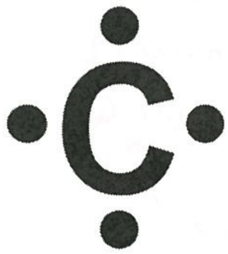
TOPIC 11.1

Introduction to Hydrocarbons

What's so special about carbon?

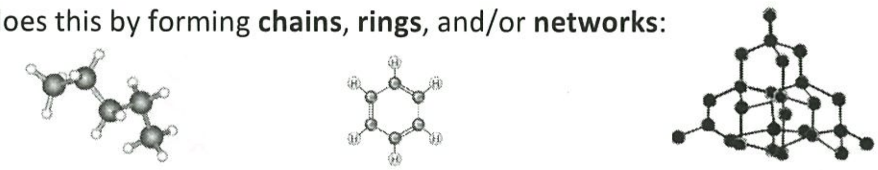
This unit is obsessed with **carbon**. And for good reason:



Carbon has __4__ valance electrons.

In order to be stable, carbon must form __4__ __covalent__ bonds.

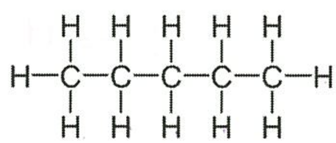
Carbon does this by forming **chains**, **rings**, and/or **networks**:



As a result of the versatility of the carbon atom, organic molecules are a wildly diverse group of compounds. We're going to start the unit by looking at one specific class of organic molecules:

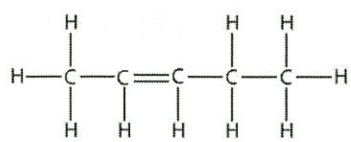
Hydrocarbons: Compounds containing hydrogen and carbon only

Saturated: max amount of H atoms ; single bonds only



C_5H_{12}

Unsaturated: not max amount of H atoms ; could contain double or triple C-C bonds



C_5H_{10}

SUMMARIZE: Use Reference Table __Q__ to fill in the missing information

Homologous Series	General Formula	Highest "Bond Order" (type of bond)	Saturated or Unsaturated?
Alkanes	C_nH_{2n+2}	single	Sat.
Alkenes	C_nH_{2n}	double	unsat.
Alkynes	C_nH_{2n-2}	triple	unsat.

Is C_2H_4 sat or unsat ?

How many H atoms in a 2-carbon alkene?

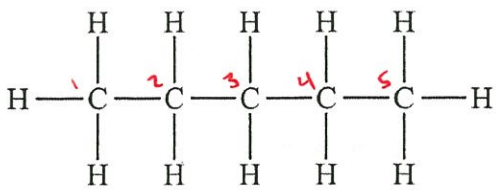
TOPIC 11.2

Naming and Drawing Hydrocarbons

How can we systematically name and represent simple hydrocarbons?

Just like we can follow general patterns for naming ionic compounds (like magnesium chloride or iron (III) oxide), organic compounds have their own set of naming rules.

Alkanes—the saturated hydrocarbons—are the most straightforward:

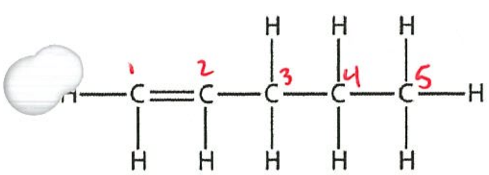


This hydrocarbon's name is:

pentane (5-carbons; single bonds)

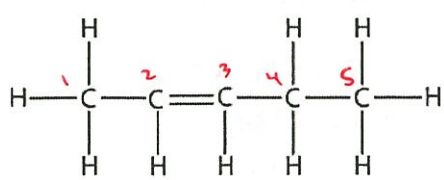
1. Number the longest continuous chain of carbon atoms. ✓
2. Use Reference Table __P__ to find the appropriate prefix
3. Add the suffix –ane to show that all carbon atoms are connected with single bonds (alkane)

