Chapter-13

NUCLEI

1. Define atomic number and mass number.

Ans: An atom is represented as

$_{z}X^{A}$

A → mass number

Z → Atomic number

Atomic number :-

It is the number of protons in the nucleus. It is denoted by Z.

Mass number

It is the total number of nucleons

Total no. of nucleons = no. of protons + number of neutrons

Mass number is denoted by A.

2. What is the number of neutrons in a nucleus $_{z}X^{A}$?

Ans: A – Z → no. of neutrons

3. Explain the discovery of neutron?

Ans: In 1932 James Chadwick observed the emission of neutral radiation when beryllium nuclei were bombarded with alpha-particles. It was found that this neutral radiation could knock out protons from light nuclei such as those of helium, carbon and nitrogen. Chadwick called the particles of this neutral radiation as neutrons.

The mass of the neutron is,

$m_n = 1.00866u = 1.6749 \times 10^{-27}$kg

A free neutron (unlike a free proton) is unstable. It decays into a proton, an electron and an antineutrino. A free neutron has a mean life of about 1000s. But a neutron is stable inside the nucleus.

Chadwick was awarded the 1935 Nobel Prize in physics for the discovery of neutron.

4. Define atomic mass unit (**amu**)

Ans: It is a smaller unit of mass which is used to express nuclear mass.

One amu is defined as $\frac{1}{12}$ times mass of **C^{12}** atom.

$$1\text{amu} = \frac{1.9992678 \times 10^{-26}\text{kg}}{12}$$

$= 1.660565 \times 10^{-27}$ kg

1amu or 1u = 1.6605×10^{-27}kg

5. Which is the unit used to express the mass of nucleus?

Ans: Mass of the nucleus is expressed in atomic mass unit **amu**

Eg: Mass of C^{12} atom = 12 amu

Mass of Cl atom = 35.47amu

Note:

Mass of proton = 1.00727 u

$= 1.67262 \times 10^{-27}$ kg.

Mass of electron = 0.00055u

$= 9.1 \times 10^{-31}$kg The

mass of the neutron = 1.00866u

$= 1.6749 \times 10^{-27}$kg

6. What are isotopes, isobars and isotones?

Ans: **Isotopes** are the atoms of the same element having different mass numbers.

Eg: $_{6}C^{12}$, $_{6}C^{14}$

$_{1}H^{1}$, $_{1}H^{2}$, $_{1}H^{3}$

$_{1}H^{1}$ – protium

$_{1}H^{2}$ – deuterium

$_{1}H^{3}$ – tritium

Isobars are the atoms of different elements having same mass numbers.

Eg: $_{1}H^{3}$ and $_{2}He^{3}$

$_{6}C^{14}$ and $_{7}N^{14}$

Isotones are the atoms with same number of neutrons

Eg: $_{80}Hg^{198}$ and $_{79}Au^{197}$ ⇒ no.of neutrons = 118

$_{1}H^{3}$ and $_{2}He^{4}$ ⇒ no. of neutrons = 2

7. Derive the relation between the radius (Size) of the nucleus and mass number.

Ans: The volume of the nucleus is proportional to the mass number.

$\frac{4}{3}\pi R^3 \alpha A$

R - radius of the nucleus

$\Rightarrow R^3 \alpha A$

$R \alpha A^{\frac{1}{3}}$

$R = R_0 A^{\frac{1}{3}}$

R_0 = a constant = 1.2×10^{-15}m

= 1.2 fm

fm → femto meter

$\mathbf{R = R_0} A^{\frac{1}{3}}$

8. Calculate the density of nucleus

Ans: density $= \frac{\text{mass}}{\text{volume}}$

$$= \frac{1.6605 \times 10^{-27} A}{\frac{4}{3}\pi R^3}$$

$$= \frac{1.6605 \times 10^{-27} \times A}{\frac{4}{3}\pi (R_0 A^{\frac{1}{3}})^3}$$

$$= \frac{1.6605 \times 10^{-27} \times \cancel{A}}{\frac{4}{3}\pi R_0^3 \cancel{A}}$$

$$= \mathbf{2.3 \times 10^{17}\ kg/m^3}$$

Density of nucleus = $\mathbf{2.3 \times 10^{17}\ kg/m^3}$

<u>Note1:</u> Density of nucleus is independent of nuclear size or density of all nuclei is the same.

