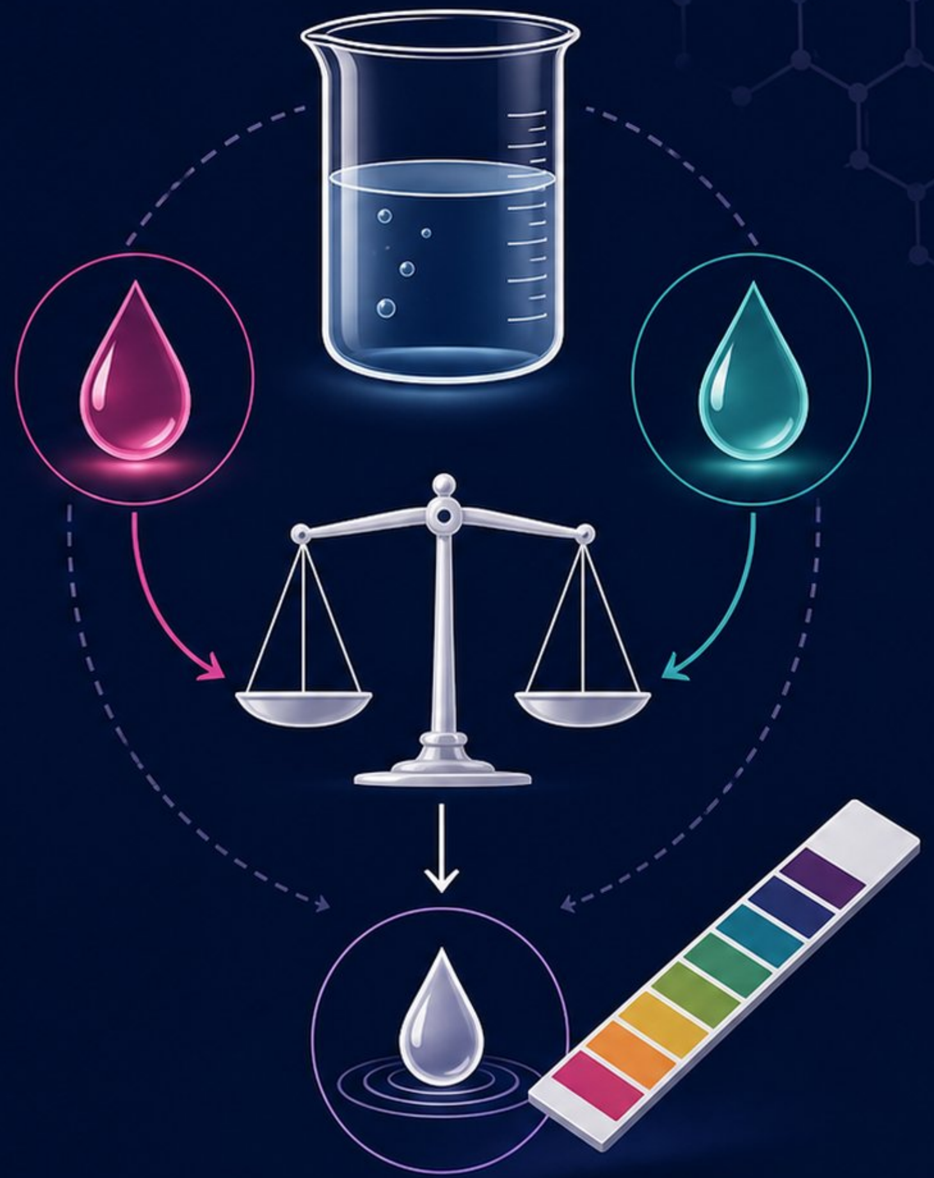
Acids, Bases, and pH: An Introduction

- Build conceptual links between acids, bases, and pH, not just memorize definitions
- Found everywhere: cooking, cleaning, farming, medicine, ocean acidification
- Recognize acid/base properties, interpret pH scale, connect strength to concentration
- Understand neutralization and buffers, then apply concepts to real-world systems



Everyday Encounters with Acids and Bases

- Acids taste sour (lemon juice, vinegar); bases feel slippery and taste bitter (soap, baking soda).
- Acids react with metals and carbonates; bases cut grease.
- Household examples: stomach acid (pH ~1.5), lemon juice (pH ~2), pure water (pH 7), baking soda (pH ~8.3), bleach (pH ~13).
- Early chemists used taste, touch, and plant dyes like litmus to classify substances.

The pH Scale

Lower numbers are more acidic.
Higher numbers are more basic.
7 is neutral.

