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Acids, Bases, and Salts

The Chemical Foundations

Acids

Bases

yield an excess of hydrogen ions in aqueous solution

yield an excess of hydroxide ions in aqueous solution

have sour taste

have bitter taste

turn litmus red

turn litmus blue

all alkali are basic

react with

each other

react

"active" metals

salts

some metals

can be classified as

strong/weak

organic, mineral acid

monobasic, dibasic and tribasic

The Evolution of Acid-Base Theory

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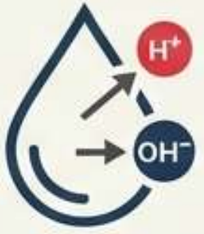
Pre-1880s

Sensory Definition

Based on observable properties like sour/bitter tastes and vegetable dye reactions.

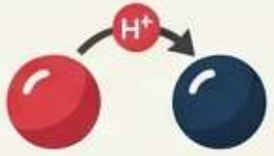
1880s



Arrhenius Concept

Aqueous definition focusing on the release of hydrogen and hydroxyl ions in water.

1923



Bronsted-Lowry Model

Proton definition focusing on the transfer of protons between substances.

Modern

Lewis Concept

Electronic definition, the most fundamental concept focusing entirely on electron pairs.

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Arrhenius and Bronsted-Lowry Concepts

Arrhenius Concept

- Acid: Yields free H^+ ions in water.

$$HA(aq) \rightleftarrows H^+(aq) + A^-(aq)$$

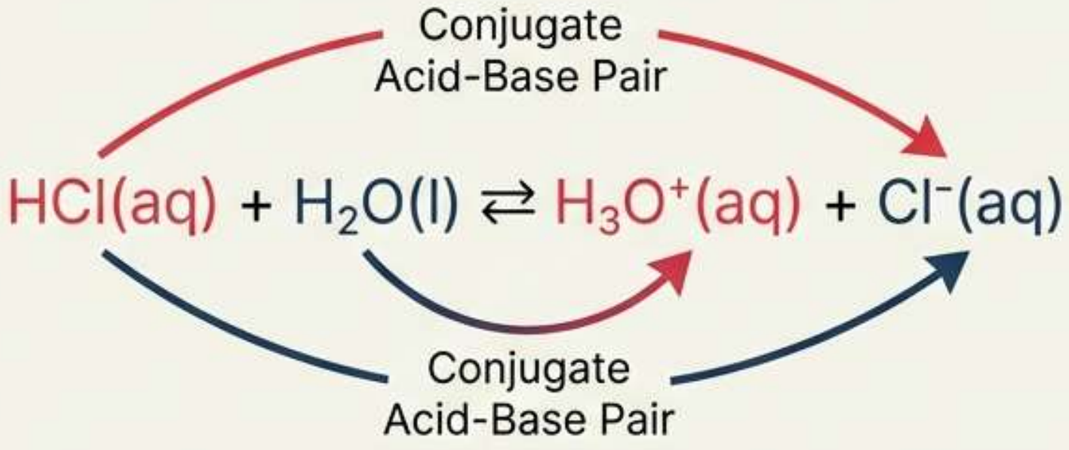
- Base: Yields free OH^- ions in water.

$$BOH(aq) \rightarrow B^+(aq) + OH^-(aq)$$

Bronsted-Lowry Concept

- Acid: Proton Donor.
- Base: Proton Acceptor.

Visualizing Conjugate Pairs



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The Lewis Electronic Concept

