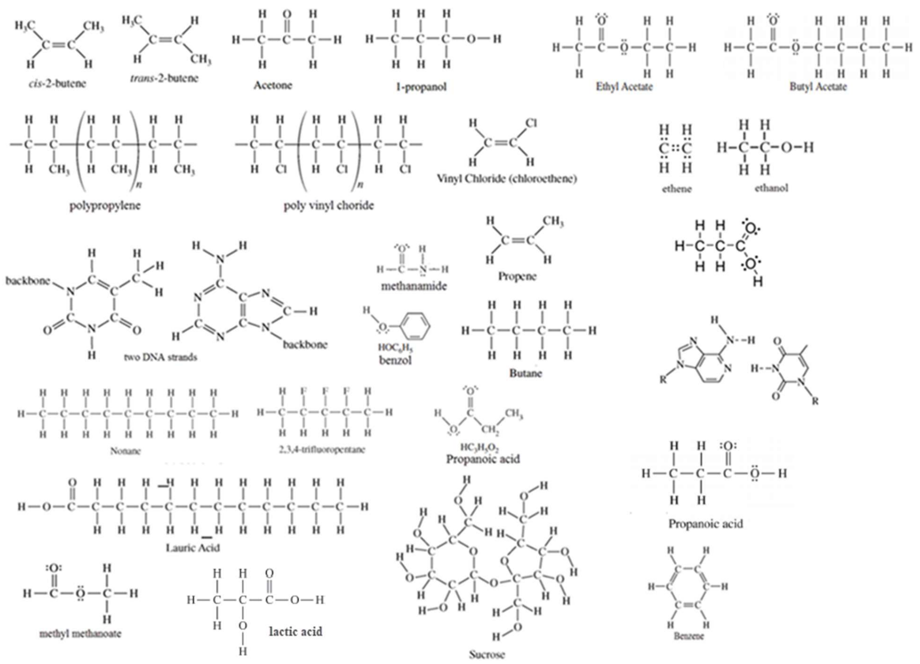
Chapter 24 Organic Chemistry and Chapter 25 Polymers

Organic Chemistry is a separate course in the college chemistry sequence. It is the most common course taken after 1st year college chemistry and has a well-deserved reputation for being difficult. It is not unusual for half the class to drop out of organic chemistry after three weeks. Organic chemistry is used as the second filter to weed out the weak and to showcase the best for most medically related programs. Don't take college organic chemistry without doing some preparation. Seriously, get ready at least two weeks before the course starts. Re-memorize the nomenclature and basic organic functional groups so that you are completely fluent. *Organic Chemistry as a Second Language* 5th Edition by David R. Klein is a book that is recommended. Organic chemistry is intense and pretraining will give you the critical breathing room that will prevent you from drowning. If you pretrain, instead of being a casualty, you will be a master of the universe.

Organic Chemistry is not officially part of the AP Curriculum, but many AP questions use organic compounds. Here are some of the compounds used on the exam.



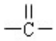
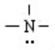
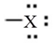
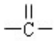
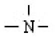
Knowing organic chemistry basics for AP Chem will make the questions with organic compounds more understandable and give you a significant edge. You need to be in the top 25% of students taking the test to get a 4 or 5, and these extras can help you get to that top tier.

Chemistry by Chang and Goldsby

Chapter 24: Organic Chemistry
24.1 Classes of Organic Compounds
24.2 Aliphatic Hydrocarbons
24.3 Aromatic Hydrocarbons
24.4 Chemistry of Functional Groups

Chapter 25: Synthetic and Natural Polymers
25.1 Properties of Polymers
25.2 Synthetic Organic Polymers
25.3 Proteins

Review this bonding table for the elements that are used to make most of the organic compounds.

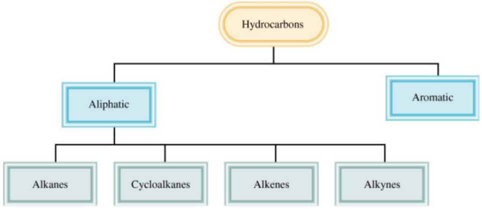
	carbon	carbon w/double bond	carbon w/triple bond	nitrogen	oxygen	oxygen w/double bond	hydrogen	halogen
Lewis Electron-Dot Diagram			—C≡				-H	
Organic Chemistry Structural Representation			—C≡		—O—	=O	-H	—X
Shape	Tetrahedral 109°	planar triangular 120°	linear	trigonal pyramidal 109°	bent 109°			
Bonds	4σ	3σ 1π	2σ 2π	3σ				
Hybridization	sp^3	sp^2	sp	sp^3				

24.1 Classes of Organic Compounds

The branch of chemistry that deals with carbon compounds is organic chemistry.