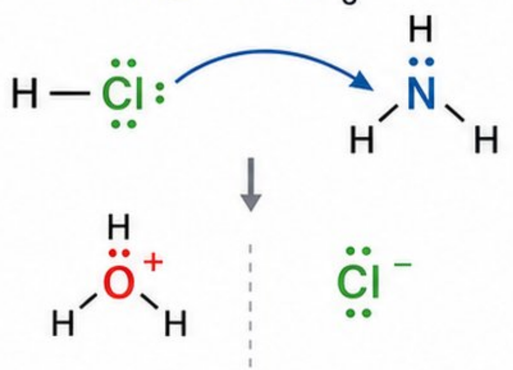
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Acidic ← Neutral → Basic

Three Models of Acids and Bases

1. Arrhenius Model

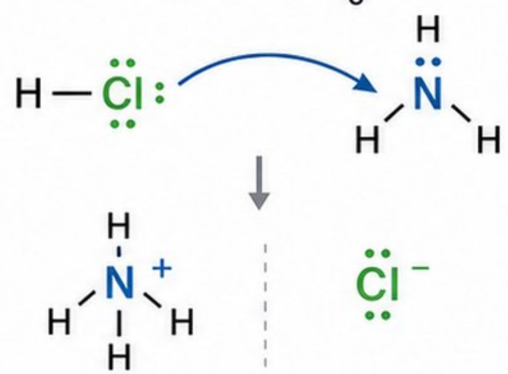
$HCl + NH_3$



Occurs in water (aqueous solution)

2. Brønsted-Lowry Model

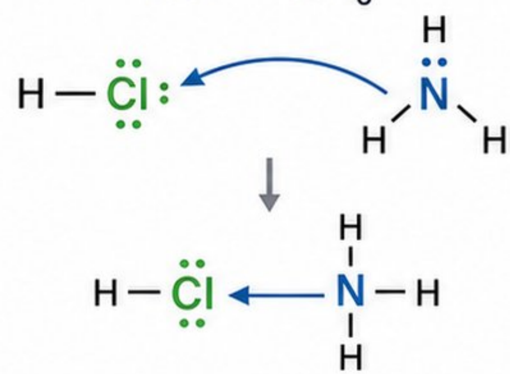
$HCl + NH_3$



Proton transfer (not limited to water)

3. Lewis Model

$HCl + NH_3$



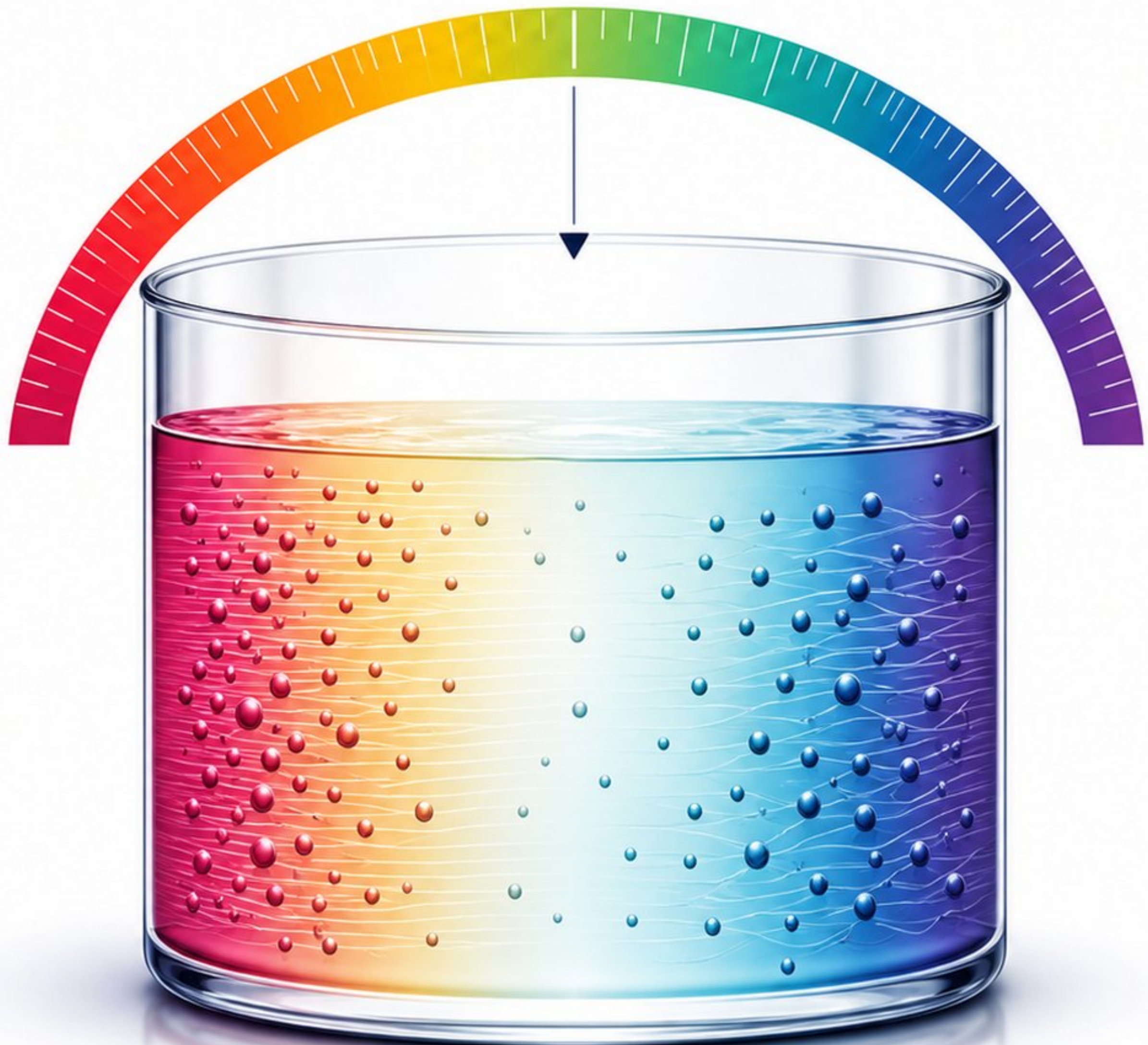
Electron pair interaction (most general)

