NDA-CDS 1 2025

GS

LIVE

PHYSICS

MISCELLANEOUS

CLASS 3

NAVJYOTI SIR

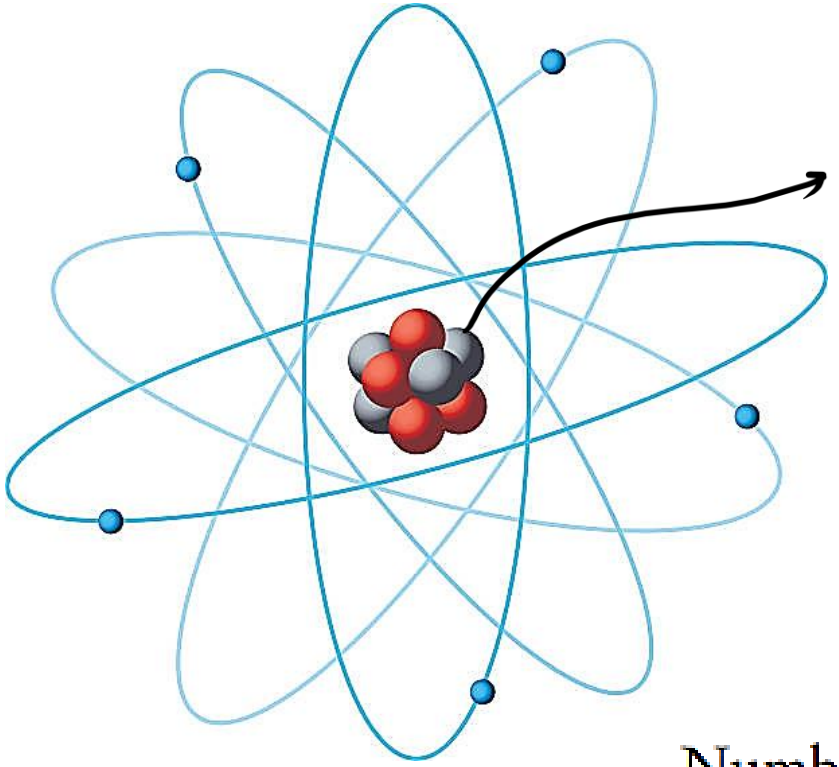
SSBCrack EXAMS

MISCELLANEOUS TOPICS - II
(NUCLEUS & RADIOACTIVITY)

WHAT WILL WE STUDY ?

- Nucleus
- Mass-Energy Equivalence
- Binding Energy
- Nuclear Fission and Fusion
- Nuclear Reactor
- Radioactivity

