THE ACIDIC ENVIRONMENT

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9.3.1 Indicators

Definitions and Common Acids, Bases and Neutral Substances

- Acid: substances which **produces H^+ ions** in solution
  - Vinegar (acetic), lemon juice (citric), fizzy drinks (H_2CO_3)
  - **Sour**, stings/burns skin, conducts electricity, litmus → **red**
- Base: substance **produces OH^- ions** in solution, soluble bases: alkalis
  - Cleaners ($NaOH/NH_3$), baking powder
  - **Bitter**, soapy, good conductors, litmus → **blue**
- Neutral – pure water, table salt, milk, sugars

Indicators

- Indicator: substance that **changes colour** in solution, depending on acidity of solution

Indicator	Initial	Middle	Final
Methyl Orange	Red (**3.1**)	Orange	Yellow (**4.4**)
Litmus	Red (**4.5**)	Purple	Blue (**8.5**)
Phenolphthalein	Colourless (**8.2**)	Pink	Dark Pink (**10.0**)
Bromothymol Blue	Yellow (**6.0**)	Green	Blue (**7.6**)

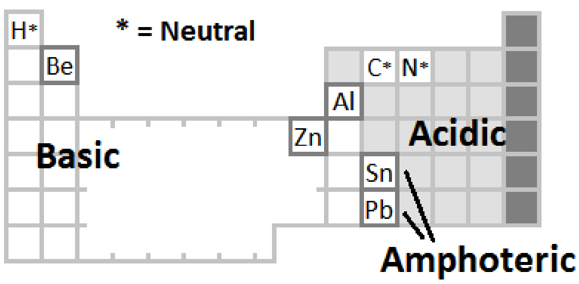
Everyday Uses of Indicators

- **Acidity of soils**: Camellias (4.5-5.5), Apples (5.8-6.8), Annual (basic)
- **Home swimming pools**: approx. neutral pH
- **Laboratory waste**: often basic, e.g. processing photographic film

9.3.2 Acidic Oxides

Acidic, Basic, Amphoteric and Neutral Oxides

- Acidic oxide: formed by **non-metals**, reacts with water to form acid, reacts with base to form salts, forms covalent compounds
- Basic oxide: formed by **metals**, reacts with water to form bases, reacts with acid to form salts, forms ionic compounds
- Amphoteric: reacts with **both acids and bases**
- Neutral: do **not react with either**
- Inert gases rarely form oxides (XeO_2 created)



Sulfur Dioxide (SO_2)

- Natural sources: **geothermal hot springs, volcanoes**
- Industrial sources: **burning/processing fossil fuels, extracting metals**
- **Equations:**
  Sulfur (in compounds) with oxygen: $S_{(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}$
  Metal sulfides: $2ZnS_{(s)} + 3O_{2\,(g)} \rightarrow 2ZnO_{(s)} + 2SO_{2\,(g)}$

NO_x (nitrous oxide **N_2O**, nitric oxide **NO** and nitrogen dioxide **NO_2**)

- Natural sources: NO/ NO_2 from **lightning**, N_2O from **bacteria** on **nitrogenous materials** in soils
- Industrial sources: NO/NO_2 **combustion**, N_2O **use of N fertilisers**
- **Equations:**
  Lightning and combustion: $N_{2\,(g)} + O_{2\,(g)} \rightarrow 2NO_{(g)}$
  NO then reacts in air: $2NO_{(g)} + O_{2\,(g)} \rightarrow 2NO_{2\,(g)}$

Effect on Health and Environment

- Evidence from Antarctic **ice core samples** and observed damage
  - Increased concentration N_2O (15% in 150 years)
  - Increased damage to **buildings, forests, aquatic organisms**
- Difficulties gathering evidence about SO_2 and NO_x
  - Measured in 0.001 ppm – instruments only available in 1970s
  - CO_2 easier – 360 ppm, ions not very soluble in water
- Effect on health: **respiratory and lung-related diseases**
  - NO_x can be toxic, increase effects of **asthma**

Acid Rain

- <u>Acid rain</u>: rain with **higher H^+ concentration** than normal (**pH < 5**)
- Sulphuric and nitric acid, unpolluted (pH 5.5-6) is carbonic acid
  - $SO_{2\,(g)} + H_2O_{(l)} \rightarrow H_2SO_{3\,(aq)}$ – forms sulfurous acid
  - $2H_2SO_{3\,(aq)} + O_{2\,(g)} \xrightarrow{catalyst} 2H_2SO_{4\,(aq)}$ – impurities in air
- Causes:
  - **Fall in soil pH**: damage to vegetation (cannot absorb Ca/K)
    - Leaves, pine forests (waxes removed)
  - **Buildings statues** erode (CO_3 reacts), **aquatic organisms**