- **Arrhenius: Acid produces H^+ in water; base produces OH^- in water (aqueous only).**
- **Brønsted-Lowry:** Acid donates a proton; base accepts a proton (broader scope).
- **Lewis:** Acid accepts an electron pair; base donates an electron pair (most general).
- **Models build on each other: All Arrhenius are Brønsted-Lowry; all Brønsted-Lowry are Lewis.**
- **Example: $BF_3 + F^- \rightarrow BF_4^-$ is Lewis only — no proton transfer involved.**

pH	0	1	2	3	4	5	6	7 Neutral	8	9	10	11	12	13	14
	Acidic								Basic						

What pH Really Means

- pH = $-\log[H^+]$ compresses huge concentration ranges to 0–14
- Each step is 10×; pH 3 is 100× more acidic than pH 5
- Below 7 = acidic (more H^+); 7 = neutral; above 7 = basic (more OH^-)
- pH applies only to water-based (aqueous) solutions

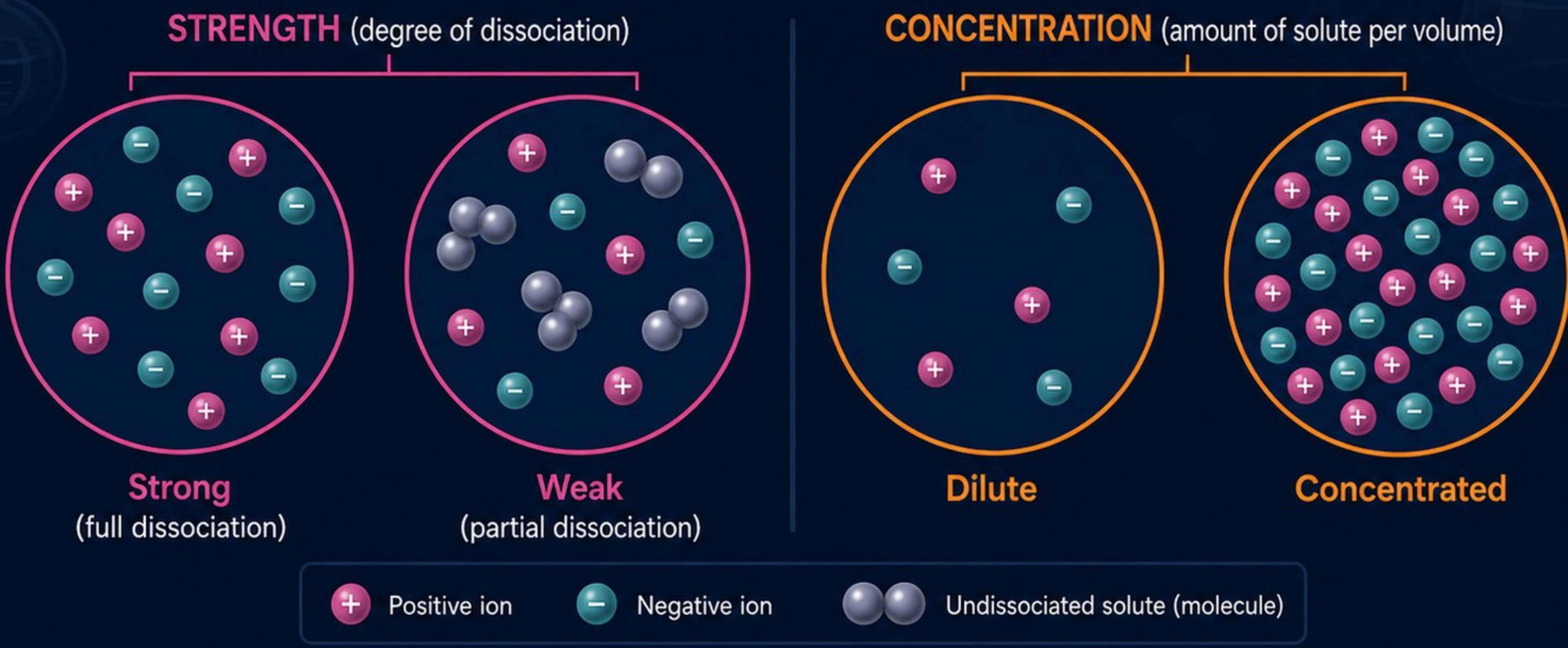


Measuring pH in Practice

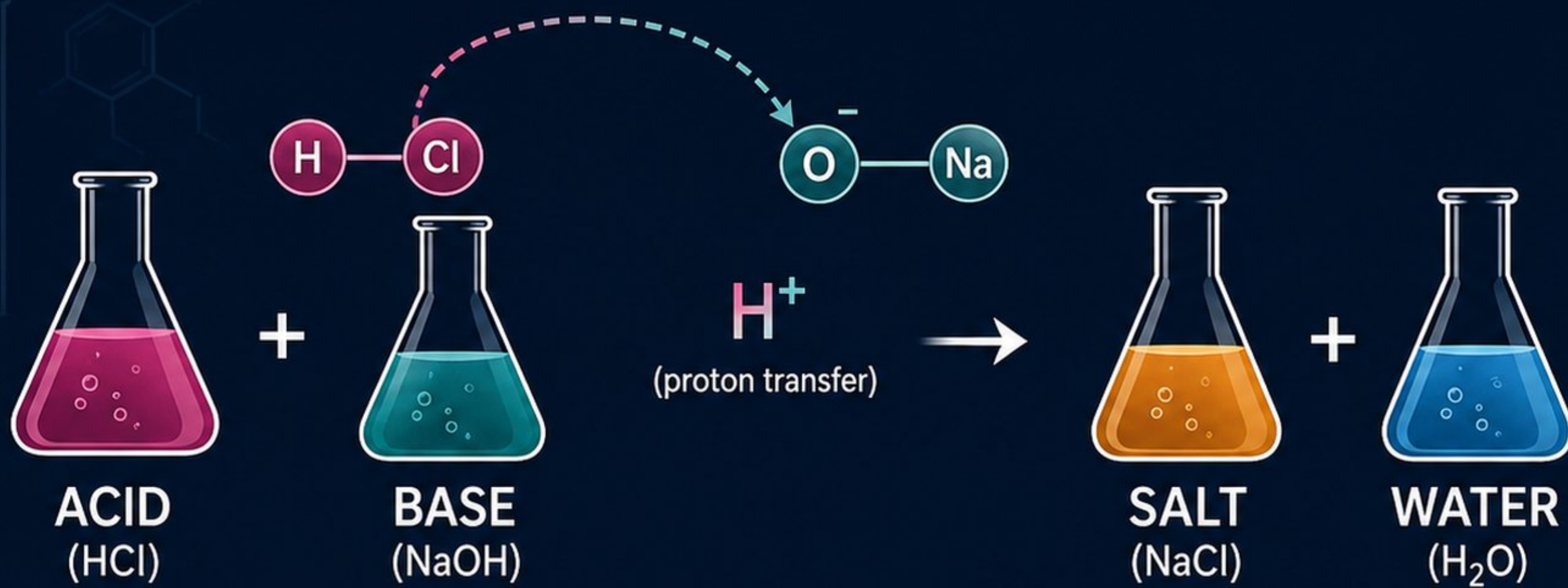
- **Indicators:** Litmus turns red in acid, blue in base — simple yes/no answer
- **Universal indicator:** Rainbow colors show approximate pH (red → green → purple)
- **Digital pH meters:** Give precise numbers; need calibration and proper electrode care
- **When to use:** Quick checks with paper; labs and medical needs with meters
- **Key reminder:** Only works on aqueous solutions — must be dissolved in water

Strength vs. Concentration: A Critical Distinction

- Strength = degree of dissociation (strong = full, weak = partial)
- Concentration = amount of solute per volume (dilute vs. concentrated)
- "Strong" is not "concentrated" — they vary independently
- pH reflects both: a dilute strong acid can outdo a concentrated weak one



