Acids and Bases

What are Acid and Bases?

- **Definition #1** of Svante Arrhenius (Sweden) in 1884

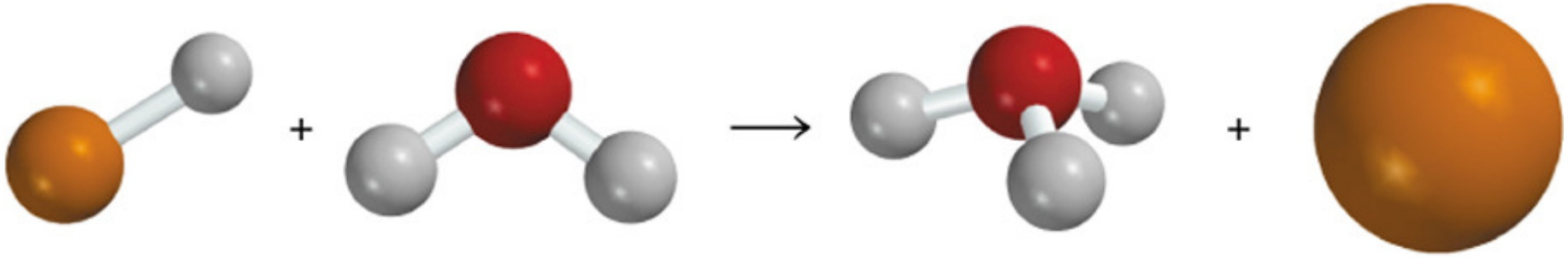
  "An Acid is a substance that can release a proton or hydrogen ion (H^+) when dissolved in water"

  $$HCl \longrightarrow H^+ + Cl^-$$

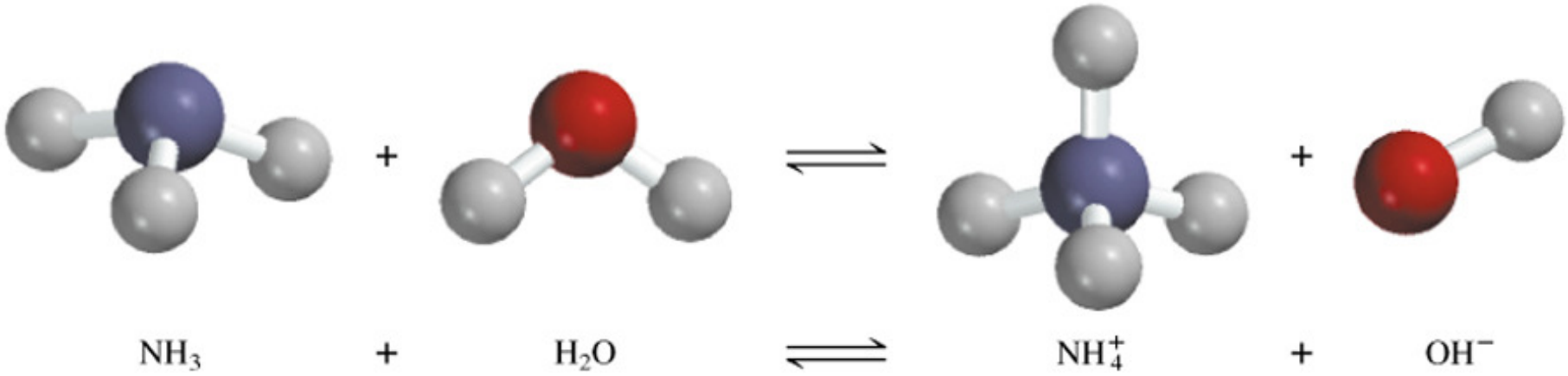
  " A Base is a substance that can release a Hydroxyl ion when dissolved in water"

  $$NaOH \longrightarrow Na^+ + OH^-$$

Arrhenius acid is a substance that produces H^+ (H_3O^+) in water



Arrhenius base is a substance that produces OH^- in water



Definition #2 According to Brønsted – Lowry :

Acids – proton donor

$HCl \rightarrow H^+ + Cl^-$

$CH3COOH \rightarrow CH3COO^- + H^+$

$NH4^+ \rightarrow NH3 + H^+$

Bases – proton acceptor

“

$OH^- + H^+ \rightarrow H2O$

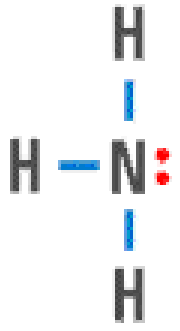
$CH3COO^- + H^+ \rightarrow CH3COOH$

$NH3 + H^+ \rightarrow NH4^+$

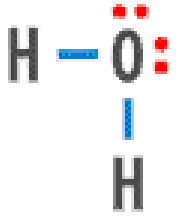
A “proton” is a hydrogen atom that has lost it’s electron

The Brønsted definition means
NH_3 is a BASE in water — and
water is itself an ACID

$$\underset{\text{Base}}{NH_3} + \underset{\text{Acid}}{H_2O} \rightleftharpoons \underset{\text{Acid}}{NH_4^+} + \underset{\text{Base}}{OH^-}$$



