ACIDS, BASES & BUFFERS

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Acid & Base Theories

Arrhenius Water Theory

Acids are substances which produce hydrogen ions in solution.

Alkalis are substances which produce hydroxide ions in solution.

NOTE: Alkalis are soluble BASES

$$HA_{(aq)} + BOH_{(aq)} \longrightarrow BA_{(aq)} + H_2O_{(l)}$$

Neutralisation happens because hydrogen ions and hydroxide ions react to produce water.

acid + base ⟶ salt + water

ACID (HA)

Dissociate to produce H^+

Donate protons

Accept electron pairs

pH <7

➕

BASE (BOH)

Dissociate to produce OH^-

Accept protons

Donate electron pairs

pH >7

⬇

SALT (BA)

➕

WATER (H_2O)

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

Neutralisation

pH = 7

Acids & Bases

Common Acids

Chemical Name	Formula	Uses	Strength
Nitric Acid	HNO_3	Explosives, fertilizer, dyes, glue	Strong
Sulfuric Acid	H_2SO_4	Explosives, fertilizer, dyes, glue, batteries	Strong
Hydrochloric Acid	HCl	Metal cleaning, food preparation, ore refining, stomach acid	Strong
Phosphoric Acid	H_3PO_4	Fertilizer, plastics and rubber, food preservation	Moderate
Acetic Acid	$HC_2H_3O_2$	Plastics and rubber, food preservation, Vinegar	Weak
Hydrofluoric Acid	HF	Metal cleaning, glass etching	Weak
Carbonic Acid	H_2CO_3	Soda water	Weak
Boric Acid	H_3BO_3	Eye wash	Weak

Common Bases

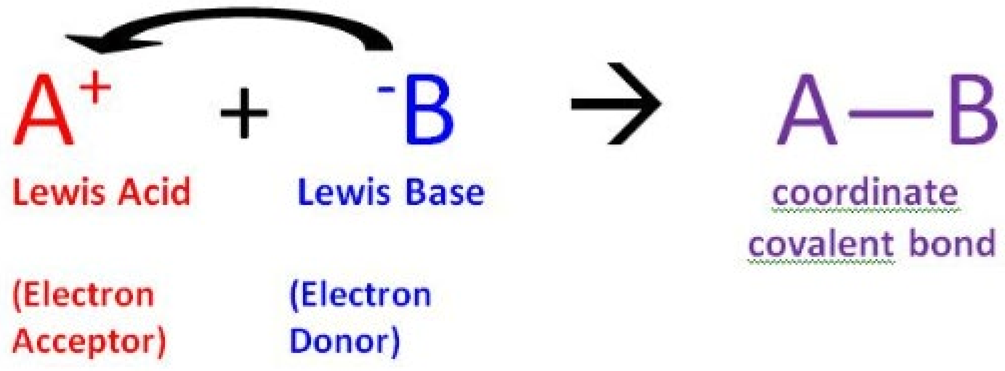
Chemical Name	Formula	Common Name	Uses	Strength
Sodium hydroxide	$NaOH$	Lye, caustic soda	Soap, plastic, petrol refining	Strong
Potassium hydroxide	KOH	Caustic potash	Soap, cotton, electroplating	Strong
Calcium hydroxide	$Ca(OH)_2$	Slaked lime	Cement	Strong
Sodium bicarbonate	$NaHCO_3$	Baking soda	Cooking, antacid	Weak
Magnesium hydroxide	$Mg(OH)_2$	Milk of magnesia	Antacid	Weak
Ammonium hydroxide	NH_4OH, $\{NH_3(aq)\}$	Ammonia water	Detergent, fertilizer, explosives, fibers	Weak

Acids & Base Theories

Lewis Acid-Base Theory

Lewis Acid: a species that accepts an electron pair (i.e., an **electrophile**) and will have vacant orbitals.

Lewis Base: a species that donates an electron pair (i.e., a **nucleophile**) and will have lone-pair electrons.



Lewis Acids are Electrophilic ie. electron attracting. Various species can act as Lewis acids.

- All cations are Lewis acids since they are able to accept electrons. (e.g., Cu^{2+}, Fe^{2+}, Fe^{3+})
- An atom, ion, or molecule with an incomplete octet of electrons can act as an Lewis acid (e.g., BF_3, AlF_3).
- Molecules where the central atom can have more than 8 valence shell electrons can be electron acceptors, and thus are classified as Lewis acids (e.g., $SiBr_4$, SiF_4).

