Learning Guide for Chapter 2 - Introduction to Organic molecules

I. Ways to represent organic molecules

The molecule which causes the odor of ripe bananas is shown in several different ways below. Identify each and explain it characteristics.

molecular formula

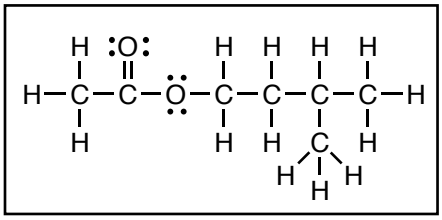
$C_7H_{14}O_2$

# of atoms of each element

1st C, then H, all others in alphabetical order

not specific enough - could be more than one compound

Lewis structure

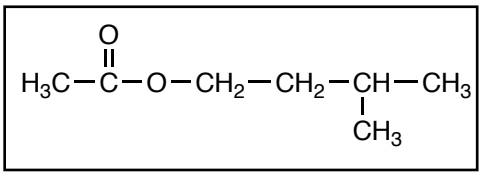


shows all atoms, bonds, e- pairs

identifies a specific molecule

takes too long to draw, uses incorrect angles

condensed structure



H's written next to C's

extra condensed version - uses ( ) to put it all on one line

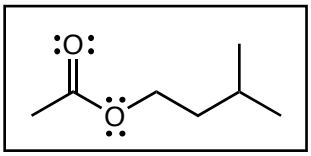
often used in print

$CH_3CO_2(CH_2)_2CH(CH_3)_2$

still takes too long to draw, uses incorrect angles

often doesn't show e- pairs

line structure



shows bonds between C atoms, O's N's, e- pairs

correct angles, easiest to draw, but requires a special program to create on computer

(draw in C's to show what it means)

name

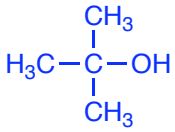
isopentyl acetate

gives structure if you know how to interpret it

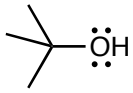
easy to print

Here is the line structure for tert-butyl alcohol. What is its molecular formula, condensed structure, and line structure?

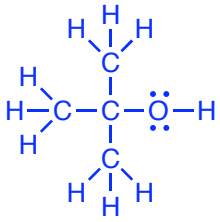
name: tert-butyl alcohol

condensed structure: 

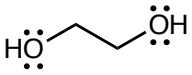
or $(CH_3)_3COH$

line structure: 

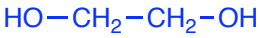
molecular formula: $C_4H_{10}O$

Lewis structure: 

Give a molecular formula and condensed structure for the following line structures.

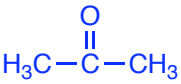


$C_2H_6O_2$

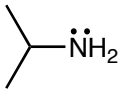


$HOCH_2CH_2OH$

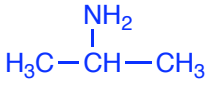
C_3H_6O



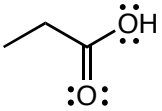
CH_3COCH_3



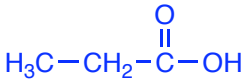
C_3H_9N



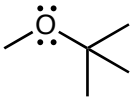
$CH_3CH(NH_2)CH_3$



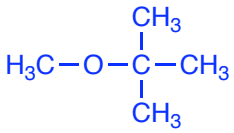
$C_3H_6O_2$



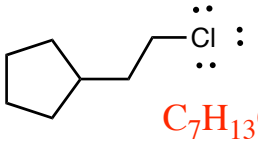
$CH_3CH_2CO_2H$



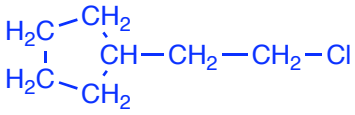
$C_5H_{12}O$



$CH_3OC(CH_3)_3$

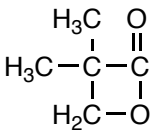


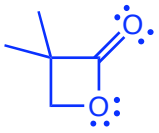
$C_7H_{13}Cl$

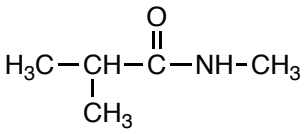


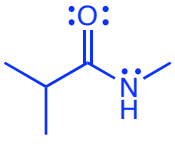
$C_5H_9CH_2CH_2Cl$

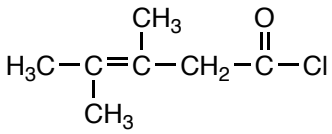
Give a line structure for the following condensed structures.

