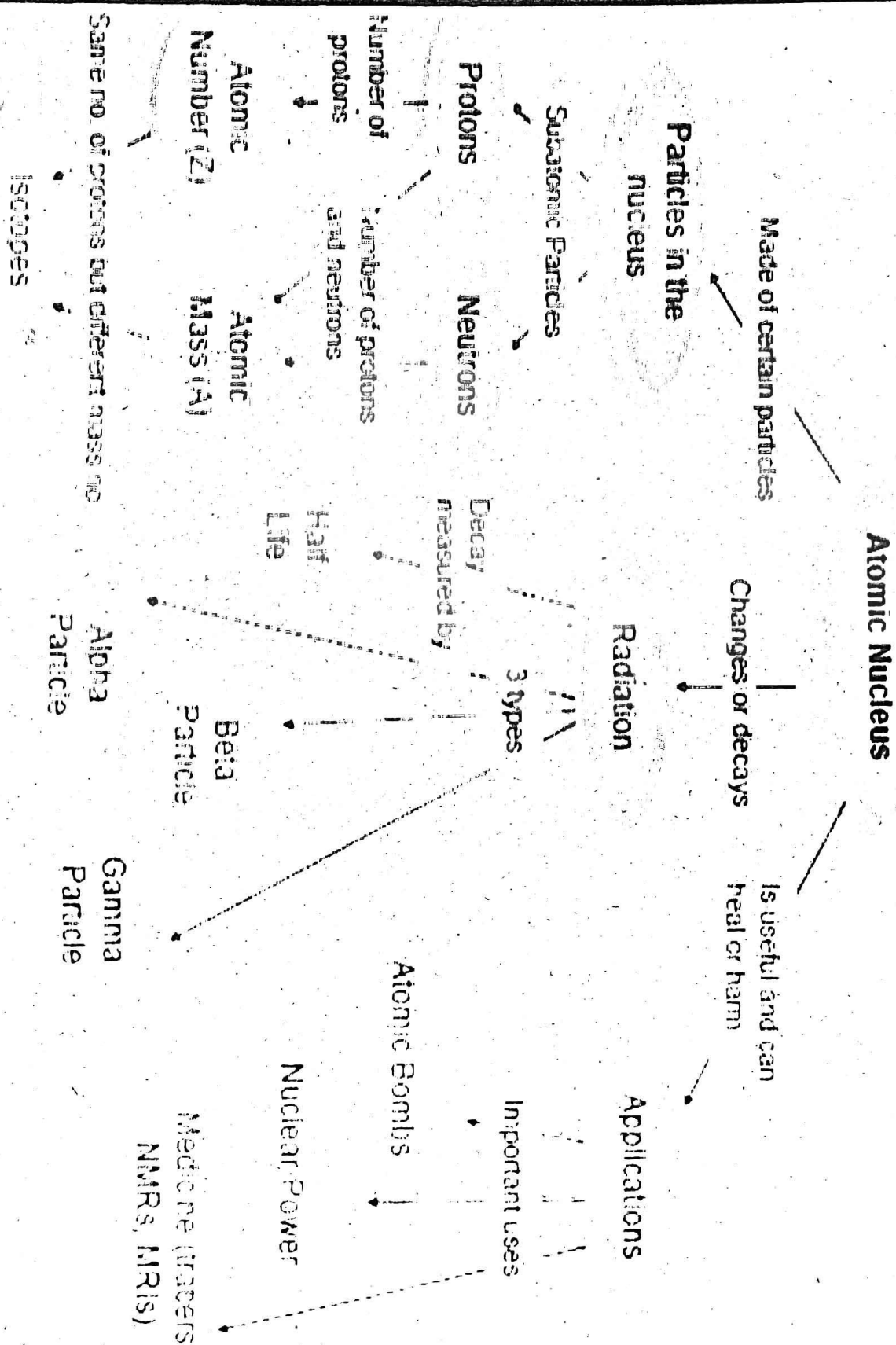




Nuclear Physics Concept Map



MULTIPLE CHOICE QUESTIONS

18.1 Atom and Atomic Nucleus

18.2 Natural Radioactivity

- (1) Which statement is correct about isotopes?
(a) Atoms of an element have same number of protons.
(b) Atoms of an element have different number of neutrons in their nuclei
(c) Protium, deuterium and tritium are isotopes of hydrogen
(d) All of above
- (2) The mass of the proton and neutron is nearly equal to:
(a) 1.67×10^{-27} kg (b) 1.67×10^{-31} kg (c) 1.67×10^{-19} kg (d) 1.67×10^{-21} kg
- (3) A nucleon is ----- times heavier than electron:
(a) 1827 (b) 1836 (c) 1841 (d) 1832
- (4) The total number of nucleons in a nucleus is:
(a) Atomic number (b) Atomic mass number (c) Isotope number (d) None of these
- (5) The total number of protons in a nucleus or total number of electrons in the orbits is:
(a) Atomic number (b) Atomic mass number (c) Isotope number (d) None of these
- (6) The atomic number is represented by:
(a) A (b) Z (c) N (d) None of them
- (7) The number of neutrons in a nucleus is represented by:
(a) A (b) Z (c) N (d) None of them
- (8) The number of protons and neutrons in a nucleus or atomic mass is represented by:
(a) A (b) Z (c) N (d) None of them
- (9) Atoms of the element which have same number of protons but different number of neutrons are:
(a) Isotopes (b) Nuclide (c) Both a & b (d) None
- (10) Rutherford discovered that the positive charge in an atom was concentrated in a small region called;
(a) atom (b) nucleus (c) molecule (d) shell
- (11) _____ are collectively called nucleons.
(a) protons in nucleus (b) electrons in shell
(c) protons and neutrons in nucleus (d) neutrons in nucleus
- (12) In which simplest atom, nucleus has only one proton?
(a) Helium (b) Carbon (c) Nitrogen (d) Hydrogen
- (13) Generally an atom is represented by the symbol;
(a) ${}^A_Z X$ (b) ${}^A_Z X$ (c) ${}^Z_A X$ (d) ${}_0^A X$
- (14) In nuclide ${}^{13}_6 X$ the number of protons are;
(a) 3 (b) 10 (c) 8 (d) 6

- (15) Isotopes of an element have the same:
 (a) Chemical properties (b) Atomic number (c) Atomic mass number (d) Colours
- (16) Tritium contains one proton, while protium and deuterium contains;
 (a) two protons (b) three protons (c) one proton (d) no proton
- (17) Who accidentally discovered that uranium salt crystals emit an invisible radiation that can darken a photographic plate;
 (a) Beequerel (b) Marie Curie (c) Pierre (d) Rutherford

18.3 Background Radiations

18.4 Nuclear Transmutations

18.5 Half-life and its Measurement

- (18) Transmutation is
 (a) unstable nuclei changes into stable nuclei
 (b) spontaneous process
 (c) Both A and B
 (d) non spontaneous process
- (19) The Earth and all living things receive radiation from outer space.
 (a) X-rays (b) Cosmic rays (c) Radon gas (d) None of these
- (20) Complete the equation ${}_{88}^{226}\text{Ra} \rightarrow {}_{86}^{222}\text{Rn} + ? + \text{energy}$;
 (a) ${}_{-1}^0\text{e}$ (b) ${}_{17}^{14}\text{N}$ (c) ${}_{2}^4\text{He}$ (d) ${}_{79}^{197}\text{Au}$
- (21) ${}_{11}^{24}\text{Na} \rightarrow ? + {}_{-1}^0\text{e} + \text{Energy}$
 (a) ${}_{11}^{24}\text{Na}$ (b) ${}_{11}^{24}\text{Na}$ (c) ${}_{11}^{24}\text{Na}$ (d) ${}_{11}^{24}\text{Na}$
- (22) ${}_{27}^{60}\text{Co} \rightarrow {}_{27}^{60}\text{Co} + {}_{0}^0\gamma + \text{Energy}$ this equation shows emission of:
 (a) β -particles (b) alpha particles (c) gamma particles (d) none of these
- (23) Charge on alpha particles is;
 (a) $2e$ (b) $3e$ (c) $4e$ (d) $5e$
- (24) Stream of high energy electrons;
 (a) β -particles (b) α -particles (c) γ -particles (d) Σ -particles
- (25) Gamma rays are also called:
 (a) photons (b) electrons (c) protons (d) positrons
- (26) Which have the greatest power of ionization as compared to others?
 (a) β -particles (b) α -particles (c) γ -particles (d) x-rays
- (27) Penetrating power of γ rays as compared to α rays and β rays is:
 (a) Greater (b) Smaller (c) Equal (d) Anyone can be
- (28) The phenomenon by which radiations split matter into positive and negative ions is called;
 (a) ionization (b) penetration (c) sublimation (d) deflection
- (29) The rate of radioactive decay is proportional to the number of:
 (a) stable nuclei present (b) unstable nuclei present
 (c) electrons present (d) protons present

(30) Radium-226 has a half-life of:

- (a) 1820 years (b) 1920 years (c) 1620 years (d) 1600 years

18.6 Radioisotopes and their uses

(31) Stable nuclei have atomic number between:

- (a) 1 – 82 (b) 2 – 89 (c) 2 – 88 (d) 2 – 85

(32) Elements are naturally unstable having atomic number greater than;

- (a) 84 (b) 89 (c) 82 (d) 88

(33) ${}^4_2\text{He} + {}^{27}_{13}\text{Al} \rightarrow ? + {}^1_0\text{n}$

- (a) ${}^{24}_{11}\text{Na}$ (b) ${}^{30}_{15}\text{P}$ (c) ${}^{23}_{11}\text{Na}$ (d) ${}^{24}_{13}\text{Na}$

(34) Which are chemical compounds containing some quantity of radioisotope?

- (a) Radioactive tracer (b) Hard compounds
(c) High energy compounds (d) Soft compounds

(35) Which compound readily accumulates in the thyroid gland and can be used for monitoring of thyroid functioning?

- (a) I – 131 (b) I – 130 (c) I – 132 (d) I – 129

(36) Which compound is used for diagnosis of brain tumor?

- (a) Phosphorus -32 (b) iodine -131 (c) hydrogen-3 (d) neon -152

(37) Radioactive isotope is used for curing cancerous tumors and cells.

- (a) P -32 (b) I-131 (c) C-14 (d) Co-60

(38) When a tree dies radioactive isotope present in plant starts decaying?

- (a) C -14 (b) P - 32 (c) I - 131 (d) Co - 60

(39) The half –life of C-14 is;

- (a) 5720 years (b) 5730 years (c) 5700 years (d) 5202 years

(40) The stable argon nuclide Ar-40 half-life:

- (a) 2.4×10^8 years (b) 2.9×10^4 years (c) 2.5×10^9 years (d) 2.4×10^{11} years

18.7 Fission Reaction

18.8 Nuclear Fusion

18.9 Hazards of Radiations and Safety Measures

(41) Mass energy equation and theory of relativity was given by:

- (a) Newton (b) Quantum (c) Einstein (d) Volta

(42) Nuclear fission was first observed in 1939 by:

- (a) Otto Hahn and Fritz Strassman (b) Otto Hahn and Curie
(c) Fritz and Curie (d) Otto Hahn and Rutherford

(43) In each fission reaction energy released;

- (a) 210meV (b) 299mV (c) 200 MeV (d) 255meV

(44) During fission of 1kg of Uranium -235 energy released is;

- (a) $67 \times 10^{10}\text{J}$ (b) $65 \times 10^8\text{J}$ (c) $60 \times 10^8\text{J}$ (d) $66 \times 10^9\text{J}$

- (45) Half-life of plutonium (${}_{94}^{242}\text{Pu}$) is 2.85 years and ${}_{94}^{242}\text{Pu}$ is;
 (a) 3.79×10^5 years (b) 7.1×10^8 years (c) 2.85 years (d) 7.1×10^{10} years
- (46) Half-life of ${}_{27}^{60}\text{Co}$ is
 (a) 20 years (b) 40 years (c) 50 years (d) 30 years
- (47) When two light nuclei combine to form a heavier nucleus, this process is called;
 (a) nuclear fission (b) nuclear fusion (c) bombardment (d) disintegration
- (48) The temperature of the centre of sun is;
 (a) 20 million kelven (b) 2 million kelvin (c) 24 million kelvin (d) 29 million kelvin
- (49) Hazards of radiation for humans are;
 (a) Leukemia (b) Sterility (c) Blindness (d) all given
- (50) In order to find the intensity of radiations, which device (s) is/are used:
 (a) Film badge (b) Dosimeter (c) Radiometer (d) Both a & b

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	d	11	c	21	d	31	a	41	c
2	a	12	d	22	c	32	c	42	a
3	b	13	b	23	a	33		43	c
4	b	14		24	a	34	a	44	a
5	a	15	b	25	a	35	a	45	a
6	b	16	c	26	b	36	a	46	d
7	c	17	a	27	a	37	d	47	b
8	a	18	c	28	a	38	a	48	a
9	a	19	b	29	b	39	b	49	d
10	b	20	c	30	c	40	a	50	c

REVIEW QUESTIONS

- (1) What is difference between atomic number and atomic mass number? Give a symbolical representation of a nuclide.

