STRUCTURE OF THE ATOM
ISOTOPES, ISOBARS AND ISOTONES

❖ ISOBARS

Atoms of different elements with different atomic number which have the same mass number, are known as isobars.

For example : Calcium and argon

$$_{20}Ca^{40} \qquad _{18}Ar^{40}$$

The atomic number of argon is 18, calcium is 20 but the mass number of these element is same.

(2) $^{14}_{6}C$ and $^{14}_{7}N$

ISOBARS	$^{14}_{6}C$	$^{14}_{7}N$
Atomic number	6	7
No. of protons	6	7
No. of electrons	6	7
No. of neutrons	8	7
Mass number	14	14

Ques. Write the electronic configuration of any one pair of isotopes and isobars. **[NCERT]**

Order of filling of electrons in orbitals :

There are different rules for filling electrons in subshells. They are described as follows.

- Pauli's exclusion principle.
- Aufbau principle
- (n + l) rule
- Hund's maximum multiplycity rule.

Pauli's Exclusion Principle :

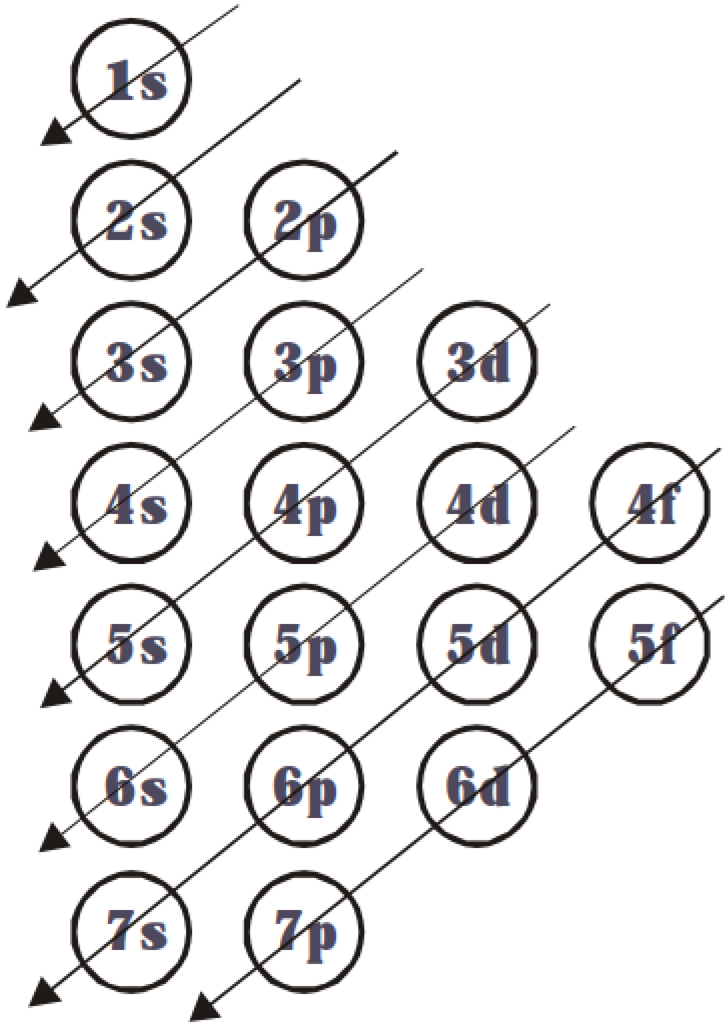
- According to **Pauli's** exclusion principle an orbital cannot accomodate more than two electrons. These two electrons should have opposite spins. eg. :

Aufbau Principle:

Aufbau is a **German word** and its meaning **building up**. Aufbau principle gives a sequence in which various subshell are filled up depending on the relative order of the energies of various subshell. The subshell with minimum energy is filled up first, when this subshell obtained maximum no. of e^- or capacity of electrons then the next subshell of higher energy starts fillings.

The order of filling of different sub-shell in represented diagrammatically as follows:

Simmon's Array :



Hund's Maximum Multiplicity Rule :

According to hund's rule electrons are distributed among the orbitals of subshell in such a way to give maximum number of unpaired electron with parallel spin.i.e. in a subshell pairing of electons will not start until and unless all the orbitals of that subshell will get one electron each with same spin.

For example :

$_7N$	$1s^2$	$2s^2$	$2p^3$
	$\boxed{\uparrow\downarrow}$	$\boxed{\uparrow\downarrow}$	$\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$
$_8O$	$1s^2$	$2s^2$	$2p^4$
	$\boxed{\uparrow\downarrow}$	$\boxed{\uparrow\downarrow}$	$\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}$

(n + l) Rule : According to it the sequence in which various subshells are filled up can also be determined with the help of (n + l) value for a given subshell. The subshell with lowest (n + l) value is filled up first when two or more subshells have same (n + l) value then the subshell with lowest value of n is filled up first.