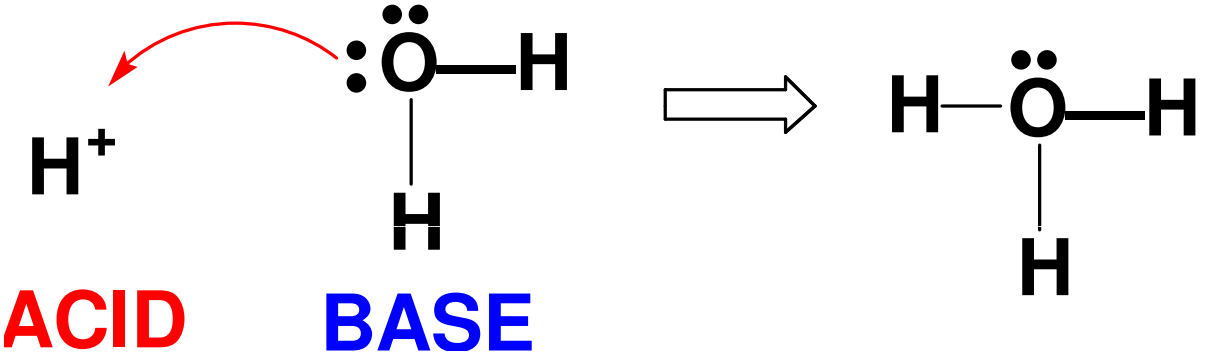
Base



Acid

Definition #3 – Lewis

Lewis acid - a substance that accepts an electron pair

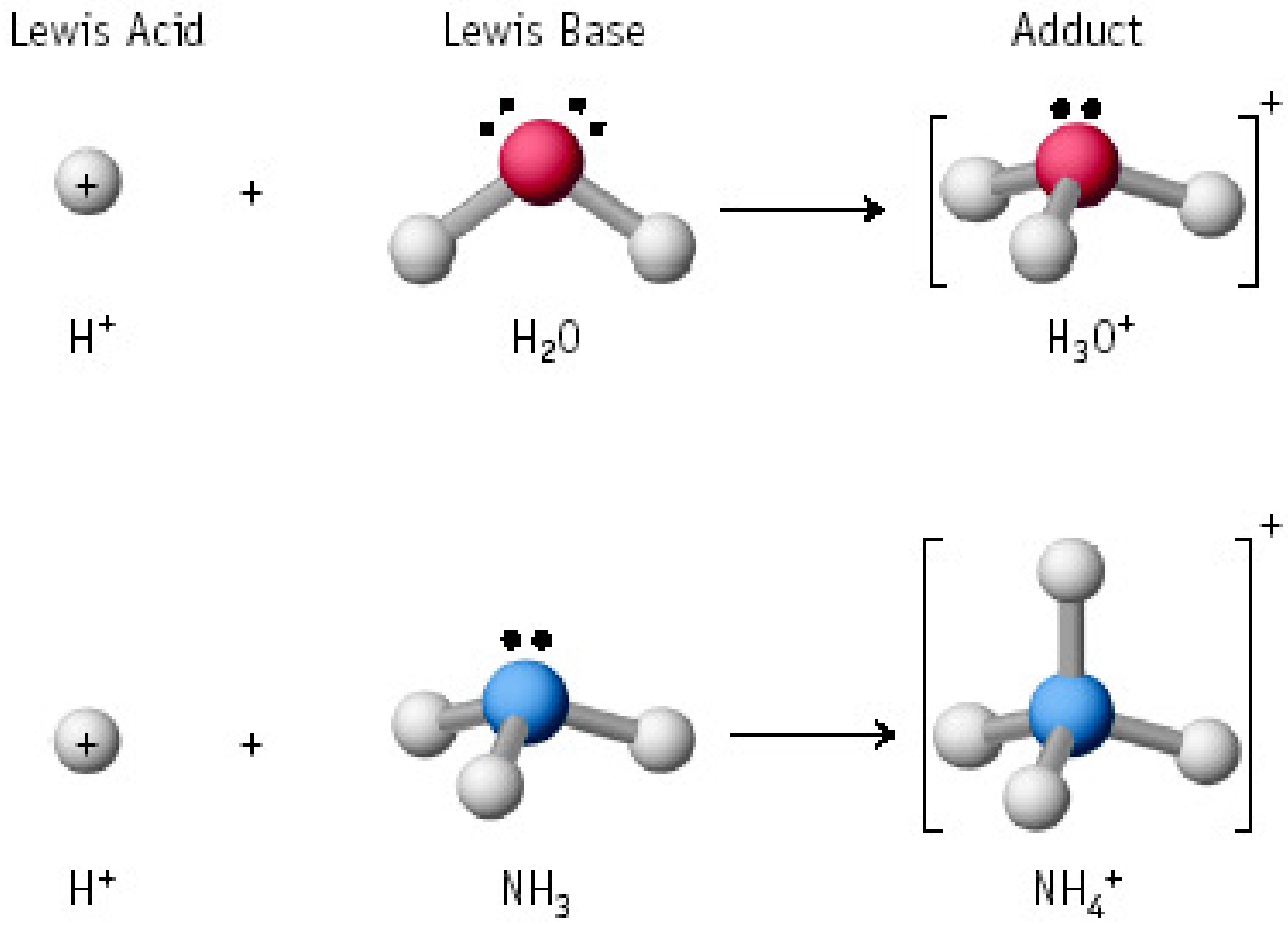


Lewis base - a substance that donates an electron pair

Formation of hydronium ion

- **Electron pair of the new O-H bond originates on the Lewis base**

Lewis Acid/Base Reaction



Acid-Base Definitions

* **Definition #1: Arrhenius (traditional)**

  Acids – produce H^+ ions (or hydronium ions H_3O^+)

  Bases – produce OH^- ions

  (problem: some bases don't have hydroxide ions!)