Le Chatelier's Principle

- The **concentration** of reactants and products at equilibrium will **shift to counteract change** in **concentration, pressure** or **temperature**
- Adding a catalyst only **speeds up movement to equilibrium**
- $\mathbf{CO_{2\,(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3\,(sq)}(+heat)} \rightleftharpoons 2H^+_{(aq)} + CO_3{}^{2-}_{(aq)}$
  - Solubility of CO_2 based on equilibrium

9.3.3 Acids and pH

Acids as Proton Donors

- Acids **produce H^+ ions** (protons), e.g. $HNO_{3\,(aq)} \rightarrow H^+_{(aq)} + NO^-_{3\,(aq)}$
  - More accurately, $HNO_{3\,(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + NO^-_{3\,(aq)}$
- Ionisation – acid forms hydronium and nitrate ions

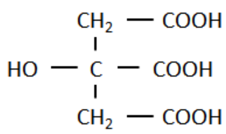
pH Scale and Formula

- pH (**potential H**): measurement covering range of **H^+ concentration**
  - Acidic < 7, neutral = 7, basic > 7
- Concentrations range from 10 mol/L to 10^{-13} mol/L $[H^+]$
- **pH = $-\log_{10}[H^+]$**
  - E.g. $[H^+]$ = **0.1** mol/L, $pH = -\log_{10} \mathbf{0.1} = 1$
  - pH from 7 to 6 goes from 10^{-7} to 10^{-6} = **ten-fold change**

Strength and Concentration

- Strong acids **ionise completely**: $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$
  - E.g. HCl, H_2SO_4, HNO_3, HBr, HI
- Weak acids **do not ionise completely**: (⇌)
  - E.g. H_2CO_3, CH_3COOH, H_2SO_3
- For $\boldsymbol{HCl_{(aq)} \rightleftharpoons H^+_{(aq)} + Cl^-_{(aq)}}$, $\mathbf{CH_3COOH_{(aq)} \rightleftharpoons H^-_{(aq)} + CH_3}\boldsymbol{COO^-_{(aq)}}$
  - HCl equilibrium lies completely to **right** (all ionised)
  - CH_3COOH equilibrium lies to **left**
- **Concentrated > 5 mol/L, dilute < 2 mol/L**
- Polyprotic acids: ability to give up protons
  - Monoprotic: 1 proton, e.g. HCl, diprotic 2 p, triprotic 3 p

Acetic, Citric, Hydrochloric and Sulfuric Acid

Acetic (ethanoic)	$CH_3 - COOH$	**Vinegar**
Citric (2-hydroxypropane-1,2,3-tricarboxylic)		Citrus **fruits**, used as a **food additive** (flavour and preservative)
Hydrochloric	$H - Cl$	**Stomach**, **cleaning** metals and bricks, **neutralising** bases, pools
Sulfuric	$H_2 - SO_4$	Most manufactured acid: **fertilisers**, **fibres**, car **batteries**

Acid	**Hydrochloric**	**Citric**	**Acetic**
pH (at 0.1 mol/L)	1	2.1	2.9
Strength	Strong	Weak	Weak
Degree of Ionisation	100%	8%	1.3%

9.3.4 Defining Acids and Bases

Historical Development about Acids

Chemist	Theory	Limitation of theory
Antoine **Lavoisier (1780)**	All acids contain oxygen and that causes acidity	Muriatic acid (HCl) did not contain oxygen, most bases contained oxygen
Humphry **Davy (1815)**	Metals could displace hydrogen in acids Acids and bases formed salts and water	Only classifies substances, without interpreting properties
Svante **Arrhenius (1884)**	Acid ionises to produce H^+ ions Base produces OH^- ions	Excludes oxides, only applies to aqueous solutions
Johannes **Brönsted**	Independently (Denmark and Britain) Acids are proton donors, Bases are proton acceptors Looked at properties relative to the solvent	
Thomas **Lowry (1923)**		

- Brönsted-Lowry theory: that a proton is transferred from an acid to a base in an acid-base reaction