Ans: The difference between the atomic number and the mass number is that the atomic number is the number of protons in the nucleus of an atom of the element. The mass number is the total number of protons and neutrons in the atom.

Atomic number = number of protons

Mass number = total number of protons + neutrons

Symbolic representation of a nuclide:

If atomic number of an atom is A and its atomic mass number is Z, then this atom is represented by the symbol A_ZX which is called a nuclide.

Example: There is only one proton in the nucleus of hydrogen atom so its atomic number is 1 and its atomic mass number is also 1. Hence it is denoted by ${}^1_1\text{H}$.

- (2) What do you mean by the term radioactivity? Why some elements are radioactive but some are not

Ans: Radioactivity: Radioactivity is such a process in which the elements with the charge number greater than 82. Naturally keep on radiating. **OR**

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

Reason of radioactivity: An isotope will be radioactive if its nuclei are unstable. Large atomic nuclei with more than 82 protons and their associated complement of neutrons are inherently unstable uranium and plutonium are examples of such elements. Small atomic nuclei may also be radioactive if the ratio of neutrons to protons exceeds certain limits. Even tiny hydrogen, the smallest of atoms, has a radioactive isotope. If the atom is stable it will not emit radiations.

- (3) How can you make radioactive elements artificially? Describe with a suitable example.

Ans:

Any stable element, besides the natural radioactive element, can be made radio-active for this purpose very high energy particles (protons, neutrons or alpha particles) are bombarded on the stable element. This bombardment excites the nuclei and the nuclei after becoming unstable become radioactive element. Such radioactive elements are called artificially produced radioactive elements.

Example: Rutherford was a Scottish scientist, who discovered artificial radioactivity. Through the bombardment of alpha particles against the nuclei of ${}^{14}_7\text{N}$ Rutherford produced ${}^{17}_8\text{O}$ and protons. Through this observation, Rutherford concluded that atoms of one specific element can be made into atoms of another element through this discovered process of artificial radioactivity

- (4) What are the three basic radioactive decay processes and how do they differ from each other?

Ans: There are following basic radioactive decay processes.

1. ALPHA(a) -decay

2. Beta (b) - decay

3. Gamma (γ)-decay

1.

General equation



Parent nuclide daughter nuclide alpha (a) – particle.

Example:



In alpha decay, the proton number or atomic number Z of the parent nuclide reduces by 2 and its mass number A decreases by 4.

2.

General equation:



Parent Nuclide	daughter nuclide	alpha (B) particle
${}_{88}^{226}\text{Ra}$ ${}_{88}^{226}\text{Ra} \rightarrow {}_{86}^{222}\text{Rn} + {}_2^4\text{He}$	${}_{86}^{222}\text{Rn}$ ${}_{86}^{222}\text{Rn} \rightarrow {}_{84}^{218}\text{Po} + {}_2^4\text{He}$	${}_2^4\text{He}$ ${}_2^4\text{He} \rightarrow {}_2^3\text{He} + {}_0^1\text{n}$



Carbon nitrogen beta (B)

In beta (B)- decay, the parent nuclide has its proton number Z increased by 1 but its mass number or nucleon number A remains unchanged.

3

General equation:



Parent nuclide daughter nuclide gamma rays

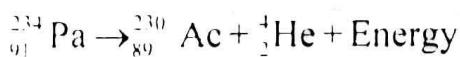


Cobalt cobalt gamma- rays

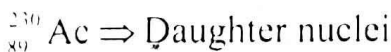
γ -rays are usually emitted at the same moment as either an alpha or a beta particle.

(5) Write the alpha decay process for ${}_{91}^{234}\text{Pa}$. Identify the parent and daughter nuclei in this decay.

Ans: Alpha decay process for ${}_{91}^{234}\text{Pa}$



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.



(6) Explain whether the atomic number an increase during nuclear decay. Support your answer with an example.

Ans: Yes, atomic number can increase during nuclear decay. During the β -decay atomic number of atom can be increased.

Beta (β) –decay:

General equation:



Parent nuclide	Daughter nuclide	beta (β) -particle
----------------	------------------	----------------------------



In beta (β) -decay, the parent nuclide has its atomic number Z increased by 1 but its mass number or nucleon number A remains unchanged.

(7) What do you understand by half-life of a radioactive element?

Ans: See Q # 6

(8) Is radioactivity a spontaneous process? Elaborate your answer with a simple experiment.

Ans: Radioactive decay involves the spontaneous transformation of one element into another. The only way that this can happen is by changing the number of protons in the nucleus. There are a number of ways that this can happen and when it does, the atom is forever changed. There is no going back.

For example, when U-238 (one of the radioactive isotopes of uranium) initially decays, it produces Th-234, which decays to Pa-234. The decay continues until, (finally, after a total of 14 steps, Pb-206 is produced. Pb-206 is stable, and the decay sequence, or series, stops)

(9) What is meant by background radiations? Enlist some sources of background radiations.

Ans: Background radiations:

Radiations present in atmosphere due to different radioactive substance are called background radiation. Every where in rocks, soil, water and air of our planet are traces of radioactive elements. This natural radioactivity is called the background radiation.

Sources of background radiation: (i) The cosmic rays entering the earth from the upper atmosphere along with sunlight. (ii) The presence of radioactive material in the atmosphere or the presence of radioactive wastes of nuclear reactor. There are a number of naturally occurring radioactive elements in the earth's crust. Uranium, radium, plutonium, and even some radio-isotopes of common elements like carbon and iodine. All of them will contribute to background radiations.

(10) Describe two uses of radioisotopes in medicine industry or research?

Ans: Use of radioactive isotope in medicine:

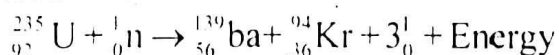
(1) Radioactive cobalt-60 is used for curing cancerous tumors and cells. The radiations kill the cells of the malignant tumor in the patient.

(2) Isotopes of Iodine-131 are used for diagnosis of goiter in thyroid gland.

Uses of radioisotope in industry or research:

(1) The radioisotopes are used in a chemical reaction to follow a radioactive element during the reaction and ultimately to determine the structure. For example, C-14, is used to label CO_2 .

(2) Radioactive isotopes are used to generate electricity by carrying out controlled nuclear fission reaction in nuclear reactors. For example, when U-235 is bombarded with slow moving neutrons, the Uranium nucleus breaks up to produce Barium-139 and krypton-94 and three neutrons.



A large amount of energy is released which is used to convert water into steam in boilers. The steam then drives the turbines to generate electricity.

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

Ans: Common radiation Hazards:

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

(2) Blindness or formation of cataract in the eye.

Precautions:

1. 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.

(12) Complete this nuclear reaction: ${}_{92}^{235}\text{U} \rightarrow {}_{54}^{140}\text{X} + ? + 2{}_0^1\text{n}$. Does this reaction involve fission or fusion? Justify your answer.

Ans: Complete reaction: ${}_{92}^{235}\text{U} \rightarrow {}_{54}^{140}\text{X} + {}_{38}^{94}\text{Sr} + 2{}_0^1\text{n} + Q \text{ Energy}$

(Xenon) (Strontium) Neutron

Justification: It is a fission reaction. Because the process of breaking up of nucleus of a heavy atom such as Uranium into two nuclei nearly of the same size with the release of energy is called fission reaction.

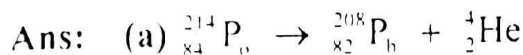
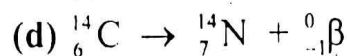
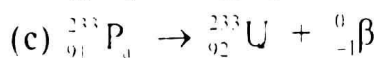
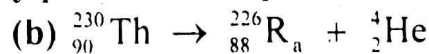
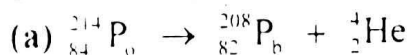
(13) Nuclear fusion reaction is more reliable and sustainable source of energy than nuclear fission chain reaction. Justify this statement with plausible arguments.

Ans: Nuclear fusion reaction is more reliable and sustainable source of energy than nuclear fission chain reaction. In case of fusion reaction, fusion reactors cannot sustain a chain reaction so they never melt down like fission reactors. Fusion reaction produces very less or, if the right atoms are chosen, no radioactive waste. In case of nuclear fission large radioactive waste is produced and disposal of radioactive waste is a complicated problem. For nuclear power, fusion is the better choice.

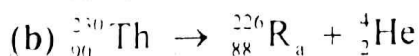
(14) A nitrogen nuclide ${}_{7}^{14}\text{N}$ decays to become an oxygen nuclide by emitting an electron. Show this process with an equation.

Ans: Equation: ${}_{7}^{14}\text{N} + {}_{-1}^0\text{e} \rightarrow {}_{8}^{14}\text{O} + {}_{1}^1\text{H}$

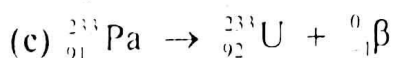
(15) Determine which of these radioactive decay processes are possible:



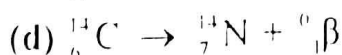
Not possible



Possible



Possible



Possible

CONCEPTUAL QUESTIONS

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

Ans Usually an element has same types of atoms. However, certain elements have different types of atoms. These atoms have same atomic mass numbers, but different atomic number. For example, there are three different types of atoms of hydrogen elements ${}^1_1\text{H}$, ${}^2_1\text{H}$ and ${}^3_1\text{H}$. These different atoms of same element are known as isotopes.

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

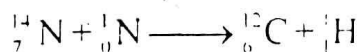
Ans: Energy released in fusion reaction is large as compared to that of fission reaction. For example, in the proton-proton fusion reaction about 6.4 MeV energy is released which is much greater than the per nucleon energy released per nucleon for fission reaction which is about 1 MeV.

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

Ans: Alpha particle is a massive particle as compared to a gamma-ray photon. Also photon is neutral but charge on alpha particle is $+2e$. Hence, alpha particle has greater ionization power and, therefore, has less penetrating power than that of gamma-ray photon.

18.4 What is the difference between natural and artificial radioactivity?

Ans: In natural radioactivity, some elements emit radiations by their own due to their unstable state. For example, ${}^{14}_6\text{C}$ is natural radioactive isotope of carbon. Some stable elements can also be transformed into radioactive elements. Such process is called artificial radioactivity. For example, when N-14 is bombarded with neutron, it changes into C-14 i.e.

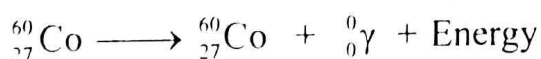


18.5 How long would you likely have to wait to watch any sample of radioactive atoms completely decay?

Ans: During one half-life, half of the parent nuclei of radioactivity element change into daughter nuclei. However, the total decay time of any radioactive element is indefinite. Thus, we have to wait for infinite amount of time to observe the complete decay.

