Acid and Base Reactions

Definitions of acids and bases

Svant Arrhenius (Sweden) 1859-1927

Johannes Bronsted (Denmark) 1879-1947

G. N. Lewis (U.S.) 1875-1946

Arrhenius definitions of acids and bases

An acid dissolves in water to yield protons

A base dissolves in water to yield hydroxide ions

Bronsted Definition

An acid is a proton donor

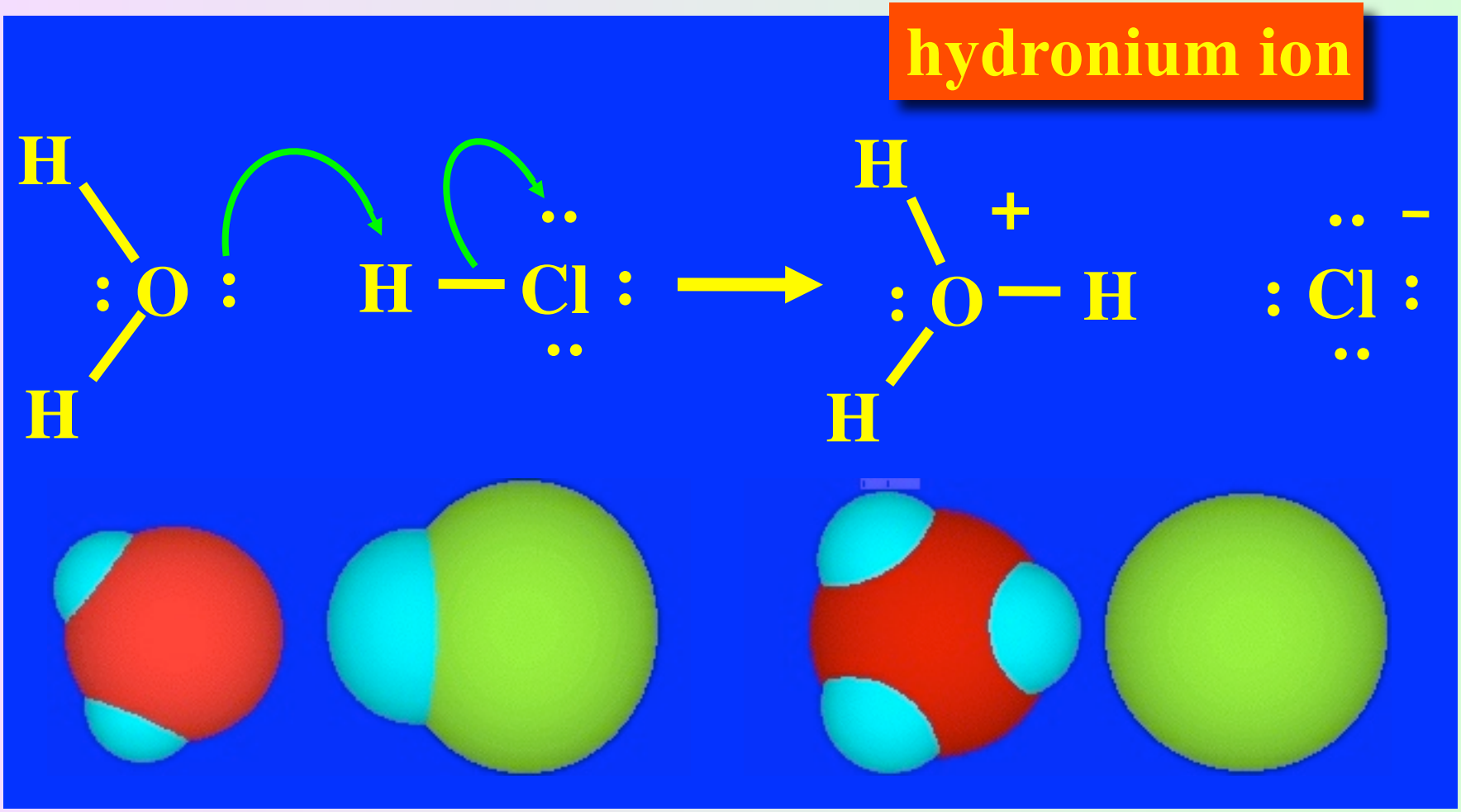
A base is a proton acceptor

An acid is a proton donor

an example is HCl

a source of hydronium ion (H_3O^+)

Proton transfer from HCl to water.