<u>Note 2:</u> The density of matter in neutron stars is comparable to this density. So neutron star resemble a big nucleus.

9. Give Einstein's Mass – Energy relation?

Ans: Einstein showed that mass and energy are equivalent. Mass is another form of energy. Mass energy can be converted into other forms of energy. The famous mass energy equivalence relation is

$\mathbf{E = mc^2}$

c = velocity of light in vacuum.

$= 3 \times 10^8$ m/s.

10. Find the energy equivalent of one amu.

Ans: $E = mc^2$

$= 1.6605 \times 10^{-27} \times (2.9979 \times 10^8)^2$

$= 1.6605 \times 10^{-27} \times 2.9979^2 \times 10^{16}$

$= 14.923585 \times 10^{-11}$ J

$= \frac{14.9235855 \times 10^{-11}}{1.602 \times 10^{-19}}$ eV

$= 931.5 \times 10^6$ eV

= 931.5 MeV

MeV – Million electron volt

$1\text{eV} = 1.6 \times 10^{-19}$J

1amu mass is equivalent to 931.5 MeV energy

11. What is mass defect?

Ans: Mass defect is the difference between total mass of the nucleons and actual mass of the nucleus.

$\Delta m = [Zm_p + (A - Z)\, m_n] - M$

Z – atomic number

A – mass number

m_p – mass of proton

m_n – mass of neutron

M – Actual mass of nucleus

12. Define binding energy of a nucleus

Ans: BE is the energy equivalent to mass defect

BE can also be defined as ***the average energy needed to separate a nucleus into its individual nucleons.***

$E_b = \Delta M \times 931.5$ MeV

13. Define Binding energy per nucleon (E_{bn})

Ans: Binding energy per nucleon

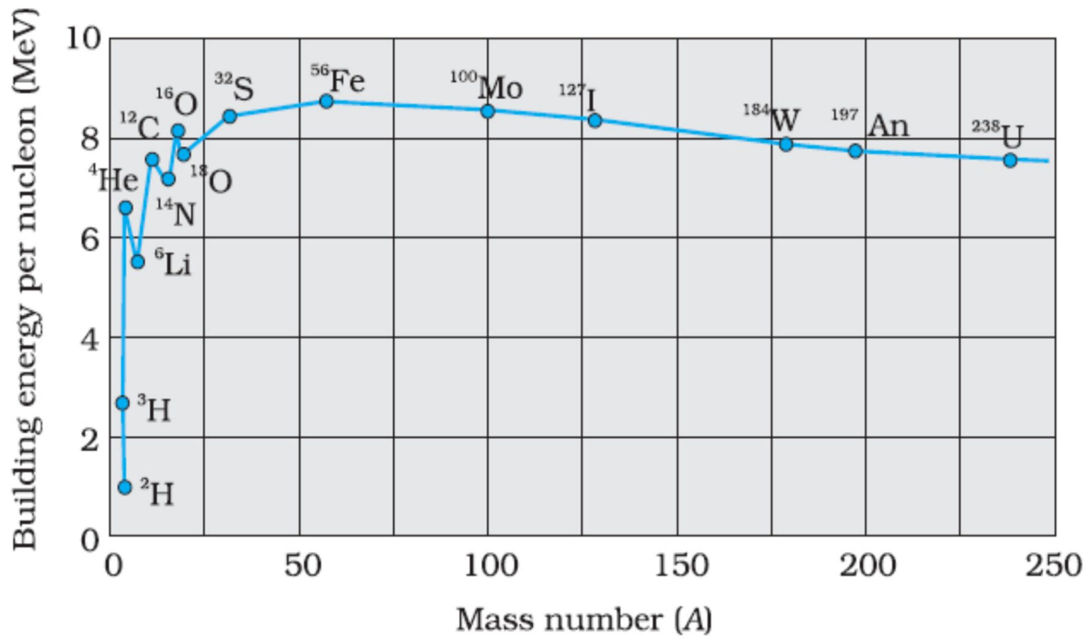
$$E_{bn} = \frac{\text{Binding energy}}{\text{mass number}}$$