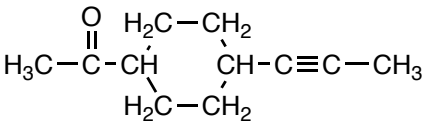


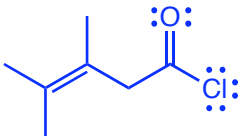


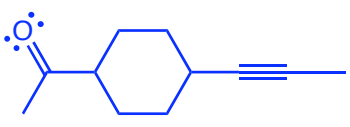












II. Classification of Organic Molecules

Why is it important to put organic compounds into categories?

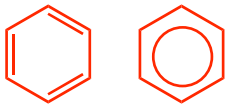
there are so many compounds, we group them together by how they behave

How do chemists decide what categories to create?

how they react

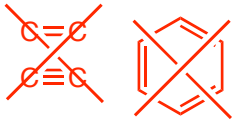
General terms:

compounds with only C, H: hydrocarbon

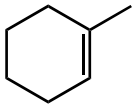
compounds containing a benzene ring: aromatic 

compounds which don't have a benzene ring: aliphatic 

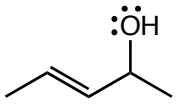
compounds containing carbon-carbon double or triple bonds (not in a benzene ring): unsaturated C=C C≡C (not in benzene rings)

compounds which don't have a carbon-carbon double or triple bond (or a benzene ring): saturated 

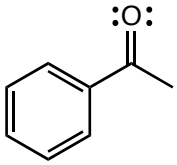
Label the following compounds with all terms that apply to them.



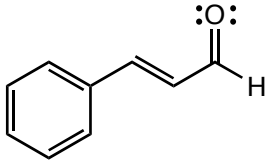
hydrocarbon
unsaturated
aliphatic



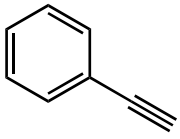
unsaturated
aliphatic



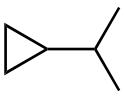
aromatic



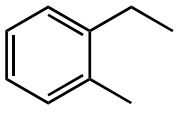
aromatic
unsaturated



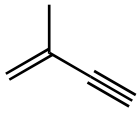
hydrocarbon
aromatic
unsaturated



hydrocarbon
saturated
aliphatic



hydrocarbon
aromatic

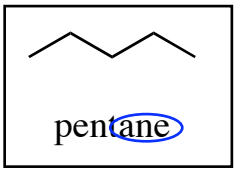
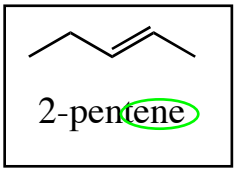
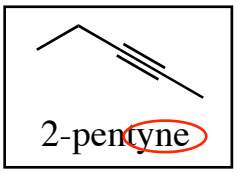


hydrocarbon
unsaturated
aliphatic

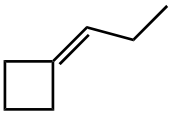
What is a functional group? the part of the compound that reacts

pattern of atoms that react a certain way

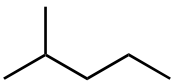
Hydrocarbon functional groups

	functional group	description	name
 pentane	alkane	only C-C single bonds	end in: -ane
 2-pentene	alkene	C=C (not in benzene ring)	end in: -ene
 2-pentyne	alkyne	C≡C (I may use C---C to indicate a triple bond in notes)	end in: -yne

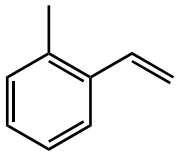
Label the alkanes, alkenes, and alkynes below.



