N36 – Acid Base

Quick Review

Acid/Base Definitions

Arrhenius Model

- Acids produce H^+ in aqueous sol'ns
- Bases produce OH^- in aqueous sol'ns

$$HNO_3 \rightarrow H^+ + NO_3^-$$
$$KOH \rightarrow K^+ + OH^-$$

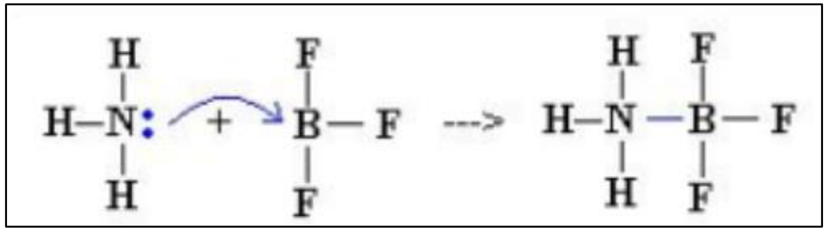
Bronsted-Lowry Model

$$NH_3 + HCl \rightleftharpoons NH_4^+ + Cl^-$$

- Acids are proton donors
- Bases are proton acceptors

Lewis Acid Model

- Acids are electron pair acceptors
- Bases are electron pair donors



Problems with Arrhenius Theory

Does not explain why:

- Molecular substances, such as NH_3, dissolve in water to form basic solutions, even though they do not contain $OH^–$ ions.
- How some ionic comp, such as Na_2CO_3 or Na_2O, dissolve in water to form basic sol’ns, even though they dont contain OH
- Why molecular substances, such as CO_2, dissolve in water to form acidic solutions, even though they do not contain H^+ ions.
- Acid–base reactions that take place outside aqueous solution.

Brønsted–Lowry Acid–Base Theory

- It defines acids and bases based on what happens in a rxn.
- Any reaction involving H^+ (proton) that transfers from one molecule to another is an acid–base reaction, regardless of whether it occurs in aqueous solution or if there is OH^- present.
- All reactions that fit the Arrhenius definition also fit the Brønsted–Lowry definition.

Brønsted–Lowry Theory

In a Brønsted–Lowry acid–base reaction, the acid molecule donates an H^+ to the base molecule.

$$H\text{–}A + :B \Leftrightarrow :A^- + H\text{–}B^+$$

$$NH_3 + HCl \rightleftharpoons NH_4^+ + Cl^-$$

- The **acid** is an H^+ donor.
- The **base** is an H^+ acceptor.
  - Base structure must contain an atom with an unshared pair of electrons.

Brønsted–Lowry Acids

- H^+ donors.
  - Any material that has H can potentially be a Brønsted–Lowry acid.
  - Because of the molecular structure, often one H in the molecule is easier to transfer than others.

- When HCl dissolves in water, the HCl is the acid because HCl transfers an H^+ to H_2O, forming H_3O^+ ions.
  - Water acts as base, accepting H^+.

$$\mathbf{HCl(\mathit{aq}) + H_2O(\mathit{l}) \rightarrow Cl^-(\mathit{aq}) + H_3O^+(\mathit{aq})}$$

Acid **Base**

Amphoteric Substances

Amphoteric substances can act as either an acid or a base because they have both a transferable H and an atom with lone pair electrons.

- Water acts as base, accepting H^+ from HCl.

$$\mathbf{HCl}(aq) + \mathbf{H_2O}(l) \leftrightarrow \mathbf{Cl^-}(aq) + \mathbf{H_3O^+}(aq)$$

- Water acts as acid, donating H^+ to NH_3.