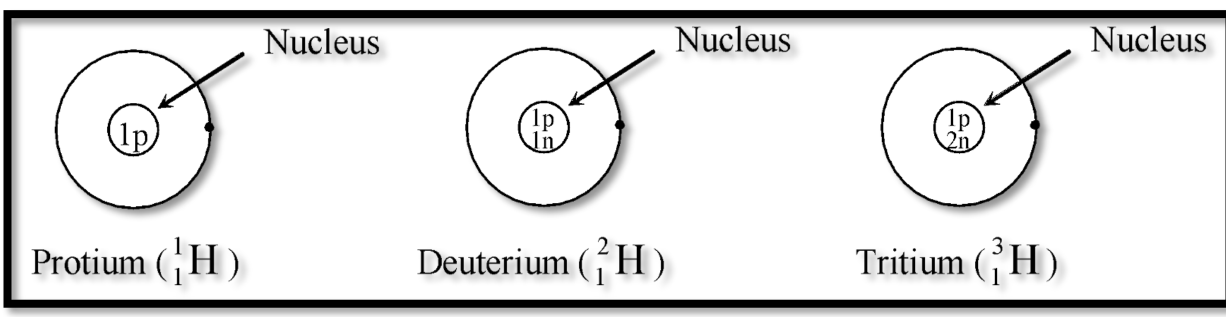
Sub Shell	**n**	**l**	**n +l**	
1s	1	0	1	
2s	2	0	2	
2p	2	1	3	(1)
3s	3	0	3]	(2)
3p	3	1	4	(1)
4s	4	0	4]	(2)
3d	3	2	5	(1)
4p	4	1	5	(2)
5s	5	0	5]	(3)
4d	4	2	6	(1)
5p	5	1	6	(2)
6s	6	0	6]	(3)

❖ ISOTONES:-

- In nature, there are several elements, whose atoms have the same atomic number but different mass number, such atoms are known as isotopes and can be defined as:
- "Isotopes are the atoms of the same element, having the same atomic number but different mass number".
- As, it is known that
- Atomic number (Z) = Number of protons = Number of electrons
- So we may conclude that isotopes contain the same number of electrons as well as protons, and we know that
- Mass number = Number of protons + Number of neutrons
- But as we know that number of protons in them are equal so we can conclude that isotopes of an element differ only in the number of neutrons present in the nucleus. This can be understood more clearly by the following examples:

  Ex. Isotopes of Hydrogen: There are three isotopes of hydrogen, namely protium, deuterium and tritium.

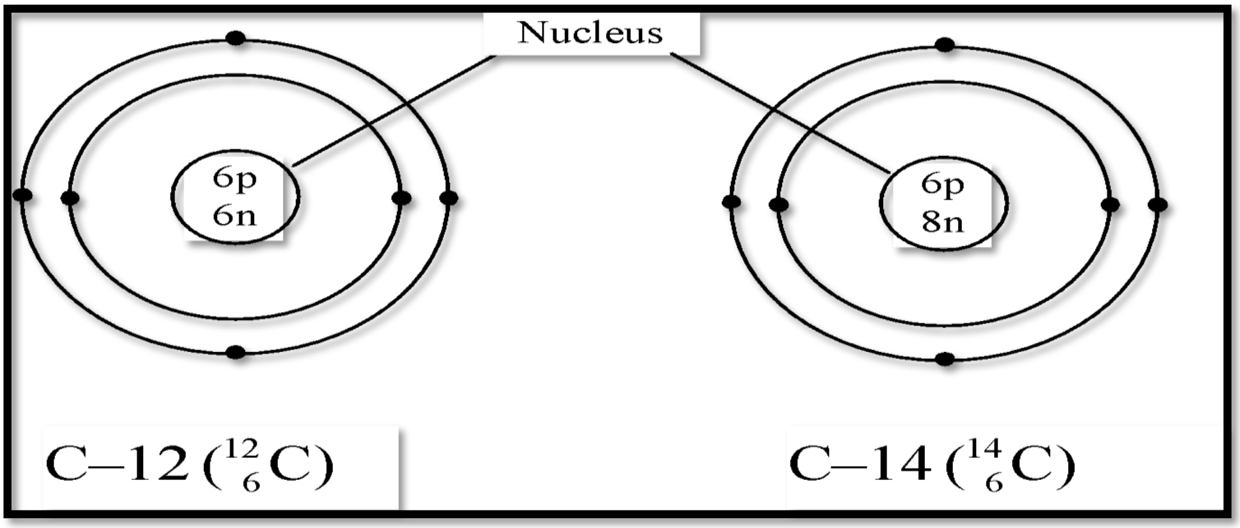
- They have only one proton, but differ in the number of neutrons and contain 0, 1, 2 neutrons in their nucleus respectively.