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

Ans. During gamma-decay process, the number of protons and the number of neutrons remains unchanged e.g.



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

Ans. Using the formula;

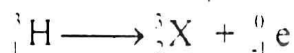
$$\text{Remaining} = \text{Original} \times \frac{1}{2^n}$$

We get

$$\begin{aligned}\text{Amount of sample after 4 half-lives} &= \frac{1}{2^4} \text{ g} \\ &= \frac{1}{16} \text{ g}\end{aligned}$$

18.8 Tritium, ${}^3_1\text{H}$ is radioactive isotope of hydrogen. It decays by emitting an electron. What is the daughter nucleus.

Ans. The decay process is



Thus, the daughter nuclei ${}^3_2\text{X}$ is of helium element i.e. ${}^3_2\text{He}$

18.9 What information about the structure of the nitrogen atom can be obtained from its nuclide ${}^{14}_7\text{N}$? in what way atom in ${}^{14}_7\text{N}$ is different from the atom in ${}^{16}_7\text{N}$?

Ans. From the nuclide ${}^{14}_7\text{N}$, We know that it is one of the isotopes of nitrogen. It has 7 protons, 7 electron and 7 neutrons. As compared to ${}^{14}_7\text{N}$, ${}^{16}_7\text{N}$ has two extra neutrons in its nucleus as its atomic mass number increases by 2.

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

Ans. Using the formula;

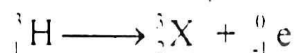
$$\text{Remaining} = \text{Original} \times \frac{1}{2^n}$$

We get

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EXERCISE

MULTIPLE CHOICE QUESTIONS

- (1) Isotopes are atoms of same element with different
☒ (a) Atomic mass (b) Atomic number (c) Number protons (d) Number of electrons
- (2) One of the isotopes of uranium is $^{238}_{92}\text{U}$. The number of neutrons in this isotope is
 (a) 238 ☒ (b) 92 (c) 330 (d) 146
- (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 capability
- (4) What happens to the atomic number of an element which emits 1 alpha particle?
 (a) Increases by 1 (b) Stays the same (c) decreases by 2 ☒ (d) decreases by 1
- (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 it
- (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) 93 protons (d) 89 protons
- (7) Release of energy by the sun is due to
 (a) Nuclear fission ☒ (b) Nuclear fusion (c) Burnings of gases (d) Chemical reaction
- (8) When 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 plant or animal dies, it stops taking in fresh carbon-14
 (c) There is so much non-radioactive carbon dioxide in the air
 (d) When a plant or an animal dies

ANSWER KEY

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	a	3	b	5	b	7	b	9	b
2	b	4	d	6	c	8	a		

SHORT QUESTIONS

18.1 Atom and Atomic Nucleus

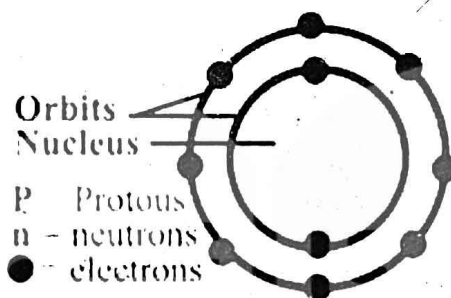
18.2 Natural Radioactivity

Q.1. Define atom and write down its parts.

Ans: The smallest part of an element is called an atom.

Parts of atom

- (i) Atom consists of two parts and its central part is called nucleus. The nucleus consists of protons and neutrons. The proton is a positively charged particle and neutron has no charge so the nucleus carries a positive charge.
- (ii) The electrons revolve around the nucleus in nearly circular orbits. Since an atom is a neutral particle, so the number of electrons in it is equal to the number of protons.



Q.2. What are Nucleons?

Ans: The mass of the proton & neutron is nearly the same i.e. 1.67×10^{-27} kg. Since the protons and neutrons exist inside the nucleus so these are called nucleons.

Q.3. What is Atomic Mass Number?

Ans: A nucleon is nearly 1836 times heavier than an electron. So the mass of an atom is nearly equal to the total sum of the masses of all the protons and neutrons present in the nucleus of that atom.

“The total number of protons and neutrons in the nucleus is called the Atomic Mass Number and is denoted by the letter A”.

Q.4. What is Atomic Number?

Ans: Since the number of protons in an atom of different elements is different so the number of protons in the nucleus indicates the charge on that nucleus.

“The number of protons in a nucleus is called the charge number or Atomic number and is denoted by the letter Z”.

The number of neutrons in the nucleus is denoted by the letter N.

Q.5. What do you know about Nuclide?

Ans: If atomic number of an atom is Z and its Atomic Mass Number is A then this atom is represented by the symbol which is called a nuclide $\left(\begin{smallmatrix} A \\ X \\ Z \end{smallmatrix} \right)$. For example there is only one proton in the nucleus of hydrogen atom so its atomic number is 1 and its atomic mass number is also 1. Hence it is denoted by ${}^1_1\text{H}$.

Q.6. What is the difference between Atomic number and Atomic Mass number?

Ans:

Atomic number	Atomic Mass number
- The total number of protons and neutrons in the nucleus is called the Atomic Mass Number. - It is denoted by the letter A.	- The number of protons in a nucleus is called the charge number or Atomic number. - It is denoted by the letter Z.

Q.7. What are radioactive isotopes?

Ans: The atoms of the same radioactive element whose atomic numbers are the same but have different atomic mass numbers are called Radioactive Isotopes.

Q.8. What are isotopes? What do they have in common and what are their differences.

Ans: Atoms of the same element having same atomic number but different mass number, are called isotope. They have same chemical properties but different physical properties. For example, Hydrogen has three isotopes

Protium $Z=1$ $A=1$ $N=A-Z=0$

Deuterium $Z=1$ $A=2$ $N=A-Z=1$

Tritium $Z=1$ $A=3$ $N=A-Z=2$

Hence, from above relations we conclude that the number of protons are same and number of neutrons are different in the isotopes of hydrogen.



Fig.18.2: Three isotopes of hydrogen
Protium (${}^1_1\text{H}$), Deuterium (${}^2_1\text{H}$) and Tritium (${}^3_1\text{H}$).

Q.9. Why Marie Curie and Pierre are famous?

The most significant investigations of the process of radioactivity were done by Marie Curie and the husband Pierre.

They discovered two new elements which emitted radiations. These were named **polonium** and **radium**. This process of emission of radiations by some elements was called natural radioactivity by Marie Curie.

Q.10. Why are heavy nuclei unstable?

Ans: Heavy nuclei are unstable due to large number of protons. The strong nuclear force cannot balance the repulsive Coulomb force which comes into play due to increase in size.

Q.11. Find the number of neutrons and protons in ${}^{238}_{92}\text{U}$

Ans: In ${}^{238}_{92}\text{U}$

$A = 238$ and $Z = 92$

$N = ?$ No of protons = ?

or $N = 146$ Ans

and No. of protons = $Z = 92$

or $Z = 92$

18.3 Background Radiations

18.4 Nuclear Transmutations

18.5 Half-life and its Measurement

Q.12. What is meant by Background Radiations ?

Background Radiations

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

Sources of background radiations

The back ground radiation present in the atmosphere is due to the following two possible causes.

(i) The presence of radioactive material under the earth

(ii) The cosmic rays entering the earth from the upper atmosphere along with the sun light

Q.13. What are cosmic radiation?

The earth and all living things on it also receive radiation from outer space. This radiation is called cosmic radiation which primarily consists of positively charged ions from protons to iron and large nuclei. The cosmic radiation interacts with atom in the atmosphere to create a shower of secondary radiation, including x-rays, muons, protons, alpha particles, electrons and neutrons.

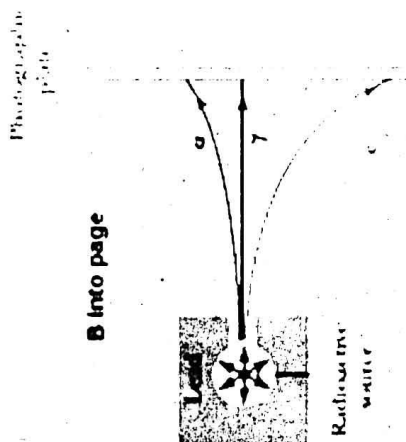
Q.14. Describe a brief account of Interaction of various types of radiations with matter.

Ans: **α -radiation:** It is a helium nuclei. When an alpha particle passes through a gas it interact with the atom of the gas and ionizes them. As its mass is comparatively more than β and γ so it has less penetrating power. Each ionization by an α -particle produces an ion pair and an average of about 3.5 electron volt energy is used to produce one ion pair. The range of α particle is around 7 cm and it can be stopped by a thick paper. α particle are capable of producing fluorescence in zinc sulphide or barium platinocyanide.

β -Radiations: These are negative charge particles they can penetrate 100 times more than α particles. The β -particle loses most its energy in a single collision. β Particle can also produce fluorescence in some materials like barium platinocyanide.

γ -Radiations: γ - rays have no charge that is why they cause very little ionization. The γ -ray photon can be absorbed by an atom and a photo electron can be ejected

(Photoelectric effect). When fast moving γ - ray photon is stopped it disintegrates into an electron positron pair (pair production). Material having large no of electron in a unit volume absorbs more γ - radiations. They have high penetration power than α & β particles and their intensity decreases exponentially with increase in depth of penetration into the material.



Q.15. Explain how α and β -particles may ionize an atom without directly hitting the electrons? What is the difference in the action of the two particles for producing ionization?

Ans: Since α and β -particles are electrically charged they can cause ionization without hitting an atom either by attracting or repelling the electrons of the target atom. α particle produces ionization by exerting electrostatic force of attraction while β -particles produce ionization by exerting electrostatic force of repulsion. α -particles cause ionization by attracting the electron while β -particles cause ionization by repelling the electron.

Q.16. A particle which produces more ionization is less penetrating why?

Ans: A particle which produces more ionization interacts strongly with the matter and loses its energy in a short distance and hence comes to rest soon, that's why it is less penetrating

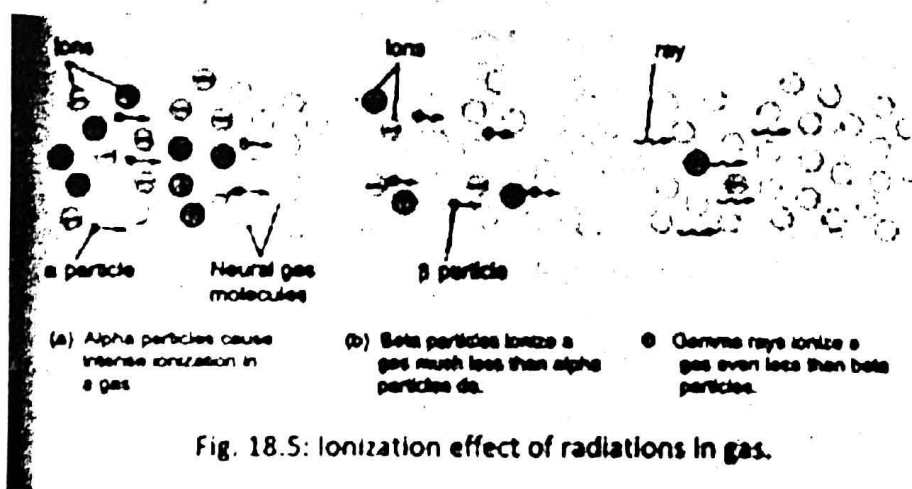


Fig. 18.5: Ionization effect of radiations in gas.

Q.17. If someone accidentally swallows an α -source and a β -source which would be the more dangerous to him? Explain why?