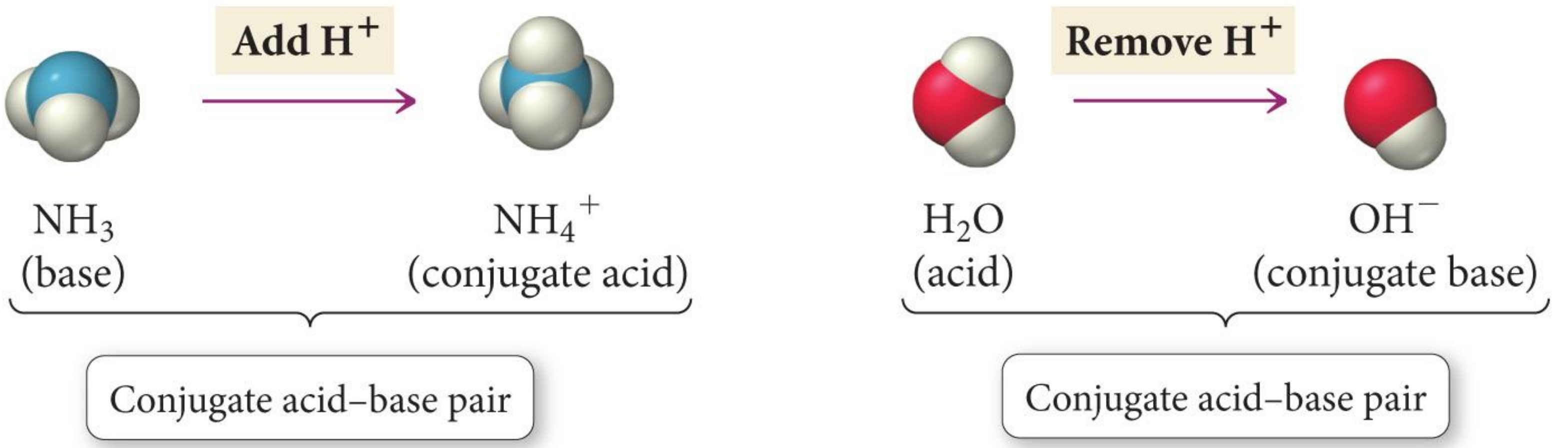
$$\mathbf{NH_3}(aq) + \mathbf{H_2O}(l) \leftrightarrow \mathbf{NH_4^+}(aq) + \mathbf{OH^-}(aq)$$

Conjugate Acid–Base Pairs

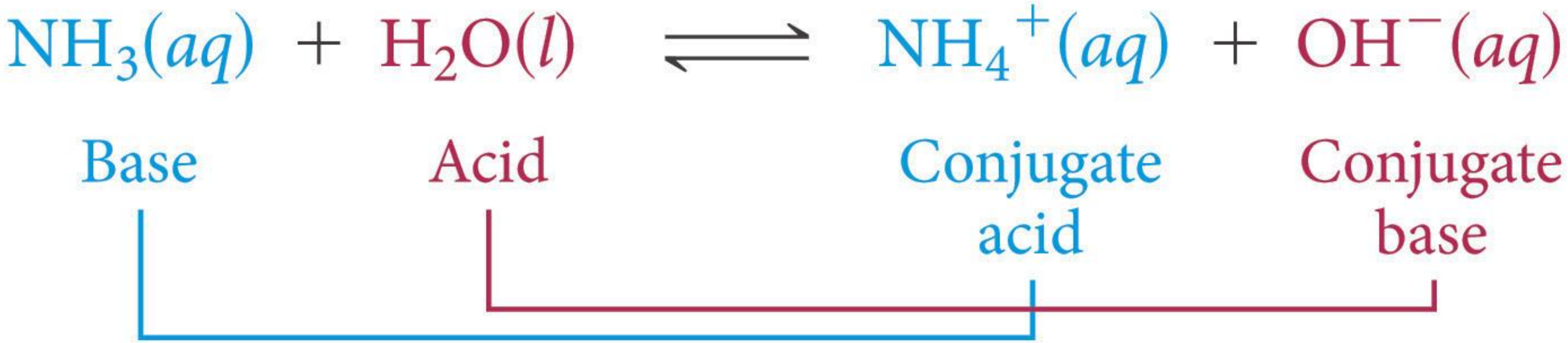
The original base becomes an acid in the reverse reaction.

