Acids and Bases

Acids: vinegar, lemons, gastric juice

Bases: ammonia, baking soda, drano

Salts: table salt

Acids

Properties

Acids: 1. sour
2. change color of dyes
3. dissolve metals to form hydrogen
4. react with carbonates to form CO_2
5. neutralize bases

water soluble acids form hydrogen ions

Bases

Properties

Bases: 1. bitter
2. change color of dyes
3. soapy feel
4. neutralize acids

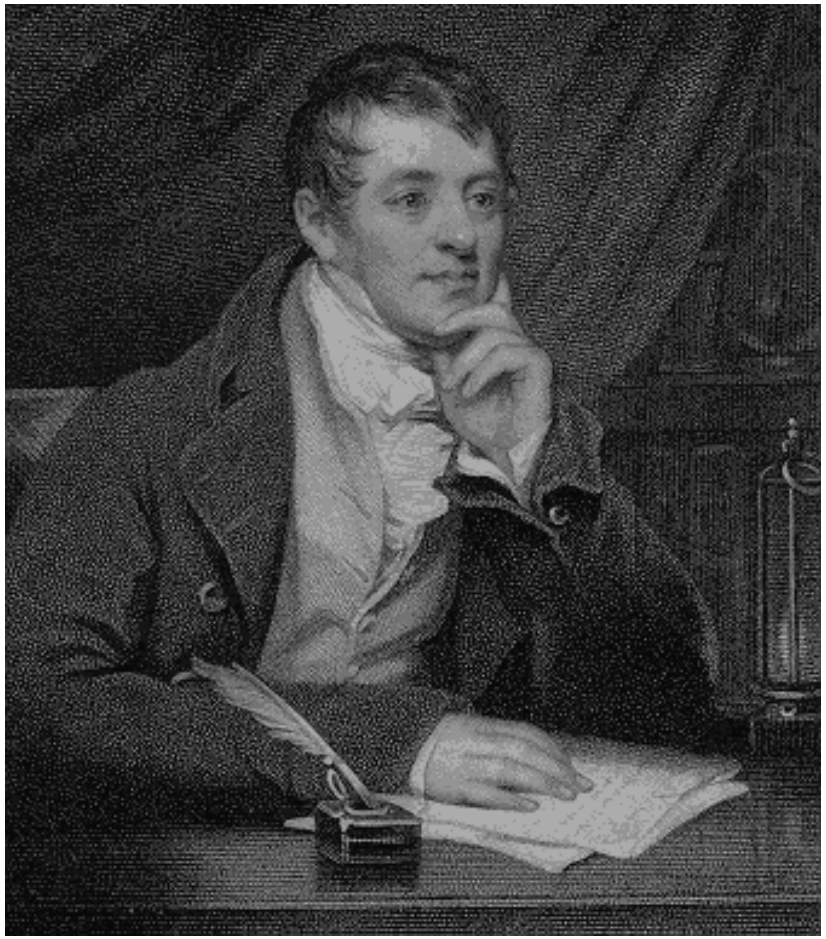
In water, soluble bases can form OH^- or CO_3^{2-} or O^{2-} ions
These ions react with H^+ ions