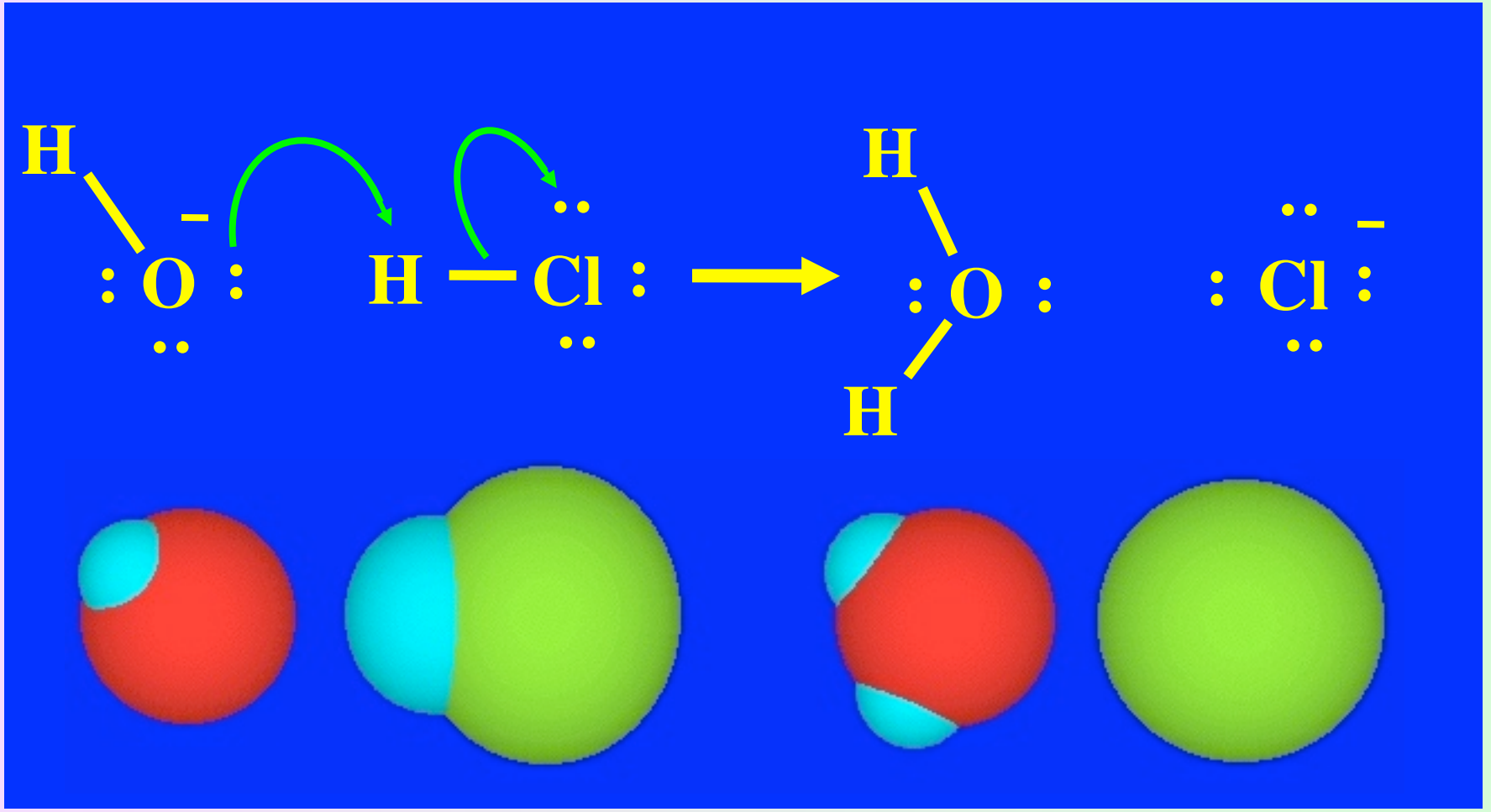


A base is a proton acceptor

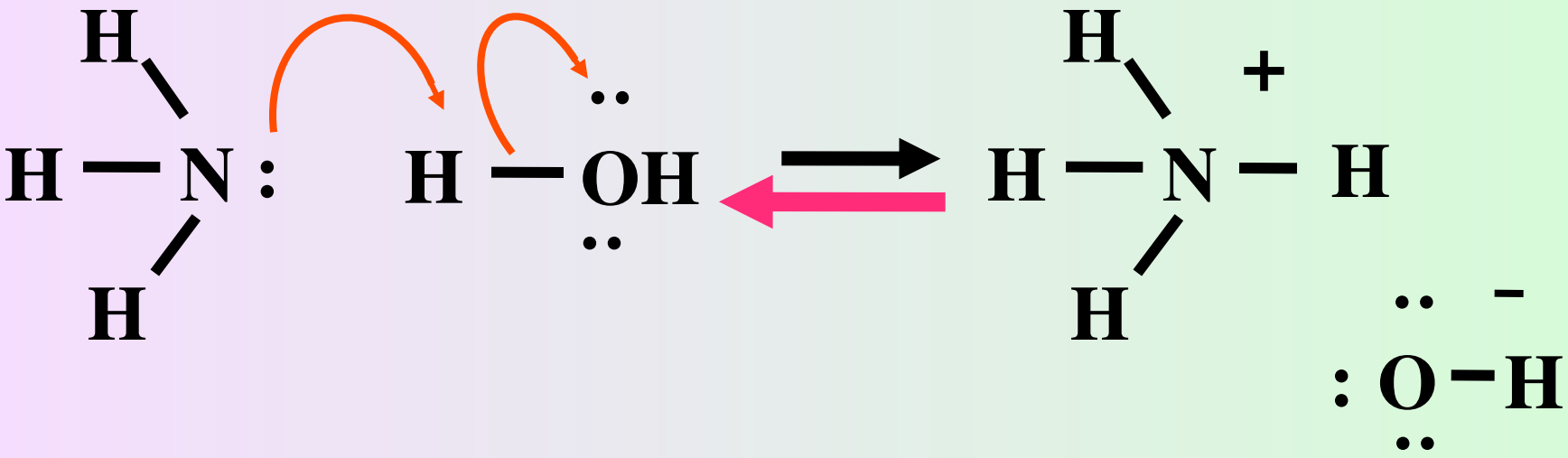
an example is NaOH

a source of hydroxide ions (OH^-)

