Brønsted-Lowry Definition

In the Brønsted-Lowry definition, an acid **donates a proton** (H^+) in a reaction, while a base **accepts** a proton in a reaction:

$$\mathbf{HCO_3^-}\ (aq) + H_2O\ (aq) \rightleftharpoons CO_3^{2-}\ (aq) + H_3O^+\ (aq)$$

$$\mathbf{HA}\ (aq) + H_2O\ (aq) \rightleftharpoons A^{2-}\ (aq) + H_3O^+\ (aq)$$

$$\mathbf{HCO_3^-}\ (aq) + H_2O\ (aq) \rightleftharpoons H_2CO_3\ (aq) + OH^-\ (aq)$$

$$\mathbf{B}\ (aq) + H_2O\ (aq) \rightleftharpoons HB^+\ (aq) + OH^-\ (aq)$$

*compounds that can behave as either an acid or a base are **amphiprotic**.

✓ Identify and describe solutions of acids and bases using Ka, pH, and pOH.

What is the conjugate base of HPO_4^{2-} ?

a. H_3PO_4

b. $H_2PO_4^-$

c. PO_4^{3-}

d. HPO_3^{2-}

The equilibrium constant for the reaction of a B-L acid with water, producing H_3O^+, is the *acid dissociation constant*, or K_a:

$$\mathbf{HCO_3^-}\ (aq) + H_2O\ (aq) \rightleftharpoons CO_3^{2-}\ (aq) + H_3O^+\ (aq)$$

For the reaction of a B-L base with water, producing OH^- the equilibrium constant is called the *base dissociation constant*, or K_b:

$$\mathbf{HCO_3^-}\ (aq) + H_2O\ (aq) \rightleftharpoons H_2CO_3\ (aq) + OH^-\ (aq)$$

✓ Describe (quantitatively and qualitatively) the relationship between the Ka of an acid, the Kb of its conjugate base, and Kw for the auto-ionization of water.

The K_a and K_b are related through K_w, the *autoionization constant for water.*

Another useful measure is the **pK_a** and **pK_b** for a compound. Like pH, this is a –log of the quantity:

$$pH = -\log(H^+) \qquad pOH = -\log(OH^-)$$

$$pK_a = -\log(K_a) \qquad pK_b = -\log(K_b)$$

✓ Describe (quantitatively and qualitatively) the relationship between the Ka of an acid, the Kb of its conjugate base, and Kw for the auto-ionization of water.

The value for K_w depends on temperature, like all equilibrium constants.

At 25°C, K_w is 1.0×10^{-14}.

At 50°C, K_w is 5.5×10^{-14}. What is the pH of pure water at 50°C?

a. Greater than 7

b. 7

c. Less than 7

What is the pH of a 0.050 M solution of $Ba(OH)_2$? Barium hydroxide dissociates completely in water.

✓ Relate Ka and pH to the equilibrium concentrations of all species present in a monoprotic acid or base solution.

A larger value of K_a means that the compound reacts more with water – it is a *stronger acid*.

A **strong acid** dissociates (nearly) completely in water. Very little of the original acidic form ("HA") remains when dissolved in water.

- approx. $K_a > 55$, or $pK_a < -1.74$
- e.g. K_a for HCl: $\sim 10^6$
- There are 7 known strong acids (*hint: they're on your Data Sheet!)*

A **weak acid** dissociates partially: on addition to water, some of the original compound reacts, but not all.

- All acids that are not "strong" (or neutral) are "weak".

A **very weak acid** (i.e. a *neutral compound)* does not produce H_3O^+ in water.

- approx. $K_a < 2\times10^{-16}$, or $pK_a > 15.74$

Strong/weak/very weak bases follow the same guidelines, based on K_b values.

Common strong bases: hydroxides of Groups 1 and 2 (These are on your Data Sheet too!)

✓ Compare the relative strengths of acids or bases using pH, pKa, pKb, and % dissociation

A 0.1 M solution of each of the compounds below is prepared. Which solution will be the *most* acidic?

a) Hydrocyanic acid - $pK_a = 9.21$

b) Benzoic acid - $pK_a = 4.20$

c) Ammonia - $pK_b = 4.74$

✓ Compare the relative strengths of acids or bases using pH, pKa, pKb, and % dissociation

What is the % ionization of a 0.1 M solution of sodium cyanide (NaCN)?

K_a for HCN is 4.9×10^{-10}.

✓ Compare the relative strengths of acids or bases using pH, pKa, pKb, and % dissociation

Ions as Acids and Bases

Many acids and bases are delivered not as their fully protonated forms, but as a salt of their conjugate acid or base.

- for example: sodium acetate (the salt of acetic acid)

Predicting whether a salt solution will be generally acidic, basic, or neutral is practically useful, and also helps direct equilibrium calculations.

Generally, salts that cause a change in pH are called *hydrolyzing salts* as they react with water in solution.

Acids/bases that are “very weak” (i.e. the conjugates of strong acid/base) **do not** hydrolyze – “weak” and “strong” acids/bases **do** hydrolyze.

✓ Predict the relative pH of a salt solution.

Cation	Anion	Hydrolyzing? (+)	(-)	pH	Example
Salt of strong base	Salt of strong acid	No	No	neutral	NaCl
Salt of strong base	Salt of a weak acid	No	Yes	Basic (>7)	NaF
Salt of weak base	Salt of strong acid	Yes	No	Acidic (<7)	NH_4Cl

*Remember! The *stronger* an acid, the *weaker* its' conjugate base – so the salt (conjugate base) of a "strong" acid is a "very weak" base! (and vice versa)

Which of the following solutions should have a pH greater than 7?

	Hint: Identify the ANION:	And CATION for each salt:
a. $Al(ClO_4)_3$		
b. $Ba(CH_3COO)_2$		
c. KNO_3		
d. NH_4Cl		
e. CH_3NH_3Br		

Cation	K_a
Fe^{2+}	3.2×10^{-10}
Zn^{2+}	2.5×10^{-10}
Ni^{2+}	2.5×10^{-11}
Fe^{3+}	6.3×10^{-3}
Cr^{3+}	1.6×10^{-4}
Al^{3+}	1.4×10^{-5}

Compound	K
Acetic acid (CH_3COOH)	$K_a = 1.8x10^{-5}$
Ammonia (NH_3)	$K_b = 1.8x10^{-5}$
Methylamine (CH_3NH_2)	$K_b = 4.4x10^{-4}$