Chapter 10: Acid, Bases, and Salts

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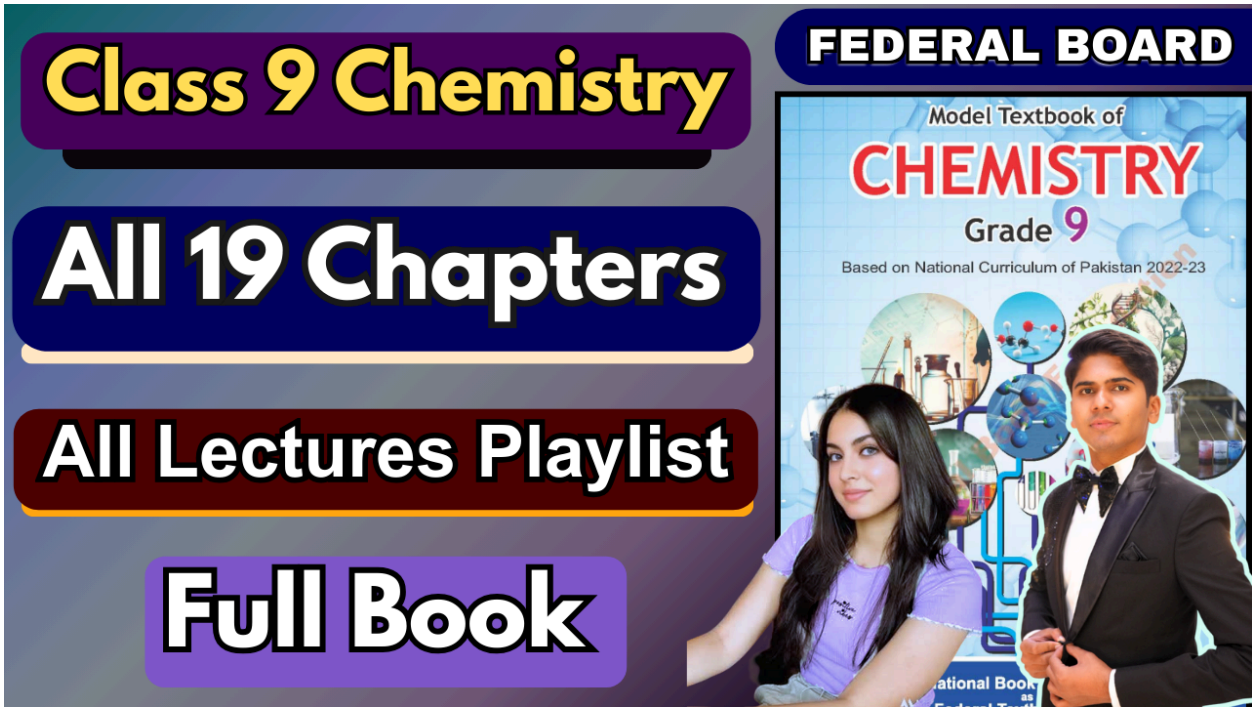
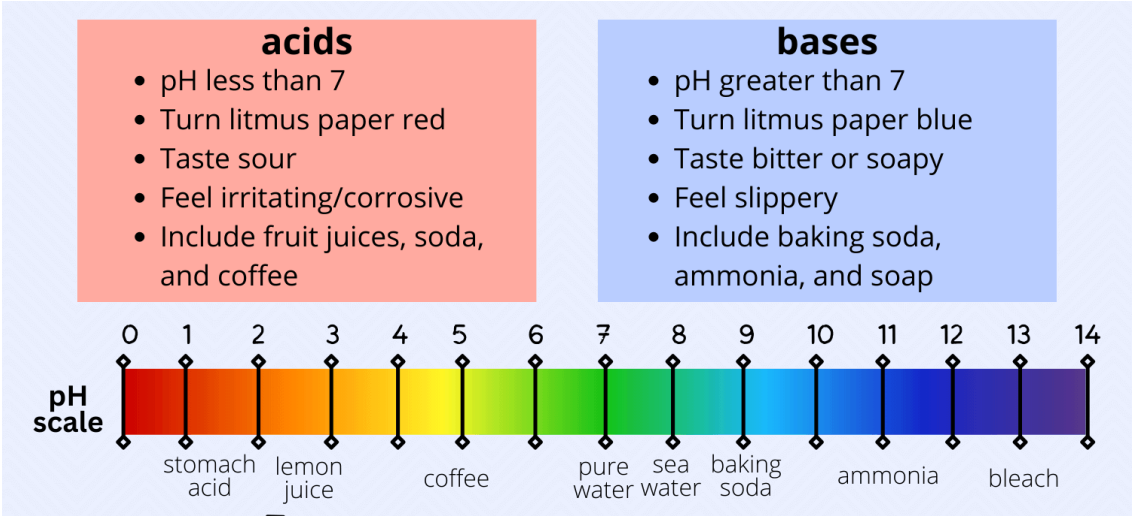