Hydrocarbons are compounds made up of only carbon and hydrogen.

They can be grouped into two major groups, aliphatic and aromatic. Aromatics contain benzene rings (see later in the summary) and aliphatics do not contain benzene rings.

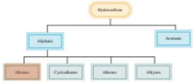


If you logically organize the organic compounds, you will understand and remember them.

24.2 Aliphatic Hydrocarbons

Memorize the carbon number names:
These are the “ABC’s” of the language. Don’t be an organic illiterate. If you can’t memorize these, skip the chapter, throw away this summary, and forget about learning organic chemistry or going into any field that uses organic chemistry.

prefix (common unofficial names)	number of carbon atoms
meth (form[1])	1
eth (acet)	2
prop	3
but	4
pent	5
hex	6
hept	7
oct	8
non	9
dec	10



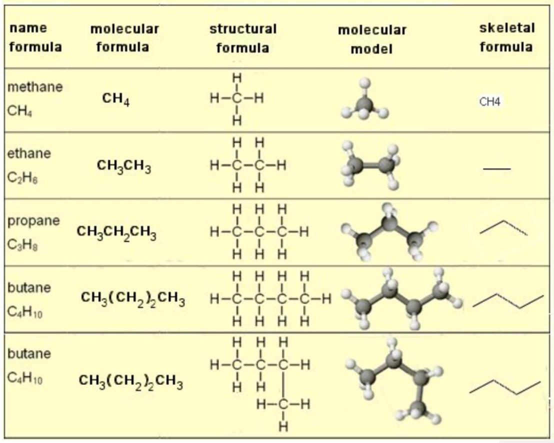
Alkanes

Alkanes are hydrocarbons that have the general formula C_nH_{2n+2}

The table shows the first four alkanes as formulas and in various forms.

The molecular formulas and skeletal formulas are very important ways of showing organic molecules. The skeletal formula presumes that **carbon atoms are at each line endpoint** and the hydrogen atoms are not shown since a good student can figure out the H atoms knowing that each carbon will have four bonds.

While skeletal formulas are difficult to understand at first, they are the most common way organic compounds are represented because they are easily drawn. Understand them!



name formula	molecular formula	structural formula	molecular model	skeletal formula
methane CH_4	CH_4			CH4
ethane C_2H_6	CH_3CH_3			
propane C_3H_8	$CH_3CH_2CH_3$			
butane C_4H_{10}	$CH_3(CH_2)_2CH_3$			
butane C_4H_{10}	$CH_3(CH_2)_2CH_3$			

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[1] “form” and “acet” are legacy prefixes that predate the modern system. Many organic compound names are better known by their older names. Formic acid and formaldehyde are used far more often than methaldehyde or methanoic acid. Also, the acetate ion is used instead of the ethanoate ion and acetic acid rather than ethanoic acid. If you remember these two legacy terms, you will be able to translate many compound names which “form” and “acet” instead of the rational 1 carbon “meth” and 2 carbon “eth”. Many of the legacy terms in organic chemistry have interesting origin backstories that can help you remember them. Form comes from cooking ants and acet goes all the way back to ancient Rome and sour wine.

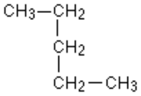
While structural drawings show right angles for bonding, there are no 90° angles in any organic compound.
The flat structural drawings are distortions of the three-dimensional structure of the molecule. All alkane angles are 109°, tetrahedral structures since all carbon atoms in alkanes are *sp*^{3} hybrids.

The atoms in alkanes can twist and turn along their carbon spines since these are sigma bonds. The table shows butane with a twist in the bottom row to show that the molecule can easily be contorted. Imagine alkane chains as strings that can easily be shaped.

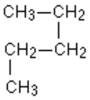
Pentane C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	$CH_3(CH_2)_3CH_3$

Here are three drawings of pentane. All are pentane since they are the same molecule just twisted. The longest continuous carbon chain is generally used as the base name of an organic compound. If you follow the 5 carbon chain, you will see that it is one continuous line with no carbon branches, just twists.

