

Intro to Organic Chemistry

“Organic”:

“Organic Chemistry”:

- Focus on carbon, with H, N, O, and halogens all major contributors
- Biochemicals are all carbon-based
 - Food, hair, skin, muscles, etc.
 - Clothes, plastics, fuels, etc.

The abundance of carbon, by mass:

Universe	<<0.1%
Earth	<1%
Body	18% (60% of body mass is water)
Non-water body mass	45%

>90% of known molecules are organic!

Why is carbon so special?

1. Versatile bonding! 4 covalent bonds per carbon enables:
 - a.
 - b.
2. Modest Electronegativity enables:
 - a. strong bonds to other C's, H's, and other nonmetals

Orbitals and Bonding: Review (Chapter 1:1-6)

1. **Atomic orbitals** for 2nd-row elements (C, N, O):
 - Note: for organic, we won't need to fuss with d or f orbitals
2. Valence electrons: electrons in an atom's outside shell
3. Octet Rule: atoms transfer or share electrons to obtain a filled shell (which is 8 for C, N, O, halogen)
 - Note: **never** draw C, N, or O with > 8 electrons!!!
4. Bond Types:
 - a. **Covalent bonds**
 - Between **nonmetals** H₂
 - Involve shared electrons H₂O
 - b. **Ionic:**
 - Negligible sharing of electrons
 - Metals transfer electron(s) to nonmetal LiF
 - If formula has a **metal**, assume **ionic** bonding
 - Special case of ionic bonding in absence of metals: ammonium salts NH₄Cl

Normal Bonding (Chapter 1)**Summary of Normal, Ideal Bonding (No Formal Charge)**

	Valence Electrons	Valence Bonds	Lone Pairs
$\begin{array}{c} \\ -\text{C}- \\ \end{array}$	4	4	0
$\begin{array}{c} \cdot\cdot \\ -\text{N}- \\ \end{array}$	5	3	1
$\begin{array}{c} \cdot\cdot \\ -\text{O}: \\ \end{array}$	6	2	2
H—	1	1	0
$\begin{array}{cc} \cdot\cdot & \cdot\cdot \\ :\text{Cl}- & :\text{Br}- \\ \cdot\cdot & \cdot\cdot \end{array}$	7	1	3
$\begin{array}{cc} \cdot\cdot & \cdot\cdot \\ :\text{I}- & :\text{F}- \\ \cdot\cdot & \cdot\cdot \end{array}$			

Rules for Drawing Lewis structures for organic molecules:

1. Try to provide normal bonding for C, N, O atoms **if possible**. (Works > 95% of time)
2. Double or triple bonds will often be involved.
 - Double or triple bonds are often required to achieve normal bonding.
3. In any formula that has a charge, there will always be an atom with that formal charge.
4. In any formula that includes a metal, assume ionic bonding.
 - Assume positive charge for the metal,
 - Assume negative charge for the organic portion.
5. Do not draw bonds between nonmetals and metals, as if they were covalently bound.
6. **Be sure to specify the formal charge on any atom that has formal charge.**
7. Always be aware of how many lone pairs are on any atom
 - Note: We will often omit lone pairs. But you must know when they are there!

Lewis Structure Practice

1. Draw Lewis structures for the following formulas: (Include lone pairs or formal charges if necessary)
 - a. CH_3CH_3
 - b. $\text{CH}_3\text{CH}_2\text{OH}$
 - c. CO_2
 - d. HCN
 - e. CH_3CHO
 - f. NaOCH_3