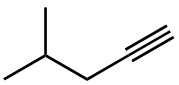
alkene



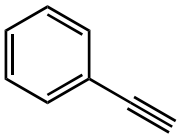
alkane



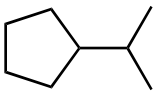
aromatic alkene



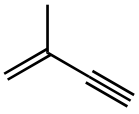
alkyne



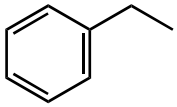
aromatic alkyne



alkane

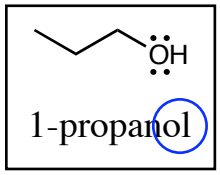
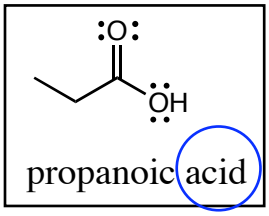
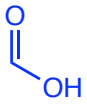
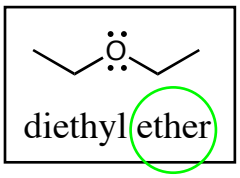
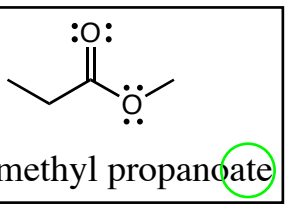
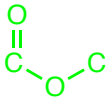
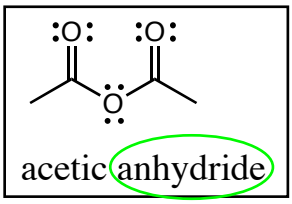
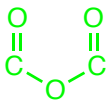
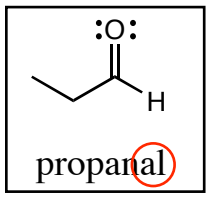
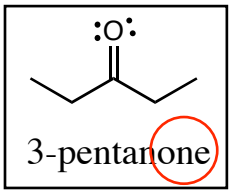
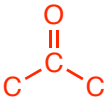


alkene & alkyne



aromatic hydrocarbon

Functional groups containing only oxygen:

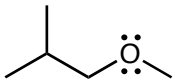
	functional group	description	name
 1-propanol	alcohol	C-OH	end in: -ol contain: -hydroxy-
 propanoic acid	carboxylic acid		end in: -acid
 diethyl ether	ether	C-O-C	end in: -ether contain: -methoxy- etc
 methyl propanoate	ester		end in: -ate
 acetic anhydride	anhydride		end in: -anhydride
 propanal	aldehyde	 H must be written!	end in: -aldehyde end in: -al contain: -oxo-
 3-pentanone	ketone		end in: -one end in: -ketone contain: -oxo

OH

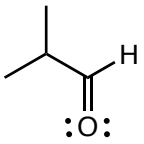
COC

only C=O

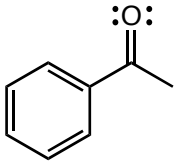
Label the following compounds with the functional group they contain.



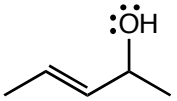
ether



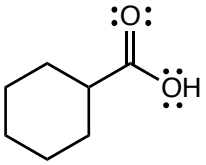
aldehyde



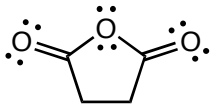
aromatic ketone



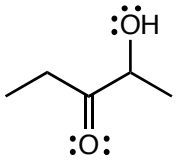
unsaturated alcohol



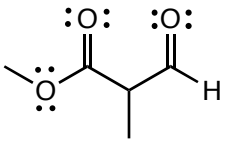
carboxylic acid



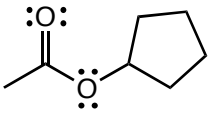
anhydride



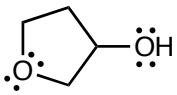
ketone alcohol



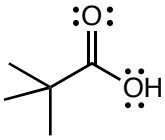
aldehyde ester



ester

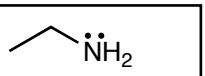
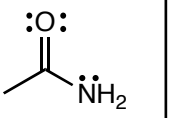
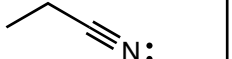
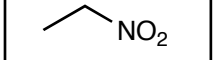


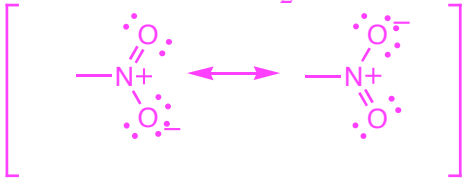
alcohol ether



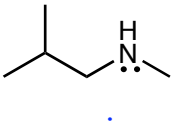
carboxylic acid

<u>Functional groups containing nitrogen:</u>

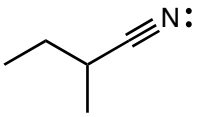
	functional group	description	name
 ethyl amine	amine	C-N	end in: -amine contain: -amino-
 acetamide	amide	C=O w/N on one side	end i: -amide
 propanenitrile	nitrile	C≡N	end in: -nitrile contain: -cyano-
 nitroethane	nitro	C-NO_2	contain: -nitro-



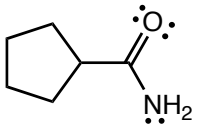
Label the compounds below.