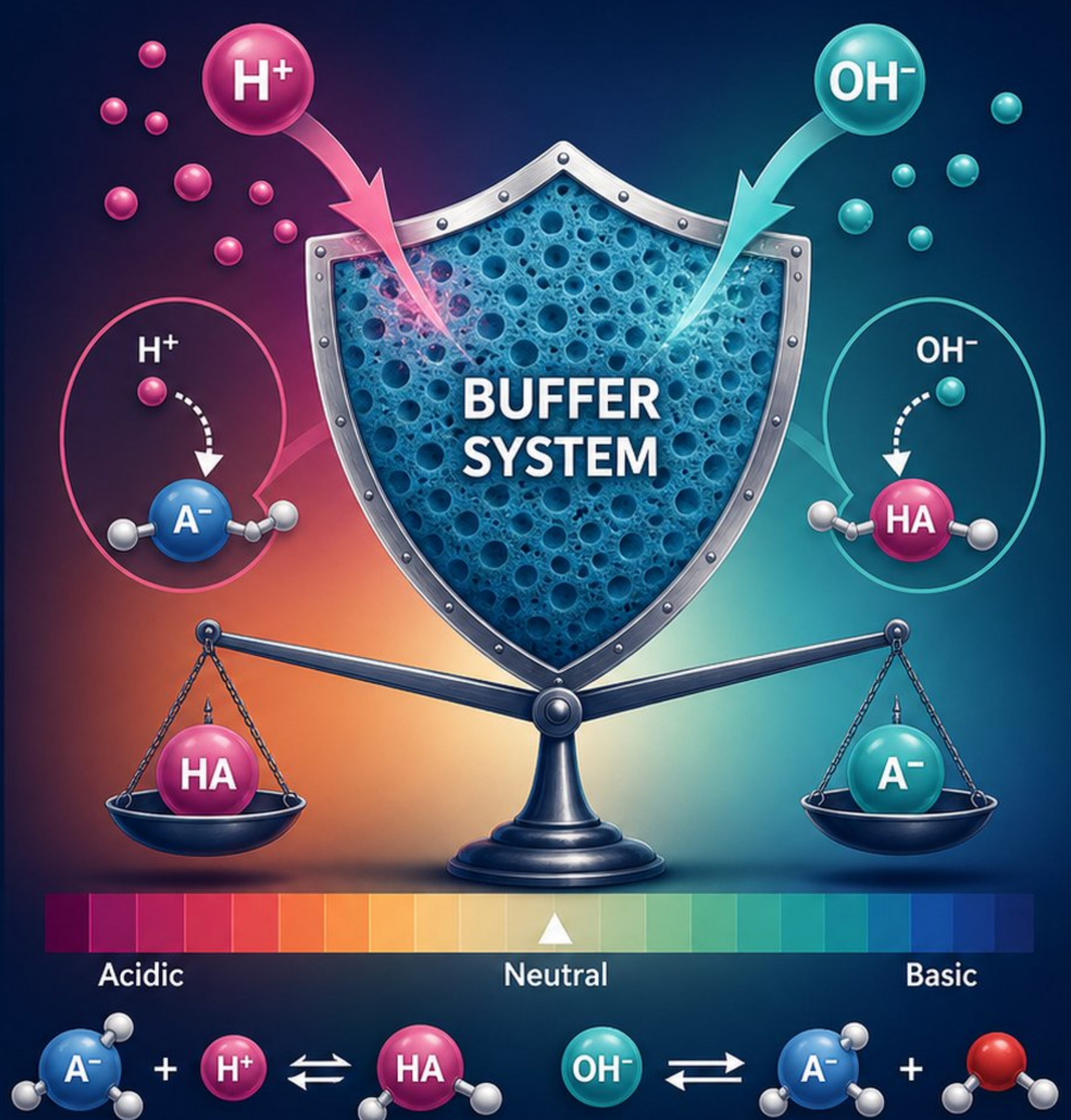
Neutralization: When Acids and Bases Meet



- Acid + Base → Salt + Water (e.g., HCl + NaOH → NaCl + H_2O)
- Antacids ($CaCO_3$) neutralize excess stomach acid
- Agricultural lime raises acidic soil pH
- Equivalence point: stoichiometric match – not always pH 7