A base is a proton acceptor



Ammonia is a Bronsted base



A Weak Base

hydroxide ion

Acid-Base Neutralization

Acid + Base  **Salt + Water**

Neutralization

Example of Neutralization

Acid + Base ⟶ Salt + Water

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

Complete ionic equation

$$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \longrightarrow$$

$$Na^+(aq) + Cl^-(aq) + H_2O(l)$$

Cancel Spectator ions

Net ionic equation

$$OH^-(aq) + H^+(aq) \longrightarrow H_2O(l)$$

Bronsted Definition

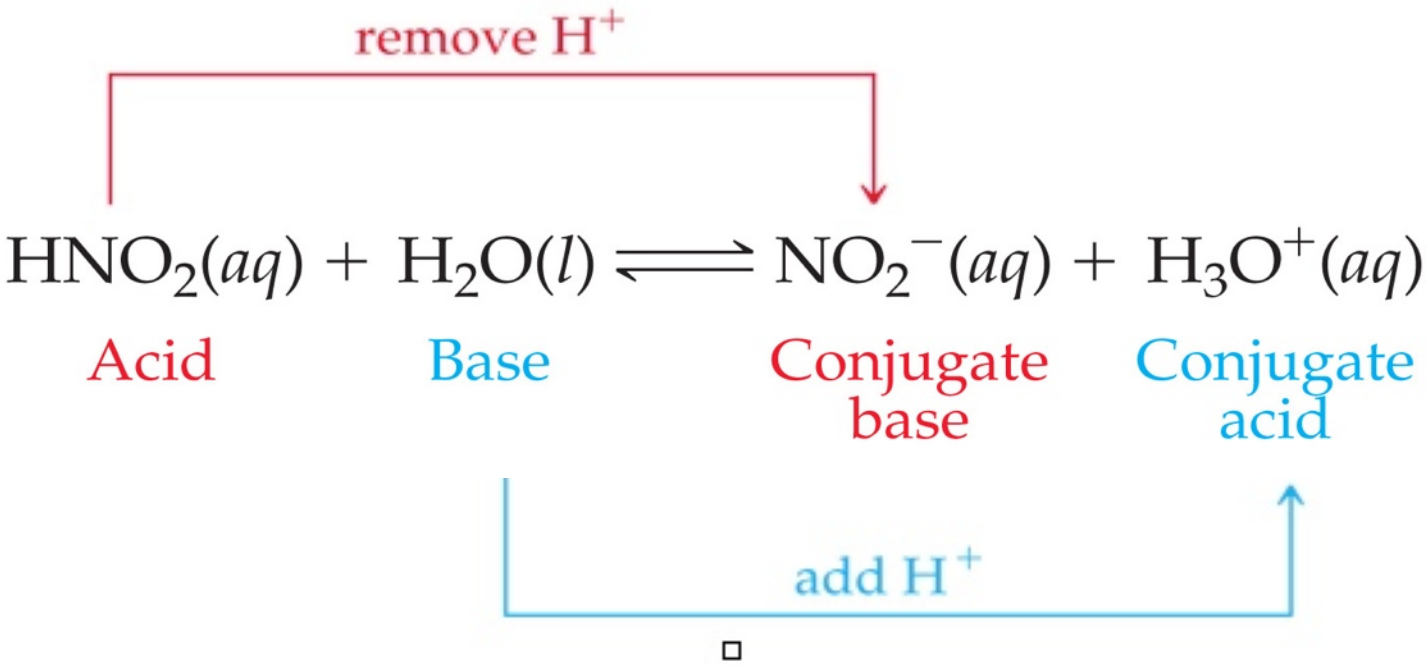
An acid is a proton donor

A base is a proton acceptor

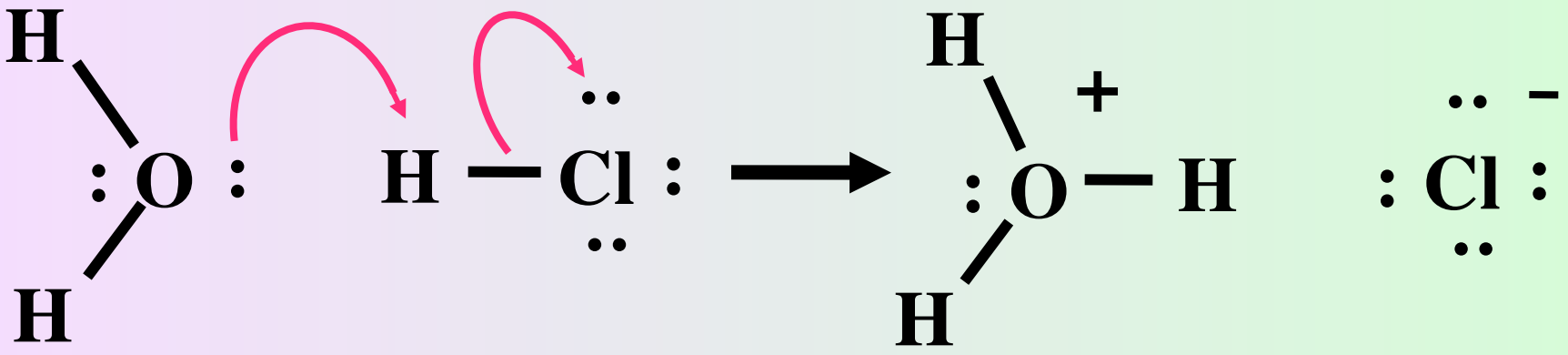
Conjugate acid-base pair

Conjugate Acids and Bases

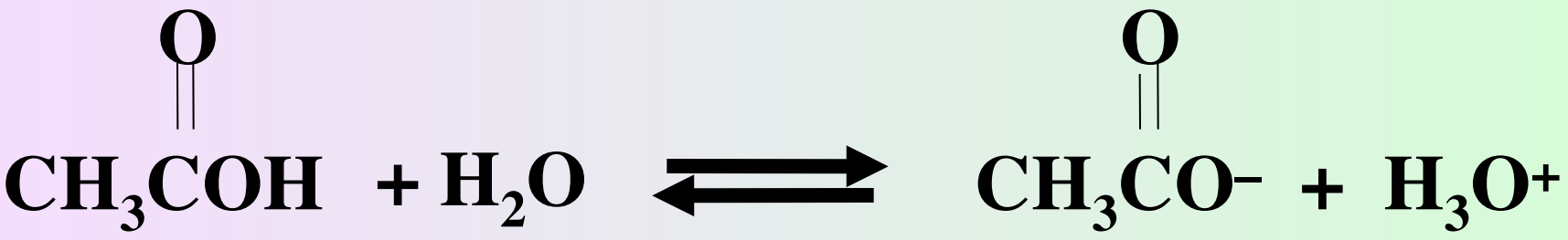
- Reactions between acids and bases always yield their conjugate bases and acids.



Consider the transfer of a proton from HCl to water.



