

Chapter – 4: Metals and Non-Metals

- Metals – discovered 1000s of years ago
- Progress of mankind – linked with discovery of metals
- Stone age to bronze age – after discovery of copper
- Discovery of iron – iron age
- Non-metals – discovered later
- 118 – known elements – divided into 3 groups – metals, non-metals, **metalloids** – show both properties – antimony and arsenic

Metals and their occurrence

- 80 known elements – metals – lose electrons to form cations – positive ions
- Some found in abundance (huge quantity) – some – rare
- Metals – rarely or do not react – **noble metals** – gold and platinum – expensive metals
- Growth of nation – decided by – consumption of metal per annum
- Wealth – in the form of gold

Occurrence

- Metals – mainly – earth's crust – also present in seas and oceans
- Aluminium – most abundant – followed by iron
- Cannot extract or obtain – from all available minerals
- Minerals – from which metals can be extracted – conveniently – **ores**
- Metals – mined, separated, purified
- Metal ores – carbonates, sulphides, oxides, chlorides, halides
- Many processes – extraction of metals from ores

Physical properties of metals

- Common physical properties
- Wires made of copper, iron, aluminium – **ductility**
- Beat metals into thin sheets – making jewellery, metal sheets – **malleability**
- Properties – characteristics – exceptions –
 - Physical state – solid at room temperatures – Mercury (liquid at room temp.)
 - Hardness – hard and very strong – Sodium, Potassium (soft metals)
 - Melting and boiling points – high melting and boiling points – Mercury, Cesium, Tellurium (low points)
 - Malleability – can be beaten up in sheets (malleable) – Zinc (not malleable)
 - Ductility – can be shaped into wires (ductile) – Zinc (not ductile)
 - Conductivity – good conductors of heat and electricity – Mercury, Tungsten (bad conductors)
 - Density – high density – Sodium, Potassium (low density)
 - Lustre – brilliant shine –
 - Sonority – make ringing sound (sonorous) – Mercury (not sonorous)

Chemical properties of metals

- Common chemical properties
- Metals react with other elements – show similar results
- Rate of reaction – depend on – reactivity
- **Reactivity series** – arrangement of metals – some metals – more reactive than others

Activity Series of Metals and Hydrogen



- Hydrogen – only non-metal in the series
 - Reaction with oxygen
 - Form basic oxides
 - Metal + oxygen → metal oxide
 - Magnesium – burns – form magnesium oxide (ash)
 - $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
 - Different metals – react under different conditions
 - Zinc, copper – react at high temperatures
 - $2\text{Zn} + \text{O}_2 \rightarrow 2\text{ZnO}$
 - Sodium, potassium – react at room temperatures – catch fire easily – kept in kerosene
 - $4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$
 - Reaction with water
 - Different metals – react at different rates – form oxides or hydroxides and hydrogen
 - Some react at room temperatures – some with boiling water – some with warm water – some with steam only
 - Metal + water → metal hydroxide + hydrogen
 - $2\text{Na} + \text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$
 - $\text{Mg} + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{H}_2$ (warm water)
 - $\text{Zn} + \text{H}_2\text{O} \rightarrow \text{ZnO} + \text{H}_2$ (boiling water)
 - $2\text{Fe} + 3\text{H}_2\text{O} \rightarrow \text{Fe}_2\text{O}_3 + 3\text{H}_2$ (steam)
 - Reaction with dilute mineral acids
 - Different metals – react under different conditions – form mineral salts and hydrogen
 - Metal + dilute acid → metal salt + hydrogen
 - Metals – top of reactivity series – react more readily – lower metals – react slowly
 - $\text{Zn} + \text{H}_2\text{SO}_4 \rightarrow \text{ZnSO}_4 + \text{H}_2$
 - $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$
 - Reaction with salt solution
 - More reactive metals – replace less reactive metals – **displacement reaction**
 - More reactive metal – higher in reactivity series
 - Copper – less reactive than Iron – no reaction
 - $\text{Cu} + \text{FeSO}_4 \rightarrow \text{no reaction}$
 - Magnesium – more reactive than Copper – displacement
 - $\text{Mg} + \text{CuSO}_4 \rightarrow \text{MgSO}_4 + \text{Cu}$

Uses of metals

- Very useful – different purposes

- Copper (Cu) –
 - Electrical wires – good conductor of electricity
 - Cooking utensils – good conductor of heat
 - Alloys – brass and bronze
- Aluminium (Al) –
 - Electrical wires – good conductor of electricity
 - Food packaging foils – malleable
 - Paints
 - Alloys – magnalium
 - Aluminium alloys – construction of aircraft
 - Cooking utensils – good conductor of heat
 - Drink cans – non-toxic
- Iron (Fe) –
 - Iron alloys – construction of buildings, bridges, car parts, engine parts, ships, etc.
- Mercury (Hg) –
 - Used in thermometers – shiny liquid at room temperatures and expand easily on boiling
- Lead (Pb) –
 - Automobile batteries and pipes
 - Water proof edgings – extremely malleable

Noble metals

- Metals – react very rarely or not at all
- Gold, platinum, silver – exist in free state
- Silver – damaged – exposed to air – react with hydrogen sulphide – form silver sulphide
- Gold –
 - Jewellery and decorations
 - Electroplating
 - Dental fillings
- Silver –
 - Jewellery and decorations
 - Electroplating
 - Photography and dental fillings
 - Electronic components
 - Silver foil (*vark*)
- Platinum –
 - Jewellery
 - Dental fillings and photography
 - Catalyst – helps in reactions
 - Manufacture of sulphuric acid and nitric acid