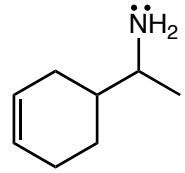
amine



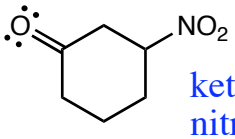
nitrile



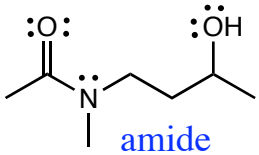
amide



unsaturated amine

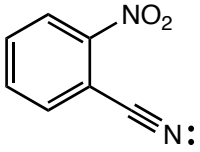


ketone
nitro



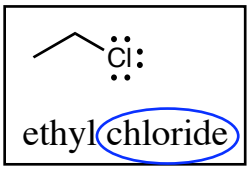
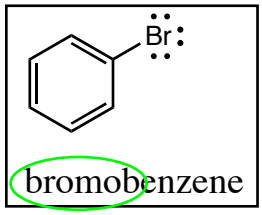
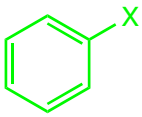
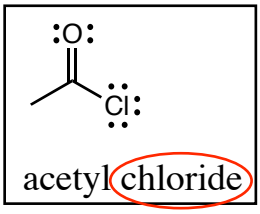
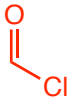
amide
alcohol

notice-not also an amine



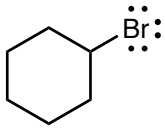
aromatic
nitrile
nitro

Functional groups containing halogens:

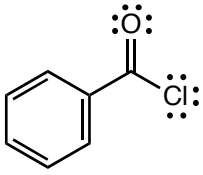
	functional group	description	name
 ethyl chloride	alkyl halide	C-X (X = halogen)	end in: fluoride, chloride bromide, or iodide contain: -fluoro-, -chloro-, -bromo-, or -iodo-
 bromobenzene	aryl halide	 directly attached!	" "
 acetyl chloride	acid chloride		end in: -chloride

(other acid halides exist, but are too reactive to be useful)

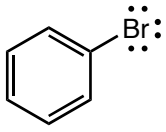
Label the compounds below.



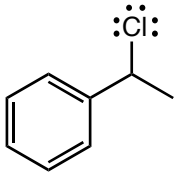
alkyl halide



aromatic
acid chloride

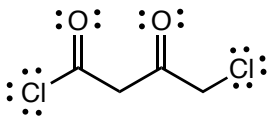


aryl halide



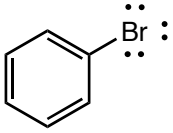
aromatic
alkyl halide

"

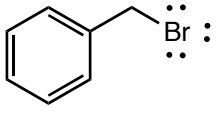


acid chloride
ketone
alkyl halide

How are these two compounds different?

