiomer of (*R*)-2-chlorobutane.



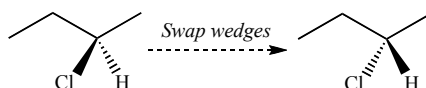
(*R*)-2-chlorobutane

Solution: Let's switch the places of the methyl and ethyl groups. This gives us (*S*)-2-chlorobutane. (Check this by determining the stereocenter's absolute configuration.)



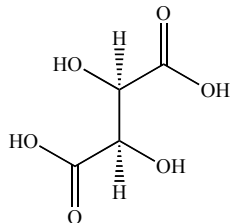
(*R*)-2-chlorobutane (*S*)-2-chlorobutane

Swapping the wedges achieves the same result. Verify this by using models to compare the two representations of (*S*)-2-chlorobutane shown below.



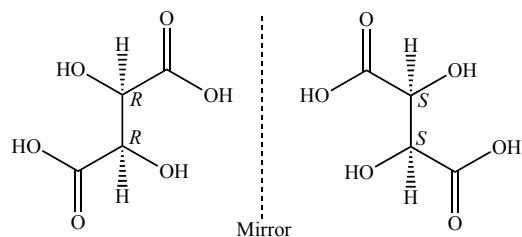
(*R*)-2-chlorobutane (*S*)-2-chlorobutane

Example: Draw the enantiomer of (2*R*,3*R*)-tartaric acid.



(2*R*,3*S*)-tartaric acid

Solution: Let's use the mirror image technique for this example. Once again, you may wish to verify the answer by labeling the stereocenters of the mirror image molecule as *R* or *S*.



(2*R*,3*R*)-tartaric acid (2*S*,3*S*)-tartaric acid

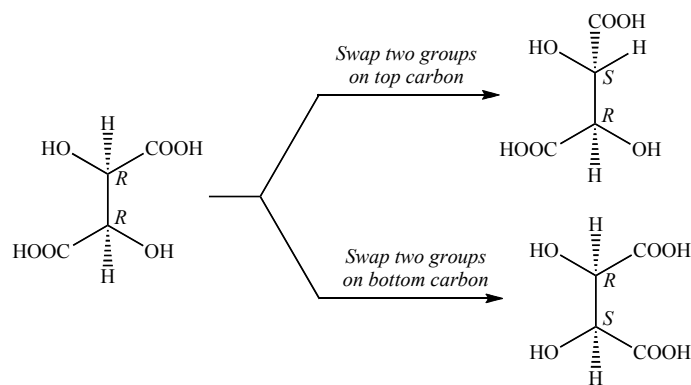
Use models to verify that the enantiomer drawn by the mirror image method is identical to the enantiomers drawn by the swap groups and swap wedges methods.

C. Drawing Diastereomers

Recall that stereoisomers differ in the position of the atoms in space, and that diastereomers are stereoisomers that are not enantiomers. We can draw the diastereomer(s) of a given structure by inverting one or more, but not all, of its stereocenters.

Example: Draw all the diastereomers of (2*R*,3*R*)-tartaric acid.

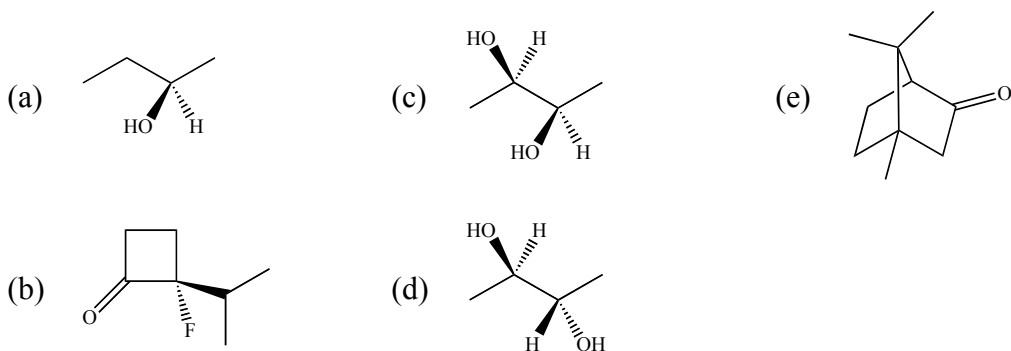
Solution: How many diastereomers can there be? Recall that for a molecule with n stereocenters, the molecule can have 2^n stereoisomers. Thus, (2*R*,3*R*)-tartaric acid, which has two stereocenters, can have at most $2^2 = 4$ stereoisomers. The (2*S*,3*S*) stereoisomer cannot be a diastereomer of (2*R*,3*R*) because both stereocenters have been inverted. This leaves two possibilities, each of which has one stereocenter the same as the given molecule: (2*R*,3*S*) and (2*S*,3*R*). The structures are drawn by inverting the stereocenter that is altered.



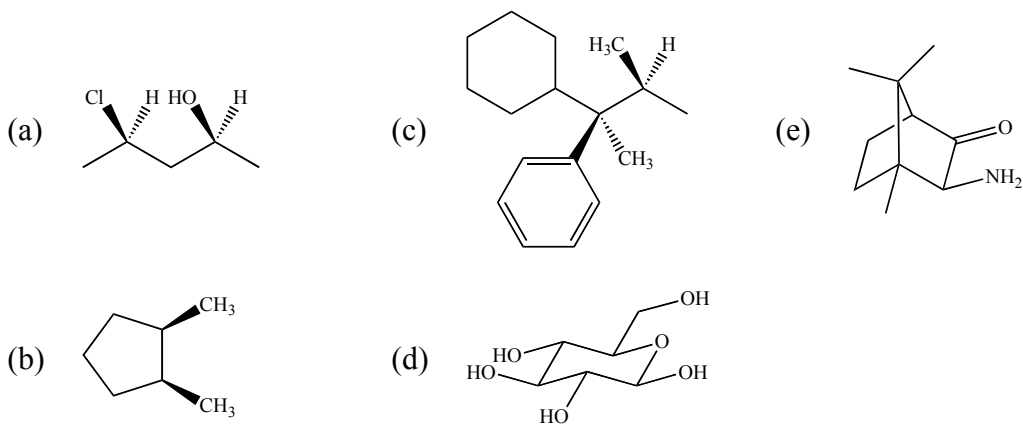
In this case, the new diastereomers are meso compounds, and are identical. This happens when the two stereocenters have the same attachments.