NUCLEUS



very small volume inside an atom

Nucleus — protons, neutrons — nucleons

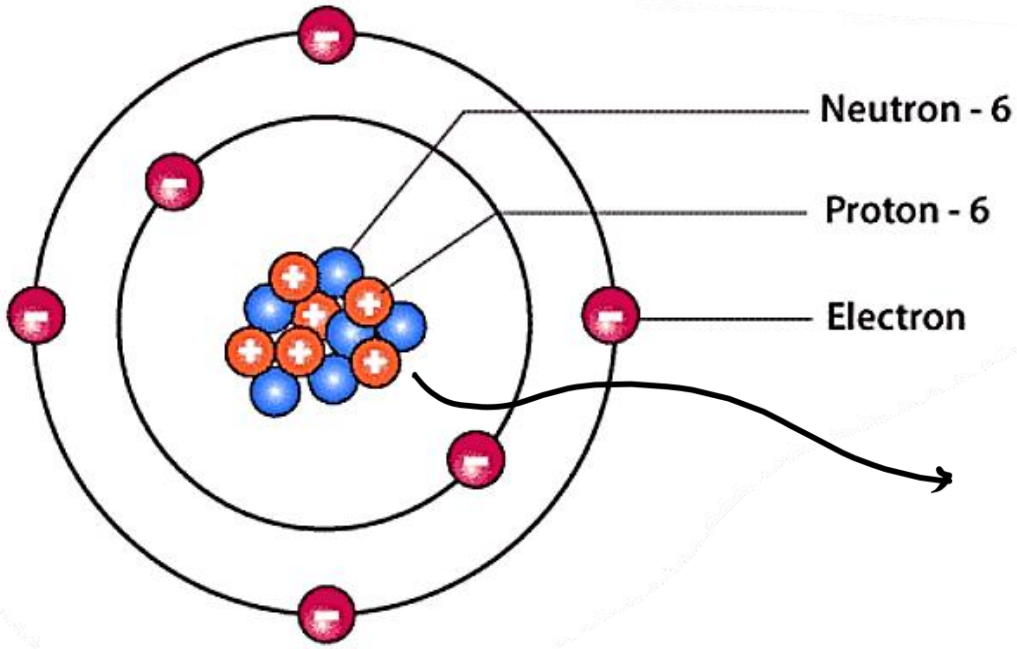
${}_{6}C^{12}$

Number of protons = Atomic number (Z)

Number of neutrons = Mass number (A) – Atomic number (Z)

Thus, the nucleus of an atom represented as ${}_{Z}X^{A}$

NUCLEUS



(Nucleus of a carbon atom)

$_6C^{12}$ → atomic mass

↓

atomic number

Force → strong nuclear force,

(attractive force)

$p^+ \longleftrightarrow p^+$

$n \longleftrightarrow n$

$n \longleftrightarrow p^+$

} acts at very small distances,

NUCLEUS

Size of the nucleus is of the order of fermi. (10^{-15} m)

The radius of the nucleus is given by $R = R_0 A^{1/3}$ where, $R_0 = 1.3$ fermi and A is the mass number.

Density of nuclear matter is of the order of 10^{17} kg/m^3

