UNIT 18

ATOMIC AND NUCLEAR PHYSICS

After studying this unit, the students will be able to:

a. Describe the structure of an atom in terms of a nucleus and electrons,
b. Describe the composition of the nucleus in terms of protons and neutrons.
c. Explain that number of protons in a nucleus distinguishes one element from the other
d. Represent various nuclides by using the symbol of proton numbers z nucleon number
e. A and the nuclide notation x.
f. Explain that some nuclei are unstable, give out radiation to get rid of excess energy and are said to be radioactive.
g. Describe that the three types of radiation are α, β, γ
h. State, for radioactive emissions:
i. Their nature
j. Their relative ionizing effects.
k. Their relative penetrating abilities.
l. Explain that an element may change into another element when

radioactivity occurs

- **m.** Represent changes in the composition of the nucleus by symbolic equations when alpha or beta particles are emitted.
- **n.** Describe that radioactive emissions occur randomly over space and time.
- **o.** Explain the meaning of half-life of a radioactive material.

- **p.** Describe what are radioisotopes. What makes them useful for various applications?
- **q.** Describe briefly the processes of fission and fusion.
- **r.** Show an awareness of the existence of background radiation and its sources.
- **s.** Describe the process of carbon dating of estimate the age of ancient objects.
- **t.** Describe hazards of radioactive materials.

Q.1 Differentiate between atomic number and atomic mass?

Answer

Atomic number

"The number of protons in the nucleus is called atomic number. It is written by the symbol 'Z'."

Number of neutrons in the nucleus is called neutron number, written by the symbol N.

For your understanding
The word atom is derived from the Greek work "otomos", meaning "indivisible". At one time, atoms were thought to be the smallest particles of matter. Today we know that atoms are composite systems and contain even smaller particles; protons, neutrons and electons.

Atomic mass number

"Number of nucleons (protons + neutrons) in the nucleus is called atomic mass number."

The term "nucleons" means protons and neutrons collectively in the nucleus.

Isotopes

"Isotopes are atoms of an element which have same number of protons but different number of neutrons in their nuclei." Three isotopes of hydrogen are shown in the figure 18.2.

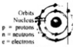


Fig. 18.1 The nucleus of an atom consists of protons and neutrons.

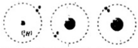


Fig.18.2 Three isotopes of hydrogen
Protium (^1_1H), Deutrium (^2_1H) and Tritium (^3_1H)

1) Protium (^1_1H) contains one proton in the nucleus and one electron revolving around the nucleus.

2) Deuterium (^2_1H) contains one proton, one neutron and one electron.

3) Tritium (^3_1H) contains one proton, two neutrons and one electron.

Q.2 What do you mean by the term (natural) radioactivity?

Answer

Natural Radioactivity

“The spontaneous emission of radiation by unstable nuclei is called natural radioactivity.”

The elements which emit such radiations are called radioactive elements.

Explanation

In 1896, Becquerel accidently discovered that uranium salt crystals emit an invisible radiation that can darken a photographic plate. He also observed that the radiation had the ability to ionize a gas.

Subsequent experiments by other scientist showed that other substances also emitted radiations.

Do you know?
The positively charged protons in a nucleus have huge electrical forces of repulsion between them. Why don't they fly apart in response to this force? Because there is an attractive force between the nucleons called the strong force. This force acts over only a very short distance. Without this strong nuclear force there would be no atoms beyond hydrogen.

Marie Curie and Pierre discovered two new elements called Polonium" and “radium.”

Decay process

“Emission of radiations due to disintegration of unstable nuclei 15 called decay process.”

Three types of radiations are usually emitted by a radioactive substance. They are: alpha (α) particles beta (β) particles; and gamma (γ) rays.

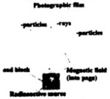


Fig. 18.3: Three types of radiations can be distinguished from their path followed in an external magnetic field

The radiation emitting from the radioactive source splits into three components when placed in a magnetic field, α and β radiations bend in opposite direction while γ radiations does not change its direction in the magnetic field.

Q.3 What are background radiations?

Answer

Background radiations

“Radiations present in atmosphere due to different radioactive substances are called background radiations.”

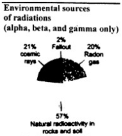


Fig. 18.4: The sources of background radiation from the enviornment

Everywhere in rocks, soil water, and air of our planet are traces of radioactive elements. This natural radioactivity is called the background radiations.

It is as much part of our environment as sunshine and rain. Fortunately, our bodies can tolerate it. Only places where radiation is very high can be injurious to health

Cosmic radiations

"The earth, and all living things on it also receive radiation from outer space. This radiation is called Cosmic radiation."

Cosmic radiation primarily consists of protons, electrons, alpha particles and larger nuclei. The cosmic radiation interacts with atoms in the atmosphere to create shower of secondary radiation, including X-rays, muons, protons, alpha particles, electrons, and neutrons.

Q.4 What are the three basic radioactive decay processes and how do they differ from each other?

Answer

Nuclear transmutation

"The spontaneous process in which 'a parent unstable changes into a more stable daughter nuclide with the emission of radiations is called transmutation." Radioactive decay can be in the form of equation in which an unstable parent nuclide X changes into a daughter nuclide Y with the emission of an alpha particle or gamma particle.

Physics Insight
When alpha and beta particles are slowed down by collisions they become harmless, in fact, they combine to form neutral helium atoms.

For your information
The SI unit of radioactivity is the Becquerel, Bq. In SI base units, 1 Bq = 1disintegration per second (dps). This is very small unit. For example, 1.0 g of radium has an activity of 3.7 × 10^{10} Bq. Therefore, the kilobecquerel (kBq) and the megabecqurel (MBq) are commonly used. The acitivity of 1.0 g of radium is 3.73 × 10^4 MBq.

Alpha (a) decay

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

(parent nuclide) (daughter nuclide) (alpha nuclide)

Example ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He + energy$

(radium) (radon)

It means in 'alpha decay, the proton number or atomic number Z of the parent nuclide reduces by 2 and its mass number or nucleon number A decreases by 4.

Beta (β) -decay

General equation: ${}^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y + {}^{0}_{-1}e + energy$

(parent nuclide) (daughter nuclide) (alpha nuclide)

Example

$${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e + energy$$
$$(carbon)(nitrogen)(betaparticle)$$

In beta (β) decay, the parent nuclide has its proton number Z increased by I, but its mass number or nucleon number A remains unchanged.

3) Gamma (y) –decay

Example ${}^{A}_{Z}X \rightarrow {}^{A}_{Z}X + \gamma + energy$

(parent nuclide) (daughter nuclide) (gama rays)

Example

$${}^{60}_{27}CO \rightarrow {}^{60}_{27}CO + {}^{0}_{0}\gamma + energy$$
$$(cobalt)(cobalt)(gamma, rays)$$

Gamma rays are usually emitted at the same moment as either an alpha or beta particle, is emitted.

Q.5 Describe the nature and properties of radioactive radiations?

Answer

Nature of radiations

1) Alpha particle is a helium nucleus comprising of two protons and two neutrons with a charge of 26.

An unstable nucleus with large protons and neutrons may decay by emitting alpha radiations

2) Beta radiation is a stream of high energy electrons.

An unstable nucleus with excess of neutrons may eject beta radiations.

3) Gamma radiations are fast moving light photons.

They are electromagnetic radiations of very high frequency emitted by unstable excited nuclei.

Properties of radiations

I) Ionizing effect

The phenomenon by' which radiations split matter into positive and negative ions is called ionization All three kinds of radiations i.e. Alpha, beta and gamma can ionize the matter.

However alpha particles have the greatest power of ionizations compared to beta particles and gamma rays.

It is due to large positive charge and large mass of alpha particles. Beta particles ionize a gas much less than alpha particles do. The ionization power of gamma rays is even less than that of beta particles Ionization of three radiations in gas is shown in figure 18.5.

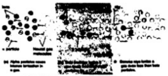


Fig 18.5 Ionization effect of radiations in gas

For your information
i) Nuclear radiation is measured in unit of roentgen equivalent mean (rem) i.e., unit of equivalent dose.
ii) Patient should be exposed to X-rays with the limit of 0.1 to 1.0 rem.
iii. Safe limit of radiation exposure is 5.0 rem per year.

Characteristics of Radiations
Alpha (α) Particles
Positively charged particles (helium nuclei) ejected at high speed with a range of only a few centimetres in air. They can be stopped by an ordinary sheet of thin aluminium foil.

Penetrating ability

The strength of radiations to penetrate a certain material is called penetrating power.

The alpha particles have the shortest range because of its strong interacting or ionizing power.

I) The gamma rays can penetrate a considerable thickness of wavelength. Their concrete. It is due to their large speed and neutral nature wavelengths and

2) The beta radiations strongly interact with matter due its energies charge and has short range as compared to gamma radiations.

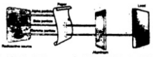


Fig. 18.6: Penetrating power of radiations in different materials

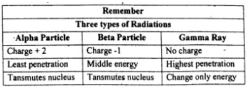
3) Alpha particle has range of only a few centimeters in air. Beta particles have range of several meters in air. However, gamma rays have a range of several hundred meters in air.

Q.6 What do you understand by half-Life of a radioactive element?

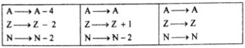
Answer

Half-life and its measurement

"The time during which half of the unstable radioactive nuclei disintegrate is called the half-life of the sample of radioactive element."



Remember		
Three types of Radiations		
Alpha Particle	**Beta Particle**	**Gamma Ray**
Charge + 2	Charge -1	No charge
Least penetration	Middle energy	Highest penetration
Tansmutes nucleus	Tansmutes nucleus	Change only energy

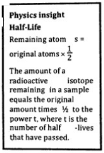


A ⟶ A − 4	A ⟶ A	A ⟶ A
Z ⟶ Z − 2	Z ⟶ Z + 1	Z ⟶ Z
N ⟶ N − 2	N ⟶ N − 2	N ⟶ N

Measurement

Process of radio activity is random and the rate of radioactive decay is proportional to the number of unstable nuclei present.

In the process, a constant fraction of large number of unstable radioactive nuclei decays in a certain time. So, the life time of the unstable nuclei is unlimited and is difficult to measure. Every radioactive element has its own characteristic half—life.



Physics insight

Half-Life

Remaining atoms = original atoms × $\frac{1}{2}$

The amount of a radioactive isotope remaining in a sample equals the original amount times ½ to the power t, where t is the number of half -lives that have passed.

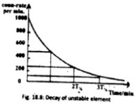


Fig. 18.8: Decay of unstable element

For example, radium -226 has a half-life of 1620 years, which means that half of a radium -226 sample will be converted to other elements by the end of 1620 years. In the next 1620 years, half of the remaining radium will decay, leaving only one-fourth the original amount of radium. If the half-life of the radioactive element is Tm.

Then at the end of this time the number of atoms in the sample will become half i.e. 1/2.

Two half-Lives Don't Make a Whole Life!
A half-life is the time a radioactive element takes for half of a given number of nuclie to decay. During a second half-life, half of the remaining nuclei decay, so in two half-lives, three-quarters of the original material has decayed, to all of it.

After a time 2 $T_{1/2}$ i.e. after second half life period, the number of remaining atoms will become 1/2, 1/2= $(1/2)^2$ =1/4, after a time 3$T_{1/2}$, the number of remaining atoms will be 1/2, 1/2 , 1/2= $(1/2)^2$ = 1/8 and at the end of 't' half-lives number of atoms that remain will be $1/2^t$

$N = N_o \times 1/2^t$

It means that if No is the original number of atoms in the sample of radioactive element, then after 't' half-lives number of atoms left in the sample can be determined by using the relation,

The process of radioactivity does not depend upon the chemical combinations or reactions.

It is also not affected by any change in physical conditions like temperature, pressure, electric or magnetic fields.

Q.7 What are the radioisotopes?

Answer

Radioisotopes

"The stable and non-radioactive elements can also be changed into radioactive elements by bombarding them with protons, neutrons or alpha particles. Such artificially produced radioactive elements are called radioactive isotopes or radio isotopes.

Few examples of production of radio isotopes are given below;

$^{1}_{0}n + ^{23}_{11}Na \rightarrow ^{24}_{11}Na + gamma(\gamma) - rays$

(neutron) (stable (a sodium radioisotope)

Sodium

Nuclide)

$^{4}_{2}He + ^{27}_{13}Al \rightarrow ^{30}_{15}P + ^{1}_{0}n$

(alpha (stable aluminum nuclide) (a phosphorous radioisotope)

Particle

Q.8 Describe two uses of radioisotopes in medicine, industry or research?

Answer

Uses of radioisotopes: 1: Traces

Radioactive tracers are chemical compounds containing some quantity of radioisotopes. They can be used to explore the metabolism of chemical reactions inside the human body, animals or plants.

Radioisotopes are used as tracers in medicine, industry and agriculture. For example:

1) Radio iodine-131 readily accumulates in thyroid gland and can be used for of thyroid functioning.

Fig. 18.9: To check the action of fertilizer researchers combine a small amount of radioactive material with the fertilizer and then apply the combination to a few plants. The amount radioactive fertilizer taken up by the plants can be easily measured with radiation detectors.

2) For the diagnosis of brain tumor phosphorous —32 can be easily measured with is used. The malignant part of the body absorbs radium more quantity of isotopes, and this helps in tracing the affected part of the body.

3) In industry tracers can be used to locate the wear and tear of the moving parts of the machinery.

4) They can be used for the location of leaks in underground pipes. By introducing a suitable radioactive tracer into pipe, the leak can be conveniently traced from higher activity in the region of crack in the pipe.

5) In agriculture radio phosphorous —32 is used as tracer to find out how well the plants are absorbing the phosphate fertilizer which are crucial to their growth.

Radiation Treatment

Gamma radiations destroy both cancerous cells and healthy cells Therefore, the beam of radiations mut be directed only at cancerous cells

For your Information

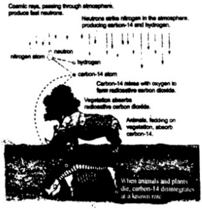
During brain radiotherapy patient is carefully positioned in the helmet to ensure that the gamma rays coverage at the desired point in the brain. A lead apron protects the body from exposure to radiation.

2) Medical treatment

Radioisotopes are also used in nuclear medicines for curing various diseases. For example, radioactivecobalt-60 is used 'for curing cancerous tumors and cells. The radiations kill the cell of the malignant tumor in the patient.

3) Carbon dating

Radioactive carbon — 14 is present in small amount in the atmosphere. Live plants use carbon-dioxide and therefore becomes slightly radioactive.


Cosmic rays, passing through atmosphere, produce fast neutrons.
Neutrons strike nitrogen in the atmosphere, producing carbon-14 and hydrogen.
neutron
nitrogen atom
hydrogen
carbon-14 atom
Carbon-14 mixes with oxygen to form radioactive carbon dioxide.
Vegetation absorbs radioactive carbon dioxide.
Animals, feeding on vegetation, absorb carbon-14.
When animals and plants die, carbon-14 disintegrates at a known rate

When a tree dies, the radio carbon —14 present inside the plant starts decaying.

Since the half-life of carbon — 14 IS 5730 years, the age of a dead tree can be calculated by comparing the activity of carbon — 14 in the live and dead tree. The activity of the live tree remains almost constant as the carbon — 14 IS being replenished while the carbon-14 in the dead tree is no more replenished.

Also, some rocks contain the unusable potassium isotope K- 40.

This decays to the stable on nuclide Ar — 40 with half-life of 2.4 x 108 years. The age of rock sample can be estimated by comparing the concentrations of K—40 and Ar-40.

Q9. Write in detail about fission reaction.

Answer

Fission reaction

Nuclear fission takes place when a heavy nucleus, such as U — 235, splits, or fissions, into two smaller nuclei by absorbing a slow moving (low energy) neutron

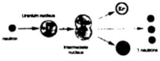
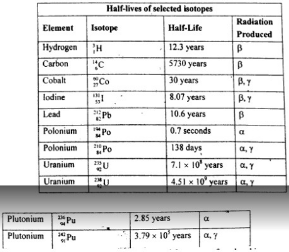


Fig. 18.11. Nuclear fission reaction

as represented by the equation.

${}_0^1n + {}_{92}^{235}U \rightarrow {}_{92}^{236}U^* \rightarrow X + Y +$neutrons where U* —> 236 is an intermediate state that lasts only for a few seconds before splitting into nuclei X and Y, called "fission fragments." Nuclear fission was first observed in 1939 by Otto Hahn and Fritz.



Half-lives of selected isotopes

Element	Isotope	Half-Life	Radiation Produced
Hydrogen	${}_1^3H$	12.3 years	β
Carbon	${}_6^{14}C$	5730 years	β
Cobalt	${}_{27}^{60}Co$	30 years	β, γ
Iodine	${}_{53}^{131}I$	8.07 years	β, γ
Lead	${}_{82}^{212}Pb$	10.6 years	β
Polonium	${}_{84}^{194}Po$	0.7 seconds	α
Polonium	${}_{84}^{210}Po$	138 days	α, γ
Uranium	${}_{92}^{235}U$	7.1×10^8 years	α, γ
Uranium	${}_{92}^{238}U$	4.51×10^9 years	α, γ
Plutonium	${}_{94}^{236}Pu$	2.85 years	α
Plutonium	${}_{91}^{242}Pu$	3.79×10^5 years	α, γ

The Uranium nucleus was split into two nearly equal fragments after absorbing a slow moving (low energy) neutron.

The process also resulted in the production of typically two or three neutrons per fission event. On the average, 2.47 neutrons are released per event as represented by the expression;

$${}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{56}^{141}Ba + {}_{36}^{92}Kr + 3\,{}_{0}^{1}n$$

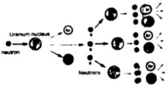


Fig. 18.12 fission chain reaction in U - 235.

In nuclear fission, the total mass of the' products is less than the original mass of the heavy- nucleus. Measurements showed that about 200 MeV of energy is released in each fission event.

This is a large amount of energy relative to the amount released in chemical processes

For example, if we burn 1 tone of coal then about 36×10^{10} J of energy is released, but, during the fission of 1 kg of Uranium — 235 about 67×10^{10} J of energy is released.

We know that neutrons are emitted when U-235 undergoes fission. These neutrons can in turn trigger other nuclei to undergo fission with the possibility of a chain reaction.

Calculations Show that if the chain reaction is not controlled, it will proceed too rapidly and possibly result in the sudden release of an enormous amount of energy (an explosion).

This fission chain reaction is controlled in nuclear reactors.

Q10 What is nuclear fusion?

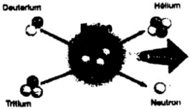
Answer

Nuclear fusion

“When two light nuclei combine to from a heavier nucleus, the process is called nuclear fusion.”

The mass of the final nucleus is always less than the masses of the original nuclei.

According to mass energy relation this loss of mass converts into energy. If an atom of Deuterium is fused with an atom of Tritium, then a helium nucleus or alpha panicle is formed as given by:



$${}_{1}^{2}H + {}_{1}^{3}H \rightarrow {}_{2}^{4}He \rightarrow {}_{0}^{1}n + \text{energy}$$

Pictorially fusion reaction is shown in the figure.

Energy coming from the sun and stars is supposed to be the result of fusion of hydrogen nuclei into helium nucleus with release of energy.

The temperature at the centre of the sun is nearly 20 million Kelvin which makes the fusion favorable.

According to this reaction four hydrogen nuclei fuse together to form a helium nucleus along with two positrons, three alpha particles and 25.7 MeV of energy,

Q.11 What are the common radiation hazards? Briefly describe the precautions that are taken against them?

Answer

Radiation Hazards

1) Radiation burn, mainly due to beta and gamma radiations, which may cause redness and sores on the skin.

2) Sterility (i.e. inability to produce children).

3) Genetic mutations in both humans and plants. Some children are born with serious deformities.

4) Leukemia (cancer of the blood cells.

5) Blindness or formation of cataract in the eye.

Precautions

I) The sources should only be handled with tongs and forceps.

2) The user should use rubber gloves and hands should be washed carefully after the experiment.

3) All radioactive sources should be stored in thick lead containers.

4) Never point a radioactive source towards a person.

5) Frequent visits to the radiation sensitive areas should be avoided.

MULTIPLE CHOICE QUESTIONS

Choose the correct answer from the following choices:

1. **Isotopes are atoms of same element with different:**

   a) atomic mass   **b)** atomic number

   c) number of protons   **d)** number of electrons

2. **One of the isotopes of uranium is 23892U. The number of neutrons in this isotope is:**

   a) 92   **b)** 146

   c) 238   **d)** 330

3. **Which among the following radiations has more penetrating power?**

   a) a beta particle   **b)** a gamma ray

   c) an alpha particle   **d)** all have the same penetrating ability

4. **What happens to the atomic number of an element which emits one alpha particle and a beta particle?**

   a) increases by 1   **b)** stays the same

   c) decreases by 2   **d)** decreases by I

5. **The half-life of a certain isotope is 1 day. What, is the quantity of the isotope after 2 days?**

   a) one half   **b)** one quarter

   c) one eight   **d)** none of these

6. **When Uranium (92 protons) ejects a beta particle, how many protons are left in the remaining nucleus?**

   a) 92 protons   **b)** 91 protons

   c) 90 protons   **d)** 93 protons

7. **Release of energy by the Sun is due to:**

   a) nuclear fission   **b)** nuclear fusion

   c) burning of gases   **d)** chemical reaction

8. **When a heavy nucleus splits into two lighter nuclei, the process would:**

   a) release nuclear energy   **b)** absorb nuclear energy

   c) release chemical energy   **d)** absorb chemical energy

9. **The reason carbon-dating works is that:**

a) plants and animals are such strong emitters of carbon -14

b) after a plant or animal dies, it stops taking fresh carbon -14

c) there is so much non-radioactive carbon dioxide in the air

d) when a plant or an animal die

ANSWERS

i) a **ii)** b **iii)** b **iv)** d **v)** b **vi)** d

vii) b **viii)** a **ix)** b

REVIEW QUESTIONS

18.1 What is difference between atomic number and atomic mass number? Give a symbolical representation of a nuclide.

Answer

Please see the topic.

18.2 What do you mean by the term radioactivity? Why some elements are radioactive but some are not?

Answer

Please see the topic.

18.3 How can you make radioactive elements artificially? Describe with a suitable example.

Answer

When a slow-moving neutron is bombarded to a stable nucleus to make it unstable, the decay process takes place and we get a new element called daughter element. Such radioactivity is called artificial radioactivity.

For example; ${}_{0}^{1}n + {}_{11}^{23}Na \rightarrow {}_{11}^{24}Na + gamma(\gamma) -$ rays

18.4 What are three basic radioactive decay processes and how do they differ from each other?

Answer

Please see the topic.

18.5 Write the alpha decay process for ^{23,4}, P_a . Identify the parent and daughter nuclei in this decay.

Answer

${}_{91}^{234}P \rightarrow {}_{89}^{230}X + {}_{2}^{4}He + energy$

(parent nuclide) (daughter nuclide) (alpha particle)

18.6 Explain whether the atomic number can increase during nuclear decay: Support your answer with an example.

Answer

Yes, the atomic number can be increased during β-decay. For example:

$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e + energy$

The above nuclear transmutation, indicates that by the emission of one p-particle from carbon -14 ($_6{}^{14}C$) , its atomic number is increased by 1 and as a resultant we get a daughter element $_7{}^{14}N$ (nitrogen -14) with atomic number 7.

18.7 What do you understand by half-life of a radioactive element?

Answer

Please see the topic (half-life of radioactive element)

18.8 Is radioactivity a spontaneous process? Elaborate your answer with a simple experiment.

Answer

Please see the topic (Natural radioactivity)

18.9 What is meant by background radiations? Enlist some sources of background radiations.

Answer

Please see the topic (background radiation)

18.10 Describe two uses of*radioisotopes in medicine, industry or research?

Answer

Please see the topic (Applications of radioisotopes)

18.11 What are two common radiation hazards? Briefly describe the precautions that are taken against them.

Answer

Please see the topic (radiation hazards).

18.12 Complete this nuclear reaction: $^{235}_{92}U \rightarrow {}^{140}_{54}X + ? + 2\,^{1}_{0}n$ Does this reaction involve fusion or fusion? Justify your answer.

$$^{235}_{92}U \rightarrow {}^{140}_{54}X + {}^{94}_{37}Y + 2\,^{1}_{0}n$$

Answer

The above equation indicates the fission process. $^{235}{}_{92}U$ is disintegrated by the bombardment of a slow-moving neutron and as a resultant we get two nuclear fragments i.e. $^{140}{}_{54}X$+ $_{37}{}^{94}Y$, with the emission of one neutron.

18.13 Nuclear fusion reaction is more reliable and sustainable source of energy than nuclear fission chain reaction. Justify this statement with plausible arguments.

Answer

In fusion process a huge quantity of (heat) energy is produced as compared to fission process.

One of the best examples is that of sun, where fusion process is taking place for billions of years and we are receiving its results on the earth is the form of heat & light.

18.14 A nitrogen nuclide $'4_{7}N$ decay to become an oxygen nuclide by emitting an electron. Show this process with an equation.

Answer

$$^{14}_{7}N \rightarrow {}^{14}_{8}O + {}^{0}_{-1}e + energy$$

By the emission of an electron (P-particle) the atomic number of daughter element is increased by 1, this process is called 13-decay.

18.15 Determine which of these radioactive decay processes are possible:

a) $^{212}_{84}P_a \rightarrow {}^{208}_{82}P_b + {}^{4}_{2}He$

b) $^{230}_{90}Th \rightarrow {}^{226}_{88}R_a + {}^{4}_{2}He$

c) $^{233}_{91}P_a \rightarrow {}^{233}_{92}U + {}^{0}_{-1}\beta$

d) $^{12}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$

Answer

a) $^{212}_{84}P_a \rightarrow {}^{208}_{82}P_b + {}^{4}_{2}He(\alpha - decay)$

b) $^{230}_{90}Th \rightarrow {}^{226}_{88}R_a + {}^{4}_{2}He(\alpha - decay)$

c) $^{233}_{91}P_a \rightarrow {}^{233}_{92}U + {}^{0}_{-1}\beta(\beta - decay)$

d) $^{12}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta(\beta - decay)$

CONCEPTUAL QUESTIONS

18.1 Is it possible for an element to have different types of atoms? Explain.

Answer

Yes, in case of isotope an element can have different types of atoms. For example:

Hydrogen may have three different atoms as protium($^{1}_{1}H$), Deuterium ($^{2}_{1}H$) and tritium ($^{3}_{1}H$).

18.2 What nuclear reaction would release more energy, the fission reaction or the fusion reaction? Explain.

Answer

Fusion reaction would release more energy, but practically it is not possible to produce and control such fusion energy, because a large amount of energy is also required to produce fusion reaction.

18.3 Which has more penetrating power, alpha a particle or gamma ray photon?

Answer

A gamma ray photon has more penetrating power than β-particle. Alpha particle can be stopped by placing 'a paper in its way while gamma ray can even penetrate through a thick aluminum foil and can be stopped by a lead wall.

18.4 What is the difference between natural and artificial radioactivity?

Answer

In natural radioactivity, decay process takes place in unstable nuclei of radioactive elements, while in artificial radioactivity, a stable nuclide is made unstable for decay process by the bombardment of slow-moving neutron.

18.5 How long would you likely have to wait to watch any sample of radioactive atoms completely decay?

Answer

As the decay, process is a random process and half-lives of different radioactive elements is different so no exact time can be predicted. But statistical calculations may give us some idea of the complete decay of any element.

18.6 Which type of natural radioactivity leaves the number' of protons and the number of neutrons in the nucleus unchanged?

Answer

The emission of gamma rays leaves the number of protons and neutrons unchanged in the nucleus. Because, when a or β emission take place in the nucleus then the nucleus comes in excited state as resultant of this a gamma ray is also emitted with no change in protons or neutrons in the nucleus.

18.7 How much of a 1g sample of pure radioactive matter would be left after four half-lives?

Answer

After four half-lives, 1g of pure radioactive matter will be left as 0.0625g. Because after 1ST half life it will be 0.5; after 2nd half life0.25g; after 3rd half life 0.125g; and after 4th half life 0.0625g will be left.

18.8 Tritium, ^3_1H is radioactive isotope of hydrogen. It decays by emitting an electron. What is the daughter nucleus?

Answer

$$^3_1H \rightarrow {}^3_2He + {}^0_{-1}e$$

^3_1H is a parent nucleus. By the emission of an electron, one of the atomic numbers is increased and we get one of the isotopes of helium (^3_2H) as a daughter element.

18.9 What information about the structure of the nitrogen atom can be obtained from its nuclide $_7{}^{14}N$.

Answer

$^{14}_7N$ have the atomic number 7 and atomic mass 14. It means that there are 7 protons and 7 neutrons in the nucleus of $^{14}_7N$. While in $^{16}_7N$, the atomic number is same but atomic mass is different i.e. 16 which shows that $^{16}_7N$ is an isotope of nitrogen.

Important Short Questions

Q2. Give short Answers.

1. **What is nuclear Physics?**

Answer

The branch of Physics. which deals with the study of the properties of isolated nuclei of atoms.

2. **What is the size of an atom and nucleus?**

Answer

- The size of an atom is the order of $10^{-1^{\circ}}$ m.
- The size of a nucleus is of the order of le° m.

3. **How much mass may be concentrated in the nucleus of an atom?**

Answer

99.9% of the total mass of an atom is concentrated in the nucleus of an atom.

4. **What are isotopes?**

Answer

Isotopes are those elements whose atomic numbers are the same but their atomic *mass* numbers are different.

5. **Define atomic mass number and atomic number.**

Answer

Atomic mass number

The total number of protons and neutrons in the nucleus of an atom is called atomic mass number. It is denoted by A.

Atomic number

The number of protons present in the nucleus of an atom is called atomic number. It is denoted by Z.

It is also called charge number.

6. **Who discovered natural radioactivity?**

Answer

Henri Becquerel discovered natural radioactivity in 1896.

7. **Define radioactivity.**

Answer

Radioactivity is such a process in which the elements with the charge number greater than 82, naturally keep on radiating.

8. What are the radioactive elements?

Answer

There are certain elements in nature with powerful radiations continuously. These elements are called radioactive elements.

Example: Plutonium, Radium, Uranium.

9. What is a-rays?

Answer

The spot on the left is due to the arc of a large circle indicating a group of positively charged particles, called a-rays.

10. Define artificial radioactivity.

Answer

The emission of radiations from the nuclei of light elements due to bombardment by some fast-moving particles is known as artificial radioactivity.

11. What are radioactive isotopes?

Answer

The radioactive elements whose atomic numbers are same but have different atomic mass numbers are called radiative elements.

12. Give two uses of radio isotopes.

Answer

Radio isotopes are used in agriculture.

Radio isotopes are used in medicines.

13. Why the nucleus of an atom becomes stable?

Answer

The nuclear forces between different nucleons are strong enough and attractive so as to overcome the repulsive electrostatic forces. This is why the nucleus remains stable.

14. What is meant by half-life of an element?

Answer

The half-life of an element is that time during which the number of atoms of that element are reduced to one half.

15. What are β-rays?

Answer

The spot situated on the arc of a small circle on the right, indicated the presence of negatively charged particles, which are known as β-rays.

16. Give an example of half-life of an element?

Answer

If the half-life time of a radioactive element is T, then at the end of this time the number of atoms in this element remains one half, after a time 2T, the number of atoms remains 25 % and after time 3T, the number of atoms is reduced to 12.5 % of the initial number.

17. Differentiate between parent element and- daughter element?

Answer

During radiation emission reaction, the original element is called the parent element and the newly formed element is called the daughter element.

18. Give some characteristics of unstable, nuclides.

Answer

- These elements have atomic number greater than 82.
- These elements are unstable in nature.
- They emit radiations all the time.
- They emit different types of strong radiations.
- They continuously change from one type of element to another.

19. How stable elements can be changed into unstable elements?

Answer

The stable elements can be changed into unstable form by bombarding them with neutrons. Such elements are called radioactive isotopes.

20. How radioactive isotopes help in the treatment of cancer?

Answer

The parts suffering from cancer absorb more quantity of isotopes, and thus indicate the correct position of the diseased part, which help in the treatment. Radioactive isotopes also cure some types of cancers.

Example: Radioactive cobalt 60 is used for curing cancerous tumors and cells.

21. What are γ-rays?

Answer

The spot in the middle indicates the particles, which do not carry any charge and are known as γ-rays.

22. Distinguish between stable and unstable nuclides.

Answer

Stable nuclide: The nuclei, which do not emit radiations naturally are called stable nuclide.

Example: Usually most of the nuclei whose atomic number are from Ito 82 are stable nuclei.

Unstable nuclei: The elements, whose atomic number is more than 82 are naturally unstable. These elements emit all the time different type of radiations and continuously change from one type of element to another.

Example: Plutonium, Radium, Uranium

23. Which type of radiations are emitted during the process of radioactivity?

Answer

During the process of radioactivity, three different types of radiations are emitted which are termed as Alpha Beta and Gamma radiations.

24. What part of radioactive atom disintegrates during radioactivity?

Answer

During the process of radioactivity, nucleus disintegrates into new elements by the emission of α, β, and γ-radiations.

25. What are artificial radioactive elements?

Answer

Using modern techniques, the elements, which are much lighter than the natural radioactive elements, are radioactive. Such elements are called artificial radioactive elements

26. What is effect on an element by the emission of α-particle?

Answer

If an α-particle is emitted by an element then

$$ {}_{Z}^{A}X + {}_{2}^{4}\alpha \rightarrow {}_{Z-2}^{A-4}X $$

The *new* element decreases 4 its atomic mass number and 2 its atomic number after the emission of an off α-particle.

27. What is effect on an element by the emission of β-particle?

Answer

If a β-particle is emitted by all element then:

$$ {}_{Z}^{A}X + {}_{-1}\beta^{o} \rightarrow {}_{Z-1}^{A}X $$

The atomic number of the newly produced element remains the same, but its charge number increases by one unit.

28. What is meant by mass energy equation?

Answer

Einstein's relation is given by:

$$ E = m\,c^2 $$

Where m = mass of Matter

c = speed of light

This relation is called mass-energy equation.

29. Which is the lightest and heaviest element found in nature?

Answer

- The lightest of all elements is hydrogen.
- The heaviest element found in nature is Uranium ${}_{92}{}^{238}U$

30. Why alpha particles are called helium nuclei?

Answer

Alpha rays consist of positively charged particles whose mass is 4-times that of Hydrogen atom and they carry a charge twice that of a proton. Hence α-particles are called Helium nuclei.

31. Why β- particles are called fast moving electrons?

Answer

β-rays are emitted by the radioactive elements with great speed (99% of the speed of light). Their mass is small and carries negative charge. Hence β-rays are called fast moving electrons.

32. What is fission reaction?

Answer

The breaking of a nucleus into two parts with the release of large amount of energy is called fission reaction.

33. Why a large amount of energy is released during fission reaction?

Answer

In the fission reaction, when a nucleus breaks, the sum of the masses of the produced nuclei and the neutrons is less than the mass of the original nucleus. This difference of mass results in the release of energy according to Einstein's mass-energy equation.

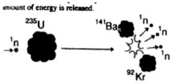
34. Give an example of nuclear fission reaction.

Answer

$_{92}^{238}U \rightarrow {}_{56}^{141}Ba + {}^{92}_{36}Kr + 3{}_0^1n$ + energy

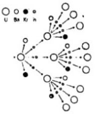
Here Ba and Kr denote Barium and Krypton respectively.

In this process of breaking a heavy element into two nuclei, a large amount of energy is released.



35. Why fission reaction becomes chain reaction? Answer

When a neutron reacts with a uranium nucleus, two or three neutrons are released. Every one of these reacts with next nuclei producing two or three more neutrons and hence, the number of available neutrons and the fission goes on increasing. Such a reaction is called the chain reaction.



36. Why chain reaction becomes uncontrollable?

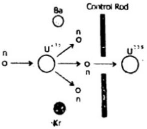
Answer

In the chain reaction, as the fission reaction builds up, the liberated energy goes on increasing. The fission reaction thus become uncontrollable and hence whole of the matter explodes which results in great destruction.

37. How fission reaction is controlled?

Answer

In the nuclear reactor, Boron or Cadmium rods absorb the surplus neutrons.



38. Whether atomic bomb is an example of fission reaction?

Answer

Yes, the fission reaction thus uncontrollable and whole of the matter explodes, which results in great destruction. Such a reaction is used in atomic bomb.

39. What is nuclear reactor? Answer

The nuclear reactor is device to produce nuclear energy in controlled manner, using fission reaction.

40. What is fusion reaction?

Answer

A process in which the light nuclei diffuse to form a heavier nucleus is called fusion reaction.

41. Write some applications of mass-energy equation. This equation shows that mass is converted into energy.

Answer

- It is helpful in determining the energy obtained from nuclear reaction.
- This equation predicts the amount of energy, which is released from the sun and the stars.

42. What is the source of solar energy?

Answer

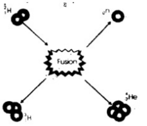
Scientists considered that the energy coming from the sun and the stars is due to the fusion nucleons. For producing a-particles hydrogen has to be converted into helium.

43. Give an example of a fusion reaction. Answer

If an atom of deuterium is fused with an atom of tritium then a helium nucleus or a-particle is formed.

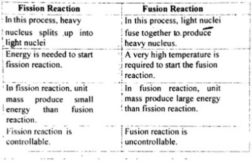
$$^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}_{0}n^{1} + energy$$

In a fusion reaction if isotopes of hydrogen form a helium nucleus, nearly 17.6 MeV of energy is liberated. But it is very difficult to produce a fusion reaction.



44. Differentiate between fission and fusion reaction.

Answer



Fission Reaction	Fusion Reaction
In this process, heavy nucleus splits up into light nuclei	In this process, light nuclei fuse together to produce heavy nucleus.
Energy is needed to start fission reaction.	A very high temperature is required to start the fusion reaction.
In fission reaction, unit mass produce small energy than fusion reaction.	In fusion reaction, unit mass produce large energy than fission reaction.
Fission reaction is controllable.	Fusion reaction is uncontrollable.

45. Why it is very difficult to produce a -fusion reaction?

Answer

It is very difficult to produce a fusion reaction because when nuclei are brought near each other for fusion, work has to be done against the electrostatic force, which requires great amount of energy or heat.

46. Give some properties of α -rays?

Answer

- α -particles are the nuclei of Helium.
- α - rays are emitted with the speed ranging between I.4x 107 and 1.7 x 107 ms^{-1}.
- They affect the photographic plate.
- α -particles ionizes the gas through which they pass.
- Penetration power of a-particles is very low.

47. Write some properties of β -rays?

Answer

- β -rays consists of fast-moving electrons and carry negative charge.
- They are affected by electric and magnetic fields.
- They can also affect the photographic plate.
- They move with the speed of light.
- They produce fluorescence in many substances.

48. Write some characteristics of γ -rays?

Answer

- γ- rays move with the speed of light.
- These rays are not affected by electric and magnetic fields.
- Their penetration power is very high.
- Their ionization power is very low.
- These are electromagnetic in nature.

49. Which reaction is responsible for the solar and stellar energy?

Answer

Bethe had suggested that a chain reaction taking place inside the sun. According to this reaction, when 4 Hydrogen nuclei fuse together to form a Helium nucleus, then along with two positron and three a-rays nearly 25.7 %. MeV of energy is also released. This reaction is responsible for the solar and stellar energy.

50. Whether hydrogen bomb is an example of fusion reaction?

Answer

Yes, hydrogen bomb is an example of fusion reaction.

For fusion reaction the required temperature is achieved by exploding a fusion bomb.

51. How one isotope of an element differs from the other isotope of the same element?

Answer

Isotope of an element has same chemical properties due to same charge number. However, their physical properties are different for every isotope of the same element.

52. Why do a-particles have highest ionization power?

Answer

a-particles have the highest ionization power due to following reason:

- It is the heaviest particle of all the three type of radioactive radiations. It is most heavily charged.

53. What is the use-of Phosphorus-32?

Answer

Phosphorus-32 is used to detect tumors in the brain.

54. Why radiations can be very harmful for us?

Answer

Radiations can be very harmful for us because:

- It can damage our body.
- Excessive radiations may cause cancer.

- They can destroy our body cells.

55. What are the precautions to minimize radiation as danger?

Answer

The following steps should be taken to minimize the radiations danger:

- One should keep a safe distance away from the radiation emitting sources.
- Only the required portion of the body should be exposed to radiation for treatment.
- The nuclear waste must he buried in the desert.
- The radioactive material must be placed in a box of the persons working in the laboratories, where radioactive. material is available must get themselves medically checked regularly.

56. What does (A-Z) value indicate?

Answer

For finding the number of neutrons we use the relation

$$N = A - Z$$

Where

N = number of neutrons

A = atomic mass

Z = atomic number

57. Why neutron source is used to produce isotopes?

Answer

A neutron source from a nuclear reactor is often used to produce isotopes. Slow neutrons with low kinetic energies are used to bombard the element or a compound. Since the neutrons are electrically neutral, they are easily captured by the nuclei of the element.

58. Name some source of radiations.

Answer

All the three types of radiations come from the unstable nuclei of elements.

Examples: Uranium, Plutonium. Radium, Radon etc..

59. Why do heavy nuclei become unstable?

Answer

As the nuclear force between the nucleons is stronger than the Coulomb's repulsive force between the protons. In case of smaller nuclei, the distance between the protons is smaller and strong nuclear force is more dominant. However, with the addition of more nuclei, the distance between the protons increases and as strong nuclear force is short range, it becomes weaker and Coulomb's repulsive force become dominant and nucleus becomes unstable.

60. How radioisotopes are made?

Answer

Bombarding a radioactive element with neutrons and other particles under suitable conditions makes radioisotopes.