* **Definition # 2 :Brønsted – Lowry**

  Acids – proton donor

  Bases – proton acceptor

  A "proton" is really just a hydrogen atom that has lost it's electron!

* **Definition #3 – Lewis**

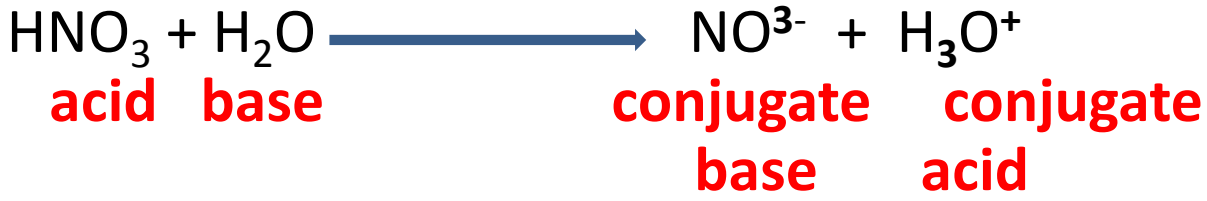
  Lewis acid - a substance that accepts an electron pair

  Lewis base - a substance that donates an electron pair

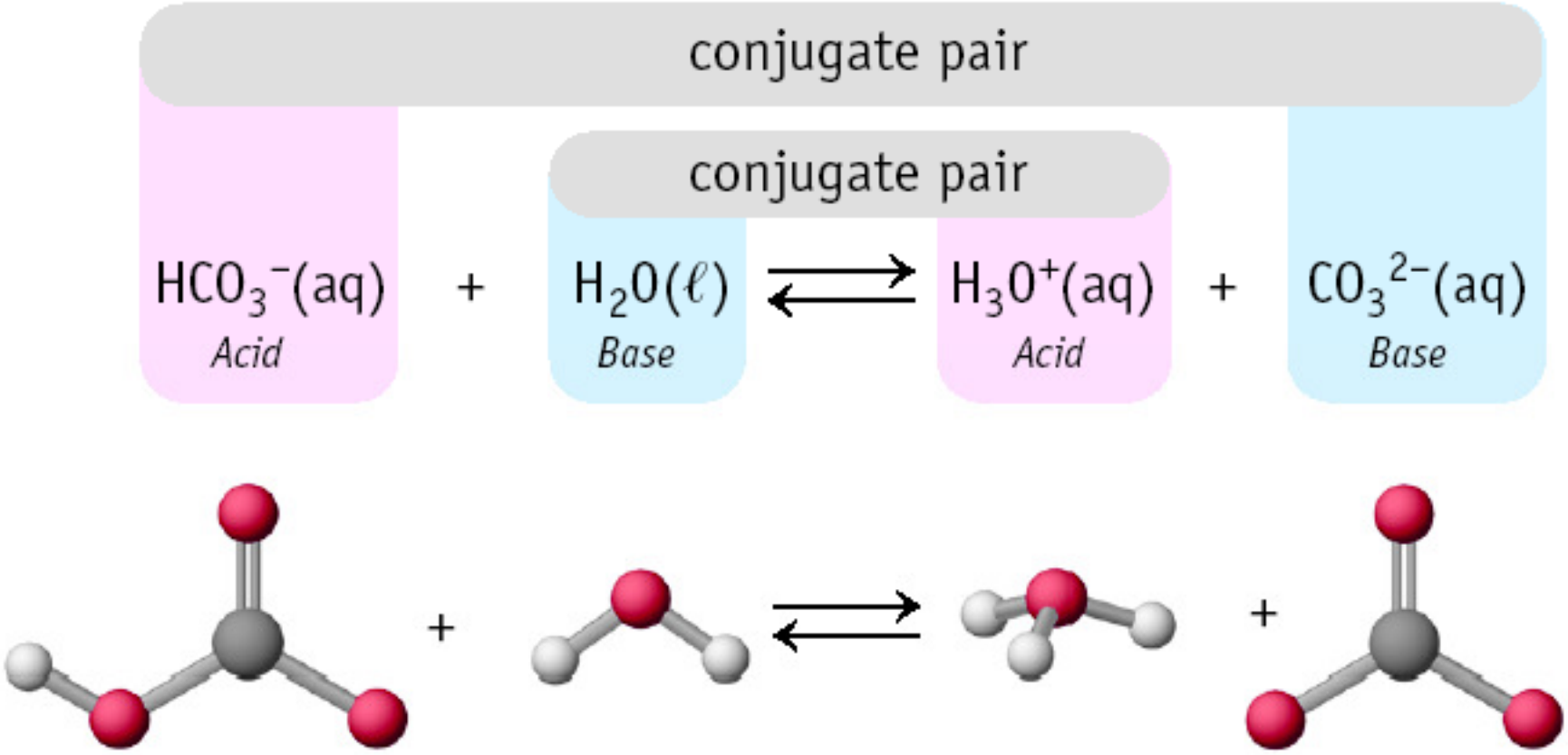
* Each ionizable pair has a proton donor and a proton acceptor. (Acids are paired with bases) .
* One can accept a proton and the other can donate a proton.
* Each acid has a proton available (an ionizable hydrogen) and another part, called the ***conjugate base***.
* When the acid ionizes, the hydrogen ion is the acid and the rest of the original acid is the conjugate base e.g:

Nitric acid, HNO3, ***dissociates*** (splits) into a hydrogen ion and a nitrate ion. The hydrogen almost immediately joins to a water molecule to make a hydronium ion.