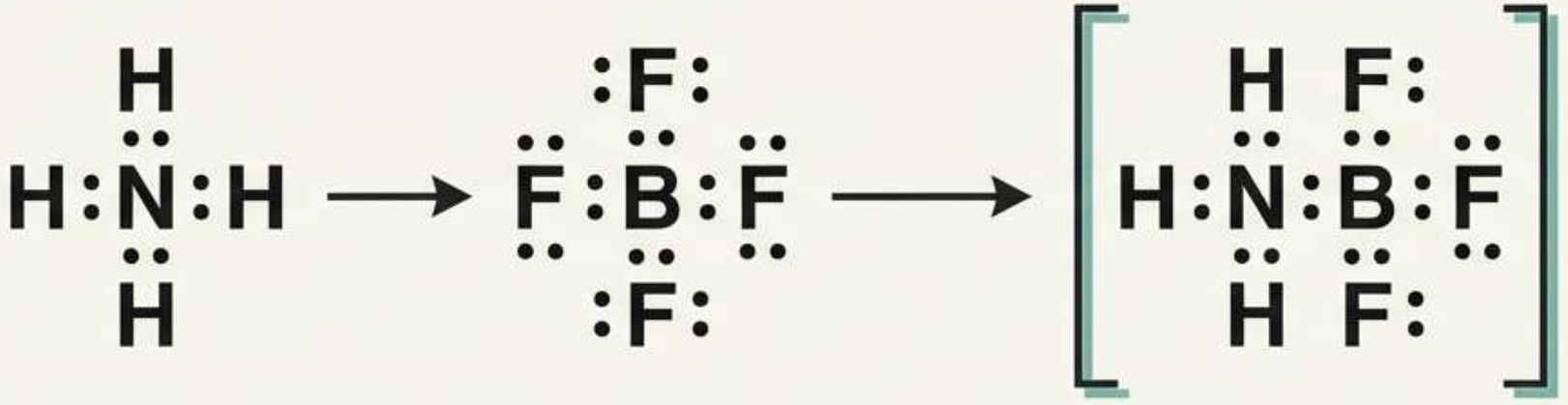
Hydrogen is not required. It's all about electrons forming coordinate bonds.

Lewis Acids (Acceptors)

Have empty orbitals to accommodate a lone pair. Examples include incomplete octets (BF_3, $AlCl_3$), simple cations (Na^+, Ag^+), and expandable octets ($SnCl_4$).

Lewis Bases (Donors)

Have at least one lone pair of electrons to donate. Examples include neutral molecules (NH_3) and anions (F^-, OH^-).



Anatomy of an Acid

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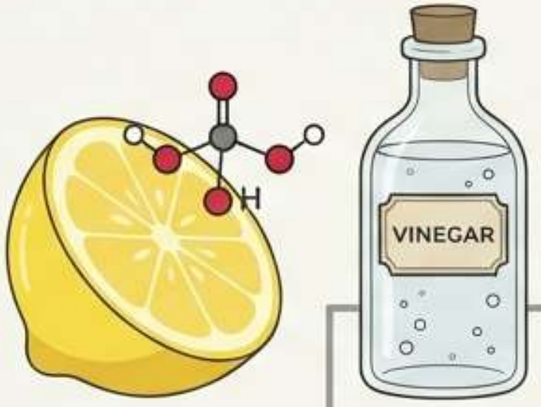
Fast Facts

Sour taste, turns blue litmus red, releases H^+ in aqueous solutions.



ACID

By Source

Mineral (Inorganic, from rocks: HCl, H_2SO_4) vs. **Organic** (From plants/animals: Formic acid, Citric acid)

By Basicity

Monobasic (1 hydronium ion: HCl) | **Dibasic** (2 ions: H_2SO_4) | **Tribasic** (3 ions: H_3PO_4)

By Composition

Binary (Hydroacids with no oxygen: HCl, HCN) vs. **Oxy acids** (Contain oxygen: HNO_3, H_2SO_4)

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Anatomy of a Base

Fast Facts

Bitter taste, soapy/slippery touch, turns red litmus blue, releases OH^- in aqueous solutions.

BASE

By Acidity

Monoacidic (1 OH^- ion: NaOH) | Diacidic (2 ions: $Ca(OH)_2$) | Triacidic (3 ions: $Al(OH)_3$).

By Concentration

Concentrated (less water) vs. Dilute (excess water).

The Alkali Rule: Bases that completely dissolve in water are called alkalis (NaOH, KOH). All alkalis are bases, but not all bases are alkalis.