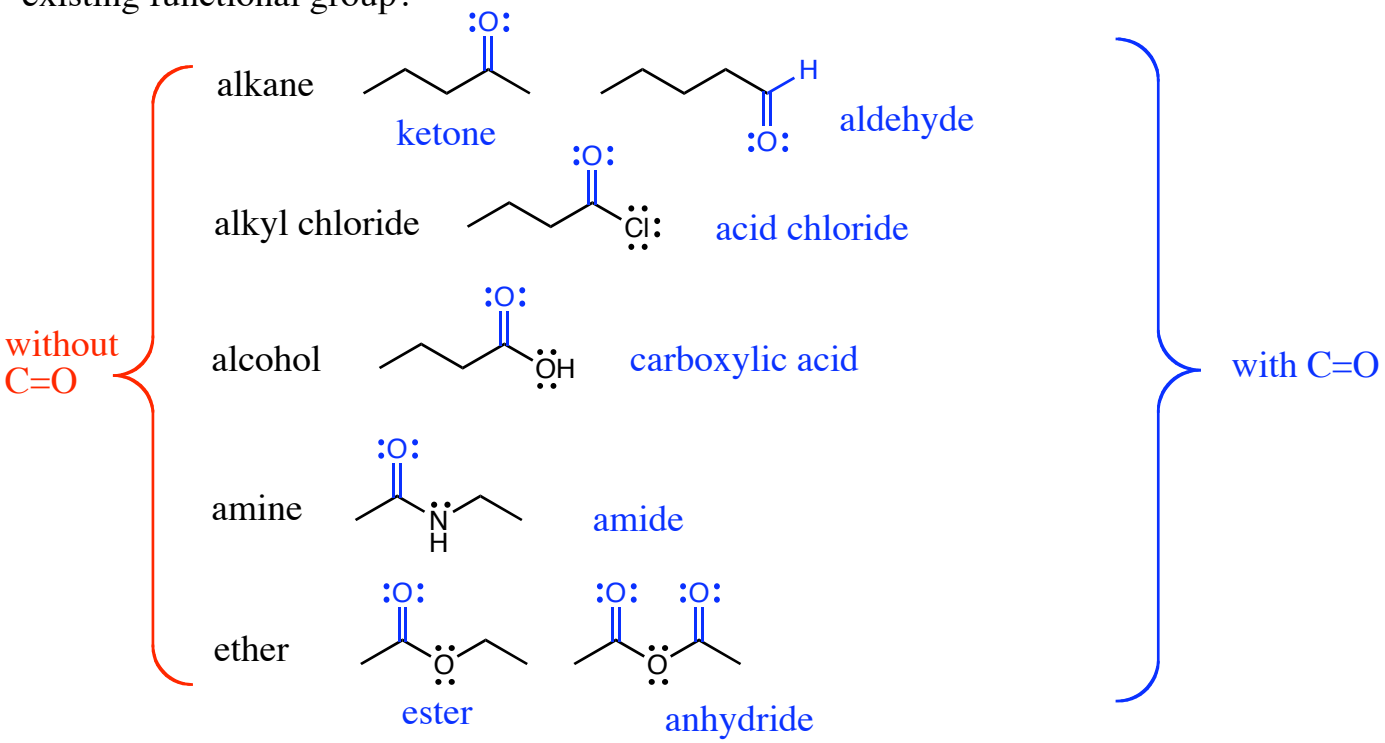


aryl halide
bromobenzene

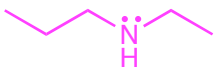


alkyl halide
benzyl bromide

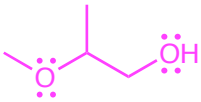
What would each of the following compounds become if a C=O was added next to the existing functional group?



What can you tell about the following compounds from their names?

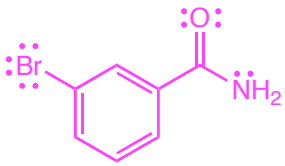


N-ethylpropanamine — amine



3-methoxy-1-propanol

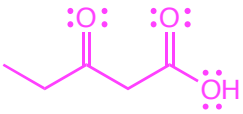
ether — alcohol



3-bromobenzamide — amide

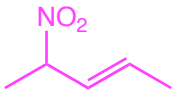
Br — aromatic

could be alkyl or aryl halide
can't tell until you know the structure



3-oxo-pentanoic acid — carboxylic acid

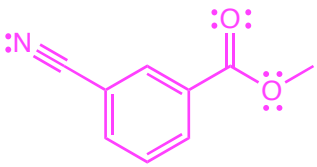
aldehyde or ketone



4-nitro-2-pentene — unsaturated (not an alkene - contains an N)

nitro group

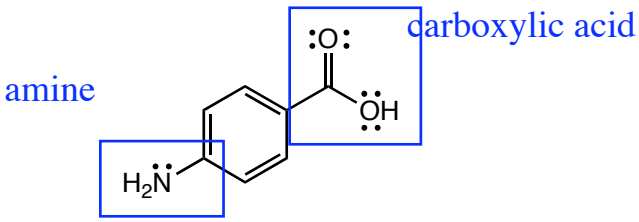
note - likewise an compound may end in ane or yne
but not be an alkane or alkyne if there is an N, O, or X



methyl 3-cyanobenzoate — ester

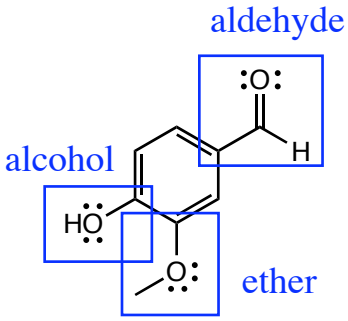
nitrile — aromatic

Identify the functional groups present in the following compounds. Which are aromatic? Which are unsaturated?