The original acid becomes a base in the reverse process.

- Each reactant and the product it becomes is called a **conjugate pair**.



Conjugate Pairs



A base accepts a proton and becomes a conjugate acid.

An acid donates a proton and becomes a conjugate base.

Acid Dissociation

$HA \rightarrow H^+ + A^-$

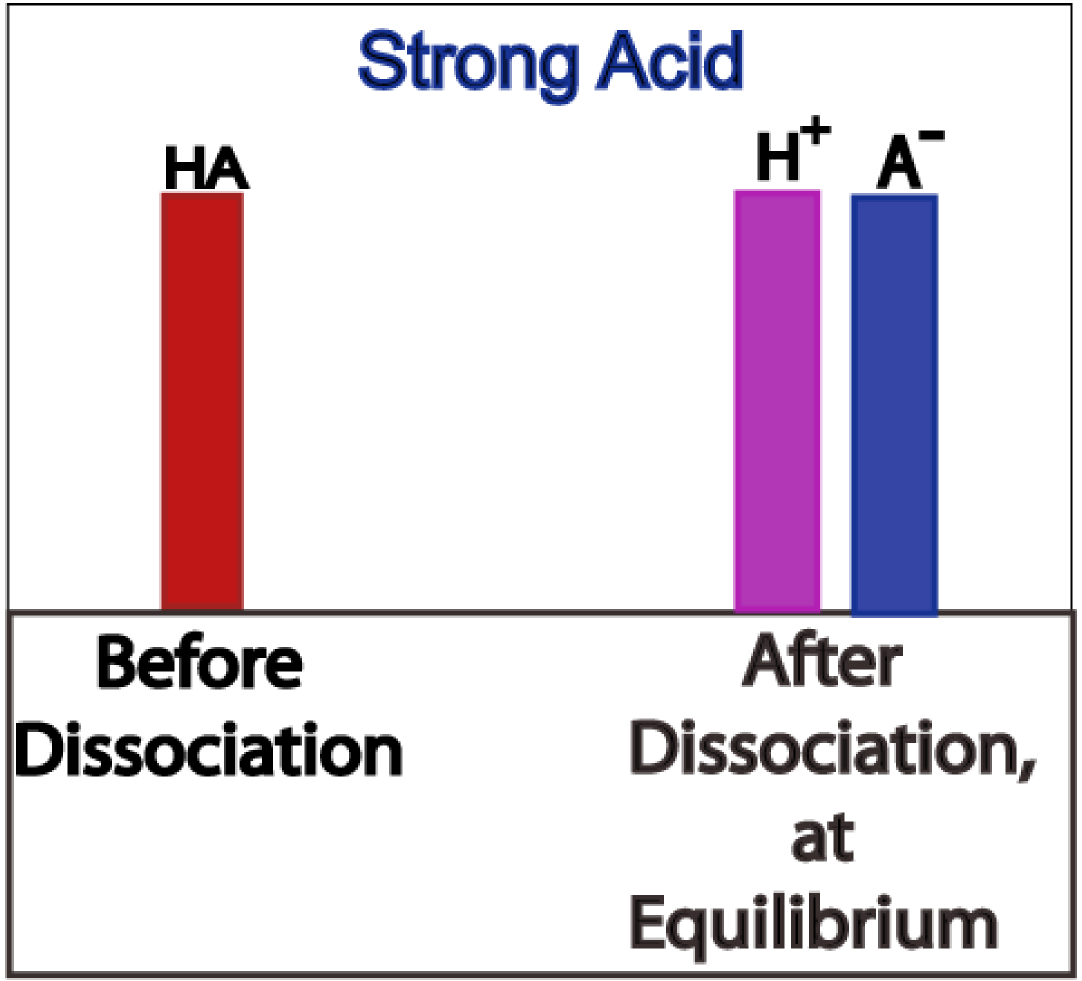
Acid — Proton — Conjugate base

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

Alternately, H^+ may be written in its hydrated form, H_3O^+ (hydronium ion)

Dissociation of Strong Acids

Strong acids are assumed to dissociate completely in solution.