Unsaturated hydrocarbons ain't too bad, either. The key caveat is that the location of the unique double or triple bond *MUST* be specified with a number before the name. Here are some examples to show you what I mean:



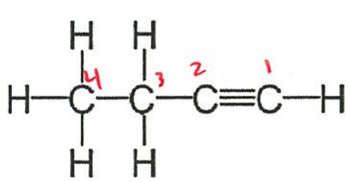
This hydrocarbon's name is:

1-pentene



This hydrocarbon's name is:

2-pentene



This hydrocarbon's name is:

1-butyne (NOT 3-butyne)

1. Number the longest continuous chain of carbon atoms.
2. Use Reference Table __P__ to find the appropriate prefix
3. Add the suffix –ene (**alkene**) or –yne (**alkyne**) to show that there is a double or triple bond contained within the molecule.
4. Add a number out in front of the molecule name to show the location of the double or triple bond within the carbon chain. Use the SMALLEST possible number—try numbering from both the right and the left! ☆

TOPIC 11.3

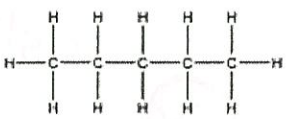
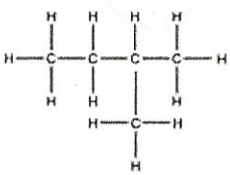
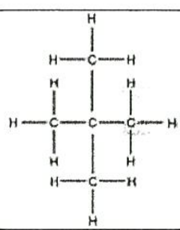
Isomers

How can we rearrange atoms to get new compounds with new properties?

We said at the beginning of this unit that carbon could arrange itself into chains, rings, and networks. So hydrocarbons certainly aren't limited to being straight-line chains. What happens if they branch out or get a bit wild and crazy? Not a problem.

Isomer: Same molecular formula, different structural formula

As you can imagine, with different structures come different functions. Long, gangly hydrocarbons tend to get all tangled up on one another (making them hard to separate – like through melting or boiling), while their branched isomers don't get all up on one another in the same way. Check out the table below and see if you can make a claim about the effect of branching on isomers' boiling points:

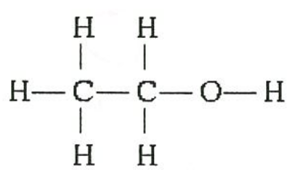
Structural Formula	Molecular Formula	Boiling Point
	C_5H_{12}	36°C
	C_5H_{12}	28°C
	C_5H_{12}	9.5°C

As the amount of branching of a hydrocarbon increases…

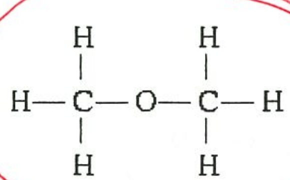
the boiling point decreases

because the intermolecular forces get weaker

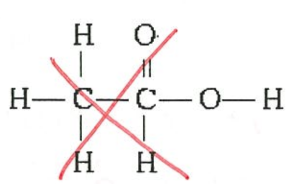
Hydrocarbons aren't the only things that have isomers. Look at the modified organic compound below. Can you identify its isomer from the three option below it? Try writing out the chemical formulas and looking for *structural* differences (remember these molecules are 3-dimensional and can be rotated around!)



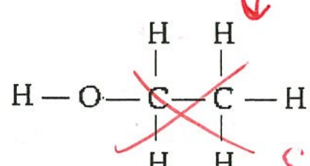
C_2H_6O



C_2H_6O

b) 

