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Pre-Health Post-Baccalaureate Program
Study Guide and Practice Problems

Course: CHM2046

Textbook Chapter: 18.1-18.4 (Silberberg 6e)

Topics Covered: Acid-Base, Part 1

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Acids and Bases in Water

We must start with the Arrhenius A-B definition, the earliest of the A-B definitions, which categorizes acids as any substance that contains H and forms H_3O^+ in water, and bases as any substance that contains OH and forms OH^- in water.

$$HA \xrightarrow{H_2O} H^+ + A^-$$

acid

↳ forms H_3O^+ from water in system

$$MOH \xrightarrow{H_2O} M^+ + OH^-$$

base

We can also examine acid strength in terms of our old friend, Q_c:

$$HA + H_2O \rightarrow H_3O^+ + A^-$$

$$Q_c = \frac{[H_3O^+][A^-]}{[HA][H_2O]}$$

Strong acids disassociate completely in water into constituent ions, because, at equilibrium, $Q_c = K_c >>> 1$.

Weak acids disassociate only partially in water into constituent ions, because, at equilibrium, $Q_c = K_c <<< 1$.

At equilibrium, we can define K_c as:

$$K_c = \frac{[H_3O^+][A^-]}{[HA][H_2O]}$$

Because the [water] is so much larger than the [HA], [water] does not show significant change over the course of the reaction. We instead choose to simplify K and multiply both sides by [water], such that:

$$[H_2O]K_c = \frac{[H_3O^+][A^-]}{[HA]}$$

We then define the term on the left side of the equal sign above as a new value, K_a:

$$K_a = [H_2O]K_c = \frac{[H_3O^+][A^-]}{[HA]}$$

This value, K_a, is called the acid ionization constant, and it gives us an idea of the strength of a particular acid. The higher the K_a value, the more ion disassociation happening in the reaction, and the more acidic the substance is.

Autoionization and the pH scale

Maybe you have asked the question, “based on what we talked about on the last two slides, what’s stopping a bottle of water from turning into a bottle of hydronium and hydroxide ions? After all, a water molecules have a H and an OH!”

That’s exactly right, and nothing is stopping this. In fact, this process, called autoionization, is happening at a very low rate in water at equilibrium.

We can come up with another K value, called K_w, or the ion product constant for water:

$$H_2O + H_2O \rightarrow H_3O^+ + HO^-$$

$$K_c = \frac{[H_3O^+][HO^-]}{[H_2O]^2}$$

$$[H_2O]^2 K_c = [H_3O^+][HO^-]$$

$$K_w = [H_2O]^2 K_c = [H_3O^+][HO^-]$$

At 25 centigrade, $K_w = 1.0 \times 10^{-14}$. This constant is a good one to have memorized, and works as a nice conversion factor to determine the concentrations of hydronium or hydroxide present in a sample.

We have talked about the Arrhenius A-B definition, but a mathematical definition is determined by the K_w equation.

If [hydronium] > [hydroxide], then the solution is acidic.

If [hydronium] = [hydroxide], then the solution is neutral.

If [hydronium] < [hydroxide], then the solution is basic.

Another mathematical definition is given by the pH scale, which I am sure you are at least somewhat familiar with. Anytime we see "p," we should thing "-log." pH, then, means $-\log[H^+]$ (or $-\log[H_3O^+]$).

$\uparrow [H_3O^+] = \uparrow A$

$\downarrow pH = \uparrow A$

If pH < 7, then the solution is acidic.

If pH = 7, then the solution is neutral.

If pH > 7, then the solution is basic.

Furthermore, we can use logarithmic math to show relationships between K_w, $[H_3O^+]$ and other values.

