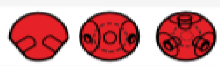
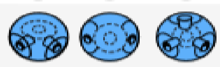
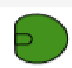
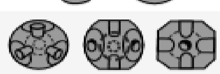
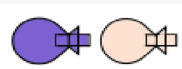
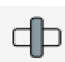
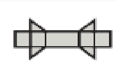
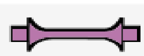
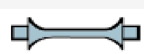
Your Duluth Labs MM-007 Student Set

First off, thanks for purchasing the Duluth Labs MM-007 Organic Chemistry Student Set! Using this set will bring to life to fundamental concepts such as bonding and VSEPR Theory to advanced concepts like Organometallic compounds, Coordination chemistry, and building Metal Complexes. Building molecules will get you hands-on experience with three-dimensional topics covered in General, Organic and Inorganic Chemistry.

The versatile molecular set accelerates memorization by allowing you to visually create common functional groups such as ketones, aldehydes, alcohols, thiols, amines, aromatics and most other families of organic compounds. We'll walk through some examples below to get you familiar with your set and introduce you to some of these essential topics in chemistry. This set has a total of 281 pieces which is why it was specifically designed to assist students throughout their entire chemistry lifetime and to cover all chemistry needs.

Your **MM-007 Molecular Student Set** includes the following:

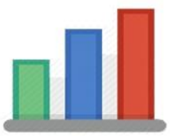
NAME	BONDS	COLOR	DIA. (MM)	QUANTITY	IMAGE
H-Hydrogen	1 ; 2	White	17	30 ; 4	
C-Carbon	4 ; 5 ; 6	Black	23	20 ; 4 ; 2	
O-Oxygen	2 ; 3 ; 4	Red	23	8 ; 2 ; 2	
N-Nitrogen	3 ; 3 ; 4	Blue	23	2 ; 2 ; 4	
S-Sulfur	2 ; 4 ; 6	Yellow	23	1 ; 2 ; 1	
P-Phosphorus	4 ; 5	Purple	23	2 ; 2	
Halogens (F, Cl, Br, I)	1	Green	23	12	
Halogens (I, Br)	5	Indigo;Orange	23	1 ; 1	
Metal	2 ; 3	Gray	23	2 ; 2	
Metal	4 ; 5 ; 6	Gray	23	4 ; 4 ; 4	
P-Orbital	1	Multi	23	16	
Short Connectors	1	White	11	30	
Medium Connectors		White	27	66	
Long Connectors (Ligands)		Purple	43	12	
Long Connectors		Gray	43	38	
Molecular Tool				1	

8 REASONS TO USE MODELS IN YOUR COURSES

1 Improve Teaching Performance

Reports firmly show that the use of models and active learning are more effective than the traditional lecture.

2 Increase Course Passing Rate



Students instructed by active learning methods were 1.5 times less likely to fail.

3 Receive Better Professor Reviews

Students which participated in hands-on learning felt more positively toward the topic and had a lower course dropout rate.

4 Improve Student Test Scores

Students who constructed physical models while learning a new concept demonstrated up to 12% higher test scores

5 Drive Quicker Memorization

Hands-on learning activates both sensory and motor skills which has been shown to increase learning and memory retention

6 Spread your Passion for Science

Students who used models in their courses increased positive attitudes toward the sciences

7 No Training Required

Students taught with science kits were equally able to increase their test scores over students taught without kits, regardless of teacher training.

8 Once Per Week

Research indicates that the use of molecular sets just once per week can be effective while increased frequency will improve the overall benefits.

Disassembly of Molecules

For easy disassembly of your molecules, use the Molecular Tool to quickly remove bonds from the atoms. With the grooves facing the bond that you're going to remove, insert the Molecular Tool between the atom and the bond. Then rotate the Molecular Tool like you would with a bottle opener to easily remove the bond from the atom.

Bonds may initially be tight fitting but will loosen up after use to make secure connections for many years to come. While many prefer the tighter fitting molecular bonds, some users prefer looser fitting bonds which can be achieved by applying Vaseline to the connector ends to allow for easier disassembly of the molecules.

Molecular Tool

Hybridizations

As a student you will hear that the difference between hybridized atoms are the shape of the orbitals and how they overlap. However, we understand that this is not a concept to grasp easily with typical 2-D drawings. This is why we've designed our MM-007 Molecular Set to help you better understand hybridization using 3-D molecules.

