Isotopes, Isobars, Isotones, Isodiaphers, Isoelectronic species, Isosters and Nuclear isomers.

(1) **Isotopes:** Atoms of a given element which have same atomic number (nuclear charge) but different mass number are called isotopes. In other words, isotopes are the atoms of the same element differing in mass number. Thus isotopes have same number of protons and electrons but different number of neutrons. They have same position in the periodic table, same chemical properties and same atomic charge. The term was first coined by **Soddy**. However, Aston using mass spectrometer first separated isotopes $(Ne^{20}$ and $Ne^{22})$.

Examples: (i) $\underset{(p=1,e=1,n=0)}{\underset{\text{Hydrogen (Protium)}}{_1H^1}}$, $\underset{(p=1,e=1,n=0)}{\underset{\text{Deuterium}}{_1H^2}}$, $\underset{(p=1,e=1,n=0)}{\underset{\text{Tritium}}{_1H^3}}$ (ii) $_6C^{12}, {_6C^{13}}$ and $_6C^{14}$

(iii) $_8O^{16}, {_8O^{17}}, {_8O^{18}}$ (iv) $_{17}Cl^{35}$ and $_{17}Cl^{37}$

Of all the elements, tin has maximum number of stable isotopes (ten).

The fractional atomic weight (35.5) of chlorine is due to the fact that in the ordinary chlorine atom, Cl^{35} and Cl^{37} are present in the ratio of 3: 1.

$\therefore$ Average atomic weight of Cl $= \dfrac{3 \times 35 + 1 \times 37}{4} = 35.5\ amu$

The percentage of a given isotope in the naturally occurring sample of an element is called **isotopic abundance**. As the isotopic abundance of an element is constant irrespective of its source, atomic weight of an element is constant.

(2) **Isobars:** Isobars are the atoms of different elements with the same mass number but different atomic numbers. In other words, isobars have different number of protons, neutrons and electrons but the sum of protons and neutrons (i.e., number of nucleons) is same.

Examples: (i) $_{18}Ar^{40}, {_{19}K^{40}}$ and $_{20}Ca^{40}$ (ii) $_{52}Te^{130}, {_{54}Xe^{130}}$ and $_{56}Ba^{130}$.

Since isobars are the atoms of different elements, they will have different physical and chemical properties.

(3) **Isotones:** Isotones are the atoms of different elements with the same number of neutrons but different mass numbers, e.g. $_{14}Si^{30}, {_{15}P^{31}}$ and $_{16}S^{32}$. Since the variable factor in isotones is the number of protons (atomic number), they must have different physical and chemical properties.

Examples:(i) $_{14}Si^{30}$, $_{14}P^{31}$ and $_{16}S^{32}$ (ii) $_{19}K^{39}$ and $_{20}Ca^{40}$

(iii) $_{1}H^{3}$ and $_{2}He^{4}$ (iv) $_{6}C^{13}$ and $_{7}N^{14}$

(4) **Isodiaphers:**Atoms having same **isotopic number** are called **isodiaphers**.

Mathematically, isotopic number (isotopic excess) = (N – Z) or (A – 2Z)

Where, N = Number of neutrons; Z = Number of protons

Examples:(i) $_{92}U^{235}$ and $_{90}Th^{231}$ (ii) $_{19}K^{39}$ and $_{9}F^{19}$ (iii) $_{29}Cu^{65}$ and $_{24}Cr^{55}$

(5) **Isoelectronic species:**Species (atoms, molecules or ions) having same number of electrons are called **isoelectronic.**

Examples:

(i) $N^{3-}, O^{2-}, F^{-}, Ne, Na^{+}, Mg^{2+}, Al^{3+}, CH_4, NH_3, H_2O$ and HF have 10 electrons each.

(ii) $P^{3-}, S^{2-}, Cl^{-}, Ar, K^{+}$ and Ca^{2+} have 18 electrons each.

(iii) H^{-}, He, Li^{+} and Be^{2+} have 2 electrons each.

(iv) CO, CN^{-} and N_2 have 14 electrons each.

(v) N_2O, CO_2 and CNO^{-} have 22 electrons each.

(6) **Isosters:**Molecules having same number of atoms and also same number of electrons are called isosters.

Examples: (i) N_2 and CO (ii) CO_2 and N_2O (iii) HCl and F_2

(iv) CaO nadMgS (v) C_6H_6 (benzene) and inorganic benzene B_6N_6.

(7) **Nuclear isomers:**Nuclear isomers (isomeric nuclei) are the atoms with the same atomic number and same mass number but with different radioactive properties. They have same number of electrons, protons and neutrons. An example of nuclear isomers is uranium-X (half-life 1.4 min) and uranium-Z (half-life 6.7 hours). **Otto Hahn** discovered nuclear isomers.

The reason for nuclear isomerism is the different energy states of the two isomeric nuclei. One may be in the ground state whereas the other should be in an excited state. The nucleus in the excited state will evidently have a different half-life.

Now-a-days as much as more than 70 pairs of nuclear isomers have been found. Few examples are as follows

(i) $\underset{(T_{1/2}=13.8\ hour)}{^{69}Zn}$ and $\underset{(T_{1/2}=57\ \text{min})}{^{69}Zn}$ (ii) $\underset{(T_{1/2}=4.4\ hour)}{^{80}Br}$ and $\underset{(T_{1/2}=18\ \text{min})}{^{80}Br}$