Chemistry Vocabulary

Introduction

1 Elements and elementary substances

1.1 Alkali metals

1.1.1 Elements

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
3	Li	Lithium	Lithium	6.94
11	Na	Sodium	Natrium	22.99
19	K	Potassium	Kalium	39.10
37	Rb	Rubidium	Rubidium	85.47
55	Cs	Cesium	Caesium	132.91
87	Fr	Francium	Francium	(223)

1.1.2 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Crystal Structure	Application/Source
Li	180.5	1342	BCC	Batteries, alloys
Na	97.7	883	BCC	Reducing agent, coolant
K	63.5	759	BCC	Fertilizer, gun powder
Rb	39.3	688	BCC	Photoelectric cells
Cs	28.4	671	BCC	Atomic clocks
Fr	27	677	—	Radioactive, no use

1.1.3 Preparation Methods

Sodium (Na): Electrolysis of molten NaCl: $2\,\mathrm{NaCl} \xrightarrow{\text{electrolysis}} 2\,\mathrm{Na} + \mathrm{Cl_2}\uparrow$

Potassium (K): Reduction of KCl with Na at high temperature: $\mathrm{KCl} + \mathrm{Na} \xrightarrow{\text{high T}} \mathrm{K}\uparrow + \mathrm{NaCl}$

1.2 Alkaline earth metals

1.2.1 Elements

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
4	Be	Beryllium	Beryllium	9.01
12	Mg	Magnesium	Magnesium	24.31
20	Ca	Calcium	Calcium	40.08
38	Sr	Strontium	Strontium	87.62
56	Ba	Barium	Barium	137.33
88	Ra	Radium	Radium	(226)

1.2.2 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Crystal Structure	Application/Source
Be	1287	2470	HCP	Alloys, X-ray windows
Mg	650	1090	HCP	Alloys, fireworks
Ca	842	1484	FCC	Reducing agent, cement
Sr	777	1382	FCC	Fireworks (red)
Ba	727	1897	BCC	Drilling fluids
Ra	700	1737	BCC	Radioactive, obsolete

1.2.3 Preparation Methods

Magnesium (Mg): Electrolysis of molten $MgCl_2$: $MgCl_2 \xrightarrow{\text{electrolysis}} Mg + Cl_2\uparrow$
Alternatively, reduction of MgO with coke: $MgO + C \xrightarrow{\text{high T}} Mg\uparrow + CO\uparrow$
Calcium (Ca): Electrolysis of molten $CaCl_2$ or reduction of CaO with Al

1.3 Transition metals

1.3.1 Elements (First Row)

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
21	Sc	Scandium	Scandium	44.96
22	Ti	Titanium	Titanium	47.87
23	V	Vanadium	Vanadium	50.94
24	Cr	Chromium	Chromium	52.00
25	Mn	Manganese	Manganese	54.94
26	Fe	Iron	Ferrum	55.85
27	Co	Cobalt	Cobaltum	58.93
28	Ni	Nickel	Niccolum	58.69
29	Cu	Copper	Cuprum	63.55
30	Zn	Zinc	Zincum	65.38

1.3.2 Important Elements (Other Rows)

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
47	Ag	Silver	Argentum	107.87
48	Cd	Cadmium	Cadmium	112.41
74	W	Tungsten	Wolframium	183.84
78	Pt	Platinum	Platinum	195.08
79	Au	Gold	Aurum	196.97
80	Hg	Mercury	Hydrargyrum	200.59

1.3.3 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Crystal Structure	Application/Source
Ti	1668	3287	HCP	Aerospace alloys, pigments
V	1910	3407	BCC	Steel alloys, catalysts
Cr	1907	2671	BCC	Stainless steel, plating
Mn	1246	2061	Cubic	Steel production
Fe	1538	2862	BCC	Construction, machinery
Co	1495	2927	HCP	Alloys, magnets
Ni	1455	2913	FCC	Alloys, catalysts, coins

Element	M.P. (°C)	B.P. (°C)	Crystal Structure	Application/Source
Cu	1085	2562	FCC	Electrical wire, plumbing
Zn	419.5	907	HCP	Galvanization, batteries
Ag	961.8	2162	FCC	Jewelry, conductors
Cd	321.1	767	HCP	Batteries, pigments
W	3422	5555	BCC	Light bulb filaments
Pt	1768	3825	FCC	Catalysts, jewelry
Au	1064	2856	FCC	Jewelry, electronics
Hg	-38.8	356.7	Rhombohedral	Thermometers, lamps

1.3.4 Preparation Methods

Iron (Fe): Reduction in blast furnace: $\mathrm{Fe_2O_3 + 3\,CO \xrightarrow{high\ T} 2\,Fe + 3\,CO_2}$
Copper (Cu): Roasting sulfide ore then reduction: $\mathrm{2\,Cu_2S + 3\,O_2 \longrightarrow 2\,Cu_2O + 2\,SO_2}$, then $\mathrm{Cu_2S + 2\,Cu_2O \longrightarrow 6\,Cu + SO_2\uparrow}$
Alternatively, leaching and electrowinning from oxide ores.
Zinc (Zn): Roasting then reduction with carbon: $\mathrm{2\,ZnS + 3\,O_2 \longrightarrow 2\,ZnO + 2\,SO_2}$, then $\mathrm{ZnO + C \longrightarrow Zn + CO}$
Chromium (Cr): Reduction of $\mathrm{Cr_2O_3}$ with aluminum (thermite process): $\mathrm{Cr_2O_3 + 2\,Al \longrightarrow 2\,Cr + Al_2O_3}$