Acids and bases are everywhere! They are in the food we eat (like lemons and apples), the medicines we take (like aspirin and antacids), and the products we use for cleaning.

10.1. Concept of Acids and Bases

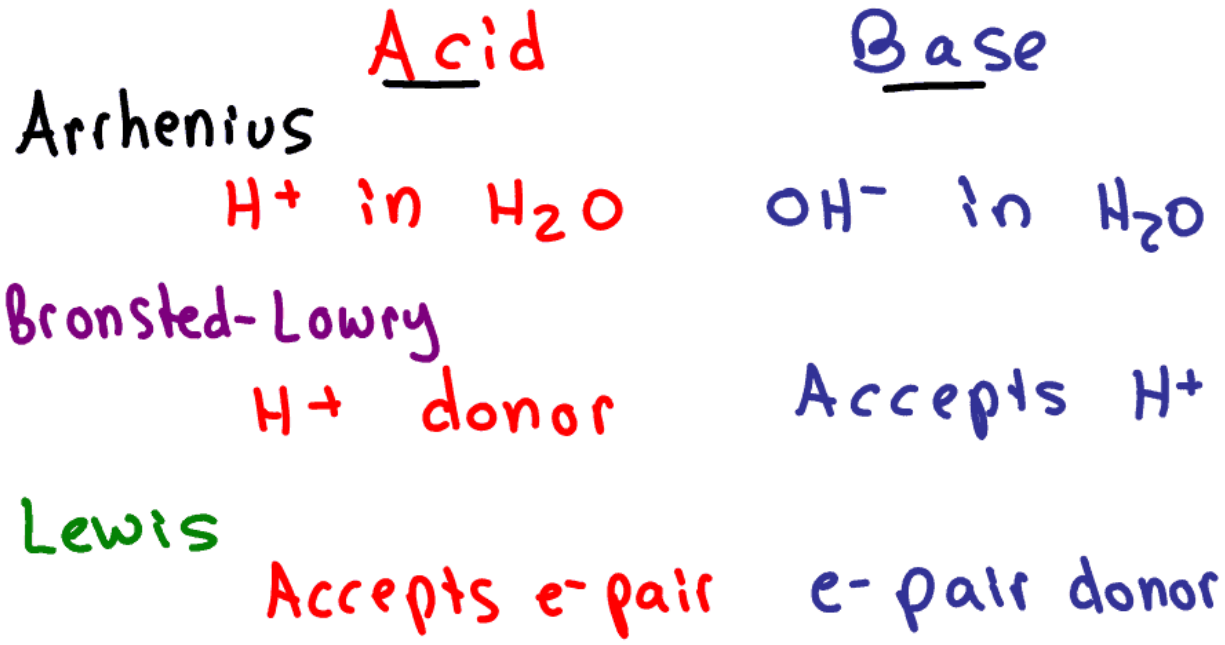
We can often identify acids and bases by their properties.