NH_3 another common base

Acids/Base Theories

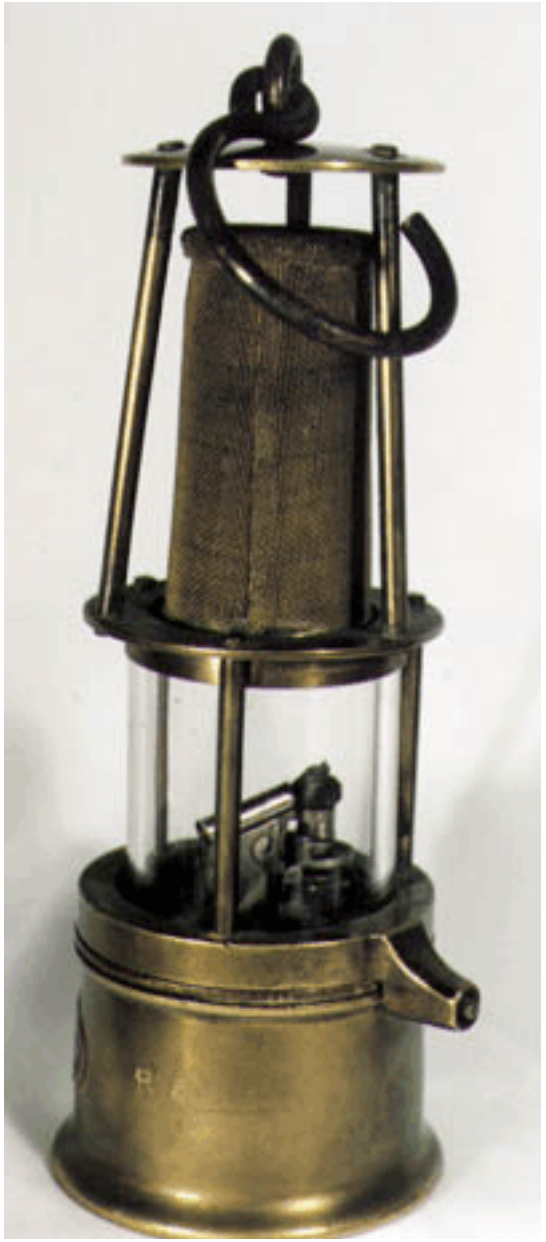
Sir Humphry Davy (1811)

All acids contain hydrogen



HCl
H_2SO_4
HNO_3

Safety Lamp



Acids/Base Theories

Savante Arrhenius (1884)

Acid:
any substance that produces hydrogen ions in water

Base:
any substance that produces hydroxide ions in water

Acids/Base Theories

Savante Arrhenius (1884)

Acid:
any substance that produces hydrogen ions in water

$HCl\ (aq) \rightarrow H^+ + Cl^-$

Base:
any substance that produces hydroxide ions in water

$NaOH\ (aq) \rightarrow Na^+ + OH^-$

Definition limited to aqueous solutions

Acids/Base Theories

Bronsted -Lowry Definition (1923)

Acid:
proton donor

Base:
proton acceptor

Explains why ammonia is a base

Acids/Base Theories

Bronsted -Lowry Definition (1923)

Acid:
proton donor

Base:
proton acceptor

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

Strong Acids/Bases

Ionize completely

HCl

Hydrochloric acid

$$HCl \rightarrow H^+ + Cl^-$$

Strong Acids/Bases

Ionize completely

$$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$$

Weak Acids/Bases

Incomplete ionization

$$HC_2H_3O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$$

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

Note: water acts as an acid

Water can also act as a base

Autoionization of water

Water is amphiprotic

Can act either as acid or base

Weak Acids/Bases

Incomplete ionization

$$HC_2H_3O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$$

$$HC_2H_3O_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$$

H_3O^+ called hydronium ion

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

Conjugate Acids/Bases

Acids and bases that are related by loss or gain of H^+

CA	CB
H_3O^+	H_2O
NH_4^+	NH_3
H_3PO_4	HPO_4^{-2}
HCl	Cl^-

Common Acids/Bases

Acids	Bases
citrus fruits	baking soda
aspirin	detergents
Coca Cola	ammonia cleaners
vinegar	Tums & Rolaids
vitamin	soap

Common Acids/Bases

Acids	Formula	Molarity
nitric	HNO_3	16
hydrochloric	HCl	12
sulfuric	H_2SO_4	18
acetic	$HC_2H_3O_2$	18

Bases	Formula	Molarity
ammonia	NH_3	18
sodium hydroxide	$NaOH$	solid

Common Acids

All are corrosive

HCl	**cleans metals, brick, cement**
H_2SO_4	**car batteries, fertilizers, industrial chemicals, nitroglycerin**
HNO_3	**fertilizers, dyes, plastics, explosives**

H_2SO_4

Assassination of President McKinley

Common Bases

$NaOH$	drain cleaner, soap manufacture
$Ca(OH)_2$	lime, mortar, plaster, cement
NH_3	cleaner
$Mg(OH)_2$	milk of magnesia

