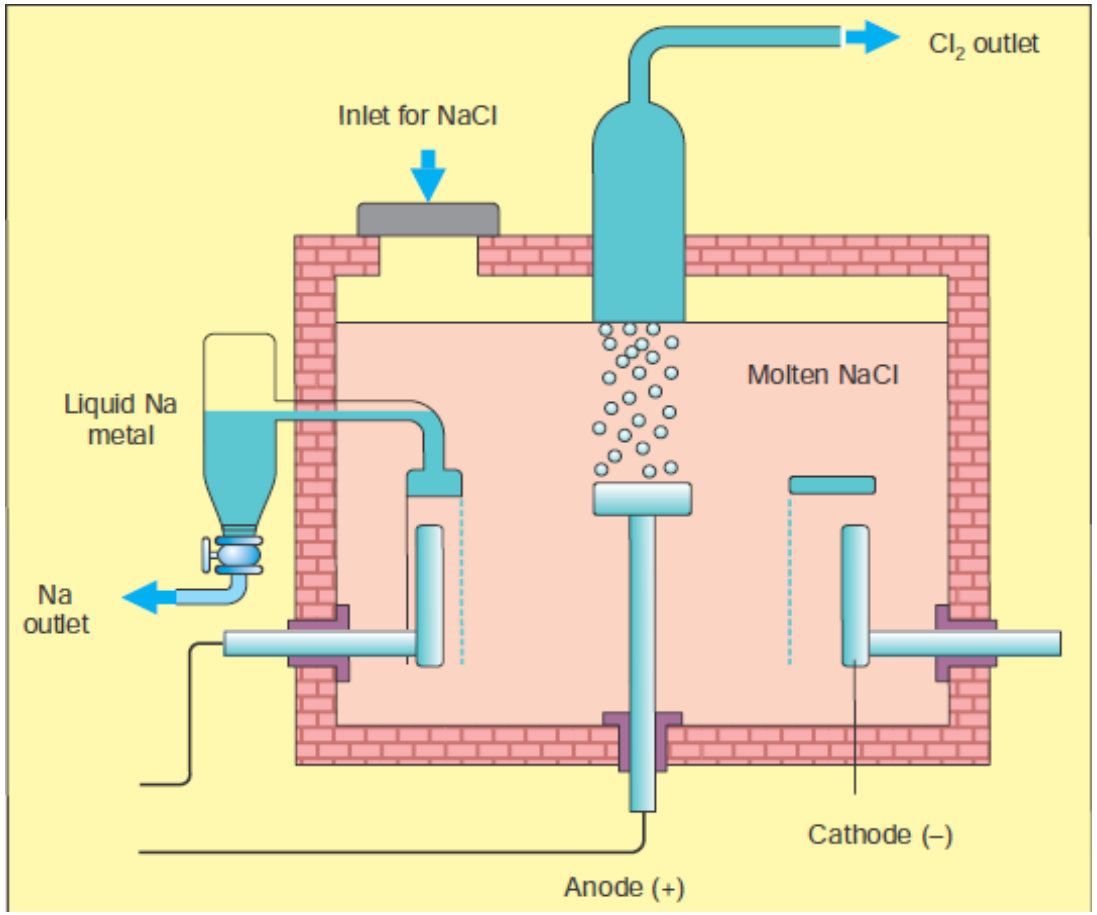
Extraction, Properties and Uses of Some Selected Metals

1. Sodium

- Sodium is obtained by the electrolysis of a molten mixture of about 40% NaCl and 60% $CaCl_2$ in a Downs cell. Calcium chloride ($CaCl_2$) is added to lower the melting point of NaCl from 800°C to 600°C.

The sodium metal formed at the cathode is in liquid state. Because sodium metal is less dense than molten NaCl, the sodium floats to the surface and is collected.

Chlorine gas forms at the anode and is collected at the top of the Downs cell.



Chemical Properties of Sodium

a) Reaction with water

- Sodium reacts with water, liberating hydrogen and forming sodium hydroxide solution.