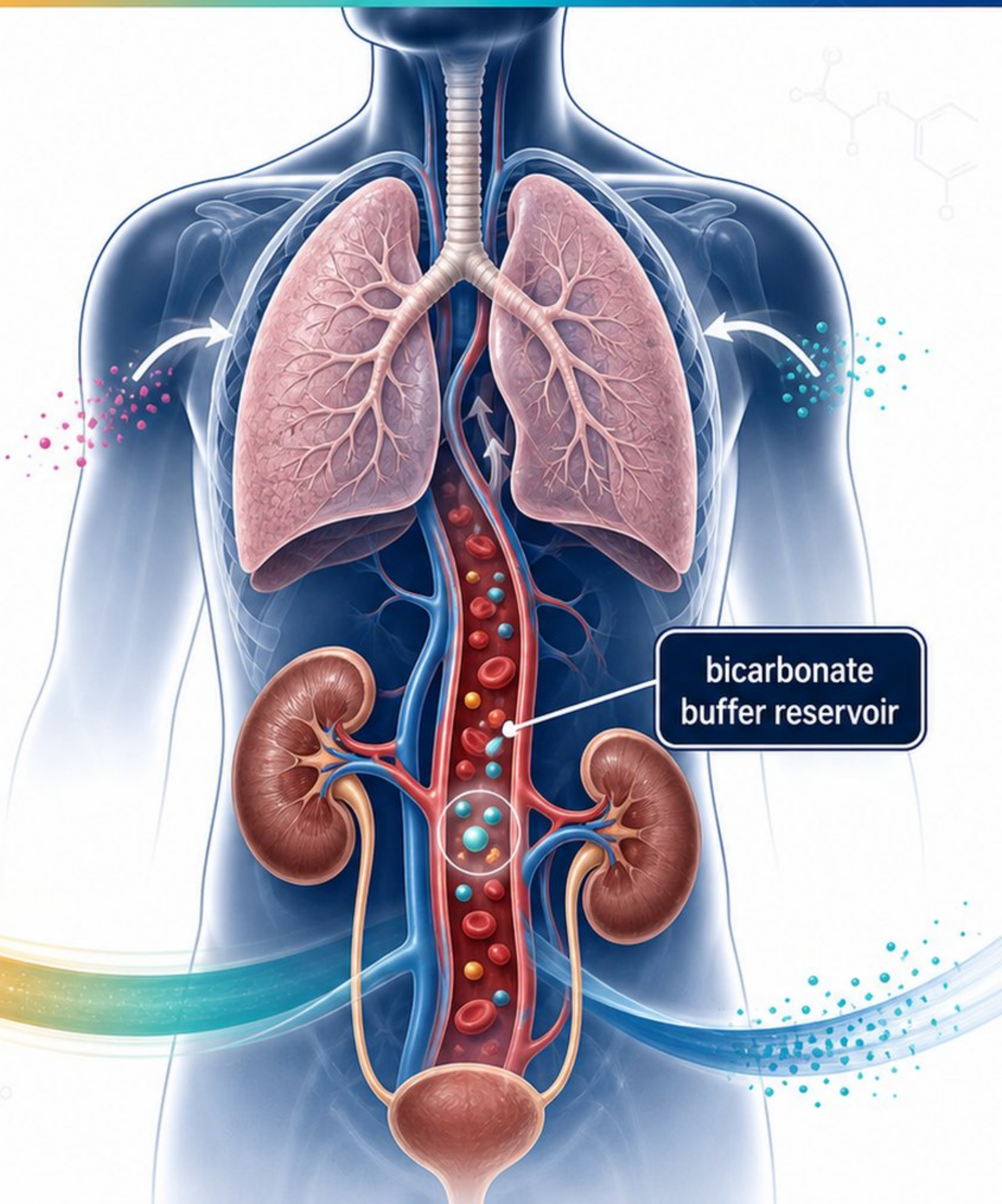
Buffers: How pH Stays Stable

- A buffer resists pH change using a weak acid and its conjugate base
- Added H^+ is absorbed by the base; added OH^- is absorbed by the acid
- Buffering is strongest within ±1 pH unit of the acid's pKa
- Capacity depends on buffer concentration; higher = more resistant
- Biological life depends on buffers — enzymes and proteins are pH-sensitive



Biological Buffers in Action