Background Notes:

Steric numbers help to tell the number of hybridized orbitals present. If,

Steric number= **4 that means, sp3 hybridization**

Steric number= **3 that means, sp2 hybridization**

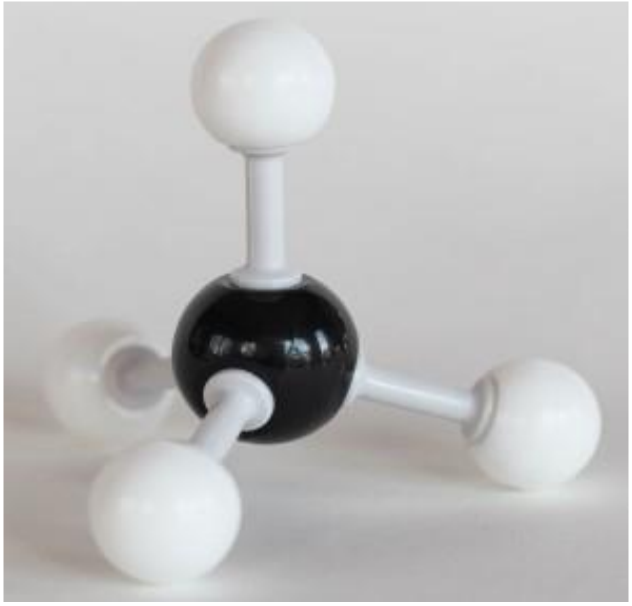
Steric number= **2 that means, sp hybridization**

Quick formula for steric number = (# of sigma bonds + # of lone pairs)

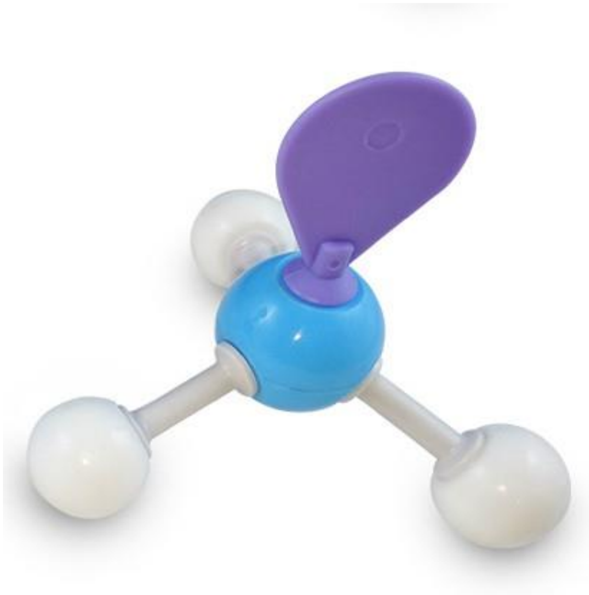
sp3 Hybridization

A sp3 atom means that there is 25% "s" character and 75% "p" character which can be easily identified by a steric number of **4**. For a molecule like methane, the Carbon is a sp3 carbon since it has 4 single covalent bonds (sigma bonds) and no lone pairs. Therefore, it has a steric number of 4 making the carbon sp3 hybridized with hydrogen atoms.

Ammonia molecule is also another example of a sp3 hybridized atom as it has 3 sigma bonds and 1 lone pair which gives a steric number of 4. However, as seen with the images below, both atoms are sp3 hybridized but they display different geometrical arrangements.