$$= \frac{E_b}{A}$$

14. What is the significance of BE per nucleon?

Ans: The greater the binding energy per nucleon the more stable is the nucleus.

15. Plot the BE curve.



Ans:

Analysis of the graph

i) For nuclei of middle mass number (**30<A<170**), binding energy per nucleon is a constant (about 8MeV)
ii) Binding energy per nucleon is lower for both light nuclei (A<30) and heavy nuclei (A>170).
iii) Binding energy per nucleon is maximum for A=56, about 8.75MeV.

16. Explain **nuclear fusion** and **nuclear fission** on the basis of B.E. curve

Ans: From the binding energy curve, it is obvious that the lighter nuclei have low binding energy per nucleon and hence low stability. Therefore they combine to form heavier nucleus, thereby increasing binding energy per nucleon and stability. This process is called nuclear fusion.

The heavier elements like uranium have low binding energy per nucleon and hence low stability. Therefore they split into lighter nuclei, thereby increasing the binding energy and stability. This process is called nuclear fission.

17. Explain why the BE per nucleon is constant in the range **30<A<170**

Ans: Consider a particular nucleon inside a sufficiently large nucleus. Since the nuclear force is short ranged it will be under the influence of only some of its neighbours. If any other nucleon is at a distance more than the range of nuclear force from the particular nucleon it will have no influence on the binding energy of the nucleon under consideration.

18. What is meant by nuclear force? Give the characteristics of nuclear force.

Ans: The strong force which binds the nucleons in a nucleus is called the nuclear force.

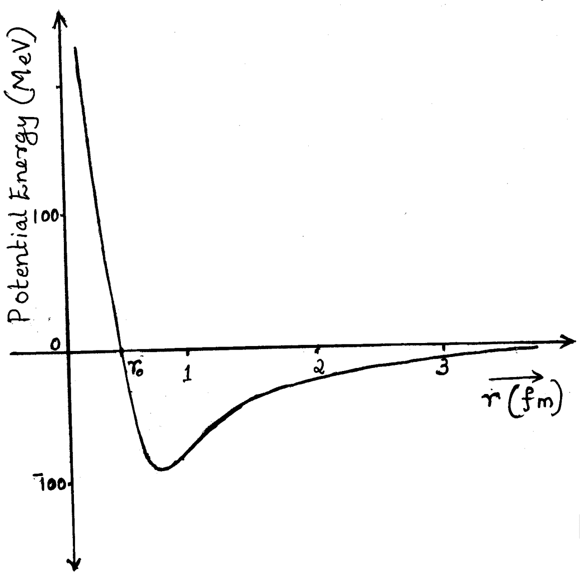
<u>Characteristics of nuclear force</u>

i) It is the strongest force existing in nature. It is 10^{38} times stronger than gravitational force.
ii) It is a short range force.
iii) Nuclear force is charge independent and mass independent. The force between two protons, two neutrons, a

proton and a neutron are of equal strength.

19. Draw the graph showing the variation of potential energy of two nucleons with the distance of separations between them. Also mark the regions of attraction and repulsion

Ans:



Analysis of the graph

i) If r > 3fm, PE is very small and force of attraction is negligible.

ii) If r is between $r_0$fm and 3 fm, PE is negative and hence nuclear force is attractive.

iii) If r is less than r_0 fm, PE become positive and hence the force becomes repulsive.

20. What is meant by radioactivity? Who discovered it?

Ans: A.H. Becquerel discovered radio activity in 1896.

