CHE 1302

Basic Principles of Modern Chemistry II

Week 8

Hello and welcome to the weekly resources for Chemistry 1302! This resource covers topics typically taught by professors during the 8^{th} week of classes.

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"Online Study Guide Resources" – If you don't see the topics you're learning right now, click here to find the weekly resources for the rest of the semester!

"How to Participate in Group Tutoring" - See if there is a Chemistry 1302 group tutoring session being hosted this semester – these are weekly question/answer sessions taught by our master tutors!

You can also view tutoring times for your course or schedule a private 30-minute appointment! Check out the website to learn more. You can also give us a call at (254)710-4135, or drop in. Our hours are Monday-Thursday 9 am – 8 pm on class days.

KEY WORDS: Arrhenius, Bronsted-Lowry, Conjugate Acid/Base, pKa, Acid Strength

TOPIC OF THE WEEK: Acid & Base Definitions

Important vocab note: "**proton**" and "**H^+**" are used interchangeably, because H^+ is a hydrogen atom that's lost an electron—that is, just a proton by itself.

There are certain chemicals that tend to have similar properties. There is, for example, a group of chemicals that corrodes metals, tastes/smells sour (don't taste/smell chemicals, because some are very dangerous!), conducts electricity, and turns litmus paper red. Furthermore, they do these things to a lesser extent when diluted with water. These chemicals have come to be known as "acids." Another group of chemicals, which feel soapy, taste bitter, and turn litmus paper blue, are called "bases."

There must be something about their molecular structure that leads to these characteristics, right? Yes, there is! It was defined different ways by different scientists. Here are some definitions that are still relevant today:

1. Arrhenius: Arrhenius noticed that all the chemicals we know as "acids" form H^+ in water, and "bases" form OH^- in water. Here's what this means in equation form:
    a. Acid in water: $HA + H_2O \rightleftharpoons A^- + H_3O^+$ Notice that the H^+ from the acid has been transferred to the water! **Why are there charges now?** A hydrogen atom is a proton plus an electron, and *only the proton has moved*. The electron stays

behind. Protons are positively charged, so when it adds to the water, the water becomes positively charged. Electrons are negatively charged, so now that the A^- has one extra electron, it is negatively charged.

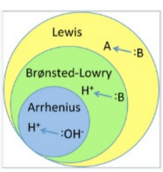
   i. *Feel free to skip this part – it just explains a little more why the proton moves alone.* Remember why atoms form bonds – they like to complete their octets. Whatever the hydrogen atom is bonded to, denoted "A," has a full octet at the start of the reaction, and it hates to lose that. Plus, hydrogen is not strong at all. So, when the water grabs hold of hydrogen's proton, and the proton tries to bring its electron with, A wins: A keeps the electron.

b. Base in water: $B + H_2O \rightleftharpoons BH^+ + OH^-$ In this case, the H^+ from the water has been transferred to the base. Sound familiar? You can think of it as a version of the equation from (a) for which $A=OH^-$.

c. *Limitation*: These equations are true, but they do not encompass *all* acids/bases, as we will see shortly.

d. However, this definition is important because it explains this fact: Mixing an **acid** and a **base** gives a **salt** and **water** (a solution that is neither acidic nor basic). This type of reaction is called a neutralization.

2. Bronsted-Lowry: Instead of defining an acid as something that donates a proton to **water** to form H_3O^+, Bronsted and Lowry said that it's something that donates a proton to **anything**. And a base, instead of something that takes a proton from **water**, leaving OH-, is something that takes a proton from **anything**. Here's what this means in equation form:



   a. Acid: $HA_{(aq)} \rightleftharpoons H^+ + A^-$ (not shown: the "something" that the proton is being donated to. Also could write this equation as $HA_{(aq)} + something \rightleftharpoons somethingH^+ + A^-$

   b. Base: $B + H^+ \rightleftharpoons BH^+$ (similarly, the "something" that the proton is attached to is not shown)

3. Lewis: Just FYI, there will be one more definition that you'll learn about in OChem! [3.2: Brønsted and Lewis Acids and Bases - Chemistry LibreTexts]

Highlight 1: Conjugate Acids & Bases

Once an acid has lost its proton, what is left is called its conjugate base. Think of the word "conjugate" as "similarly structured." Why "base?" Well, we know that this molecule **has the capacity to be bonded to an additional proton**, which means that it is able to act as a base and take a proton back. Every acid has a conjugate base.

Example: HA is an acid. What is its conjugate base? *What's left after it donates a proton?* A^- is the conjugate base.

Example 2: H_2O acts as an acid. What is its conjugate base? *What's left after it donates a proton?* The conjugate base is OH^-.

Once a base has taken a proton, the *protonated base* is called its conjugate acid. This molecule is an acid because it has the **capacity** to act as an acid, or to **donate a proton**.

Example: A acts as a base. What is its conjugate acid? *What do you get after adding a proton to A?* The conjugate acid is HA^+.

Example 2: H_2O acts as a base. (Notice that water can act as both an acid and a base! That is, it can donate a proton, but it can also accept one.) What is its conjugate acid? What do you get after adding a proton to H2O? H3O+.

Often, you'll be asked to recognize conjugate acid/base pairs. Check for the following:

1. **Does one of them have one more proton than the other?** (If yes, it is a conjugate base pair, and the one with more protons is the conjugate acid.)
2. **Does one of them have +1 charge as compared to the other?** (If yes, it is a conjugate base pair, and the one with a more positive charge is the conjugate acid.)

Highlight 2: Acid Scale

Let's consider the reaction of acid with water. Remember, when (aq) is the subscript, it means that the substance is dissolved in water!