$CH_3{-}CH_2{-}CH_2{-}CH_2{-}CH_3$



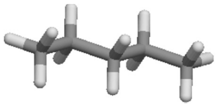
$$\begin{array}{ll} CH_3{-} & CH_2 \\ & | \\ & CH_2 \\ & | \\ & CH_2{-}CH_3 \end{array}$$



$$\begin{array}{ll} CH_3{-} & CH_2 \\ & | \\ CH_2{-} & CH_2 \\ | & \\ CH_3 & \end{array}$$

Go to a commonly used 3D molecular model generator:

Molinspiration Galaxy 3D Structure Generator
https://www.molinspiration.com/cgi/galaxy



Type CCCCC into the SMILES box and [GENERATE 3D]. You will get a 3-D model that you can view in CPK, dotted, tubes or wires. More importantly you can grab and move the molecule.

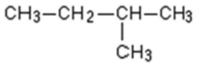
Now for the skeletal structure. Chemists know that carbon will have four bonds and to save time, they do not include the hydrogen atoms or even the carbon atoms. The molecules are drawn in zigzag pattern since the carbon atoms are *sp*^{3} hybridized with 109° angles.

The dots represent the carbon atoms.

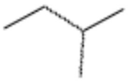
In the skeletal formula the dots are omitted

There are other ways to combine 5 carbon alkanes, C_5H_{12}, that are not pentane.

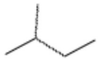
To the right is a new compound, 2-methyl butane.
2-methyl butane has the same molecular formula as pentane, C_5H_{12}, but 2-methyl butane has a lower boiling temperature and a slightly different reactivity than pentane.

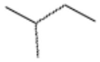


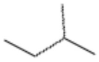
$$\begin{array}{l} CH_3{-}CH_2{-}\underset{\underset{CH_3}{|}}{CH}{-}CH_3 \end{array}$$

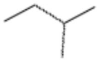


To rearrange a pentane molecule into 2-methly butane, you would have to break and reform bonds.
The skeletal drawings below are all 2-methylbutane molecules, just drawn with different views.









2-methyl butane's longest continuous chain is four carbons long, so its root name is butane.
2-methyl butane has a methyl group branched off the second from the end carbon[2] atom. The "meth-" and "but-" prefixes add up to the total number of carbons as, "pent-".
Organic chemistry's logical naming tells you how the molecule is constructed. While the AP Chem exam will not have you name compounds, knowing this logical naming system will help you understand the molecular structure.

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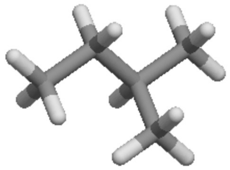
[2] The numbering of the attached branches always starts from the side which will produce the lowest number set. 3-methyl-butane would be incorrect. Since the only unique location for a methyl group is on the second carbon, the number is often omitted, an alternative name is simply methyl butane. Also, its common name isopentane indicating that it is an isomer of pentane.

Pentane and 2-methyl butane are **structural isomers**.[3] Structural isomers have the same base formula but different structures to make truly different compounds.

Commented [PM1]:

Some organic chemistry courses require students to buy molecular model kits to build models of these molecules. However, computer based molecular drawing programs are replacing the physical models. As you go over this unit, use the Molinspiration Galaxy 3D Structure Generator to visualize the different views of the same compound.



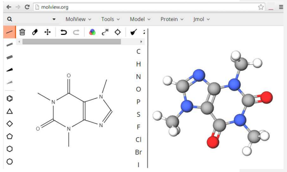
Go to Molinspiration Galaxy 3D Structure Generator again and type in
SMILES: CCC(C)C

https://www.molinspiration.com/cgi/galaxy

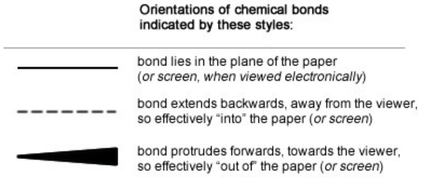
View the 3-D structure of this isomer of pentane with its hydrogen atoms. Twist it to get a good 3-D understanding which is essential in organic chemistry.

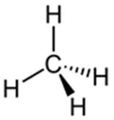
There are many other commercial molecular modeling programs. In addition to Molinspiration, a commonly used modeling program is Moleview. (http://molview.org/).

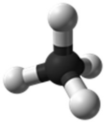
Using the Moleview program, you can generate an information card that includes the SMILES data for the molecule and get an excellent 3-D view of the molecule.