Drugs: cocaine, morphine, nicotine

Autoionization of water

Water is **amphiprotic**

$$H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$$

$$K_w = [H_3O^+][OH^-]$$

$$= 1.0 \times 10^{-14} \quad \text{at } 25^\circ C$$

$[H_2O]$ is constant, included in K_w

Autoionization of water

H^+ and OH^- always present in aqueous solutions

Only for a neutral solution are their concentrations equal

pH scale

Neutral $[H^+] = 10^{-7}\ M = [OH^-]$

Acidic $[H^+] > 10^{-7}\ M > [OH^-]$

Basic $[H^+] < 10^{-7}\ M < [OH^-]$

pH scale

Scale to measure acid and base concentrations over large concentration range

pH Scale

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

Logarithmic scale

$[H^+]$ = no. moles H^+ per liter of solution molarity

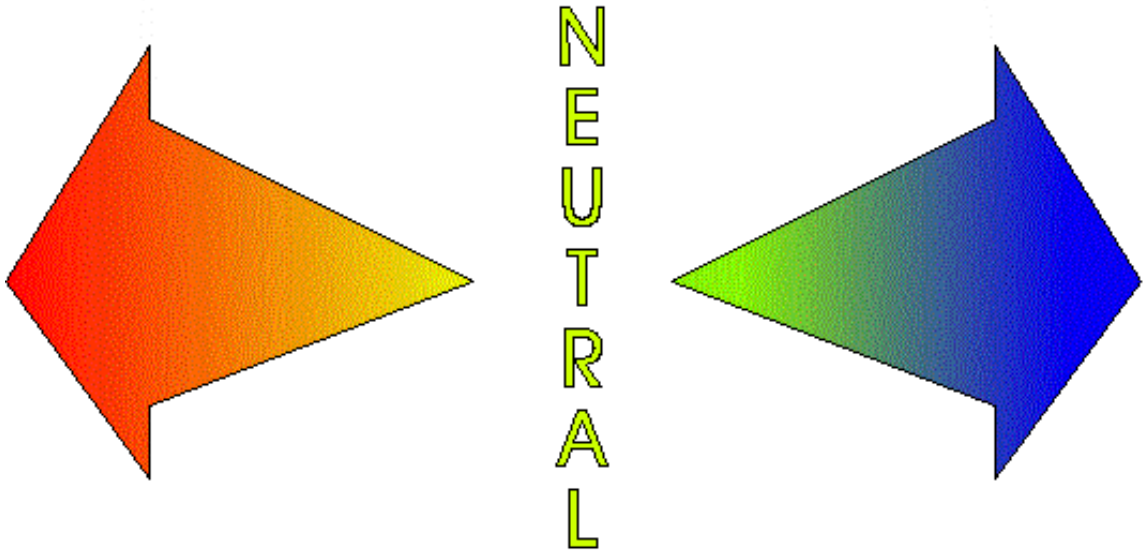
$$pOH = - \log [OH^-]$$

$$pH + pOH = 14$$

pH scale

scale: 0 - 14

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

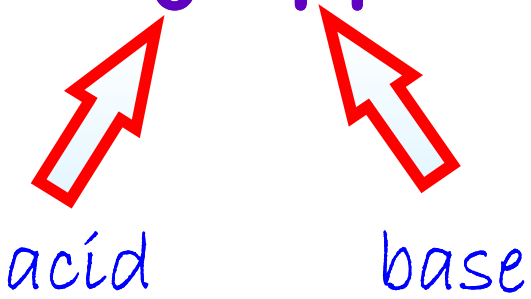


Stronger acid **Stronger base**

pH Scale

Measures acidity

scale:
0 - 14



pH calculations

Find pH of 0.015 M HCl

$$HCl \rightarrow H^+ + Cl^-$$

$$0.015\ M\ HCl \rightarrow 0.015\ M\ H^+ + 0.015\ M\ Cl^-$$

$$pH = -\log[H^+] = -\log[0.015] = 1.8$$

pH calculations

Find pH of 0.30 M $Ca(OH)_2$

$Ca(OH)_2 \rightarrow Ca^{2+} + 2\ OH^-$

0.3 M → 2×0.3 M

$= 0.6$ M OH^-

$[H^+][OH^-] = 10^{-14}$

$[H^+] = 10^{-14} \div [OH^-] = 10^{-14} \div 0.6$

$= 1.7 \times 10^{-14}$ M

$pH = -\log (1.7 \times 10^{-14}) = 13.8$

pH calculations

Find $[H^+]$ for HCl solution having pH = 9.0

$9.0 = - \log [H^+]$ find antilog

$[H^+] = 1.0 \times 10^{-9}$ M

If $[OH^-]$ needed use $[H^+][OH^-] = 10^{-14}$

Acid dissociation constant, K_a

Ionization of weak acids is equilibrium

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

Weak acid strength related to K_a

Note: water omitted from expression

Base dissociation constant, K_b

Ionization of weak bases is equilibrium

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

$$K_b = \frac{[OH^-][BH^+]}{[B]}$$

Weak base strength related to K_b

Note: water omitted from expression

K_a and K_b values

Always < 1

Size of K_a indicates acid strength

Size of K_b indicates base strength

Most acids and bases are weak

For a conjugate acid-base pair:

$$K_a \times K_b = 10^{-14}$$

What are polyprotic acids?

- Possess two or more replaceable protons (H^+)
- Examples of polyprotic acids are:
  - Carbonic acid - H_2CO_3
  - Phosphoric acid - H_3PO_4
  - Citric acid - a tricarboxylic acid

Polyprotic acids

$$H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$$

$$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$$

More difficult to remove each subsequent H^+

pH of weak acid solutions

Find the pH of a 0.05 M acetic acid solution

K_a for $HC_2H_3O_2 = 1.8 \times 10^{-5}$

$$HC_2H_3O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$$

pH of weak acid solutions

Find the pH of a 0.05 M acetic acid solution

K_a for $HC_2H_3O_2 = 1.8 \times 10^{-5}$

$HC_2H_3O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$

$$K_a = \frac{[H^+]_{eq}[C_2H_3O_2^-]_{eq}}{[HC_2H_3O_2]_{eq}}$$

pH of weak acid solutions

	$HC_2H_3O_2 \rightleftharpoons$	H^+ +	$C_2H_3O_2^-$
[initial]	0.050 M	0	0
Change	-x	+x	+x
[equ]	0.050-x	x	x

Solve for x

pH of weak acid solutions

$$\frac{x \times x}{0.050 - x} = 1.8 \times 10^{-5}$$

pH of weak acid solutions

$$\frac{x \times x}{0.050 - x} = 1.8 \times 10^{-5}$$

Use quadratic equation to solve x

X = 9.24×10^{-4} = $[H^+]_{eq}$

pH = - log(9.24×10^{-4}) = 3.03

Salts

Product of acid + base reaction

$$HCl + NaOH \rightarrow NaCl + H_2O$$

when an acid reacts with a base a salt and water form

when the base is a carbonate also form CO_2 gas

Some Reactions

$$Mg + 2\,HCl \rightarrow MgCl_2 + H_2$$

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Both are neutralization reactions