Corrosion of metals

- Metal reactive – surface attacked by air and moisture
- Chemical reaction – result – metal get damaged – corrosion
- Surface gets damaged – corrosion happens on the inside – Iron

- Copper, silver – only surface damage
 - Silver
 - Exposed to air – gets damaged – lose their shine
 - Silver – not much reactive – does not react with oxygen but hydrogen sulphide – form black coating – silver sulphide
 - $\text{Ag} + \text{H}_2\text{S} \rightarrow \text{Ag}_2\text{S} + \text{H}_2$
 - Gold
 - Highly non-reactive – does not react – does not corrode
 - Gold used for electroplating other elements
 - Aluminium
 - Aluminium vessels – lose shine – formation of aluminium oxide – non-reactive – protects from further corrosion
 - This case – corrosion is useful
 - $4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$
 - Copper
 - Non-reactive – some extent
 - Corrodes slowly – exposure to moist air – formation of greenish layer – copper carbonate (basic)
 - $2\text{Cu} + (\text{H}_2\text{O} + \text{CO}_2 + \text{O}_2) \rightarrow \text{Cu}(\text{OH})_2 + \text{CuCO}_3$
 - Statue of Liberty – copper – golden colour – turned to green colour – corrosion of copper
 - Iron
 - Exposed to moist air – formation of reddish brown substance – **rust**
 - Corrosion of iron – **rusting**
 - $4\text{Fe} + 3\text{O}_2 + 3\text{H}_2\text{O} \rightarrow \text{Fe}_2\text{O}_3$ (ferrous oxide) + $2\text{Fe}(\text{OH})_2$ (rust – ferric hydroxide)

Prevention of corrosion

- Corrosion – serious problem
- Prevented – metal – not allowed to contact moist air
- Some of the methods –
 - Applying grease or oil
 - Cuts contact from moist air
 - Painting
 - Coating of paint – prevents contact from moist air
 - Galvanization
 - Layer of Zinc – prevents contact
 - Iron dipped in molten Zinc
 - Alloying
 - Create alloys with other metals
 - Iron – alloyed with nickel, chromium, carbon – forms stainless steel
 - Electroplating
 - Thin layer – protective metal – by electroplating
 - Steel – coating of chromium – make car parts
 - Steel – coating of tin – food packaging cans

Non-metals and their occurrence

- Elements – accept electrons – anions – negatively charged
- Non-metals – used in pure form or compounds
- Hydrogen – most common in universe
- Oxygen – most abundant (earth's crust) – followed by silicon

Occurrence

- Both states – free as well as compounds
 - Hydrogen
 - Combined form – water, methane – earth's crust
 - Also present in coal, petroleum
 - Free form – outer space, Sun, other stars
 - Carbon
 - Free form – coal, diamond, graphite
 - Combined form – carbohydrates, fats, proteins, vitamins, CO₂ – required for photosynthesis
 - Also present in coal gas, petroleum, natural gas, as carbonates
 - Oxygen
 - Air around us
 - Combined form – water, oxides, carbonates
 - Nitrogen
 - Main constituent in air
 - Combined state – nitrates, ammonia,
 - Also present in soil and all living things

Physical properties of non-metals

- Show different properties – vary too much – different from metals
- Properties – characteristics – exceptions –
 - Physical state – either solid (carbon, Sulphur, phosphorous) or gaseous (oxygen, hydrogen, chlorine) – Bromine (only liquid non-metal)
 - Density – lower density – Diamond (density comparable to aluminium)
 - Malleability and ductility – neither malleable nor ductile (brittle – powdery mass) –
 - Thermal and electrical conductivity – poor conductors – Graphite (good conductor)
 - Lustre – do not lustre – Iodine crystals, graphite (shiny)
 - Hardness – soft – Diamond (extremely hard)

Chemical properties of non-metals

- Reaction with oxygen
 - React on heating – form oxides
 - $C + O_2 \rightarrow CO_2$
 - Oxides – dissolve in water – form acids
 - $CO_2 + H_2O \rightarrow H_2CO_3$ (carbonic acid)
- Reaction with water
 - Do not react with water or steam

- Reaction with acids
 - Do not react with acids
 - Exception – Silicon, Sulphur

Uses of non-metals

- Oxygen –
 - Sustain life – needed for respiration
 - Also needed for burning
- Carbon –
 - Components of food – carbohydrates, fats, etc.
 - Other compounds – textiles, dyes, plastics, paper, fuels
 - Diamond, graphite – 2 forms
 - Diamond – jewellery – graphite – food conductor – electrodes – pencil leads
- Hydrogen –
 - Manufacture of ammonia
 - Manufacture vegetable ghee – hydrogenation of oils
 - Welding of metals
 - Liquid hydrogen – fuel in rockets
- Nitrogen –
 - Food packaging
 - Liquid nitrogen – freezing food
 - Presence of nitrogen – reduces rate of combustion
- Sulphur –
 - Manufacture of several chemicals
 - Manufacture of vulcanized rubber – tough and strong – used in automobiles tyres
 - Used in fungicide
- Phosphorus –
 - Manufacture of safety matches, fireworks
- Chlorine –
 - Used in water purification

Alloys

- Metals and non-metals – mixed with other metals – form **alloys**
- Melt main metal – dissolve other metals or non-metals – fixed ratio
- Properties – improve this way
 - Increasing hardness
 - Iron, copper – not hard enough for construction
 - Pure iron – mixed with 0.5 % Carbon – form **steel** – hard enough for construction
 - Increasing resistance to corrosion
 - Metals – corrode easily
 - Iron, nickel, chromium, carbon – stainless steel
 - Changing physical or chemical properties
 - Tin and lead – high melting points
 - Tin and lead – mixed together – form solder – low melting point