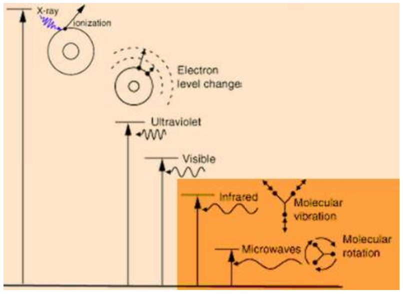
A common method to show the dimensionality of molecules on paper involves using different types of lines.







Organic compounds with complex segments and rotating groups will absorb infrared light because the energy of infrared photons is sufficient to cause vibrations and molecular rotations. Thus, infrared light is used to investigate and identify organic compounds. While most alkanes are transparent to visible light as liquids, they are not transparent to longer wavelengths such as infrared. The molecular motions resulting from absorbing infrared photons can be used to analyze the structure of organic compounds.



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[3] There are also optical isomers that occur when the mirror image of an isomer is different.

Alkane Nomenclature[4]

While naming alkanes is not part of AP Chemistry, naming will help you understand isomers.

1. Find the longest continuous chain for the root name.
2. Find the attachments to the chain. These attachments can be alkyl groups or substituent groups.
   All chemistry students should know the alkyl groups: methyl, ethyl, and propyl (Table 24-2).
3. The attachments locations are listed by numbering the root chain carbon atoms from right to left **or** left to right using the lowest consistent numbering system.

A more complete set of rules is found in Chang. While naming inorganic compounds can be explained in a page or two, organic compound nomenclature is a book.

Reactions and properties of Alkanes that you should know for AP

All pure alkanes are nonpolar and thus only have LDF's as their sole intermolecular attractions.
The larger the alkane, the greater its electron surface area and a are more easily polarized.
Methane, ethane, propane, and butane have weaker LDF's and are gases at room temperature.
It takes 7 carbons, heptane C_7H_{16}, for LDF's to attain a boiling temperature, 98°C, that is comparable to water's hydrogen bonding intermolecular forces.
Alkanes have low solubility in water.

Combustion:

Hydrocarbons burn with oxygen to produce carbon dioxide and water. Balancing the reactions can be tricky since oxygen is diatomic and the unbalanced products may have an odd number of oxygen atoms requiring a fractional number of oxygen molecules. If the alkane has an even number of carbons, balancing the reaction with whole numbers will require a coefficient of 2 in front of the alkane. Knowing this will make balancing easier

carbon alkane

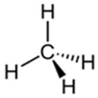
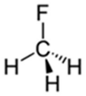
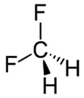
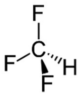
$C_1H_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

$C_2H_6 + 3\tfrac{1}{2}\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$ $\qquad$ $2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$

Halogenated compounds:

A halogen atom can be substituted for a hydrogen atom in an alkane. The halogens, especially F and Cl, are more electronegative than the hydrogen atom and may unbalance the molecule creating a dipole moment and the molecules can become polar. The asymmetry of the molecule and dipole moment will increase the intermolecular attractions and raise the boiling temperature.

These molecules are often used in intermolecular attraction questions on the AP Chem exam.

	methane	fluoromethane	difluoromethane	trifluoromethane	tetrafluoromethane
					
Polarity	nonpolar	polar	most polar	less polar	nonpolar
Boiling point	-161°C	-74°C	-52°C	-82°C	-128°C

Once methane becomes tetrafluoromethane, the molecule becomes symmetrical again and its dipole moment is lost. Also note that the tetrafluoromethane has a higher boiling temperature than nonpolar methane since the fluorine atoms have a more polarizable electron surface because each fluorine has 2nd energy level electrons.

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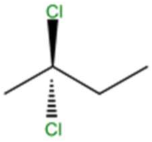
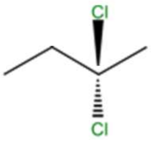
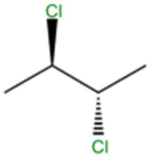
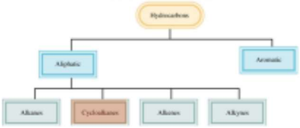
[4] There are some newer ways of naming organic compounds, but the method I use is used on the AP Chemistry exam.

In longer chain molecules, the locations and numbers of the attached halogen atoms are indicated in the name. There are also structural isomers resulting from the placement of the halogen atoms on the carbon chain. Here are two very distinct structural isomers of $C_4H_8Cl_2$.