1.4 Post-transition metals

1.4.1 Elements

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
13	Al	Aluminum	Aluminium	26.98
31	Ga	Gallium	Gallium	69.72
49	In	Indium	Indium	114.82
50	Sn	Tin	Stannum	118.71
81	Tl	Thallium	Thallium	204.38
82	Pb	Lead	Plumbum	207.2
83	Bi	Bismuth	Bismuthum	208.98

1.4.2 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Crystal Structure	Application/Source
Al	660.3	2519	FCC	Packaging, construction
Ga	29.8	2204	Orthorhombic	Semiconductors, LEDs
In	156.6	2072	Tetragonal	LCD screens, solders
Sn	231.9	2602	Tetragonal	Solder, coatings
Tl	304	1473	HCP	Rat poison (obsolete)
Pb	327.5	1749	FCC	Batteries, radiation shield
Bi	271.4	1564	Rhombohedral	Alloys, cosmetics

1.4.3 Preparation Methods

Aluminum (Al): Hall-Héroult process (electrolysis of $\mathrm{Al_2O_3}$ dissolved in molten cryolite):
$\mathrm{2\,Al_2O_3 \xrightarrow{electrolysis} 4\,Al + 3\,O_2\uparrow}$
Lead (Pb): Roasting galena (PbS) then reduction: $\mathrm{2\,PbS + 3\,O_2 \longrightarrow 2\,PbO + 2\,SO_2}$, then $\mathrm{PbO + C \longrightarrow Pb + CO}$
Tin (Sn): Reduction of cassiterite ($\mathrm{SnO_2}$) with carbon: $\mathrm{SnO_2 + 2\,C \longrightarrow Sn + 2\,CO\uparrow}$

1.5 Metalloids

1.5.1 Elements

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
5	B	Boron	Borium	10.81
14	Si	Silicon	Silicium	28.09
32	Ge	Germanium	Germanium	72.64
33	As	Arsenic	Arsenicum	74.92
51	Sb	Antimony	Stibium	121.76
52	Te	Tellurium	Tellurium	127.60
84	Po	Polonium	Polonium	(209)

1.5.2 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Crystal Structure	Application/Source
B	2075	4000	Rhombohedral	Glass, detergents
Si	1414	3265	Diamond cubic	Semiconductors, solar cells
Ge	938.3	2833	Diamond cubic	Semiconductors, optics
As	817	614 (subl.)	Rhombohedral	Alloys, pesticides
Sb	630.6	1587	Rhombohedral	Flame retardants, alloys
Te	449.5	988	Hexagonal	Alloys, solar cells
Po	254	962	Cubic	Radioactive, no common use

1.5.3 Preparation Methods

Silicon (Si): Reduction of silica (SiO_2) with carbon in electric furnace: $SiO_2 + 2\,C \xrightarrow{\text{high T}} Si + 2\,CO\uparrow$
For ultrapure silicon (semiconductors): Trichlorosilane reduction: $SiHCl_3 + H_2 \xrightarrow{\text{high T}} Si + 3\,HCl$

1.6 Halogen

1.6.1 Elements

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
9	F	Fluorine	Fluorum	19.00
17	Cl	Chlorine	Chlorum	35.45
35	Br	Bromine	Bromum	79.90
53	I	Iodine	Iodum	126.90
85	At	Astatine	Astatium	(210)

1.6.2 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Physical State	Application/Source
F_2	-219.6	-188.1	Pale yellow gas	Toothpaste, Teflon
Cl_2	-101.5	-34.0	Yellow-green gas	Disinfectant, PVC
Br_2	-7.2	58.8	Red-brown liquid	Flame retardants, dyes
I_2	113.7	184.3	Purple-black solid	Disinfectant, photography
At_2	302	337	Solid (radioactive)	No practical use

1.6.3 Preparation Methods

Chlorine (Cl_2): Electrolysis of brine (chlor-alkali process): $2\,NaCl + 2\,H_2O \xrightarrow{\text{electrolysis}} Cl_2\uparrow + H_2\uparrow + 2\,NaOH$
Laboratory: Oxidation of HCl: $MnO_2 + 4\,HCl \xrightarrow{\text{heat}} MnCl_2 + Cl_2\uparrow + 2\,H_2O$
Bromine (Br_2): Oxidation of bromide in seawater: $2\,Br^- + Cl_2 \longrightarrow Br_2 + 2\,Cl^-$
Iodine (I_2): Oxidation of iodide from brine or seaweed: $2\,I^- + Cl_2 \longrightarrow I_2 + 2\,Cl^-$
Or from Chile saltpeter: $2\,NaIO_3 + 5\,NaHSO_3 \longrightarrow I_2 + 3\,NaHSO_4 + 2\,Na_2SO_4 + H_2O$
Fluorine (F_2): Electrolysis of KF in anhydrous HF: $2\,HF \xrightarrow{\text{electrolysis}} H_2 + F_2\uparrow$