Density of nuclear matter is independent of the mass number.

EINSTEIN'S MASS-ENERGY EQUIVALENCE

$E = mc^2$

$m \rightarrow$ mass

$c \rightarrow$ speed of light (3×10^8 m/s)

→ mass and energy are equivalent.

MASS DEFECT

It is found that mass of the nucleus is less than the total mass of protons and neutrons, this mass difference is called mass defect.

M — Mass of nucleus

m_p — mass of proton

A — Mass number

m_n — mass of neutron

$^{A}X_{Z}$

(Δm)

$$\Delta m = \{Z m_p + (A-Z) m_n\} - M$$

$(A-Z)$ → number of neutrons

NUCLEAR BINDING ENERGY

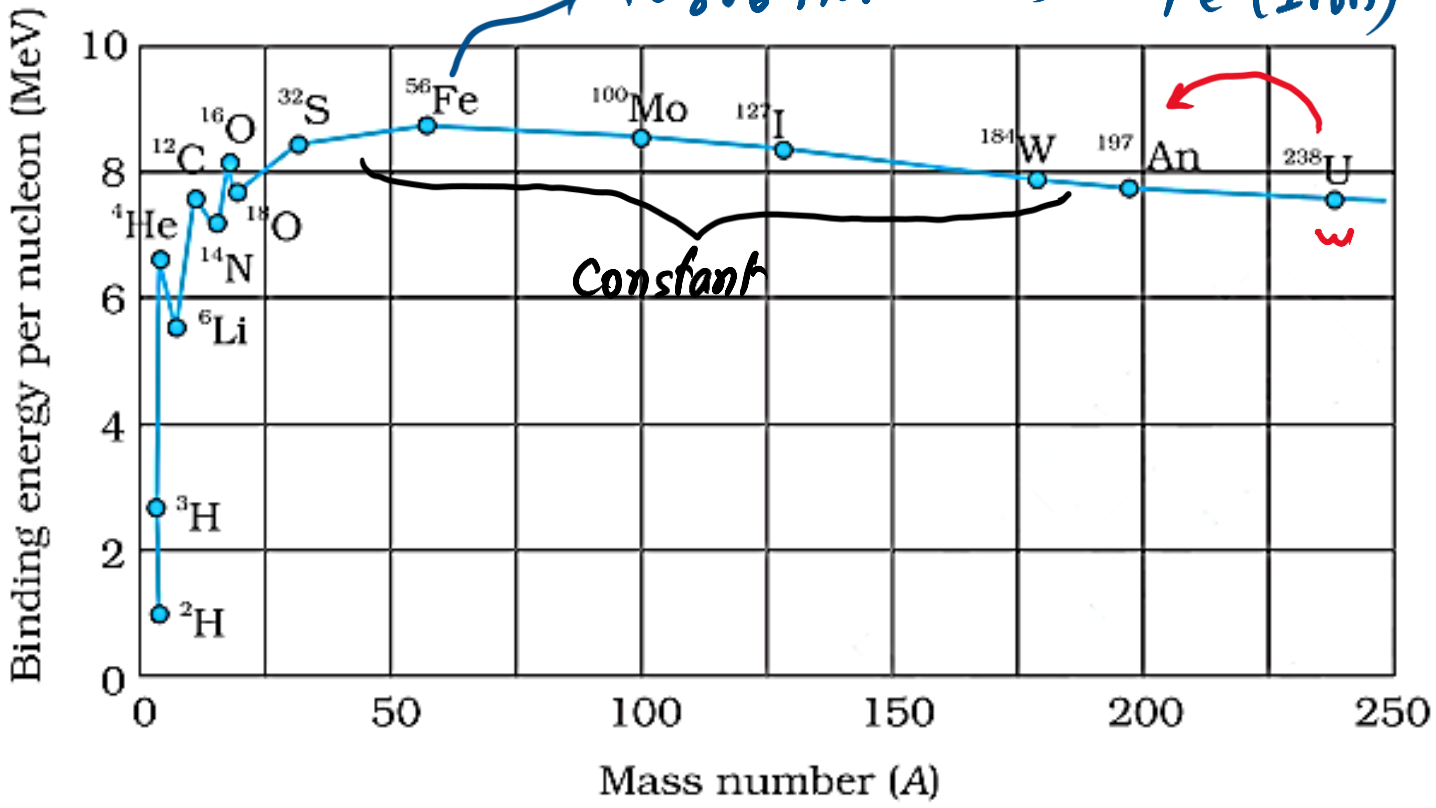
The minimum energy required to separate the nucleons up to an infinite distance from the nucleus, is called nuclear binding energy.