The nitrate ion is the conjugate base of the hydrogen ion. In the same reaction, water is a base (because it can accept a proton) and the hydronium ion is its conjugate acid.



Conjugate Pairs



Label the acid, base, conjugate acid, and conjugate base in each reaction:

$HCl + OH^- \rightarrow Cl^- + H_2O$

$H_2O + H_2SO_4 \rightarrow HSO_4^- + H_3O^+$

Properties of acids

- Acids release a hydrogen ion into water (aqueous) solution
- Acids neutralize bases in a neutralization reaction 

  An acid and a base combine to make a ***salt*** and water. A salt is any ionic compound that could be made with the anion of an acid and the cation of a base.

  $HCl + NaOH \rightarrow NaCl + H_2O$

PROPERTIES OF ACIDS

- Acids
  - Produce hydrogen ions (H^+) in H_2O (the hydronium ion is a hydrogen ion attached to a water molecule)
  - Taste sour
  - pH less than 7
  - Turn blue litmus (vegetable dye) $\Rightarrow$ red
  - Act as electrolytes in solution
  - Neutralise solutions containing hydroxide ions (OH^-)
  - React with several metals releasing $H_{2(g)} \Rightarrow$ corrosion
  - React with carbonates releasing $CO_{2(g)}$
  - Destroy body tissue

Examples of Some Acids

- Stomach acid is hydrochloric acid.
- Acetic acid is the acid ingredient in vinegar.
- Citrus fruits such as lemons, grapefruit, oranges, and limes have citric acid in the juice.
- Sour milk, sour cream, yogurt, and cottage cheese have lactic acid from the fermentation of the sugar lactose.
- Carbon dioxide formed in the body, dissolves in water to form an acid carbonic acid:

  $CO_2 + H_2O \longrightarrow H_2CO_3$ [carbonic acid]
- Proteins are acidic at pH below their isoelectric point, and can give out hydrogen ions.

Properties of bases

- Bases release a hydroxide ion into water solution
- Bases neutralize acids in a neutralization reaction.

- **Bases**
  - Produce or cause an increase in hydroxide ions (OH^-) in H_2O
  - Taste bitter
  - pH greater than 7
  - Turn red litmus $\Rightarrow$ blue
  - Act as electrolytes in solution
  - Neutralise solutions containing hydrogen ions (H^+)
  - Have a slippery, 'soapy' feel
  - Destroy body tissue/ dissolve fatty (lipid) material

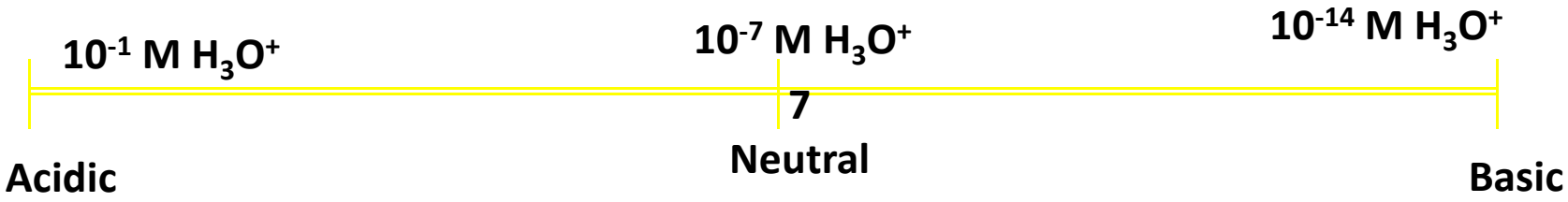
pH

- pH is a way to express acidity or alkalinity of an aqueous solution.
- It is the negative log of the hydrogen ion concentration.
- It is a measure of the concentration of protons in solution $[H_3O^+]$

$$pH = -\log_{10}[H^+] \quad \text{or}$$

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

- pH Scale:



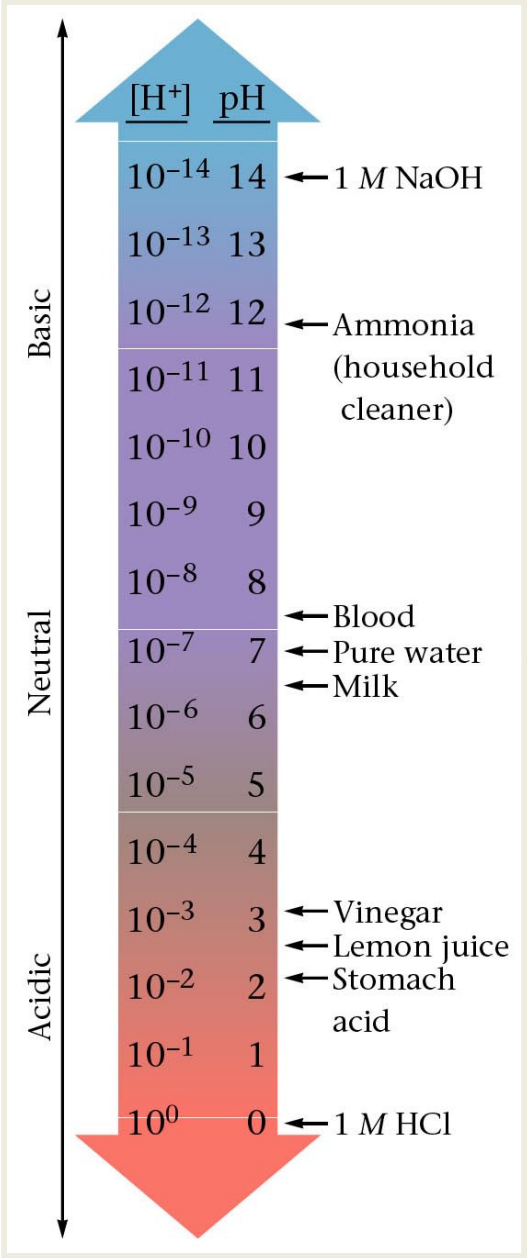
The pH scale is a way of expressing the strength of acids and bases. Instead of using very small numbers, use the NEGATIVE power of 10 on the Molarity of the H^+ (or OH^-) ion.

Under 7 = acid

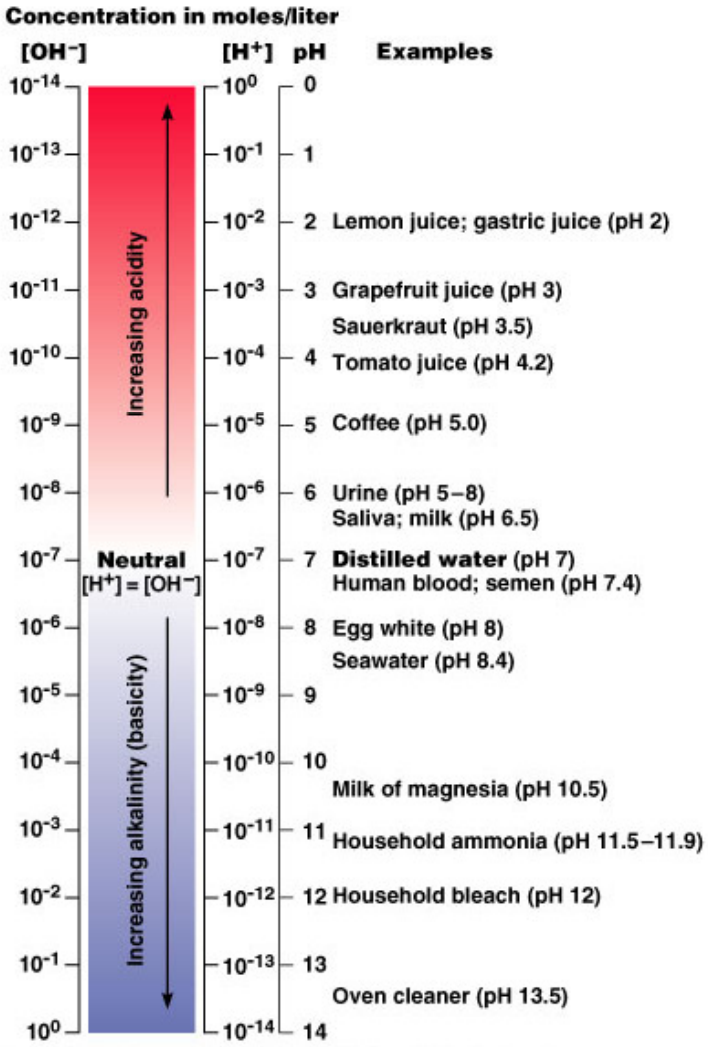
7 = neutral

Over 7 = base

pH is a log scale and one number represents a H_3O^+ concentration that is either 10 times greater or ten times smaller in magnitude then the next. e.g. 10^{-2} M is ten times greater than 10^{-3} .



On the pH scale, values below 7 are acidic, a value of 7 is neutral, and values above 7 are basic.