Lewis Bases are Nucleophilic meaning that they “attack” a positive charge with their lone pair.

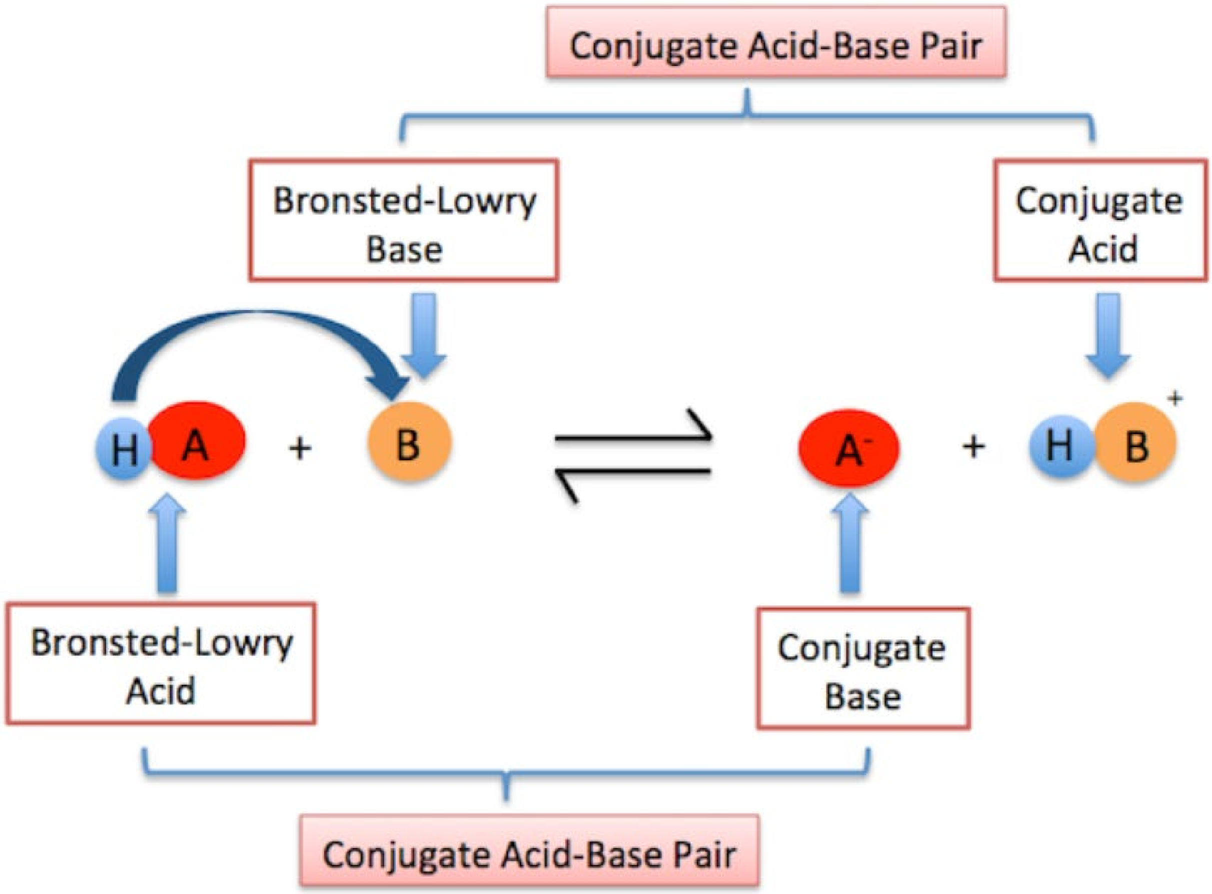
- Atoms, ions, or molecules with a lone-pair of electrons can thus be a Lewis base e.g., OH^- , CN^- , CH_3COO^- , $:NH_3$, $H_2O:$, CO:

Acids & Base Theories

Bronsted-Lowry Acid-Base Theory

An **acid** is a proton (hydrogen ion) donor.

A **base** is a proton (hydrogen ion) acceptor.



Properties of Acids

Acids change the colour of litmus from blue to red.

Some **Acids** are highly **corrosive**

Acids react with active **metals** to **evolve hydrogen gas**

Acids lose their acidity when mixed with a base.

