



## Gen Chem Study Guide

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Hi, gang, and welcome to the Gen Chem study guide on jOeCHEM! Since this is the **first** study guide (yeehaw, let's go), let me provide some background for what I envision these guides to be and how they are supposed to help you kick organic butt.

For all chapters or units (aka "Gen Chem Boot Camp", for example), I want these study guides to be a central summary point. If you're starting to study for an exam, and you want to have a general idea of what is contained within a given unit, I hope you can turn to these study guides and get that overview.

Of course jOeCHEM can't be a perfect substitute for every Organic Chemistry class (each teacher/class is different), but I'll aim to include:

1. Terms you need to know + their definitions
2. An overview of all the key concepts in a given unit/chapter
3. Tips, Tricks, or General Advice I think could be helpful and may not necessarily fit in the other sections

# Terms to Know

Below are a list of terms that you should have a working understanding of. There's a lot of science-y jargon in Organic Chemistry, so to be able to walk-the-walk (do reactions and stuff), we have to have to be able to talk-the-talk (talk and stuff).

Don't be intimidated by this section, especially for the Gen Chem + early chapters/units: there is a LOT of new words to add to your vocabulary, and chances are you've been hearing/saying all of these terms. But trust me when I say the comfort you get with the terminology, the more sense your class time will be; it's easy to get lost when these words are flying around when you're learning more and more new material.

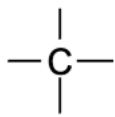
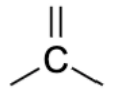
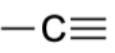
- **Ionic Bond** – a chemical bond between two differently charged ions, a cation (+) & anion (-). In solution, you will hear people refer to ionic compounds as **salts** (e.g. NaCl).
- **Covalent Bond** – a chemical bond between two atoms where an electron pair (aka 2 electrons) are shared between the atoms involved (e.g. C-H in CH<sub>4</sub>).
- **Lone Pair** – 2 electrons **not** in a covalent bond, completely owned by a single atom
- **Lewis Dot Structure** – a diagram of a structure used to visually show how the atoms within a structure/compound are bonded together + which atom(s) have lone pair electrons
- **Bond Line Structure** – the “zig zag” style of drawing organic (aka carbon containing molecules) that you think of when you think of Organic Chemistry
  - **Methyl Carbon** – a carbon that is attached to **no** OTHER carbons (e.g. CH<sub>4</sub>)
  - **Primary (1°) Carbon** – a carbon that is attached to **one** OTHER carbon
  - **Secondary (2°) Carbon** – a carbon that is attached to **two** OTHER carbons
  - **Tertiary (3°) Carbon** – a carbon that is attached to **three** OTHER carbons
  - **Quaternary (4°) Carbon** – a carbon that is attached to **four** OTHER carbons
- **Formal Charge** – the charge associated with an atom within a structure. We determine this by (# of valence electrons - # of electrons the atom controls)
- **Curved Arrows** – arrows used to show the movement of electrons. They **START** at electrons and point to where the electrons are going to, and can be single or double headed (single headed to show 1 e<sup>-</sup> moving, double to show 2 moving)
- **Resonance** – the idea that structures can delocalize (aka share) electrons or across its structure (if the situation permits), which we can illustrate with curved arrows

- **Overall Resonance Hybrid** – the total summation of all possible resonance structures for a given molecule—the more “stable” a resonance structure is, the more it contributes to the overall hybrid
- **VSEPR** – Valence Shell Electron Pair Repulsion, which means that atoms take on different geometries in order for the bonds that they are a part of (which have 2 electrons in them) to space and minimize the repulsion they have on each other.
  - Tetrahedral
    - the geometry we get with atoms that have 4 bonds aka **sp<sub>3</sub>** hybridization
    - 109.5° bond angles
  - Trigonal Planar
    - the geometry we get with atoms that have 3 bonds aka **sp<sub>2</sub>** hybridization
    - 120° bond angles
  - Linear
    - the geometry we get with atoms that have 2 bonds aka **sp** hybridization
    - 180° bond angles
- **Hybridization** – a bonding theory we use heavily in OChem that says that atoms mix their orbitals together based on the amount of bonding/electron areas they have
- **Sigma Bond** – a head to head orbital overlap between atoms. Atoms are ONLY connected if a sigma bond exists between them. The first bond made between atoms is a sigma bond
- **Pi Bond** – a bond between two atoms that each have a p orbital and those p orbitals are parallel to one another. This is a weaker bond than a sigma bond since there is no direct overlap—only being parallel keeps it together
  - Pi bonds are always perpendicular to all sigma bonds + other pi bonds they are next to
- **Lewis Acid** – an electron pair acceptor (we don’t typically use this definition of an acid, but it comes up every now and then).
  - BH<sub>3</sub> is an example since it only has 3 bonds and could accept an electron pair
- **Lewis Base** - an electron pair donator (we don’t typically use this definition of an acid, but it comes up every now and then)
  - OH<sup>-</sup> is an example since it has excess lone pairs
- **Brønsted-Lowry Acid** – a proton donator (aka a source of H<sup>+</sup>)
  - Some examples: H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>O<sup>+</sup>, HCl, HBr, HI, etc
- **Brønsted-Lowry Base** – a proton acceptor (aka something that grabs H<sup>+</sup>)