Here's the equation, which you saw in the Arrhenius definition: $HA + H_2O \rightleftharpoons A^- + H_3O^+$.

Next, we'll write the equation for Kc (review: Week 5): $K_c\ for\ an\ acid\ is\ denoted\ K_a = \frac{[H_3O^+][A^-]}{[HA]}$ *Remember, liquids (H_2O) don't need to go in K equations*.

Say that we know we're dealing with a strong acid. What must be true of K? The acid is good at donating its proton, so we'll end up with a lot of proton-less acid (aka conjugate base) and H_3O^+. In other words, K_c will be very large.

To check your understanding, ask yourself: what does this mean about the bases? Which is a better base, H_2O or A^-? What we've stated is that the right side of the equilibrium is favored. **H_2O is much better** at accepting a proton (and becoming H_3O^+) than A^- is at accepting a proton (and becoming HA). HA is strong, so if A^- accepts a proton, HA will just give it away straight off. This introduces a need-to-know concept: A strong acid has a weak conjugate base.

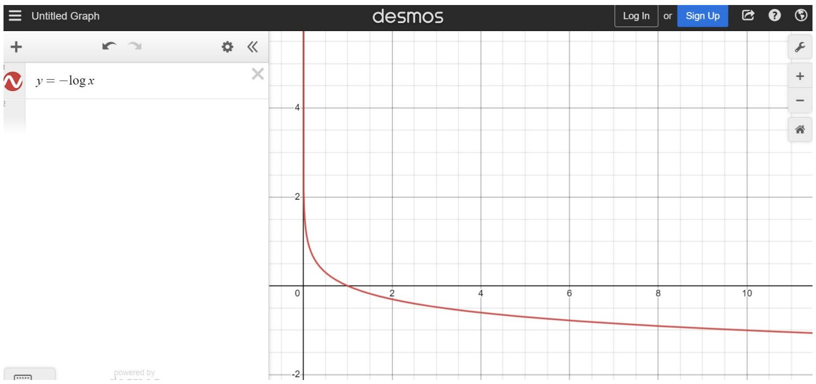
What about a weak acid? It is not very good at donating its proton, so we'll keep a lot of starting acid, which means K_c will be very small.

In this case, **A^- is a better base** than H_2O.

Often, since K_a values can be so small, they will be expressed as pK_a values instead.

p is an abbreviation that means negative log

As K_a increases, pK_a decreases. Think mathematically about why this would be – here's a graphical representation:



Comparing Acid Strengths:

1. The higher the pKa value, the lower the acidity
2. The higher the Ka value, the higher the acidity
3. Between oxyacids, the molecule with more oxygens will be more acidic (e.g. HClO4 > HClO3)
4. Between oxyacids, the more electronegative the element, the higher the acidity (e.g. HOF > HOCl)
5. Between binary acids, the more electronegative the element, the lower the acidity (e.g. HF < HCl)

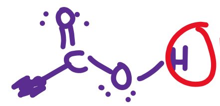
Highlight 3: Strong/Weak Acids/Bases to Know

Check with your professor to find out which strong/weak acids/bases you need to be able to identify as such! But here are some to get you started, and some reasoning to make them easier to remember.

This paragraph isn't generally a focus but may help with remembering strong/weak acids/bases! Keep in mind: a strong acid is something that will "like" to lose a proton – it will be **stable** in its conjugate base form. What does stable mean? Uncharged is ideal; **if the acid starts out positive**, it'll want to get rid of that charge. **If the acid starts out neutral**, its conjugate base will be negative, so to be strong, the conjugate base has to be something that's able to handle the negative charge. And what can handle the negative charge? Just FYI for now:

Electronegative atoms do well; large molecules are typically good because they can spread the charge out more. *Resonance* is especially helpful in spreading the charge out – see Gen Chem I.

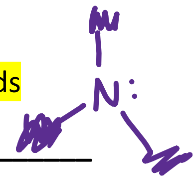
Strong acids: HCl, HBr, HI, HNO_3, $HClO_4$, H_2SO_4


hard to remove

Weak acids: carboxylic acids (anything with -COOH)

Strong bases: group 2 metal (except Be) + hydroxides

Weak bases: ammonia and derivatives (aka "amines"); any nitrogen with 3 covalent bonds



Check Your Learning

1. Write an equation showing what happens to this acid dissolved in water: $HNO_{3(aq)}$
2. Which of the following is a conjugate acid/base pair?
   a. HCl/HBr
   b. HNO_3/HNO_3^+
   c. H_2SO_4/HSO_4^-
   d. Br^-/I^+
3. As Ka increases, pKa _________
4. Acid X is stronger than Acid Y. Acid X will have a (<u>higher/lower</u>) pKa than Acid Y.
5. Which of the following is a weak acid? Hydroiodic acid, acetic acid, ammonia

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Things You May Struggle With

1. Practice writing the equations for acid and base dissociation in water. These become important for understanding other content!
2. If a compound has more than one proton, it may be hard to tell which of the protons is the one being donated! If there is an H at the front of the formula, it's that one—the most notable exception is carboxylic acids, which are sometimes written …COOH. In this case, the proton being donated is the H at the very end!

a. It depends on which proton is *most available*. You'll learn more about this in ochem!

That's all this week! Please reach out if you have any questions and don't forget to visit the Tutoring Center website for further information at www.baylor.edu/tutoring. Answers to Check Your Learning are below.

1. $HNO_{3(aq)} + H_2O_{(l)} \rightleftharpoons NO_3^-{}_{(aq)} + H_3O^+_{(aq)}$
2. c
3. decreases
4. lower
5. acetic acid CH_3COOH (a carboxylic acid)