1.7 Noble gases

1.7.1 Elements

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
2	He	Helium	Helium	4.00
10	Ne	Neon	Neon	20.18
18	Ar	Argon	Argon	39.95
36	Kr	Krypton	Krypton	83.80
54	Xe	Xenon	Xenon	131.29
86	Rn	Radon	Radon	(222)

1.7.2 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Physical State	Application/Source
He	-272.2	-268.9	Colorless gas	Balloons, cryogenics
Ne	-248.6	-246.0	Colorless gas	Neon signs, lasers
Ar	-189.3	-185.8	Colorless gas	Welding, light bulbs
Kr	-157.4	-153.2	Colorless gas	Flash lamps, lasers
Xe	-111.8	-108.1	Colorless gas	Anesthesia, ion drives
Rn	-71	-61.7	Colorless gas	Radioactive tracer

1.7.3 Preparation

Noble gases are obtained by fractional distillation of liquid air (except He and Rn).
Helium (He): Extracted from natural gas wells.
Radon (Rn): Decay product of radium, collected from uranium/thorium ores.

1.8 Other Nonmetals

1.8.1 Elements

Atomic No.	Symbol	English Name	Latin Name	Rel. Atomic Mass
1	H	Hydrogen	Hydrogenium	1.008
6	C	Carbon	Carboneum	12.01
7	N	Nitrogen	Nitrogenium	14.01
8	O	Oxygen	Oxygenium	16.00
15	P	Phosphorus	Phosphorus	30.97
16	S	Sulfur	Sulfur	32.07
34	Se	Selenium	Selenium	78.96

1.8.2 Elementary Substances

Element	M.P. (°C)	B.P. (°C)	Form/Structure	Application/Source
H_2	-259.2	-252.9	Colorless gas	Fuel, ammonia synthesis
C (graphite)	3825	4827 (subl.)	Hexagonal layers	Pencils, electrodes
C (diamond)	3550	—	Cubic crystal	Jewelry, cutting tools
C (fullerene)	—	—	Molecular cage	Research, electronics
N_2	-210.0	-195.8	Colorless gas	Fertilizers, inert atm.
O_2	-218.8	-183.0	Colorless gas	Respiration, combustion
O_3 (ozone)	-192.5	-112.0	Blue gas	Sterilization, UV shield
P (white)	44.2	280	Molecular solid	Incendiaries, match
P (red)	590	431 (subl.)	Amorphous	Safety matches
P (black)	—	—	Layered	Research
S (rhombic)	115.2	444.6	Orthorhombic	Sulfuric acid, vulcanize
S (monoclinic)	119	444.6	Monoclinic	Allotrope of sulfur
Se (gray)	221	685	Hexagonal	Photocells, glass

1.8.3 Preparation Methods

Hydrogen (H_2):

- Steam reforming of methane: $\mathrm{CH_4 + H_2O \underset{\text{high T}}{\overset{\text{catalyst}}{\rightleftharpoons}} CO + 3\,H_2}$
- Electrolysis of water: $\mathrm{2\,H_2O \xrightarrow{electrolysis} 2\,H_2\uparrow + O_2\uparrow}$
- Laboratory: Reaction of metals with acids: $\mathrm{Zn + 2\,HCl \longrightarrow ZnCl_2 + H_2\uparrow}$

Oxygen (O_2):

- Fractional distillation of liquid air
- Electrolysis of water: $\mathrm{2\,H_2O \xrightarrow{electrolysis} 2\,H_2\uparrow + O_2\uparrow}$
- Laboratory: Decomposition of $KMnO_4$: $\mathrm{2\,KMnO_4 \xrightarrow{heat} K_2MnO_4 + MnO_2 + O_2\uparrow}$
- Or: $\mathrm{2\,KClO_3 \xrightarrow{MnO_2,\,heat} 2\,KCl + 3\,O_2\uparrow}$

Nitrogen (N_2): Fractional distillation of liquid air
Chlorine (Cl_2): See Halogen section
Sulfur (S):

- Frasch process: Melting underground sulfur with superheated water
- Recovered from petroleum refining and natural gas processing

Phosphorus (P): Reduction of phosphate rock with coke and silica:
$\mathrm{2\,Ca_3(PO_4)_2 + 6\,SiO_2 + 10\,C \xrightarrow{high\ T} 6\,CaSiO_3 + 10\,CO\uparrow + P_4\uparrow}$

2 Acids and bases ions

2.1 Hydrogen halides

2.1.1 Hydrofluoric acid

HF (Hydrofluoric acid, Hydrogen fluoride)
Properties: Weak acid in aqueous solution (unlike other hydrogen halides), can dissolve glass.
Reactions:

- Etching glass: $SiO_2 + 4\,HF \longrightarrow SiF_4\uparrow + 2\,H_2O$
- With calcium: $Ca + 2\,HF \longrightarrow CaF_2 + H_2\uparrow$
- Formation of hexafluorosilicate: $SiO_2 + 6\,HF \longrightarrow H_2SiF_6 + 2\,H_2O$

2.1.2 Hydrochloric acid

HCl (Hydrochloric acid, Hydrogen chloride)
Properties: Strong acid, colorless gas, forms white fumes in moist air.
Reactions:

- Oxidation by manganese dioxide: $MnO_2 + 4\,HCl \xrightarrow{\text{heat}} MnCl_2 + Cl_2\uparrow + 2\,H_2O$
- With ammonia: $NH_3 + HCl \longrightarrow NH_4Cl$ (white smoke)
- Dissolving metals: $Fe + 2\,HCl \longrightarrow FeCl_2 + H_2\uparrow$
- With permanganate: $2\,KMnO_4 + 16\,HCl \longrightarrow 2\,KCl + 2\,MnCl_2 + 5\,Cl_2\uparrow + 8\,H_2O$

2.1.3 Hydrobromic acid

HBr (Hydrobromic acid, Hydrogen bromide)
Properties: Strong acid, stronger reducing agent than HCl.
Reactions:

- Oxidation by sulfuric acid: $2\,HBr + H_2SO_4 \longrightarrow Br_2 + SO_2 + 2\,H_2O$
- With silver nitrate: $HBr + AgNO_3 \longrightarrow AgBr\downarrow + HNO_3$ (pale yellow precipitate)

2.1.4 Hydroiodic acid

HI (Hydroiodic acid, Hydrogen iodide)
Properties: Strong acid, strongest reducing agent among hydrogen halides.
Reactions:

- Oxidation by sulfuric acid: $8\,HI + H_2SO_4 \longrightarrow 4\,I_2 + H_2S + 4\,H_2O$
- Reduction of Fe(III): $2\,Fe^{3+} + 2\,I^- \longrightarrow 2\,Fe^{2+} + I_2$
- With chlorine: $2\,HI + Cl_2 \longrightarrow 2\,HCl + I_2$

2.2 Oxyacid

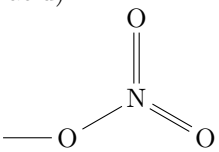
2.2.1 Nitrogen oxyacids

HNO_2 (Nitrous acid)
Structure: H—O—N=O
Valence: N is +3
Properties: Weak acid, unstable, exists only in solution.
Reactions:

- Decomposition: $3\,HNO_2 \longrightarrow HNO_3 + 2\,NO\uparrow + H_2O$
- Oxidation of iodide: $2\,HNO_2 + 2\,HI \longrightarrow I_2 + 2\,NO\uparrow + 2\,H_2O$

- Reduction by reducing agents: $2\,HNO_2 + 2\,HI \longrightarrow 2\,NO\uparrow + I_2 + 2\,H_2O$

HNO_3 (Nitric acid)

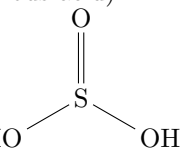


Structure:
Valence: N is +5
Properties: Strong acid, strong oxidizing agent.
Reactions:

- With copper: $3\,Cu + 8\,HNO_3(\text{dilute}) \longrightarrow 3\,Cu(NO_3)_2 + 2\,NO\uparrow + 4\,H_2O$
- Concentrated with copper: $Cu + 4\,HNO_3(\text{conc}\cdot) \longrightarrow Cu(NO_3)_2 + 2\,NO_2\uparrow + 2\,H_2O$
- Nitration reaction: $C_6H_6 + HNO_3 \xrightarrow{H_2SO_4} C_6H_5NO_2 + H_2O$
- With phosphorus: $P_4 + 20\,HNO_3 \longrightarrow 4\,H_3PO_4 + 20\,NO_2\uparrow + 4\,H_2O$
- Passivation of iron: $Fe + 6\,HNO_3(\text{conc}\cdot) \longrightarrow Fe^{3+}$ (passive layer)

2.2.2 Sulfur oxyacids

H_2SO_3 (Sulfurous acid)

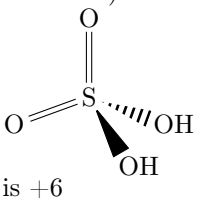


Structure:
Valence: S is +4
Properties: Weak acid, exists only in solution, reducing agent.
Reactions:

- Oxidation by oxygen: $2\,H_2SO_3 + O_2 \longrightarrow 2\,H_2SO_4$
- Reduction by hydrogen sulfide: $H_2SO_3 + 2\,H_2S \longrightarrow 3\,S\downarrow + 3\,H_2O$
- With bromine: $H_2SO_3 + Br_2 + H_2O \longrightarrow H_2SO_4 + 2\,HBr$

H_2SO_4 (Sulfuric acid)

Structure:

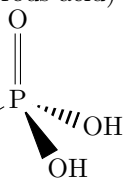


Valence: S is +6
Properties: Strong acid, strong dehydrating agent, strong oxidizing agent (concentrated).
Reactions:

- With carbon (dehydration): $C_{12}H_{22}O_{11} \xrightarrow{H_2SO_4(\text{conc}\cdot)} 12\,C + 11\,H_2O$
- Hot concentrated with copper: $Cu + 2\,H_2SO_4(\text{conc}\cdot) \xrightarrow{\text{heat}} CuSO_4 + SO_2\uparrow + 2\,H_2O$
- With NaCl (making HCl): $NaCl + H_2SO_4 \xrightarrow{\text{heat}} NaHSO_4 + HCl\uparrow$
- Esterification: $CH_3COOH + C_2H_5OH \rightleftharpoons[H_2SO_4] CH_3COOC_2H_5 + H_2O$

2.2.3 Phosphorus oxyacids

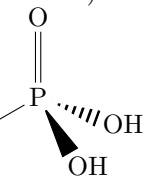
H_3PO_3 (Phosphorous acid)

Structure: 

Valence: P is +3
Properties: Dibasic acid (only 2 acidic H), reducing agent.
Reactions:

- Reduction of silver nitrate: $H_3PO_3 + 2\,AgNO_3 + H_2O \longrightarrow H_3PO_4 + 2\,Ag\downarrow + 2\,HNO_3$
- Disproportionation: $4\,H_3PO_3 \xrightarrow{\text{heat}} 3\,H_3PO_4 + PH_3\uparrow$

H_3PO_4 (Phosphoric acid)

Structure: 

Valence: P is +5
Properties: Weak tribasic acid, non-oxidizing.
Reactions:

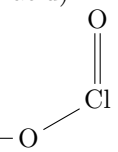
- Dehydration to pyrophosphoric acid: $2\,H_3PO_4 \xrightarrow{\text{heat}} H_4P_2O_7 + H_2O$
- With ammonia: $H_3PO_4 + NH_3 \longrightarrow NH_4H_2PO_4$
- Esterification: $H_3PO_4 + 3\,C_2H_5OH \longrightarrow (C_2H_5O)_3PO + 3\,H_2O$

2.2.4 Chlorine oxyacids

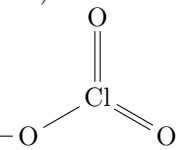
HClO (Hypochlorous acid)
Structure: H—O—Cl
Valence: Cl is +1
Properties: Very weak acid, strong oxidizing agent, unstable.
Reactions:

- Disproportionation: $3\,HClO \longrightarrow HClO_3 + 2\,HCl$
- Oxidation: $HClO + H_2S \longrightarrow HCl + S\downarrow + H_2O$
- Bleaching: $HClO + [\text{dye}] \longrightarrow [\text{oxidized dye}]\,(\text{colorless})$

$HClO_2$ (Chlorous acid)

Structure: 

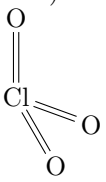
Valence: Cl is +3
Properties: Weak acid, unstable, exists only in solution.
$HClO_3$ (Chloric acid)

Structure: 

Valence: Cl is +5
Properties: Strong acid, strong oxidizing agent.
Reactions:

- Oxidation of sulfur: $3\,S + 6\,HClO_3 \longrightarrow 3\,H_2SO_4 + 3\,Cl_2\uparrow$
- Decomposition: $8\,HClO_3 \longrightarrow 4\,Cl_2\uparrow + 6\,O_2\uparrow + 4\,H_2O$

$HClO_4$ (Perchloric acid)

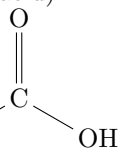


Structure:
Valence: Cl is +7
Properties: Very strong acid, strongest common acid, powerful oxidizing agent when hot/concentrated.
Reactions:

- Oxidation of organic compounds: $C_6H_{12}O_6 + 24\,HClO_4 \xrightarrow{\text{heat}} 6\,CO_2\uparrow + 12\,Cl_2\uparrow + 18\,H_2O$
- With metals: $Mg + 2\,HClO_4 \longrightarrow Mg(ClO_4)_2 + H_2\uparrow$

2.2.5 Carbon oxyacids

H_2CO_3 (Carbonic acid)

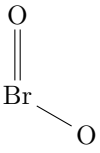


Structure:
Valence: C is +4
Properties: Weak acid, unstable, exists in equilibrium with CO_2 and H_2O.
Reactions:

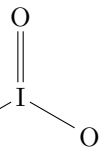
- Decomposition: $H_2CO_3 \rightleftharpoons CO_2\uparrow + H_2O$
- With ammonia: $H_2CO_3 + 2\,NH_3 \longrightarrow (NH_4)_2CO_3$
- Formation: $CO_2 + H_2O \rightleftharpoons H_2CO_3$

2.2.6 Bromine and iodine oxyacids

HBrO (Hypobromous acid)
Structure: H — O — Br
Valence: Br is +1
$HBrO_3$ (Bromic acid)



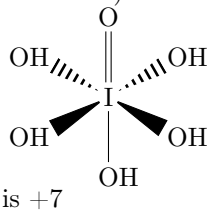
Structure:
Valence: Br is +5
HIO_3 (Iodic acid)