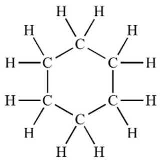
 or 	
2,2-dichlorobutane	2,3-dichlorobutane

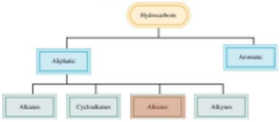
There also could be a 1,1-dichlorobutane, 1,2-dichlorobutane, 1,3-dichlorobutane, and a 1,4-dichlorobutane.



Cycloalkanes

Cycloalkanes are another branch of the aliphatic compounds. These hydrocarbons have a general formula of C_nH_{2n} because they form rings where each end of the hydrocarbon chain connects. Such as cyclohexane.



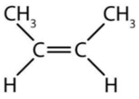


Alkenes

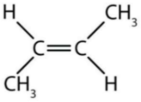
Alkenes have double bonds that decrease the number of hydrogen atoms (2 H atoms are lost for each pi bond). The double bond forces the carbon atom into a sp^2 hybrid form. The pi bond prevents the carbon chain from twisting. This can create geometric isomers which are either cis- or trans-.

Alkene nomenclature uses numbers to indicate the location of double bonds and whether the molecule is a *cis*- or *trans*-isomer.

Cis and *trans* 2-butene molecules would both have a C-C=C-C chain. But there are two ways of making this chain because the pi bonds of the carbon double bond prevent twisting locking the attached groups in place.



cis-2-butene

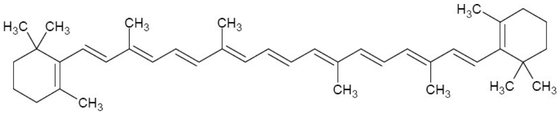


trans-2-butene

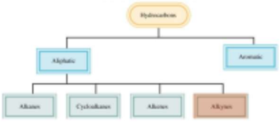
Go to your molecular model program and use this SMILE: C\C=C/C code for the *cis*- version. Then try the SMILE C\C=C\C for the *trans*- version.

The term saturated is associated with hydrocarbons without double bonds. Saturated carbon compounds are saturated with hydrogen atoms and have no C=C double bonds. Unsaturated means that hydrogen atoms are missing because of double bonds. An unsaturated compound must contain double bonds.

Saturated and unsaturated fats have long carbon chains (18 carbons is typical). Plant fats typically have double bonds (unsaturated) while animal fats do not have double bonds and are saturated with hydrogen. Another important feature of double bonding is when double bonds alternate, creating conjugated bonds, the alternating pi bonding of conjugated bonds can absorb energy in the visible region.



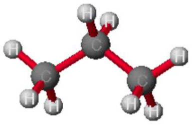
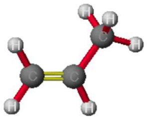
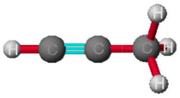
The above carotene molecule's alternating double bonds absorb blue to cyan wavelengths of light. As a result, white light that goes through a solution of carotene will have its blue-cyan wavelengths removed and the remaining wavelengths will blend to have the appearance of orange. Many dyes have conjugated bonds which absorb specific segments of visible light, and the remaining wavelengths will produce the dye's color. Breaking a double bond in a dye will disrupt the conjugated system and "bleach" the dye. UV light photons can have enough energy to break double bonds so UV can fade dyes.

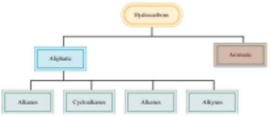


Alkynes

Alkynes are aliphatic compounds that have triple bonds. The triple bond produces a linear molecule. Alkynes will have *sp* hybrid bonding.

Compare the bond angles, hydrogen atoms and hybridization as this alkane is converted to an alkene and then an alkyne.

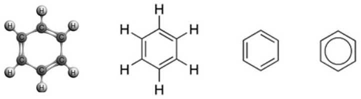
		
propane C_3H_8 *sp*^{3}	propene C_3H_6 *sp*^{2}	propyne C_3H_4 *sp*

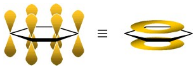


24.3 Aromatic Hydrocarbons

C_6H_6 should be called 1,3,5-cyclohexatriene. This is a planar molecule with double bonds that resonate around the ring. This molecule is known by the special name, benzene.