$C_2H_5O_2$

c) 

same structure

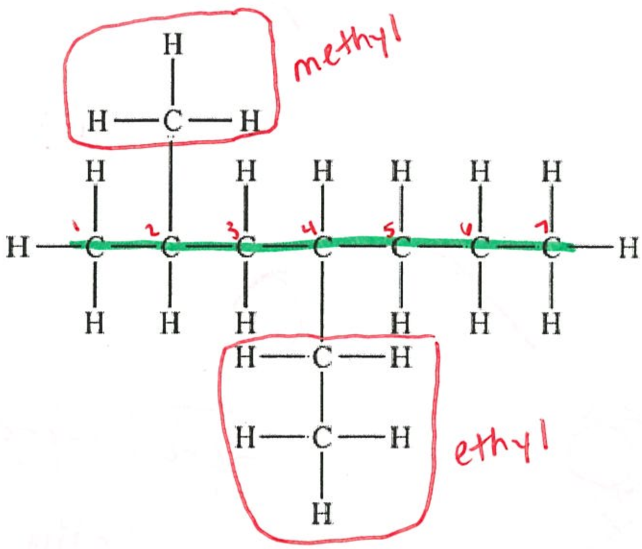
C_2H_6O

TOPIC 11.4

Naming Hydrocarbon Isomers

How can we apply naming rules to more complex hydrocarbons?

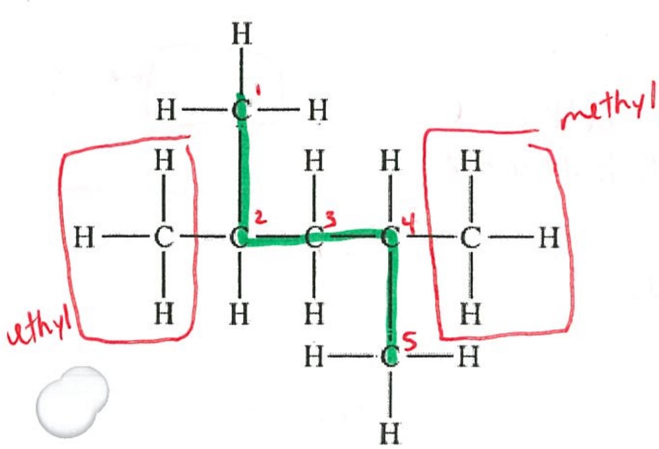
looked at different ways of arranging the atoms of a hydrocarbon last lesson. As you can imagine, messing with the nice, all-the-carbons-in-a-row arrangement creates some complications for naming. The naming rules for branched hydrocarbons tend to be a cause for frustration for many students. If so, CALM DOWN. STOP. Take this one step at a time and, eventually, this will be something that you can master *with practice*. At the end of the day, this is a semi-obscure thing that organic chemists really love and that no one else particularly cares about. So learn it for June, then it's up to you what you do with it.



This hydrocarbon's name is:

2-methyl-4-ethyl-heptane

1. Put a line through the longest continuous carbon chain. Name it following normal alkane naming rules.
2. Put boxes around the "branches" sticking off the longest chain. Use prefixes from Reference Table to describe how long those branches are.
3. Add the suffix "-yl" to the branches.
4. Use lowest, consistent numbers (from the longest carbon chain) to describe the locations of each of the branches.
5. String these numbers and branch names together and stick them ahead of the name of the longest chain.*
*If there happens to be more than one "branch" of the same length, chemists try to save space by naming them together. For instance, instead of having 2-ethyl-3-ethyl octane, we "smush" it together to become 2,3-diethyl octane ("di" tells us that there are two ethyl branches present in the molecule).



This hydrocarbon's name is:

2,4-dimethyl-pentane

(or 2-methyl-4-methyl-pentane)

TOPIC 11.5

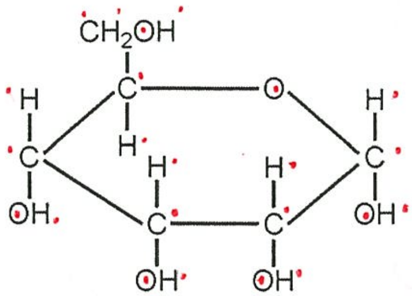
Empirical Formulas

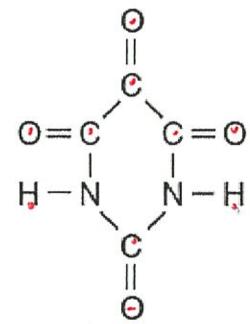
How can we determine molecular formulas when given empirical formulas and molecular mass?

call the definition of an empirical formula:

Empirical Formula: shows the smallest whole # mole ratio of elements in a compound

Write the molecular and empirical formula for the structures shown.