When equal amounts of acid and base are combined the process of neutralisation occurs and salt and water is formed,

Acids have a **pH value of less than 7**

Acids are sour in taste.

Acids react with **carbonates and hydrogen carbonates** to form a **salt, water, and carbon dioxide gas**.

Acids react with **sulphites and bisulphites** to form a **salt, water and sulfur dioxide**

Acids and metal sulphides react to form **salt and hydrogen sulphide.**

Acids are classified on the basis of their sources, strength, concentration, the presence of oxygen and its basicity.

The different types of acids are **organic acids, mineral strong acids, weak acids, concentrated acids, dilute acids, Oxy-acids, Hydracids, monobasic acids, dibasic acids, and tribasic acids**.

Properties of Bases

Bases change the colour of litmus from red to blue.

Bases have a **bitter taste**.

Bases lose their basicity when mixed with acids.

Bases react with **acids** to form **salt and water**.

Bases feel slippery or soapy.

Strong bases are highly **corrosive** in nature whereas other bases are mildly corrosive.

The **pH** value of bases ranges from 8-14.

Bases and **ammonium salts produce ammonia**.

Bases are classified on the basis of strength, concentration and acidity.

The different kinds of acids are **strong base acid, weak base acid, concentrated base, dilute base, monoacidic base, diacidic base and triacidic base**.

Reactions of Acids & Bases

Acid + Base $\longrightarrow$ Salt + Water **(Neutralisation)**

eg. $HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$

Acid + Reactive Metal $\longrightarrow$ Salt + Water

eg. $H_2SO_{4(aq)} + Cu_{(s)} \longrightarrow CuSO_{4(aq)} + H_{2(g)}$

Acid + Carbonate $\longrightarrow$ Salt + Carbon Dioxide + Water

eg. $HNO_{3(aq)} + CaCO_{3(aq)} \longrightarrow CaCO_{3(aq)} + CO_{2(g)} + H_2O_{(l)}$

Acid + Sulfite $\longrightarrow$ Salt + Sulfur Dioxide + Water

eg. $2HCl_{(aq)} + Na_2SO_{3(aq)} \longrightarrow 2NaCl_{(aq)} + SO_{2(g)} + H_2O_{(l)}$

Acids & Bases

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

pH	$[H^+]$ M	$[H^+]$ M	Examples
0	1	10^{0}	Battery acid
1	0.1	10^{-1}	Stomach acid
2	0.01	10^{-2}	Lemon Juice
3	0.001	10^{-3}	Vinegar
4	0.0001	10^{-4}	Tomato juice
5	0.00001	10^{-5}	Black coffee
6	0.000001	10^{-6}	Saliva
7	0.0000001	10^{-7}	Pure Water
8	0.00000001	10^{-8}	Sea water
9	0.000000001	10^{-9}	Baking soda
10	0.0000000001	10^{-10}	Bar of soap
11	0.00000000001	10^{-11}	Ammonia
12	0.000000000001	10^{-12}	Household bleach
13	0.0000000000001	10^{-13}	Oven cleaner
14	0.00000000000001	10^{-14}	Sodium hydroxide

Strong Acids & Bases

Strong acids (HA) and bases (BOH) completely dissociate into their ions in water.

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

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

Strong Acids	Strong Bases
HCl: hydrochloric acid	LiOH: lithium hydroxide
HNO_3: nitric acid	NaOH: sodium hydroxide
H_2SO_4: sulfuric acid	KOH: potassium hydroxide
HBr: hydrobromic acid	RbOH: rubidium hydroxide
HI: hydroiodic acid	CsOH: cesium hydroxide
$HClO_4$: perchloric acid	$Ca(OH)_2$: calcium hydroxide
	$Sr(OH)_2$: strontium hydroxide
	$Ba(OH)_2$: barium hydroxide

Weak Acids & Bases

Weak acids and bases partially dissociate in water.

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

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

The extent to which weak acids and bases dissociate is given by their dissociation constant value.

Acid dissociation constant, $K_a = \frac{[H^+[A^-]}{[HA]}$

Base dissociation constant, $K_b = \frac{[B^+[OH^-]}{[BOH]}$

The higher the value if K_a, K_b, the stronger the weak acid or base.

