pH

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What is an Acid?

* An acid is a substance which, when dissolved in water, releases protons.
* The extent of dissociation, that is, the amount of protons released compared to the total amount of compound, is a measure of the strength of the acid.
* For example, HCl (hydrochloric acid) is a strong acid, because it dissociates completely in water, generating free [H^+] and [Cl^-].

Pure Water is Neutral

Pure water contains small, but equal amounts of ions: H_3O^+ and OH^-

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

	H_3O^+	OH^-
	hydronium ion	hydroxide ion
	1×10^{-7} M	1×10^{-7} M

H_3O^+ OH^-

Ion Product of Water K_w

[ ] = Molar concentration

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

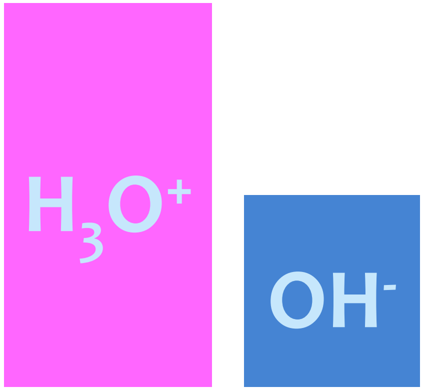
= $[1 \times 10^{-7}][1 \times 10^{-7}]$

= 1×10^{-14}

Acids

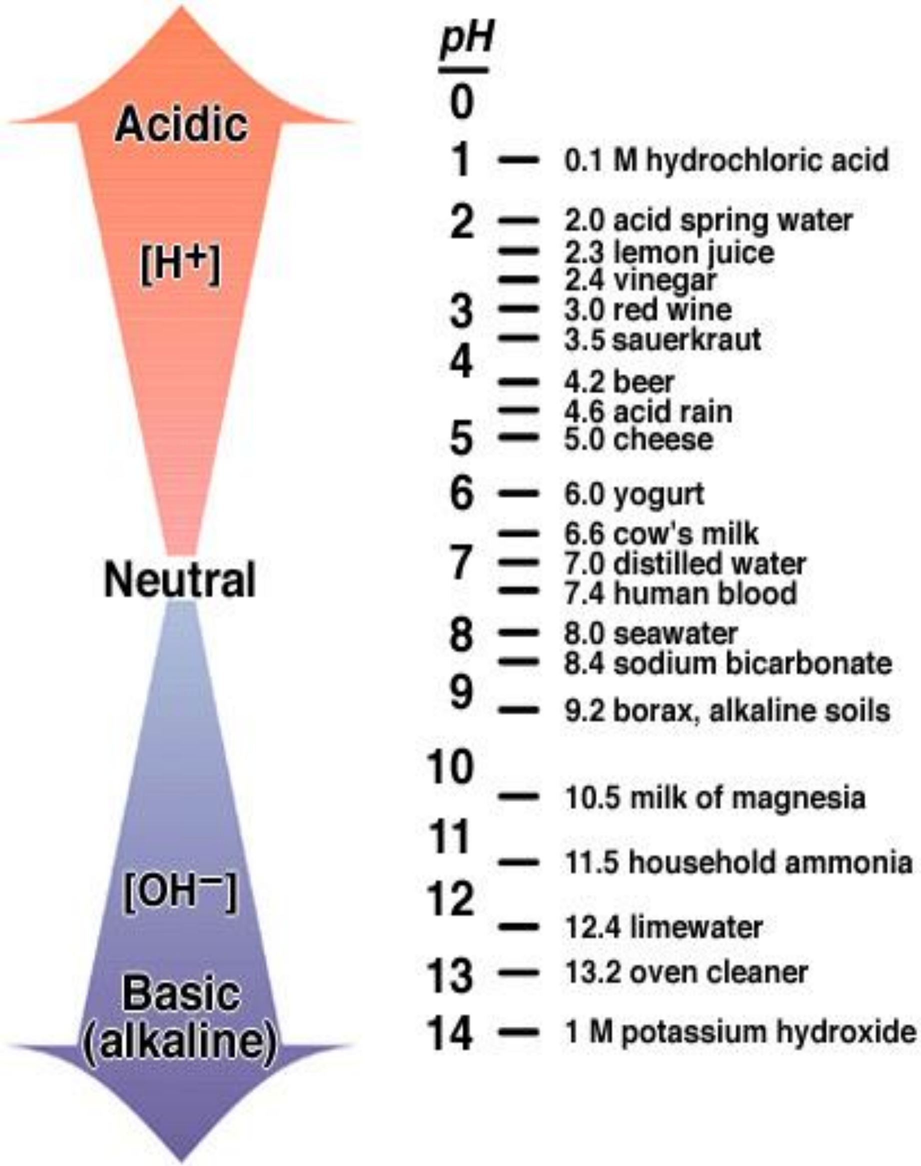
- Increase H^+
- $HCl\ (g) + H_2O\ (l) \longrightarrow H_3O^+\ (aq) + Cl^-\ (aq)$
- More $[H_3O^+]$ than water $> 1 \times 10^{-7}$M
- As H_3O^+ increases, OH^- decreases

$$[H_3O^+] > [OH^-]$$



What is the pH scale?