Molecular: $C_6H_{12}O_6$ $C_4H_2O_4N_2$

Empirical: CH_2O C_2HO_2N

hy do we care about empirical formulas? Chemists can use analytical equipment, such as a mass spectrometer, to determine two important things about an unknown hydrocarbon: its **molecular mass** and the ratio of carbon to hydrogen (aka its **empirical formula**). From these two important things, we can determine the **molecule formula.**

How to determine molecular formula when given empirical formula and molecular mass:

Example: Chemists determine the molecular mass of an unknown hydrocarbon to be 86 g/mol and the empirical formula is C_3H_7. Find the molecular formula of the hydrocarbon being analyzed.

1st: Calculate the **mass** of the **empirical formula**.

C: 3(12) = 36
H: 7(1) = 7 +
43 g/mol

2nd: Determine the # that relates the empirical and molecular formulas by **dividing** the experimentally determined molecular mass by the mass of the empirical formula.

$$\frac{86}{43} = 2$$

3rd: Multiply the subscripts of the empirical formula by the # determine in step 2.

$C_{3 \times 2}H_{7 \times 2}$ = C_6H_{14}

TOPIC 11.6

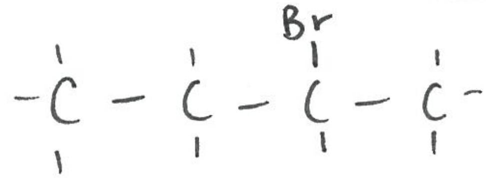
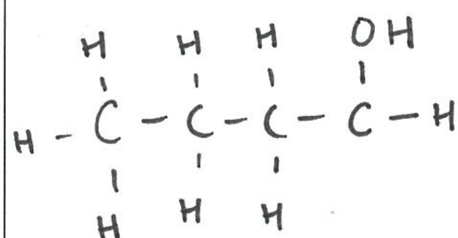
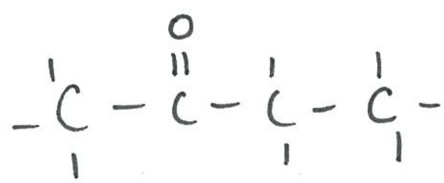
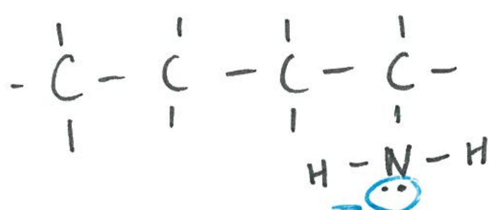
Functional Groups: Part 1 (Edge)

How can we name organic molecules with modified structures and functions?

Functional group: a group of atoms responsible for the specific physical & chemical properties of a compound

We'll look at a whole bunch of functional groups, all listed on Reference Table __R__. I have broken them up into three different "types": 1 - functional groups that can go anywhere around the molecule's edges, 2 - functional groups that are always found on the end carbon, and 3 - functional groups that can "interrupt" the middle of a molecule.

Addressing the "**classes**" of organic molecules with "anywhere around the edges" functional groups is much like naming unsaturated hydrocarbons. Let's take a look at examples from 4 classes of molecules:

Class of Compound	Example Structure	Corresponding Name
Halocarbon / Halide		(2)- bromobutane location of halogen; Br; 4C chain
Alcohol **NOT A BASE.**		(1)- butanol location of OH; 4C; ending
Ketone		(2)- butanone location of $-\overset{O}{\overset{\|\|}{C}}-$; 4C; ending
Amine ★ base!		(1)- butanamine location of NH_2; 4C; ending