- **Conjugate Base** – when you're talking about a particular acid, the conjugate base is the form of that structure **after it donates**  $H^+$ 
  - For example, the conjugate base of  $HCl$  is  $Cl^-$
- **Conjugate Acid** – when you're talking about a particular base, the conjugate acid is the form of that structure **after it accepts/picks up**  $H^+$ 
  - For example, the conjugate acid of  $H_2O$  is  $H_3O^+$
- **Weak Acid/Base** – in the acid base world, weak === stable, and weak means an acid/base that is NOT good at doing its job. So a weak acid is not a good producer of  $H^+$ , and a weak base is NOT good at picking up  $H^+$
- **Strong Acid/Base** – in the acid base world, strong === reactive, and strong means an acid/base that IS good at doing its job. So a strong acid is a good producer of  $H^+$ , and a strong base is good at picking up  $H^+$
- **pK<sub>a</sub>** – a numerical measure of how acidic a proton within a molecule is. The **lower** the pK<sub>a</sub> (which **can** dip below zero!), the more acidic.\*
  - \*Remember, the pK<sub>a</sub> scale is logarithmic, SO a difference between a pK<sub>a</sub> of 7 and 10 (which is seemingly a difference of 3) means the structure with pK<sub>a</sub> 7 is  $10^3$  **more acidic**
- **pK<sub>b</sub>** – a numerical measure of how basic a molecule is (how good it is at picking up  $H^+$ ). The **lower** the pK<sub>b</sub> (which **can** dip below zero!), the more basic.\*
  - pK<sub>b</sub>'s are less commonly used in OChem—you'll typically work with pK<sub>a</sub>'s, but you should feel comfy understanding what a pK<sub>b</sub> value means if someone gives you one (e.g. a pK<sub>b</sub> of like ~35 is a weak base, but that base would have a strong conjugate acid)
- **Reaction Equilibrium** – a reaction that is constantly going in a forward and reverse direction, denoted by having back and forth arrows (e.g.  $A + B \rightleftharpoons C + D$ ). One direction may be going faster/more than the other, but you'll never settle on one side.
- **Le Chatelier's Principle** – a principle that states that if an equilibrium is disturbed, it will counter-react to offset any change that is introduced
- **Energy Diagram** – a graph we use to show changes in energy as a reaction proceeds, compare energies of molecules, and so much more. These never, **never** go away 😊.
  - Being higher (vertically) on an E Diagram means a molecule has **more** energy and is **more** unstable. Being lower means lower E and more stable for a given molecule.

# Overview of Concepts

- Lewis Dot Drawing Strategy
  - For Lewis Dot Drawing, the foolproof approach is to:
    1. Count the total # of electrons in the molecule
    2. Correctly lay out the atoms in the structure, bond them together with **single** bonds, and give every atom a full octet by filling in lone pairs
    3. Count up the total number of electrons: if you've exceeded the total you counted in step #1, make double bonds and consolidate lone pairs
    4. Once you achieve the correct # of electrons, assign formal charges...
- Formal Charges
  - To assign formal charges, remember the rough "formula" is:
    1. (**# valence electrons for an atom - # electrons that atom controls**)
      - a. **# valence electrons for an atom** is gotten from the atom's column in the periodic table
      - b. **# electrons that atom controls** is gotten by counting an atom's lone pairs straight up (one lone pair counts as **two**) and "splitting" each bond the atom has and counting that as **one**
- VSEPR + Hybridization for carbons

Hybridization	Sigma + Pi Breakdown	Appearance	Geometry	Bond Angles
sp <sub>3</sub> (4 bonding areas)	4 sigma (sp <sub>3</sub> )		Tetrahedral	109.5
sp <sub>2</sub> (3 bonding areas)	3 sigma (sp <sub>2</sub> ), 1 pi (p)		Trigonal Planar	120
sp (2 bonding areas)	2 sigma (sp), 2 pi (p)		Linear	180

- General Strategy for Resonance
  - Resonance, in my opinion, is best learned by **doing**, so make sure to check out the resonance videos + guided worksheets on jOeCHEM. That being said, here are some good guiding principles to follow when drawing it:
    1. Move electrons (aka double bonds + lone pairs) **towards** positive charges/atoms that lack a full octet