10.1.1. The Arrhenius Theory (A Simple Scientific Definition)

In 1887, Svante Arrhenius gave a clear scientific definition:

- An Acid is a substance that, when dissolved in water, produces Hydrogen ions (H^+).
- A Base is a substance that, when dissolved in water, produces Hydroxide ions (OH^-).



Examples:

· Hydrochloric Acid: $HCl \rightarrow H^+(aq) + Cl^-(aq)$ (So, HCl is an acid)

· Sodium Hydroxide: $NaOH \rightarrow Na^+(aq) + OH^-(aq)$ (So, NaOH is a base)

Common Acids and Their Uses:

Name	Formula	Common Uses
Hydrochloric Acid	HCl	Cleaning metals, bricks; removing scale from boilers

Nitric Acid	HNO_3	Making fertilizers and explosives
Sulphuric Acid	H_2SO_4	Making chemicals, drugs, dyes, paints, and explosives
Phosphoric Acid	H_3PO_4	Making fertilizers; used as an acidulant in foods

Common Bases and Their Uses

Name	Formula	Common Uses
Sodium Hydroxide	NaOH	Making soap, drain cleaners
Potassium Hydroxide	KOH	Making liquid soap, shaving cream
Calcium Hydroxide	$Ca(OH)_2$	Making mortar, plaster, and cement
Magnesium Hydroxide	$Mg(OH)_2$	Used in antacids and laxatives

Alkalis: A Special Type of Base

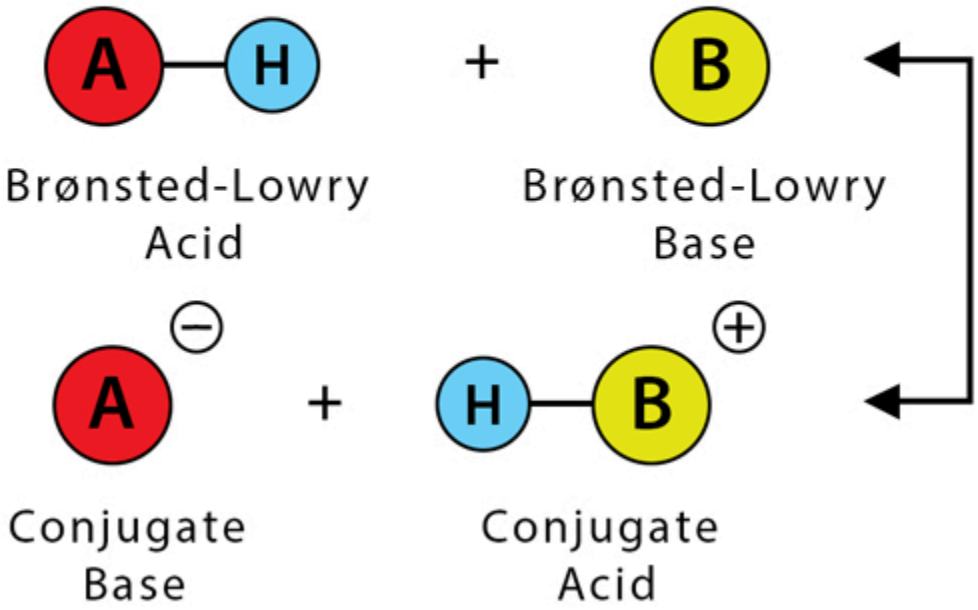
An alkali is a base that is soluble in water. All alkalis are bases, but not all bases are alkalis. Examples of Alkalis (Water-Soluble Bases): KOH (Potassium hydroxide), NaOH (Sodium hydroxide)

Examples of Bases that are NOT Alkalis (Water-Insoluble): $Cu(OH)_2$ (Copper hydroxide), $Al(OH)_3$ (Aluminium hydroxide), $Fe(OH)_3$ (Ferric hydroxide).

Common Use: Alkalis are found in many household items like soaps, detergents, shampoos, and toothpaste.