Ans: α -particles have greater ionizing power as compare to β -particles. So, they can cause more damage to tissues, if swallowed.

Q.18. Rn^{222} decays to a new element 'y' by two alpha and two β -emissions. What you can say about new element?

Ans: ${}_{80}\text{Rn}^{222} \longrightarrow {}_{82}\text{Y}^{214} + 2 {}_2\text{He}^4 (\alpha\text{-particles})$

After two β -emissions

${}_{82}\text{Y}^{214} \longrightarrow {}_{84}\text{Y}^{214} + 2 {}_{-1}^0\text{e}^0 (\beta\text{-particle})$

Hence, new element will be ${}_{84}\text{Y}^{214}$.

Q.19. Do α, β and γ radiations emit from the same element? Why they are found in many radioactive elements?

Ans: α, β and γ rays emit from the same element. But, an element can not emit α and β rays simultaneously.

When a radioactive element emit α or β rays, it decays into new element and so on. Hence, we find all the three radiations in many radioactive element.

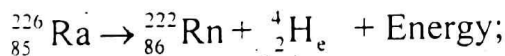
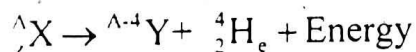
Q.20. Define nuclear transmutation?

"The spontaneous process in which a parent unstable nuclide changes into a more stable daughter nuclide with the emission of radiations is called nuclear transmutation".

Examples of radioactive decay

There are three processes given as

(i) Alpha (α) decay



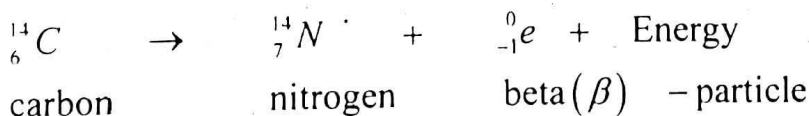
(ii) Beta (β) decay

General Equation



Parent nuclide daughter nuclide beta (β) -particle

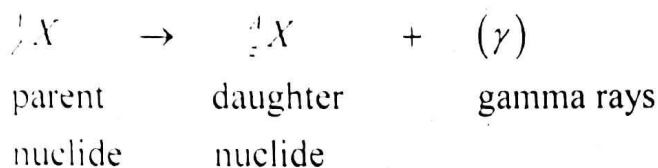
Example



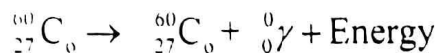
In (β) - decay, the parent nuclide has its proton number Z increased by 1 but its mass number or nucleon number remains unchanged.

(iii) **Gamma (γ) = decay**

General Equation



Example:



γ - rays are usually emitted at the same moment as either an alpha or a beta particle.

Q.21. What is the use of α, β and γ -radiation?

Ans: α -particles

They are used to treat skin cancer because their penetrating power is small.

β -particles

They are used to treat the tumors under the skin due to their large penetration power

γ -particles

They are used to treat the infection in interior parts of the body due to their longest penetration power.

Q.22. What is the difference between an electron and β -particles?

Ans: β -particle is negatively charged particle emitted from the nucleus of radioactive element. An electron is negatively charged particle which revolves around the nucleus.

Q.23. What do you know about half life?

Ans: "The half life of an element is that time during which the numbers of atoms of that element are reduced to one half".

Example

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 remain one half, after a time $2T$, the number of atoms remain 25% and after time $3T$, the number of atoms are reduced to 12.5% of the initial number.

Q.24. What is meant by Penetrating ability?

Penetrating ability

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

All kind of radiations penetrate but penetrating range is different for each.

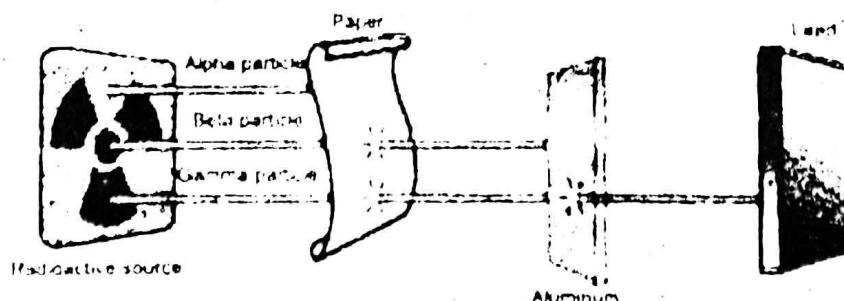


Fig 18.6 Penetrating power of radiations in different materials

18.6 Radioisotopes and their uses

Q.25. What are radioactive isotopes?

Ans: The atoms of the same radioactive element whose atomic numbers are the same but have different atomic mass numbers are called Radioactive Isotopes.

Q.26. What are stable nuclides?

Ans: Nuclei which do not emit radiations naturally are called stable nuclei. Most of the nuclei whose atomic number is from 1 to 82 are stable nuclei. They do not change from one type of element to another. The stable elements can also be changed into unstable form by bombarding them with neutrons. Such elements are called radio isotopes.

Q.27. What are unstable nuclides?

Ans: Nuclei which do not emit radiations naturally are called stable nuclei. Some elements, whose atomic number is greater than 82, are naturally unstable. These elements depending upon their characteristics, emit, all the time, different types of radiations and they continuously change from one type of element to another.

Q.28. Differentiate between stable and unstable nuclides?

Ans:

Stable elements	Unstable elements
• Nuclei which do not emit radiations naturally are called stable nuclei. • Most of the nuclei whose atomic number is from 1 to 82 are stable nuclei. • They do not change from one type of element to another.	• Nuclei which emit radiations naturally are called unstable nuclei. • The elements, whose atomic number is greater than 82, are naturally unstable. • They continuously change from one type of element to another.

Q.29. What is a radioactive tracer? Describe one application each in medicine, agriculture and industry.

Ans: A definite quantity of radio isotope introduced into a mechanical or biological system to enable its route through the system.

- Tracers are widely used in medicine to detect malignant tumors, blockage in the blood vessels, e.g brain and thyroid tumors are detected using I-131. Radio sodium has been largely used in medical research to study the action of various medicines
- Tracers are also used in agriculture to study the uptake of a fertilizer by a plant, e.g P^{32} is incorporated in fertilizer and added to the soil.
- Tracer technique is also very useful in industry in detecting the cracks and leakage in the pipes and welding joints e.g Iridium 192- is used to test the welds.

Q.30. How can radioactivity help in the treatment of cancer?

Ans: Medical applications of radio isotopes can be divided into two parts (i) diagnostic and (ii) therapy. Radiotherapy with γ - rays from cobalt-60 is often used in the treatment of cancer. The γ - rays are carefully focused on to the malignant tissue.

Radioactive Iodine-131 is used to fight with cancer of the thyroid gland.

Skin Cancers: for skin cancers, phosphorus-32 or strontium-90 may be used. They produce β radiation.

Q.31. How can radioactivity help in the treatment of Cancer?

Ans: Radioactivity & Treatment of Cancer: Cancerous cells are always weak as compared to the normal cells, and hence are destroyed by firing β -radiation or γ -radiation from radioactive source. Some times encapsulated "seeds" made from radioactive source are implanted in the malignant tissues for local and short ranged treatment.

For example:

- γ -rays from Co-60 in general
- Iodine-131 for treatment of cancer of thyroid gland.
- Phosphorus-32 or strontium-90 may be used for skin-cancers.

Q.32. How a radioisotope be used to determine the effectiveness of fertilizer?

Ans: Radioactive phosphorus or nitrogen used as a tracer in agriculture, provide information about the best fertilizer to supply to a particular crop and soil. Due to their use, varieties of crops such as rice, wheat and cotton have improved. Moreover, plants have shown more resistance to disease and give better yield and grain quality.

18.7 Fission Reaction

18.8 Nuclear Fusion

18.9 Hazards of Radiations and Safety Measures

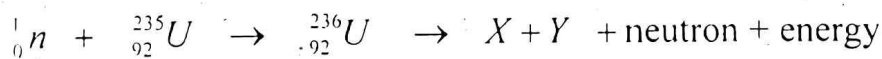
Q.33. What is positron?

Ans: Positron is a particle with mass equal to the mass of an electron having opposite and equal charge.

Q.34. What is by Nuclear fission

Nuclear fission

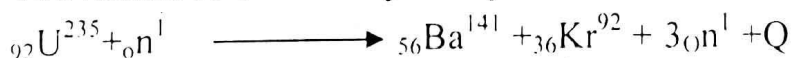
Nuclear fission takes place when a heavy nucleus, such as U-235, splits or fissions, into two smaller nuclear by bombarding a slow moving (low- energy) neutron represent in equation.



U-236 in an intermediate state that lasts only for few seconds before splitting into nuclei X and Y, called fission fragments.

Q.35. Briefly explain how heat is produced in a nuclear reactor?

Ans: The fission of U-235 may be represent as:



Where Q is the amount of energy released and it is nearly equal to 200 Mev. This energy is appeared in the form of heat.

Q.36. Why does water is used to slow down the neutrons rather than lead?

Ans: When neutrons collide with lead nuclei, they are bounced back. While lead atoms remain at rest due to their greater mass. But, in case of water, collision b/w neutrons and hydrogen nuclei, present in water is perfectly elastic. In this collision, neutrons are slowed down, while proton starts moving.

Hence, water may be used efficiently to slow down the neutrons rather than lead.

Q.37. Write a note on Einstein's mass energy equation.

Ans: In classical physics, the various forms of energy were related under the law of conservation of energy but no relationship was established between the energy and mass. In 1905, when Einstein gave his theory of relativity, it also contained the idea that the energy and matter are interchangeable. For this change an equation was also given which is known as Einstein's mass-energy equation. It is

$$E=mc^2$$

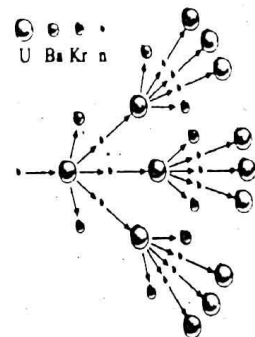


Which means that if mass m of matter is converted into energy, then this will be equal to E , where in this mass-energy equation c is the speed of light that is $3 \times 10^8 \text{ ms}^{-1}$.

Q.38. What is do you know about Fission chain reaction

Fission chain reaction

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.

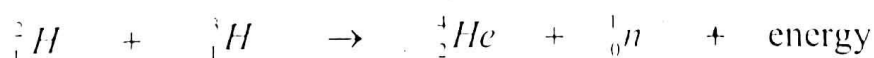


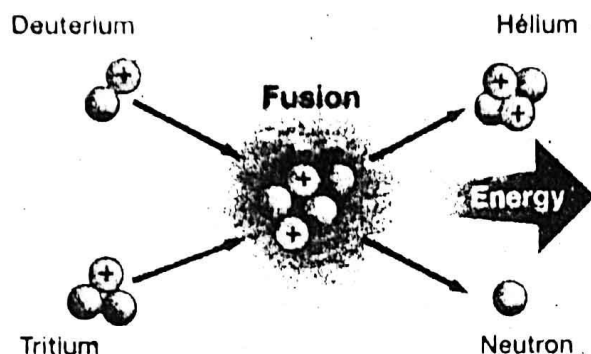
Q.39. Define Fusion Reaction.

Ans: 'When two light nuclei combine to form a heavier nucleus, the process is called nuclear fusion'.

Equation:

If an atom of Deuterium is fused with an atom of Tritium, the a Helium nucleus or alpha particle is formed as given by





Pictorially fusion reaction is shown in the following figure.

Q.40. Why it is more difficult to start a fusion reaction rather than fission reaction?

Ans: because, in bringing two nuclei closer to each other, great work has to be done against repulsive forces of nuclei. Hence, more energy is needed. On the other hand fission may be proceeded with slow neutrons.

Q.41. Differences between nuclear fission and nuclear fusion.