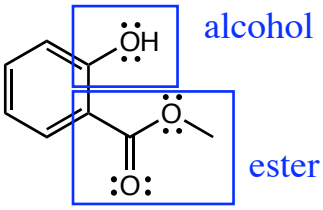
p-aminobenzoic acid - PABA
(used in sunblocks)

aromatic



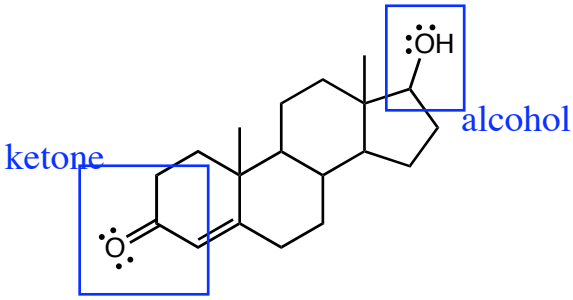
vanillin

aromatic



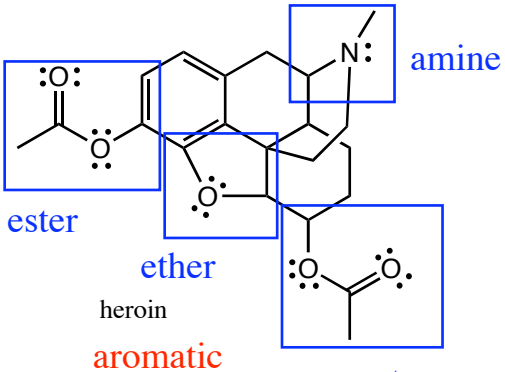
methyl salicylate
(oil of wintergreen)

aromatic



testosterone

unsaturated



heroin

aromatic

III. Physical Properties of Organic Molecules

List some physical properties of organic compounds.

color, odor, state of matter, melting point, boiling point, density, water solubility, etc

What determines the physical properties of a compound?

the structure of its molecules

What can we predict by looking at the structure of molecules?

water solubility, density compared to water

relative bp/mp of 2 compounds

Intermolecular forces

What is an intermolecular force? force that attracts molecules to each other

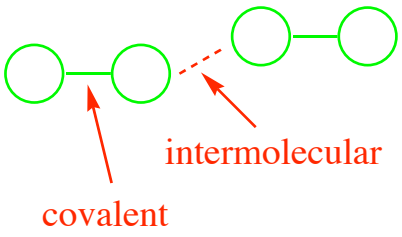
What are the three intermolecular forces? How do they compare in strength?

van der Waals < dipole < H-bonding

weakest strongest

How are these different from covalent and ionic bonds?

covalent - between atoms the same molecule
ionic - between two ions in the same compound
intermolecular - between two molecules



Which is stronger, a covalent bond or a hydrogen bond?

even the strongest IMF is weaker than a chemical bond

What causes Van der Waals forces?

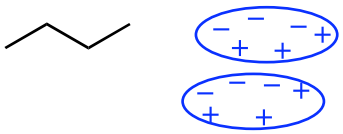
temporary dipoles - caused by collisions between molecules

What kinds of molecules experience Van der Waals forces? all molecules

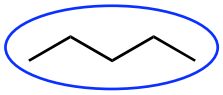
In what kinds of molecules will van der Waals forces be significant?

molecules that don't have any polar bonds

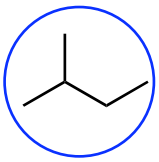
Example: butane



What factors affect the strength of Van der Waals forces? surface area



more surface area



less surface area

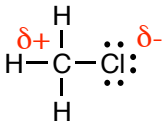
more surface area = more Van der Waals attraction