Radioactivity is the spontaneous disintegration of heavy nucleus by emitting radiations.

Eg: Ra, V, Th etc show natural radioactivity.

21. Which are the three types of radioactive decay?

Ans: Three types of radioactive decay occurring in nature are:

i) α-decay in which a helium nucleus $_2He^4$ is emitted.

ii) β - decay in which electrons or positrons are emitted.

iii) γ - decay in which high energy photons are emitted.

22. What are positrons?

Ans: Positrons are particles with the same mass of electrons, but with a charge exactly opposite to that of electron.

23. State the law of radioactive decay

Ans: It states that "***the rate of disintegration at any instant of time is directly proportional to the number of radioactive atoms present in the sample at that instant***".

$$\frac{dN}{dt} \propto N$$

24. Derive the relation to find no. of atoms present at any instant of disintegration t

Or

Derive the relation **$N = N_0e^{-\lambda t}$**

Ans: From decay law,

$$\frac{dN}{dt} \propto N$$

$$\frac{dN}{dt} = -\lambda N$$, λ is the disintegration constant or decay constant

$$\frac{dN}{N} = -\lambda dt$$

Integrating both sides,

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt$$

$$\Rightarrow [\log \mathbf{N}]_{N_0}^{N} = -\lambda[\mathbf{t}]_0^t$$

$$\Rightarrow \log N - \log N_0 = -\lambda[t - 0]$$

$$\Rightarrow \log \frac{N}{N_0} = -\lambda t$$

Taking exponential on both sides

$$e^{\log\left[\frac{N}{N_0}\right]} = e^{-\lambda t}$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$\Rightarrow \mathbf{N = N_0\, e^{-\lambda t}}$$

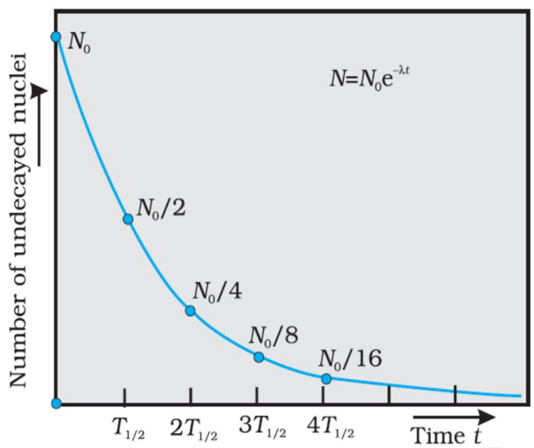
$e^{\log x} = x$

$\log e^x = x$

N → no. of atoms at any instant

N_0 → Initial no. of atoms

25. Draw a graph showing the variation of number of particles left with time



Ans:

26. Define activity

Ans: Activity R is defined as,

$$\mathbf{R} = \frac{-dN}{dt}$$

It is the total decay rate which means the number of nuclei disintegrating per unit time.

By decay law we have

$$\frac{dN}{dt} = -\lambda N$$

$$\therefore R = -\frac{dN}{dt} = \lambda N$$

$$\mathbf{R = \lambda N}$$

SI unit of activity is Becquerel.

1 **Becquerel** (1Bq) means one disintegration per second.

Another unit of activity is **curie** (Ci)

1 curie = 3.7×10^{10} decays per second

$= 3.7 \times 10^{10}$Bq.

27. Define Half life period (**$T_{½}$**). Derive the relation for half life period.

Ans: It is the time taken by any radioactive material to disintegrate half its original amount.

