Unit – 5
SOME ELEMENTS IN NATURE AND INDUSTRY

✓ *Main contents: 2*

5.1. Some Elements in Nature and Recycling

5.2. Some Elements in Industry

5.1. SOME ELEMENTS IN NATURE AND RECYCLING

Startup activity (Text book page 221)

There are more than 103 elements known at present. 92 elements occur in nature.

- A solid material that occurs naturally in the earth's crust is called ***mineral***.
- A mineral from which an element can be extracted easily and economically is called ***ore***. (Refer to Table 5.2, page 224 for main types of minerals).

5.1.1. Occurrence of Elements

Activity 5.1 (Text book page 222)

The most abundant element in the earth's crust is oxygen (45.5 %) followed by silicon (27.2 %). Aluminum (8.3 %) and iron (6.2 %) are the first and second most abundant metals. In the atmosphere, nitrogen takes the highest percentage (78%) followed by oxygen (21%). Hydrogen is the most abundant gas in the universe.

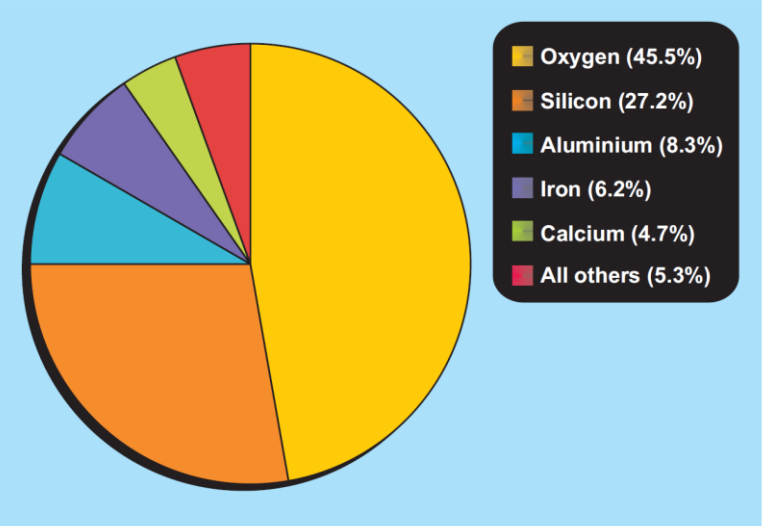


Figure 5.1 Abundance of elements in the Earth's crust.

Exercise 5.1 (Text book page 224)

5.1.2. The Recycling of Elements in Nature

Activity 5.2 (Text book page 225) and Activity 5.3 (Text book page 227)

The elements carbon, nitrogen and phosphorus are known for their recycling in nature. Here are the key processes taking place during this cycle.

Cycle	Enters into the living world	Returns back to its origin
Carbon cycle	. Photosynthesis by plants use atmospheric CO_2 . Animals (including humans) eat plants and other animals that have eaten plants.	. Respiration by both animals and plants releases CO_2 . Decomposition of organic matter . Combustion of fossil fuels
Nitrogen cycle	. Nitrogen fixation: Lightening converts N_2 to NO_2; bacteria in the nodules of leguminous plants convert N_2 to NO_3^-, Haber process converts N_2 to NH_3 . Animals eat plants and convert plant proteins into animal proteins	. Excretion by animals (as urea and uric acid) . Decomposition of dead animals and plants by bacteria releases ammonia . De nitrification (by anaerobic bacteria) converts NH_3 and NH_4^+ salts back to atmospheric N_2
Phosphorus cycle (slow process)	. Phosphate rocks release phosphate salts by rain fall, weathering, etc. and roots of plants absorb the soluble phosphates . Animals eat plants & other animals that eat plants	. Decomposition of dead animals & plants return phosphorus into soil and water

Exercise 5.2 (Text book page 227), Exercise 5.3 (Text book page 229) and Activity 5.4 (Text book page 230).

5.2. Some Elements in Industry

Activity 5.4 (Text book page 232)

5.2.1. Metallurgy

Metallurgy: is the science and technology of extracting metals from their natural sources and preparing them for practical use.

- The principal steps carried out include concentrating the ore (beneficiation), pre – treatment, extracting the metal and refining (purifying) the crude metal.

1. Concentrating the ore

This is done to increase the fraction of metal – bearing ore by eliminating most of the accompanying rock and soil called ***gangue***. The step may involve:

(i) Gravity separation: (for high density substances such as gold)

(ii) Magnetic separation: for ferromagnetic minerals such as Fe_3O_4 (magnetite) using strong electromagnets.

(iii) Froth floatation: which involves adding ore – bearing material into a mixture of water, oil and a detergent. The ore floats in a form of froth or foam while the gangue settles down.
This is particularly used for sulfide ores.

(iv) Amalgamation: involves forming an amalgam with mercury. Gold and silver are concentrated by this method.

(v) Leaching: a chemical process used to dissolve only the target substance, leaving the impurities un–dissolved.

Activity 5.5 and Exercise 5.5 (Text book page 234)

2. Pre-treatment

This step converts an ore to a form that is easy to reduce. The conversion is mainly to an oxide for chemical reduction and to a chloride for electrolytic reduction. Sulfide ores are converted to oxides (by roasting) for chemical reduction; magnesium ion from sea water is precipitated as a hydroxide (Dow process) and then to chloride for electrolysis, etc.

3. Extracting the metal

Very reactive metals (Groups IA and IIA, and aluminum) are extracted by electrolytic reduction of the chloride (oxide for aluminum). Other metals are reduced chemically by using appropriate reducing agents, such as a more reactive metal, hydrogen, carbon and carbon monoxide.

4. Refining of metals

This step is used for impure metals that are obtained by chemical reduction only. The process may involve distillation (for low melting metals), electrolysis or zone – refining.

Activity 5.6 (Text book page 237) and Exercise 5.6 (Text book page 238)

5.2.2. *Extraction, Properties and Uses of Some Selected Metals*

Activity 5.7 (Text book page 238)

Metal	Ore	Metallurgy	Properties & Uses
Sodium	NaCl (Halite)	Electrolysis of a molten mixture of 40 % NaCl and 60 % $CaCl_2$ in a Down cell. working temperature decreases from 800 to 600^{0}C because of $CaCl_2$	. A soft, very reactive metal which must be kept under paraffin; used to make Na / Pb alloy needed to produce tetra ethyl lead (TEL) (anti – knock additive); coolant for nuclear reactors in liquid state
Tin	SnO_2 (cassiterite)	Chemical reduction by coke at high temperature: SnO_2 (s) + 2C (s) → Sn (ℓ) + 2CO (g)	. Reacts with steam producing SnO_2 & H_2 . Reacts with dilute and conc. acids and halogens . Used for electroplating of iron, to make tin plate, and alloys (bronze, solder, etc)
Lead	PbS (galena)	Concentrating the ore by *froth floatation*, then roasting to an oxide followed by reduction using carbon	. Forms protective oxide film hence inert towards H_2O . Dissolves in dilute HCl and HNO_3 but not in H_2SO_4 . Reacts with alkalis to form plumbates e.g. $Na_2Pb(OH)_6$, hence lead is amphoteric . Used to make lead storage battery, paints and pigments
Zinc	ZnS (Zinc blende)	The ore is concentrated by froth floatation and then roasted to ZnO, finally reduced to zinc by CO (g)	. Dissolves in dilute HCl as well as in NaOH solution, hence it is amphoteric . Used for galvanizing iron, to make brass, as an electrode in batteries, for making white pigment in ZnO form
Chromium	$FeCr_2O_4$ (Chromite)	Reduction in an electric furnace $FeCr_2O_4 + 4C$ → Fe + 2Cr + 4CO, or Converting the ore into Cr_2O_3 then reduction by aluminum $Cr_2O_3 + 2$ Al → 2 Cr + Al_2O_3	. Active metal but forms protective oxide in air, in conc. HNO_3 & other oxidizing agents . Dissolves in HCl and dilute H_2SO_4 to form blue Cr^{2+} ion . Used to make alloy with nickel (nichrome) and iron (ferrochrome), for electroplating, an oxidizing agent as $Cr_2O_7^{2-}$ & CrO_3
Silicon (metalloid)	SiO_2 (Silica or quartz)	Heating silica with coke at about 3000 ^{0}C in an electric furnace, purified by reducing its chloride with magnesium and zone refining	. Silica is resistant to attack by all acids except HF. It forms SiF_4 with HF, a chemical process used in the *etching of glass* . Used to construct transistors & micro processors . Quartz is used to control the frequency of radio & TV transmission . Silicon polymers are used in making lubricants, lipstick, car polish, etc.

Exercises

- ***5.7 (Text book page 240), 5.8 (Text book page 242), 5.9 (Text book page 243), 5.10 (Text book page 244), 5.11 (Text book page 246), 5.12 (Text book page 248-249) and 5.13 (Text book page 250).***

Activities

- ***5.8 (Text book page 242), 5.9 (Text book page 250) and 5.10 (Text book page 242)***

Experiment 5.1

- ***Text book page 246***

5.2.3. Industrial Chemicals of Some Nonmetals

Activities

- ***5.11 (Text book page 251-252) and 5.12 (Text book page 254)***

Chemical	Industrial Preparation	Properties	Uses
NH_3 (Ammonia)	*Haber process* (Nitrogen fixation) N_2 (g) + $3H_2$ (g) ⇆ $2NH_3$ (g); ΔH = –92 kJ, using iron catalyst at 380 – 450 ^{0}C and 200 atm. (high pressure)	Colorless gas with pungent odor, liquid at –33 ^{0}C, has high heat of vaporization	To make fertilizers, HNO_3, explosives (TNT and nitro glycerin
H_2SO_4 (Sulfuric acid)	*Contact process* ⇨ (i) S (s) + O_2 → SO_2 (g) (ii) $2SO_2$ (g) + O_2 (g) ⇆ $2SO_3$ (g) at 400 ^{0}C using V_2O_5 catalyst (contact on the catalyst) (iii) SO_3 (g) + H_2SO_4 (aq) → $H_2S_2O_7$ (oleum), this can be diluted to required concentration	m. p. = 10.5 ^{0}C; b. p. = 338 ^{0}C $\Delta H_{sol.}$ = –880 kJ/mol, Oxidizing agent when concentrated or hot, good dehydrating agent for gases, an electrolyte	For the production of fertilizers, detergents, plastics & paints (most important industrial chemical)
HNO_3 (Nitric acid)	*Ostwald process*: Combustion of NH_3 using Pt catalyst at 850 ^{0}C & 5.0 atm $4NH_3 + 5O_2$ ⇆ $4\mathbf{NO} + 6H_2O$ $2\mathbf{NO} + O_2 \rightarrow 2NO_2$ ⇨ + H_2O → HNO_3	Colorless liquid, but turns brown on exposure to sunlight, strong oxidizing agent	To synthesize NH_4NO_3, To make plastics, drugs and explosives

Di ammonium hydrogen phosphate (DAP) $(NH_4)2HPO_4$: is a white crystalline, soluble fertilizer.

- ✓ It is prepared from ammonia and phosphoric acid as follows.

$$2NH_3\ (g) + 2H_3PO4\ (l) \rightarrow (NH_4)_2HPO_4\ (s) + NH_4H_2PO_4\ (recycled)$$

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

Uses: In addition to a fertilizer, DAP can be used as fire retardant, a yeast nutrient in wine making and brewing beer.

Exercises

- ✓ ***5.14 (Text book page 253)***
- ✓ ***5.15 (Text book page 254)***
- ✓ ***5.16 (Text book page 255)***

❖ *REVIEW EXERCISE FOR UNIT 5 (Text book page 258-261)*