- Bicarbonate buffer (H_2CO_3/HCO_3^-): maintains blood pH at 7.35–7.45
- Lungs adjust CO_2 rapidly; kidneys regulate HCO_3^- for long-term control
- Phosphate and protein buffers dominate inside cells and urine
- Hemoglobin is the most abundant protein buffer in red blood cells
- Bone carbonate serves as a long-term mineral reserve in chronic acidosis

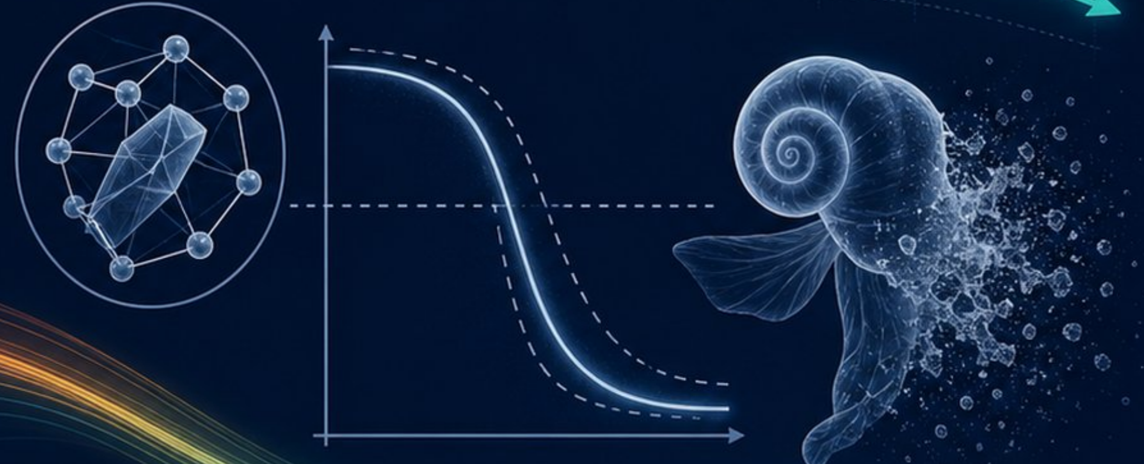


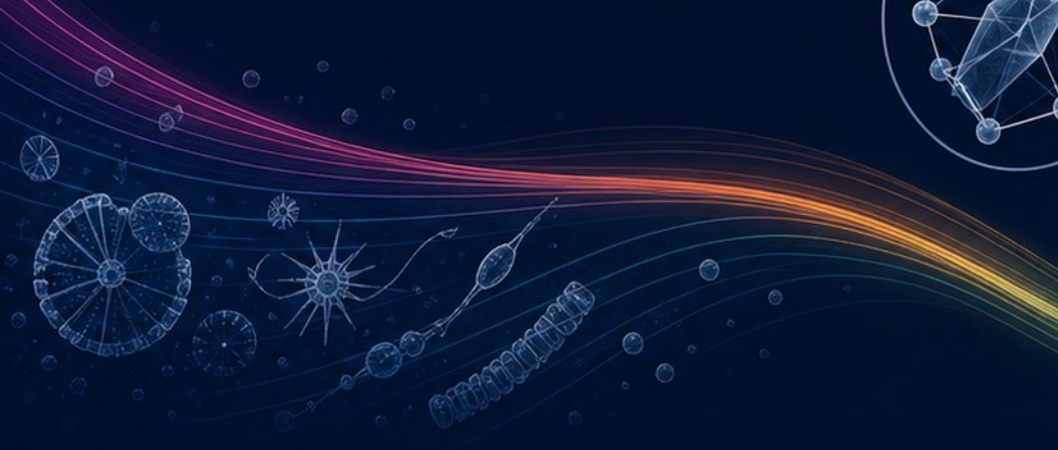
Acids, Bases, and pH in Industry and Daily Life