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

b) Reaction with air

- Sodium tarnishes readily in dry air to form sodium peroxide and sodium oxide.

$$6Na(s) + 2O_2(g) \rightarrow Na_2O_2(s) + 2Na_2O(s)$$

- major product minor product

c)Reaction with hydrogen

- Sodium reacts with hydrogen to form sodium hydride.

$$2Na(s) + H_2(g) \rightarrow 2NaH(s)$$

d) Reaction with halogens (F_2, Cl_2, Br_2 and I_2)

- Sodium reacts with halogens to form sodium halides.

$$2Na(s) + F_2(g) \rightarrow 2NaF(s)$$

- ***Uses of Sodium***
- The largest use of sodium is to make a Na/Pb alloy needed to make tetraethyl lead ($PbEt_4$) and tetramethyl lead ($PbMe_4$). These compounds are used as anti-knock additives to petrol.
- Another important use is to reduce $TiCl_4$ and $ZnCl_4$ to the metals.
- Liquid sodium metal is used as a coolant in nuclear reactors.
- It is also used to make

  Na_2O_2 and NaH, and for street lights.

- ***2. Calcium***
- ***Occurrence of Calcium***
- Calcium is the 5_{th} most abundant element in the earth's crust.
- The main ores of calcium are: limestone, chalk, and marble ($CaCO_3$), dolomite ($CaCO_3.MgCO_3$), gypsum ($CaSO_4.2H_2O$), fluorite (CaF_2), and hydroxylapatite, $Ca_5(PO_4)_3OH$.
- In Ethiopia, gypsum deposits are found in the Danakil depression.
- Calcium is prepared by the electrolysis of molten calcium chloride ($CaCl_2$).
- ***Anode (oxidation) :*** $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$
- ***Cathode (reduction) :*** $Ca^{2+}(l) + 2e^- \rightarrow Ca(l)$
- ***Overall reaction :*** $Ca^{2+}(l) + 2Cl^-(l) \rightarrow Ca(l) + Cl_2(g)$
- Calcium can also be prepared by the reduction of CaO by aluminium in vacuum, where the calcium produced distills off.

Chemical properties of Calcium

a. Reaction with water

Calcium reacts with cold water quite readily, liberating hydrogen gas and forming calcium hydroxide.

$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$$

b. Reaction with oxygen

Calcium reacts with oxygen to form calcium oxide.

$$2Ca(s) + O_2(g) \rightarrow 2CaO(s)$$

c. Reaction with nitrogen

Calcium reacts with nitrogen at high temperatures to form calcium nitride.

$$3Ca(s) + N_2(g) \xrightarrow{\text{hightemperature}} Ca_3N_2(s)$$

d. Reaction with halogens

Calcium reacts with F_2, Cl_2, Br_2 and I_2 to form CaF_2, $CaCl_2$, $CaBr_2$ and CaI_2 respectively.

$$Ca(s) + F_2(g) \rightarrow CaF_2(s)$$

e. Reaction with hydrogen

Calcium combines with hydrogen to form calcium hydride.

$$Ca(s) + H_2(g) \rightarrow CaH_2(s)$$

Uses of Calcium

Calcium is an essential element in living matter. It is the ***major component of bones and teeth.***

- A characteristic function of Ca^{2+} ions in living systems is in the activation of a variety of metabolic processes. For example, calcium plays a vital role in ***heart action, blood clotting, muscle contraction, and nerve-impulse transmission***.

3. *Tin*

Occurrence

- The only important ore of tin is cassiterite, SnO_2.

Extraction of Tin……..

Chemical Properties of Tin

a) Reaction with water

- Tin does not react with cold water, but it reacts with steam to form SnO_2 and H_2.

$$Sn(s) + 2H_2O(g) \xrightarrow{heat} SnO_2(s) + 2H_2(g)$$

b) Reaction with acids

Tin reacts with dilute and concentrated acids.

$$Sn(s) + \textit{dil.}\ 2HCl(aq) \rightarrow SnCl_2(aq) + H_2(g)$$

$$Sn(s) + \textit{conc.}\ 4HNO_3(aq) \rightarrow Sn(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$

c. Reaction with halogens

Tin reacts with Cl_2 and Br_2 in the cold and with F_2 and I_2 on warming, forming the corresponding tin tetrahalide.

$$Sn(s) + 2Cl_2(g) \xrightarrow{cold} SnCl_4(s)$$

$$Sn(s) + 2F_2(g) \xrightarrow{warm} SnF_4(s)$$

Uses of Tin

- The main uses of tin are for electroplating steel, to make tin-plate, and alloys. Tinplate is extensively used for making cans for food.
- Tin is a constituent of many alloys, including type metal (Sn, Sb and Pb), bronze (Sn and Cu), and solder (Sn and Pb).