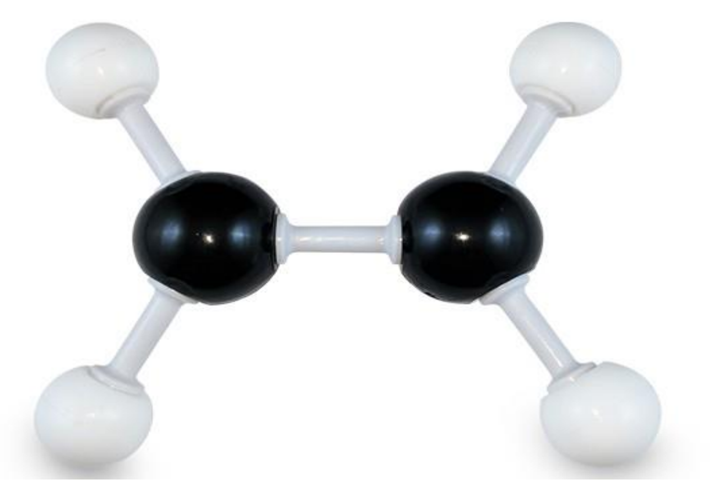
Methane



Ammonia

sp2 Hybridization

A sp2 hybridized atom is identified by a steric number of **3.** In the example below, we can see that there are 3 sigma bonds and no lone pairs which give a steric number of 3. Therefore, each Carbon is sp2 hybridized. The sp2 atoms included in your set are able to show the proper geometrical arrangements. In this case, it has a bond angle of 120° and is said to be trigonal planar in arrangement.



sp2 Hybridized Atoms- Spatial Arrangement

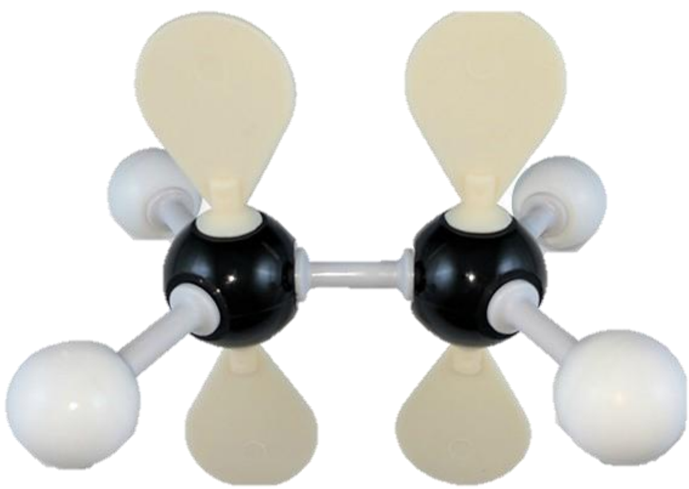
Sp Hybridization

A sp hybridized atom is identified by a steric number of **2**. In our example, we can see that there are only 2 bonds and no lone pairs which give a steric number of 2. Therefore, each carbon is sp hybridized. The sp atoms included in your set are able to show the proper geometrical arrangements. In this case, it has a bond angle of 180° and is said to be linear in arrangement.

sp Hybridized Atoms- Spatial Arrangement

Trigonal Bipyramidal Atoms (5- hole Atoms)

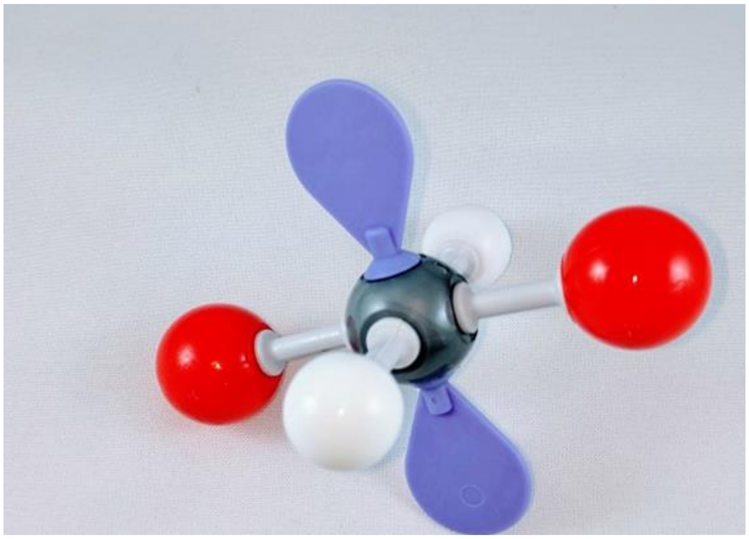
Another complicated area of chemistry is visualizing atoms which display trigonal bipyramidal arrangements. Our MM-007 can be used to clearly demonstrate an Ethylene molecule and its arrangement. The chemical formula for ethylene is C_2H_4, which means it consists of a double bond, sp2 hybridized atoms, and unhybridized p orbitals. Using both of the 5-bond carbon atoms provided in the MM-007 we can display the bond types, orbitals, and hybridization present in the ethylene molecule.