Nuclear Fission	Nuclear Fusion
1. A bigger heavier nucleus splits into smaller (lighter) nuclei.	1. Lighter nuclei fuse together to form the heavier nucleus.
2. It does not require temperature.	2. Extremely high temperature is require for fusion to take place.
3. A chain reaction sets in.	3. It is not a chain reaction.
4. It can be controlled and energy released can be used for peaceful purpose.	4. It cannot be controlled and energy released cannot be used properly.
5. The products of the reaction are radioactive in nature.	5. The products of a fusion reaction are non-radioactive in nature.
6. At the end of the reaction nuclear waste is left behind.	No nuclear waste is left at the end of fusions reaction.

Q.42. Discuss uses and the hazards of radiations

Some of harmful effects on human beings due to large doses or prolonged small doses of radiations.

1. Radiation burns, 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 human and plants. Some children are born with serious deformities.
4. Leukernia (Cancer of the blood cells)
5. Blindness or formation of cataract in the eye.

Q.43. Describe the precaution to minimize radiations dangers (safety measures)

Precautions to minimize radiation dangers

Because we cannot detect radiations directly, we should strictly follow safety precautions, even when the radioactive sources are very weak.

1. Sources should not be handled with tongs and forceps.
2. The user should use rubber gloves and hand should be washed carefully after the experiment.
3. All radioactive sources should be stored in thick lead containers.
4. Never point radioactive source towards a person.
5. Frequent visits to the radiation sensitive areas should be avoided.

LONG QUESTIONS

Q.1 Describe the structure of an atom. Differentiate between atomic number and atomic mass number? Write the symbol of atom.

Structure of Atom

There are two main parts of an atom.

- (i) Central part (Nucleus)
- (ii) Circular part (Orbits)

Rutherford's concept of structure of atom

Nucleus:

Rutherford discovered that the positive charge in an atom was concentrated in a small region called nucleus.

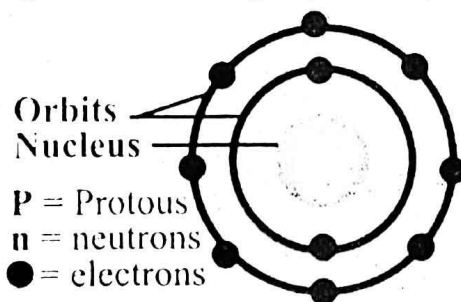
Nucleons:

“The nucleus contains protons and neutrons which are collectively called nucleons”.

Circular Orbits:

Atom contains electrons which revolve in nearly circular orbits about nucleus.

Example: Simplest atom of hydrogen contain single proton.



Difference between atomic number and atomic mass number	
Atomic Number	Atomic mass number
1. The number of protons inside the nucleus is called the atomic number.	1. The sum of protons and neutrons present inside the nucleus of an atom is called its atomic mass number.
2. Atomic number depends upon the number of protons or electrons of atom.	2. Atomic mass number depends upon the number of neutrons.
3. Atomic number is represented by Z.	3. It is represented by 'A' which is written as: $A = Z + N$
4. It is written at the bottom left side of the symbol of an element. e.g. ${}^4_2\text{He}$	4. It is written at the top left side of the symbol of an element e.g. ${}^4_2\text{He}$.

Comparison of the masses of the fundamental particles of atom

The mass neutron is nearly equal to the mass of proton. But proton is about 1836 times heavier than an electron. Hence the mass of the atom is equal to the sum of the masses of protons and neutrons.

Symbol of atom (Nuclide)

Generally an atom is represented by the symbol A_ZX , which is called nuclide.

Example:

Nuclide of hydrogen atom having only one proton is ${}^1_1\text{H}$.

Q.2 What is meant by isotopes? Give example.

Isotopes:

Isotopes are atom of an element which have same number of protons but different number of neutrons in their nuclei.

Example:

Hydrogen has three Isotopes.

(i) Protium (${}^1_1\text{H}$)

Protium contains one proton and one electron

(ii) Deuterium (${}^2_1\text{H}$)

Deuterium contains one proton, one neutron and one electron.

(iii) Tritium (${}^3_1\text{H}$)

Tritium contains one proton, two neutrons and one electron.



Fig. 18.2: Three isotopes of hydrogen
Protium (${}^1_1\text{H}$), Deuterium (${}^2_1\text{H}$) and Tritium (${}^3_1\text{H}$)

Q.3 What is meant by natural radioactivity? Explain how it is discovered and how radiations are identified?

Natural Radioactivity

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

Radioactive elements

“The elements which emit radiations naturally are called radioactivity elements”.

Explanation

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

Marie Curie

The most significant investigations of the process of radioactivity were done by Marie Curie and the husband Pierre.

They discovered two new elements which emitted radiations. These were named **polonium** and **radium**. This process of emission of radiations by some elements was called natural radioactivity by Marie Curie.

Henry Becquerel performed some experiments and suggested that radioactivity was the result of the decay unstable nuclei.

How these radiations are identified?

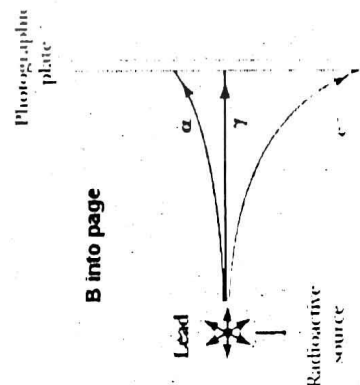
Three types of radiation are usually emitted by a radioactive element (substance). e.g.

(i) Alpha (α) particles.

(ii) Beta (β) particles.

(iii) Gamma (γ) rays.

These three forms of radiations were studied by the following scheme. The radioactive source is placed inside the lead block. The radiations emitting from the source allow to pass through the magnetic field. These radiations split into three components. Alpha (α) and Beta (β) radiations bend in opposite direction in magnetic field but gamma (γ) radiation does not change direction.



Q.4 What is meant by background radiations? Enlist some sources of background radiations.

Background Radiations

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

Sources of background radiations

Everywhere in rocks, soil, water and air of our planet (Earth) there are traces of radioactive elements. They emit the radiation every time, this natural radioactivity is called the background radiation. It is as much part of our environment as sunshine and rain. Fortunately, our bodies can tolerate it. Only those places can be injurious to health where radiations are very height in magnitude.

The earth and all living things on it also receive radiation from outer space. This radiation is called cosmic radiation which primarily consists of positively charged ions from protons to iron and large nuclei. The cosmic radiation interacts with atom in the atmosphere to create a shower of secondary radiation, including x-rays, muons, protons, alpha particles, electrons and neutrons.

Q.5 Define nuclear transmutation? Explain the radioactive decay of nuclide.

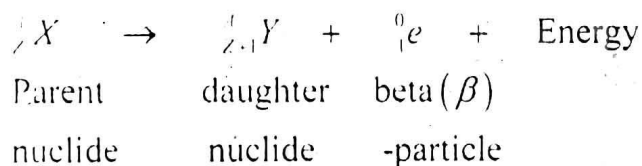
"The spontaneous process in which a parent unstable nuclide changes into a more stable daughter nuclide with the emission of radiations is called nuclear transmutation".

Examples of radioactive decay

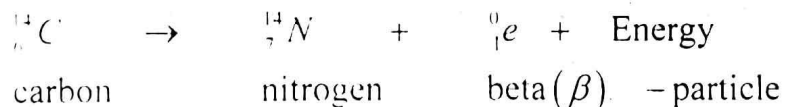
There are three processes given as

(i) Beta (β) decay

General Equation



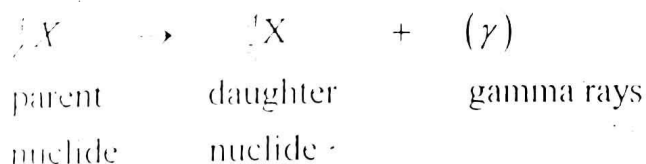
Example



In (β) - decay, the parent nuclide has its proton number Z increased by 1 but its mass number or nucleon number remains unchanged.

(iii) Gamma (γ) - decay

General Equation



γ - rays are usually emitted at the same moment as either an alpha or a beta particle.

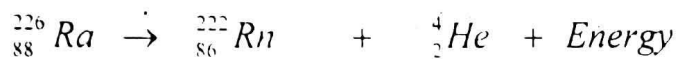
Q.6 Discuss the nature and properties of radiation.

There are three types of radiations which show different properties.

(1) Nature of Radiations

(i) Alpha (α) particles

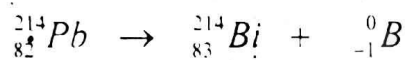
Alpha particle is a helium nucleus comprising two protons and two neutrons with a charge of +2. Alpha particles are emitted by the decay of unstable heavy nucleus, i.e



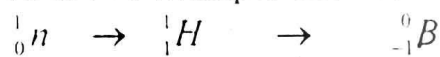
Radium radon Alpha particle

(ii) Beta (β) particles

Beta radiation is a stream of high-energy electrons. An unstable nuclei with excess of neutrons any eject beta radiations. i.e



In above example one neutron is converted into proton with the emission of Beta particles



iii. Gamma (γ) rays

Gamma radiations are fast moving light photons. They are electromagnetic radiations of very high frequency and short wavelength. These radiations are emitted by the unstable excited nuclei.

(2) Ionizing Effect

"The phenomena by which radiations split matter into positive and negative ions is called ionization". All three kinds of radiations ionize the matter but in different extent.

i. Alpha (α) particles:

Alpha particles have the greatest power of ionization of all. It is due to large positive charge and large mass of alpha particles.

ii. Beta (β) particles:

Beta particles ionize a gas much less than alpha particles do. It is due to high speed and negligible mass.

iii. Gamma (γ) rays:

The ionization of power of gamma rays is even less than that of beta particles.

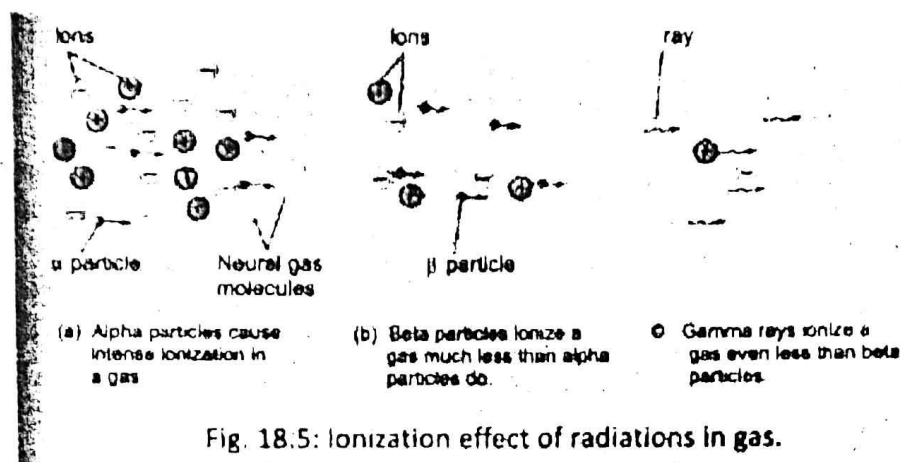


Fig. 18.5: Ionization effect of radiations in gas.

(3) Penetrating ability

"The strength of radiations to penetrate a certain material is called penetrating power". All kind of radiations penetrate but penetrating range is different for each.

i. Alpha (α) particles

Alpha particles has the shortest range because of its strong interacting or ionizing power. Alpha particle has a rang of only a few centimetres in air.

ii. Beta (β) p articles:

Beta particle also penetrate to matter but their penetration is less than gamma rays and more than alpha particles. It is due to beta radiation strongly interacts with matter due to its charge. Beta particle has a range of several meters in air.

iii. Gamma (γ) rays:

The gamma ray can penetrate a considerable thickness of concrete. It is due to their large speed and neutral nature. Gamma radiations have a range of several hundred meters in air.