4. *Lead*

Occurrence of Lead

The main ore of lead is galena, PbS. It is black, shiny and very dense.

Extraction of Lead

- Galena is mined and separated from its impurities by froth flotation.

There are two methods of extracting the element:

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$

$$2PbO(s) + C(s) \rightarrow 2Pb(l) + CO_2(g)$$

- In second method, PbS is partially oxidized by heating and blowing air through it. After some time the air is turned off and heating is continued, and the mixture undergoes self–reduction.

$$3PbS(s) + O_2(g) \xrightarrow{\text{heated in air}} PbS(s) + 2PbO(s) \xrightarrow{\text{heated in absenceof air}} 3Pb(l) + SO_2(g)$$

Chemical Properties of Lead

- Lead is not affected by water because the metal is covered by a thin oxide film.
- It dissolves slowly in dilute HCl, forming the sparingly soluble $PbCl_2$ and quite readily in dilute HNO_3, forming $Pb(NO_3)_2$ and oxides of nitrogen.
- However, it does not dissolve in dilute H_2SO_4 because a surface coating of $PbSO_4$ is formed.
- Lead is slowly attacked by cold alkali, and rapidly by hot alkali, giving the plumbates $Na_2Pb(OH)_6$.
- Thus, lead is amphoteric. It also reacts with F_2 in the cold, forming PbF_2, and with Cl_2 on heating, giving $PbCl_2$.

Uses of Lead

- The major use of lead is to make ***lead-acid storage batteries***.
- It is also used in the manufacture of **PbEt4** as an additive for petrol, in ***paints*** and ***pigments***.
- In addition, lead is used for the production of ***lead sheets, lead pipes*** and ***solder***.

5. *Zinc*

Occurrence of Zinc

Zinc is the 24th most abundant element in the earth's crust. The most important ore of zinc is zinc blende (ZnS).

Extraction of Zinc

- ZnS is concentrated by froth flotation and then roasted in air to give ZnO and SO_2.
- The SO_2 is used to make H_2SO_4.
- Zn is extracted from the oxide by two different processes.

1. ZnO may be reduced by carbon monoxide at 1200°C

$$ZnO(s) + CO(g) \rightarrow Zn(g) + CO_2(g)$$

- 2. ZnS is heated in air at a lower temperature, yielding ZnO and $ZnSO_4$. These are dissolved in H_2SO_4. Zinc dust is added to precipitate Cd, and then the $ZnSO_4$ solution is electrolyzed to give pure zinc. This method is more expensive than the first.

Uses of Zinc

- Zinc is used in large amounts for coating iron to prevent it from rusting. This process is called galvanizing. A thicker layer may be applied by dipping a metal in molten zinc.
- Large amounts of Zn are used to make alloys. The most common alloy is brass, which is an alloy of copper and zinc.
- Zinc is also used as the negative electrode (anode) in sealed 'dry' batteries such as Le-clanche’ cells, mercury cells and alkaline manganese cells.
- Zinc oxide is sometimes used as a white pigment in paint. It is particularly bright as it absorbs UV light and reemits it as white light.

6. *Chromium*

Occurrence

- Chromium is the 21st most abundant element, by weight, in the Earth's crust. The most important ore of chromium is chromite ($FeCr_2O_4$).
- ***Extraction***
- Chromium is produced in two forms which are ferrochrome and pure chromium metal.
- Ferrochrome is mainly an alloy of chromium and iron. It is prepared by reducing chromite with carbon.
- $FeCr_2O_4(s) + 4C(s) \xrightarrow{\text{electricfurnance}} Fe + 2Cr + 4CO$

  ferrochrome
- Four basic steps are followed to get pure chromium.

