Unit - II

NUCLEAR CHEMISTRY

2.1. Natural Radioactivity :

It is defined as the phenomenon in which the nucleus of the atom of an element undergoes spontaneous and uncontrollable disintegration (or decay) and emits α, β and γ rays.

Elements like U, Th, Ra and Po undergoes spontaneous emission of α, β and γ rays.

$${}_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_{2}He^{4}$$

$${}_{88}Ra^{226} \longrightarrow {}_{86}Th^{222} + {}_{2}He^{4}$$

$${}_{90}Th^{234} \longrightarrow {}_{91}Pa^{234} + {}_{-1}e^{0}$$

Radioactive disintegration series

Most of the natural radio-active elements of higher atomic numbers exist in nature as a number of radio-active isotopes. All the radio-active isotopes, which are about 40 in number, belong to definite chains of successive decays. These are called **radioactive series**. They are **uranium, thorium, actinium** and **neptunium** series.

The first three radio active series have been named after a prominent member in each decay series. Uranium and thorium are having longest half-lives in their series. So the respective series are named after them. Long ago it was thought that the actinium series originated from actinium. But now it is known that U^{235} is the parent of that series with a longer half life than actinium. The thorium series is also referred to as 4n series because the mass numbers of its members are divisible by 4. The uranium series is known as 4n + 2 series because its mass number is divisible by 4 with a remainder 2. The actinium series is known an 4n + 3 because its mass number is divisible by four with a remainder of 3.

The first three series have close similarities. Their modes of decay are also similar. The ultimate product in each of the three families is a stable, but different in each case, isotope of lead.

Although there is considerable similarity among the three radio active series, they are not specifically related. In other words, an isotope in one series will not decay to a particular isotope belonging to another series. This lack of interchange is to be expected , since mass changes can take place only by the loss of α - particles of 4 mass units each and the characteristic mass of each family is either **4n, 4n + 2** or **4n + 3**.

A radio-active chain is not always straight forward. There are branched disintegrations in each series. In such cases an isotope breaks down in two different ways. This gives rise to branched products. Interestingly, the isotopes produced by a branched disintegration always decay into the same product.

The (4n +1) series - The Neptunium series : We have seen that the three serious of natural radio elements contain members whose masses are divisible by 4 or by 4 with remainders of 2 and 3 But the series containing members whose masses are divisible by 4 with a remainder of 1, that is (4n +1) series could not be found. The most acceptable explanation for the absence of this series in nature was that no member of this series was sufficiently long lived.

The first five members of this series were discovered during World War II. The other members have been discovered and studied later.

The (4n + 1) series, derives it's name from the longest lived member of the series , neptunium. Thus it is called neptunium series. The member of the series are man-made. It is an artificial series.

1. Natural radio active series
   i. Thorium, 232   ii. Uranium - I, 238   iii. Uranium - I, 235

2. Artificial radio active series
   i. Neptunium, 237

Sl. No.	Series	Formula	Parent element	Particles emitted		End element
				α	β	
1.	Thorium	4n	$_{90}Th^{232}$	6	4	$_{82}Pb^{208}$
2.	Uranium - I	4n+2	$_{92}U^{238}$	8	6	$_{82}Pb^{206}$
3.	Uranium - II	4n+3	$_{92}U^{235}$	7	4	$_{82}Pb^{207}$
4.	Neptunium	4n+1	$_{93}Ne^{237}$	7	4	$_{83}Bi^{209}$

This series differs in several respects from the naturally occurring radio active series. They are as follows :

1) The end product in the series is the stable isotope of bismuth, $_{83}Bi^{209}$ where as the end products of the three natural radioactive series are stable isotopes of lead.

2) The only member of the series to be found in nature is the stable end product bismuth $_{83}Bi^{209}$.

3) The series contains no gaseous emition as in the case of the three natural series.