Ethylene

Additional Feature: Octahedral Atom

Our MM-007 contains 6-hole atoms which can be used to display sp3d2 hybridized atoms and octahedral arrangement with a bond angle of 90º. Our example below displays the proper arrangements and bond angles. Since our MM-007 is our largest molecular set it allows students who are taking inorganic and advanced chemistry to have more trigonal bipyramidal and octahedral atoms as needed.



Octahedral Metal Complex

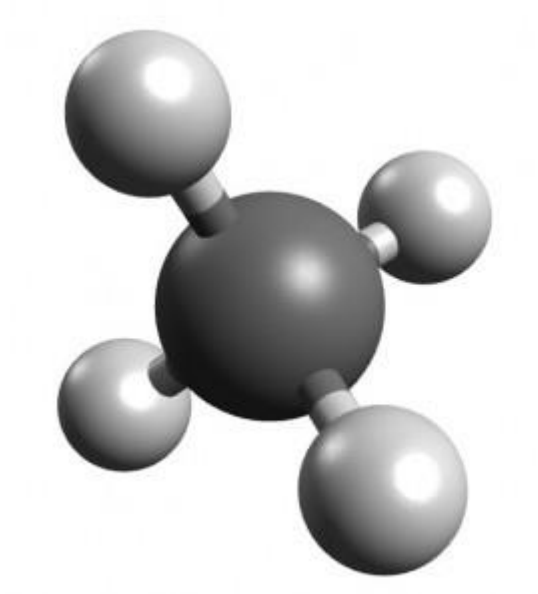
Other Fundamentals

We'll walk through some examples below to get you familiar with how to build molecules using your set. This exercise will also introduce you to some important molecules in chemistry.

Methane

One of the simplest organic molecules is methane with a molecular formula of CH_4 meaning it contains one carbon and four hydrogens. A 3-dimensional representation of a methane molecule is shown below.

To create methane with your molecular set, first find a black carbon atom and four white hydrogen atoms. Since the hydrogen atoms connect to the carbon atom by single covalent bonds, either four short connectors (creates more compact models) or four medium connectors can be used. Simply attach one side of the connector to a hole in the carbon atom and the other side to a hydrogen atom. Once you've connected all of the hydrogen atoms to the carbon, you've created your first molecule and can show your family or friends what natural gas molecules look like.



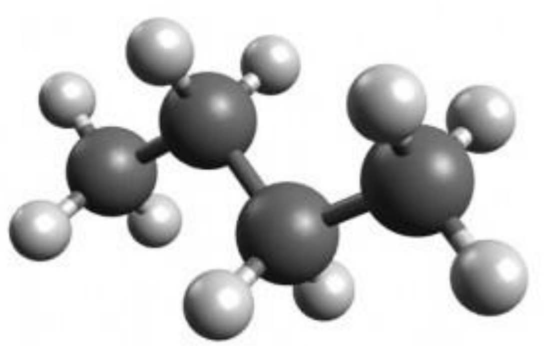
Methane

Methane

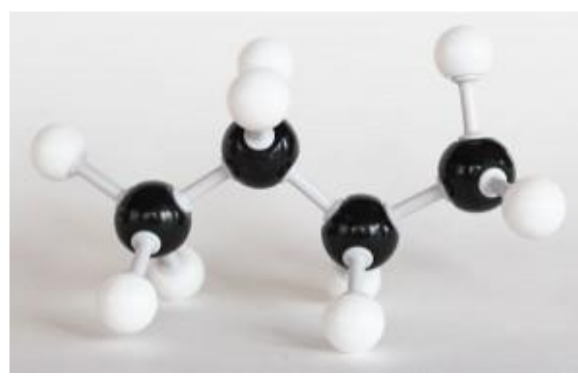
Butane

Butane is an alkane that has a total of four carbon atoms, ten hydrogen atoms and a molecular formula of C_4H_{10}. Since butane has two structural isomers, we will be more specific that that we're going to build normal butane (also written as n-butane). Normal butane can be used as a fuel and is commonly mixed with propane to create Liquefied Petroleum Gas or LPG. It can also be used as a blend stock in gasoline or as a propellant in aerosol sprays.