- The pH scale measures how *acidic* or *basic* a solution is.



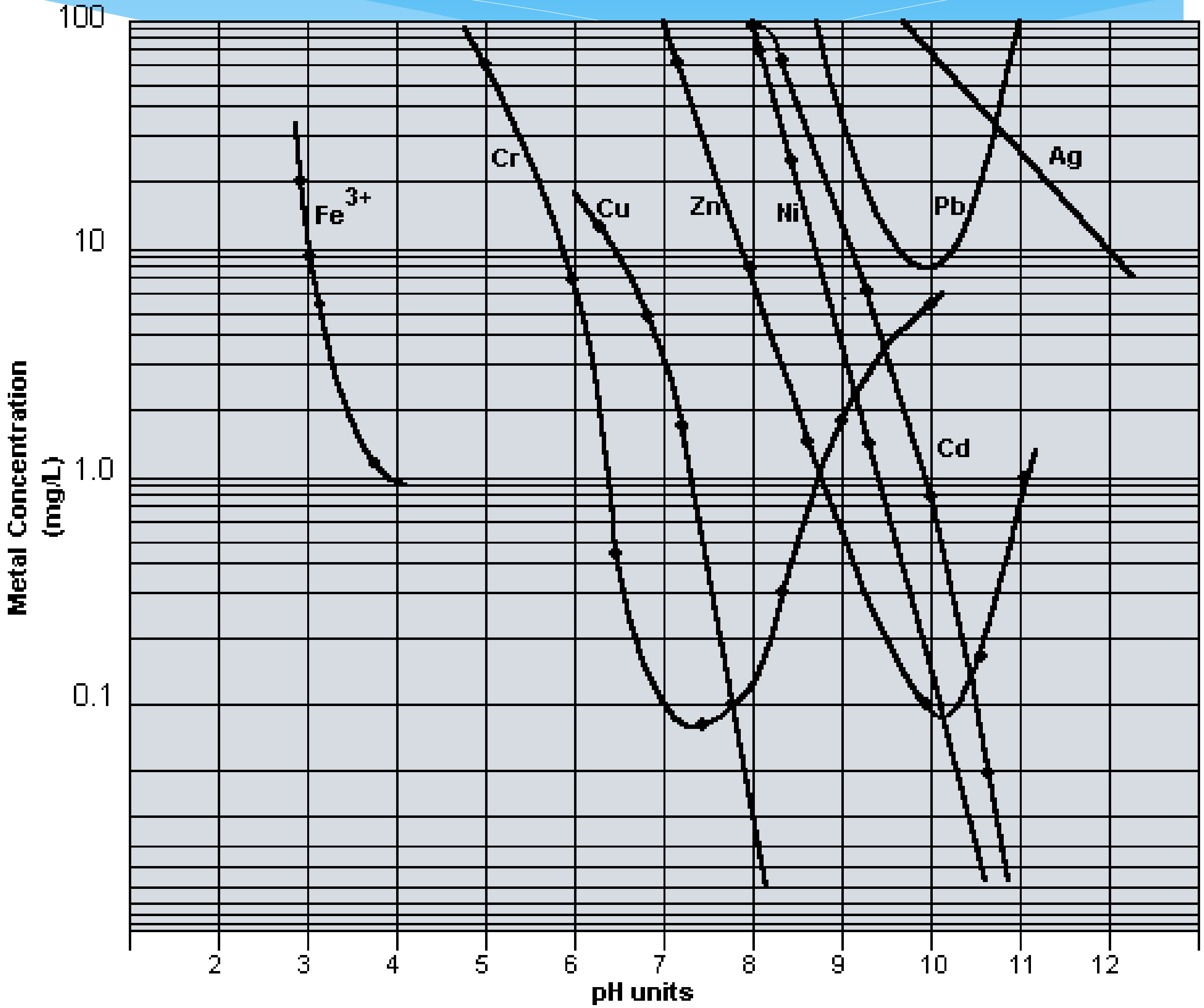
Importance of pH in environmental engineering

In environmental engineering pH must be considered in:

* Chemical coagulation
* Disinfection
* Water softening
* Corrosion control
* Microorganisms in biological treatment
* Sludge dewatering
* Oxidation of certain substances (such as cyanide)

Precipitation of Metals from Wastewater

The Solubility of Metals is Dependent on pH



Hydroxide Precipitation

Minimum Solubility (Best Removal) Value for Some Metals

From Chart

Cadmium
pH 11.0

Copper
pH 8.1

Chromium
pH 7.5

Nickel
pH 10.8

Zinc
pH 10.1

Dissociation Constants

* For a generalized acid dissociation,

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

  the equilibrium expression is

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

* This equilibrium constant is called the acid-dissociation constant, K_a.