“VSEPR” and Molecular Shape: Valence Shell Electron Pair Repulsion

Concept: electron groups repel, determine structure

4 electron groups: tetrahedral, 109° angle

3 electron groups: trigonal planar, 120° angle

2 electron groups: linear, 180° angle

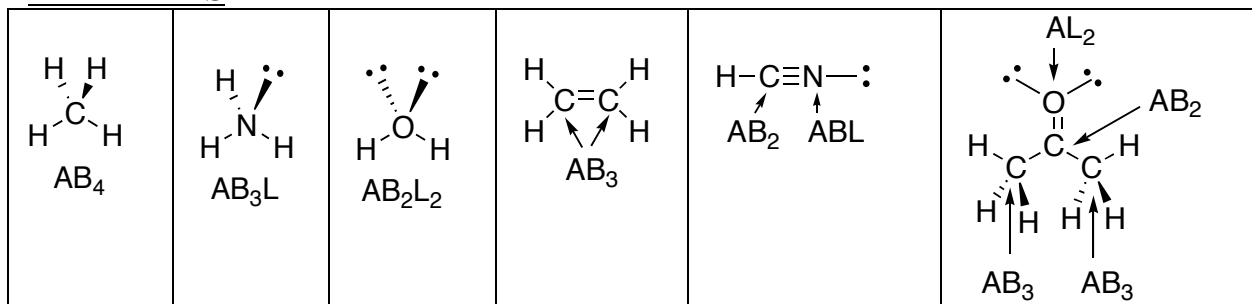
2 Types of “Electron Groups”

1. “B” = bonds to other atoms.

- Whether it’s a single, double, or triple bond, it still counts as one “electron group” or one “bond group”

2. “L” = Lone pairs

B+L	Electron Geometry	Bond Angle	Hybridization	Remaining P-orbitals
4	Tetrahedral	≈109°	sp ³	0
3	Trigonal Planar	≈120°	sp ²	1
2	Linear	≈180°	sp	2

EXAMPLES

DRAWING 3-D

Guidelines for Drawing Models:

A. In-Plane/Out-of-Plane

- Designate an atom **in front** of plane with a **wedge**
- Designate an atom **behind** plane with a **hash**
- Designate an atom **in the plane** with a **straight line**

B. 3-D Perspective

1. Keep as many atoms as possible in a single plane (plane of the paper) by zig-zagging. Connections within the plane are drawn with straight lines.
2. Use wedges to indicate atoms that are in front of the plane.
3. Use hashes to indicate atoms behind the plane.

C. For any tetrahedral atom, only 2 attachments can be in the plane, 1 must be in front, and 1 behind.

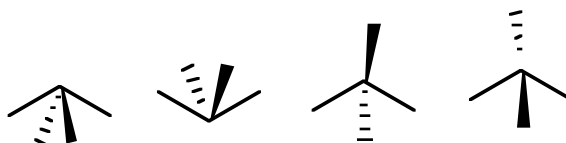
-if the two in the plane are “down”, the hash/wedge should be up

-if the two in plane are “up”, the hash/wedge should be down.

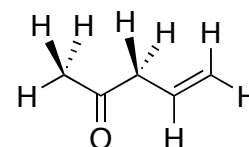
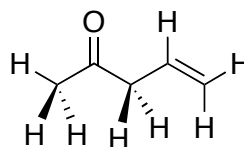
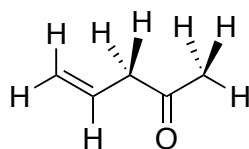
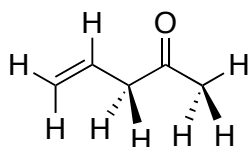
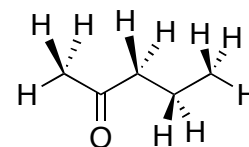
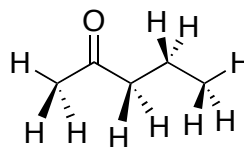
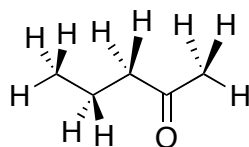
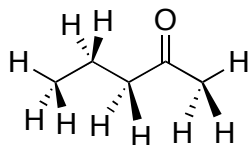
-the hash/wedge should never point in same direction as the in-plane lines, or else the atom doesn't look tetrahedral

-for polyatomic molecules, it is strongly preferable to NOT have either of the in-plane atoms pointing straight up. Straight-up in-plane atoms do not lend themselves to extended 3-D structures.

Good! Look tetrahedral



Bad! These don't look tetrahedral!

Draw:
C₂H₆C₄H₁₀CH₃COCH₃CH₃CH=CHCl

Hybrid Orbitals; π bonding (Chapter 1.7-11)

$1s + 3p \rightarrow 4 sp^3$ hybrids	109°
$1s + 2p$ (+ 1 unhybridized p) $\rightarrow 3 sp^2$ hybrids (+ 1 unhybridized p)	120°
$1s + 1p$ (+ 2 unhybridized p's) $\rightarrow 2 sp$ hybrids (+ 2 unhybridized p's)	180°

Why does hybridization occur?