To build normal butane, you'll need four black carbon atoms, ten white hydrogens and thirteen short or medium connectors. First, attach all the carbons together in a line with single covalent bonds. Fill in the rest of the available bonds from the carbon atoms with the ten hydrogens and now you've got n-butane. For extra credit, see if you can figure out which two bonds to switch around to easily change the molecule into iso-butane:)



Normal Butane



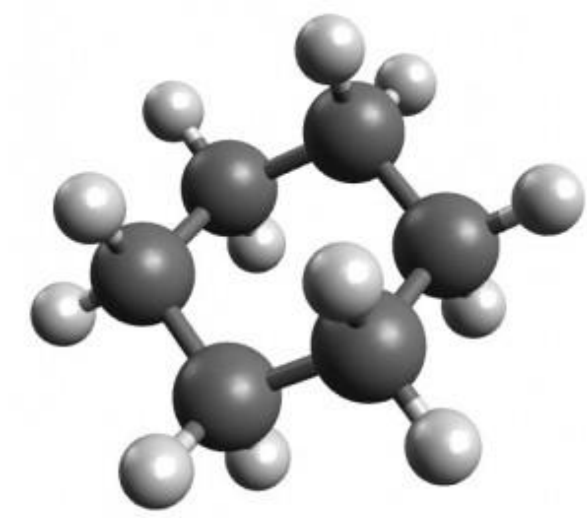
Normal Butane

Cyclohexane

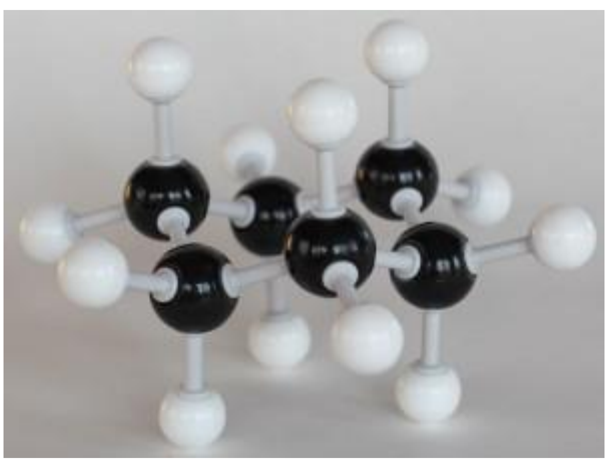
The next molecule that we'll build is cyclohexane which is classified as a cycloalkane. Since cyclohexane's molecular formula is C_6H_{12}, you'll need six black carbons and twelve white hydrogens (along with eighteen small or medium connectors) to build this molecule. To start on this molecule, first connect the six carbons together into a circle. Once you have the carbon ring, fill in the rest of the carbon bonds with white hydrogen atoms.

The cyclohexane molecule that you just made can be really helpful to understand conformations. Cyclohexane can flip its ring to rotate between chair and boat conformations. The 3-dimensional picture of cyclohexane shows the molecule in its chair conformation which is the lowest energy state or most stable structure. The Duluth Labs set has been designed so you can easily flip cyclohexane from the chair to the boat conformation to see the differences between the two.

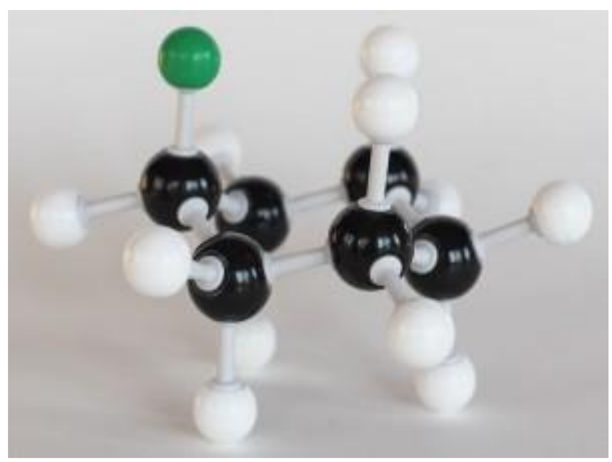
Another useful topic that you can use your model to visualize is equatorial or axial locations of substituted cyclohexane. One way to do this is to substitute one hydrogen atom with a green halogen atom. With the cyclohexane molecule in the chair conformation, the green halogen atom will either be in the equatorial (essentially on the outside of the ring) or in the axial position. By rotating the carbons in the cyclohexane ring, you can change the position of the halogen from equatorial to axial and back again.