The benzene ring is the basis of the aromatics. Many simple aromatic compounds have distinctive aromas. You should know the basic structure and the skeletal structure drawings of benzene. The six hydrogen atoms are not shown in the skeletal drawing.





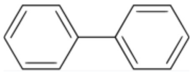
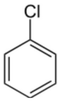
Here is an excellent example of resonance. A circle is often used to depict the three double bonds of benzene in a delocalized way.

Unhybridized *p* orbitals are involved in pi bonding. You can see how the six unhybridized *p* orbitals could delocalize to rings above and below the carbon chain.

The resonance of benzene creates an extra stability factor for that makes benzene more stable than would be expected for an alkene.

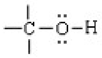
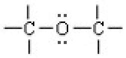
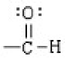
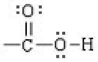
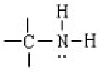
While benzene is an important organic compound it is classified as a carcinogen. Working with benzene requires special safety precautions. Benzene is used extensively in organic chemistry since it is a nonpolar liquid and is the starting substance for many important and useful compounds that are not carcinogenic.

When a benzene ring has one of its H atoms removed and is replaced by some other element or compound, it is called the phenyl group often abbreviated Ph.

	 Cl
Biphenyl	Phenyl chloride

24.4 Chemistry of Functional Groups

Organic functional groups modify the chemical characteristics of organic compounds. Functional groups can be applied to alkanes, alkenes, alkynes, and aromatic compounds to make a myriad of compounds. Questions on Lewis Electron Dot Diagrams and intermolecular forces are commonly found on the AP Chem exam.

Name and IMFs	*Functional Group*	*Example molecular formula*
Alcohol (LDF & H-Bonding)	 $-\overset{\mid}{\underset{\mid}{C}}-\ddot{\underset{..}{O}}-H$	$CH_3CH_2CH_2OH$ 1-propanol
Ether (LDF & Dipole-dipole)	 $-\overset{\mid}{\underset{\mid}{C}}-\ddot{\underset{..}{O}}-\overset{\mid}{\underset{\mid}{C}}-$	$CH_3OCH_2CH_3$ methyl ethyl ether
Aldehyde (LDF & Dipole-dipole)	 $-\overset{:O:}{\overset{\Vert}{C}}-H$	CH_3CHO ethaldehyde (acetaldehyde)
Ketone (LDF & Dipole-dipole)	 $-\overset{:O:}{\overset{\Vert}{C}}-$	CH_3COCH_3 propanone (acetone)
carboxylic acid (LDF & H-Bonding)	 $-\overset{:O:}{\overset{\Vert}{C}}-\ddot{\underset{..}{O}}-H$	CH_3COOH ethanoic acid (acetic acid)
Ester (LDF & Dipole-dipole)	 $-\overset{:O:}{\overset{\Vert}{C}}-\ddot{\underset{..}{O}}-$	$CH_3COOCH_2CH_3$ ethyl ethanoate (ethyl acetate)
Amine (LDF & H-Bonding)	 $-\overset{\mid}{\underset{\mid}{C}}-\underset{..}{\overset{\overset{H}{\mid}}{N}}-H$	$CH_3CH_2NH_2$ ethyl amine

If you need some extra help or want to be a better organic chemist, Chemguide UK is an excellent starting point.

Chemguide is designed to help students in England with their version of AP Chemistry, A Level Chemistry.

http://www.chemguide.co.uk/orgmenu.html#top

Science and Ink
http://www.lab-initio.com/b.html

You have already learned about intermolecular attractions and should be able to apply that knowledge to organic compounds. One topic we have not covered yet is solubility. As a general rule for organic compounds, solutes will dissolve if their intermolecular attractions are similar to the solvent in which they are dissolving.

There are always questions on the AP Chemistry exam on intermolecular forces between organic compound molecules.

(1) London forces (or dispersion forces)

Pure hydrocarbon compounds do not have significant dipoles. **Organic aliphatic compounds (alkanes, alkenes, alkynes) are all nonpolar** because the C-H electronegativities are similar and their symmetry is such that the covalent bonds are equally shared. As with all molecules, London forces increase with the electron surface area of the molecule thus making the molecule more polarizable. This is especially relevant for organic compounds since organic molecules can be very large.

(2a) Dipole-Dipole Forces

Dipoles only occur when another element (functional group) with a different electronegativity than carbon is in the compound.