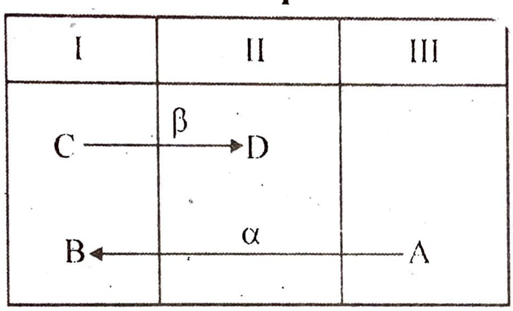
4) The series contain isotopes of francium and astatine as direct and successive members of the decay chain. These elements appear only as minor branched disintegration products in the natural series.

5) Branched disintegration appears more frequently in the natural radioactive series than in the neptunium series.

Group Displacement Law (Fajan - Russel - Soddy)

We know that when an α-particle is emitted the daughter element has atomic number two units less than that of the parent element. So its position in the periodic table will be two places left to the parent element. Similarly when a β-particle is emitted the daughter element has atomic number one unit more than that of the parent element. So its position in the periodic table will be one place right to the parent element. This is called ***group displacement law***.

Groups



Element C emits a β - particle giving the daughter element D and moves to the right from Group I to Group II. Element A emits an α - particle giving the daughter element B and moves left from Group III to Group I.

Use :

This law is helpful in predicting the nature of the daughter element if the mode of decay of a particular parent element is known.

E.g.,

(i) $_{84}Po^{215}$ under goes α-emission. From this detail we can predict the nature of the daughter element. According to the group displacement law the daughter element in this case will be two places left of Po in the periodic table i.e., it is Pb.

ii) $_{82}Pb^{211}$ undergoes β-emission. So the daughter element will be one place right of Pb in the periodic table i.e., it is Bi.

2.2. Nuclear Binding Energies

Mass defects

The mass of the proton has been determined accurately as 1.00758, the mass of neutron as 1.00893 and that of an electron as 0.0005486 mass unit (on the physical atomic weight scale in which the mass of the O^{16} atom is taken as the standard with mass exactly 16.00000 units). So we can calculate accurately the mass of an atom knowing the number of protons. neutrons and electrons present in it. For examples, the helium atom contains 2 electrons, 2 protons and 2 neutrons. Therefore its mass should be

$$(2 \times 0.0005486) + (2 \times 1.00758) + (2 \times 1.00893) = 4.03411$$

But actually the mass of the helium atom is 4.00390 units.

The difference between the expected mass and the actual mass is

$$4.03411 - 4.00390 = 0.03021 \text{ mass unit}$$

and this difference is called the **mass defect**.

Thus the difference between expected mass of an atom of an element (calculated from the number of protons; neutrons and electrons and their respective accurate masses) and the actual mass is known as the ***mass defect****.*

Experimental mass of nucleus – (mass of proton + mass of neutron)

= mass defect

Thus when the helium atom is formed from its constituent particles 0.03021 mass units of mass is converted into energy.

We know 1 mass unit = 1.661×10^{-24}g. Therefore $0.03021 \times 1.661 \times 10^{-24}$g of mass has been coverted into energy. This energy is the binding force which binds two protons and two neutrons together to form the helium nucleus.

From Einstein's mass energy equation

$$E = mC^2$$

$$E = 0.03021 \times 1.661 \times 10^{-24} \times (3 \times 10^{10})^2$$

$$= 4.5119 \times 10^{-5} \text{ erg.}$$

We now 1.60×10^{-6} erg = 1 MeV

$$\therefore 4.5119 \times 10^{-5} \text{ erg} = \frac{4.5119 \times 10^{-5}}{1.602 \times 10^{-6}}$$

$$= 28.12 \text{ MeV}$$

Since the helium atom contains four particles, the binding energy per nucleon in He^4 is 28. 28 ÷ 4, i.e., approximately 7.0 MeV.