10.1.2. The Brønsted-Lowry Theory

The Arrhenius theory couldn't explain why substances like ammonia (NH_3), which has no OH^- ions, act as bases. The Brønsted-Lowry theory provides a broader definition.



· An Acid is a proton (H^+ ion) donor.

· A Base is a proton (H^+ ion) acceptor.

How does this work with Ammonia?

When ammonia gas dissolves in water, it accepts a proton (H^+) from a water molecule.

$H_2O + NH_3 \longrightarrow NH_4^+ + OH^-$

· Here, H_2O donates a proton, so it acts as an acid.

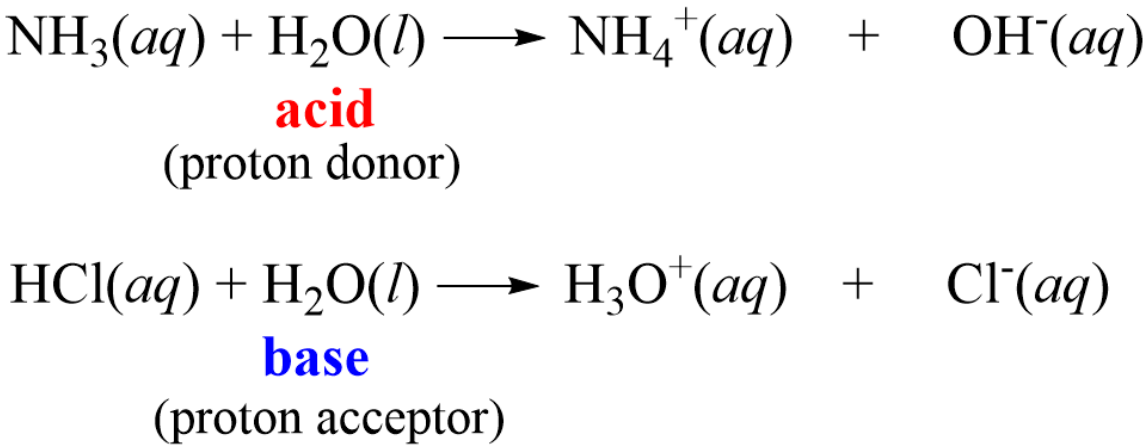
· NH_3 accepts the proton, so it acts as a base.

The Special Case of Water: Amphoteric Nature

· In the reaction with HCl, water accepts a proton (acts as a base).

· In the reaction with NH_3, water donates a proton (acts as an acid).

· A substance that can act as both an acid and a base is called amphoteric. Water is a great example of an amphoteric substance.



