CHEM 241 IN-CLASS #4 MOLECULAR MODELS EXERCISE

Names _____

Stereoisomerism

Construct a model containing a tetrahedral carbon (black ball) that is attached to four different atoms (use the green, orange, purple and white balls). This model will be referred to as A.

Construct a model that is the mirror image of A. This model will be referred to as B.

1. Are A and B superimposable--can you fuse the molecules together and have the like atoms share the same space? If they are superimposable this is another way to say they are 'Identical'.

Make another model of B (make sure they're superimposable) and switch the white and green balls on this model. This model will be referred to as C. Keep track of which models are A, B and C as you will refer to them later in the assignment.

2. Are A and C superimposable (identical)?

3. Are A and C mirror images of each other?

Construct a model containing a tetrahedral carbon that is attached to 3 different atoms (use the green, orange and two white balls). This model will be referred to as D. Construct a model that is the mirror image of D. This model will be referred to as E. (Keep track of which models are which)

4 Are D and E superimposable (identical)?

5 Are D and E mirror images of each other?

New terms: Plane of symmetry and Chiral.

Plane of symmetry: A plane that passes through an object (or molecule) such that the part on one side of the plane is the exact mirror reflection of the part on the other side. In other words can you chop the object in half such that one half it the exact reflection of the other half? Where you 'chop' would be considered the **plane of symmetry**.

Chiral: A **chiral** object is not superimposable upon its mirror image. A **chiral** object contains the property of "handedness".

6. Which of the molecules (A-E) have a plane of symmetry?

7. For those molecules that have a plane of symmetry listed in the question 6 above, draw the molecule(s) and depict the plane of symmetry (hint: you can use the plane of the paper as the plane.)
8. Which of the molecules (A-E) would you consider chiral objects (molecules)?

9. Make a statement regarding the relationship between having a plane of symmetry and being chiral.

New Terms: **Constitutional isomers and Stereoisomers.**

Constitutional isomers are molecules with the same molecular formula but have a *different sequence/ connectivity* of atoms.
Stereoisomers are molecules with the same molecular formula and have the *same sequence/ connectivity* of atoms, but differ in the fixed three-dimensional spacial arrangement of these atoms.

Stereoisomer example: Molecules A and B. They have the same molecular formula and the same connectivity (Carbon attached to green orange, purple and white) but they are not the same molecule 'in space'--they are not identical/superimposable. Verify that A and B are stereoisomers.

10. Would you consider 1-propanol and 2-propanol constitutional isomers or stereoisomers?

New Term: **Enantiomers.** If a pair of stereoisomers also happen to be mirror images of each other, we more specifically call them **enantiomers**. We could also state that **enantiomers** are stereoisomers that are mirror images of each other. A and B are and and example of enantiomers –(Verify this)

11. Are your left and right hands enantiomers?

12. What are the relationship(s) of A and C? (identical, stereoisomers, enantiomers) circle all that apply.

13. What are the relationship(s) of B and C? (identical, stereoisomers, enantiomers) circle all that apply.

14. What are the relationship(s) of D and E? (identical, stereoisomers, enantiomers) circle all that apply.

15. What are the relationship(s) of cis and trans 2-butene? (identical, stereoisomers, enantiomers)

Review:

16. If a molecule is chiral, will it be superimposable upon is mirror image?

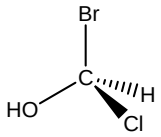
17. If a molecule is chiral, will it have an enantiomer?

18. If a molecule is not chiral (we call this 'achiral') will it be superimposable upon its mirror image?

19. If a molecule is 'achiral' (not chiral) will it have an enantiomer?

20. How many <u>different atom</u>s does a carbon need to be connected to in order for it to be a chiral molecule (we call these chiral carbons)?