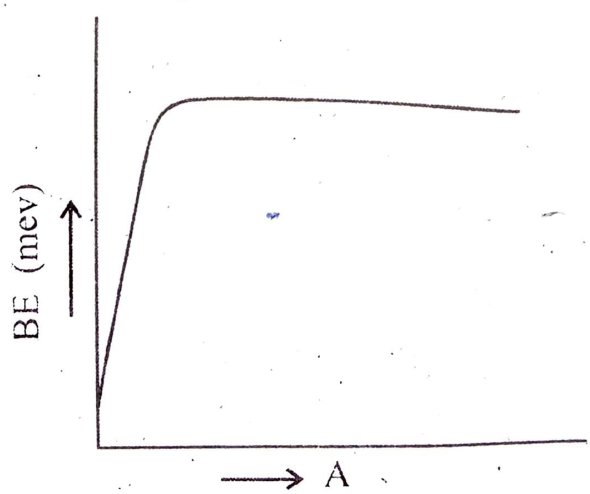
[We can also calculate straight away using 1 mass unit = 931 MeV]

(Thus binding energy may be defined as the energy released when a given number of proton and neutrons combine to form a nucleus. It can also be defined as the energy recquired to disrupt a nucleus into its constituent protons and neutrons.

This binding energy comes from the mass which has been lost during the formation of the nucleus. This mass has been converted into energy which is used to bind the nucleons together in nucleus.

Significance of Binding Energy :

Binding energy may be taken as a measure of the relative stability of the nucleus. Binding energies increase progressively with atomic mass and are fairly constant except for the very light elements. If we plot the binding energy per nucleon against the mass number we get a graph.



BE = Binding energy per particle

From this graph the following observation can be made.

1. In the mass-number range between 25 and 140, the binding energy per particle is nearly constant and it is approximately equal to 8.5 MeV/nucleon.

2. Nuclei with both small and large mass numbers have a smaller binding energy per particle. So these nuclei are less stable

3. For nuclei with small mass numbers considerable irregularities occur i.e., the curve raises abruptly.

Some qualitative inferences may also be drawn.

1. The value of 8.5 MeV/nucleon, seems to be an average for a wide range of nuclei, and it represents a saturation of binding energy forces.

2. Beginning with the lighter nuclei, as the mass increases the average binding energy per nucleon also increases because of a surface: volume ratio decrease. This effect may be compared with the surface tension of liquids.

3. The binding energy per particle for nuclei with large masses is small. This is because of the repulsion between large number of protons. Therefore they are less stable than those with average mases.

Problem

1. The helium nucleus consists of protons and two neutrons making a total mass of 4.0319 a m.u. But the actual mass if found to be 4.0015 a.m.u. calculate the binding energy per nucleon.

Solution

Expected mass	=	4.0319 a.m.u.
Actual mass	=	4.0015 a.m.u
∴ Mass defect	=	4.0319 - 4.0015 a.m.u

		=	0.5719 amu
We know	1 amu	=	931 MeV
∴	0.5719 amu	=	931 x 0.5719
		=	532.4389 MeV

∴ Binding energy of the nucleus = 532.4389 ÷ 64

= 8.337 MeV

Answer : Binding energy per nucleon in Ni^{64}

= **8.337 MeV**

Exercise

The aluminium isotope $_{13}Al^{27}$ has a mass of 26.9815 amu. The mass of proton is 1.0081 amu and that of neutron is 1.0090 amu Calculate the binding energy per nucleon of the aluminium nucleus (1 amu = 931 MeV) (Ans : 8.222 MeV)

2.3. Nuclear Fission

Definition : Splitting of a nucleus into nearly equal parts with release of energy is called **nuclear fission.**

Explanation : It is a type of disintegration. For example when uranium-235 is bombarded with slow moving neutrons, first a neutron is captured by the uranium nucleus. Then the whole nucleus splits into two nuclei, one of barium and other of krypton. In this process 3 extra neutrons are released. Such a process is known as nuclear fission. Some of the liberated neutrons attack other uranium nuclei and thus cause a chain reaction, while the others get annihilated and are converted into energy.

$$_{92}U^{235} + {}_0n^1 \longrightarrow {}_{92}U^{*236} \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_0n^1 + \text{Energy}$$

Importance of nuclear fission

In fission reactions there is a loss of mass. This is converted into energy. The energy produced in nuclear fission is extremely large as compared to conventional sources. For example, when $_{92}U^{235}$ undergoes fission reaction on bombardment with slow moving neutrons about 0.2 units of mass per gram atom of uranium 235, is annihilated. It amounts $0.2 \times [3 \times 10^{10}]^2$ ergs according to Einsteins equations [$E = mc^2$] This equal to six million horse power hours.

