Acids and Bases: The Basics: Student Review Notes

Acid-base chemistry has a great deal (maybe everything) to do with the equilibrium position of the **dissociation of water**.

$$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$$

Note: It is generally accepted that you can write the water dissociation reaction with the products as a proton and the hydroxide anion. In reality, it has been experimentally determined that protons attach themselves to a water molecule and exist as the hydronium ion, H_3O^+ in aqueous solution. It is easier to write H^+ than H_3O^+ and the notes will reflect that simplification.

The equliibirum constant for the **dissociation of water** is called K_w

$$K_w = [H^+][OH^-] = 1 \times 10^{-14} \text{ at } 25\ ^\circ C$$

* Water is a pure liquid and therefore not included in the equilibrium constant expression.
* The water dissociation constant is a function of temperature, as are all equilibirum constants.

Fundamental to acid-base chemistry is the fact that this equlibrium condition must be satisfied. The product of the hydrogen ion concentration and the hydroxide ion concentration must equal K_w and at 25 °C $K_w = 1 \times 10^{-14}$

Know Water Equilibrium
$K_w = [H^+][OH^-] = 10^{-14}$

To "p" something in chemistry means to take the negative logarithm base 10.

So,

$pH = -\log[H^+]$

$pOH = -\log[OH^-]$

$pbrain = -\log[brain]$

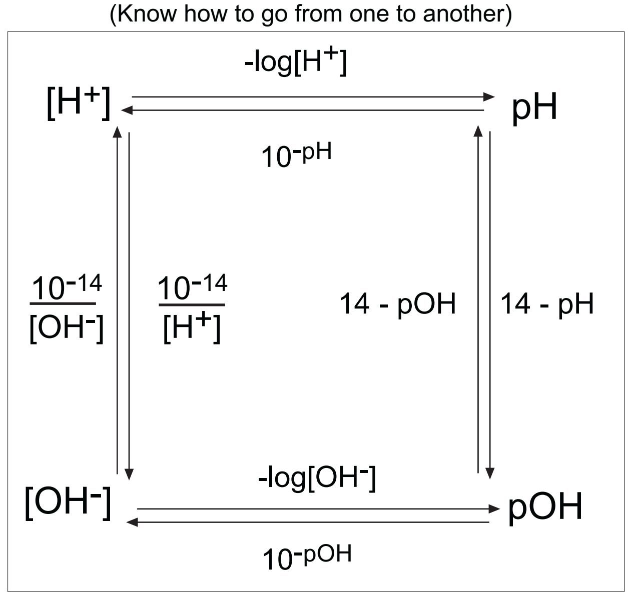
Using log rules and the K_w expression you can see where: $pH + pOH = 14$

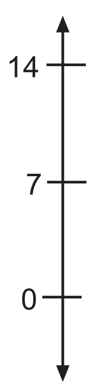
Exponentiation is the inverse operation of taking a log, so:

$[H^+] = 10^{-pH}$

$[OH^-] = 10^{-pOH}$

(Know how to go from one to another)





above pH = 7 a solution is considered to be basic: $[H^+] < [OH^-]$

pH = 7 is neutral. At 25 °C $[H^+] = [OH^-] = 1 \times 10^{-7}$

below pH = 7 a solution is considered to be acidic: $[H^+] > [OH^-]$

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Tricky example: What is the pH of a 5×10^{-8} M solution of the strong acid HCl? (strong acid means that it dissociates 100%)

Here is the typical mistake: Assume $[H^+] = 5 \times 10^{-8}$ M. It dissociates 100%, right?
Then the pH $= -\log(5 \times 10^{-8}) = 7.3$. BUT, that doesn't make sense. How can you add an acid to water and end up with a basic pH?

The calculation failed to take into account the $[H^+]$ that is already in solution.
In a neutral solution $[H^+] = 1 \times 10^{-7}$ M. The acid does dissociates 100%, and the hydrogen ions add to those already in solution. Therefore $[H^+] = 1 \times 10^{-7}\text{ M} + 5 \times 10^{-8}\text{ M} = [H^+] = 1.5 \times 10^{-7}$ M
Then the pH $= -\log(1.5 \times 10^{-7}) = 6.8$. An acidic pH value.

There are three definitions for acids and bases. They are both historically and practically based. The newest, the Lewis definition, is the most general, but it is a little more abstract. So the oldest, the Arrhenius definition, the most limiting but easiest to understand, is still around. The intermediate one, Bronsted-Lowry, is both easy and fairly general so it's a popular in-between. The long and short of it is that you could use the Lewis definition all of the time, but it is not quite friendly enough so the other two are still hanging on--it's like buying new sneakers.

1. **Arrhenius Concept:** Acids dissociate to produce H^+
   Bases dissociate to produce OH^-

   Works for HCl, H_2SO_4, NaOH but doesn't work for NH_3, etc.

2. **Bronsted-Lowry Concept:** An acid is a substance that can donate a proton (H^+) and a base is a substance that can accept a proton. (This is the conjugate acid-base pair idea)

   Works for NH_3 but doesn't work for metal hydroxides or other substances that react with H_2O to form H^+

"conjugate acid" -- formed by a base accepting a proton
"conjugate base" -- formed by an acid donating a proton

$$CH_3COO^-_{(aq)} + H_2O \rightleftharpoons CH_3COOH_{(aq)} + OH^-_{(aq)}$$

base | acid | conjugate acid | conjugate base

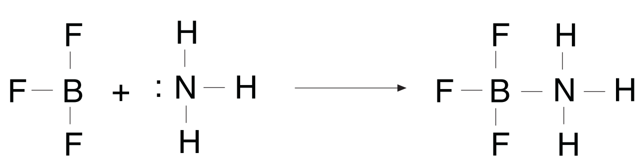
3. **Lewis Concept:** Acids are electron pair acceptors
   Bases are electron pair donors

   Works for all acids and bases

(These can be kind of weird, like: $Zn^{2+} + 4\,H_2O \longrightarrow Zn(H_2O)_4^{2+}$

Zn^{2+}: Lewis Acid; H_2O: Lewis Base

Or



Lewis acid   Lewis base