Structure:
Valence: I is +5
Reactions:

- Oxidation: $5\,HI + HIO_3 \longrightarrow 3\,I_2 + 3\,H_2O$
- With sulfur dioxide: $HIO_3 + 3\,H_2SO_3 \longrightarrow HI + 3\,H_2SO_4$

H_5IO_6 (Periodic acid)

Structure: 

Valence: I is +7
Reactions:

- Oxidative cleavage of diols: Used to cleave vicinal diols (glycols) to aldehydes or ketones

2.3 Bases from metal oxides

2.3.1 Alkali metal hydroxides

NaOH (Sodium hydroxide, Caustic soda, Lye)
Valence: Na is +1
Properties: Strong base, deliquescent, corrosive.
Reactions:

- With aluminum (amphoteric): $2\,Al + 2\,NaOH + 2\,H_2O \longrightarrow 2\,NaAlO_2 + 3\,H_2\uparrow$
- With silicon dioxide: $SiO_2 + 2\,NaOH \xrightarrow{heat} Na_2SiO_3 + H_2O$
- Saponification of esters: $CH_3COOC_2H_5 + NaOH \longrightarrow CH_3COONa + C_2H_5OH$
- With chlorine (disproportionation): $Cl_2 + 2\,NaOH \longrightarrow NaCl + NaClO + H_2O$
- With sulfur: $3\,S + 6\,NaOH \xrightarrow{heat} 2\,Na_2S + Na_2SO_3 + 3\,H_2O$

KOH (Potassium hydroxide, Caustic potash)
Valence: K is +1
Properties: Strong base, more hygroscopic than NaOH.
Reactions:

- With CO_2: $2\,KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$
- Excess CO_2: $K_2CO_3 + CO_2 + H_2O \longrightarrow 2\,KHCO_3$
- With haloalkanes (elimination): $C_2H_5Br + KOH \xrightarrow{alcohol} C_2H_4\uparrow + KBr + H_2O$

LiOH (Lithium hydroxide)
Valence: Li is +1
Properties: Strong base, used in CO_2 scrubbers.
Reactions:

- CO_2 absorption: $2\,LiOH + CO_2 \longrightarrow Li_2CO_3 + H_2O$

2.3.2 Alkaline earth metal hydroxides

$Ca(OH)_2$ (Calcium hydroxide, Slaked lime, Hydrated lime)
Valence: Ca is +2
Properties: Moderately strong base, sparingly soluble in water (lime water).
Reactions:

- With CO_2 (limewater test): $Ca(OH)_2 + CO_2 \longrightarrow CaCO_3\downarrow + H_2O$
- Excess CO_2: $CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$ (soluble)
- With chlorine: $2\,Ca(OH)_2 + 2\,Cl_2 \longrightarrow CaCl_2 + Ca(ClO)_2 + 2\,H_2O$
- Preparation from quicklime: $CaO + H_2O \longrightarrow Ca(OH)_2$ (exothermic)

$Mg(OH)_2$ (Magnesium hydroxide, Milk of magnesia)
Valence: Mg is +2
Properties: Weak base, very sparingly soluble, antacid.
Reactions:

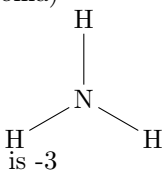
- Decomposition: $Mg(OH)_2 \xrightarrow{\text{heat}} MgO + H_2O$
- With acids (antacid action): $Mg(OH)_2 + 2\,HCl \longrightarrow MgCl_2 + 2\,H_2O$

$Ba(OH)_2$ (Barium hydroxide)
Valence: Ba is +2
Properties: Strong base, more soluble than $Ca(OH)_2$.
Reactions:

- With sulfuric acid: $Ba(OH)_2 + H_2SO_4 \longrightarrow BaSO_4\downarrow + 2\,H_2O$
- With ammonium salts (endothermic): $Ba(OH)_2 \cdot 8\,H_2O + 2\,NH_4Cl \longrightarrow BaCl_2 + 2\,NH_3\uparrow + 10\,H_2O$

2.3.3 Ammonia and related bases

NH_3 (Ammonia)
Structure:



Valence: N is -3
Properties: Weak base, pungent gas, very soluble in water.
Reactions:

- Complex formation with Cu^{2+}: $Cu^{2+} + 4\,NH_3 \longrightarrow [Cu(NH_3)_4]^{2+}$ (deep blue)
- With HCl: $NH_3 + HCl \longrightarrow NH_4Cl$ (white smoke)
- Haber process: $N_2 + 3\,H_2 \underset{\text{high T, P}}{\overset{\text{Fe catalyst}}{\rightleftharpoons}} 2\,NH_3$
- Oxidation by oxygen: $4\,NH_3 + 5\,O_2 \xrightarrow{\text{Pt catalyst}} 4\,NO + 6\,H_2O$ (Ostwald process)
- With chlorine: $2\,NH_3 + 3\,Cl_2 \longrightarrow N_2 + 6\,HCl$
- Reduction of CuO: $3\,CuO + 2\,NH_3 \xrightarrow{\text{heat}} 3\,Cu + N_2 + 3\,H_2O$