ISOTOPE	ATOMIC NO.	MASS NO.	NO. OF PROTONS	NO. OF NEUTRONS	NO. OF ELECTRONS
^1_1H	1	1	1	1 – 1 = 0	1
^2_1H	1	2	1	2 – 1 = 1	1
^3_1H	1	3	1	3 – 1 = 2	1

Ex. Isotopes of Carbon: Carbon has mainly two isotopes which are as follows:

Isotope	Atomic No.	Mass No.	No. of protons	No. of neutrons	No. of electrons
${}^{12}_{6}C$	6	12	6	12 – 6 = 6	6
${}^{14}_{6}C$	6	14	6	14 – 6 = 8	6



Ex. Isotopes of Chlorine: There are two isotopes of chlorine which are as follows:

Isotope	Atomic No.	Mass No.	No. of protons	No. of neutrons	No. of electrons
${}^{35}_{17}\boldsymbol{Cl}$	17	35	17	35 – 17 = 18	17
${}^{37}_{17}\boldsymbol{Cl}$	17	37	17	37 – 17 = 20	17

GENERAL CHARACTERISTICS OF ISOTOPES:

- **Same atomic number:** The isotopes of an element have the same atomic number i.e. they have same number of protons and same number of electrons.
- **Different mass number:** They have different mass number and hence differ in the number of neutrons present in the nucleus.
- **Same chemical properties:** They have same chemical properties as they have same number of electrons and therefore same electronic configuration and valence electrons.

- **Different physical properties:** Since they have different mass number hence they differ in their physical properties such as melting point, boiling point, density, etc.
- **Different nuclear properties:** Due to the difference in the number of neutrons in their nucleus they show different nuclear properties **e.g. C–14** isotope of carbon is radioactive whereas **C–12** isotope is non-radioactive. The radioactive isotope of an element is known as radioisotope.

FRACTIONAL ATOMIC MASSES AND CALCULATION OF AVERAGE ATOMIC MASSES:

The mass of an atom of any natural element is taken as the average mass of all the naturally occurring atoms of that element. Hence, if an element has no isotope then the atomic mass of its atom would be the same as its mass number. But if an element occurs in isotopic form, then we have to know the percentage of each isotopic form to calculate its average atomic mass.

Ex. Calculation of average atomic mass can be explained with the help of the following example: In nature, the two isotopic forms of chlorine viz.,

$^{35}_{17}\mathbf{Cl}$ and $^{37}_{17}\mathbf{Cl}$ are found in the ratio of **3:1**. Hence,

Average atomic mass = $$\left[\left(35\times\frac{75}{100}+37\times\frac{25}{100}\right)\right]$$

$$=\left[\left(35\times\frac{3}{4}+37\times\frac{1}{4}\right)\right]$$

$$=\left[\frac{105}{4}+\frac{37}{4}\right]=\left[\frac{142}{4}\right]$$

$$= 35.5\text{ u}$$

This does not mean that any one atom of chlorine has a fractional mass of **35.5 u.** It means that if we take a certain amount of chlorine, which consists of both the isotopes of chlorine, then it will have the average atomic mass of **35.5 u.** The reason for those fractional atomic masses is that for an element existing in different isotopes, i.e., atoms with different mass numbers, the atomic mass of the elements is the average value which comes out to be fractional.