Dissociation and Hydronium Formation

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The Hydronium Ion

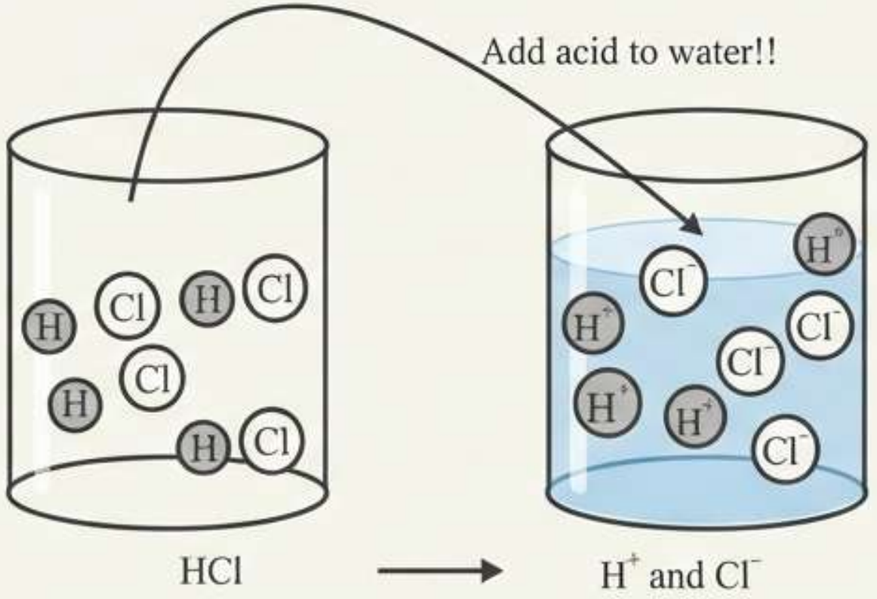
H^+ does not exist independently; it combines with water.

$$H^+ + H_2O \rightarrow H_3O^+$$

Strong (Complete Ionization)

Almost entirely dissociates.

Example: Mineral acids (HCl → $H^+ + Cl^-$) and strong bases (NaOH → $Na^+ + OH^-$).



Weak (Incomplete Ionization)

Only a small fraction ionizes, creating an equilibrium state.

Example: Organic acids ($CH_3COOH \rightleftarrows H^+ + CH_3COO^-$) and weak bases ($Mg(OH)_2$).

The Power of Visual Indicators

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Indicator	Neutral Color	Acidic Color	Basic Color
Litmus (Natural lichen dye)	Purple	Red	Blue
Phenolphthalein (Synthetic)	Colourless	Colourless	Pink
Methyl Orange (Synthetic)	Orange	Red	Yellow
Red Cabbage Juice	Purple	Red/Pink	Green
Turmeric Juice	Yellow	Yellow	Deep Brown/Reddish

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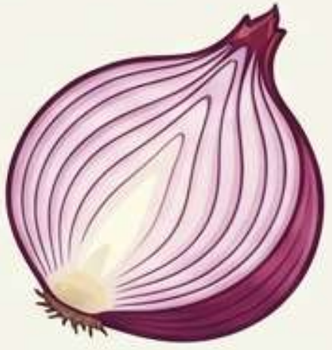
Olfactory Indicators

Certain substances emit a distinct odor in an acidic medium, but lose or change that odor in a basic medium.



The Big Three: Onion, Vanilla Essence, Clove Oil

Preparation

Keep chopped onion and cloth strips in a fridge overnight.

Testing

Place drops of dilute **HCl** (**acid**) on one strip and **NaOH** (**base**) on another.

Observation

Rinse and check if the characteristic smell remains to identify the medium.

Reaction with Metals: The ‘Pop’ Test

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Active metals displace hydrogen from acids to form salts.