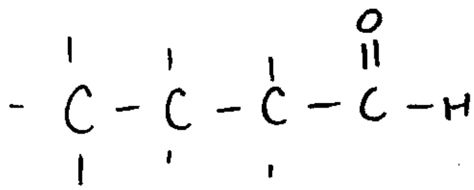
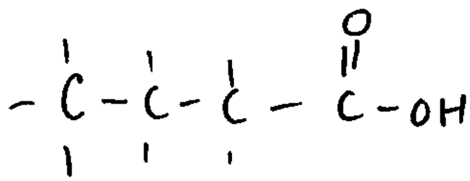
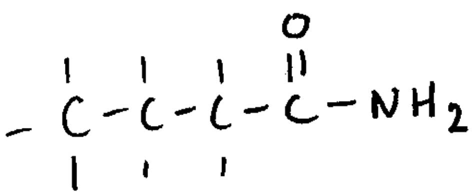
proton acceptor

TOPIC 11.7

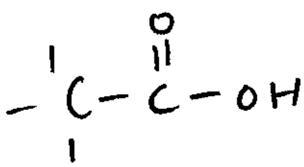
Functional Groups: Part 2 (End)

How can we name organic molecules with modified structures and functions?

More functional groups, more fun. These ones are always found on the last carbon of an organic molecule and, therefore, do not require any special numbers.

Class of Compound	Example Structure	Corresponding (Dissected) Name
Aldehyde		butanal (but → 4C; al → ending)
Organic Acid		butanoic acid (but → 4C; oic acid → ending)
Amide		butanamide (but → 4C; amide → ending)

Vinegar is an example of an organic acid; its IUPAC name is ethanoic acid. Draw its structure below. (eth → 2C)



Though both alcohols and organic acids have "OH" visible in their formulas, neither are basic. Explain why, in terms of ions produced.

Organic acids produce H^+ ions

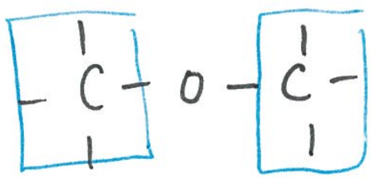
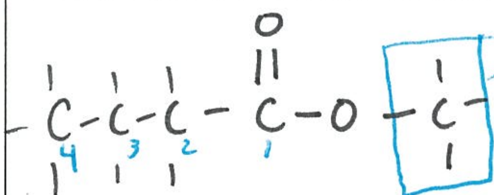
Alcohols do not produce ions.

TOPIC 11.8

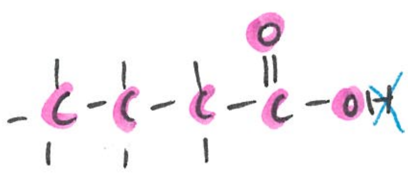
Functional Groups: Part 3 (Interrupting)

How can we name organic molecules with modified structures and functions?

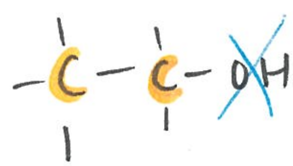
The last group of functional groups create compounds with the strangest names, as they "interrupt" molecules mid-carbon-chain.

Class of Compound	Example Structure	Corresponding (Dissected) Name
Ether		methyl methyl ether OR dimethyl ether ↓ groups surrounding O — ending
Ester		methyl butanoate ↓ group after ester — ↓ 4C chain ("parent chain") — ending

Esters are creating using a chemical reaction that mashes together an organic acid and an alcohol. To create an ester that smells like pineapples, you have to smush together butanoic acid and ethanol. Draw the two reactants below.



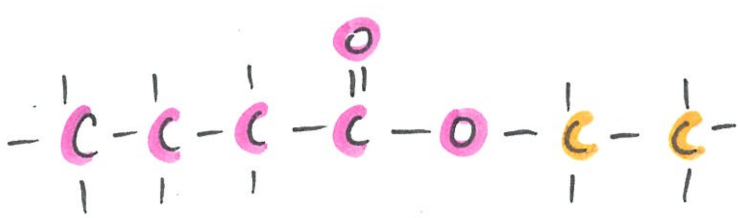
+



Butanoic acid + *Ethanol*

↓ 4C ↓ 2C

Combine the two reactants to make the ester (and water as a byproduct). Draw and write the name of the resultant ester.