$$2\,HCl + Na_2CO_3 \rightarrow 2\,NaCl + CO_2 + H_2O$$

Titrations

Methods based on volume

Need: buret, pipet, balance, indicator

$$2\ HCl + Na_2CO_3 \rightarrow 2\ NaCl + CO_2 + H_2O$$

2 moles acid = 1 mole base

$$2\ M_A V_A = 1\ M_B V_B$$

$$2\ M_A V_A = 1\ \frac{mass_B}{form.\ Wt._B}$$

Indicators

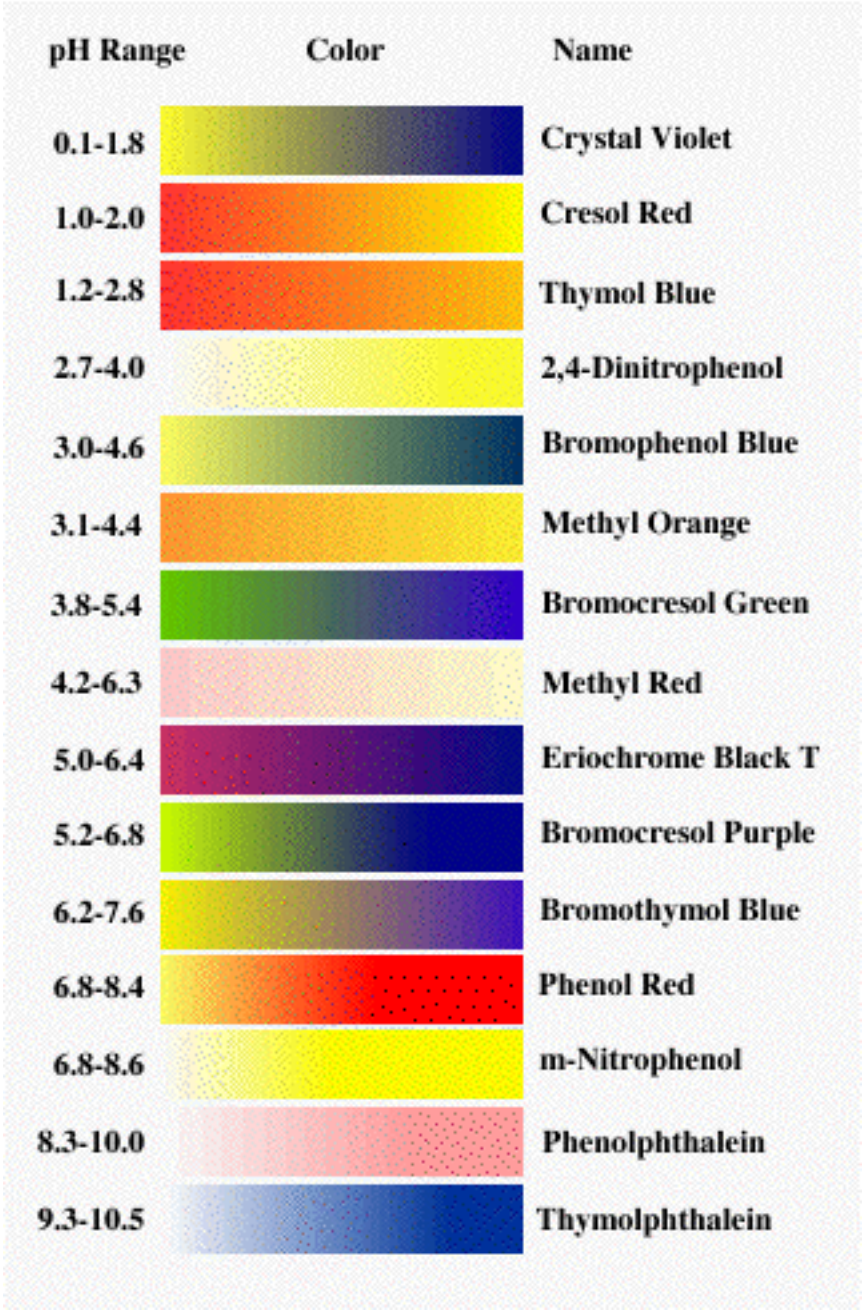
Weak organic acids

$$\text{H-Indic} \rightleftharpoons \text{Indic}^- + \text{H}^+$$

color 1 **color 2**

Change color at end-point

Coincides with equivalence point


pH Range
Color
Name
0.1-1.8
Crystal Violet
1.0-2.0
Cresol Red
1.2-2.8
Thymol Blue
2.7-4.0
2,4-Dinitrophenol
3.0-4.6
Bromophenol Blue
3.1-4.4
Methyl Orange
3.8-5.4
Bromocresol Green
4.2-6.3
Methyl Red
5.0-6.4
Eriochrome Black T
5.2-6.8
Bromocresol Purple
6.2-7.6
Bromothymol Blue
6.8-8.4
Phenol Red
6.8-8.6
m-Nitrophenol
8.3-10.0
Phenolphthalein
9.3-10.5
Thymolphthalein

pH of ions

Acid: NH_4^+ Al^{3+} HSO_4^- Fe^{3+}

Base: CH_3COO^- CN^- S^{2-} F^- O^{2-} CO_3^{2-}

Neutral: group 1,2 metal ions

ClO_4^- Cl^- Br^- I^- NO_3^{2-} SO_4^{2-}

pH of ions

Predict the following:

ammonium chloride

calcium nitrate

lithium sulfide

ammonium acetate

pH of ions

Find the pH of a 0.10 M KCH_3COO solution

Write ionization equation

$$KCH_3COO \rightarrow K^+ + CH_3COO^-$$

$$CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$$

Find $[OH^-]$ → $[H^+]$ → pH

Neutralization

Strong acid + strong base → neutral

Strong acid + weak base → weak acid

Weak acid + strong base → weak base

Weak acid + weak base → ?

Lewis acid-base theory

Acids: acept pair of electrons

Positive ions: H^+ Ag^+ BF_3

Bases: donate pair of electrons

Negative ions: F^- OH^- NH_3