Weak Acids

Acid	Formula
Formic	HCOOH
Acetic	CH_3COOH
Trichloroacetic	CCl_3COOH
Hydrofluoric	HF
Hydrocyanic	HCN
Hydrogen sulfide	H_2S
Water	H_2O

Weak Bases

Acid	Formula
Ammonia	NH_3
Pyridine	C_5N_5N
Methylamine	CH_3NH_2
Water	H_2O

Water Dissociation Constant (K_W)

Water partially dissociates (**autoionises**):

$$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$$

H^+ is a proton and combines with a molecule of water to form the hydroxonium ion, H_3O^+

$$2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

Water behaves as both a weak acid and a weak base.

The Water Dissociation Constant (KW) is just another acid dissociation constant.

This gives you:

$$K_W = [H^+]\,[OH^-]$$

Kw always equals **mol^2dm^{-6}**

In pure water, $[H^+] = [OH^-]$. Under normal temperature and pressure, $[H^+] = 1 \times 10^{-7}$ M.

$$\text{pH of pure water} = -\log_{10}[1 \times 10^{-7}] = 7$$

Buffers

A buffer solution is one which resists changes in pH when small quantities of an acid or an alkali are added to it.

Acid Buffer: mixtures of a weak acid (HA) and its conjugate base (A-)

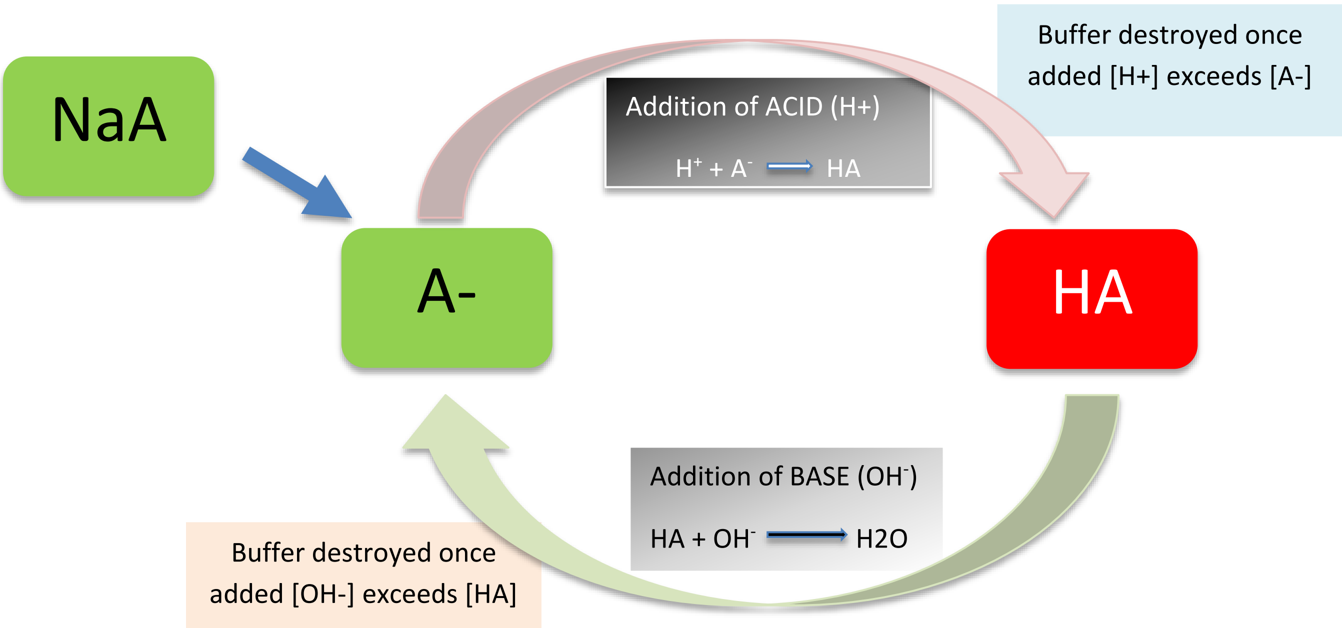
HA/NaA

The presence of A^- from the dissolution of NaA suppresses the dissociation of HA.