Calculating the pH

$pH = - \log [H^+]$

(Remember that the [ ] mean Molarity)

Example: If $[H^+] = 1 \times 10^{-10}$

$pH = - \log 1 \times 10^{-10}$

$pH = - (- 10)$

$pH = 10$

Example: If $[H^+] = 1.8 \times 10^{-5}$

$pH = - \log 1.8 \times 10^{-5}$

$pH = - (- 4.74)$

$pH = 4.74$

- **pH describes $[H^+]$ & $[OH^-]$**

∴ Indicates if a fluid is :

0	**Acidic**	**$[H^+] = 10^0$**	**$[OH^-] = 10^{-14}$**
7	**Neutral**	**$[H^+] = 10^{-7}$**	**$[OH^-] = 10^{-7}$**
14	**Basic**	**$[H^+] = 10^{-14}$**	**$[OH^-] = 10^0$**

- **Acidic solution**

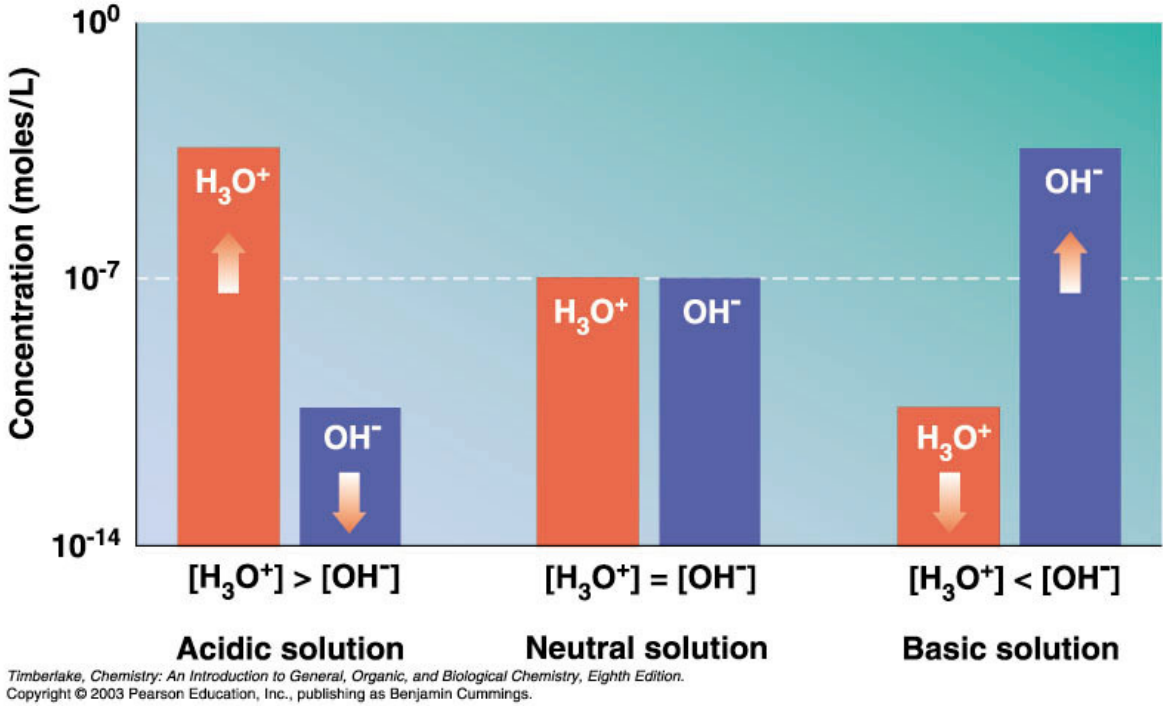
  $[H^+] > [OH^-]$

- **Neutral solution**

  $[H^+] = [OH^-]$

- **Basic solution**

  $[H^+] < [OH^-]$



Timberlake, Chemistry: An Introduction to General, Organic, and Biological Chemistry, Eighth Edition.

Dissociation of Water

❑ **Ion Product of Water**

Pure H_2O at 25°C
Some molecules ionise

$H_2O \Leftrightarrow H^+ + OH^-$

- **Equilibrium constant for water = K_w**
- **$K_w = [H_3O^+]\,[OH^-] = 1.00 \times 10^{-14}$ at 25 °C**
  H_2O can function as both an ACID and a BASE.

$K_w = [H_3O^+]\,[OH^-] = 1.00 \times 10^{-14}$ at 25 ^oC

In a neutral solution $[H_3O^+] = [OH^-]$

so $K_w = [H_3O^+]^2 = [OH^-]^2$

and so $[H_3O^+] = [OH^-] = 1.00 \times 10^{-7}$ M

pH for some fluids liquids

	pH	H^+ conc [M]
Gastric Juice	1 - 2	10^{-1} to 10^{-2}
Coca cola	3	10^{-3}
Urine	5-8	10^{-5} to 10^{-8}
Saliva	6.4	4×10^{-7}
Blood	7.4	4×10^{-8}
Pure water	7.0	10^{-7}

Strong acids and strong bases

- **Strong acids that are almost one hundred percent ionized in aqueous solution .** $HCl \longrightarrow H^+ + Cl^-$
- **Very few ,eg:**

  HNO_3 - nitric acid
  HCl - hydrochloric acid
  H_2SO_4 - sulfuric acid
  $HClO_4$ - perchloric acid
- **Strong bases are almost one hundred percent ionized in aqueous solution.** $NaOH \longrightarrow Na^+ + OH^-$
- **eg:**

  LiOH - lithium hydroxide
  NaOH - sodium hydroxide
  KOH - potassium hydroxide

  Mg(OH)2 - magnesium hydroxide
  Ca(OH)2 - calcium hydroxide

Strong acids are:

- Strong electrolytes
- ~ 100% ionisation $\Rightarrow$ good conductors
- Severe burns to body tissue

*** Stomach lining protected against HCl by mucus

Dissociation in Water : ❖

Strong acid $\Rightarrow$ ions

Eg.