10.2. Strength of Acids and Bases

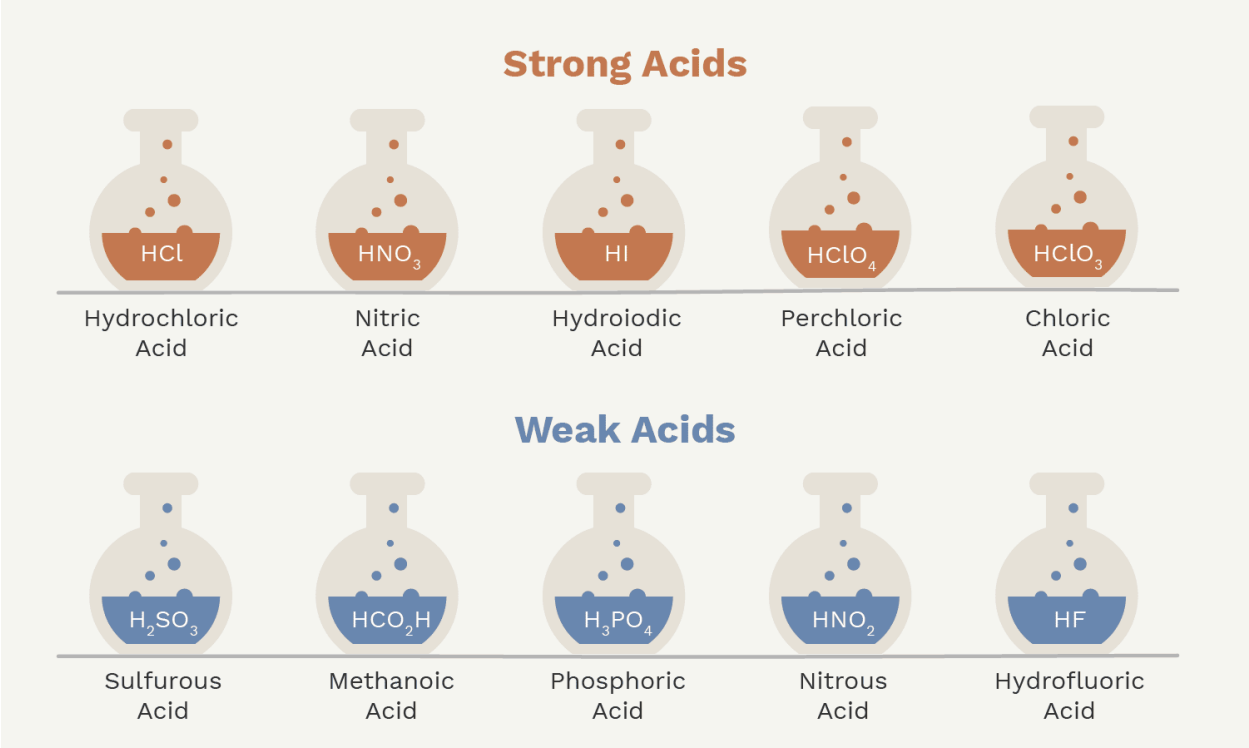
Strength refers to how completely an acid or base ionizes (breaks apart into ions) in water.

10.2.1. Strong vs. Weak Acids

Property	Strong Acids	Weak Acids
Ionization	Ionize completely (100%) in water.	Ionize only partially in water.
Ions Produced	Produce a high concentration of H^+ ions.	Produce a low concentration of H^+ ions.

Examples (Strong Acids):
Hydrochloric Acid (HCl), Nitric Acid (HNO_3), Sulphuric Acid (H_2SO_4)
Reaction Examples:
Acetic Acid (CH_3COOH, found in vinegar), Carbonic Acid (H_2CO_3)

· Strong Acid: $HCl \longrightarrow H^+(aq) + Cl^-(aq)$ (All molecules split into ions)
· Weak Acid: $CH_3COOH \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$ (Only a few molecules split; reaction is reversible)



10.2.2. Strong and Weak Bases

Property	Strong Bases	Weak Bases
Ionization	Ionize completely (100%) in water.	Ionize only partially in water.
Ions Produced	Produce a high concentration of OH^- ions.	Produce a low concentration of OH^- ions.

Examples:

Sodium Hydroxide (NaOH), Potassium Hydroxide (KOH)Ammonia (NH_3), Aluminium Hydroxide ($Al(OH)_3$)

Reaction Examples:

· Strong Base: $NaOH \longrightarrow Na^+(aq) + OH^-(aq)$ (All molecules split into ions)

· Weak Base: $NH_3 + H_2O \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ (Only a small amount of OH^- is produced; reaction is reversible)