Fig. 18.6: Penetrating power of radiations in different materials

The three types of Radiation

Alpha particle	Beta particle	Gamma ray
Charge +2	Charge -1	No charge
Least penetration	Middle penetration	Highest penetration
Transmutes nucleus:		
$A \rightarrow A - 4$	$A \rightarrow A$	$A \rightarrow A$
$Z \rightarrow Z - 2$	$Z \rightarrow Z + 1$	$Z \rightarrow Z$

Q.7 What do you understand by the half life of a radioactive elements? Explain with one example.

Half Life

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

Explanation

Every radioactive element has its own characteristic half-life. 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 (Fig. 18.7) In the next 1620 years, half of the remaining radium will decay, leaving only one-fourth the original amount of radium, and so on.

If the half-life of the radioactive element is $T_{1/2}$, then at the end of this time the number of atoms in the sample will become half i.e. $1/2$. After a time $2T_{1/2}$. After second half-life period, the number of remaining atoms will become $1/2 \times 1/2 = 1/2^2 = 1/4$, after a time $3T_{1/2}$, the number of remaining atoms will be $1/2 \times 1/2 \times 1/2 = 1/2^3 = 1/8$, and at the end of t half lives number of atoms that remain will be $1/2^t$.

amount of radium, and so on.

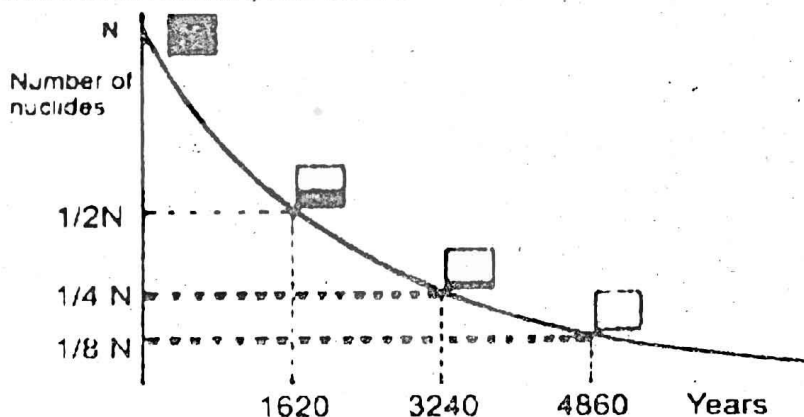


Fig.18.7 Radioactivity of radium

It means that if N_0 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,

Remaining atoms = Original atoms $1/2^t$

Or $N = N_0 \times 1/2^t$

Radioactivity is a nuclear process

Radioactivity is a nuclear process because radiations are emitted by the disintegration of nucleus.

Conclusion

The process of radioactivity does not depend upon the chemical combinations or reactions. It also not affected by any change in physical conditions like temperature, pressure, electric or magnetic fields.

Q.8 Define stable and unstable nuclei? How radioisotopes are produced?

Stable nuclei:

Nuclei which do not emit radiations naturally are called stable nuclei. The elements with atomic number 1 to 82 are stable nuclei. E.g. Sodium; ${}_{11}^{23}\text{Na}$, ${}_{20}^{40}\text{Ca}$ etc.

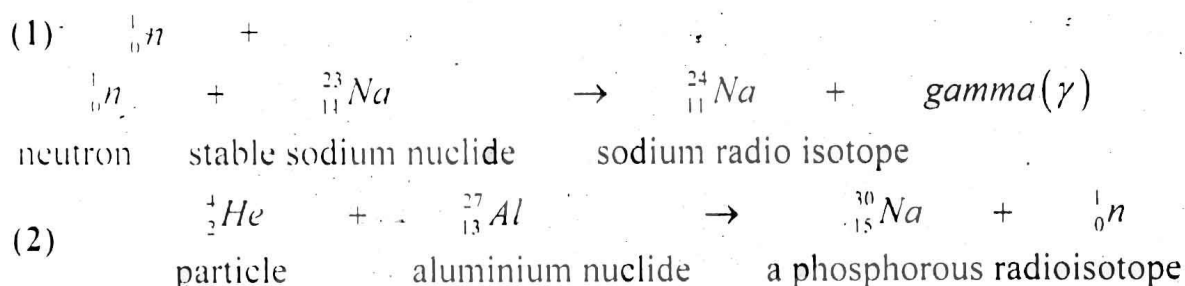
Unstable nuclei

The elements whose atomic number is greater than 82 are naturally radiating all the time called unstable nuclei. They emit different types of radiations and hence continuously change one type of element to another.

How radioisotopes are formed?

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

Examples:



Q.9 Describe the uses of radioisotopes in different fields?

Radioisotopes are frequently used in medicine, industry and agriculture for variety of useful purpose.

Important applications of radioisotopes

(1) Traces:

Radioactive tracers are chemical compounds containing some quantity of radioisotope.

Radioactive traces are used to explore the metabolism of chemical reactions inside the human body, animal or plant.

i. Tracers in medicine (Medical field)

Radio isotopes are used for the diagnosis and treatment of diseases in hospitals.

(a) Iodine - 131

Radio iodine - 131 is used in treating cancer of thyroid glands.

Iodine - 131 readily accumulates in the thyroid gland and can be used for the monitoring of thyroid functioning.

(b) Phosphorous -32

P-32 is used to diagnose the brain tumour and for the treatment of leukaemia. The malignant part of the body absorbs more quantity of isotopes and this helps in tracing the affected part of the body.

(c) Cobalt - 60

The gamma-rays from cobalt - 60 are used for treatment of cancer because this powerful radiation kills the cancerous cells.

(d) Gallium - 67

Ga-67 is used to identify tumours in the lymph region of the throat and neck.

ii. Tracers in industry

In industry tracers can be used to locate wear and tear of the moving parts of the machinery, e.g. Co-60. They can be used for the location of leaks in underground pipes. By introducing a suitable radioactivity tracer into the pipe, the leak can be conveniently traced from higher activity in the region of crack in the pipe.

γ -rays radiography is used in metals. It shows any flaw in metal castings any welded joints.

Traces of radio isotopes are used to monitor the flow of oil and gas through pipe. They are used to check and control the thickness or density of finished products.

iii. Tracers in agriculture:

In agriculture radio phosphorus - 32 is used as a tracer to find out how well the plants are absorbing the phosphate fertilizers which are crucial to their growth.

(2) Medical Treatment

Radio isotopes are also used in nuclear medicines for curing various diseases. For example, radioactive cobalt - 60 is used for curing cancerous tumors and cells. The radiations kill the cells 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 become slightly radioactive.

When a tree dies, the radio carbon - 14 present inside the plant starts decaying. Since the half-life of carbon - 14 - 5730 year, the age of 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 trees is no more replenished. Therefore, by measuring the activity in the ancient relic, scientists can estimate its age.

Other radio isotopes are also used to estimate the age of geological specimens. For example, some rocks contain the unstable potassium isotope K-40. This decays to the stable argon nuclide Ar-40 with half life of 2.4×10^8 years. The age of rock sample can be estimated by comparing the concentrations of K-40 and Ar-40.

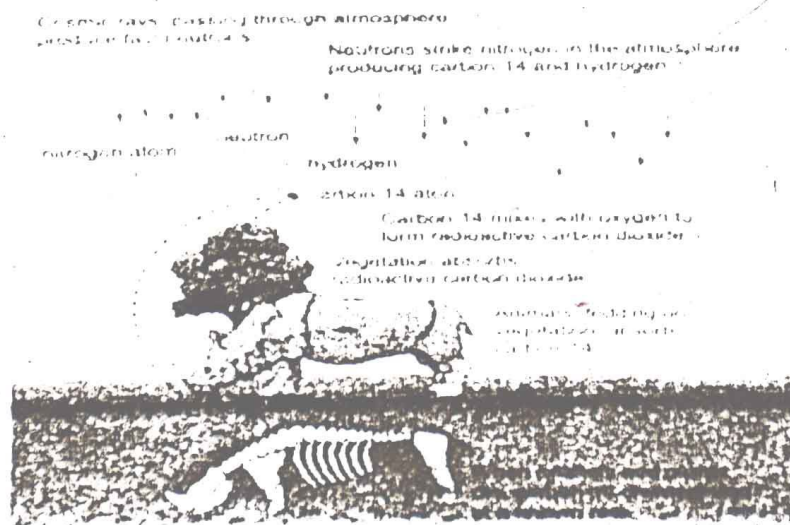


Fig. 18.10: Radio carbon dating is possible because plant and animal life

Q.10 Define and explain the phenomenon of nuclear fission?

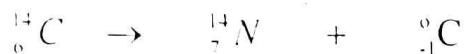
Nuclear fission

"The process of splitting of heavy nuclei into lighter nuclei is called fission reaction".

Natural Nuclear Transmutation

A nuclear transmutation in which an unstable nucleus changes into more stable nucleus is called natural nuclear transmutation.

Example



Artificial Transmutation

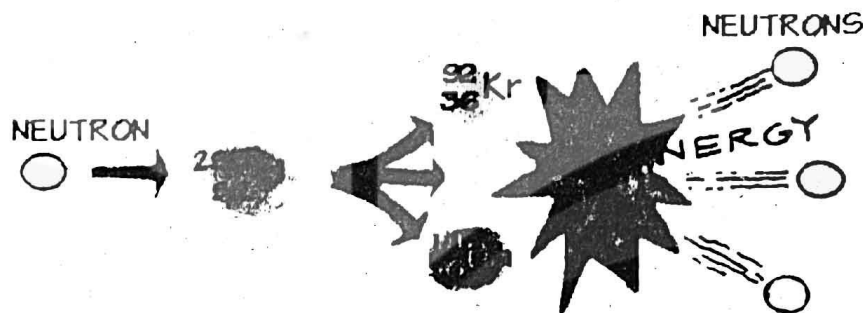
A nuclear transmutation reaction in which an unstable nucleus changes into more stable nucleus when it is bombarded with particle like neutron is called artificial transmutation.

Example:

Famous example of artificial transmutation is the nuclear fission reaction.

Nuclear fission

Nuclear fission takes place when a heavy nucleus, such as U-235, splits or fissions, into two smaller nuclear by bombarding a slow moving (low- energy) neutron represent in equation;



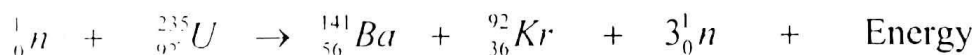
U-236 in an intermediate state that lasts only for few seconds before splitting into nuclei X and Y, called fission fragments.

When and who nuclear fission discovered

Nuclear fission was first observed in 1939 by Otto Han and Fritz Strassman.

How fission take place?

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 average, 2.47 neutrons are released per event such as given below



Enormous energy released

In nuclear fission, the total mass of the products is less than the original mass of the heavy nucleolus. From measurements it is showed that about 200 MeV of energy is released in each fission event. This is large amount of energy relative to the energy released in chemical processes.

Example:

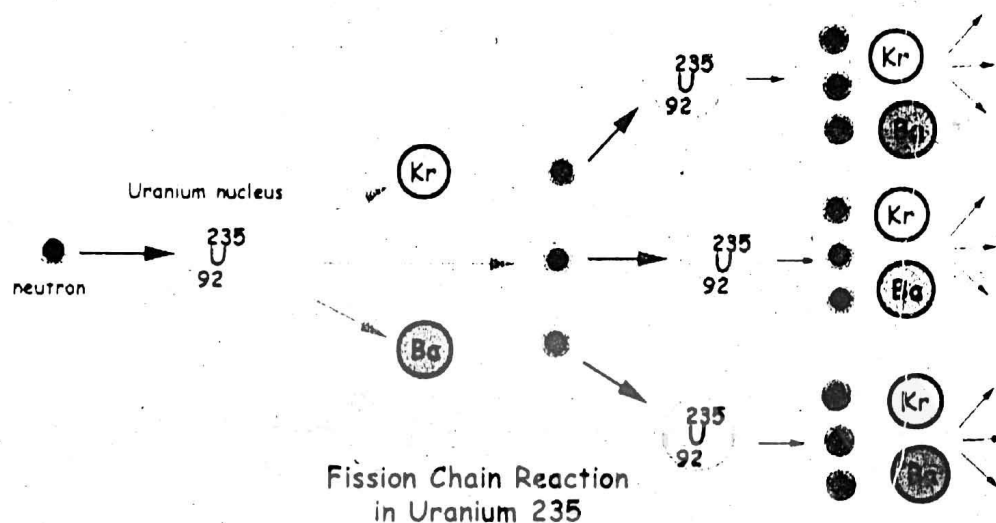
If we burn one tonne of coal then about $36 \times 10^9 \text{ J}$ of energy is released.