2. Take lone pairs and make double bonds in the direction toward other, pre-existing double bonds—this will allow you to “bounce” the pre-existing double bond up to be a lone pair (aka think of negative charge moving in a direction and forcing a double bond to move away and become a lone pair)
- Picking Best Contributor to Overall Resonance Hybrid
    - Luckily, we have some well-defined rules for this, in order of importance:
      1. Ensure all atoms have a full octet
      2. Place formal charges on atoms that can best accommodate them (e.g. -1 on an Oxygen versus a Carbon)
      3. If multiple charges, that are opposite, exist place them close to/next to each other (positive-negative electrostatic stabilization)
  - Interpreting pKa/pKb's
    - A pKa is the  $-\log(K_a)$ : That is a gen-chem concept, but I bring that up to say that the pKa scale is **logarithmic**. Just had to say it again cause it is confusing 😊
      1. A **lower pKa/pKb** (meaning  $< 10$  & especially close to or even **below zero**), means an acid/base is **stronger**. A stronger acid is more reactive and better at producing  $H^+$ , while a strong base is also more reactive but better at picking up  $H^+$
      2. A **higher pKa/pKb** means an acid/base is **weaker**. A weaker acid is less reactive aka more **stable**: it's NOT very good at producing  $H^+$ , while a weak/stable base is also NOT good at picking up  $H^+$
      3. Note: call acids and bases strong and weak can be done in an absolute or relative sense, but generally if an acid has a pKa below 10 it's on the stronger side. My personal frame of reference is that  $H_2O$  has a pKa of 16 and is a weak acid (which is good cause we drink the stuff)
  - Acid-Base Equilibriums
    - Remember, in the acid-base world, an equilibrium will always drive **to the weak acid/base side**. This is because the other side will have the stronger acid/base, which will do their jobs better than the weaker acid/base.
      1. If you are given pKa's/pKb's or have a pKa table handy, the equilibrium will rest on the side with the HIGHER pKa's/pKb's (because that indicates weaker acids/bases)
      2. If you aren't given pKa's, remember the 5 rules we learned to evaluate stability qualitatively for acid-base equilibriums. Use them to help you identify the **more stable** side of the equilibrium, which is also the **weaker** side—that will be the side the equilibrium favors
        - a. Size
        - b. Electronegativity

- c. Resonance
- d. Hybridization
- e. Inductive Effect
- Reaction Equilibrium -- Le Chatelier's Principle
  - If your class includes Le Chatelier's Principle (which is definitely taught in Gen Chem courses and sometimes OChem), just remember that an equilibrium acts to counter-act and changes introduced in terms of temperature, pressure, etc.
- E Diagram
  - Remember that higher up on an E Diagram signifies that a molecule(s) have **more** energy and are **more** reactive/unstable. Being lower means less energy and more unreactive/stable

# Tips, Tricks & General Advice

Phew. I know that was a lot, gang. And of course, reading all of that dense writing will not make you an expert in each of those individual topics. But, what I hope it provides is a “home base” that lists out the big, important topics in one place, so that you have an overview on what to work on, definitions if you need them, etc.

Now, this section will usually just be my “two cents” on what I think is really important plus any helpful tips and tricks (if I don't touch on something it's not that it's unimportant).

- Get very comfortable assigning **formal charges**. Of course this material is new, but formal charges never go away, and I've seen this only slow students down as more advanced stuff comes their way in OChem I and II. Plus, a general policy from teachers is a missed formal charge is a -1 point on quizzes/exams, so get them on lock now.
- **Resonance** also never, never, NEVER goes away. Just know, I sucked at resonance when I first started OChem. It's weird and mind bending at first. But truly, practice, practice, practice. It took me reworking examples I had done so many times, really trying to deeply understand what was going on to really get it. If you're struggling, maybe try that approach as well.
- **Hybridization** also never goes away. Get quick with being able to look at any atom and determine whether it's  $sp_3$ ,  $sp_2$ , or  $sp$ , whether it's a carbon, oxygen, nitrogen, etc. Understand the geometry that an atom of a certain hybridization takes on (e.g. tetrahedral for an  $sp_3$  carbon with 4 bonds). This will be important throughout OChem.
- Really understand/be able to interpret **pKa/pKb** values and understand what it means to be a **strong or weak** acid/base. The acid-base world can be wickedly confusing, but if you get the terminology down, your time in OChem will be much more enjoyable, I promise.
- Be able to read/use E diagrams to illustrate molecules being more or less stable than one another. I personally missed many E diagram questions in my OChem career because I *thought* I had a good working knowledge of E diagrams...until someone asked me to read one/create one. Just remember that going  $\uparrow$  on an E diagram means **more energy, more reactive/unstable** and going  $\downarrow$  means **less energy, more unreactive/stable**.