- Hybrid orbitals are big and point in one direction. Their **directionality** leads to **better overlap** which leads to **strong bonds**.
- Hybrid orbitals leads to nice VSEPR angles

If hybridization is so great, why aren't pure monatomic atoms hybridized?

- For an isolated atom, having 1 s and 3 p atomic orbitals is better than 4 sp^3 hybrid orbitals
- However, when covalent bonds can result, the small price of hybridizing is paid off a thousandfold by the payoff of making strong, good VSEPR bonds

If hybridization is so great, why aren't all carbons sp^3 hybridized? Why do some stay sp^2 or sp , and withhold some p orbitals from hybridization?

- p orbitals are withheld from hybridization for the sole purpose of using them to make π bonds.
- Only when double bonds or triple bonds are involved is the hybridization less than the full sp^3
- Each π bond requires the attached atoms to use p orbitals

2 Kinds of Covalent Bonds

- sigma (σ) bonds: electron density is along the axis between the nuclei
 - σ bonds always involve the overlap of s or s-containing hybrids (s, sp, sp^2 , sp^3)
- pi (π) bonds: electron density is either above/below or before/behind, but not along the internuclear axis
 - π bonds involve the overlap of parallel p orbitals

The first bond in any bond (whether single, double, or triple), is a σ bond. The "extra" bonds in a double or triple bond are π bonds.

Bond σ π

Single	1	0
Double	1	1
Triple	1	2

π bonds are weaker and more reactive than σ bonds. Most organic reactions involve π bonds

Formal Charge (Section 2.3): When an atom does not have its normal bonding

- Atoms with formal charge dominate reactivity. Therefore the ability to recognize and identify atoms with formal charge is really important!
- **Skills:**
 1. Identify the formal charge for any atom that does not have normal bonding
 2. Identify the number of bonds and lone pairs associated with any atom whose formal charge is specified
- Note: Designation of formal charge is required. If you don't write the charge sign next to an atom that should have formal charge, you will lose test points!

Formal Charge Equations:

1. $FC = \text{group \#} - (\text{bonds} + \text{unshared e's})$ (use to calculate FC)
2. $\text{Group \#} - FC = \text{bonds} + \text{unshared electrons}$ (given formal charge, use to find lone pairs)

Practical: (memorize)

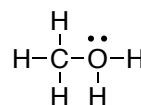
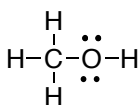
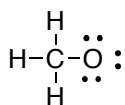
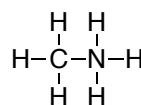
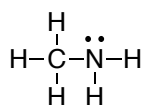
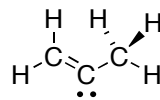
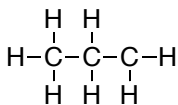
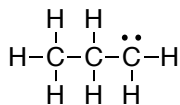
C	4 bonds	↔	neutral
	3 bonds and zero lone pairs	↔	cation +1
	3 bonds and one lone pair	↔	anion -1
N	4 bonds	↔	cation +1
	3 bonds and one lone pair	↔	neutral
O	3 bonds and one lone pair	↔	cation +1
	2 bonds and 2 lone pairs	↔	neutral
	1 bond and three lone pairs	↔	anion -1

FORMAL CHARGE

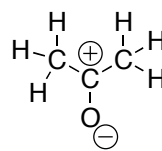
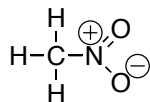
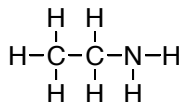
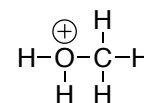
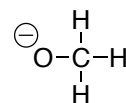
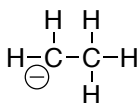
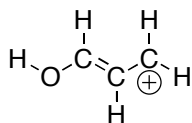
# of bonds	C	N	O	F
4	0	+1		
3	-1 or +1	0	+1	
2		-1	0	
1			-1	0

Formal Charge Practice (Section 2.3)