Large K_a or small K_a?

Large K_a

Reactant favored or product favored?

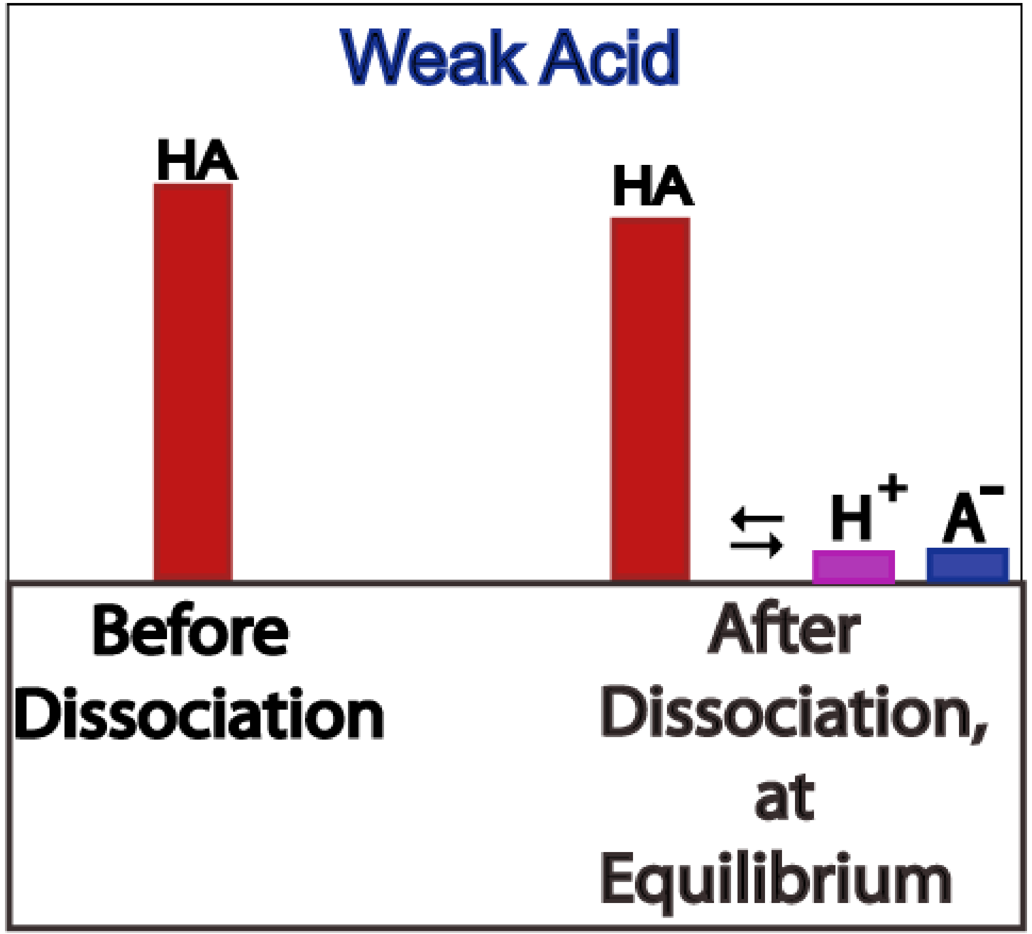
Product Favored

Dissociation Constants: Strong Acids

Acid	Formula	Conjugate Base	K_a
Perchloric	$HClO_4$	ClO_4^-	Very large
Hydriodic	HI	I^-	Very large
Hydrobromic	HBr	Br^-	Very large
Hydrochloric	HCl	Cl^-	Very large
Nitric	HNO_3	NO_3^-	Very large
Sulfuric	H_2SO_4	HSO_4^-	Very large
Hydronium ion	H_3O^+	H_2O	1.0

Dissociation of Weak Acids

Weak acids are assumed to dissociate only slightly (less than 5%) in solution.