NH_4OH (Ammonium hydroxide)
Formula: NH_4^+ and OH^- ions in aqueous solution
Valence: N is -3
Properties: Aqueous ammonia solution, weak base.
Reactions:

- Precipitation of metal hydroxides: $Fe^{3+} + 3\,NH_4OH \longrightarrow Fe(OH)_3\downarrow + 3\,NH_4{}^+$
- With excess ammonia (complex formation): $Zn(OH)_2 + 4\,NH_3 \longrightarrow [Zn(NH_3)_4]^{2+} + 2\,OH^-$

2.3.4 Transition metal hydroxides

$Fe(OH)_2$ (Iron(II) hydroxide, Ferrous hydroxide)
Valence: Fe is +2
Properties: Weak base, white-green solid, easily oxidized.
Reactions:

- Oxidation: $4\,Fe(OH)_2 + O_2 + 2\,H_2O \longrightarrow 4\,Fe(OH)_3$ (turns brown)
- Decomposition: $Fe(OH)_2 \xrightarrow{\text{heat}} FeO + H_2O$

$Fe(OH)_3$ (Iron(III) hydroxide, Ferric hydroxide)
Valence: Fe is +3
Properties: Very weak base, brown precipitate.
Reactions:

- Decomposition: $2\,Fe(OH)_3 \xrightarrow{heat} Fe_2O_3 + 3\,H_2O$

$Al(OH)_3$ (Aluminum hydroxide)
Valence: Al is +3
Properties: Amphoteric, white precipitate, antacid.
Reactions:

- With acid: $Al(OH)_3 + 3\,HCl \longrightarrow AlCl_3 + 3\,H_2O$
- With base: $Al(OH)_3 + NaOH \longrightarrow NaAlO_2 + 2\,H_2O$
- Decomposition: $2\,Al(OH)_3 \xrightarrow{heat} Al_2O_3 + 3\,H_2O$

$Cu(OH)_2$ (Copper(II) hydroxide, Cupric hydroxide)
Valence: Cu is +2
Properties: Weak base, blue precipitate.
Reactions:

- Decomposition: $Cu(OH)_2 \xrightarrow{heat} CuO + H_2O$
- With ammonia: $Cu(OH)_2 + 4\,NH_3 \longrightarrow [Cu(NH_3)_4]^{2+} + 2\,OH^-$ (deep blue solution)
- With tartaric acid (Fehling's reagent): Forms copper tartrate complex

3 Ores and alloys

3.1 Ores

English Name	Properties	Formula
Hematite	Red-brown iron ore, most important iron ore	Fe_2O_3
Magnetite	Black magnetic iron ore, high iron content	Fe_3O_4
Limonite	Yellow-brown hydrated iron oxide	$2\,Fe_2O_3 \cdot 3\,H_2O$
Siderite	Iron carbonate, light colored	$FeCO_3$
Pyrite	Brass-yellow, fool's gold, used for sulfuric acid	FeS_2
Chalcopyrite	Brass-yellow copper ore, most abundant copper ore	$CuFeS_2$
Chalcocite	Dark gray copper sulfide	Cu_2S
Malachite	Green basic copper carbonate	$Cu_2CO_3(OH)_2$
Azurite	Blue basic copper carbonate	$Cu_3(CO_3)_2(OH)_2$
Cuprite	Red copper oxide	Cu_2O
Bauxite	Reddish aluminum ore, clay-like	$Al_2O_3 \cdot nH_2O$
Cryolite	White, used as flux in aluminum production	Na_3AlF_6
Corundum	Very hard aluminum oxide, includes ruby/sapphire	Al_2O_3
Galena	Lead-gray, cubic crystals, main lead ore	PbS
Cerussite	White lead carbonate	$PbCO_3$
Anglesite	White lead sulfate	$PbSO_4$
Sphalerite (Zinc blende)	Yellow-brown to black, main zinc ore	ZnS
Smithsonite	White zinc carbonate	$ZnCO_3$

English Name	Properties	Formula
Zincite	Red-orange zinc oxide	ZnO
Cassiterite	Brown-black tin oxide, main tin ore	SnO_2
Cinnabar	Bright red mercury sulfide, main mercury ore	HgS
Argentite	Dark gray silver sulfide	Ag_2S
Calamine	Zinc silicate ore	$Zn_4Si_2O_7(OH)_2 \cdot H_2O$
Chromite	Black chromium iron oxide, main chromium ore	$FeCr_2O_4$
Pyrolusite	Black manganese dioxide ore	MnO_2
Rhodochrosite	Pink manganese carbonate	$MnCO_3$
Rutile	Red-brown titanium dioxide	TiO_2
Ilmenite	Black iron titanium oxide	$FeTiO_3$
Barite	White barium sulfate, heavy	$BaSO_4$
Witherite	White barium carbonate	$BaCO_3$
Scheelite	White tungsten calcium ore	$CaWO_4$
Wolframite	Black iron manganese tungsten ore	$(Fe, Mn)WO_4$
Molybdenite	Gray, soft molybdenum sulfide	MoS_2
Carnallite	White-red potassium magnesium salt	$KCl \cdot MgCl_2 \cdot 6\,H_2O$
Sylvite	White-red potassium chloride	KCl
Halite (Rock salt)	Transparent-white sodium chloride	$NaCl$
Fluorite (Fluorspar)	Colorful calcium fluoride	CaF_2
Limestone	White-gray calcium carbonate sedimentary rock	$CaCO_3$
Dolomite	White-pink calcium magnesium carbonate	$CaMg(CO_3)_2$
Gypsum	White calcium sulfate dihydrate	$CaSO_4 \cdot 2\,H_2O$
Anhydrite	White calcium sulfate	$CaSO_4$
Apatite	Green-blue calcium phosphate	$Ca_5(PO_4)_3(F, Cl, OH)$
Phosphorite	Gray-brown calcium phosphate rock	$Ca_3(PO_4)_2$