Buffer mixture contains 'reservoirs of HA and A^-

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

$$NaA \longrightarrow Na^+ + A^-$$



Buffering capacity determined by concentrations of HA and A-

pH of buffer influenced by $[A^-]/[HA]$ ratio

Buffers

Basic Buffer: mixtures of a weak base (BOH) and its conjugate base (B+)

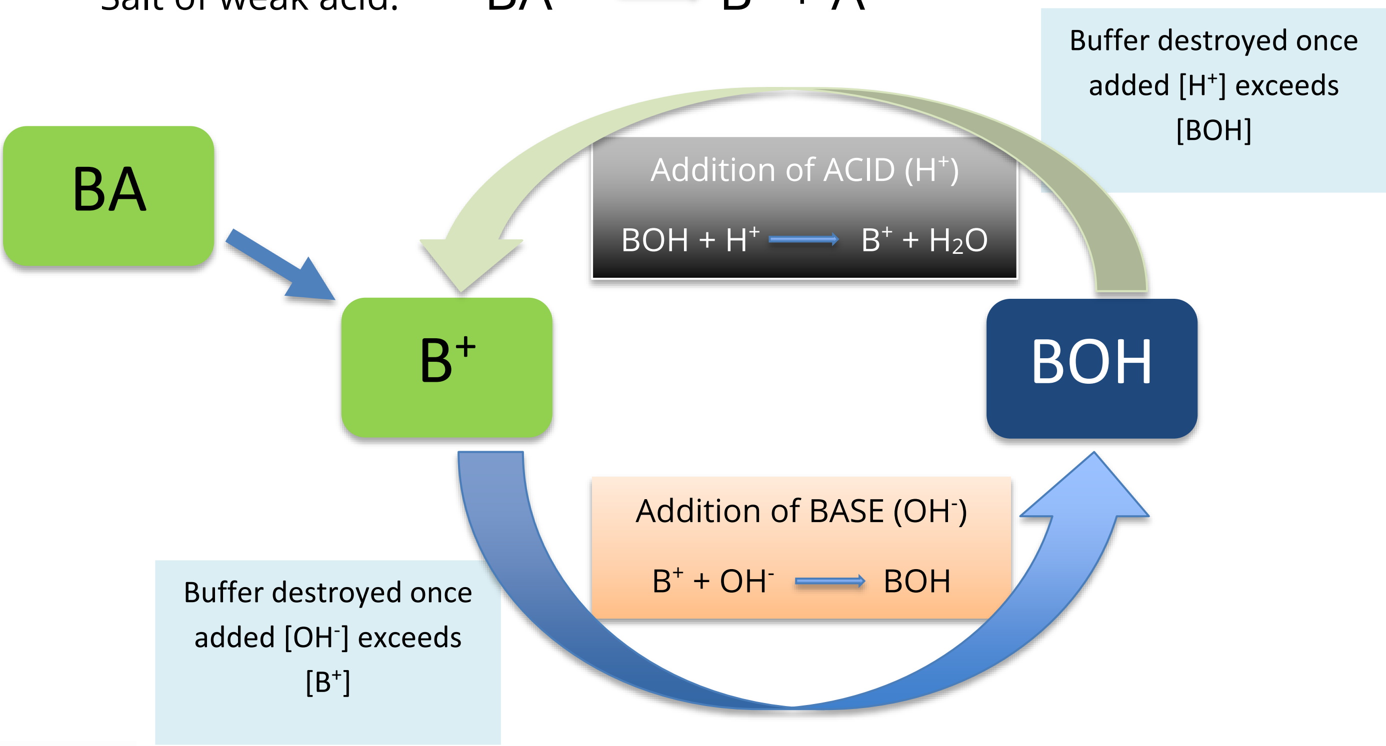
BOH/BA

The presence of B+ from the dissolution of BA suppresses the dissociation of BOH.

Buffer mixture contains 'reservoirs of BOH and B^+

Weak acid: $BOH \rightleftharpoons B^+ + OH^-$

Salt of weak acid: $BA \longrightarrow B^+ + A^-$



Buffering capacity determined by concentrations of BOH and B^+

pH of buffer influenced by $[B^+]/[BOH]$ ratio

pH of Buffers

Henderson-Hasselbalch equation

Acidic Buffers

$$pH = pK_a + \frac{\log[A^-]}{[HA]}$$

Basic Buffers

$$pOH = pK_b + \frac{\log[B]}{[BOH]}$$

$pK_a = -\log K_a$

$K_a = 10^{-pKa}$

$pK_b = -\log K_b$

$K_a = 10^{-pKb}$