+ H_2O

ethyl butanoate

TOPIC 11.9

Organic IMFs and Properties

How do organic molecules interact and why?

Hydrocarbons tend to be ___nonpolar___ molecules. Let's revisit where that has them fall in terms of strength of intermolecular forces:

NONPOLAR — POLAR COVALENT — H-bonding molecules ↑ — IONIC

low BP — higher BP — highest BP

Increasing ___polarity___ →

Increasing strength of intermolecular forces (IMFs) of attraction →

−OH   −C(=O)−OH

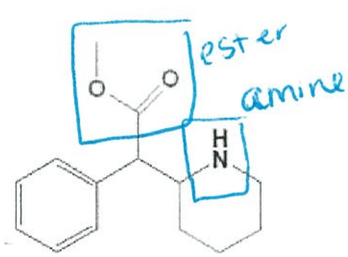
Alcohols and organic acids tend to have substantially higher boiling points than hydrocarbons of comparable size. Identify the intermolecular force responsible for this difference.

Hydrogen bonding! −C−OH(+) ⋯ HO(−)−C−

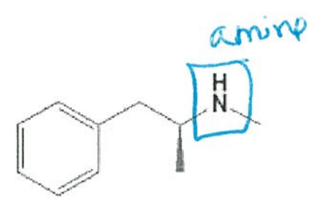
Analyze the two organic structures to the right.

1. *Circle and identify any functional groups you see present.*
2. *Why might they have similar chemical properties? What might account for their differences?*

↳ Both have amine groups (could act as bases) methylphenidate has an ester group, so it will behave differently.



Methylphenidate



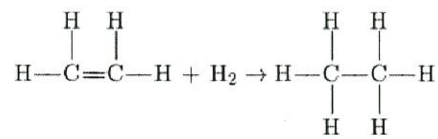
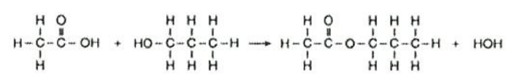
Methamphetamine

TOPIC 11.10

Organic Reactions

How can we use chemical change to modify organic compounds?

ke with the inorganic reactions of synthesis, decomposition, single replacement, and double replacement, these are reaction types that you must simply memorize. Nothing fancy—just know it. Make no excuses.

Reaction Type	Description	Example
Substitution	Replace (substitute) ONE hydrogen with a halogen (*e.g.* Br, Cl) on an alkane	$CH_3CH_3 + Cl_2 \rightarrow CH_3CH_2Cl + HCl$
Addition	Changes an alkene to an alkane by "adding" BOTH atoms of a diatomic molecule like Cl_2, H_2, or Br_2	
Polymerization	Creating large molecules (polymers) by joining together one type of small compound (monomer) in long chains	$nC_2H_4 \rightarrow (-C_2H_4-)_n$
Esterification	Creation of an ester from an organic acid and an alcohol	
Fermentation	Transformation of a sugar into an alcohol and carbon dioxide, usually done by yeast or enzyme	$C_6H_{12}O_6 \xrightarrow{zymase} 2C_2H_5OH + 2CO_2$ ethanol carbon dioxide
Saponification	Using a strong base to break down a fat (ester) into soap and glycerol molecules	$C_3H_5(C_{17}H_{35}COO)_3 + 3NaOH \rightarrow 3\,C_{17}H_{35}COONa + C_3H_5(OH)_3$ Fat + Strong Base → Soap + Glycerin
Combustion	Hydrocarbon reacting with oxygen burns to give off carbon dioxide and water	$2\,C_4H_{10} + 13O_2 \rightarrow 8\,CO_2 + 10H_2O$ carbon dioxide water