The large amount of energy liberated in nuclear fission can be utilised in two important ways:

i. Preparation of the super explosive or **atom bomb** (destructive purpose).
ii. Super power plant (constructive purpose).

The atom bomb works on fast neutron chain. It is **accomplished** bringing together two pieces of fissionable material (U^{235} or Pu^{239}) into intimate contact. When these two pieces are kept separted they are stable. But when they are put together by a **mere** mechnical operation, they explode violently.

Controlled Fission Reaction

What is it? Atom bomb explosion is due to an uncontrolled chain reaction. If this chain reaction is put under control, after some time, a steady state is established. When such a steady state is established the number of neutrons produced and the number of neutrons consumed becomes nearly equal. The energy produced attains a constant level. Such a reaction is known as ***Controlled fission reaction***.

How is this brought about? Controlled fission reactions are brought about in nuclear reactors. In nuclear reactions the fissionable material also called nuclear fuels) like U^{235} or Pu^{239} is **staked** with heavy water or graphite called moderaors. The neutrons produced in the fission pass through the moderators and they lose some of their energies. So they start moving slowly. Thus fission reactions are controlled.

Applications

It is used for preparing radioisotopes or generating electricity.

Nuclear Fusion

Definition :

It is the process of combining or fusing two lighter nuclei into stable and heavier nuclide with release of energy is called **nuclear fusion**

E.g., $4\,{}_1H^1 \longrightarrow {}_2He^4 + 2\,{}_{+1}e^o + \text{Energy}$

Explanation :

We may consider the formation of helium nucleus it is formed by the combination of two hydrogen atoms (i.e., 2 protons and 2 electrons) and two neutrons. In this case also an enormous amount of energy is released by the formation of a heavier nucleus from those of lighter elements on account of loss of mass.

Thermo nuclear reactions :

Nuclear fusion can take place by allowing highly accelerated protons and deuterons, etc, to fall on nuclei of lighter elements. Such processes occur at reasonable rates only at very high temperatures of the order of a million degree centigrade which exist only in the interior of stars. Therefore, such processes are called **thermo-nuclear reaction.** Once a fusion reaction is initated, the energy released is sufficient to maintain the temperature and to keep the process going.

Stellar Energy (Energy source of sun and stars)

Stellar energy is the energy of the sun and stars. It is proposed that the stellar energy is due to a series of nuclear reactions involving the fusion of four protons to form one helium nucleus and two positrons with an evolution of tremendous quantity of energy. On the sun the fusion of four H- nuclei into helium nucleus does not take place in a single step but takes place through deuterium ($_1H^2$) as shown below.

i. $\left[2\,_1H^1 \longrightarrow \,_1H^2 + \,_1e^0 + \text{Energy}\right] \times 2$

ii. $\left[_1H^2 + \,_1H^1 \longrightarrow \,_2He^3 + \text{Energy}\right] \times 2$

iii. $2\,_2He^3 \longrightarrow \,_2He^4 + 2\,_1H^1 + \text{Energy}$

on adding $4\,_1H^1 \longrightarrow \,_2He^4 + 2\,_{+1}e^0 + \text{Energy}$

In the above reaction 26.7 MeV of energy is released. This is a tremendous quantity.

Hydrogen bomb:

The thermo nuclear reactions among nuclei of hydrogen isotopes, deuterium and tritium, can serve as possible sources of energy on earth as these can occur more rapidly, provided the temperature is very high such an energy obtained from thermonuclear reactions is called **thermonuclear energy**. These reactions may be represented as.

$$_1D^2 + \,_1D^2 \longrightarrow \,_2He^3 + \,_0n^1 + \text{Energy} = 3.2 \text{ MeV}$$

$$_1D^2 + \,_1D^2 \longrightarrow \,_1T^3 + \,_1H^1 + \text{Energy} = 4.0 \text{ MeV}$$

$$_1D^2 + \,_1T^3 \longrightarrow \,_2He^4 + \,_0n^1 + \text{Energy} = 17.6 \text{ MeV}$$

These fusion processes are responsible for the release of a tremendous amount of energy in the form popularly known as a hydrogen bomb. But the above nuclear reactions can take place only at very high temperatures. Therefore, an external sources of energy to provide an atmosphere with required high temperatures is necessary. In the preparation of a hydrogen bomb, a suitable quantity of deuterium or tritium or a mixture of both, is combined with an atom bomb. The atom bomb provides an atmosphere of required high temperature. A hydrogen bomb is far more powerful than an atom bomb.