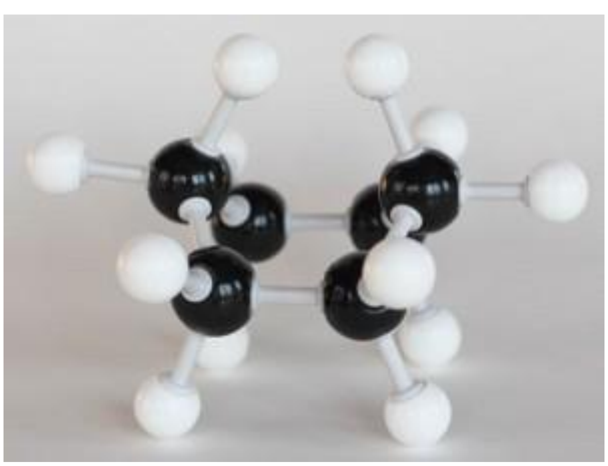
Cyclohexane - Chair Conformation



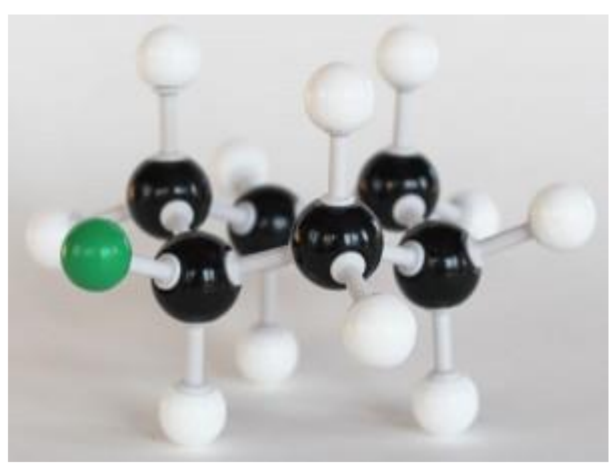
Cyclohexane - Chair Conformation



Cyclohexane Axial



Cyclohexane - Boat Conformation

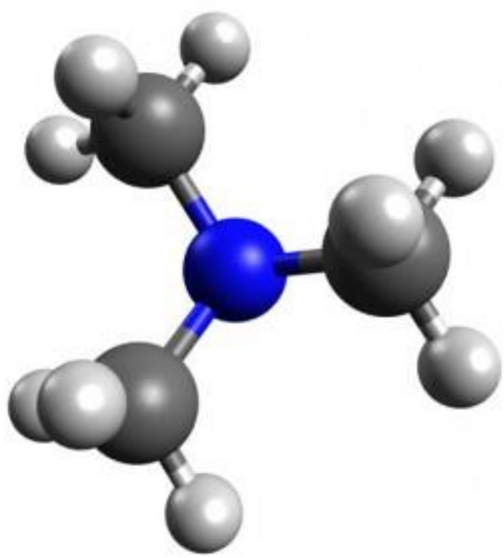


Cyclohexane Equatorial

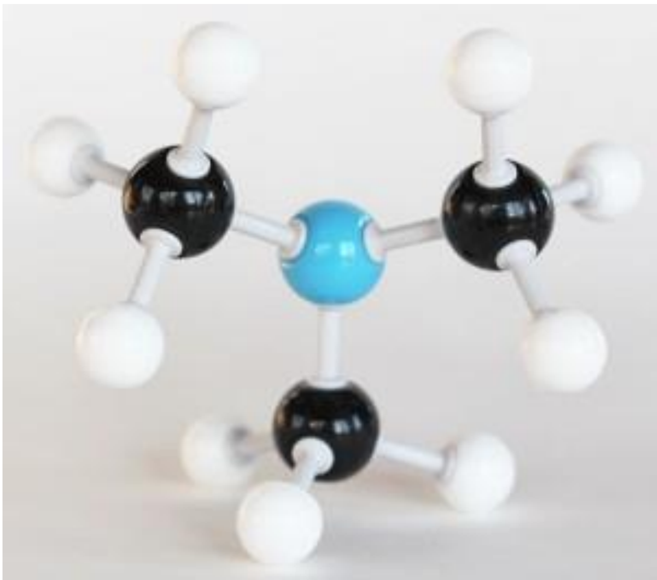
Trimethylamine

While the first three molecules we've built just have hydrogen and carbon atoms, the next one that we'll build also contains nitrogen. Trimethylamine has a formula of $N(CH_3)_3$ which is a tertiary amine. Trimethylamine is found as a byproduct of decomposing plants and animals and produces an odor typically associated with rotting fish. While your Duluth Labs set has been designed to accurately visualize numerous organic structures, it does not simulate the odors of these molecules so you don't have to worry about a rotten fish smell when you build it:)