What are dipole forces?

attraction of partially positive and partially negative ends of two different molecules

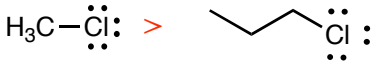
What kinds of molecules experience dipole forces?

molecules with polar bonds (except those involving H)

Example: chloromethane 

What factors affect the strength of dipole forces? how strong the polar bond is
how many nonpolar bonds are also present

C-F is more polar than C-Cl



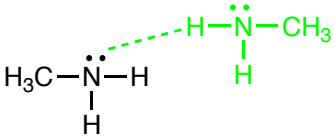
lots of nonpolar C-H bonds dilute the effect

What is hydrogen bonding?

an attraction between partially + H and lone pair of e- on O or N

What kinds of molecules experience hydrogen bonding?

molecules with N-H and O-H bonds (alcohols, amines, COOH, amides)

Example: methyl amine 

the H's on the N are attracted to the lone pair of electrons on the nitrogen

What factors affect the strength of hydrogen bonding?

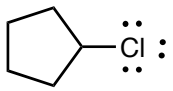
bigger effect 

O is more EN than N - stronger dipole = more attraction

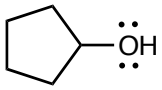
smaller effect 

more H's on N or O = more opportunities for H-bonding

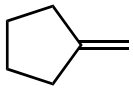
What will be the most important intermolecular force for each of the following molecules?



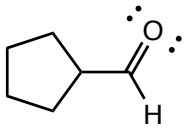
dipole forces



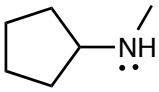
H-bonding



van der Waals



dipole



H-bonding

<u>States of matter and transitions between them</u>

What are the three states of matter that an organic compound can be in?

solid, liquid, gas

Consider a container of fireflies, a container of apples, and a container of snakes.

Which is most like a gas? Why? fireflies

lots of movement, lots of energy, lots of space between them
fairly small "molecules"
no organization, escape if container is opened

Which is most like a solid? Why? apples

no movement, low energy, not much space between them
high degree of organization (especially if carefully stacked!)
keep the same shape

Which is most like a liquid? Why? snakes

some movement, some energy, some space between them
medium sized "molecules"
not much organization - similar to gas
flow, but don't expand

What happens when a solid changes to a liquid? it melts

molecules break out of their arrangement
start moving around, spread out

What is a melting point?

the temperature at which a specific compound melts

water: 0° C; liquid at room temp - mp below RT (25°C)
sucrose: 185°C; solid at room temp - mp above RT

How does the size of the molecule affect the melting point? Why is this so?

bigger molecule = higher mp

it takes more energy to get big molecules moving, break up IMF

How does the strength of the intermolecular forces affect the melting point and why?

stronger IMF = higher mp

takes more energy to pull the molecules apart from each other

Does atmospheric pressure affect the melting point? no

What happens when a liquid changes to a gas? evaporates, or boils

molecules separate from each other
start flying around

What is a boiling point?

the temperature where a specific compound changes from liquid to gas
inside the liquid, not just at the surface

propane: -42.1°C; gas at RT - bp below RT

water: 100° C; liquid at room temp - bp above RT

How does the size of the molecule affect the boiling point? Why is this so?

higher mass = higher bp

it takes more energy to get big molecules flying around

How does the strength of the intermolecular forces affect the boiling point and why?

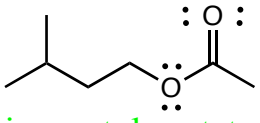
stronger IMF = higher mp

it's harder to pull the molecules apart from each other

Does atmospheric pressure affect the boiling point? Why? yes

for gas to form, vapor pressure must equal atmospheric pressure

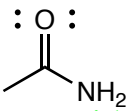
What state of matter will the following compounds be in at room temperature?



isopentyl acetate

mp -78°C; bp 142 °C

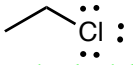
liquid - it will have melted
but not yet boiled



acetamide

mp 80°C; bp 221 °C

solid - it hasn't reached mp yet

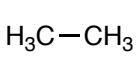


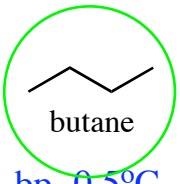
ethyl chloride

mp -139°C; bp 12.3 °C

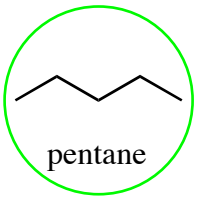
gas - has already melted and boiled

Which of the two molecules below would you expect to have a higher melting and boiling point? Why?