1. Assign any **formal charges** to atoms that need them:



2. Fill in lone pairs on any atoms that need them (whether atoms with formal charge or neutral atoms):

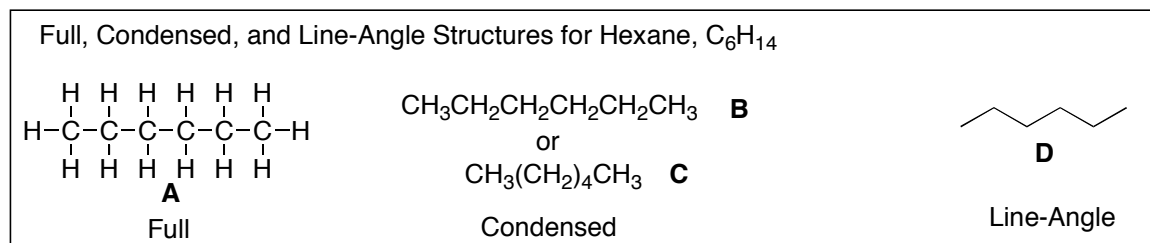


Notice: **With the exception of carbocations, all other C/N/O atoms end up with a combined total of four when you sum up their bonds and lone-pairs.** So apart from carbocations, if you know the number of bonds, you can fill in the correct number of lone pairs without even thinking much!

Structural Formulas (Section 2-12)

1. Full Structural Formulas
2. Condensed Formulas
3. Line-Angle (Skeletal) Formulas

Since organic structures are large and complex, full Lewis structures are often a hassle. You'll need to be proficient in both condensed and line-angle formulas.

**Condensed Formulas: Central atoms are shown with attached atoms, essentially in sequence**

- Challenges:
 1. Handling parentheses
 2. Handling double and triple bonds
 3. Handling branches
 4. Handling ketones/aldehydes/esters/amides/carboxylic acids
 5. In general, recognizing when an oxygen is double-bonded off a carbon, and when it is single bonded both to carbon and to something else.

Line-Angle (Skeletal) Formulas:

1. Each vertex represents a carbon
2. C-H bonds are often omitted: assume enough H's to give four bonds or the appropriate formal charge
3. Oxygen and Nitrogen atoms must be specified, and O-H and N-H bonds are **not** omitted
 - Line-angle formulas are routinely the fastest and cleanest to draw.
 - Line-angle is essential and optimal for showing 3-dimensional organic shape.

Formula Practice (Section 1-10)

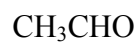
3. Time race: Draw as many copies of C₆H₁₄ hexane as you can in 20 seconds:

Full:

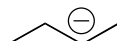
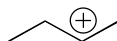
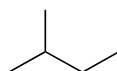
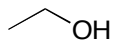
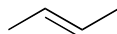
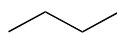
Condensed:

Line-Angle:

4. Draw the full structure, given the condensed structure. (Note:



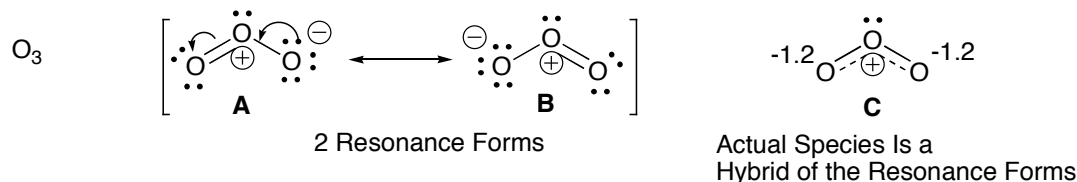
5. Fill in the full structure, including attached hydrogens and attached lone pairs, for the following line-angle structures. If given a condensed structure, convert it to a line-angle.



Resonance Structures (Sections 2:4-6)

Sometimes a single Lewis structure does not provide an adequate picture.

Example: O₃ (ozone)