We have $N = N_0e^{-\lambda t}$ …….. (1)

When $t = T_{½}$, $N = \frac{N_0}{2}$

$$\therefore \text{eqn (1)} \rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}}$$

$$\frac{1}{2} = e^{-\lambda T_{1/2}}$$

Taking reciprocal

$$2 = e^{\lambda T_{½}}$$

$$\log_e \mathbf{2} = \boldsymbol{\lambda} \mathbf{T_{1/2}}$$

$$\therefore \mathbf{T_{1/2}} = \frac{\log_e \mathbf{2}}{\boldsymbol{\lambda}}$$

$$T_{½} = \frac{2.303 \times \log_{10} 2}{\lambda}$$

$$T_{1/2} = \frac{0.693}{\lambda}$$

λ → decay constant

28. Define average life of mean life (τ). Derive an equation for mean life

Ans: ***It is the time taken for the radioactive sample to disintegrate to $\frac{1}{e}$ times the initial amount.***

We have $N = N_0e^{-\lambda t}$ ……….. (1)

When $t = \tau$, $N = \frac{1}{e}N_0$

$$\therefore (1) \rightarrow \frac{1}{e}N_0 = N_0e^{-\lambda \tau}$$

$$\frac{1}{e} = e^{-\lambda \tau}$$

$$\Rightarrow \frac{1}{e} = \frac{1}{e^{\lambda \tau}}$$

Taking reciprocal

$$e = e^{\lambda \tau}$$

$$\Rightarrow 1 = \lambda \tau$$

$$\Rightarrow \tau = \frac{1}{\lambda}$$

29. Derive the relation between τ and $T_{½}$

Ans: We have $T_{1/2} = \frac{0.693}{\lambda}$

but $\lambda = \frac{1}{\tau}$

$$\therefore T_{1/2} = \frac{0.693}{\frac{1}{\tau}} = 0.693\tau$$

$$T_{½} = 0.693\tau$$

30. Explain alpha decay

Ans: The general representation of α – decay is

$_{Z}X^{A} \rightarrow {}_{Z-2}Y^{A-4} + {}_{2}He^{4}$ + energy

Eg: $_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4}$ + energy

$_{2}He^{4}$-the helium nucleus is the α particle.

The total mass of the decay products is less than the mass of the parent nucleus. This difference in mass appears as the kinetic energy of the products.

The disintegration energy or Q-value

$Q = (m_x - m_y - m_{He})c^2$

<u>**Note**</u> : When a nucleus emits α – particle the **mass number decreases by 4 and the atomic number decreases by 2**. Thus the element shifts two places to the left in the periodic table.

31. Explain beta decay

Ans: In beta decay a nucleus spontaneously emits an electron (β^- decay) or a positron (β^+ decay)

<u>**β^- decay**</u>

β^- particle = electron

General representation of β^- decay is

$_{Z}X^{A} \rightarrow {}_{Z+1}Y^{A} + e^{-} + \bar{\upsilon}$ + energy

A common example of β^- decay is

$_{15}P^{32} \rightarrow {}_{16}S^{32} + e^{-} + \bar{\upsilon}$ + energy

32. How β^- decay occurs?

Ans: At the time of **β^- decay** a neutron in the nucleus splits into proton, electron and antineutrino. The electron and antineutrino come out of the nucleus. This electron is called β^- particle. The proton remains inside the nucleus. Therefore, the atomic number increases by one and there is no change in the mass number.

$n \rightarrow p + e^{-} + \bar{\upsilon}$

33. How β^+ decay occurs?

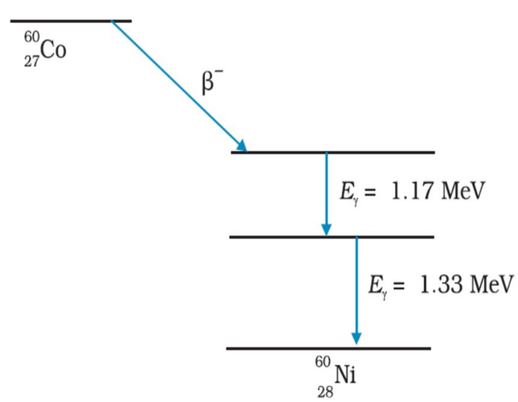
Ans: At the time of **β^+ decay** a proton a in the nucleus splits into, neutron positron and neutrino. The positron and neutrino come out of the nucleus. This positron is called β^+ particle. The neutron remains inside the nucleus. Therefore, the atomic number decreases by one and there is no change in the mass number.