Large K_a or small K_a?

Small K_a

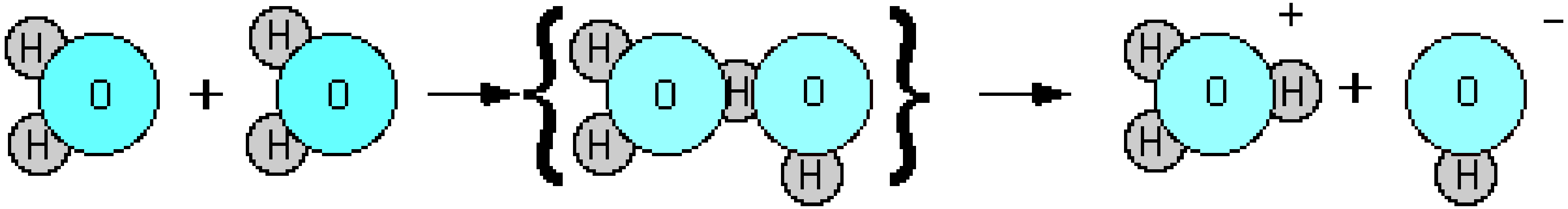
Reactant favored or product favored?

Reactant Favored

Dissociation Constants: Weak Acids

Acid	Formula	Conjugate Base	K_a
Iodic	HIO_3	IO_3^-	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$HC_2O_4^-$	5.9×10^{-2}
Sulfurous	H_2SO_3	HSO_3^-	1.5×10^{-2}
Phosphoric	H_3PO_4	$H_2PO_4^-$	7.5×10^{-3}
Citric	$H_3C_6H_5O_7$	$H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	NO_2^-	4.6×10^{-4}
Hydrofluoric	HF	F^-	3.5×10^{-4}
Formic	HCOOH	$HCOO^-$	1.8×10^{-4}
Benzoic	C_6H_5COOH	$C_6H_5COO^-$	6.5×10^{-5}
Acetic	CH_3COOH	CH_3COO^-	1.8×10^{-5}
Carbonic	H_2CO_3	HCO_3^-	4.3×10^{-7}
Hypochlorous	HClO	ClO^-	3.0×10^{-8}
Hydrocyanic	HCN	CN^-	4.9×10^{-10}