Now man is capable of controlling nuclear fission and obtainin energy in a controlled manner in a nuclear reactor and using it for peacef purposes. Similarly, man in future, probably will be able to control nucle fusion processes and to obtain an abundance of energy for the benefit mankind.

Comparison of nuclear fission and nuclear fusion.

a. ***Similarities :***

Both release very large amount of energy.

b. ***Differences :***

i. Fission involves the breaking up of a heavy nucleus into lighte nuclei. Fusion involves combining of two lighter nuclei into on heavy nucleus.

ii. The links of the fission process are neutrons. The links of a fusio process are protons.

iii. Fission proceed with thermal neutrons where thermal means room temperature; Fusion proceeds with thermal particles where thermal means millions of degrees in Kelvin scale.

2.4. Application of Radio Isotopes (or) Isotopes as tracers :

A given isotope may be identified, among other isotopes by their 'unusual masses' and 'radio activity'. Either of these properties may be utilised to trace the course of an element in various processes. An isotope used for this purpose is known as an **'isotopic tracer'**, and the element which is labelled by the particular isotope is called a **'tracer element'**.

General principles in the uses of tracers : An element may be labelled by changing its natural isotopic composition. Stable isotopes are used as tracers, but such isotopes are limited in number. Oxygen, hydrogen, carbon, nitrogen and sulphur isotopes are stable isotopes which are very widely employed in tracer studies.

The use of either radio-active or non radio-active isotopes depends upon the investigation to be carried out. The advantages and disadvantages of both types are given below :

Radio active isotope	***Non radio-active isotope***
1. Detection and qualitative estimation is very easy.	Detection and qualitative estimation is very difficult
2. They survive for a very short time (half - life period is very small).	They servive for a very long time.
3. They are readily available for a large number of the elements.	They are not readily available for a large number of elements.
4. They are harmful to the operator and to which it is injected.	They are not harmful at all.
5. They follow a sequence of changes	They do not follow a sequence of changes.

Each radioactive isotope has specific property and by which the isotope can be easily detected and estimated quantitatively. Since the radioactive isotope of an element possesses identical chemical properties. with stable isotope by mixing a small quantity of radioactive isotope with non-radio active isotope of an element the course of a chemical reaction can be studied. Thus the radioactive isotope is acting as a tracer element. The presence of radioactive tracer in the product can be detected and estimated quantitatively using sensitive instruments.

We have to select suitable isotope for tracer. Radio isotopes of either very short lives or very long lives are not usually used in tracer work. Radiation from radioactive elements can be detected by

i. Photographic measurement method

ii. Electroscope method

iii. Ionisation chamber method

iv. Geiger -Mullar tubes method and

v. Scintillation counters method.

1. Application in the determination of the mechanism of reactions

a) Photosynthesis reaction :

In photosynthesis, the green plants, when exposed to sunlight, take up CO_2 and H_2O which are converted into sugars and starch. However, at the same time, plants give out oxygen, whether, the oxygen produced by plants originates from CO_2 or from H_2O or from both has been answered by the use of radioactive O^{18} So it is clear that the evolved oxygen comes from water and not from CO_2^{18}. Thus the reaction that takes place in photosynthesis is as follews :

$$6CO_2^{18} + 12H_2O \longrightarrow C_6H_{12}O_6^{18} + O_2 + 6H_2O^{18}$$

b) Ester hydrolysis reaction :

The course of ester hydrolysis can be studied by using stable O^{18} isotope as the labelled atom. The hydrolysis of an ester by water enriched with heavy oxygen is indicated as :

$$R-\overset{\overset{O}{||}}{C}-OR' + HO^*H \rightleftharpoons R-\overset{\overset{O}{||}}{C}-O^*H + R'OH$$

This clearly indicates that the labelled oxygen is present in the acid which proves that the OR' group has been substituted by the OH group in the hydrolytic reaction.