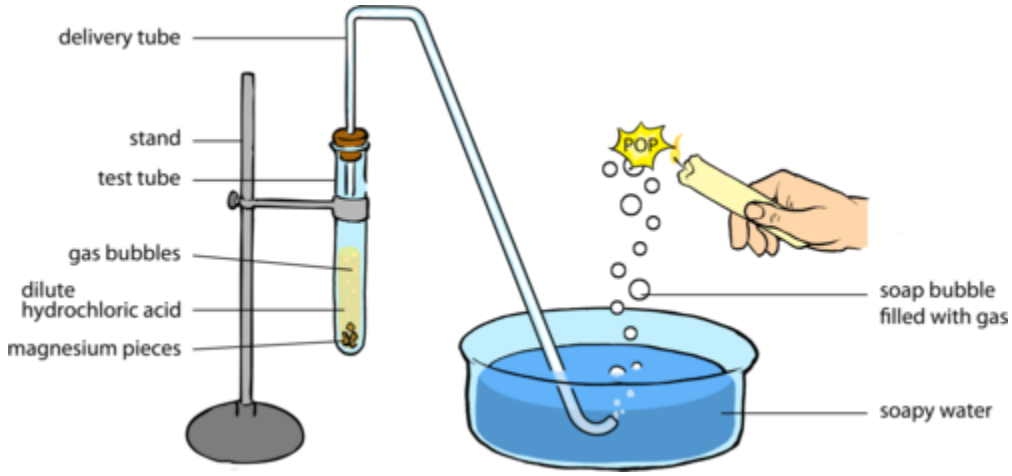
10.3. Characteristic Properties of Acids (How Acids Behave)

Acids have several key chemical reactions:

1. Reaction with Metals

Acids react with many common metals (like Zn, Mg, Al) to produce a salt and hydrogen gas (H_2).

You can see bubbles of hydrogen gas being released.



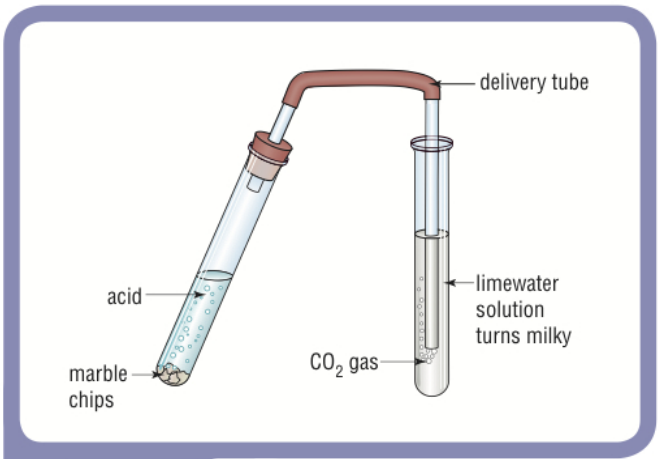
General Equation: Metal + Acid ⟶ Salt + Hydrogen

Examples:

- $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$
- $Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$

2. Reaction with Metal Carbonates

Acids react with metal carbonates (like washing soda, limestone, marble) to produce salt, water, and carbon dioxide gas (CO_2). The CO_2 gas causes fizzing or bubbling.



General Equation: Metal Carbonate + Acid ⟶ Salt + Water + Carbon Dioxide

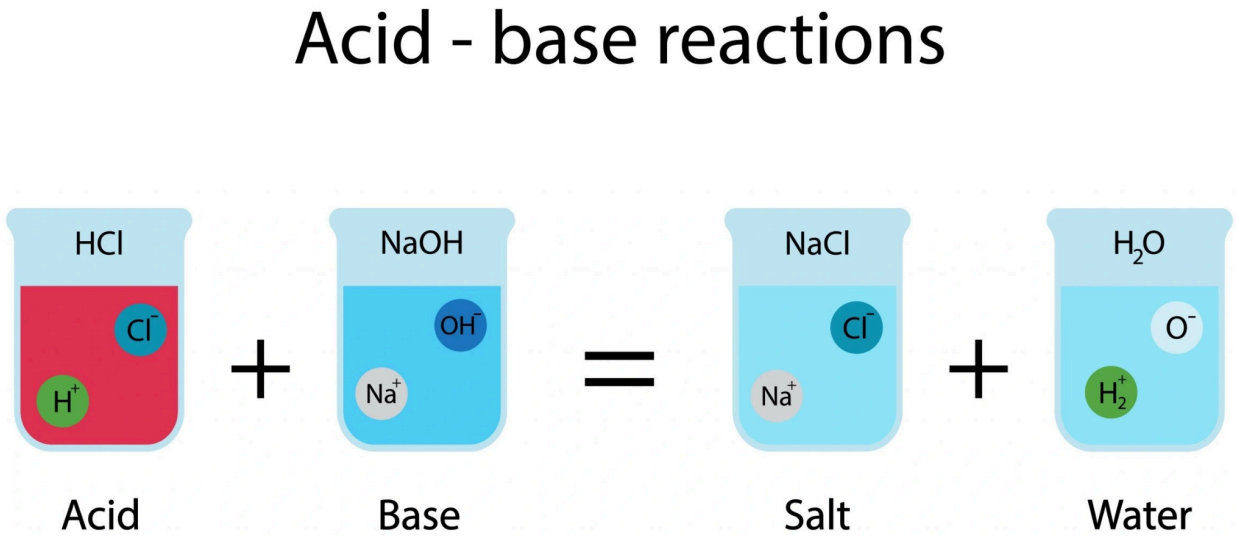
Examples:

- $Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$
- $CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$

Use: This reaction is used in industries to make glass, paper, and soap.

3. Neutralization Reaction with Bases

This is a fundamental reaction where an acid and a base cancel each other out, producing salt and water.



General Equation: Acid + Base ⟶ Salt + Water

Examples:

- o HCl + NaOH ⟶ NaCl + H_2O
- o H_2SO_4 + 2KOH ⟶ K_2SO_4 + $2H_2O$

Real-World Impact: Acid Rain

Normal rain is slightly acidic due to dissolved CO_2.Acid rain is formed when pollutants like sulfur and nitrogen oxides dissolve in rainwater, creating sulfuric and nitric acids.Because acids react with carbonates and metals, acid rain corrodes buildings, statues (especially marble, which is $CaCO_3$), and metal structures.

10.4. Characteristic Properties of Bases (How Bases Behave)

1. Neutralization Reaction with Acids

As shown above, this is the primary reaction of a base with an acid.

General Equation:

Base + Acid ⟶ Salt + Water

2. Reaction with Ammonium Salts

When a base is heated with an ammonium salt, it produces a salt, ammonia gas (NH_3), and water. Ammonia gas has a strong, pungent smell.

General Equation: Base + Ammonium Salt ⟶ Salt + Ammonia + Water Examples:
o $NaOH + NH_4Cl \longrightarrow NaCl + NH_3 + H_2O$
o $KOH + NH_4Cl \longrightarrow KCl + NH_3 + H_2O$

10.5. Oxides and Hydroxides

Formation of Metal Oxides

Metals react with oxygen in the air to form metal oxides.
Examples:
o $4Na + O_2 \longrightarrow 2Na_2O$ (Sodium Oxide)
o $2Mg + O_2 \longrightarrow 2MgO$ (Magnesium Oxide)

Metal Oxides are Basic

Most metal oxides are basic in nature. When they dissolve in water, they form metal hydroxides (alkalis).
How it works: The oxide ion (O^{2-}) from the metal oxide is unstable in water. It acts as a base (a proton acceptor) and takes a proton (H^+) from a water molecule, forming two hydroxide ions (OH^-).
General Equation: Metal Oxide + Water ⟶ Metal Hydroxide
Examples:
o $MgO + H_2O \longrightarrow Mg(OH)_2$
o $Na_2O + H_2O \longrightarrow 2NaOH$
o $CaO + H_2O \longrightarrow Ca(OH)_2$

Most metal oxides/hydroxides are basic, but a special few can react with both acids and bases. These are called amphoteric oxides/hydroxides.
Examples: Aluminium Oxide (Al_2O_3), Aluminium Hydroxide ($Al(OH)_3$), Zinc Oxide (ZnO), Zinc Hydroxide ($Zn(OH)_2$).

- Acids are characterized by their reactions with metals (producing H_2), carbonates (producing CO_2), and bases (neutralization).
- Bases neutralize acids and can release ammonia gas when heated with ammonium salts.
- Metal Oxides are generally basic and form metal hydroxides (alkalis) in water.
- A few metal oxides/hydroxides are amphoteric, meaning they can behave as either an acid or a base.

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