$p \rightarrow n + e^{+} + \upsilon$

34. Explain gamma decay

Ans: Like an atom, a nucleus has discrete energy levels – the ground state and the excited states. The atomic energy level spacings are of the order of **eV**, while difference in nuclear energy levels is of the order of **MeV**.

After the emission of an **α** or a **β** particle, the nucleus will be in an excited state. Then the nucleus returns to the ground state by the emission of single gamma photon or by successive emissions of more than one gamma photons.



A familiar example is the successive emission of gamma rays of energies **1.17MeV** and **1.33 MeV** in the de-excitation of ${}_{28}Ni^{60}$ nuclei formed from β^- decay of ${}_{27}Co^{60}$.

35. Compare the energy released in nuclear reactions with that in chemical reactions

Ans: Both in nuclear fission and fusion energy is emitted. In a nuclear reaction, the energy release is of the order of **MeV**. A nuclear reaction produces a million times more energy than an exothermic chemical reaction (like combustion of petroleum or coal). Fission of 1kg of uranium generates 10^{14}J of energy while burning of 1kg of coal gives only 10^7J.

36. What is artificial radioactivity?

Ans: A nucleus which is not naturally radioactive can be made into radioactive by bombarding it with other nuclear particles such as proton, neutron, α-particle etc. This is called artificial radio activity. This was discovered by Rutherford.

37. Explain **nuclear fission**

Ans: In nuclear fission a heavier nucleus when bombarded with neutron splits into two or more lighter nuclei, with the emission of large amount of energy.

Eg:

${}_0n^1 + {}_{92}U^{235} \rightarrow {}_{92}U^{236} \rightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89} + 3\,{}_0n^1$

The same reaction can produce other pairs of intermediate fragments.

The energy released (the Q – value) in the fission reaction of nuclei like uranium is of the order of **200MeV** per fissioning nucleus.

The disintegration energy in fission first appears as the kinetic energy of the fragments and neutrons. Then it is transferred to the surrounding matter appearing as heat.

Nuclear Reactor

38. What is **chain reaction**?

Ans: Self sustained nuclear reaction is called chain reaction.

Controlled chain reaction is the source of energy in **nuclear reactors**.

Uncontrolled chain reaction produces enormous energy in **atom bombs**.

39. What is the use of a nuclear reactor?

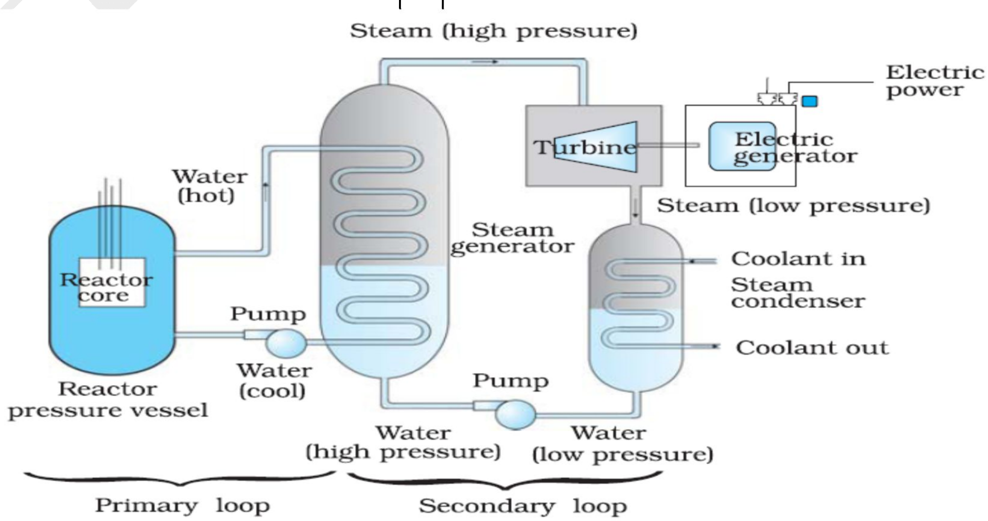
Ans: Nuclear reactors are used to produce electrical energy.