D. Exercises

1. Draw the enantiomer of each structure.

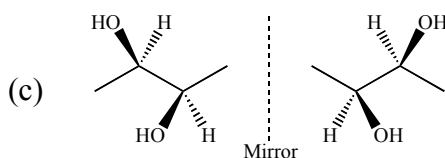
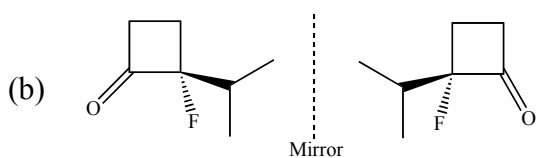
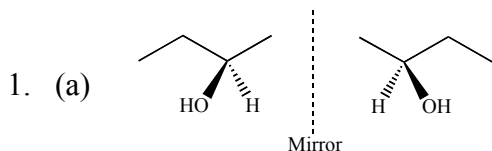


2. Draw a diastereomer of each structure.

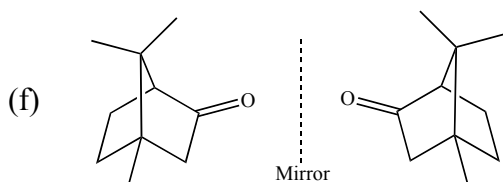


E. Solutions to Exercises

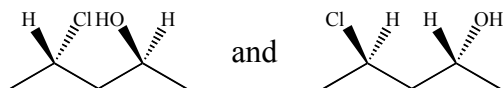
You may find it useful to build models of your answer and the answers given here for comparison purposes. Alternately, relative stereochemical relationships can be compared by assigning the stereocenters as *R* or *S*. Recall that all the stereocenters are inverted between a pair of mutual enantiomers, and at least one, but not all, stereocenters will be identical in mutual diastereomers.



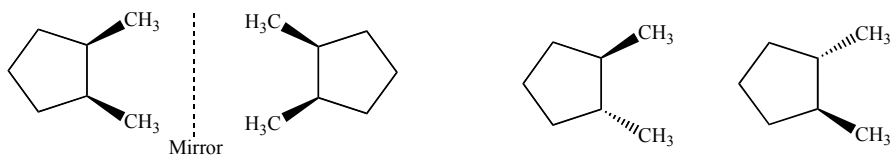
- (d) This is a meso compound. This molecule has a mirror image (as do all things except a vampire), but the original object and mirror image are superposable. Because it has stereocenters and is superposable on its mirror image, this is a meso compound. Because of their mirror image superposability, meso compounds cannot have enantiomers.



2. (a) This molecule has two stereocenters, so it has four possible stereoisomers, one of which is the enantiomer of the given structure. The remaining diastereomers are:



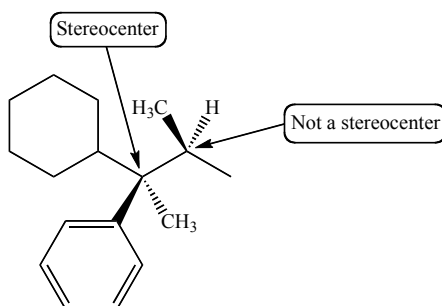
- (b) This compound has two stereocenters, so it can have at most four stereoisomers: two pairs of enantiomers. However, one pair of 'enantiomers' is actually superposable mirror images, so this is a meso compound. (Verify this superposability with models.) Therefore this compound has three stereoisomers: the original compound plus two diastereomers of the original compound.



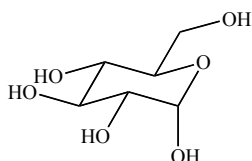
Given structure and mirror image are superposable: a meso compound.

Two additional diastereomers.

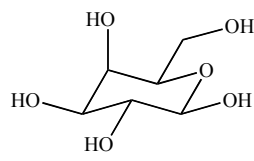
- (c) This compound has only one stereocenter, so it cannot have any diastereomers. Don't be fooled by the presence of solid and broken wedges. These are used to indicate position relative to the plane of the paper (or computer screen). Their presence does not define a stereocenter. In this case the 'stereocenter' on the left end of the given structure is not a stereocenter because two of its attachments (methyl groups) are identical.



- (d) This molecule is β -D-glucopyranose, the most abundant natural aldohexose monosaccharide. Glucopyranose has five stereocenters, and therefore $2^5 = 32$ possible stereoisomers. One of these is the given molecule and another is its enantiomer (β -L-glucopyranose). This leaves 30 possible diastereomers. The two diastereomers shown here are among the more common aldohexoses.



α -D-Glucopyranose



β -D-Galactopyranose

- (e) This compound has three stereocenters and therefore $2^3 = 8$ possible stereoisomers. However, inverting just one of the two bridgehead stereocenters results in an impossibly strained "inside out" molecule. (Verify with your models.) The only stereocenter whose change results in a reasonable molecule is the amine stereocenter, so this molecule has just one viable diastereomer, shown here.