2. Application in Analytical Chemistry

a) Using tracer techniques we can detemine the solubility of sparingly soluble substances like $PbSO_4$ in water. A known quantity of radioactive lead is mixed with ordinary lead in known proportion. The entire amount consisting of radioactive and ordinary lead is dissolved in dilute HNO_3. To this solution dilute H_2SO_4 is added. $PbSO_4$ is precipitated. It is filtered off. The radioactivity of the solution is measured. This gives the amount of radioactive lead in the solution. From the ratio of the two varieties of lead originally taken, the amount of ordinary lead present in solution is calculated. In a similar way the solubility of AgCl in water may be determined.

b) Using tracer techniques we can show that the two sulphur atoms in thiosulphate ion are chemically non equivalent.

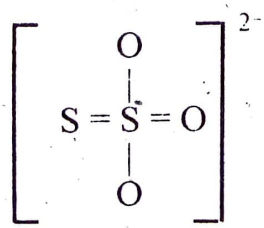
When sulphur is heated in the presence of labelled sulphite ion the thio sulphur ion is produced according to the following reaction :

$$S + S^*O_3^{2-} \rightleftharpoons S^*{}_2O_3^{2-}$$

When this thio sulphate containing a labelled sulphur atom is treated with an acid solution, it breaks down as follows :

$$S^*{}_2O_3^{2-} \rightleftharpoons S^*O_3^{2-} + S$$

This shows that the bonding of the labelled sulphur is NOT affected either in the synthesis or in the decomposition of the thiosulphate. Thus the structure of thio sulphate is as follos :



This shows that the two sulphur atoms in thiosulphate ion are chemically non equivalent.

3. Applications in Medicine

Applications of radio - isotopes in medicine are two fold :

i) For diagnosis of bodily disorders,

ii) Treatment of certain diseases,

For diagnosis :

Fe^{59} is used to diagnose diseases caused by difficiency of red blood cells. ${}_{6}C^{12}$ is used to determine cholesterol content in blood. The functioning of liver, kidneys etc. have been studied using radio isotopes and different diseases have been detected.

For treatment :

Radio active phosphorus in the form of phosphate is used in the treatment of certain blood disorders. Radio active iodine and stable iodine are preferentially absorbed by the thyroid gland. This property is used in destroying abnormal tissues in the thyroid gland. This checks abnormal body growth. Radio active iodine has also been used in locating brain tumours and to determine the extent of their growth Radio cobalt ${}_{27}Co^{60}$ is used to treat deep rooted cancers more efficiently than radium. ${}_{11}Na^{24}$ is used to check the circulation of blood and for working of the heart.

Some of the examples are given below.

Uses of radio isotopes in the treatment of diseases : (Radiotherapy)

The treatment of a disease using radioisotope is called **radiotherapy.** Some of the examples of radiotherapy are given below.

1. Treatment of cancer growth :

Radio cobalt (Co^{60}) and radio gold (Au^{198}) are used in the treatment of cancer.

2. Treatment of hyperthyroidism :

Radio active iodine (I^{131}) is used in the treatment of hypothyroidism and cancer of the thyroid.

3. Treatment of skin disorder :

Radio phosphorus (P^{30}) is used in the treatment of skin disease.

4. Treatment of leukemia : (Blood cancer)

Radio isotope of phosphorus is being used in the treatment of leukemia.

4. Applications in Agriculture :

$_{15}P^{32}$ is incorporated in fertilizers and the rate and the manner of its absorption by plant have been studied. From this study we can determine the proportion of the plant's phorphorus that comes from the soil and the proportion that comes from the fertilizer.

5. Applications in Industry

Radio phosphorus is useful in steel making. To find out whether the phosphorus impurity has been completely removed, some radio phosphorus is added. When radioactivity disappears from the molten steel, we conclude that all the phosphorus has been removed.

The water and tear of engines can be determined by making the metal of the piston rings radioactive. The appearance of radioactivity in engine oil shows that the process of wear and tear of the piston has started.

6. Applications in Scientific research

We can study the kinetics of reactions, complexes, catalysis and various other research operations.