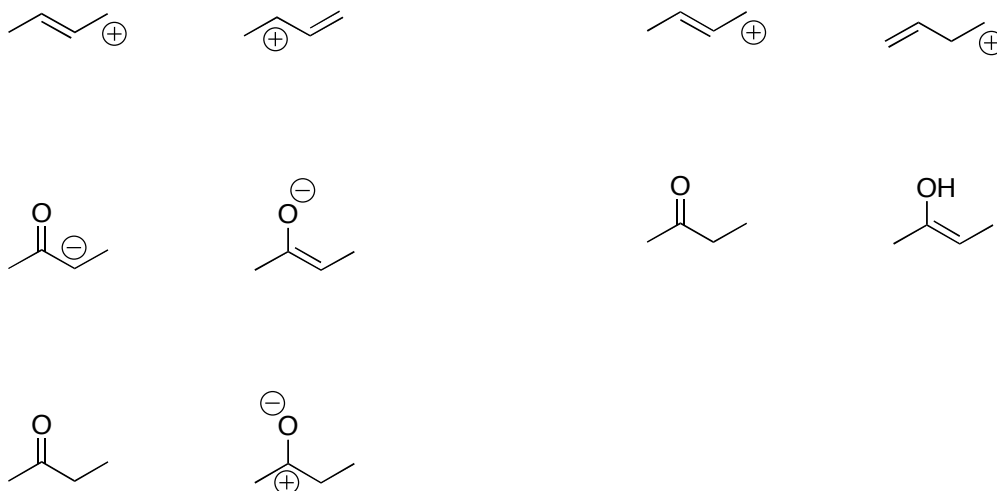


Notes/observations:

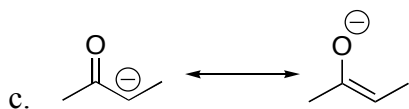
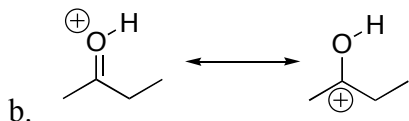
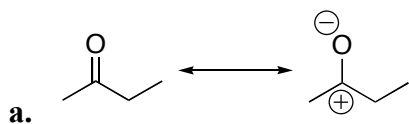
- Neither form **A** nor **B** can avoid formal charges.
 - The majority of resonance situations have some formal charge involvement
 - The real molecule is hybrid: see picture C
 - The central oxygen has + charge
 - Each of the outside oxygens is -1/2
 - Both of the bonds to the outside oxygens are equal in length/strength
 - The actual length/strength of the oxygen-oxygen bonds reflect 1.5 bonds (shorter and stronger than single bonds; longer and weaker than double bonds)
 - Why not just draw the hybrid?
 - Hard to do, without first working through resonance structures first.
 - Hard to keep track of the electrons, which is essential for understanding reactivity
 - When are Two Structures related as Resonance Structures?
 - Atoms must be connected in exactly the same way. Resonance forms differ **only in the placement of electrons.**
 - If two Lewis structures have the same atomic connectivity, but differ **only** in the placement of some electrons, they are related as resonance structures.
 - If the placement/connectivity of atoms differ, then the two structures are not resonance structures (they may perhaps be related as “isomers”, see later.)
- **KEY: FOR RESONANCE STRUCTURES, ELECTRONS MOVE BUT ATOMS DO NOT MOVE. IF ATOMS MOVE, YOU DON'T HAVE RESONANCE STRUCTURES**
- Note: The real molecule is represented by the hybrid, and electrons are not actually jumping back and forth.
 - Resonance, when it exists, involves the **delocalization of electrons and charge**
 - In ozone, instead of one of the outside oxygens getting stuck with a full negative charge, that negative charge is shared with the other outside oxygen, and both have a more manageable -1/2 charge
 - This delocalization of electrons/charge is stabilizing.
 - KEY: RESONANCE IS STABILIZING**
 - Resonance, when it exists, always involves electrons in double bonds and/or lone pairs (π electrons)
 - One of the most frequent resonance situations we'll see is when you a charged atom attached to a double bonded atom (“allylic” situation”)
 - When resonance structures are equal in stability, the hybrid is the average of the resonance forms
 - When resonance structures are unequal, the more stable structure dominates the hybrid
 - Ranking Stability:**
 - More bonds \rightarrow more stable (but don't exceed octet rule!). (Priority rule)
 - Bonds being equal (tiebreaker rule): **negative charge** is better on **more electronegative atom**;
 - positive charge** is better on **less electronegative atom**

Resonance Problems

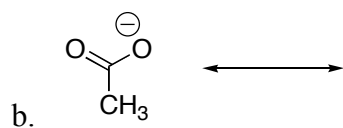
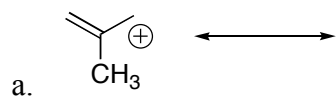
1. Which of the following are related as resonance structures?



2. Which Resonance Structure is Better and would make a more than 50% contribution to the actual hybrid? Why, bonds or electronegativity?