$$\Delta E = \Delta mc^2 = \Delta m \times 931.5 \text{ MeV}$$

(10^6 eV) → Unit of energy

$$\text{Nuclear binding energy per nucleon} = \frac{\text{Nuclear binding energy } (\Delta E)}{\text{Total number of nucleons } (A)}$$

NUCLEAR BINDING ENERGY



~ 8.6 MeV ⟶ Fe (Iron) nucleus is most stable.

More BE per nucleon ⇒ more stability

→ A < 30 & A > 150 ⇒ (BE per nucleon is less) ⇒ comparatively weaker nuclei

30 < A < 150 ⇒ BE per nucleon is higher ⇒ stronger nuclei (plural of nucleus)

NUCLEAR ENERGY

- The process by which the identity of a nucleus is changed when it is bombarded by an energetic particle is called nuclear reaction.

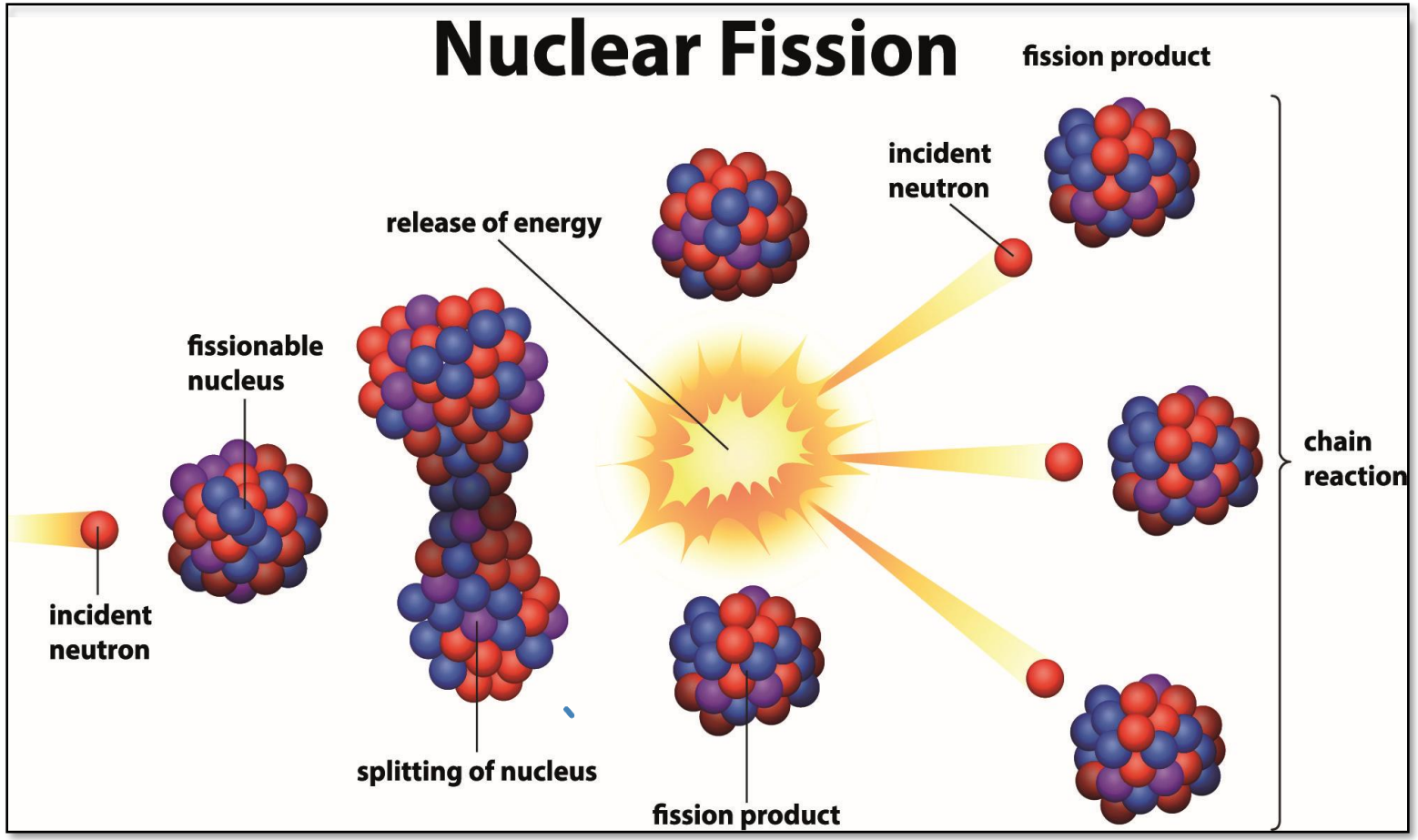
- There is a loss of mass, and this appears in the form of energy. This energy is released during nuclear reaction.
- Two distinct ways of obtaining energy from nucleus are as

(i) Nuclear fission

to break

(ii) Nuclear fusion

to join



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

(Barium) (Krypton)

CHAIN REACTIONS

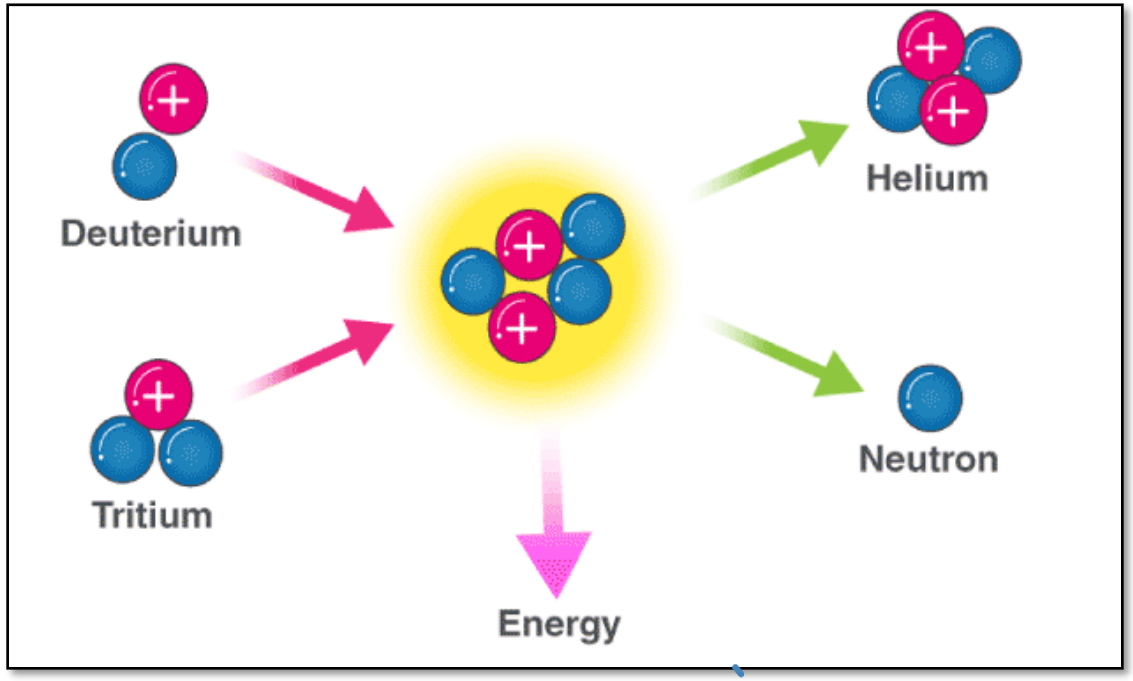
- If the particle starting the nuclear fission reaction is produced as a product and further take part in the nuclear fission reaction, then a chain of fission reaction gets started.
- Nuclear chain reaction are of two types

