SECTION – A

Questions 1 to 10 carry 1 mark each.

1. The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for helium nucleus. The implies that helium nucleus is:
   (a) radioactive
   (b) unstable
   (c) easily fissionable
   (d) more stable nucleus than its neighbours.

2. Which of the following statement about nuclear forces is NOT true?
   (a) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometres.
   (b) The nuclear force is much weaker than the Coulomb force.
   (c) The force is attractive for distances larger than 0.8 fm and repulsive if they are separated by distances less than 0.8 fm.
   (d) The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same.

3. When two nuclei ($A \leq 10$) fuse together to form a heavier nucleus, the:
   (a) binding energy per nucleon increases
   (b) binding energy per nucleon decreases
   (c) binding energy per nucleon does not change
   (d) total binding energy decreases.

4. Fusion reaction takes place at high temperature because:
   (a) atoms get ionised at high temperature.
   (b) kinetic energy is high enough to overcome the coulombic repulsion between nuclei.
   (c) molecules break up at high temperature.
   (d) nuclei break up at high temperature.

5. The ratio of order of magnitudes for nuclear density of Copper (Cu) ($A = 63$) and Aluminum ($A = 27$) is: ($m_p = 1.67 \times 10^{-27}$ kg)
   (a) 9 : 1   (b) 1 : 9   (c) 1 : 1   (d) 1 : 3

6. Which of the following statements are NOT true about binding energy?
   (I) Binding energy per nucleon increases linearly with the mass number.
   (II) The larger value of binding energy means the nucleus is unstable.
   (III) Binding energy per nucleon is maximum for iron ($A = 56$).
   (a) (I) only   (b) (II) only   (c) (I) and (III) only   (d) (I) and (II) only.

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7. If the number of nucleons increases, then binding energy per nucleon of the nucleus:
   (a) first increases and then decreases with mass number
   (b) continuously increases with mass number
   (c) continuously decreases with mass number
   (d) remains constant with mass number

8. Consider a proton moving towards a stationary alpha particle with speed v.
   Which of the following statements is NOT true?
   (a) Kinetic energy of the proton will get converted into the potential energy and it will stop at a distance from the alpha particle.
   (b) The force responsible for proton stopping is the repulsive nuclear force.
   (c) The nuclear force is attractive for distances larger than 0.8 fm and repulsive for distances shorter than 0.8 fm.
   (d) None of the above.

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** The nucleus $_3^7 X$ is more stable than the nucleus $_3^4 Y$.

   Reason (R): $_3^7 X$ contains more number of protons.

10. **Assertion (A):** The curve between the binding energy per nucleon versus mass number drops at high mass number (A > 170) as well as at low mass numbers (A < 30).
    Reason (R): Nuclei with middle mass numbers (30 < A < 170) have higher binding energy per nucleon.
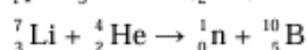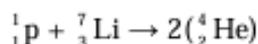
SECTION – B
Questions 11 to 14 carry 2 marks each.

11. How is the size of a nucleus found experimentally? Write the relation between the radius and mass number of a nucleus.

    OR

    Identify if the two nuclear reactions mentioned below are endothermic or exothermic. Show your calculations.

    $$_1^1 p + _3^7 Li \rightarrow 2(_2^4 He)$$
    $$_3^7 Li + _2^4 He \rightarrow _0^1 n + _5^{10} B$$

    Use the information below to answer the question:
    $_1^1 p = 1.00728$ amu, $_3^7 Li = 7.0160$ amu, $_2^4 He = 4.0026$ amu, $_0^1 n = 1.0087$ amu and $_5^{10} B = 10.01294$ amu

12. Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge?

    OR

    Calculate the binding energy of an alpha particle in MeV. Given:
    Mass of a proton = 1.007825 u
    Mass of a neutron = 1.008665 u
    Mass of He nucleus = 4.002800 u
    1u = 931 MeV/c^2.

13. (i) What characteristic property of nuclear force explains the constancy of binding energy per nucleon (BE/A) in the range of mass number 'A' lying $30 < A < 170$?

(ii) Show that the density of nucleus over a wide range of nuclei is constant independent of mass number A.
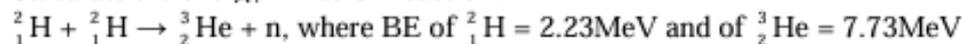
OR

Prove that the density of a nucleus is independent of its mass number.

14. Define the term, mass defect. How is it related to stability of the nucleus?

OR

Calculate the energy in fusion reaction:

$_1^2H + _1^2H \rightarrow _2^3He + n$, where BE of $_1^2H = 2.23$MeV and of $_2^3He = 7.73$MeV

SECTION – C
Questions 15 to 17 carry 3 marks each.

15. Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon $\left(\dfrac{BE}{A}\right)$ versus the mass number A.

16. (a) Distinguish between nuclear fission and fusion giving an example of each.

(b) Explain the release of energy in nuclear fission and fusion on the basis of binding energy per nucleon curve.

OR

(a) State two distinguishing features of nuclear force.

(b) Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions on the graph where the force is:

(i) attractive, and (ii) repulsive.

17. A given coin has a mass of 3.0 g. Calculate the nuclear energy that would be required to separate all the neutrons and protons from each other. For simplicity assume that the coin is entirely made of $_{29}^{63}Cu$ atoms (of mass 62.92960 u).

