

U-3: Some Important Non- metals

- **Non-metals** can be obtained naturally in the form of monoatomic, diatomic and polyatomic forms. For example: - Oxygen exist in diatomic form & Carbon in polyatomic form.
- Air is composed of mainly Nitrogen & Oxygen and some Argon & CO₂. The components of all these species are a non-metal. Oxygen is the most important components of air used for respiration.
- The key components of food items are made of non-metals.
- Some non-metals and their uses:-
 - ✓ **Oxygen** is used for breathing.
 - ✓ **Chlorine** is used for Purifying water.
 - ✓ **Phosphorous** is used in crackers.
 - ✓ **Graphite** is used as a good conductor of electricity, in making leads & electrodes.
 - ✓ **Nitrogen** is used by plants.
 - ✓ **Carbon** is used as a fuel and its compounds are used for various purposes which are primarily hydrocarbons and also present in our body.
 - ✓ **Bromine** is used in dyes and plastics.
- ❖ In general non-metals are used as food, beverage and clothing. They are also used in the manufacture of fertilizers, medicines, fabrics, plastics, building materials and other significant chemical substance.
- Where do plants get the carbohydrates, proteins, fats and vitamin they contain?
 - ⇒ The plant themselves make these nutrients. The process by which a plant makes sugar is called **photosynthesis**. To make sugar the plant uses water & carbon dioxide as raw materials and light energy from the sun. The process of photosynthesis takes place mainly in the green leaves of plants.
- Do you know the chemical process behind this?



⇒ **Carbon dioxide + Water + Light Energy**
Sugar + Oxygen

-Water is absorbed by the roots of the plants. The water moves along the stem and into the leaf along tubes called veins.

✚ During Photosynthesis water is made to react with carbon dioxide. -----Sugar is produced as food and oxygen as waste product.

➤ What are the ways in which trees support human life?

-Not only plants support humans, they support animals too. If there weren't any trees giving off oxygen, there would be no humans and if there is no humans no carbon dioxide for the plants.

-So having lots of plants around is good for people & animals – plants & trees make the oxygen that we need to breathe.

-Without trees, there would be no life on Earth at least, not one habitable by humans. It is as simple as that: **“NO TREES, NO HUMANS. It is worth repeating!!! NO TREES, NO HUMANS”**

3.1 General properties of non-metals

-All non-metals except hydrogen (**H**: *the most common element in the universe. it is estimated that about three out of every four atoms in the universe are hydrogen. B/c it consists of just 1proton & 1electron*–**Is in a class by itself in the periodic table**) are found on the right hand side of the periodic table (p-block). *Only 18 elements of the periodic table are classified as **non-metals**.

❖ **General properties of most non-metals include:-**

✓ They exist in the 3 states of matter

✚ H₂, O₂, N₂, F₂, Cl₂,

-Noble gases (He, Ne, Ar, Kr, Xe, Rn

--are

Gases

✚ S, C, P & I₂

are Solids



✚ **Br₂** is the only liquid non-metal at room T°.

✓ They are **poor thermal & electrical** conductor except Carbon in the form of **Graphite** (**The only non-metallic conductor**).

✓ They are non-malleable, non-ductile & not sonorous.

✓ They are generally non-lustrous & dull.

NB: Iodine & diamond are **the only lustrous non-metal**.

✓ They have low B.P. & M.P. except Carbon (graphite).

✓ They have low densities.

✓ They are **softer** than metals except diamond.

✓ They *gain electrons* and form negative ions.

✓ They form acidic and neutral oxides.

✓ They show **Allotropy**.

3.2 Carbon©: Occurrences & uses of C

- ©*The basis of all life forms on the earth*). Carbon compounds are the basis of all organic compounds.

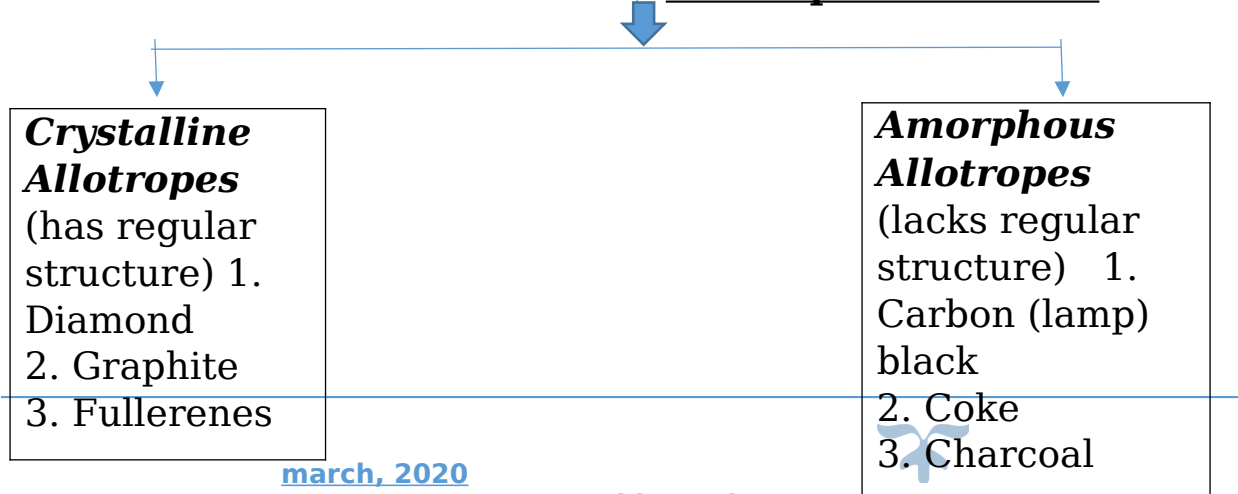
- Carbon occurs both in elemental and combined form as CaCO₃, CaCO₃.MgCO₃, FeCO₃. Carbon is present as carbon dioxide in the atmosphere and dissolved in all natural water.

-It constitutes about 0.03% of the earth's crust.

-Element carbon exists in nature mainly in three allotropic forms as diamond, graphite & fullerenes. **What are Allotropes?**

Allotropy is the existence of an element in more than one form, having the same chemical properties but different physical properties. The various forms of an element are called **allotropes**.

Allotropes of Carbon



❖ **Physical Property of Diamond & Graphite includes:-**

1. Diamond

- Has rigid structure (Tetrahedral shape: each C atom is bonded to four other C atom) _
- Colorless transparent & brilliant
- Acts as an excellent electrical insulator
- **Hardest substance on**

2. Graphite

- Has layered structure (Hexagonal shape: (each C atom is bonded to three other C atom)
- Black opaque & metallic to earthy looking
- **A good conductor of electricity**
- **Quit Soft** known materials

NB: The hardness of minerals is compared using the **Mohs Hardness Scale**, a relative scale numbered 1 (softest) to 10 (hardest). Graphite has a hardness of 1 to 2 & Diamonds have a hardness of 10.

❖ **The uses of diamond & graphite related to their property includes: -**

***Diamond**

***Graphite**

Jewellery -Attractive appearance

Cutting & grinding -Very hard

Slippery

Heat sinks -Good thermal conductors
motors & in dry cell

Pencils -Softness

Graphite grease -

Electrodes -In

3.3 Nitrogen (N₂)

➤ **Occurrence**

- Nitrogen occurs in nature in the elemental form. It also



exists in the form of compounds as sodium nitrate (Chile *salt peter*, NaNO_3) & potassium nitrate (*Salt peter*, KNO_3).

-In the elemental state, it exists as a diatomic molecule, N_2 , in atmospheric air. It constitutes about 80% by volume of the atmosphere **or** about $\frac{4}{5}$ ths of the atmospheric air is free nitrogen.

(So, **N_2** is the most abundant element in the atmospheric air).

-It is also found in DNA molecules and proteins of all living things.

NB: The

Bell jar experiment: a practical method of estimating the nitrogen content of air by removing oxygen and CO_2 with limitations of accuracy of this method as it does not remove **Argon** that exists in air either physically or chemically.

➤ **Uses of Nitrogen:**

-It is an essential element to living organisms to make proteins. Animals get N_2 through food.

-What about Plants? Did you know about NPK?

-NPK (Nitrogen, phosphorus & potassium) are the major elements (macronutrients) that plants should get through fertilizers. Among these, nitrogen is the most important one.

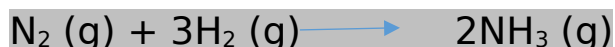
Why the N_2 molecule first must be “fixed”?

NB: The chief components of dry air are N_2 , O_2 & Ar. Nitrogen must be fixed for use by plants, animals and humans.

-When substances are heated in air they react with O_2 far more than N_2 , b/c nitrogen is much less reactive than oxygen. The importance of nitrogen for plant growth is probably the reason why most fertilizers are composed of N_2 . Most plants cannot absorb atmospheric nitrogen, **b/c** atmospheric nitrogen is toxic to plants. Plants absorb N_2 in the form of nitrogenous compounds like nitrates & nitrogen cycle, (ammonium compounds, urea) in soil water.

-Nitrogen is mainly used to produce Ammonia by reacting it with Hydrogen by the process called **Haber process**.





Research: *The role of nitrogen-fixing and denitrifying bacteria in the root nodules of leguminous plants and in the soil.*

- Plants get only a very small amount of nitrogen through microorganisms, whereas the decomposition and decay of dead plants & animals provide large amount of nitrogen.

-Bacteria are the microorganisms that are able to convert atmospheric nitrogen.

- ❖ Generally, **Nitrogen** is used in food packaging to prevent oxidation. Liquid nitrogen is used as a refrigerant to preserve bulls 'semen and blood.
- ❖ Its major use is in the production of ammonia used in the manufacture of fertilizers and also for the production of HNO_3 : **Ostwald Process**

3.4 Phosphorous

➤ Occurrence

-Phosphorous (P) is a relatively abundant element, ranking 12th in the earth's crust. P is a reactive elements which does not occur freely in nature (never found free in nature). It exists only in the combined state. Which are largely phosphates. For this reason P is usually kept under water. *The principal source of P is *ground rock phosphate* mainly in the form of $\text{Ca}_3 (\text{PO}_4)_2$. It is also found in teeth, bones and DNA. *Phosphorous reacts with oxygen and chlorine.

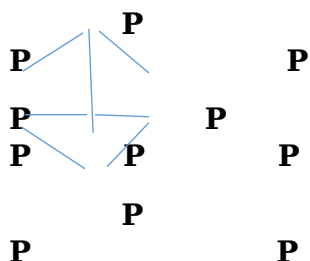
-P exists in two common allotropic forms known as – White and **red** phosphorous.

1) **White Phosphorus** is a **very poisonous**, white waxy-looking substance. Its density is 1.8g/mL. It consists of individual tetra-atomic (P_4) molecules and is an **unstable** form of phosphorus. It is soluble in CS_2 , C_6H_6 & Ether.

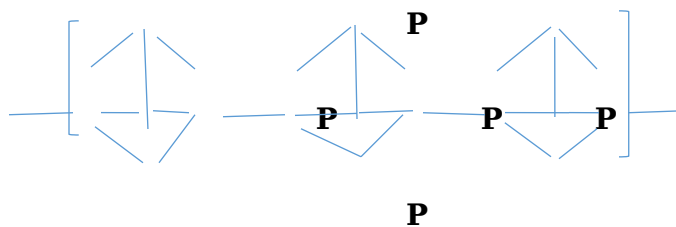


-Reacts with chlorine and forms PCl_3 & PCl_5 . *B/c of its reactivity with oxygen, white Phosphorus is stored under water. Catches fire in the air and glows in the dark.

2) **Red Phosphorous** is the **stable** form of phosphorus. It is denser (2.16g/mL) and is much less reactive than white phosphorous at normal T° . Does not glow in the dark and it is **not kept under water**. It consists of P_4 molecules linked together to form a polymer (large molecule).



White Phosphorous
Phosphorous



Red

NB. When white phosphorous is heated to about 300°C in the absence of air, it is transformed to red phosphorous.

❖ Uses of phosphorous

-Elemental phosphorous is used in the formation of phosphoric acid, in making incendiary bombs for military applications, in making matches, in making alloys such as phosphor bronze an alloy made of P, Cu & Sn. Phosphorous forms two impotent oxides (P_4O_6 & P_4O_{10} , are used for drying gases and for removing water from solvents).

3.5 Oxygen

❖ Occurrence

-**Oxygen** is the **most abundant element on earth**. It constitutes about 46.6% by weight of the earth's crust in the form of compounds such as oxides, silicates, carbonates, phosphates etc. It exists in nature in the elemental state in atmospheric air



constituting about 20% by volume **or** Oxygen forms around 1/5ths of the air and it is the active components of air and the major component water, that it can be obtained by **electrolysis** of water. **Electrolysis** is the process by which electrical energy is used to produce a chemical change.



- Oxygen forms compounds with all the elements accepts the lighter noble gases (He, Ne & Ar) and noble metals such as Au, Ag, & Pt under normal conditions.

- **Oxygen** has two allotropes, known as **O₂ and O₃**. Ozone (O₃) in the stratosphere protects living organisms by absorbing ultraviolet radiation (UV).

✚ Ozone, O₃, is less stable than O₂.

❖ Uses of oxygen

-oxygen is essential for combustion and for respiration (life giving), for cutting and welding and as rocket fuel.

-Ozone is used for pathogenic germs, treatment of cancer, AIDS, gangrene & many other illness.

***Other uses of ozone includes:-**Wastewater treatment, Bleaching (paper & pulp), Bottled water/ Beverage industry, Drinking water (pre / post treatment), Food processing (sterilization/Fruit washing), Textile processes (Dye removal) and Air pollution control (odor control).

3.6 Sulphur(S)

Occurrence

- Sulphur occurs in nature as a free element and in the form of compounds such as Sulphides & Sulphates. Elemental Sulphur exists in molecular form as S₈. The major source of Sulphur is *underground deposit of elemental Sulphur* and extracted by the **Frasch process**.



- It is found in many minerals & and ores, such as Iron pyrite (FeS_2), galena (PbS), cinnabar (HgS), Sphalerite (ZnS), Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), Epsom salt (MgSO_4) & in mineral springs and other waters. Sulphur occurs with coal, petroleum & natural gas. Sulphur is a component of all living cells.

-China, Canada and Russia are the main producers of Sulphur in the world. Sulphur is obtained in North –East Ethiopia (Afar regional state) in Dallol located in the Danakil depression.

-Sulphur sometimes occurs in bright yellow layers on the top of the earth. It sharp, offensive odor. When it burns, it gives off a strong, suffocating smell. The odor is like that produced when a match is struck.

-Sulphur exists in **three allotropic** forms known as ***Rhombic Sulphur, Monoclinic Sulphur and plastic Sulphur.***

-**Rhombic** Sulphur is the **most stable** form of Sulphur consisting of S_8 molecules and is a yellow translucent crystal. If rhombic Sulphur is heated until it melts and then cooled, it is converted to **monoclinic** Sulphur. Monoclinic Sulphur is amber crystal.

- When Sulphur is heated to about 200°C and then poured into cold water, a **red-brown** material, called **Plastic Sulphur** is obtained.

-The advantages of recycling elemental Sulphur includes: - Reducing demand on resources and also helps in reducing atmospheric pollution resulting from Sulphur dioxide.

❖ Uses of Sulphur

- ***The uses of elemental Sulphur includes:*** - in Preparation of match, preparation of Sulphur dioxide (*fumigant-which is used as insecticide*), Vulcanization of natural rubber, (**Vulcanization** *is the process of hardening rubber by heating natural rubber in the presence of Sulphur*), Preparation of Sulphuric acid &



Preparation of gun powder. In daily household products such as detergents, paints, paper and carpets.

- It is also used in many *life-saving* medicines.
- Sulphur is essential to life. It is a minor constituent of fats, body fluids and skeletal minerals.

3.7 Uses of common compounds of non-metals

- **Calcium disulphide (CaS_2)** – A flammable, volatile liquid that is a good solvent for Sulphur, bromine, iodine, fats and oils.
- CaS_2 is an important *intermediate* in the manufacture of rayon & cellphone.
- **Carbon tetrachloride (CCl_4)** – Extensively used as a solvent, dry-cleaning agent, and *fire extinguisher*. CCl_4 is declining in importance b/c it causes liver & kidney damage and it is suspected *human carcinogen*.
- **Calcium Sulphate hydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)** – Is known as gypsum, is the primary material used for wall board in the construction industry. As the hydrate $2\text{CaSO}_4 \cdot \text{H}_2\text{O}$, Calcium Sulphate is known as *plaster of Paris*, a substance used to make casts and molds.
- **Aluminum Sulphate ($\text{Al}(\text{SO}_4)_3$)** – Used in water treatment, purifying the water by removing suspended matter.
- **Calcium carbide (CaC_2)** – A convenient solid reagent that can be transported & then generate the gaseous fuel acetylene (C_2H_2) simply by adding water. **NB: Acetylene (C_2H_2)** is used in oxyacetylene flame for welding.
- **Carbon dioxide (CO_2)** – Fire extinguishers (especially for electrical fires), carbonated drinks (used to carbonate soft drinks, soda water, beer & wine).
- **Sodium carbonate (NaCO_3)** – **Solvay process** (NaCl , CaCO_3 , & **Ammonia**): Washing soda, making glass (when



combined with silica & CaCO_3 & heated to high T° , then cooled rapidly, glass is produced. known as *Soda lime glass*).

- **Nitric acid (HNO_3)** - **Ostwald Process**: Fertilizers (NH_4NO_3), explosives (i.e. TNT...)
- **Phosphoric acid (H_3PO_4)** - Food processing(a common additive for bottled solutions like soft drinks) , chemical reagent
- **Calcium phosphate (CaPO_4)** - used in baking as a Raising agent, in the production of phosphoric acid & fertilizers.
- **Sulphur dioxide (SO_2)** - *Bleaching agent* in the manufacture of paper products, oil, sugar & starch), *preparation of Sulphuric acid*, as a **fumigant** (a chemical that produces fumes used to disinfect or purify an area).
- **Sulphuric acid (H_2SO_4)** - **Contact process**(S, Air & H_2O): Chemical reagent in most industries.

-The End of the Chapter-