$$HCl_{(l)} \xrightarrow[\leftarrow]{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$$

$$HNO_{3(l)} \xrightarrow[\leftarrow]{H_2O} H^+_{(aq)} + NO_3^-{}_{(aq)}$$

$$H_2SO_{4(l)} \xrightarrow[\leftarrow]{H_2O} 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

Strong bases are:

- Strong electrolytes
- ~ 100% dissociation in water $\Rightarrow$ good conductors
- Severe damage to skin & eyes

(Group 1A elements)

❖ <u>Dissociation in Water : Strong bases</u>

Metal hydroxides $\Rightarrow$ ions

Eg.

$$NaOH_{(s)} \xrightleftharpoons{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

$$Mg(OH)_{2(s)} \xrightleftharpoons{H_2O} Mg^{2+}_{(aq)} + OH^-_{(aq)}$$

$$Al(OH)_{3(s)} \xrightleftharpoons{H_2O} Al^{3+}_{(aq)} + OH^-_{(aq)}$$

Weak Acids and Weak Bases

- **Weak acids and weak bases dissociate partially in aqueous solution**

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

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

$$BOH \rightleftharpoons B^+ + OH^-$$

$$NH_3 + H^+ \rightleftharpoons NH_4^+$$

- Weak Acids (most acids in nature)