OR

(i) Briefly discuss three characteristics of the forces between nucleons.

(ii) Which out of $_4^8X$ and $_3^5Y$ nuclei is more stable and why?

SECTION – D
Questions 18 carry 5 marks.

18. Asha's mother read an article in the newspaper about a disaster that took place at Chernobyl. She could not understand much from the article and asked a few questions from Asha regarding the article. Asha tried to answer her mother's questions based on what she learnt in Class XII Physics.

(a) What was the installation at Chernobyl where the disaster took place? What, according to you, was the cause of this disaster?

(b) Explain the process of release of energy in the installation at Chernobyl.

(c) A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks into two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the released energy.

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19. **Nuclear Force:** Neutrons and protons are identical particle in the sense that their masses are nearly the same and the force, called nuclear force, does into distinguish them. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Shape of nucleus is calculated by quadrupole moment and spin of nucleus depends on even or odd mass number. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centred at the nucleus.
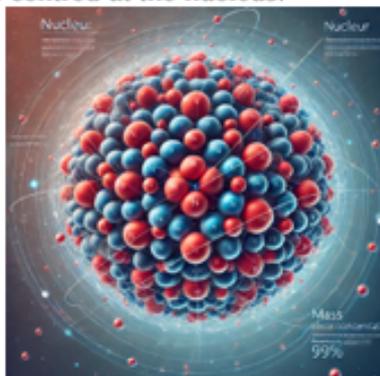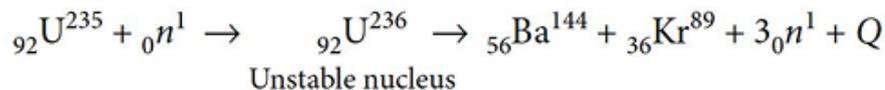

(i) The correct statements about the nuclear force is/are
(a) change independent
(b) short range force
(c) non-conservative force
(d) all of these.

(ii) The range of nuclear force is the order of
(a) 2×10^{-10} m
(b) 1.5×10^{-20} m
(c) 1.2×10^{-4} m
(d) 1.4×10^{-15} m

(iii) A force between two protons is same as the force between proton and neutron. The nature of the force is
(a) electrical force
(b) weak nuclear force
(c) gravitational force
(d) strong nuclear force.

(iv) Two protons are kept at a separation of 40 Å. Fn is the nuclear force and Fe is the electrostatic force between them. Then
(a) $F_n \ll F_e$
(b) $F_n = F_e$
(c) $F_n \gg F_e$
(d) $F_n \approx F_e$

OR

(v) All the nucleons in an atom are held by
(a) nuclear forces
(b) van der Waal's forces
(c) tensor forces
(d) coulomb forces

20. **Nuclear Fission:** In the year 1939, German scientist Otto Hahn and Strassmann discovered that when an uranium isotope was bombarded with a neutron, it breaks into two intermediate mass fragments.

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It was observed that, the sum of the masses of new fragments formed were less than the mass of the original nuclei. This difference in the mass appeared as the energy released in the process. Thus, the phenomenon of splitting of a heavy nucleus (usually $A > 230$) into two or more lighter nuclei by the bombardment of proton, neutron, α-particle, etc with liberation of energy is called nuclear fission.

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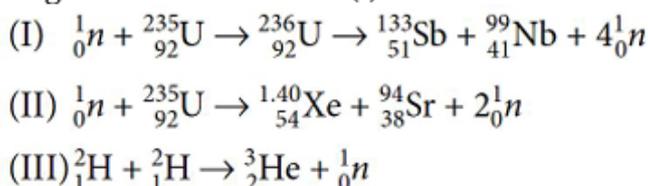
Unstable nucleus

(i) Nuclear fission can be explained on the basis of
(a) Millikan's oil drop method
(b) Liquid drop model
(c) Shell model
(d) Bohr's model.

(ii) For sustaining the nuclear fission chain reaction in a sample (of small size) of $_{92}^{235}U$, it is desirable to slow down fast neutrons by
(a) friction
(b) elastic damping/scattering
(c) absorption
(d) none of these.

(iii) Which of the following is/are fission reaction(s)?

$$(I) \quad _0^1n + {}_{92}^{235}U \rightarrow {}_{92}^{236}U \rightarrow {}_{51}^{133}Sb + {}_{41}^{99}Nb + 4{}_0^1n$$

$$(II) \quad _0^1n + {}_{92}^{235}U \rightarrow {}_{54}^{1.40}Xe + {}_{38}^{94}Sr + 2{}_0^1n$$

$$(III) {}_1^2H + {}_1^2H \rightarrow {}_2^3He + {}_0^1n$$

(a) Both II and III
(b) Both I and III
(c) Only II
(d) Both I and II

(iv) On an average, the number of neutrons and the energy of a neutron released per fission of a uranium atom are respectively
(a) 2.5 and 2 keV
(b) 3 and 1 keV
(c) 2.5 and 2 MeV
(d) 2 and 2 keV

OR

(v) In any fission process, ratio of mass of daughter nucleus to mass of parent nucleus is
(a) less than 1
(b) greater than 1
(c) equal to 1
(d) depends on the mass of parent nucleus.

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