6.4 Comparing the Strength of Acids and Bases

pages 582-590 in Health

***Reminder: A base is a proton* (H^+) acceptor and an acid is a proton donor.

A strong base readily accepts a proton.

Comparing the strength of acids and bases allows us to make predictions about chemical reactions. (Referring to Table 14)

ex: When sodium bicarbonate and hydrofluoric acid are combined in an aqueous solution, what reaction is likely to occur?

$$HCO_3^- + HF$$

If we look at our table we can see that HF is a stronger acid than HCO_3^- therefore HF will act as the acid in the reaction and give up the proton

$$\underset{base_2}{HCO_3^-} + \underset{acid_1}{HF} \rightleftharpoons \underset{acid_2}{H_2CO_3} + \underset{base_1}{F^-}$$

In addition, the K_a and K_b values can help us determine hydronium and hydroxide ion concentrations within a solution of weak acid or base.

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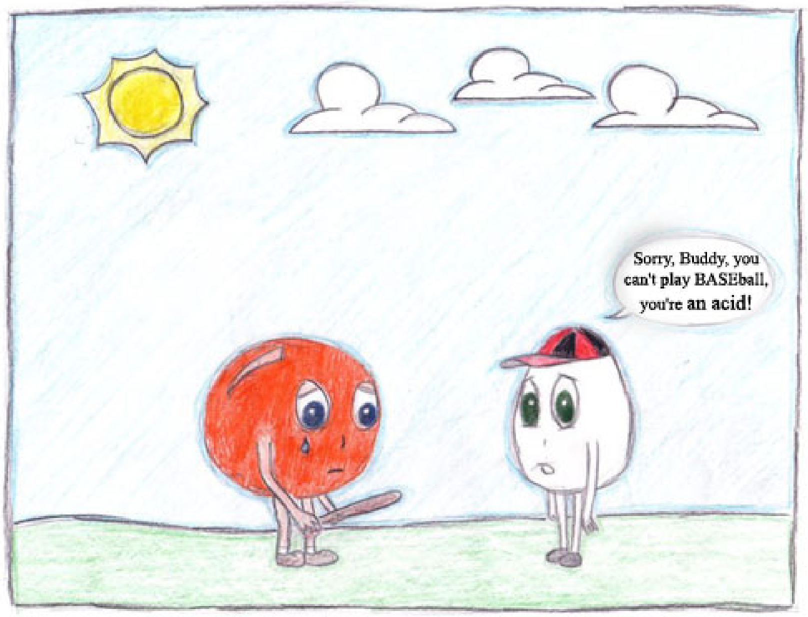

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K_a and K_b Values

Name of Acid	Acid	K_a	Name of Base	Base	K_b
Sulfuric acid	H_2SO_4	large	hydrogen sulfate ion	HSO_4^-	very small
Hydrochloric acid	HCl	large	chloride ion	Cl^-	very small
Nitric acid	HNO_3	large	nitrate ion	NO_3^-	very small
Hydronium ion	H_3O^+	55.5	water	H_2O	1.8×10^{-16}
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	sulfate ion	SO_4^{2-}	8.3×10^{-13}
Phosphoric acid	H_3PO_4	7.5×10^{-3}	dihydrogen phosphate ion	$H_2PO_4^-$	1.3×10^{-12}
Hexaaquairon(III) ion	$Fe(H_2O)_6^{3+}$	6.3×10^{-3}	pentaaquahydroxoiron(III) ion	$Fe(H_2O)_5OH^{2+}$	1.6×10^{-12}
Hydrofluoric acid	HF	7.4×10^{-4}	fluoride ion	F^-	1.4×10^{-11}
Formic acid	HCO_2H	1.8×10^{-4}	formate ion	HCO_2^-	5.6×10^{-11}
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	benzoate ion	$C_6H_5CO_2^-$	1.6×10^{-10}
Acetic acid	CH_3CO_2H	1.8×10^{-5}	acetate ion	$CH_3CO_2^-$	5.6×10^{-10}
Hexaaquaaluminum ion	$Al(H_2O)_6^{3+}$	7.9×10^{-6}	pentaaquahydroxoaluminum ion	$Al(H_2O)_5OH^{2+}$	1.3×10^{-9}
Carbonic acid	H_2CO_3	4.2×10^{-7}	hydrogen carbonate ion	HCO_3^-	2.4×10^{-8}
Hydrogen sulfide	H_2S	1×10^{-7}	hydrogen sulfide ion	HS^-	1×10^{-7}
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	hydrogen phosphate ion	HPO_4^{2-}	1.6×10^{-7}
Hypochlorous acid	$HClO$	3.5×10^{-8}	hypochlorite ion	ClO^-	2.9×10^{-7}
Ammonium ion	NH_4^+	5.6×10^{-10}	ammonia	NH_3	1.8×10^{-5}
Hydrocyanic acid	HCN	4.0×10^{-10}	cyanide ion	CN^-	2.5×10^{-5}
Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	3.2×10^{-10}	pentaaquahydroxoiron(II) ion	$Fe(H_2O)_5OH^+$	3.1×10^{-5}
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	carbonate ion	CO_3^{2-}	2.1×10^{-4}
Hydrogen phosphate ion	HPO_4^{2-}	3.6×10^{-13}	phosphate ion	PO_4^{3-}	2.8×10^{-2}
Water	H_2O	1.8×10^{-16}	hydroxide ion	OH^-	55.5
Hydrogen sulfide ion	HS^-	1×10^{-19}	sulfide ion	S^{2-}	1×10^{5}