Chain Reaction

"A fission reaction where the neutrons from a previous step continue to propagate and repeat the reaction, termed as chain reaction".

Explanation of chain reaction

During fission reaction neutrons are emitted. These neutrons can in turn trigger other uranium nuclei to undergo fission with the possibility of a chain reaction.

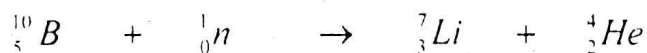


Explosion

Calculations show that if the chain reaction is controlled, it will proceed too rapidly and possibly result in the sudden release of an enormous amount of energy which is considered as an explosion.

How chain reaction is controlled?

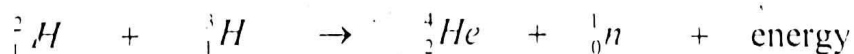
The fission chain reaction is controlled in a nuclear reactor. In a nuclear reactor the extra neutrons liberated in fission reactions are absorbed using some material to stop the chain reaction. e.g.



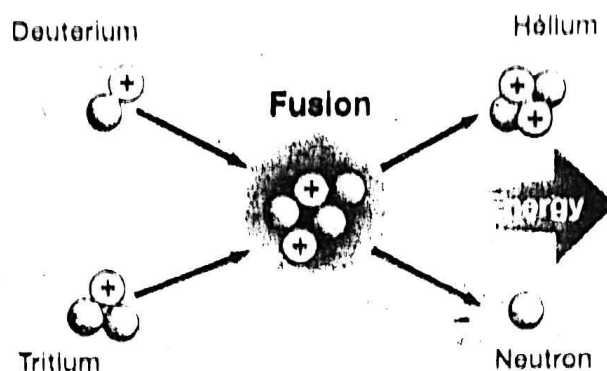
Thus a chain reaction is prevented from going too fast. Hence the energy is controlled, so a nuclear reactor provides energy for useful purposes.

Q.11 Nuclear Fusion

When two light nuclei combine to form 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 the 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 particle is formed as given by



Pictorially fusion reaction is shown in the following figure.



Source of Energy

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 favourable. 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.12 Differences between nuclear fission and nuclear fusion.

Nuclear Fission	Nuclear Fusion
1. A bigger heavier nucleus splits into smaller (lighter) nuclei.	1. Lighter nuclei fuse together to form the heavier nucleus.
2. It does not require temperature.	2. Extremely high temperature is required for fusion to take place.
3. A chain reaction sets in.	3. It is not a chain reaction.
4. It can be controlled and energy released can be used for peaceful purpose.	4. It cannot be controlled and energy released cannot be used properly.
5. The products of the reaction are radioactive in nature.	5. The products of a fusion reaction are non-radioactive in nature.
6. At the end of the reaction nuclear waste is left behind.	No nuclear waste is left at the end of fusion reaction.

Q.13 Describe the half-lives of some important isotopes? Also write the radiation produced by this decay process.

Element	Isotope	Half-Life	Radiation Produced
Hydrogen	${}^3_1\text{H}$	12.3 years	β
Carbon	${}^{14}_6\text{C}$	5730 years	β
Cobalt	${}^{60}_{27}\text{Co}$	30 years	$\beta - \gamma$
Iodine	${}^{131}_{53}\text{I}$	8.07 days	$\beta - \gamma$

Lead	$^{212}_{82} Pb$	10.6 hours	β
Polonium	$^{194}_{84} Po$	0.7 seconds	α
Polonium	$^{210}_{84} Po$	138 days	$\alpha - \gamma$
Uranium	$^{238}_{92} U$	7.1×10^8 years	$\alpha - \gamma$
Uranium	$^{235}_{92} U$	4.51×10^8 years	$\alpha - \gamma$
Plutonium	$^{239}_{94} Pu$	2.85 years	α
Plutonium	$^{242}_{94} Pu$	3.79×10^5 years	$\alpha - \gamma$

Q.14 Discuss uses and the hazards of radiations? Describe the precaution to minimize radiations dangers (safety measures)

Important fields where radiations are uses as follow

Radiations are very useful in medicine, agriculture and industry, they can also cause considerable damage if not used with precautions. Radioactive, nuclear materials are now widely used in nuclear power plants, nuclear – powered submarines, intercontinental ballistic missiles etc.

Radiations Hazards

Some of harmful effects on human beings due to large doses or prolonged small doses of radiations.

6. Radiation burns, mainly due to beta and gamma radiations, which may cause redness and sores on the skin.
7. Sterility (i.e. inability to produce children).
8. Genetic mutations in both human and plants. Some children are born with serious deformities.
9. Leukernia (Cancer of the blood cells)
10. Blindness or formation of cataract in the eye.

Explosion of nuclear reactor at Chernogyl

During the nuclear accident at Chernobyl, Russia the explosion of the nuclear reactors melted through a few meters thick concrete housing. This caused a massive destruction of local community and also contaminated vegetation and livestock in the large surrounding area. Millions of dollars were lost as the contaminated vegetable and livestock had to be destroyed.

Precautions to minimize radiation dangers

Because we cannot detect radiations directly, we should strictly follow safety precautions, even when the radioactive sources are very weak.

6. Sources should not be handled with tongs and forceps.
7. The user should use rubber gloves and hand should be washed carefully after the experiment.
8. All radioactive sources should be stored in thick lead containers.
9. Never point radioactive source towards a person.
10. Frequent visits to the radiation sensitive areas should be avoided.

NUMERICAL PROBLEMS

18.1 The half-life of ${}^{16}_7\text{N}$ is 7.3s. A sample of this nuclide of nitrogen is observed for 29.2s. Calculate the fraction of the original radioactive isotopes remaining after this time.

Solution: Given that,

$$\text{Half-life of } {}^{16}_7\text{N} = 7.3$$

$$\text{Time } t = 29.2 \text{ s}$$

To Find: Remaining fraction of original radioactive isotope = ?

Solution: During 29.2 s, four half-lives are elapsed. If N_0 is the original fraction of the nuclide of nitrogen, then after four half-lives i.e., $4T_{1/2}$

$$\text{Remaining fraction} = \text{Original} \times \frac{1}{2^t}$$

$$\text{Or } N = N_0 \times \frac{1}{2^4}$$

Or

$$\frac{N}{N_0} = \frac{1}{16}$$

Ans.

Thus, the fraction of the original radioactive isotope remaining after 4 half-lives will be $1/16^{\text{th}}$.

18.2 Cobalt-60 is a radioactive element with half-life of 5.25 years. What fraction of the original sample will be left after 26 years.

Solution: Given that,

$$\text{Half-life of C-14 } T_{1/2} = 5730 \text{ years}$$

$$\text{Time } t = 26 \text{ years}$$

To Find: Remaining fraction = ?

During the 26 years, five half-lives are elapsed so

$$\text{Remaining fraction} = \text{Original} \times \frac{1}{2^5}$$

$$\text{Or } N = N_0 \times \frac{1}{2^5}$$

$$\text{Or } \frac{N}{N_0} = \frac{1}{32} \text{ Ans.}$$

Thus, the fraction of the original isotope remaining after 5 half-lives will be $\frac{1}{32^{\text{th}}}$.

18.3 Carbon-14 has a half-life of 5730 years. How long will it take for the quantity of carbon-14 in a sample to drop to one-eighth of the initial quantity?

To Find: Time t = ?

Calculations: As quantity of C-14 drops to $\frac{1}{8^{\text{th}}}$ of the original quantity after 3 half-lives, therefore,

$$\text{Time} = \text{No. of half-lives} \times \text{half-life}$$

$$\text{Or } \text{Time} = 3 \times T_{1/2}$$

$$\text{Or } \text{Time} = 3 \times 5730 \text{ years}$$

$$\text{Time} = 1.72 \times 10^4 \text{ years Ans.}$$

18.4 Technetium-99 m is a radioactive element and is used to diagnose brain, thyroid, liver and kidney disease. This element has half-life of 36 hours. If there is 200 mg of this technetium present, how much will be left in six hours.

Solution: Given that,

$$\text{Half-life } T_{1/2} = 36 \text{ hours}$$

$$\text{Time } t = 6 \text{ hours}$$

$$\text{Original quantity} = 200 \text{ mg}$$

Since during 36 hours, 6 half-lives are elapsed, therefore,

$$\begin{aligned}\text{Remaining amount} &= \text{Original} \times \frac{1}{2^t} \\ &= 200 \text{ mg} \times \frac{1}{2^6} \\ &= \frac{200 \text{ mg}}{64}\end{aligned}$$

$$\text{Remaining amount} = 3.125 \text{ mg Ans.}$$

18.5 Half-life of a radioactive element is 10 minutes. If the initial count rate is 368 counts per minute, find the time for which count rate reaches 23 counts per minutes.

Solution: Given that

$$\text{Half-life} \quad T_{1/2} = 10 \text{ min.}$$

$$\text{Initial count rate} = 368 \text{ counts per min.}$$

$$\text{Final count rate} = 23 \text{ count per min.}$$

To Find: Time taken $t = ?$

Calculations: For the count rate to decrease from 368 counts per min. to 23 counts per min., it takes 4 half-lives, therefore