- **Agriculture:** Soil pH controls nutrient uptake; lime raises pH, sulfur lowers it.
- **Food:** Acids preserve and flavor (pickles); bases leaven (baking soda).
- **Cleaning:** Acidic cleaners dissolve scale (vinegar); alkaline cleaners cut grease (ammonia).
- **Medicine:** IV fluids are pH-balanced; antacids neutralize excess stomach acid.
- Blood gas analysis measures pH to diagnose life-threatening conditions.

Ocean Acidification: A Planetary Case Study

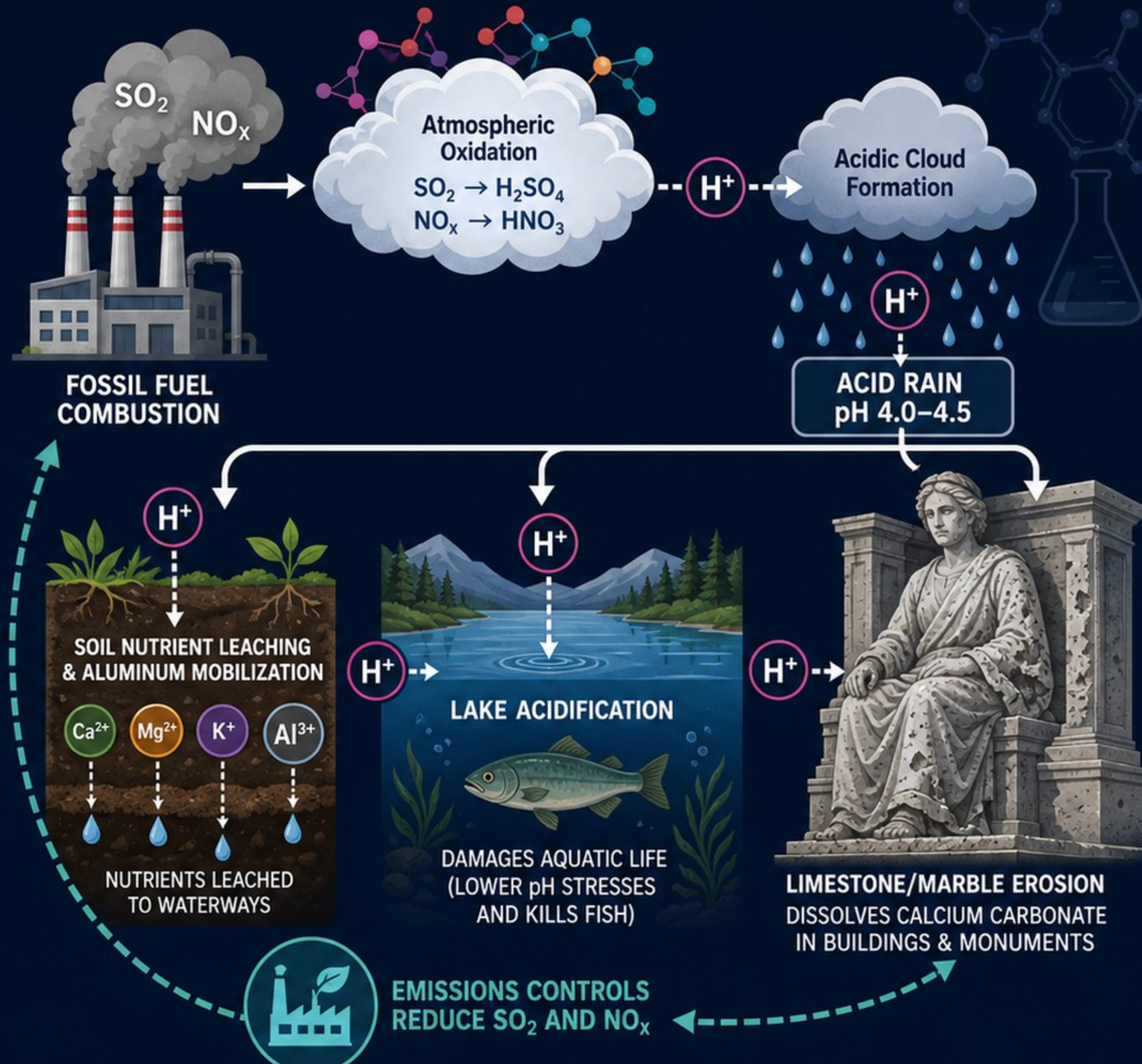
- “Atmospheric CO_2 forms carbonic acid in seawater, lowering pH and carbonate availability”
- “Since the 1980s, surface ocean pH dropped ~0.06 units—a ~10% decline in aragonite saturation”
- “Up to 60% of subsurface ocean crossed biogeochemical boundaries; 43% coral habitat loss”
- “Threatens shellfish fisheries, coral reef tourism, and marine food webs globally”