Acid Reaction

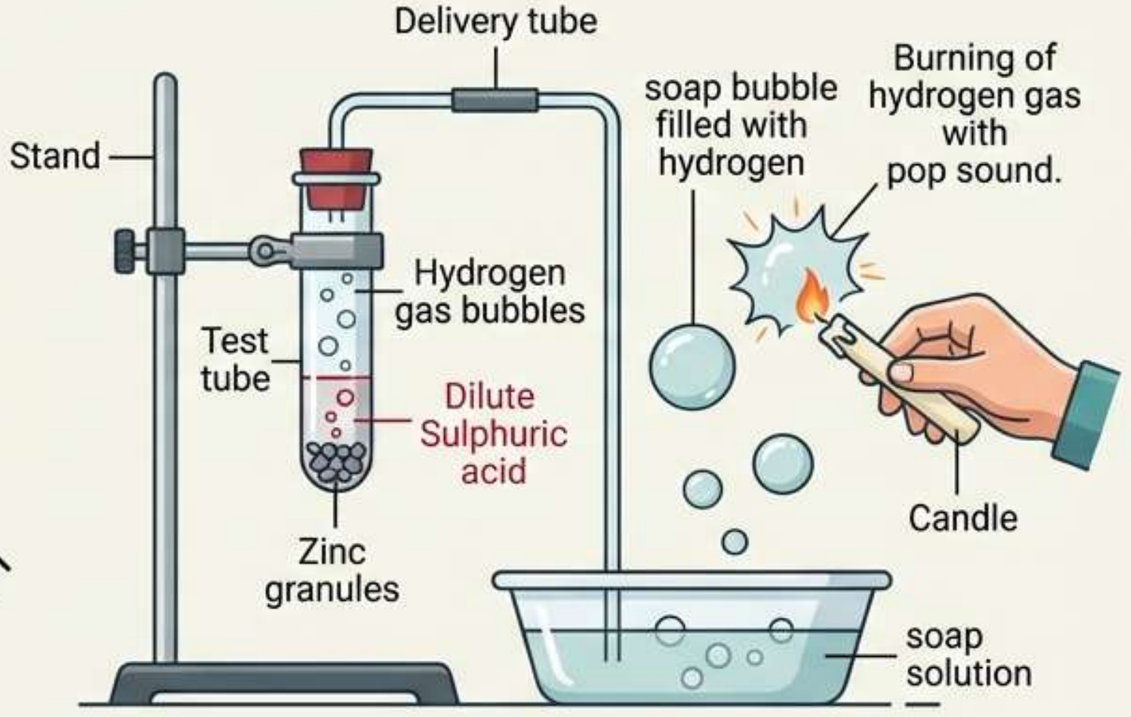
$Zn(s) + \text{dil. } H_2SO_4 \rightarrow ZnSO_4(aq) + H_2(g) \uparrow$

(Note: Cu, Hg, Ag do not react with dilute acids)

Base Reaction

$Zn(s) + 2NaOH(aq) \rightarrow Na_2ZnO_2(aq)$ [Sodium Zincate] $+ H_2(g) \uparrow$

Diagnostic Test: The evolved gas burns with a distinct popping sound.



Reaction with Oxides

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Acids + Metal Oxides

Metal oxides are basic. Reaction yields Salt + Water.

$$CuO + 2HCl \rightarrow CuCl_2 + H_2O$$

Copper Oxide Copper Chloride

Bases + Non-Metallic Oxides

Non-metallic oxides (CO_2, SO_2) are acidic. Reaction yields Salt + Water.

$$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$$

Reaction with Carbonates: The Limewater Test

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Metal carbonates + Acid → Salt + Carbon Dioxide + Water.

Step 1 (Effervescence):