  (i) Controlled chain reaction (Nuclear Reactor)

  (ii) Uncontrolled chain reaction (Atom Bomb)

- A nuclear chain reaction releases several million times more energy per reaction than any chemical reaction.

NUCLEAR FUSION



$$_1H^2 + {}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4 + {}_1H^1 + {}_0n^1 + 21.6\,MeV$$

Deuterium

(Isotope of hydrogen (H))

(Helium)

- Hydrogen bomb is based on nuclear fusion.
- The source of sun's energy is the nuclear fusion taking place in the interior of sun.

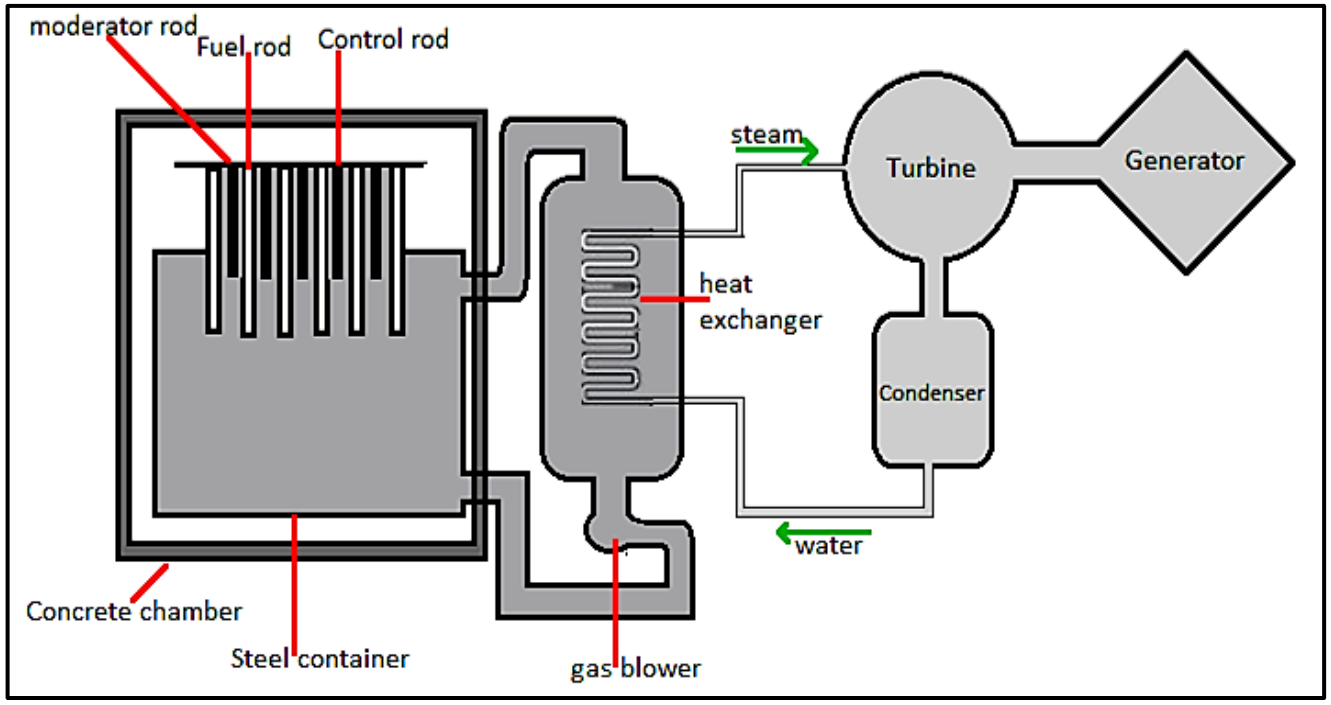
NUCLEAR FUSION

$$_1H^2 + {}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4 + {}_1H^1 + {}_0n^1 + 21.6\,\text{MeV}$$

- Fusion reaction is also called thermonuclear reaction and energy released is called thermonuclear energy.
- The fusion of nuclei is an uncontrolled process. Till now there is no method available for controlling the release of fusion energy. Therefore, fusion cannot be used for the service of mankind.

NUCLEAR REACTOR

It is a device that can initiate a self-sustaining controlled chain reaction of a fissionable material. They are used at nuclear power plants for generating electricity and in propulsion of ships. It is based upon controlled nuclear chain reaction.



- **Nuclear Fuel** Fissionable material are used link U^{235}, U^{233}, PU^{239} etc.
- **Moderator** Used to slow down the fast moving neutrons produced during the fission.
  e.g. Heavy water graphite, deuterium, etc.
- **Control Rods** They have the ability to capture the slow neutrons.
- **Coolant** Used to remove the heat produced.
  e.g. Liquid sodium.

RADIOACTIVITY

- **The spontaneous emission of some types of invisible rays from some substances is called radioactivity and these substances are called radioactive substances.**

- **It is a nuclear phenomenon in which an unstable nucleus undergoes a decay.**

Three types of radioactive decay occur in nature :

(i) α-decay in which a helium nucleus ^4_2He is emitted;

(ii) β-decay in which electrons or positrons (particles with the same mass as electrons, but with a charge exactly opposite to that of electron) are emitted;

(iii) γ-decay in which high energy (hundreds of keV or more) photons are emitted.

The hydrogen bomb and the uranium bomb are based, respectively on

(a) nuclear fusion and fission

(b) fission and thermonuclear fusion

(c) geothermal fission and fusion

(d) geothermal fusion and fission

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Answer: (A)

Nuclear energy is generated by

(a) nuclear fission and its expression was proposed by Einstein.

(b) nuclear fission and its expression was proposed by Rutherford.

(c) nuclear fusion and its expression was proposed by Bohr.

(d) nuclear fusion and its expression was proposed by Heisenberg.

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Answer: (A)

The rest mass of Higgs boson is estimated to be close to

~ 125 GeV

(a) 0·5 MeV

(b) 900 MeV

(c) 100 GeV

(d) 1000 GeV

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Answer: (C)

Of the following, which does ***not*** belong to a nuclear reactor ?

(a) A turbine

(b) A heat exchanger

(c) A mechanism to reduce CO_2 emission

(d) A reaction chamber

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Answer: (C)

Which one of the following is not a form of stored energy?

(a) Nuclear energy
(b) Potential energy
(c) Electrical energy
(d) Chemical energy

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Answer: (A)

The main source of energy of the sun is

(a) fusion of heavy nuclei
(b) fusion of light nuclei
(c) fission of light nuclei
(d) Both fusion and fission

Fission : heavy → light

Fusion : light → heavy

The main source of energy of the sun is

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Answer: (B)

A nuclear reactor is a device to produce nuclear energy with the help of

(a) nuclear fusion
(b) uncontrolled chain reaction
(c) controlled chain reaction
(d) graphite as fuel

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Answer: (C)

Nuclear forces are stronger than

(a) magnetic force

(b) gravitational force

(c) electrostatic force

(d) All of the above

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Answer: (D)

If the nuclear forces between two protons, two neutrons and between proton and neutron is denoted F_{pp}, F_{nn} and F_{pn} respectively, then

(a) $F_{pp} = F_{pn} = F_{nn}$ (b) $F_{pp} = F_{pn} \neq F_{nn}$

(c) $F_{pp} = F_{nn} \neq F_{pn}$ (d) $F_{pp} \neq F_{pn} \neq F_{nn}$

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Answer: (A)

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