Acetic acid



acid

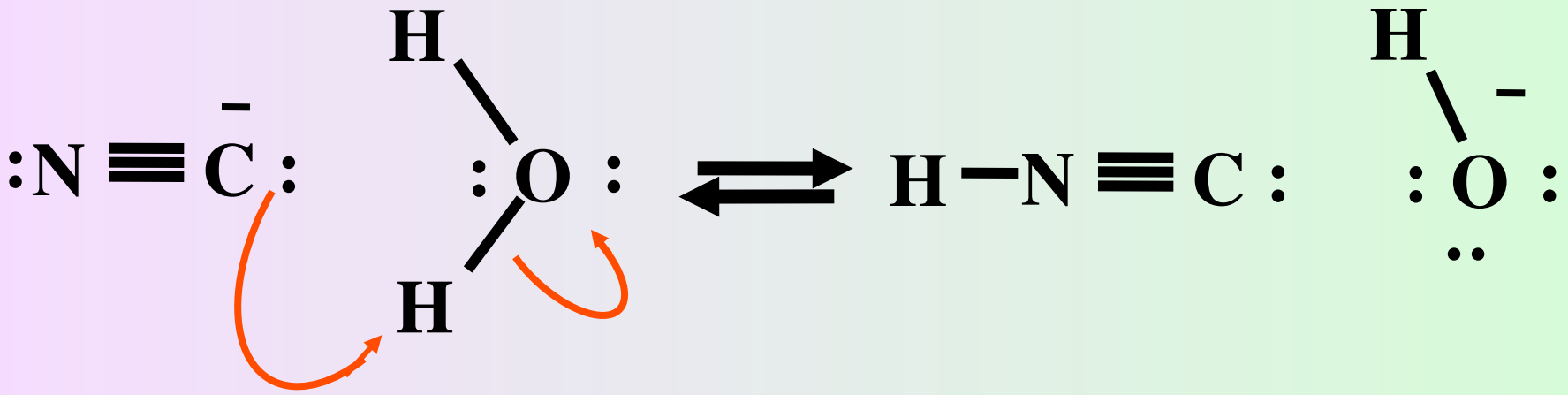
base

Conjugate base

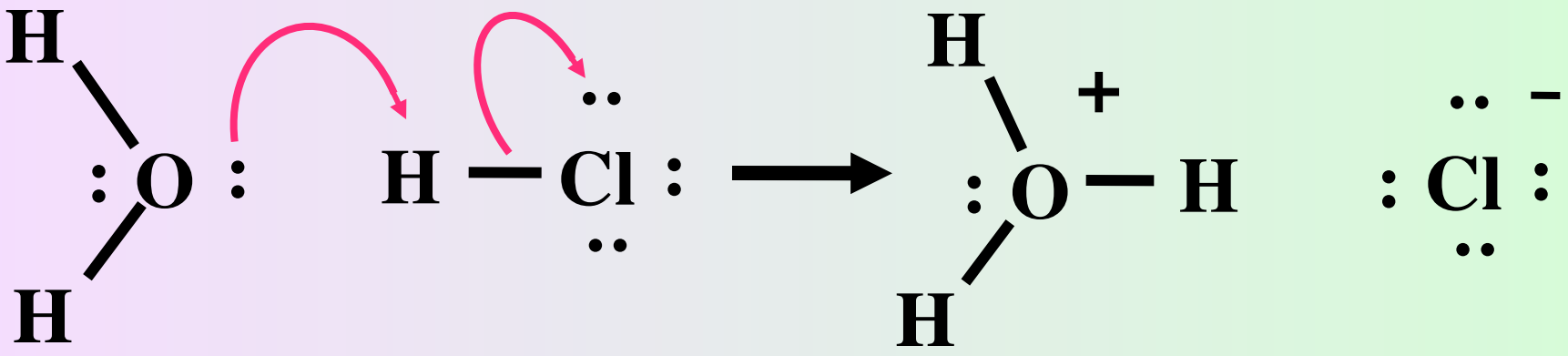
Conjugate acid

Practice Exercise

Identify the conjugate acid-base pairs for the reaction



Equilibrium constant for proton transfer



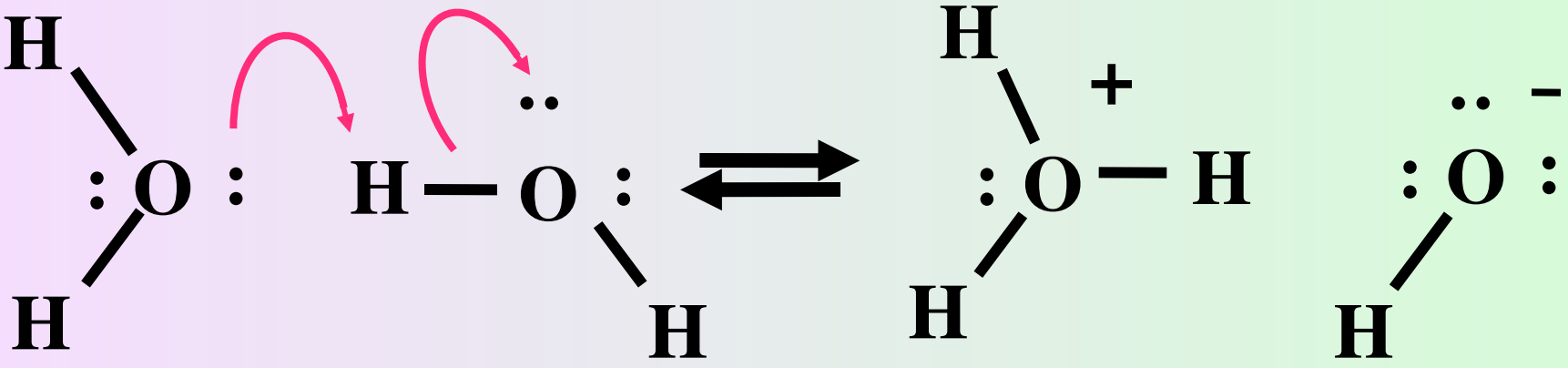
$$\frac{[H_3O^+][Cl^-]}{[H_2O]\,[HCl]}$$