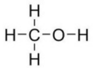
Halogenated alkanes, ketones, aldehydes, ethers, and esters are polar molecules because they have an electronegative oxygen attached to a carbon atom in an unsymmetrical molecule. They will have dipole-dipole intermolecular attractions. The oxygen in these molecules will have a partial negative charge, -δ, with the positive charge, +δ, distributed over the rest of the molecule.

(2b) Hydrogen bonding

Hydrogen bonding occurs when an organic compound has an –O-H or –N-H functional group**,** (e.g. alcohols, carboxylic acids, amines and amides). Organic molecules with hydrogen bonding will usually have higher boiling temperatures than similar molecules with ordinary dipoles.

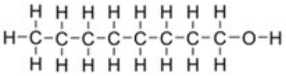
Of special note: Water's major intermolecular attraction is due to hydrogen bonding. As a result, organic molecules that exhibit hydrogen bonding as their primary intermolecular attractions will dissolve in water.

If a substance's primary intermolecular attractions are London, the substance is less likely to dissolve in water.



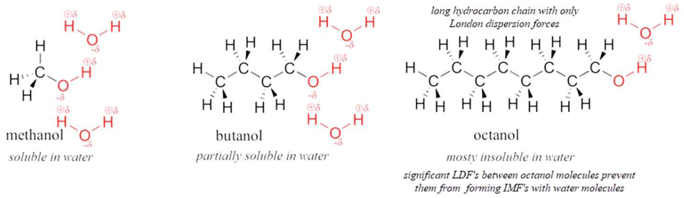
$\mathrm{H{-}\overset{H}{\underset{H}{C}}{-}O{-}H}$

Methanol has primarily hydrogen bonding intermolecular attractions and will dissolve in water in all proportions 100% solubility (miscible[5]).



$\mathrm{H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}O{-}H}$

Even though 1-octanol has an -OH , because of its long hydrogen chain its London dispersion forces will be the primary intermolecular attraction and only 0.3 grams will dissolve in 1 L of water.



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[5] Miscibility normally applies to a liquid's ability to dissolve in another liquid in all proportions. If two liquids are miscible they must have identical intermolecular attractions.

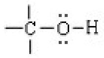
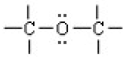
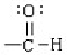
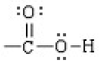
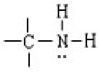
Organic molecules that are primarily nonpolar (London forces) will not significantly dissolve in water. The term hydrophobic is used with these molecules that cannot dissolve into water.

CAVEAT:

> The term hydrophobic is misleading in that the word hydrophobic implies that these molecules repel water. **Hydrophobic properties are not repulsions**. Instead "hydrophobic" molecules stick to one another rather than water molecules.

Organic molecules with significant polar bonds, hydrogen dipoles ($^{\oplus}\delta$H-N-C, $^{\oplus}\delta$H-O-C), attract polar water molecules and are called hydrophilic. However, if the molecule has a large aliphatic, nonpolar chain, the nonpolar section of the molecule will be hydrophobic. The solubility of a molecule will be decreased by the section of the molecule that is hydrophobic.

Some molecules with polar and nonpolar segments such as soaps can do double duty. The soap molecules can attract nonpolar molecules such as nonpolar portions of oils using the soap molecule's nonpolar segment. At the same time, the opposite polar segment of the soap molecule will dissolve in water.

Name	*Functional Group*	***Intermolecular attractions***
aliphatics	no functional group only C and H	**London dispersion forces**, hydrophobic (nonpolar) The electronegativity differences between C and H are so small that no permanent dipoles are found on these molecules.
alcohol		**hydrogen bonding** London forces become important as molecular size increases.
ether		**dipole-dipole** polar, hydrophilic with limits London forces become important as molecular size increases.
aldehyde		**dipole-dipole** Very polar molecules that will dissolve in water. London forces become important as molecular size increases
ketone		**dipole-dipole** London forces become important as molecular size increases.
carboxylic acid		**hydrogen bonding** dipole-dipole London forces become important as molecular size increases.
ester		**dipole-dipole** London forces become important as molecular size increases.
amine		**hydrogen bonding** London forces become important as molecular size increases.

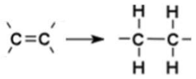
Chapter 25 Synthetic and Natural Organic Polymers Sections 1,2,3

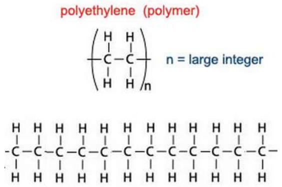
The sections in this chapter go into more detail than is required by the AP Chem exam. Rather than studying these sections in detail, use the summary as your primary source and then the text to help for further clarification.