Self-Ionization of Water



$H_2O + H_2O \leftrightarrows H_3O^+ + OH^-$

At 25°, $[H_3O^+] = [OH^-] = 1 \times 10^{-7}$

***K_w* is a constant at 25 °C:**

$K_w = [H_3O^+][OH^-]$

$K_w = (1 \times 10^{-7})(1 \times 10^{-7}) = 1 \times 10^{-14}$

Calculating pH, pOH

$$pH = -\log_{10}(H_3O^+)$$

$$pOH = -\log_{10}(OH^-)$$

Relationship between pH and pOH

$$pH + pOH = 14$$

Finding $[H_3O^+]$, $[OH^-]$ from pH, pOH

$$[H_3O^+] = 10^{-pH}$$

$$[OH^-] = 10^{-pOH}$$

pH and pOH Calculations

H^+ → OH^-: $[OH^-] = \frac{1 \times 10^{-14}}{[H^+]}$

OH^- → H^+: $[H^+] = \frac{1 \times 10^{-14}}{[OH^-]}$

H^+ → pH: $pH = -\log[H^+]$

pH → H^+: $[H^+] = 10^{-pH}$

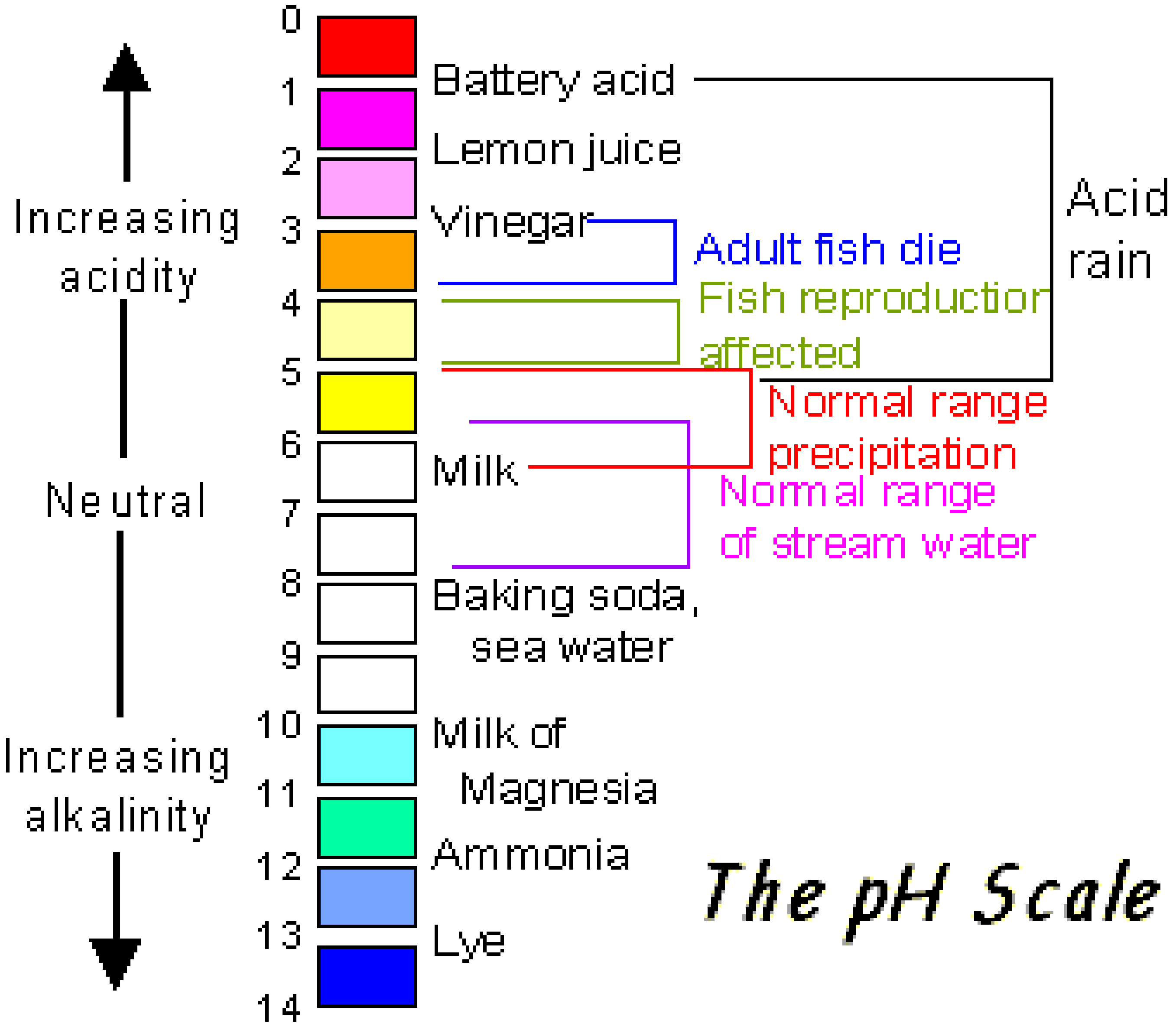
OH^- → pOH: $pOH = -\log[OH^-]$

pOH → OH^-: $[OH^-] = 10^{-pOH}$

pH → pOH: pOH = 14 - pH

pOH → pH: pH = 14 - pOH

pH Scale



Courtesy of Environment Canada (http://www.ns.ec.gc.ca/)