Finding ion concentrations for **weak** acids and bases require the following approach.

Remember that if you look on your chart of strong and weak acids and you see a small K_a value, you have a weak acid

Steps:
1. Write the balanced ionization or dissociation equation.

2. Find the K_a value from the relative strengths of acids and chart. K_b values will be given in the question.

3. Use the equilibrium constant expression to solve for the concentrations.

Note - the reason why we cannot use the same method for strong acids and bases is because weak acids or bases do not completely ionize.

Ex) Calculate the hydrogen ion concentration in a 0.10 M acetic acid solution.

Ex) Calculate the hydroxide ion concentration in a 0.025 M solution of analine, $C_6H_5NH_2$, a weak base with $K_b = 4.3 \times 10^{-10}$.

Calculating [OH^-] in WEAK Acids and [H_3O^+] in WEAK Bases

Again, we may be asked to find [OH^-] in an **acid** or the [H^+] in a **base**.

Remember that we are calculating the ion concentrations for acid/base **solutions**, which means they are mixed with water.

If we mix an acid with water, we are adding OH^- to the acid because water does ionize a bit. Therefore, we can use K_w to calculate [OH^-].

Ex) What is [OH^-] for a 0.100 M solution of HNO_2?

Likewise, if we are adding water to a base, we are actually adding H^+ ions. We also use K_w to calculate [H_3O^+] in a basic solution.

Ex) What is the [H_3O^+] in a 0.025 M solution of NaOH (a strong base)?

Ex) For the last two examples, are the solutions acidic or basic?

6.4 – Comparing the Strength of Acids and Bases Assignment

Hint: check to see whether you are dealing with a strong or weak acid/base before starting the question.

1. Calculate $[H^+]$ in a 2.00 L solution of HCl in which 3.65 g of HCl is dissolved.

2. Calculate $[H^+]$ in a solution containing 3.20 g of HNO_3 in 250 mL of solution.

3. An acetic acid ($HC_2H_3O_2$) solution is 0.25 M. Find $[H_3O^+]$.

4. A 500.0 mL solution contains 12.0 g of hydrofluoric acid. Calculate $[H^+]$.

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5. When 1.22 g of benzoic acid (C_6H_5COOH) is dissolved to make 1.00L of solution, the resulting equilibrium $[H^+] = 8.0x10^{-4}$ M. Determine the K_a of the acid. *(Hint: think ICEBOX)*

6. Calculate $[H^+]$ **and** $[OH^-]$ at 25° C in:

   a. a 5.0 M NaOH solution. NaOH is a strong base.

   b. a 0.025 M $Ca(OH)_2$ solution. $Ca(OH)_2$ is a strong base.

   c. a 0.10 M hypochlorous acid solution.

   d. a 0.010 M Nitrous acid solution.