  Step 1: When chromite is fused with NaOH in air, chromium (III) is oxidized to chromium (VI).

$$4FeCr_2O_4(s)+16NaOH(s)+7O_2(g) \xrightarrow{100^\circ C} 8Na_2CrO_4(s)+2Fe_2O_3(s)+8H_2O(l)$$

Step 2: Ferric oxide (Fe_2O_3) is insoluble, but sodium chromate (Na_2CrO_4) is soluble in water. Thus the sodium chromate is separated from ferric oxide by dissolving with water, followed by decantation or filtration. The sodium chromate solution is acidified to convert it to a less soluble sodium dichromate.

$$2Na_2CrO_4(aq) + 2HCl(aq) \rightarrow Na_2Cr_2O_7(s) + 2NaCl(aq) + H_2O(l)$$

Step 3: The sodium dichromate is reduced to Cr_2O_3 by heating with carbon.

$$Na_2Cr_2O_7(s) + 2C(s) \rightarrow Cr_2O_3(s) + Na_2CO_3(s) + CO(g)$$

Step 4: Finally, Cr_2O_3 is reduced to the metal by Al.

$$Cr_2O_3(s) + 2Al(s) \rightarrow 2Cr(s) + Al_2O_3(s)$$

Chemical Properties

- Chromium is an active metal but it is protected from corrosion by a very thin transparent oxide film.

$$4Cr(s) + 3O_2(g) \rightarrow 2Cr_2O_3(s)$$

- Concentrated nitric acid and other oxidizing agents build up the oxide film to the point where chromium becomes passive, that is, it no longer dissolves in the acid solution.
- Chromium dissolves in HCl and dilute H_2SO_4 to form blue chromium (II) ions, which are stable only in the absence of air.

$$Cr(s) + 2H^+(aq) \rightarrow Cr^{2+}(aq) + H_2(g)$$

- The unstable chromium (II) state is readily oxidized to the chromium (III) state.
- It can remove traces of oxygen by bubbling the gas through a solution containing chromium (II) ions.

$$4Cr^{2+}(aq) + O_2(g) + 4H^+(aq) \rightarrow 4Cr^{3+}(aq) + 2H_2O(l)$$

Uses

- Nichrome wire, commonly used in chemistry laboratories for flame tests, is an alloy of nickel and chromium. Ferrochrome, iron–chromium alloy, is used in the production of stainless steel. Cr_2O_3 is dissolved in H_2SO_4 and deposited electrolytically (*electroplating*) on the surface of a metal. This protects the metal from corrosion and gives it a shiny appearance.
- Sodium and potassium chromates and dichromates are used as pigments and corrosion inhibitors in heating systems and air-conditioning systems.
- Chromium (VI) oxide, CrO_3, appears as a bright-red precipitate when saturated potassium dichromate is treated with excess of concentrated sulphuric acid.
- $Cr_2O_7^{2-}(aq) + 2H^+(aq) \rightarrow 2CrO_3(s)\ H_2O(l)$
- $CrO_3(s) + H_2O(l) \rightarrow H_2CrO_4$
- The resulting acid mixture (also known as chromic acid) is a powerful oxidizing agent.
- It can oxidize grease and was used as a cleaning solution for laboratory glassware.

Silicon

Occurrence

- Silicon is the second most abundant element, after oxygen, in the Earth's crust. It occurs as silica (SiO_2) and silicate compounds containing the silicate ion, (SiO_4^{4-}).
- Quartz is a pure crystalline form of silica, and flint is a hard amorphous form.