$$K = \frac{[H_3O^+][Cl^-]}{[HCl]}$$

$$K = \frac{[H^+]\,[Cl^-]}{[HCl]}$$

The Acid - Base Properties of Water

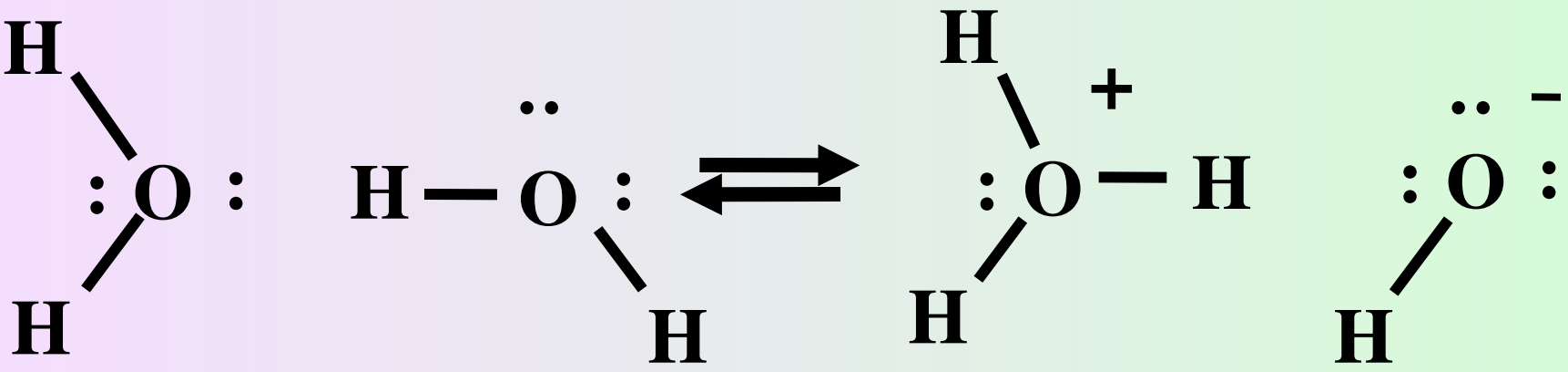
Water as an Acid and a Base



Ion Product of Water (K_w)

The equilibrium constant for the ionization of water into H^+ and OH^- ions

Ion Product of Water (K_w)



base acid Conjugate acid Conjugate base

$$K_w = [H_3O^+][HO^-] = [H^+][HO^-]$$

$$= 1.0 \times 10^{-14}$$

$$K_w = [H^+][HO^-] = 1.0 \times 10^{-14}$$

Neutral solution: $[H^+] = [HO^-]$

$= 1 \times 10^{-7}\ M$

Acidic solution: $[H^+] > [HO^-]$

Basic solution: $[H^+] < [HO^-]$

Practice Exercise

Calculate the concentration of HO^- ions in a hydrochloric acid solution whose hydrogen ion concentration is 1.3 *M*.