21. Does the molecule depicted below have an enantiomer? If so draw it.



Molecules with Two Chiral Carbons (you can break apart models A-E as you are done with them)

Construct a model with four different atoms attached to carbon. Use white, green, orange and red balls to represent the different atoms. Make another model that is identical with the first (make sure they are superimposable). Remove the orange atom from both models and connect the two carbon atoms with a bond. This model contains **two chiral carbons** (verify this). It will be referred to as F.

Construct a model that is the **mirror image** of F. This model will be referred to as G.

22. Do any of the conformations of F or G contain a plane of symmetry? If yes, draw their location. (Rotate about the carbon-carbon bond to observe the different possible conformations).

23. Would you consider F and G chiral molecules?

24. What are the relationship(s) of F and G? (Identical, stereoisomers, enantiomers) circle all that apply.

Build another model of G, and exchange the white and green atoms on one of the carbon atoms. This model will be referred to as H. Keep track as to which models are F, G and H (and 'I' made below)

New Term: **Diastereoisomers** are stereoisomers that are not mirror images of each other.

25. What are the relationship(s) of F and H? (identical, stereoisomers, enantiomers, diastereoisomers)

Construct the mirror image of H. This will be referred to as I.

26. Do any of the conformations of H or I contain a plane of symmetry? If yes, draw their location. (Rotate about the carbon-carbon bond to observe the different possible conformations).

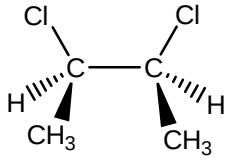
27. Would you consider H and I chiral molecules?

28. What are the relationship(s) of H and I? (identical, stereoisomers, enantiomers, diastereoisomers)

29. Note that you built models F and G as mirror images and models H and I as mirror images. How can you explain the differences in your answer to questions 24 and 28?

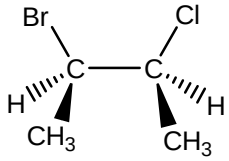
30. For the compound 2,3-dichlorobutane how many 'chiral' carbons does it have?

31. Draw all the possible stereoisomers of 2,3-dichlorobutane (think of models F,G,H and I). Use dash wedge formulation to show the 3-D of the 'chiral carbons'. One of the possible stereoisomers is drawn below.



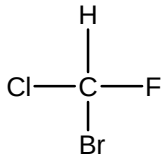
32. For the compound 2-bromo-3-chlorobutane, how many 'chiral' carbons does it have?

33. Draw all the possible stereoisomers of 2-bromo-3-chlorobutane. Use dash wedge formulation to show the 3-D of the 'chiral carbons'. One of the possible stereoisomers is draw below.

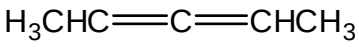


34**.** a. For questions 31 and 33, show which structures are enantiomeric pairs.
b. For questions 31 and 33, show which structures are diastereomeric pairs.

35. If carbon atoms were planar (flat) and had 90˚ bond angles would the compound below have an enantiomer? A diastereomer? If yes, depict them.



36**.** Make the model of the allene shown below (use the long grey flexible bonds for the double bonds).



a.Draw all the stereoisomers of the allene.

b.What is the relationship of the stereoisomers depicted?

38. What if the relationship of cis and trans 2-butene? (Identical, Enantiomer or Diastereomer)

Summary of Important Definitions

Isomers: Two or more molecules that have identical molecular formulas, but different arrangements of their atoms.

Plane of symmetry: A plane that passes through an object such that the part on one side of the plane is the exact mirror reflection of the part on the other side.

Superimposable: Two objects are superimposable if when they are put together in space <u>all</u> parts of each object coincide. If two objects are superimposable they are also considered identical.

Chiral: Containing the properties of "handedness." A chiral object is not superimposable upon its mirror image.

Stereoisomers: Isomers having the *same sequence or connectivity* of atoms, but differ in the fixed three-dimensional spacial arrangement of these atoms. Stereoisomer are interconvertible only by breaking and making bonds. Stereoisomers may have different physical and chemical properties.

Enantiomers: Stereoisomers that are mirror images of each other.
Diastereomers: Stereoisomers that are not mirror images of each other..