Worksheet – Chirality

Some Definitions:
Optical isomers are chiral molecules containing 1 or more stereocenters, carbon atoms bonded to four different substituents. If a molecule contains only one stereocenter, there will be one pair of isomers called enantiomers. Drawn below are the two optical isomers of 2-chlorobutane. Dashed bonds go into the paper, wedge bonds come out of the paper and line bonds are in the plane of the paper.

\[
\begin{align*}
\text{Cl} & \quad \text{Cl} \\
\text{H} & \quad \text{H} \\
\text{C}_2\text{H}_5 & \quad \text{C}_2\text{H}_5 \\
\end{align*}
\]

enantiomers: non-superimposable mirror images

If a molecule contains \(n\) stereocenters, there can be a maximum of \(2^n\) optical isomers with that formula. Drawn below are representations of the 4 optical isomers of 2,3-dichlorobutanoic acid.

\[
\begin{align*}
\text{COOH} & \quad \text{COOH} \\
\text{Cl} & \quad \text{Cl} \\
\text{H} & \quad \text{H} \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{I} & \quad \text{II} & \quad \text{III} & \quad \text{IV} \\
\end{align*}
\]

Structures I and II are a pair of enantiomers. Structures III and IV are another pair of enantiomers. The relationship between I and III or II and IV is that of non-mirror image stereoisomers. These are called diastereomers.

Some compounds have fewer that \(2^n\) optical isomers. An example is 1,2-dichloro-1,4-butanediol. Carbons 2 and 3 are stereocenters.

\[
\begin{align*}
\text{CH}_2\text{OH} & \quad \text{CH}_2\text{OH} \\
\text{Cl} & \quad \text{Cl} \\
\text{H} & \quad \text{H} \\
\text{Cl} & \quad \text{Cl} \\
\text{I} & \quad \text{II} & \quad \text{III} & \quad \text{IV} \\
\end{align*}
\]

I and II are a pair of enantiomers, but III and IV are the same compound, superimimposable mirror images. There is a plane of symmetry in this compound (dotted line) making it non-chiral and not optically active. This is called a meso compound.
1. Which of the following compounds contain stereocenters? Draw them and mark stereocenters with *.
   
   a. 2-bromobutane

   b. 2,2-dibromobutane

   c. 3,4,5-trimethylheptane

2. Which of the following compounds have a plane of symmetry?

   a. cis-1,2-dibromocyclobutane

   b. trans-1,2-dibromocyclobutane

   c. cis-1,3-dibromocyclobutane

   d. trans-1,3-dibromocyclobutane

3. Draw the enantiomers of 1-bromo-2-chloropropane

4. Draw the meso isomer of 1,2-dichlorocyclopentane
5. What are the maximum number of optical isomers for each of the molecules shown below?

a) 

b) 

c) 

d) 

6. Draw the enantiomer of compound c) in problem 5.

7. Draw a diastereomer of compound c) in problem 5, as well as its enantiomer.

8. Compound c) in problem 5 is optically active. When treated with LiAlH₄ it loses its optical activity. Draw the product and explain why.

9. Compound c) in problem 5 also loses its optical activity when it is treated with MnO₄⁻. Draw the product and explain why.
10. How many stereoisomers are possible for 2-chlorocyclopentanol? Which are pairs of enantiomers and which are meso compounds?

11. How many stereoisomers are possible for 3,4-dimethylheptane? Which are pairs of enantiomers and which are meso compounds?