$$K_w = 1 \times 10^{-14} = [H_3O^+][HO^-]$$

$$1 \times 10^{-14} = (1.3)[HO^-]$$

$$7.7 \times 10^{-15}\ M = [HO^-]$$

pH: A Measure of Acidity

The pH Scale

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

The pH of a neutral solution is 7 at 25°C

Acidic solutions have pH < 7

$pH = -\log\ (10^{-6}) = 6$

Basic solutions have pH > 7

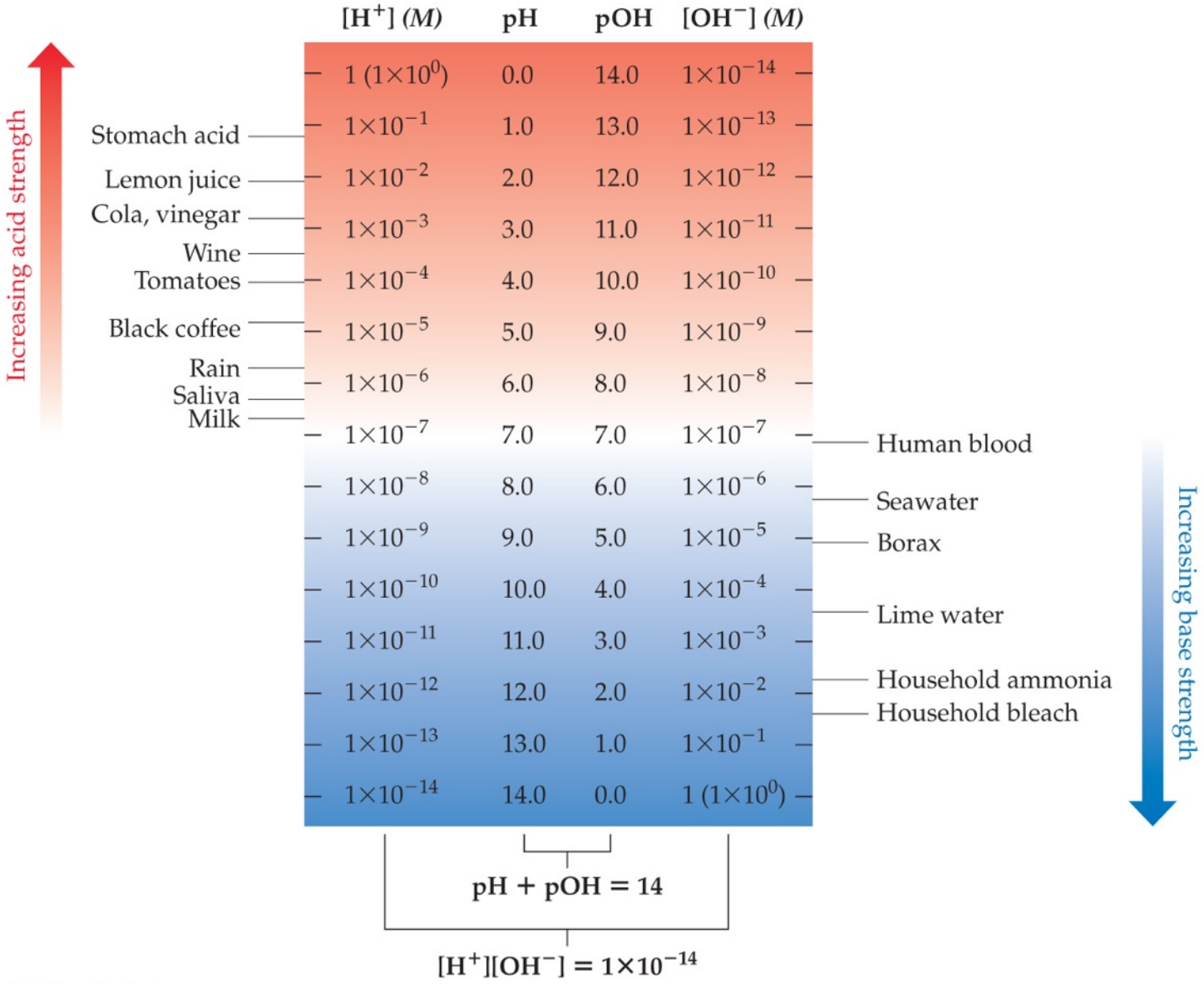
$pH = -\log\ (10^{-8}) = 8$

the pH scale is useful in that it lets us express acidity by numbers that are not exponentials