3. Draw a resonance structure for the following



2.1-2 Polarity

-molecular dipole: vector sum of bond and lone-pair dipoles

A simple molecule is totally nonpolar only if:

1. Central atom has no lone pairs
2. All attached atoms are the same

Practical:

- Lone pairs and O-H or N-H bonds usually dominate
- C-C, C-H, and C-halogen bonds are practically nonpolar or at best only weakly polar

Problems: Classify as totally nonpolar or polar.

- | | | | |
|---------------------|---------------------|---------------------------------------|-----------------------------------|
| a. CO ₂ | b. CCl ₄ | c. CH ₄ | d. C ₄ H ₁₀ |
| e. H ₂ O | f. NH ₃ | g. CH ₃ CH ₂ OH | h. CHCl ₃ |

Intermolecular Forces and Boiling Points

1. Hydrogen bonds (O-H or N-H)
2. Dipole-Dipole
 - Much weaker than hydrogen bonds
3. London Forces
 - Increases with increasing molecular weight

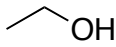



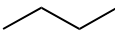
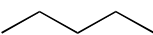
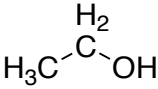
Intermolecular Forces impact:

1. Boiling points and melting points
2. Solubility

For Boiling Points:

1. If weight is about equal → H-bonder > polar > nonpolar
2. If H-bonding/polarity is comparable: high mw > lower mw

Problem: Rank the boiling points, 1 being highest

- a.   
- b.   
- c. $\text{H}_3\text{C}-\text{OH}$ 

Polarity and Solubility2 Practical Rules:

1. The more N's or O's in a molecular, the greater it's water solubility
2. The more C's, the lower it's water solubility

Facts/Theory

1. "Like dissolves like"
 - enthalpy and entropy factors

Good solubility

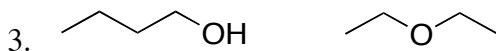
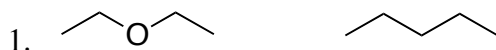
- a. Polar solvent-polar solute
- b. Nonpolar solvent-nonpolar solute

Bad solubility

- a. Polar solvent-nonpolar solute
- b. Nonpolar solvent-polar solute

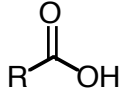
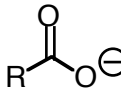
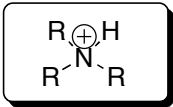
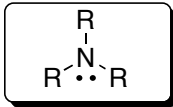
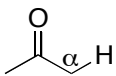

2. Water is very polar
3. Any molecules with N or O can H-bond with water (even if it can't necessarily H-bond itself) (Rule 1)
4. Adding C's adds C-C, C-H nonpolar bonds → reduces water solubility (Rule 2)
5. Hydrocarbons and halocarbons are insoluble in water
 - Many other organics have low solubility in water
 - Depends on the ratio of nonpolar/polar, N or O to C

Problems: Circle the more water soluble of the following pairs:



Problem: Box the higher boiling in each pair. Does water solubility and boiling point always correspond? Why or why not?

Acid-Base Chemistry (Sections 2:7-11)**Acidity/Basicity Table**

Entry	Class	Structure	K _a	Acid Strength	Base	Base Strength
1	Strong Acids	H-Cl, H ₂ SO ₄	10 ²		Cl [⊖] , HO-S(=O) ₂ -O [⊖]	
2	Hydronium	H ₃ O ⁺ , ROH ₂ ⁺ cationic	10 ⁰		H ₂ O, ROH neutral	
3	Carboxylic Acid		10 ⁻⁵			
4	Ammonium Ion (Charged)	 Charged, but only weakly acidic!	10 ⁻¹²		 Neutral, but basic!	
5	Water	HOH	10 ⁻¹⁶		HO [⊖]	
6	Alcohol	ROH	10 ⁻¹⁷		RO [⊖]	
7	Ketones and Aldehydes		10 ⁻²⁰			
8	Amine (N-H)	(iPr) ₂ N-H	10 ⁻³³		(iPr) ₂ N [⊖] Li [⊕]	
9	Alkane (C-H)	RCH ₃	10 ⁻⁵⁰		RCH ₂ [⊖]	

Quick Checklist of Acid/Base Factors

1. Charge
2. Electronegativity
3. Resonance/Conjugation
4. Hybridization
5. Impact of Electron Donors/Withdrawers
6. Amines/Ammoniums