* pH = - log {H^+}
* pH range 0 -14
* pH 7 @25°C represent absolute neutrality
* Neutrality @ 0°C → pH 7.5
* Neutrality @ 60°C → pH 6.5
* K_w changes with change in temperature → pH of neutrality changes with temperature

Interpretation of pH Data

* pH data should be interpreted in terms of hydrogen ion activity
* Approximately we can assume

$$[H^+] = \{H^+\}$$

pH + pOH = 14

$[H^+]$ and $[OH^-]$ can never be zero

Activity and Concentration

Until now we have assumed that activity, *a*, is equal to concentration, *c*, by setting $\gamma = 1$ when dealing with dilute aqueous solutions…

- Activity – "effective concentration"
- Ion-ion and ion-H_2O interactions (hydration shell) cause number of ions available to react chemically ("free" ions) to be less than the number present
- Concentration can be related to activity using the activity coefficient γ, where $[a] = \gamma\,(c)$

But ions don't behave ideally . . .

* Concentration related to activity using the activity coefficient γ, where $[a] = \gamma\,(c)$
* The value of γ depends on:
  * Concentration of ions and charge in the solution
  * Charge of the ion
  * Diameter of the ion
* Ionic strength, I = concentration of ions and charge in solution

$$I = 1/2\ \Sigma m_i z_i^2$$

  * where m_i = concentration of each ion in moles per L, z_i = charge of ion
* Activity coefficient $\gamma_z \rightarrow 1$ as concentrations $\rightarrow 0$ and tend to be <1 except for brines

Interpretation of pH Data

* pH does not measure total acidity.
* Compare the pH of 0.1N Sulfuric acid and acetic acid
  * They have the same neutralizing value

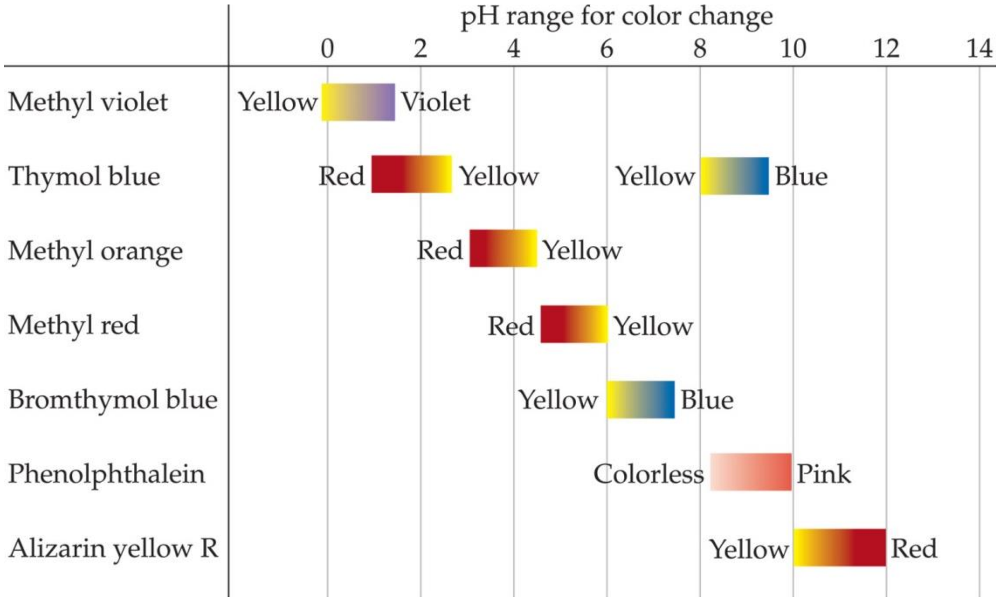
Testing the pH of Solutions

The pH of solutions can be determined using

- a pH meter
- pH paper
- indicators that have specific colors at different pH values

(a) (b) (c)

How Do We Measure pH?



- Litmus paper
  - "Red" paper turns blue above ~pH = 8
  - "Blue" paper turns red below ~pH = 5
- An indicator
  - Compound that changes color in solution.