Extraction

- Silicon is prepared by heating silica with coke to approximately 3000°C in an electric furnace:

$$SiO_2(s) + 2C(s) \rightarrow Si(l) + 2CO(g)$$

- The molten silicon is taken from the bottom of the furnace and allowed to cool producing a shiny blue-gray solid. Extremely high-purity silicon is needed for the electronics industry. Purifying raw silicon requires additional steps. First, the silicon in the impure sample is allowed to react with chlorine to convert the silicon to liquid silicon tetrachloride.

$$Si(s) + 2Cl_2(g) \rightarrow SiCl_4(l)$$

- Silicon tetrachloride (*boiling point* 57.6°C) is carefully purified by distillation and then reduced to silicon, using magnesium:

$$SiCl_4(g) + 2Mg(s) \rightarrow 2MgCl_2(s) + Si(s)$$

- The magnesium chloride is washed out with water, and the silicon is remelted and cast into bars. A final purification is carried out by zone refining.

Chemical Properties

- Silica is resistant to attack by all acids except HF, with which it reacts to give SiF4 and H2O. This chemical attack is involved in the etching of glass. It also dissolves slowly in hot, molten NaOH or Na2CO3 to give Na4SiO4:

$$SiO_2(s) + 4HF(l) \rightarrow SiF_4(g) + 2H_2O(l)$$

$$SiO_2(s) + 2Na_2CO_3(l) \rightarrow Na_4SiO_4(s) + 2CO_2(g)$$

- Silicon and methyl chloride (CH_3Cl) react at 300°C in the presence of copper powder as a catalyst. The main product of this reaction is $(CH_3)_2SiCl_2$.

$$Si(s) + 2CH_3Cl\ (g) \rightarrow (CH_3)_2SiCl_2(l)$$

- When it reacts with water, initially it produces $(CH_3)_2Si(OH)_2$, and the reaction continues to form a polymer.

$$(CH_3)_2SiCl_2(l) + 2H_2O(l) \rightarrow (CH_3)_2Si(OH)_2(l) + 2HCl(g)$$

$$n(CH_3)_2Si(OH)_2(l) \rightarrow [(CH_3)_2SiO]_n(s) + nH_2O(l)$$

- Silicone polymers are non-toxic and have good stability to heat, light, moisture, and oxygen.

- ***Uses***
- Silicon is a semiconductor and is used in the construction of transistors and microprocessors.
- Quartz crystals are used to control the frequency of radio and television transmissions.
- Silicone polymers are used in making lubricants, lipstick, car polish and other materials.

Some Important Compounds of Selected Non-metals

1. Ammonia (NH_3)

• 2. *Nitric Acid (HNO_3)*

- Pure nitric acid is a colourless liquid, but on exposure to light it turns brown because
- of slight decomposition into NO_2 (*brown*) and O_2.
- $4HNO_3(l) \longrightarrow 4NO_2(g) + O_2(g) + 2H_2O(l)$

brown

Nitric acid is a strong oxidizing agent, particularly when it is hot and concentrated.

- Nitric acid is produced industrially from ammonia by the three-step Ostwald process:

Step 1: Ammonia is burned in excess oxygen over a platinum catalyst to form nitric oxide (NO):

$$4NH_3(g) + 5O_2(g) \xrightarrow{850\ C,\ 5\ atm\ ,\ Pt} 4NO(g) + 6H_2O(g)$$

Step 2: Additional air is added to cool the mixture and oxidize NO to NO_2:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Step 3: The NO_2 gas is bubbled into warm water where it reacts to give nitric acid and nitric oxide:

$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$$ recycled

The nitric oxide (NO) is recycled in Step 2.

- The largest percentage of nitric acid is used to synthesize ammonium nitrate, a water soluble fertiliser.
- Large quantities are also used to make plastics, drugs, and explosives such as trinitrotoluene (TNT) and nitroglycerine.

3. *Sulphuric Acid (H_2SO_4)*

- Sulphuric acid is the world's most important industrial chemical, and the rate of consumption of sulphuric acid is a measure of a country's industrialization.
- Sulphuric acid is prepared industrially by the contact process, using four steps:

Step 1: Burning sulphur in air:

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

Step 2: Converting SO_2 to SO_3

$$2SO_2(g) + O_2(g) \xrightarrow{V2\ O5\ catalyst\ ,\ 400°C} 2SO_3(g)$$

- The conversion of SO_2 to SO_3 is slow, but it is increased by heating the reaction mixture to 400_oC in the presence of V_2O_5 catalyst. Because the SO_2 and O_2 molecules react on contact with the surface of V_2O_5, the process is called Contact process.