$$\text{Time taken} = 4 \times T_{1/2}$$

$$= 4 \times 10 \text{ min}$$

$$t = 40 \text{ min Ans.}$$

18.6 In an experiment to measure the half-life of a radioactive element, the following results were obtained:

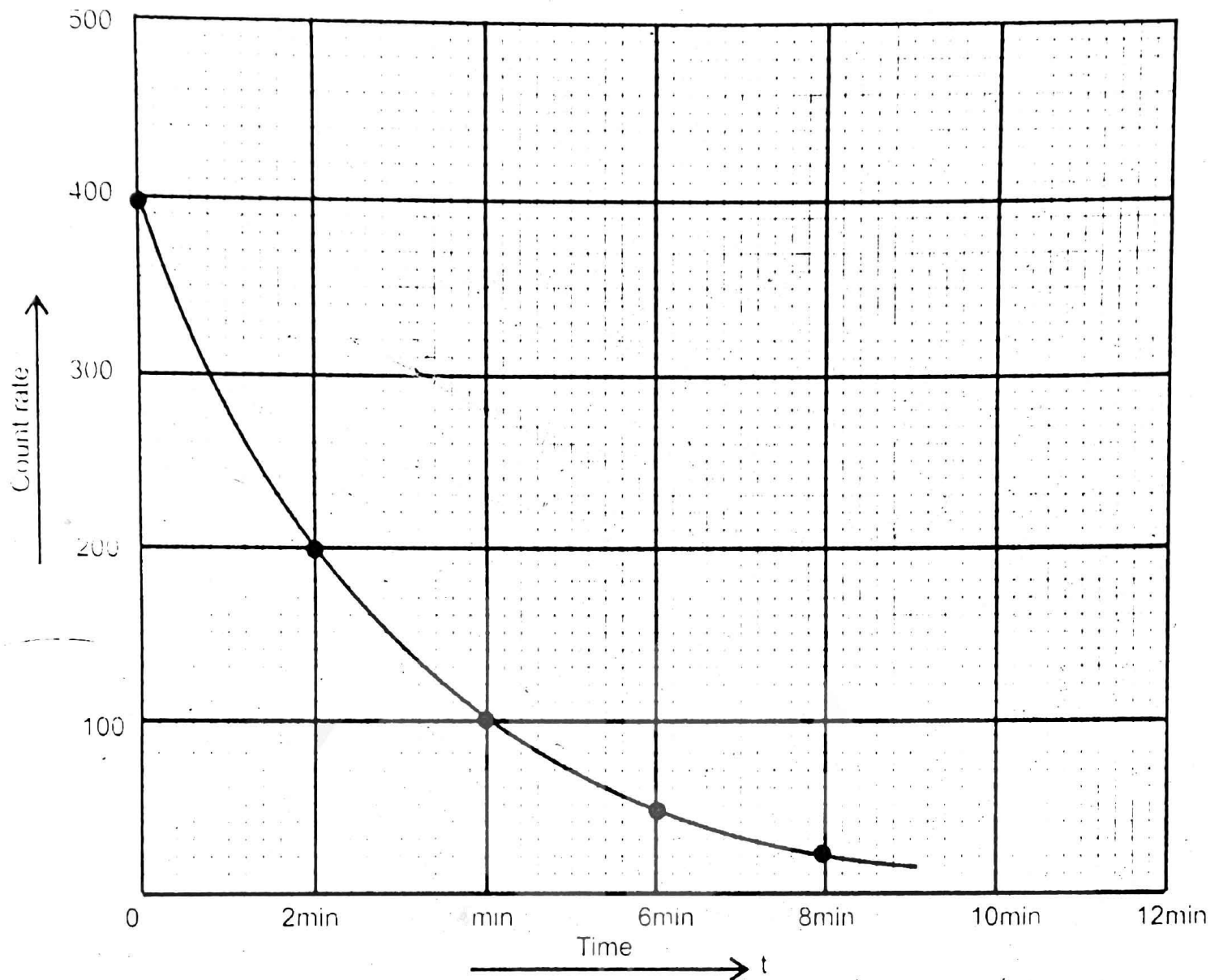
Count rate	400	200	100	50	25
Time (in minutes)	0	2	4	6	8

Plot a graph between the count rate and time in minutes. Measure the value for the half-life of the element from the graph.

Solution: Scale

One big division = 2 min. (along x-axis)

One big division = 100 counts (along y-axis)



From the graph, it is clear that half-life of the radioactive element is 2 minutes.

- 18.7 A sample of certain radioactive element has a half-life of 1500 years. If it has an activity of 32000 counts per hour at the present time, then plot a graph of the activity of this sample over the period in which it will reduce to $\frac{1}{16}$ of its present value.

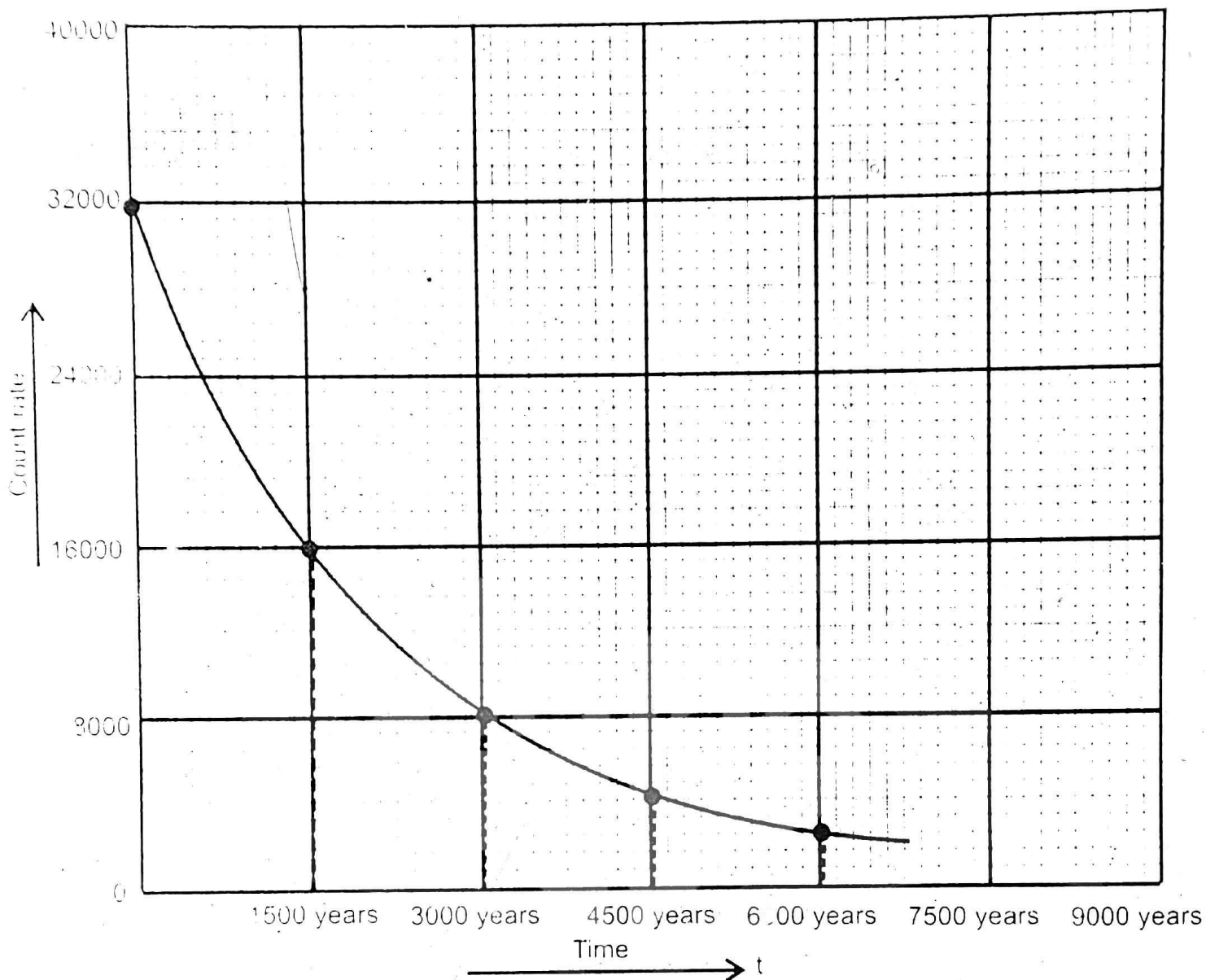
Solution:

$$\begin{aligned}
 \text{Half-life } T_{1/2} &= 1500 \text{ years} \\
 \text{Activity} &= 32000 \text{ counts per hour} \\
 \frac{1}{16} \text{th of the activity} &= \frac{32000}{16} = 2000
 \end{aligned}$$

Scale

One big division = 1500 years (along x-axis)

One big division = 4000 counts per hour

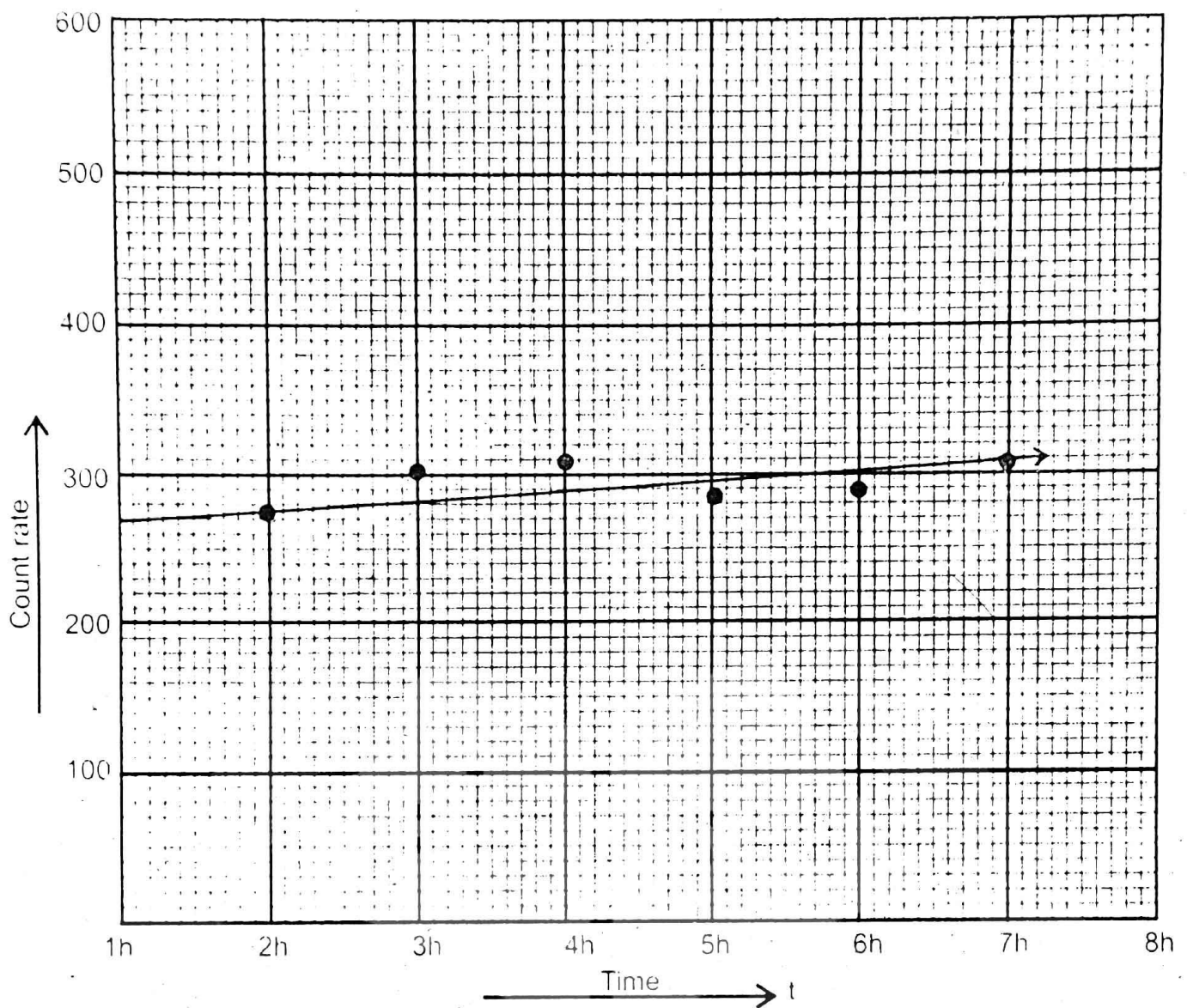


18.8 Half-life of a radioactive element was found to be 4000 years. The count rates per minute for 8 successive hours were found to be 270, 280, 300, 310, 285, 290, 305, 312. What does the variation in count rates show? Plot a graph between the count rates and time in hours. Why the graph is a straight line rather than an exponential?

Solution: Scale

One big division = 1 hour (along x-axis)

One big division = 100 counts (along y-axis)



Variation in count rates show s the random nature of radioactive decay, the graph is almost a horizontal line rather than an exponential curve, which is due to long half-life as compared to period of 8 hours

18.9 Ashes from a campfire deep in a cave show carbon-14 activity of only one-eighth the activity of fresh wood. How long ago was that campfire made?

Solution: Given that,

Activity of C - 14 from ashes = $\frac{1}{8}$ th of fresh wood

Half life of C - 14 $T_{1/2}$ = 5730 years

To find: Time t = ?

Calculations: Since activity of C - 14 from ashes is $\frac{1}{8}$ th of fresh wood, hence 3 half-lives have been elapsed. Therefore,

Time = No. of half-lives $\times T_{1/2}$

$t = 3 \times 5730$ years

$t = 17190$ years **Ans.**