40. Explain the construction and working of **nuclear reactor**

Ans:

Controlled & self-sustained nuclear fission is the source of energy in nuclear reactors.

Construction and working



The main components of a nuclear reactor are the following:

i) **Core**
The core of the reactor is the site of nuclear fission

ii) **Fissionable material**
The core of the reactor contains the fuel elements in suitably fabricated form. **Nuclear fuel** is Uranium 235. In some reactors, Plutonium 239 is also used. Fissionable material is sealed in aluminium cylinders. These cylinders are inserted in the holes drilled in carbon blocks.

iii) **Source of neutrons**
Beryllium and polonium powder are used as neutrons source.

iv) **Moderator**
The moderator is the material which is used to slow down the neutrons produced by nuclear fission.
Graphite and heavy water (D_2O) are used as moderator

v) **Control rods**
The control rods are used to absorb neutrons without suffering disintegration.
Cadmium and boron are used as control rods.

vi) **Coolant**
It is the material which is used to absorb heat generated in a reactor.
Liquid sodium and heavy water are the most commonly used coolants.
The coolant transfers this heat energy into water. This water turns to high pressure steam. This steam is used to run the turbine.

vii) **Shield**
Shield is generally made of thick massive concrete. It can be 10m thick. Shield is to prevent the radiations from coming out of the reactor.

41. What is the use of moderator in a nuclear reactor?

Ans: The average energy of a neutron produced in fission of $_{92}U^{235}$ is 2MeV. These fast neutrons liberated in fission would escape instead of causing another fission reaction. So they are to be slowed down.

42. Explain the term multiplication factor (K) in a reactor.

Ans: Multiplication factor (K) is the ratio of number of fissions produced in a given generation of neutrons to the number of fissions of the preceding generation. It is the measure of growth rate of neutrons in a reaction. For K = 1, the operation of the reactor is said to be critical. This is needed for a steady power operation. Unless the factor K is brought down very close to-unity, the reactor may explode.

In addition to control rods reactors are provided with safety rods which, when required, can be inserted into the reactor and 'K' can be reduced rapidly to less than unity.

43. Protons are not used to trigger nuclear fission. Why?

Ans. Protons are positively charged particles. Hence they experience repulsion from the target nucleus. So very high energy is needed for a proton to make a collision with a target nucleus.

44. Neutrons are commonly used to trigger nuclear fission. Why?

Ans: Since neutrons are uncharged particles, do not experience any repulsion from the target nucleus. So they need very less amount of energy to collide with the target nucleus.

Nuclear Fusion

45. What is source of energy of stars?

Ans: Nuclear fusion

46. Explain nuclear fusion

Ans: In nuclear fusion, when two light nuclei fuse to form a larger nucleus, energy is released.

Some examples of nuclear fusion reactions are:

$_1H^1 + {_1H^1} \rightarrow {_1H^2} + e^+ + \upsilon + 0.42MeV$

$_1H^2 + {_1H^2} \rightarrow {_2H^3} + n + 3.27MeV$

47. Fusion is called a thermonuclear reaction. Why?

Ans: Nuclear fusion occurs at very high temperatures (~ 10^9K) only. So it is called thermonuclear reaction.

48. Why fusion occurs at very high temperature only?

Ans: When two nuclei come closer they should have enough energy to overcome the coulombic repulsion barrier. The nuclei get enough kinetic energy to overcome the coulombic repulsion at very high temperatures (~ 10^9K) only.

49. Explain the nuclear fusion in sun.

Ans: The fusion reaction in the sun is a multistep process in which the hydrogen is burnt into helium. This process is called **proton-proton** cycle. The following are the steps of proton-proton cycles.