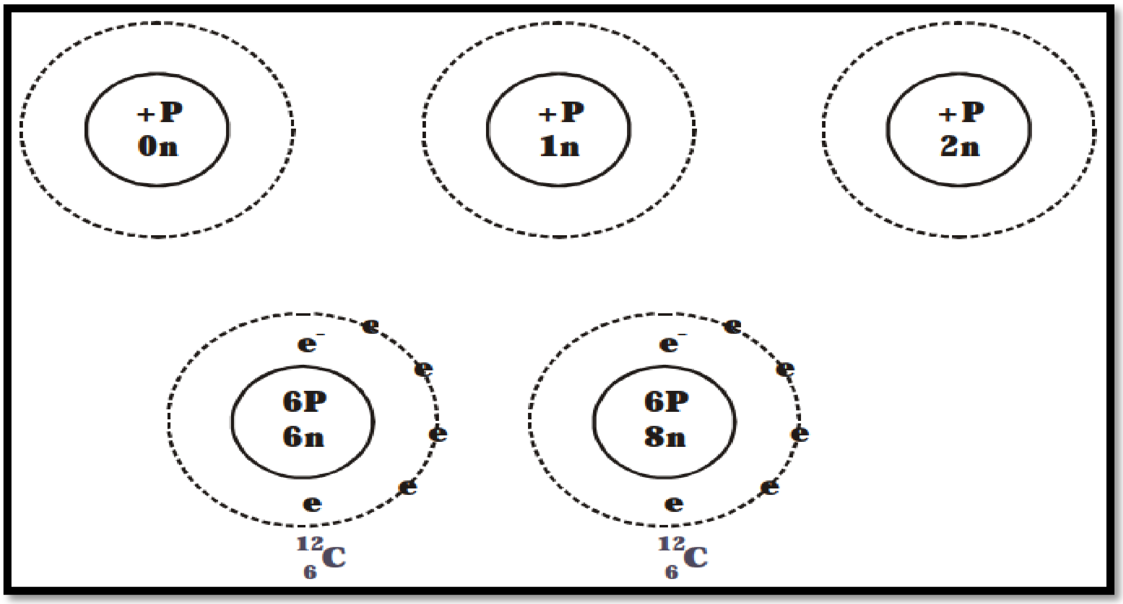
APPLICATIONS OF ISOTOPES:

- **In agriculture:** Certain elements such as boron, cobalt, copper, manganese, zinc and molybdenum are necessary is very minute quantities for plant nutrition. By radioactive isotopes we can identify the presence and requirements of these element in the nutrition of plants.
- **In industry:** Coating on the arm of clock to seen in dark. To identify the cracks in metal casting.
- **In medicine :** Thyroid, bone diseases, brain tumours and cancer and diagnosed, controlled or destroyed with the help of radioactive isotopes like
  $^{60}_{27}$**CO,**Na, iodine, phosphorus etc.
- **Determination of the mechanism of chemical reaction:** By replacing an atom or molecule by its isotope.
- **In carbon dating :** Will and Libby (1960) developed the technique of radiocarbon dating to determine the age of plants, fossils and archeological samples.
  Isotopes (Like **Uranium - 238)** are used in nuclear reactor to produce energy and power.

❖ ISOTOPES:-

Isotopes are atoms of the same element, having the same atomic number but different mass number. For example, isotopes of hydrogen atom, namely protium ($_1H^1$) deuterium($_1H^2$) tritium ($_1H^3$). The atomic number of each one is 1, but the mass number is 1, 2, and 3 respectively.

Exampe of Isotopes



Isotopes of carbon $^{12}_{6}C$ and $^{14}_{6}C$

CARBON ISOTOPES	$^{12}_{6}C$	$^{14}_{6}C$
Atomic number	6	6
No. of protons	6	6
No. of electrons	6	6
No. of neutrons	6	8
Mass number	12	14

Applications of Isotopes:

Since the chemical properties of all isotopes of an element are the same but same isotopes have special properties which find them useful in various fields. Some of them are :

- Uranium ($^{238}_{92}U$) is used as a fuel in nuclear reactors.
- Cobalt ($^{60}_{27}Co$) is used in the treatment of cancer.
- Iodine ($^{128}_{53}I$) is used in the treatment of goitre.
- Sodium ($^{24}_{11}NA$) is used for differentiating cancerous tissues from the normal tissues.
- Carbon $^{14}_{6}C$ is used in dating of fossil samples.

How to calculate the atomic mass of an element from the mass number of its isotopes.

The atomic mass of an element is the weighted arithmetic mean of the atomic masses of its isotopes present in the sample of the element.

Let us consider a sample of an element X containing its two isotopes X_1 and X_2.

Atomic mass of the element X $= \frac{\%\text{ of }X_1 \quad \text{Mass Number}X_1 \quad \%\text{ of}X_2 \quad \text{Mass NUmber of }X_2}{100}$

Ex. This method is illustrated by taking the case of chlorine. The two isotopes of chlorine, $^{35}_{17}\mathbf{Cl}$ and $^{37}_{17}\mathbf{Cl}$ occur in the ratio **3 : 1**. Then,

Atomic mass of chlorine : $\frac{(35u \quad 3) \quad (37u \quad 1)}{3 \quad 1} \quad \frac{105u \quad 37u}{4} \quad \frac{142u}{4}$ **35.5u**

Ques. If bromine occurs is in the form of say two isotopes $^{79}_{35}\mathbf{Br}$ **(49.7%)** and $^{81}_{35}\mathbf{Br}$ **(50.3%)**, then calculate the atomic mass of bromine atom.