▪ **When neutral acids are involved, it's best to draw the conjugate anionic bases, and then think from the anion stability side. The more stable the anion, the less basic the anion will be and the more basic the mother acid will be.**

More Detailed Discussion of Acid/Base Patterns/Factors to remember

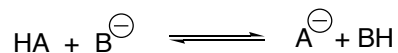
- Charge: all else equal, cations are more acidic than neutrals, and anions more basic than neutrals.
- Electronegativity:
 - Acidity: $\text{H-X (halogen)} > \text{H-O} > \text{H-N} > \text{H-C}$
 - Basicity: $\text{X}^- < \text{O}^- < \text{N}^- < \text{C}^-$
 - Anion Stability: $\text{X}^- > \text{O}^- > \text{N}^- > \text{C}^-$
 - Why: **The more stable the anion Z⁻ that forms, the more acidic the parent H-Z will be.** All acids H-Z must give up H⁺. The better off the resulting anion Z⁻ is, the more willing H-Z will be to sacrifice H⁺.
 - The anion stability directly correlates the love for electrons.**
 - Notice three things:
 - ANION STABILITY and the ACIDITY OF A NEUTRAL ACID PRECURSOR ARE DIRECTLY RELATED.
 - ANION STABILITY and the BASICITY OF THE ANION ARE INVERSELY RELATED (more stable anion, less basic anion)
 - ANION BASICITY AND THE ACIDITY OF THE CONJUGATE ACID ARE INVERSELY RELATED (the stronger the acidity of the parent acid, the weaker the basicity of the conjugate anion)
 - KEY: WHEN THINKING ABOUT ACIDITY AND BASICITY, FOCUS ON THE ANION. THE STABILITY OF THE ANION DETERMINES ACID/BASE BEHAVIOR.
- Resonance/Conjugation: Since anion resonance is stabilizing, **an acid that gives a resonance-stabilized anion is more acidic.** And an anion that forms with resonance will be more stable and less basic.
 - Oxygen Series Examples:
Acidity: sulfuric acid > carboxylic acid > water or alcohol
 - Anion Basicity: $\text{HO-SO}_3^- < \text{CH}_3\text{COO}^- < \text{CH}_3\text{CH}_2\text{O}^-$
 - Anion Stability: $\text{HO-SO}_3^- > \text{CH}_3\text{COO}^- > \text{CH}_3\text{CH}_2\text{O}^-$
- Note: Resonance is often useful as a tiebreaker (for example, molecules in which both have O-H bonds and both have equal charge, so that neither the charge factor nor the electronegativity factor could predict acidity/basicity)
- NOTE: Resonance can sometimes (not always) trump electronegativity or even charge.
 - Example of resonance versus charge: A carboxylate anion, with serious resonance stabilization, ends up being so stabilized that it is even less basic than a neutral, uncharged amine! A hydrogen sulfate anion from sulfuric acid is less basic than not only neutral amines but also neutral oxygen (water, etc.)

Choose the More **Basic** for Each of the Following Pairs (Single Variable)**Predicting Acid/Base Equilibria: Any acid base equilibrium favors the side that has the more stable, less reactive base**

6. Draw arrow to show whether equilibrium favors products or reactants. (Why?)



Generic acid/base reaction, with anionic base and neutral acid:

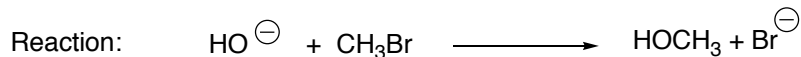
Stronger acid \rightarrow weaker conjugate baseWeaker acid \rightarrow stronger conjugate base

- Acid-base reactions always favor formation of the weaker acid and weaker base
- The weaker acid and weaker base are always on the same side
- The more stable anion is the weaker base

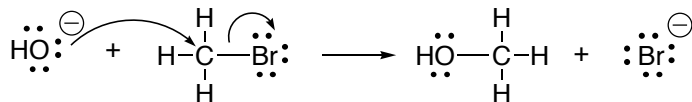
THEREFORE:

- The equilibrium will always favor the WEAKER, MORE STABLE ANION
- **IF YOU CAN IDENTIFY WHICH ANION IS MORE STABLE, YOU CAN PREDICT THE DIRECTION THE REACTION WILL GO.**
- This logic can be used to predict whether an anion can successfully deprotonate a neutral species.