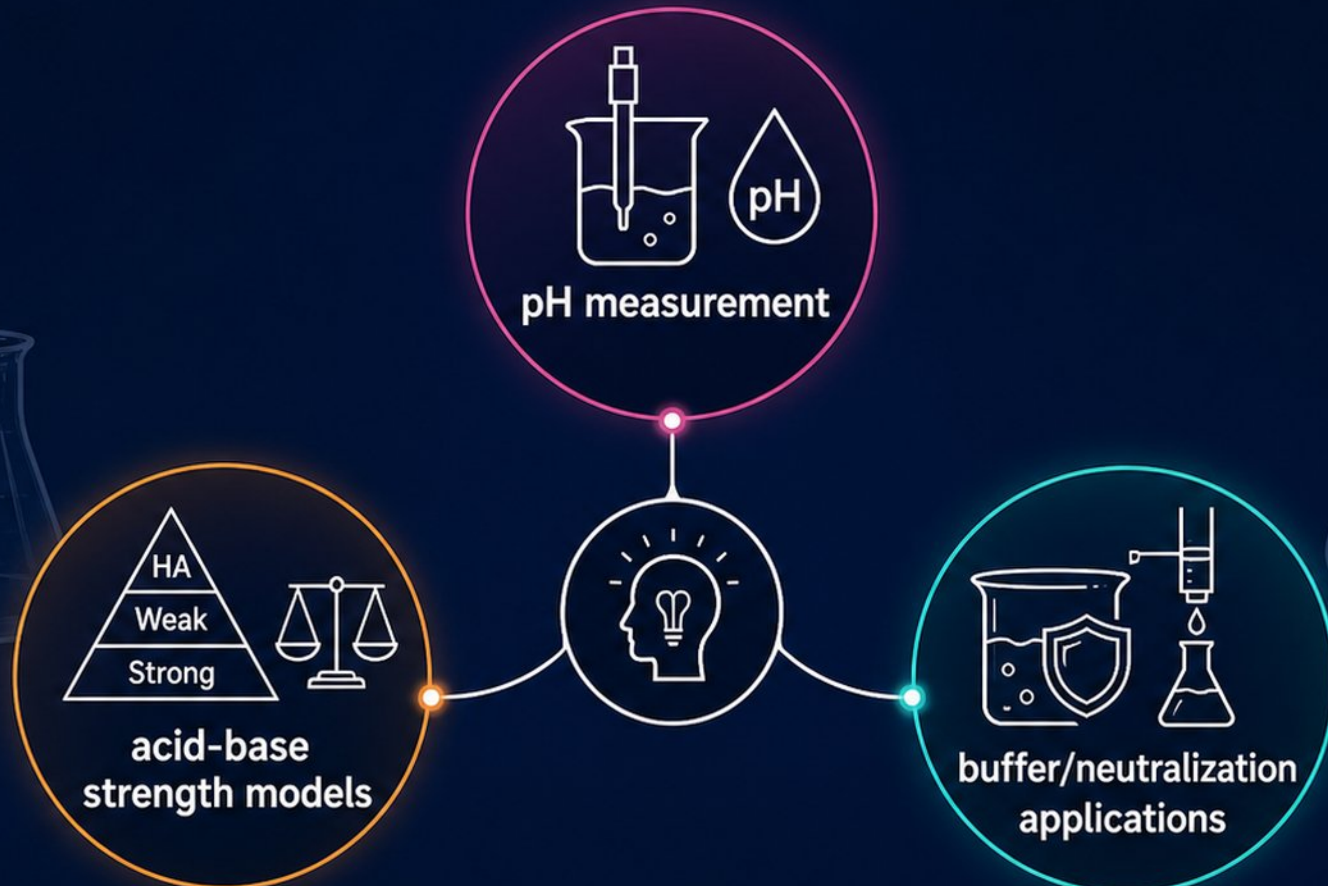


Acid Rain and Environmental Consequences

- "- SO_2 and NO_x from fossil fuels form sulfuric and nitric acids in the atmosphere."
- "- Normal rain pH ≈ 5.6; acid rain pH 4.0–4.5 — 10× to 40× more acidic."
- "- Leaches soil nutrients, mobilizes toxic aluminum, and acidifies lakes."
- "- Damages aquatic life and erodes limestone buildings and monuments."
- "- Emissions controls have cut acid rain sharply, proving policy can reverse damage."



Conceptual Integration and Review



- pH measures acid/base behavior defined by three progressive models
- Strength and concentration independently influence pH in real systems
- Neutralization and buffers control pH rather than eliminate changes
- 'Strong' ≠ 'concentrated'; ocean acidification is measured, not predicted