To build this molecule, you'll need three black carbons, nine white hydrogens and one blue nitrogen with three holes in it. Note that your set includes two blue nitrogen atoms with three holes and two other nitrogen atoms with four holes. Since nitrogen can form molecules with three covalent bonds (like trimethylamine) or four covalent bonds (like ammonium), we included both types to allow more flexibility for building these different molecules. To create trimethylamine, connect the three black carbons to the nitrogen atom. After you do that, you can build the rest of your methyl groups by adding in the other three hydrogens to each carbon.



Trimethylamine



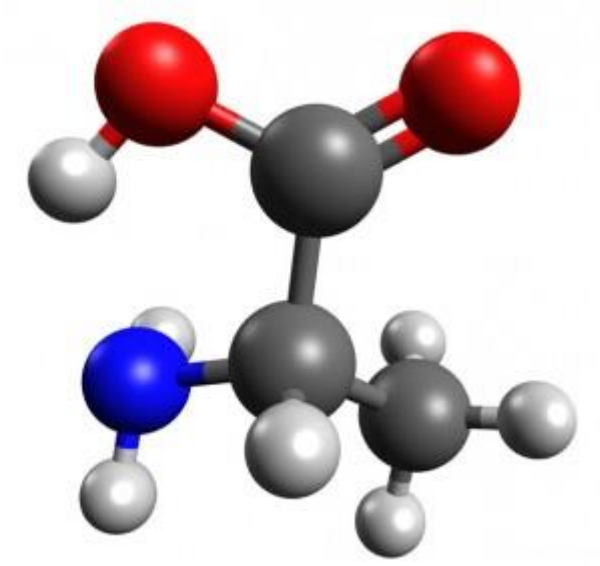
Trimethylamine

Alanine

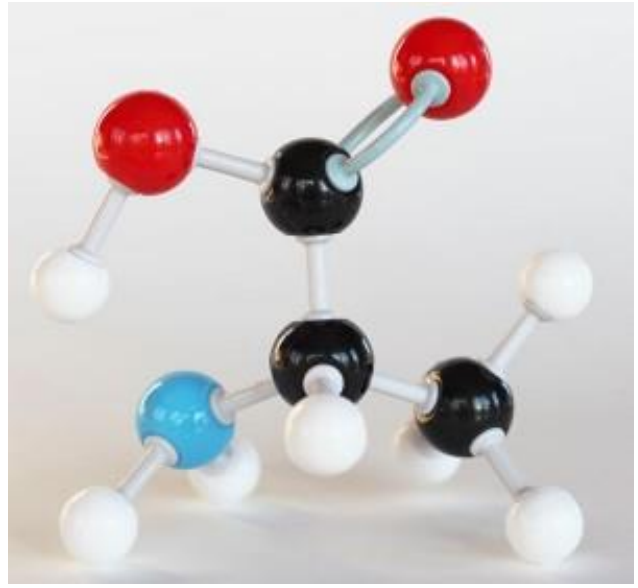
Alanine's chemical formula or $CH_3CH(NH_2)COOH$ looks intimidating but we will walk our way through creating this amino acid. The left handed isomer (or L-isomer) of alanine is one of the twenty amino acids that is found in the human genomic code. To build this molecule, you'll need three black carbons, two red oxygens, one blue three bond nitrogen and seven hydrogens. Since this molecule contains a double bond between one of the oxygen atoms and a carbon, we'll need to use two long connectors for this double bond along with eleven medium connectors for the single covalent bonds.

To make this atom, we can start by making all of the functional groups in the molecule. First, we can make the carboxyl group which is the COOH part of the formula (shown at the top of the 3-dimensional picture below). To make the carboxyl group, connect a red oxygen to a carbon with a medium covalent bond and add a hydrogen to the other available bond of that oxygen. Next, use two long connectors to create a double bond to connect the other oxygen to the carbon atom.