$_1H^1 + {_1H^1} \rightarrow {_1H^2} + e^+ + \upsilon + 0.42MeV$………(1)

$e^+ + e^- \rightarrow \gamma + \gamma + 1.02$ MeV …. (2)

$_1H^2 + {_1H^1} \rightarrow {_2He^3} + \gamma + 5.49MeV$ ….. (3)

$_2He^3 + {_2He^3} \rightarrow {_2He^4} + {_1H^1} + {_1H^1} + 12.86MeV$. (4)

For the forth reaction to occur the 1st three reactions must occur twice.

2 × (1) + 2 × (2) + 2 × (3) + (4) → $4\,{_1H^1} + 2e^- \rightarrow {_2He^4} + 2\upsilon + 6\gamma + 26.7$ MeV.

Thus in p-p cycle, four hydrogen atoms combine to form an $_2He^4$ atom with a release of 26.7 MeV of energy.

In a star, when hydrogen in the core gets completely depleted the carbon cycle may start. In carbon cycle Helium nuclei combine to form carbon.

The age of the sun is about 5×10^9 y and it is estimated that there is enough hydrogen in the sun to keep it going for another 5 billion years. After it the sun may become a red giant.

50. Is nuclear fusion controllable? Explain

Ans: Nuclear fusion cannot be controlled at present. Experiments are going on to make nuclear fusion controllable and use it to generate steady power. But the main challenge is to confine the fuel in the plasma state, since no container can with stand such a high temperature.

If successful, fusion reactors will hopefully supply almost unlimited power to humanity.

Problems

m_H = 1.007825 u	m_n = 1.008665 u
$m(^4_2He)$ = 4.002603 u	m_e = 0.000548 u

1. Obtain the binding energy (in MeV) of a nitrogen nucleus $(^{14}_7N)$, given $m(^{14}_7N)$ = 14.00307u

2. Obtain the binding energy of nuclei $(^{56}_{26}Fe)$ and $(^{209}_{83}Bi)$ in units of MeV from the following data:
   $m(^{56}_{26}Fe)$ = 55.934939 u
   $m(^{209}_{83}Bi)$ = 208.980388 u

3. Calculate the binding energy per nucleon of $^{40}_{20}Ca$ nucleus. Given mass of $^{40}_{20}Ca$ =39.962589 u
1u=931MeV/c^2

4. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split in to two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV.

5. Calculate the amount of energy released during the alpha decay of $^{238}_{92}U \to ^{234}_{90}Th + ^{4}_{2}He$
Given :

Atomic mass of $^{238}_{92}U$ =238.05079 u

Atomic mass of $^{234}_{90}Th$ =234.04363 u

Atomic mass of $^{4}_{2}He$ =4.00260 u

1 u=931.5MeV/c^2

6. (a) In the following nuclear fission reaction, N is the number of neutrons released. What is the value of N?
$$^{235}_{92}U + ^{1}_{0}n \to ^{94}_{38}Sr + ^{140}_{54}Xe + N$$
(b) Complete the following nuclear reaction equation.
$$^{9}_{4}Be + ^{4}_{2}He \to ^{1}_{0}n + ...$$
(c) Two nuclei have mass numbers in the ratio 1:8. What is the ratio of their nuclear radii?

7. Write down the similarities and dissimilarities between nuclear fission and nuclear fusion.

8. For a nuclear reaction given with masses of nuclei P, Q, R and S taking part in it is given below
(1amu=931MeV)
$$\underset{(1.003amu)}{P} + \underset{(1.004amu)}{Q} \longrightarrow \underset{(1.002amu)}{R} + \underset{(1.0025amu)}{S} + Energy$$
How much energy is released by the reaction in MeV?

9. The half life of Radon is 3.8 days.
(a) Define half-life
(b) Calculate how much of 15mg of Radon will remain after 14.2 days.

10. After 1 hour, 1/8 of the initial mass of a certain radioactive isotope remains undecayed. What is the half-life of the isotope?