- CH_3COOH Acetic Acid

antimicrobial solution $\rightarrow$ ears, plastics, dyes, insecticides

- H_2CO_3 Carbonic Acid

Bicarbonate buffer system, carbonated drinks

- H_3PO_4 Phosphoric Acid

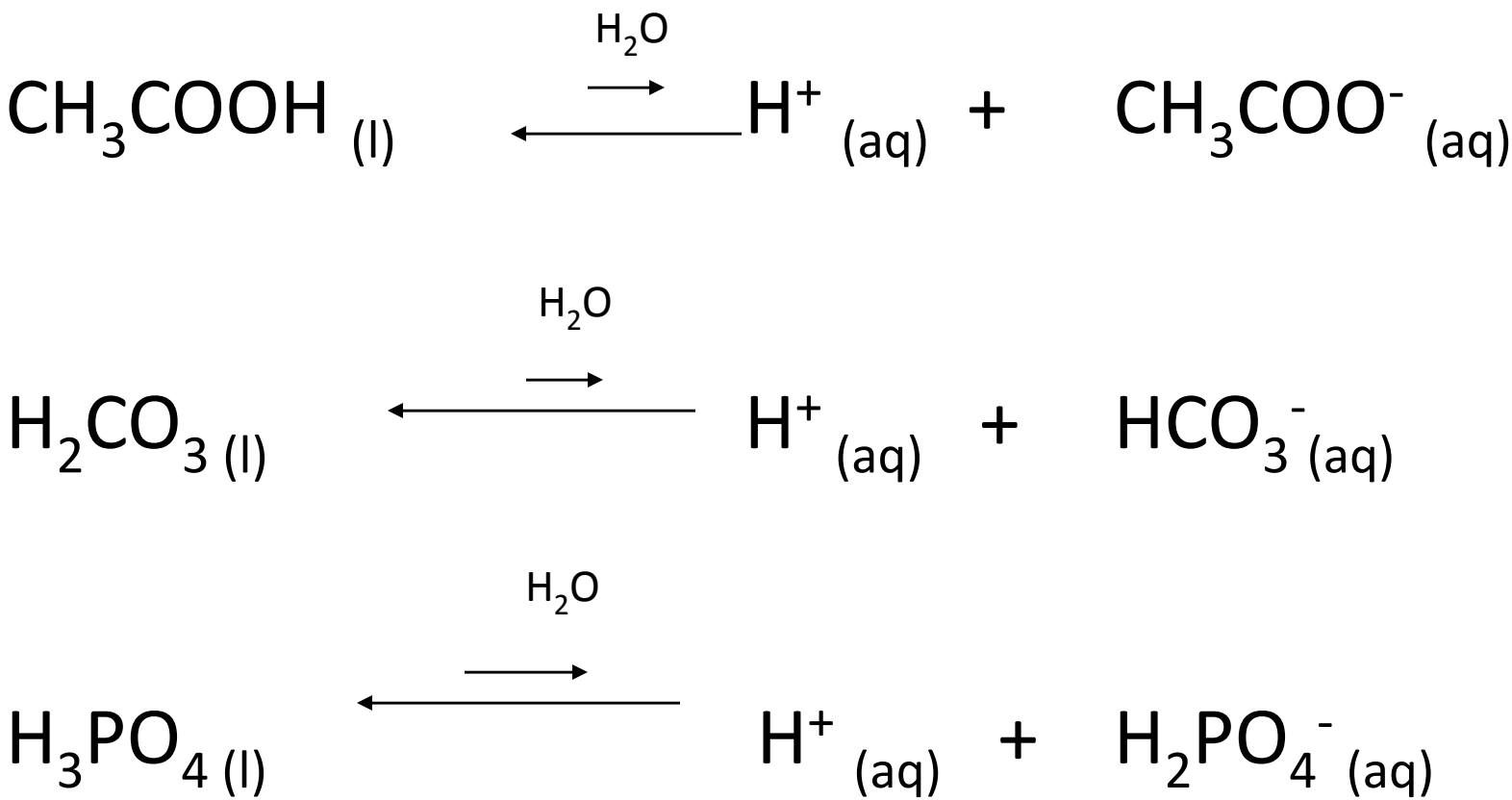
Drugs, fertilisers, soaps, detergents

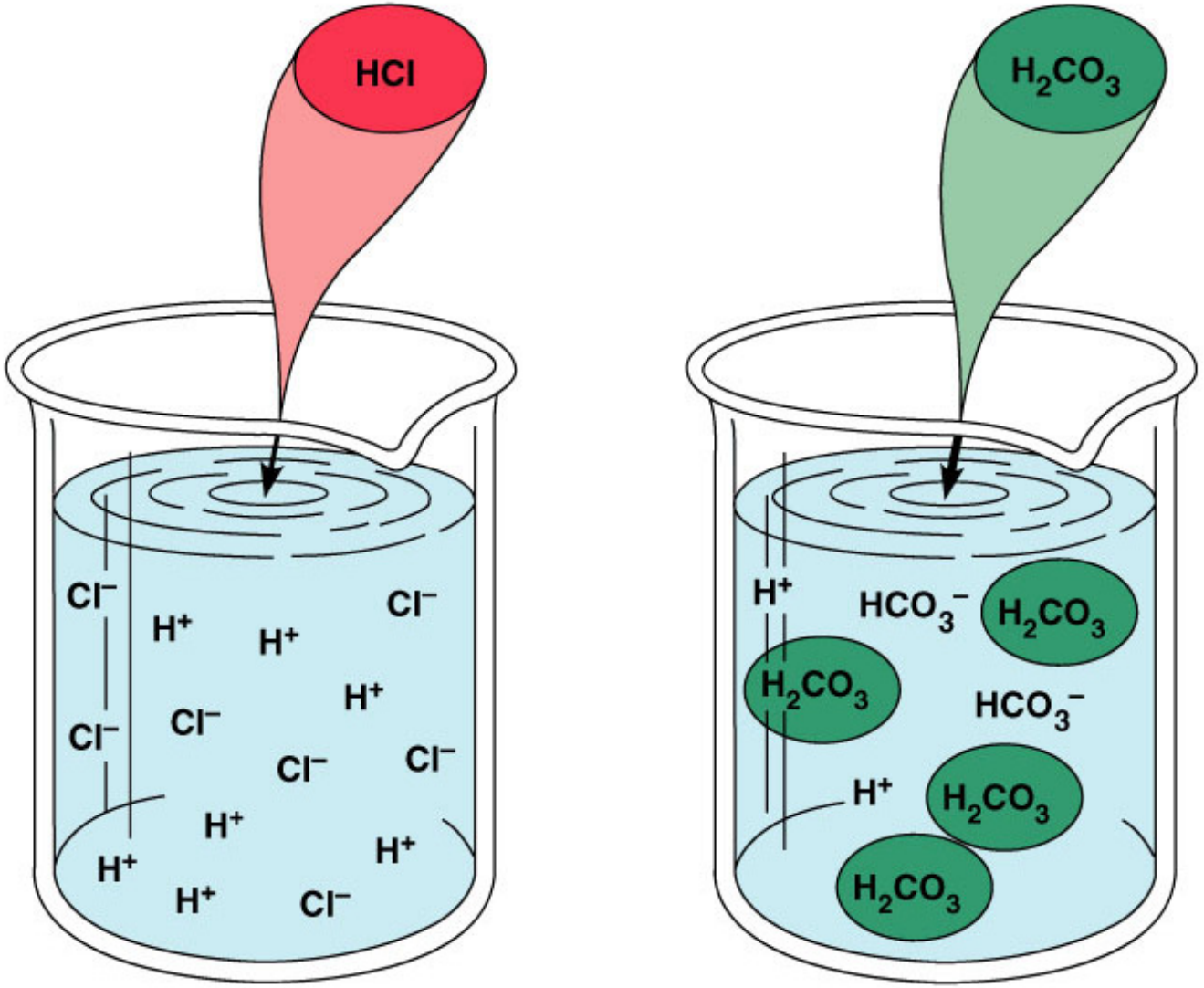
- Weak acids are:
  - Weak electrolytes
  - Small % ionisation $\Rightarrow$ weak conductors

❑ <u>Dissociation in Water : Weak acids</u>

$\Rightarrow$ Mainly stay as molecules

- Dissociation in water : Weak acids (cont)





❑ <u>Weak Bases</u>

Eg

❖ NH_3 Ammonia

~ Waste product of protein break down in body.

❖ CO_3^{2-} In antacids

❖ HCO_3^- In antacids, buffers

❖ HPO_4^{2-} In buffers

- Weak bases are:
  - Weak electrolytes
  - Do not contain OH^- but react with $H_2O \Rightarrow$ small numbers of OH^-

❑ Reaction with Water : Weak bases

$$NH_{3(g)} + H_2O \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

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

ACID-BASE NEUTRALISATION

- Neutralisation Reaction

Acid	+	Base	$\rightarrow$	Salt	+	Water
HCl	+	NaOH	$\rightarrow$	NaCl	+	H_2O

Neutralise each other

Must be equal concentrations

Key Concepts: