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## **PROPERTIES OF HYDROGEN, OXYGEN, NITROGEN AND CARBON**

### **Hydrogen**

- In the periodic table, hydrogen is the lightest element, its atomic weight is merely 1.008.
- The symbol of hydrogen is 'H' and the atomic number is '1.'
- In the early 16<sup>th</sup> century, hydrogen gas was first artificially produced by the reaction of acids and metals.
- Henry Cavendish first recognized the hydrogen gas as a discrete substance during the period of 1766-81, as it produces water when it is burned.

### **Salient Features of Hydrogen**

- In their plasma state, the non-remnant stars are primarily composed of hydrogen.
- At standard temperature and pressure, hydrogen appears colourless, tasteless, odourless, non-metallic, non-toxic, and highly combustible diatomic gas.
- The molecular formula of hydrogen is H<sub>2</sub>.
- On the earth, hydrogen exists in molecular forms, for example, water or other organic compounds.
- Hydrogen also plays an important role in acid–base reactions.
- Hydrogen gas is highly flammable in the air.
- Pure hydrogen-oxygen flames radiate ultraviolet light; further, with high oxygen mix are nearly invisible to the naked eye.
- Hydrogen can react with almost every oxidizing element.
- At room temperature, Hydrogen normally reacts spontaneously and viciously with chlorine and fluorine and forms the corresponding hydrogen halides.

### **Occurrence of Hydrogen**

- Consisting roughly about 75 percent of all baryonic mass, hydrogen is the most abundantly found chemical subsistence in the universe.
- Throughout the universe, hydrogen is typically found in the atomic and plasma states; however, the properties quite different from those of the molecular hydrogen.
- On the earth, hydrogen exists as the diatomic gas, i.e. H<sub>2</sub>.
- Because of having light weight, hydrogen easily escapes from the earth's atmosphere.
- Hydrogen is the third most abundant element found on the Earth's surface, but largely found in form of hydrocarbons and water.

### **Compounds of Hydrogen**

Following are the major compounds of hydrogen –

- Water - H<sub>2</sub>O
- Ammonia - NH<sub>3</sub>
- Hydrogen chloride – HCl

- Hydrogen fluoride – HF
- Hydrogen sulfide -  $\text{H}_2\text{S}$
- Methane -  $\text{CH}_4$
- Hydroxide -  $\text{OH}^-$
- Hydrogen bromide – HBr
- Hydrogen iodide – HI
- Hydrogen cyanide – HCN
- Phosphine -  $\text{PH}_3$
- Hydrogen selenide -  $\text{H}_2\text{Se}$
- Methanol -  $\text{CH}_3\text{OH}$
- Lithium hydride – LiH
- Bicarbonate -  $\text{HCO}_3^-$
- Hydrogen telluride -  $\text{H}_2\text{Te}$
- Liquid hydrogen -  $\text{H}_2$
- Cyanide – CN
- Calcium hydride -  $\text{CaH}_2$
- Heavy water -  $\text{D}_2\text{O}$
- Diborane -  $\text{B}_2\text{H}_6$
- Sodium hydride – NaH
- Potassium hydride - KH

### Uses of Hydrogen

- The largest amount of  $\text{H}_2$  is used in the processing of fossil fuels as well as in the production of ammonia.
- Hydrogen ( $\text{H}_2$ ) is extensively used in the petroleum and chemical industries.
- $\text{H}_2$  is typically used as a hydrogenating agent, especially in increasing the saturation level of unsaturated fats and oils.
- $\text{H}_2$  is also used as a shielding gas in welding procedures, such as atomic hydrogen welding, etc.

### Oxygen

- Oxygen is the member of group 16 on the periodic table; however, most of the time, it is treated differently from its group.
- The symbol of oxygen is 'O' and atomic number is '8.'
- Oxygen has about nine allotropes and the most common allotrope is diatomic oxygen (i.e.  $\text{O}_2$ ). Other important allotrope is Ozone i.e.  $\text{O}_3$ .
- Oxygen, first time, was noticed by Swedish pharmacist Carl Wilhelm Scheele.

### Salient Features of Oxygen

- Oxygen is characteristically categorized as the member of "chalcogen" group.
- The word "chalcogen" is derived from a Greek word "khalkós," which means "copper" and the Latin-Greek word "Genēs," which means born or produced.

- Oxygen is a highly reactive gas (or nonmetallic element); hence, it is an oxidizing agent that readily forms oxides with most of the elements and compounds.
- Oxygen has six valence electrons.
- The melting point of oxygen is  $-218.8^{\circ}\text{C}$  and the boiling point is  $-183^{\circ}\text{C}$ .

### Occurrence of Oxygen

- With about 20.8 percent share (in total earth's atmospheric constituents), oxygen is the second ranked element of the earth's atmosphere.
- Oxygen occurs almost in sphere of the earth namely atmosphere, hydrosphere, and lithosphere.
- During the photosynthesis process, free oxygen is produced by all green plants.
- Oxygen occurs as constituent copper ores.
- A human body contains about 65 percent oxygen.
- By mass, almost half of the earth's crust is composed of oxygen (i.e., its oxides).
- By mass, oxygen is the third-most abundant element that found in the universe; the first and second are hydrogen and helium accordingly.
- Oxygen ( $\text{O}_2$ ) is a colourless and odourless diatomic gas.
- Oxygen dissolves in water very easily; however, the solubility of oxygen in the water is temperature-dependent.

### Compounds of Oxygen

Following are the major compounds of oxygen –

- Oxide
- Peroxide
- Carbon dioxide -  $\text{CO}_2$
- Hydroxide -  $\text{OH}^-$
- Ozone -  $\text{O}_3$
- Mercury (II) oxide –  $\text{HgO}$
- Chlorate -  $\text{ClO}_3$
- Aluminum oxide -  $\text{Al}_2\text{O}_3$
- Carbon monoxide –  $\text{CO}$
- Hypochlorite -  $\text{ClO}^-$
- Silicon dioxide -  $\text{SiO}_2$
- Hypofluorous acid –  $\text{HOF}$
- Sodium peroxide -  $\text{Na}_2\text{O}_2$
- Potassium chlorate -  $\text{KClO}_3$
- Oxygen difluoride -  $\text{OF}_2$

- Sodium oxide -  $\text{Na}_2\text{O}$

## Uses of Oxygen

- Oxygen ( $\text{O}_2$ ) is the most essential requirements for the respiration, without it, life cannot be imagined.
- Oxygen is used in medicine.
- Oxygen therapy is typically used to treat some diseases, such as, emphysema, pneumonia, some heart disorders, etc.
- Some of the underwater activities, such as scuba diving, submarines, etc. also use artificial oxygen.
- Aircrafts, mountaineers, etc. also use artificial oxygen.
- Oxygen is also used in some of the industries, e.g. smelting of iron ore into steel – in this process, about 55% of oxygen is used.

## Nitrogen

- Nitrogen is a chemical element of group of 15 of the periodic table; among all the elements of group 15, it is the lightest element.
- The symbol of nitrogen is '**N**' and atomic number is **7**.
- In 1772, Scottish physician Daniel Rutherford, first discovered and isolated carbon.
- However, the name 'nitrogen' was first given by Jean-Antoine-Claude Chaptal in 1790.

## Salient Features of Nitrogen

- Nitrogen has two stable isotopes namely  $^{14}\text{N}$  and  $^{15}\text{N}$ .
- Free nitrogen atoms normally easily react with most of the elements and form nitrides.
- The molecules of  $\text{N}_2$  is colorless, odorless, tasteless, and diamagnetic gas at standard conditions.
- The melting point of  $\text{N}_2$  is  $-210^\circ\text{C}$  and the boiling point is  $-196^\circ\text{C}$ .
- Nitrogen compounds repetitively interchange between the atmosphere and living organisms, making a nitrogen cycle.

## Occurrence of Nitrogen

- Nitrogen is most abundantly found element on the earth, as it constitutes about 78.1% of the entire volume of the earth's atmosphere.
- Nitrogen gas, which is an industrial gas, largely produced by the fractional distillation of liquid air.

## Compounds of Nitrogen

Following are the major compounds of Nitrogen –

- Ammonium -  $\text{NH}_4^+$
- Ammonia -  $\text{NH}_3$
- Nitric acid -  $\text{HNO}_3$
- Nitrite -  $\text{NO}_2^-$
- Nitrogen dioxide -  $\text{NO}_2$

- Dinitrogen pentoxide -  $\text{N}_2\text{O}_5$
- Hydrazine -  $\text{N}_2\text{H}_4$
- Dinitrogen -  $\text{N}_2$
- Cyanide –  $\text{CN}$
- Ammonium nitrate -  $(\text{NH}_4)(\text{NO}_3)$
- Nitrogen trichloride -  $\text{NCl}_3$
- Nitrogen trifluoride -  $\text{NF}_3$
- Nitrogen triiodide -  $\text{NI}_3$
- Pyridine -  $\text{C}_5\text{H}_5\text{N}$
- Nitronium ion -  $\text{NO}_2^+$
- Hydrazoic acid -  $\text{HN}_3$
- Ammonium sulfate -  $(\text{NH}_4)_2\text{SO}_4$

### Uses of Nitrogen

- Nitrogen compounds are extensively used in wide range of fields and industries.
- Pure nitrogen is used as food additive.
- Used in fire suppression systems especially for the information technology equipment.
- Also used in manufacturing stainless steel.
- Nitrogen is also used to inflate the tires of some of the aircraft and race cars.
- Liquid nitrogen is used as a refrigerant.

### Carbon

- Carbon is a non-metallic and tetravalent element.
- Tetravalent means – carbon makes four electrons available to form the covalent chemical bonds.
- Carbon has three isotopes that occur naturally – namely  $^{12}\text{C}$ ,  $^{13}\text{C}$ , and  $^{14}\text{C}$ .
- Among them,  $^{12}\text{C}$  and  $^{13}\text{C}$  are stable, but  $^{14}\text{C}$  is a radioactive isotope. Half-life of  $^{14}\text{C}$  is about 5,730 years.

### Salient Features of Carbon

- The physical properties of carbon largely depend on its allotropes.
- Major allotropes of carbon are graphite, diamond, and amorphous carbon.
- Graphite is opaque, black, and very soft; hence, it used to form a streak on the paper.
- Diamond very hard (the hardest naturally occurring material) and transparent.
- Graphite is a good conductor of electricity.
- Diamond is bad conductor of electricity.
- Carbon most likely has the highest sublimation point among all the elements.

### Occurrence of Carbon

- In terms of mass, carbon is the fourth most abundant chemical element found in the universe (after hydrogen, helium, and oxygen).

- Carbon is available in abundance in the Sun, stars, comets, and in the atmospheres of most of the planets.
- Carbon is found in the earth's atmosphere and dissolved in water.
- Hydrocarbons, such as coal, petroleum, and natural gas, all of them contain carbon.
- Carbon is also found in methane hydrates, which found in polar regions and under the seas.
- Some of the rocks enriched of carbon are coal, limestone, dolomite, etc.
- Coal is very rich in carbon; hence, it is the largest commercial source of mineral carbon.
- Coal shares about 4,000 gigatonnes or 80% of total fossil fuel.

### Compounds of Carbon

Following are the major compounds of Carbon –

- Cyanogen -  $\text{CN}_2$
- Hydrogen cyanide –  $\text{HCN}$
- Cyanamide -  $\text{CN}_2\text{H}_2$
- Isocyanic acid –  $\text{HNCO}$
- Cyanogen chloride –  $\text{CNCl}$
- Chlorosulfonyl isocyanate -  $\text{CNCIO}_3\text{S}$
- Cyanuric chloride -  $\text{NCCl}_3$
- Carbon disulfide -  $\text{CS}_2$
- Carbonyl sulfide –  $\text{OCS}$
- Carbon monosulfide -  $\text{CS}$

### Uses of Carbon

- Depending upon the allotrops, carbon is used in range of applications.
- Carbon is one of the most essential elements of life without it, we cannot imagine life on the earth.
- The fossil fuel namely methane gas and crude oil (petroleum), coal etc. are used in everyday life.
- Graphite, combining with clay, used in making 'lead' used in pencils.
- Charcoal is also used as a drawing material in artwork, iron smelting, barbecue grilling, etc.
- Diamond is usually used in jewellery.
- Industrial diamonds are used in cutting, drilling, and polishing tools for machining the metals and stone.
- Fossil hydrocarbons, and carbon fibre are used in making plastic.





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