$CaCO_3(s) + 2HCl(dil.) \rightarrow CaCl_2(aq) + H_2O(aq) + CO_2(g) \uparrow$

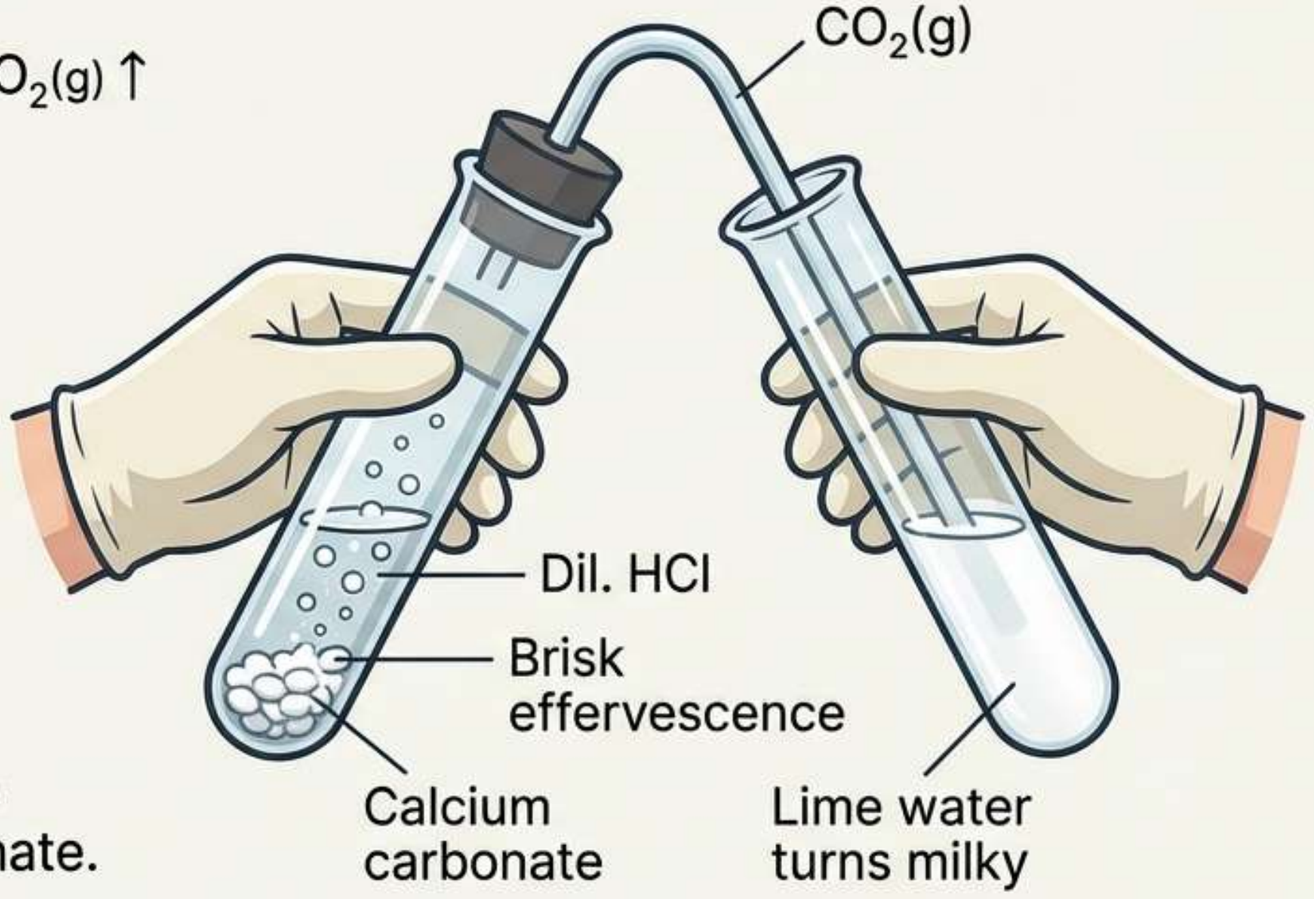
Egg shells are primarily $CaCO_3$ and dissolve in nitric acid.

Step 2 (Diagnostic Test):

Pass the CO_2 through limewater. It turns milky due to insoluble Calcium Carbonate.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3(s) + H_2O(l)$

Note: Passing excess CO_2 makes the milkiness disappear by forming soluble Calcium Bicarbonate.



The Mechanics of Neutralization

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Macro Equation

Acid + Base → Salt + Water

Micro Equation

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

The Process: When an acid and base mix, the hydronium and hydroxyl ions cancel each other out to form undissociated water molecules. The remaining ions form a salt, which is generally neutral to litmus.

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Neutralization in the Real World

Human Health

Excessive gastric juice (HCl) causes **acidity**.

Solution: Antacid tablets containing **bases** like baking soda or Magnesium Hydroxide neutralize the **acid**.

Stings & Bites

Ant/Bee stings inject corrosive formic **acid**. Neutralized by rubbing mild **alkali** (soap).

Wasp stings inject **alkaline** poison. Neutralized by weak **acid** (vinegar).

Agriculture

Acid rain turns soil **acidic**, harming crops.

Solution: Farmers add slaked lime (Calcium Hydroxide) to **neutralize** the soil.

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The Chemical Landscape