Now you can also make a methyl group ($-CH_3$) and an amine group ($-NH_2$) to build the other functional groups of alanine. Finally, you can connect these three using medium covalent bonds to a final carbon and finish off the molecule by adding the last hydrogen atom.



Alanine



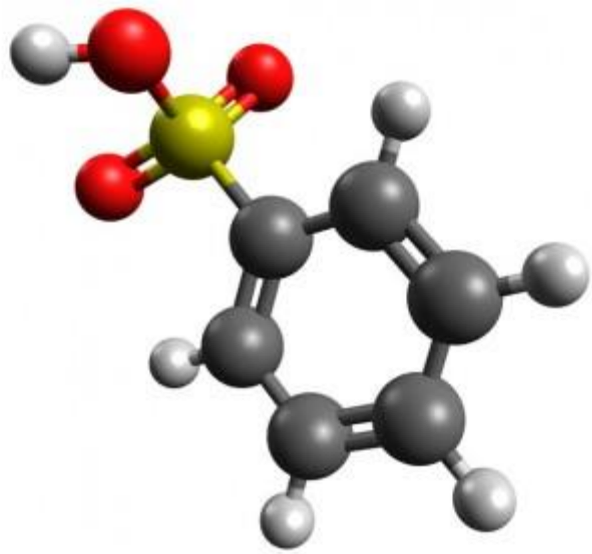
Alanine

Benzenesulfonic Acid

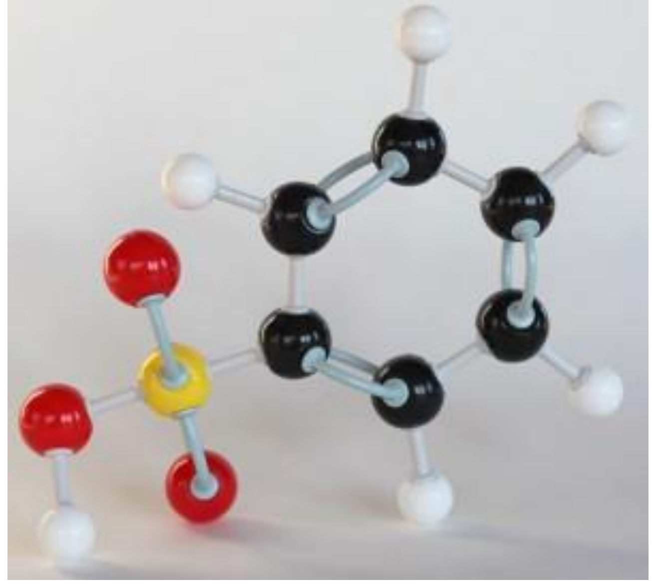
The last molecule that we'll build is benzenesulfonic acid which has the chemical formula of $C_6H_5SO_3H$. To build this molecule, you'll need a total of six black carbons, three red oxygens, one six bond yellow sulfur and six white hydrogens. The molecule also contains five double bonds so we'll need ten long connectors and eleven medium single covalent bonds. Like nitrogen, sulfur can have a varying number of covalent bonds in different molecules so two different yellow sulfur atoms were included in your set. The sulfur atom with four holes can be used to make sulfur compounds with four covalent bonds like sulfur dioxide, SO_2, or sulfur compounds with two covalent bonds like hydrogen sulfide, H_2S (for this type of molecule you'd just leave two holes open on the four-hole sulfur). The sulfur with six holes can be used to make molecules like benzenesulfonic acid where sulfur has a total of six covalent bonds.

We'll break this molecule down into two pieces and build the aromatic ring (benzene) and the sulfonic acid groups separately at first. To create benzene which is an aromatic ring, you'll need the six carbons and a total of five hydrogens. Connect the carbons together alternating between single and double bonds until the six carbons have formed a ring. Fill in the open holes on the carbon atoms with the five hydrogens and leave the last carbon bond open to connect to the sulfonic acid group.

To create the sulfonic acid group, you'll need to connect two oxygens to the sulfur atom using double bonds. A third oxygen can be attached to the sulfur using a single bond and that oxygen can be saturated with a hydrogen atom. Finally, you can connect these two functional groups together with a single bond to form benzenesulfonic acid. Great work!



Benzenesulfonic Acid



Benzenesulfonic Acid