1)  ethane — alkane — bp -88°C

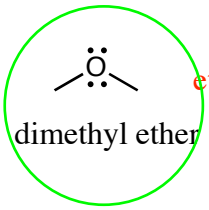
 butane — alkane — bp -0.5°C

mass - one is larger
IMF: same - vdW

2)  pentane — alkane — bp 36°C

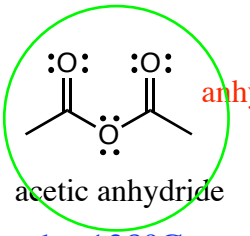
 2,2-dimethylpropane — alkane — bp 10°C

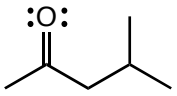
mass - about the same
IMF - both have van der Waals forces; one has more surface area

3)  dimethyl ether — ether — bp -25°C

 propane — alkane — bp -42°C

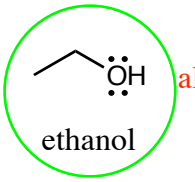
mass - about the same
IMF - dipole forces > van der Waals

4)  acetic anhydride — anhydride — bp 138°C

 4-methyl-2-pentanone — ketone — bp 117°C

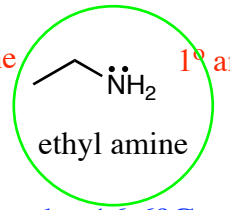
mass - about the same
IMF - both have dipole forces, but one has more polar bonds

5)  dimethyl ether — ether — bp -25°C

 ethanol — alcohol — bp 78°C

mass - about the same
IMF - hydrogen bonding > dipole

6)  dimethyl amine — 2° amine — bp 7°C

 ethyl amine — 1° amine — bp 16.6°C

mass - about the same
IMF - both have hydrogen bonding, but one has more H's

Solubility

What does it mean to say that two substances are soluble in each other?

their molecules (or ions) mix freely with each other

Give an example of:

a solid dissolving in a liquid salt or sugar in water (sea water)

a gas dissolving in a liquid CO_2 in water (soda)

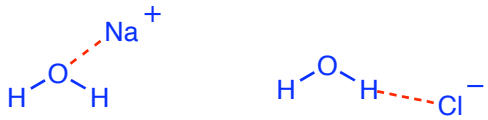
a liquid dissolving in another liquid ethanol and water (beer)

What does it look like when one substance dissolves in another?

solids - disappear, liquids - mixed, don't form boundary

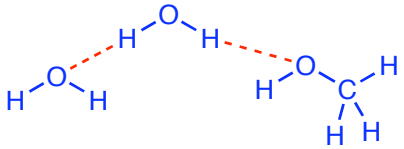
Why does salt dissolve in water?

ions are attracted to the partial charges



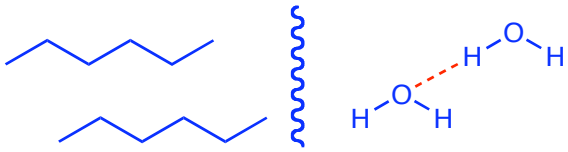
Why do ethanol and water dissolve in each other?

both form H-bonds



Why doesn't hexane dissolve in water?

hexane can't get in between the H-bonds

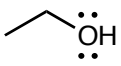


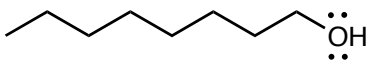
Why are all gases soluble in each other?

the molecules are so far apart that they don't interfere with each other

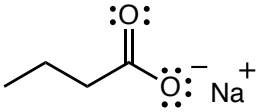
Would the following compounds be more likely to dissolve in water or hexane?

propylene  hexane - can slip into the van der Waals forces

ethanol  water - can join in the H-bonding

1-octanol  hexane - too many C-H bonds

acetone  both - polar bond (dipole forces), but also lots of nonpolar bonds

sodium butanoate  water - charges are attracted to polar molecules