7. Rock-dating-Age of earth

A knowledge of the rate of decay of certain radioactive isotope helps us to determine the age of various rock deposits. Let us consider rock containing U^{238} formed many years ago. The age of this rock can b determined using the following equation.

$$t = \frac{2.303\,T}{0.693} \log\left(1 + \frac{Pb^{206}}{U^{238}}\right)$$

Where t = the age of the rock

T = Half life period of U^{238} (known : 4.5×10^9 years)

Pb^{206} = Amount of Pb^{206} present in the sample in moles

U^{238} = Amount of U^{238} present in the sample in moles

Problem

The ratio of the mass of Pb^{206} in a certain rock apecimen is found t be 0.5. Assuming that rock originally contained no lead, estimate its ag Half life period of $U^{238} = 4.5 \times 10^2$ years.

Solution :

The age of the rock is given by

$$t = \frac{2.303\,T}{0.693} \log\left(1 + \frac{Pb^{206}}{U^{238}}\right)$$

$T = 4.5 \times 10^9$ Years

$$\frac{Pb^{206}}{U^{238}} = 0.5$$

$$t = \frac{2.303 \times 4.5 \times 10^9}{0.693} \log(1 + 0.5) \text{ years}$$

$$= \frac{2.303 \times 4.5 \times 10^9}{0.693} \log 1.5 \text{ years}$$

$$= \frac{2.303 \times 4.5 \times 10^9}{0.693} \times 0.1761 \text{ years}$$

$= 2.63 \times 10^9$ years

Exercise

A sample of uranium ore is found to contain 11.6 g of U^{238} and 10.3 g of Pb^{206} calculate the age of the ore. Half life period of uranium is 4.5×10^9 years.

(*Ans : 4.5×10^9 years; Clue :* The amount of U^{238} and Pb^{206} have been given in grams. Convert them into moles by dividing their weights by their respective mass number and calculate Pb^{206}/U^{238}. This is given. Calculate using the formula.

$$t = \frac{2.303\ T}{0.693} \log \left(1 + \frac{Pb^{206}}{U^{238}}\right)$$

8. Isotopic dilution method

It is an example of radio-metric method of tracer analysis. It is used to determine the quantity of constituent (radio active or non radioactive) in a mixture of closely related compounds which are difficult to separate and to estimate quantitatively by the usual conventional methods.

The method involves the following steps.

i) Let the mass of a given non radio active element, which is to be determined be m. An amount of m of the same compound, isotopically labelled, is added to it. Let the isotopic compound have an activity of S'. The two are mixed thoroughly to obtain an uniform mixture. Now by some suitable method the compound is isolated in a pure form. Now the activity of the compound is measured. Let it be S.

Since the total activity is constant m can be calculated as follows.

$$m = m' \left[\frac{S'}{S} - 1\right]$$

Thus knowing m, S' and S we can calculate m.

Uses :

1. Zn, Cu, Hg and other cations have been determined by this method.
2. This method is used to analyse the mixture of amino acids obtained by hydrolysing proteins outside the body using labelled aminoacids containing N^{15} to act as the tracer

C-14 Dating

The age of a piece of wood or **animal fossil** can be determined by C-14 dating technique. This technique is based on the determination of C^{14}/C^{12} ratio.

Plants take up CO_2 from the atmosphere. The CO_2 in the atmosphere contains a small amount of radioactive C^{14} also. When the plant is alive $_6C^{14}$ decays as follows.

$$_6C^{14} \rightarrow {_7N^{14}} + {_1n^0}$$

(T = 5760 years). But the loss is compensated by taking C^{14} from the atmosphere. So the ratio C^{14}/C^{12} remain always constant. But when the plant dies the ratio $_6C^{14}$ continues to disintegrate. But the loss is not compensated. So C^{14}/C^{12} continuously decreases. Thus by measuring C^{14}/C^{12} and knowing T, the age of the plant can be determined using the formula.

$$t = \frac{2.303\ T}{0.693} \log \left[1 + \frac{\text{Amount of } C^{14} \text{ in fresh wood}}{\text{Amount of } C^{14} \text{ in dead wood}} \right]$$