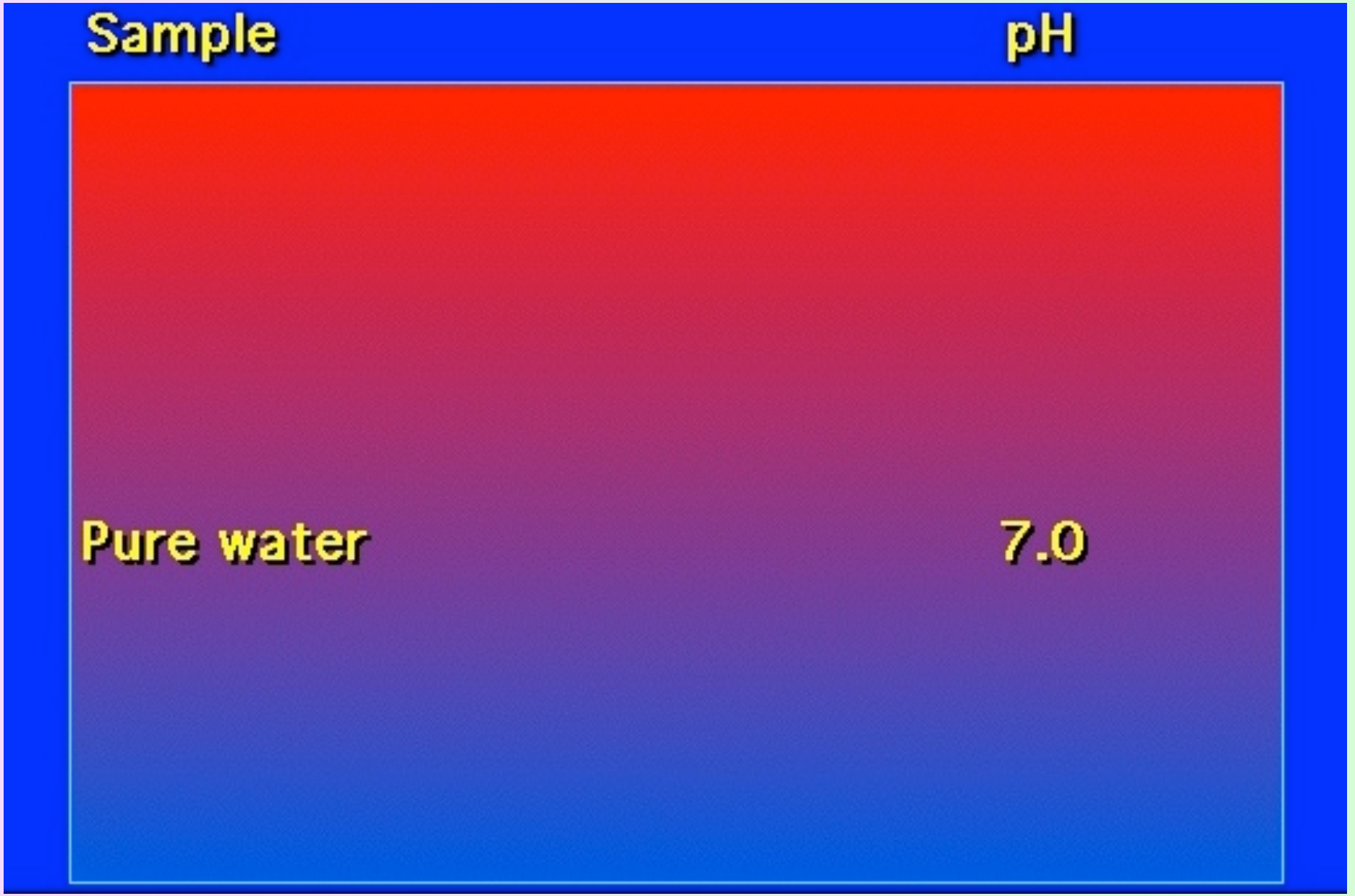
but we must keep in mind that a difference of 1 pH unit is equivalent to a factor of 10 acidity

thus, a solution with a pH of 2 is not twice as acidic as one with a pH of 4 it is 10^2 (or 100) times as acidic

pH



pH values of common fluids



pH values of common fluids

Sample	pH
Gastric juice in the stomach	1.0-2.0
Lemon juice	2.4
Vinegar	3.0
Grapefruit juice	3.2
Water exposed to air	5.5
Milk	6.5
Pure water	7.0

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Milk	6.5
Pure water	7.0
Blood	7.35-7.45
Tears	7.4
Milk of magnesia	10.6
Household ammonia	11.5

Practice Exercise

The pH of a certain fruit juice is 3.33 Calculate [H^+] .

$$pH = 3.33 = -\log_{10}[H^+]$$

$$\log [H^+] = -3.33$$

$$[H^+] = 10^{-3.33}$$

$$[H^+] = 4.7 \times 10^{-4} M$$

Other “p” Scales

- The “p” in pH tells us to take the negative base-10 logarithm of the quantity (in this case, hydronium ions).
- Some similar examples are
  - pOH: $-\log [OH^-]$
  - pK_w: $-\log K_w$

Practice Exercise

The OH- concentration of a blood sample is 2.5×10^{-7} *M* . What is its pH?

$$pOH = -\log_{10}[OH^-] = -\log[2.5 \times 10^{-7}]$$

$$pOH = 6.60$$

$$pH = 14 - pOH$$

$$pH + pOH = 14$$

pH = 7.40

The pH Scale

$$pH = \log_{10} = \frac{1}{[H^+]} = \log_{10} \frac{1}{[H_3O^+]}$$

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