$$K_w = [H_3O^+][HO^-] = 1 \times 10^{-14}$$

$$-\log K_w = (-\log[H_3O^+]) + (-\log[HO^-]) = -\log(1 \times 10^{-14})$$

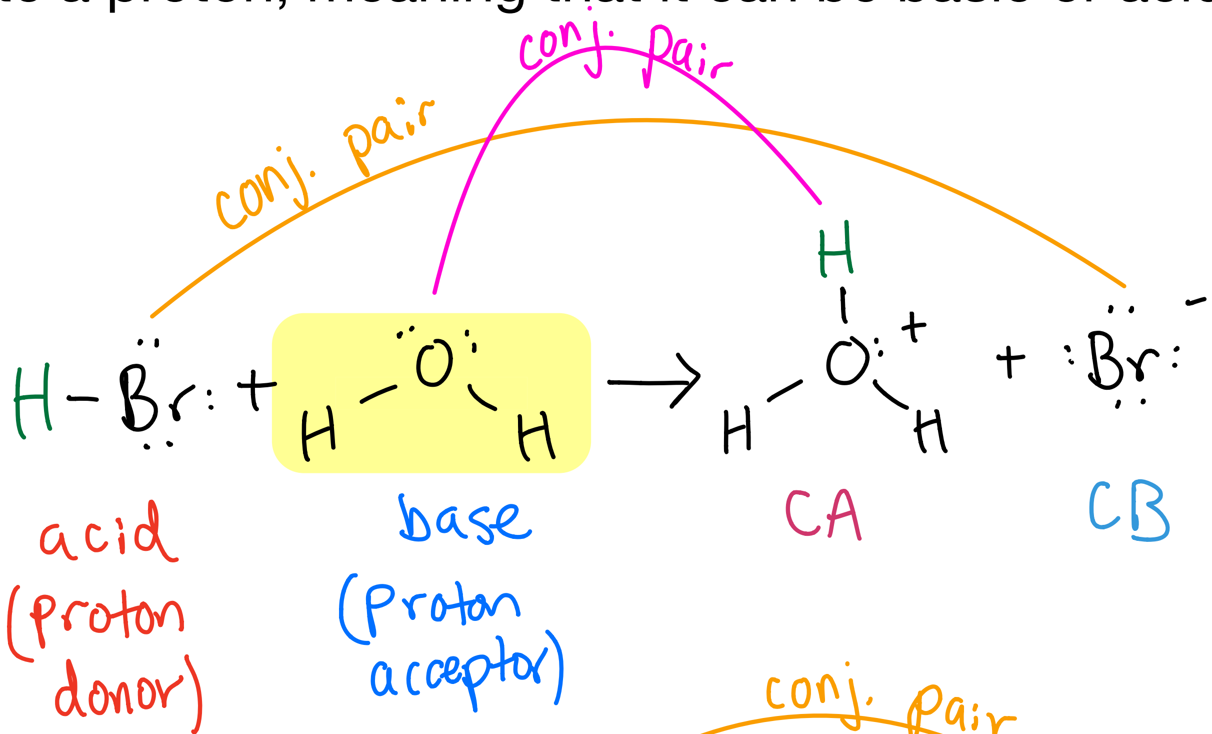
$$pK_w = pH + pOH = 14$$

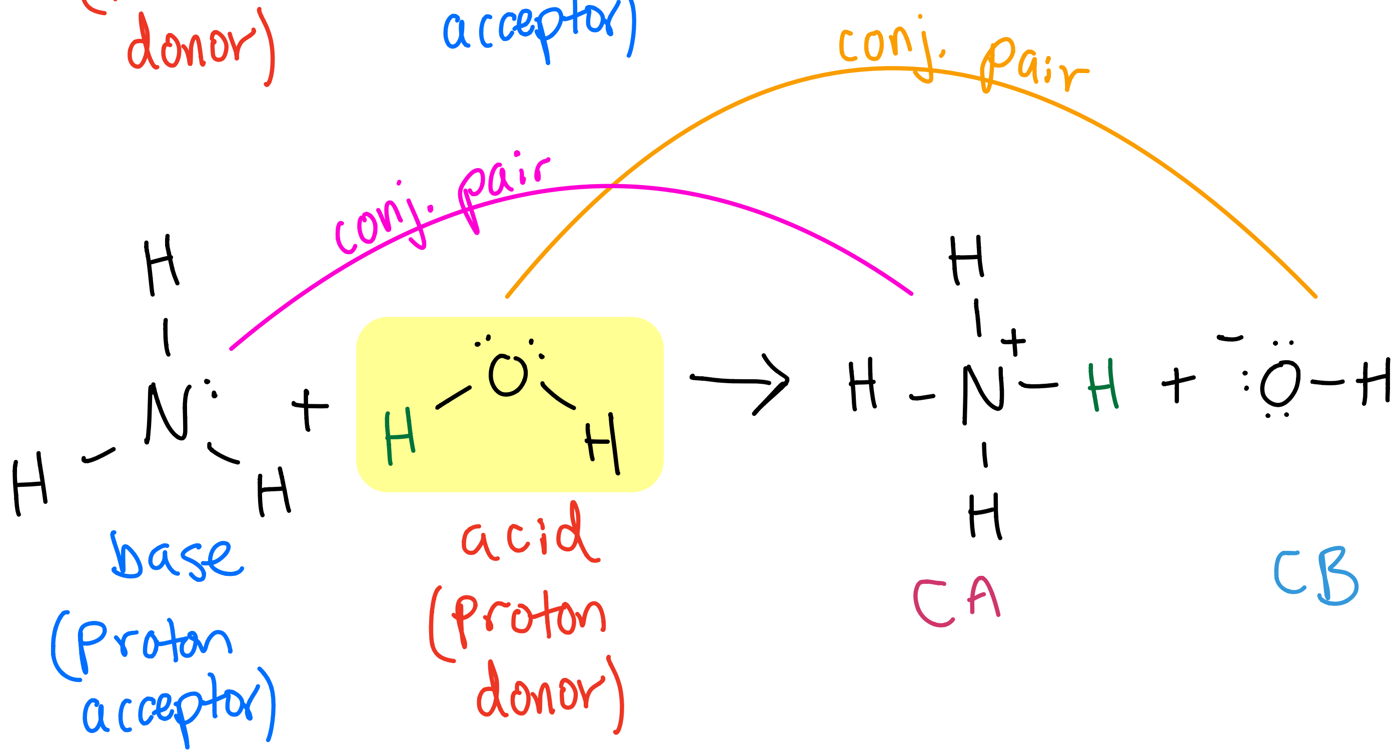
*at 25°C

Proton Transfer and the Brønsted-Lowry A-B Definition

Let's cover yet another A-B definition: the Brønsted-Lowry definition. The basis of this theory is that certain chemical species donate protons (H^+), while other chemical species accept protons.

Look at the following examples. Note: water can accept OR donate a proton, meaning that it can be basic or acidic!





Problems:

(1) Propanoic acid (CH_3CH_2COOH or HPr) is a carboxylic acid used to prevent mold growth. What is the $[H_3O^+]$ of 0.10 M HPr ($K_a = 1.3 \times 10^{-5}$)?

① Propanoic acid (CH_3CH_2COOH or HPr) is a carboxylic acid used to prevent mold growth. What is the $[H_3O^+]$ of 0.10 M HPr ($K_a = 1.3 \times 10^{-5}$)?

	HPr	+ H_2O	$\rightleftharpoons$ H_3O^+	+ Pr^-
