Bronsted-Lowry Acids & Bases
Ka and pKa

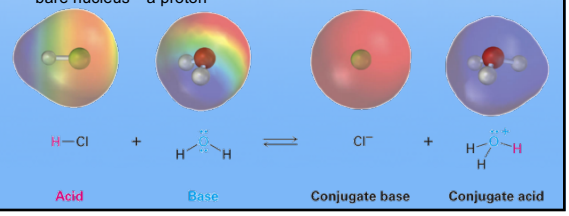
Organic Chemistry
Mrs. Dormer

Acids and Bases: The Brønsted–Lowry Definition

- The terms "**acid**" and "**base**" can have different meanings in different contexts
- For that reason, we specify the usage with more complete terminology
- The idea that acids are solutions containing a lot of "H^+" and bases are solutions containing a lot of "OH^-" is not very useful in organic chemistry
- Instead, Brønsted–Lowry theory defines acids and bases by their role in reactions that transfer protons (H^+) between donors and acceptors

Brønsted Acids and Bases

- "**Brønsted-Lowry**" is usually shortened to "**Brønsted**"
- A **Brønsted acid** is a substance that donates a hydrogen cation (H^+)
- A **Brønsted base** is a substance that accepts the H^+
  - "proton" is a synonym for H^+ - loss of an electron from H leaving the bare nucleus—a proton



Acid and Base Strength

- The **acidity constant** (K_a) for the reaction of an acid (HA) with water to form hydronium ion and the conjugate base (A^-) is a measure related to the strength of the acid
- Stronger acids have larger K_a
- Note that brackets [ ] indicate concentration, moles per liter, M.

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

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

The Acidity Constant for Water

- The concentration of water as a solvent does not change significantly when it is protonated
- The molecular weight of H_2O is 18 and one liter weighs 1000 grams, so the concentration is ~ 55.6 M at 25°
- Allows for the comparison of other weak acids with water.
- K_a ranges from 10^{15} for the strongest acids to very small values (10^{-60}) for the weakest

$$\underset{\text{(acid)}}{H_2O} + \underset{\text{(solvent)}}{H_2O} \rightleftharpoons OH^- + H_3O^+$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{[H_3O^+][OH^-]}{[H_2O]} = \frac{[1.0 \times 10^{-7}][1.0 \times 10^{-7}]}{[55.4]} = 1.8 \times 10^{-16}$$

pK_a – the Acid Strength Scale

- $pK_a = -\log K_a$
- A smaller value of pK_a indicates a stronger acid and is proportional to the energy difference between products and reactants
- The pK_a of water is 15.74

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$$pK_a = 15.74$$

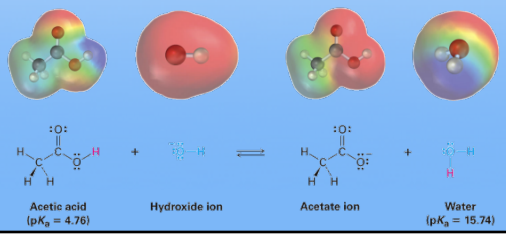
pK_a's of Some Common Acids

Table 1.2 Relative Strengths of Some Common Acids and Their Conjugate Bases

	Acid	Name	pK_a	Conjugate base	Name	
Weaker acid	CH_3CH_2OH	Ethanol	16.00	$CH_3CH_2O^-$	Ethoxide ion	Stronger base
	H_2O	Water	15.74	HO^-	Hydroxide ion	
	HCN	Hydrocyanic acid	9.31	CN^-	Cyanide ion	
	$H_2PO_4^-$	Dihydrogen phosphate ion	7.21	HPO_4^{2-}	Hydrogen phosphate ion	
	CH_3CO_2H	Acetic acid	4.76	$CH_3CO_2^-$	Acetate ion	
	H_3PO_4	Phosphoric acid	2.16	$H_2PO_4^-$	Dihydrogen phosphate ion	
	HNO_3	Nitric acid	−1.3	NO_3^-	Nitrate ion	
Stronger acid	HCl	Hydrochloric acid	−7.0	Cl^-	Chloride ion	Weaker base

Predicting Acid–Base Reactions from pK_a Values

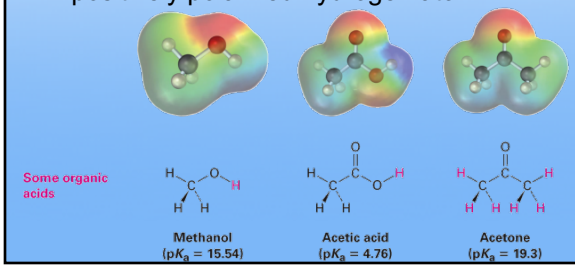
- pK_a values are related as logarithms to equilibrium constants
- Useful for predicting whether a given acid-base reaction will take place
- The stronger base holds the proton more tightly



Acetic acid (pK_a = 4.76) | Hydroxide ion | Acetate ion | Water (pK_a = 15.74)

Organic Acids and Organic Bases

- Organic Acids:
  - characterized by the presence of positively polarized hydrogen atom



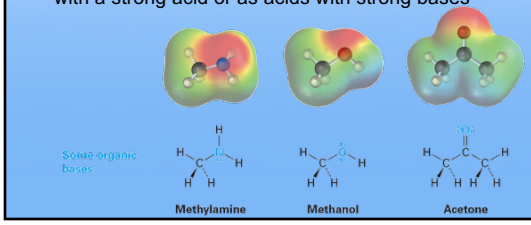
Methanol (pK_a = 15.54) | Acetic acid (pK_a = 4.76) | Acetone (pK_a = 19.3)

Organic Acids

- Those that lose a proton from O–H, such as methanol and acetic acid
- Those that lose a proton from C–H, usually from a carbon atom next to a C=O double bond (O=C–C–H)

Organic Bases

- Have an atom with a lone pair of electrons that can bond to H^+
- Nitrogen-containing compounds derived from ammonia are the most common organic bases
- Oxygen-containing compounds can react as bases when with a strong acid or as acids with strong bases



Methylamine | Methanol | Acetone