Step 3: Passing SO_3 into concentrated H_2SO_4:

$SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$, Pyrosulphuric acid (oleum or fuming sulphuric acid)

Step 4: Addition of water to pyrosulphuric acid

$$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(aq)$$

- ***Uses of sulphuric acid***
- Sulphuric acid is used in the production of fertilisers, detergents, plastics and paints. It is used in the production of a number of explosives. Sulphuric acid is an oxidizing agent and a good dehydrating agent. It is often used to dry neutral and acidic gases such as nitrogen, oxygen, and carbon dioxide. It is also used as electrolyte in car batteries. It is also used as a catalyst in the manufacture of many chemicals.

4. *Diammonium monohydrogen phosphate (DAP), $(NH_4)_2HPO_4$*

- Diammonium monohydrogen phosphate (DAP) is a white crystalline compound that is completely soluble in water.
- It can be produced when ammonia reacts with phosphoric acid by the following two steps:

Step 1: Anhydrous ammonia reacts with phosphoric acid to form monoammonium dihydrogen phosphate and diammonium monohydrogen phosphate

$$3NH_3(g) + 2H_3PO_4(l) \rightarrow NH_4H_2PO_4(s) + (NH_4)_2HPO_4(s)$$

Step 2: Recycling monoammonium dihydrogen phosphate for further reaction with anhydrous ammonia yields DAP:

$$NH_4H_2PO_4(s) + NH_3(g) \rightarrow (NH_4)_2HPO_4(s)$$

- DAP is used as a fertiliser. DAP has the advantage of having both nitrogen and phosphorus, which are essential for plant growth.

- DAP can be used as fire retardant. It lowers the combustion temperature of the material, decreases weight-loss rates, and causes an increase in the production of residue or char.

- DAP is also used as a yeast nutrient in wine making and beer brewing.

Multiple Choice Questions

1. Which of the following statements is incorrect?
   a. all the materials on earth are made of the 92 naturally-occurring elements.
   b. all minerals are ores.
   c. most metals are solids at 25°C.
   d. None of the above.
2. The four most abundant elements, in increasing order of abundance, are:
   a. silicon, oxygen, iron and aluminium
   b. oxygen, silicon, aluminium, and iron
   c. iron, aluminium, silicon, and oxygen
   d. aluminium, iron, silicon, and oxygen
3. Which of the following elements does not exist in native state in nature?
   a. platinium
   b. gold
   c. silver
   d. sodium
4. The element that is a liquid at 25°C is:
   a. oxygen
   b. bromine
   c. chlorine
   d. nitrogen

5. Which of the following ores contains carbonates?

a. dolomite
c. epsomite
b. bauxite
d. cassiterite

6. Which of the following processes fix atmospheric carbon dioxide?

a. Photosynthesis
c. Burning of fossil fuels
b. Respiration
d. b and c

7. Which one of the following statements is incorrect about the nitrogen cycle?

a. nitrogen is the most abundant gas in the atmosphere
b. atmospheric nitrogen is less reactive
c. the process of releasing nitrogen gas back into the atmosphere is called nitrogen fixation
d. lightning converts atmospheric nitrogen into nitrogen oxides

8. What makes the phosphorus cycle different from the nitrogen and carbon cycles?

a. The phosphorus cycle is very slow

b. Phosphorus cannot be found in the atmosphere in the gaseous state

c. It is not an essential element for plants and animals

d. a and b

9. If a mineral is denser than its gangue, the appropriate method of separation is:

a. magnetic separation

b. froth floatation

c. amalgamation

d. gravity separation

10. Metals that have low melting points, such as mercury, magnesium, and zinc can be purified from other metals that have high melting points by:

a. zone refining

b. electrolysis

c. distillation

d. leaching

Polymers

- Polymers are *macro (large) molecules* made from smaller repeating units called monomers. Hence, monomers are the building blocks of polymers.
- A polymer might be made from identical monomers or different types of monomers.

➢ Homopolymers are made from only one type of monomer. For example, polyethylene is synthesized by the polymerization of one type monomer, ethene (ethylene).