7. Can H_3C^- deprotonate H_2O ?

Lewis Acids and Bases: Examples of “Arrow Pushing” and “Mechanism” (Section 2.11)

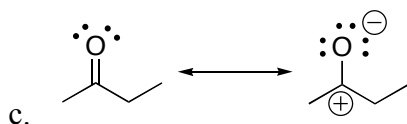
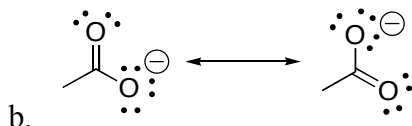
Mechanism, with arrows to show how electrons move, how the new bond forms, and how an old bond breaks:



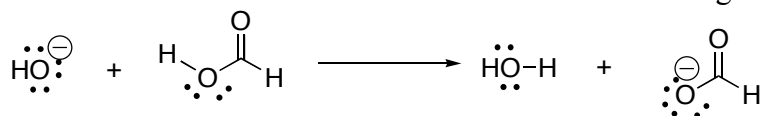
Notes:

- Arrows are drawn to show how electron pairs are moving as new bonds form or old bonds break.
- Mechanisms help us to understand and generalize when and why bonds make or break, so that we can understand when and why reactions will occur and what products will form.
- Each arrow always goes from an electron source (either an atom with a lone pair or else a bond pair) to an acceptor atom
- **Terms:**
 - a. “**Nucleophile**” = source of electron pair (“**Lewis base**”)
 - b. “**Electrophile**” = acceptor (“**Lewis acid**”)
- c. An arrow always proceeds from a nucleophile and points toward an electrophile.
- d. Arrow-pushing is very helpful in relating two resonance structures

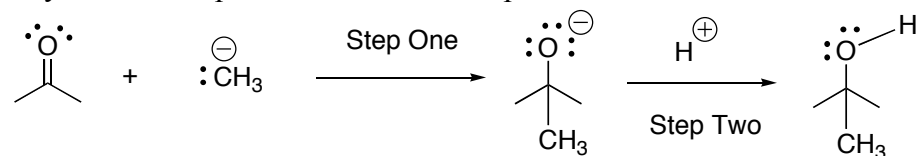
1. Use arrows to show how the electrons “move” from the first to the second resonance structures:



2. Use arrows to show the mechanism for the following acid-base reaction.



3. Use arrows to show the mechanism for the following two-step reaction. For the first step, identify the “nucleophile” and the “electrophile”.



Some Arrow-Pushing Guidelines (Section 2.11)

1. Arrows follow electron movement.
2. Some rules for the appearance of arrows
 - The arrow must begin from the electron source. There are two sources:
 - a. An atom (which must have a lone pair to give)
 - b. A bond pair (an old bond that breaks)
 - An arrow must always point directly to an atom, because when electrons move, they always go to some new atom.
3. Ignore any Spectator Atoms. Any metal atom is always a “spectator”
 - When you have a metal spectator atom, realize that the non-metal next to it must have negative charge
4. Draw all H's on any Atom Whose Bonding Changes
5. Draw all lone-pairs on any Atom whose bonding changes
6. **KEY ON BOND CHANGES**. Any two-electron bond that changes (either made or broken) must have an arrow to illustrate:
 - where it came from (new bond made) or
 - an arrow showing where it goes to (old bond broken)
7. **Watch for Formal Charges and Changes in Formal Charge**
 - If an atom's charge gets more positive \Rightarrow it's donating/losing an electron pair \Rightarrow arrow must emanate from that atom or one of its associated bonds. There are two “more positive” transactions:
 - When an anion becomes neutral. In this case, an arrow will emanate from the atom. The atom has donated a lone pair which becomes a bond pair.
 - When a neutral atom becomes cationic. In this case, the atom will be losing a bond pair, so the arrow should emanate from the bond rather than from the atom.
 - If an atom's charge gets more negative \Rightarrow it's accepting an electron pair \Rightarrow an arrow must point to that atom. Ordinarily the arrow will have started from a bond and will point to the atom.
8. **When bonds change, but Formal Charge Doesn't Change, A “Substitution” is Involved**
 - Often an atom gives up an old bond and replaces it with a new bond. This is “substitution”.
 - In this case, there will be an incoming arrow pointing directly at the atom (to illustrate formation of the new bond), and an outgoing arrow emanating from the old bond that breaks