Polymers[6] are extremely long carbon chains (typically thousands of carbons long). All polymers will be solids at room temperature because of their large polarizable electron surface area creating very large London forces. Polymers will be solids at room temperature.

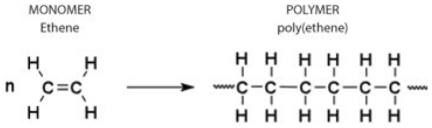
Synthetic polymers (plastics) are made by taking one or two simple molecules (mers) and reacting them to form long chains that repeat these monomers many times, hence the term poly-mers. The molecule is drawn with the mer in brackets or parentheses.

The most common mer used in polymers is ethene. The pi bond in ethene has the two *p* orbitals in the pi bond change back into sigma bonds by hybridizing into sp^3 sigma bonds and attaching their newly available orbitals to other ethene pi bonds thus forming long chains.





The names of polymers come from the monomer that is used to create the polymer.

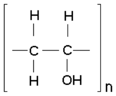


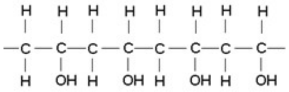
The older, archaic name for ethene is vinyl and it is used often in the naming of polymers based on ethene (e.g. PVC polyvinyl chloride.)

Nonpolar polyethylene only has London forces as its intermolecular attraction. If the molecular strands are parallel and closely packed, it will be high density polyethylene, HDPE. The London forces will be stronger because the molecular strands are aligned and close together allowing for greater Coulombic attractions. If the polyethylene has a low density and randomly arranged molecular strands, the low-density polyethylene LDPE will be flexible and not as strong. LDPE is used as plastic wrap and plastic bags. Instead of paper or plastic at the checkout in a store, it should be paper[7] of polyethylene.

Polyethylene is hydrophobic in that polar water will not be attracted to the polyethylene's London forces. Water beads (sticks to itself) on polyethylene. One of the most hydrophobic polymers is Teflon® which has fluorine atoms instead of hydrogen atoms.

Functional groups can be part of a mer in the polymer. A polymer can have functional groups with dipoles and have hydrogen bonding as its intermolecular attraction.





In polyvinyl alcohol[8], the repeating unit is an alcohol. Polyvinyl alcohol's name is based on its monomer's name, vinyl alcohol. PVA is hydrophilic in that the –OH group is polar enough to have water molecules attracted to it. This polymer will dissolve in water.

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[6] https://en.wikipedia.org/wiki/Polymer

[7] Paper is made of a natural polymer using starch as its mer.

[8] Vinyl was the original name for the functional group based on ethene.

Natural Polymers- Large Biomolecules

In contrast to synthetic polymers with repeating simple mers, natural polymers have multiple functional groups resulting in a polymer chain with complex combinations.

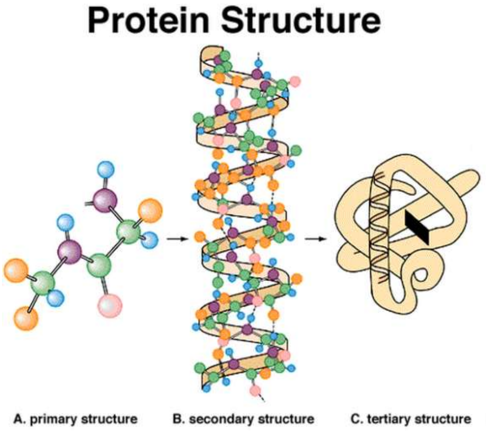
Proteins are chains of amino acids[9].

The **primary structure** of a protein consists of **covalently bonded units**, the amino acid polymer chain and are governed by intramolecular attractions.

The **secondary structure** is the twisting within the polymer chain that **is caused by intermolecular attractions** along the chain. **Polar, hydrogen bonding between the amino acids in the chain will cause a spiral to form, the alpha-helix.**

The tertiary structure forms when the secondary structure folds in response to **intermolecular forces** with the surroundings. These are responsible for enzymes and protein structures.

You do not have to know the protein structure primary, secondary, tertiary terminology, but you should understand that the secondary and tertiary structures are produced by intermolecular attractions.



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[9] An amino acid is an organic compound with an amine, $-NH_2$, and acid, $-COOH$, functional groups.