Acid and Base Strength

Sections 9.3-9.4

Strength

- Determined by the amount of acid (or base) that dissociates in water
- The more dissociation, the stronger the acid (or base)
- A strong acid (or base) dissociates 100% in water
  - Use a single reaction arrow
  - Product is greatly favored at equilibrium

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

strong acid conjugate base

Strength

- Weak acids (or bases) only partially dissociate when dissolved in water
  - Use double reaction arrow
  - Reactants are favored at equilibrium

$$CH_3COOH(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + CH_3COO^-(aq)$$

weak acid

conjugate base

Strength

Table 9.1 Relative Strength of Acids and Their Conjugate Bases

Acid			Conjugate Base		
Increasing acid strength	**Strong Acids**				Increasing base strength
	Hydroiodic acid	HI	I^-	Iodide ion	
	Hydrobromic acid	HBr	Br^-	Bromide ion	
	Hydrochloric acid	HCl	Cl^-	Chloride ion	
	Sulfuric acid	H_2SO_4	HSO_4^-	Hydrogen sulfate ion	
	Nitric acid	HNO_3	NO_3^-	Nitrate ion	
	Hydronium ion	$\mathbf{H_3O^+}$	$\mathbf{H_2O}$	**Water**	
	Weak Acids				
	Phosphoric acid	H_3PO_4	$H_2PO_4^-$	Dihydrogen phosphate ion	
	Hydrofluoric acid	HF	F^-	Fluoride ion	
	Acetic acid	CH_3COOH	CH_3COO^-	Acetate ion	
	Carbonic acid	H_2CO_3	HCO_3^-	Bicarbonate ion	
	Ammonium ion	NH_4^+	NH_3	Ammonia	
	Hydrocyanic acid	HCN	CN^-	Cyanide ion	
	Water	H_2O	OH^-	Hydroxide ion	

Example #1

Which is the stronger acid in each pair?

a. H_2SO_4 or H_3PO_4

b. HF or HCl

c. HCN or HF

Example #1 Solved

a. **H_2SO_4** or H_3PO_4

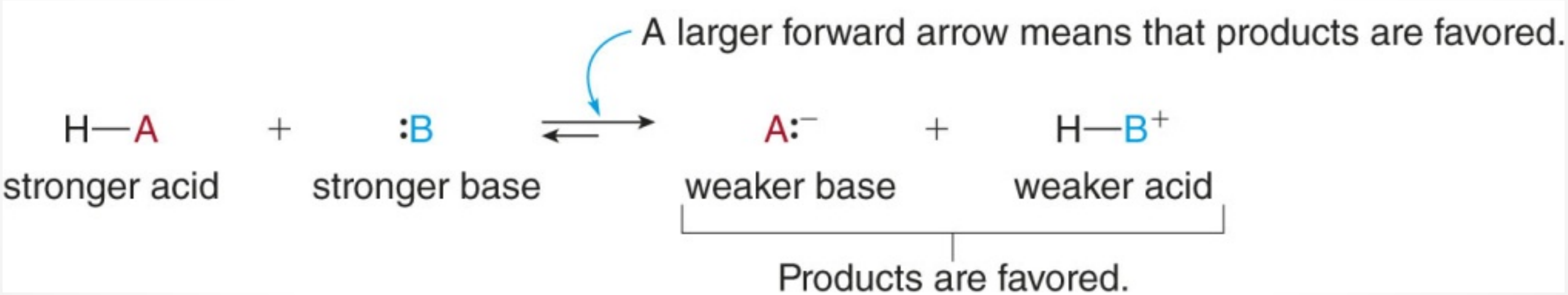
b. HF or **HCl**

c. HCN or **HF**

According to table of relative acid strengths

Equilibrium Direction

- Stronger acid reacts with stronger base to form weaker acid and weaker base



- Equilibrium favors weaker acid

Example #2

Are the reactants or products favored at equilibrium in the following reaction?

$$NH_4^+(aq) + Cl^-(aq) \rightleftarrows NH_3(aq) + HCl(aq)$$

Example #2 Solved

- Identify the acid in the reactants and the acid in the products

$$NH_4^+(aq) + Cl^-(aq) \rightleftarrows NH_3(aq) + HCl(aq)$$

acid acid

- Identify which is the weaker acid: NH_4^+
- NH_4^+ is a reactant, so **reactants are favored**

Dissociation Constants

- A qualitative value which represents amount of dissociation of acid (or base)

- When acids (or bases) reach equilibrium, concentrations are constant just like before

Reaction

$$HA(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + A^-(aq)$$

Equilibrium Constant

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

K

- Equilibrium constant, K, from chapter 7
- Same concept, same set up
- For acids, we label it $\mathbf{K_a}$

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

acid dissociation constant

K_a and Acid Strength

- The stronger the acid, the more dissociation
- The more dissociation, the higher concentration of products, $[H_3O^+]$ and $[A^-]$
- The higher the concentrations of the products, the higher the K_a value
- **The stronger the acid, the higher the K_a value**

K_a

Table 9.2 Acid Dissociation Constants (K_a) for Common Weak Acids

	Acid	Structure	K_a
Increasing acidity ↑	Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}
	Phosphoric acid	H_3PO_4	7.5×10^{-3}
	Hydrofluoric acid	HF	7.2×10^{-4}
	Acetic acid	CH_3COOH	1.8×10^{-5}
	Carbonic acid	H_2CO_3	4.3×10^{-7}
	Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}
	Ammonium ion	NH_4^+	5.6×10^{-10}
	Hydrocyanic acid	HCN	4.9×10^{-10}
	Bicarbonate ion	HCO_3^-	5.6×10^{-11}
	Hydrogen phosphate ion	HPO_4^{2-}	2.2×10^{-13}

Example #3

Rank the following acids in order of increasing strength.

HCN, HF, CH_3COOH

Example #3 Solved

Increasing strength means start with weakest.

$HCN < CH_3COOH < HF$

Example #4

Which is the stronger base in each pair?

a. CN^- or NH_3

b. NO_3^- or OH^-

c. Cl^- or F^-

Example #5

Are the reactants or products favored at equilibrium in the following reaction?

$$H_3O^+(aq) + HCO_3^-(aq) \rightleftarrows H_2CO_3(aq) + H_2O(l)$$

Example #6

Consider the weak acids. HCN and H_2CO_3

a. Which acid has the larger K_a?

b. Which acid is stronger?

c. Which acid has the stronger conjugate base?

d. When each acid is dissolved in water, for which acid does the equilibrium lie further to the right?