3.2 Alloys

English Name	Elements	Properties	Application
Steel	Fe, C ($< 2\%$)	Strong, hard, malleable	Construction, tools
Stainless steel	Fe, Cr (10-20%), Ni	Corrosion-resistant, strong	Cutlery, medical
Cast iron	Fe, C (2-4%)	Brittle, hard, good casting	Engine blocks, pipes
Brass	Cu (55-95%), Zn	Golden, corrosion-resistant	Musical instruments, fittings
Bronze	Cu (88%), Sn (12%)	Hard, corrosion-resistant	Sculptures, bearings
Aluminum bronze	Cu, Al (5-11%)	Strong, corrosion-resistant	Marine hardware, coins
Cupronickel	Cu (75%), Ni (25%)	Silver-colored, corrosion-resistant	Coins, marine uses
German silver	Cu, Ni, Zn	Silver-white, no silver	Cutlery, jewelry base
Phosphor bronze	Cu, Sn, P	Elastic, wear-resistant	Springs, electrical
Gunmetal	Cu, Sn (10%), Zn (2%)	Corrosion-resistant, tough	Gears, bearings
Duralumin	Al (94%), Cu (4%), Mg	Light, strong, age-hardenable	Aircraft, aerospace
Magnalium	Al (70-95%), Mg	Very light, strong	Aircraft parts
Alnico	Al, Ni, Co, Fe	Strong magnetic	Permanent magnets

English Name	Elements	Properties	Application
Solder	Sn (60%), Pb (40%)	Low melting point	Electrical joints
Lead-free solder	Sn, Cu, Ag	Low melting, no lead toxicity	Electronics
Pewter	Sn (85-99%), Sb, Cu	Soft, silvery, malleable	Decorative items
Babbitt metal	Sn, Sb, Cu	Low friction, soft	Bearing surfaces
Type metal	Pb, Sn, Sb	Expands on cooling	Printing type
Wood's metal	Bi, Pb, Sn, Cd	Very low melting (70°C)	Fire sprinklers, fuses
Rose's metal	Bi, Pb, Sn	Low melting (98°C)	Fusible alloys
Nichrome	Ni (80%), Cr (20%)	High electrical resistance, heat-resistant	Heating elements
Monel metal	Ni (67%), Cu (30%)	Corrosion-resistant, strong	Marine, chemical
Invar	Fe (64%), Ni (36%)	Very low thermal expansion	Precision instruments
Permalloy	Fe (20%), Ni (80%)	High magnetic permeability	Transformers, sensors
Constantan	Cu (55%), Ni (45%)	Constant electrical resistance	Thermocouples
Manganin	Cu (86%), Mn (12%), Ni	Stable resistance vs. temperature	Precision resistors
Stellite	Co, Cr, W, C	Very hard, wear-resistant	Cutting tools
Hastelloy	Ni, Mo, Cr, Fe	Excellent corrosion resistance	Chemical equipment
Titanium alloy	Ti (90%), Al (6%), V (4%)	High strength-to-weight ratio	Aerospace, implants
Amalgam	Hg, Ag, Sn, Cu	Soft, hardens over time	Dental fillings
Elektron	Mg (90%), Al, Zn	Extremely light	Aircraft parts
Beryllium copper	Cu (98%), Be (2%)	Non-sparking, elastic	Explosion-proof tools
White gold	Au, Ni/Pd, Zn	White-silver appearance	Jewelry
Rose gold	Au (75%), Cu (22.5%), Ag	Pink-red color	Jewelry
Sterling silver	Ag (92.5%), Cu (7.5%)	Harder than pure silver	Jewelry, tableware
Britannia silver	Ag (95.8%), Cu	Softer, higher silver content	High-end silverware
Nitinol	Ni (55%), Ti (45%)	Shape memory effect	Medical devices, actuators
Zamak	Zn, Al, Mg, Cu	Good castability, moderate strength	Die castings
Babbitt	Sn, Sb, Cu (or Pb base)	Low friction, good embeddability	Bearings
Bell metal	Cu (78%), Sn (22%)	Resonant, hard	Bells, cymbals