I	0.10	—	0	0
C	−x	—	+x	+x
E	0.10−x	—	x	x

$$K_a = \frac{[H_3O^+][Pr^-]}{[HPr]} = \frac{(x)(x)}{0.10-x} = 1.3 \times 10^{-5}$$

$$\Rightarrow \frac{x^2}{0.1} = 1.3 \times 10^{-5}$$

$$x = [H_3O^+] = 1.1 \times 10^{-3}\ M$$

(2) A chemist adds a measured amount of $HCl_{(g)}$ to water at 25°C and obtains a solution with $[H_3O^+] = 3 \times 10^{-4}$ M. Calculate the $[HO^-]$ and determine if the solution is acidic, neutral, or basic.

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$$K_w = [H_3O^+][^-OH] = 1\times10^{-14}$$

$$[^-OH] = \frac{K_w}{[H_3O^+]} = \frac{1\times10^{-14}}{3\times10^{-4}} = 3.3\times10^{-11}\,M$$

$$[H_3O^+] > [^-OH]$$

$$3\times10^{-4}\,M > 3.3\times10^{-11}\,M$$

Solution is acidic

③ Classify the following as SA, WA, SB, WB:

a) KOH

b) $(CH_3)_2CHCOOH$

c) H_2SeO_4

d) $(CH_3)_2CHNH_2$

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a) KOH SB

b) $(CH_3)_2CHCOOH$ WA

c) H_2SeO_4 SA

d) $(CH_3)_2CHNH_2$ WB