INDIAN SCHOOL AL WADI AL KABIR		
Class: XII	**DEPARTMENT OF SCIENCE: 2026-27** **SUBJECT: PHYSICS**	**DATE: 10/11/2026**
WORKSHEET NO: 13 (WITH ANSWERS)	**CHAPTER: NUCLEI**	**A4 FILE FORMAT (PORTFOLIO)**
CLASS & SEC:	**NAME OF THE STUDENT:**	**ROLL NO.**

OBJECTIVE TYPE QUESTIONS (1 MARK)

1) The ratio of the radii of two nuclei with mass numbers 8 and 27, respectively, is: (CBSE 2026)
   a) 4:9
   b) 2:3
   c) 8:27
   d) 1:3

2) Which of the following statements about the strong nuclear force is INCORRECT? (CBSE Gulf Region)
   a) They are short-range forces (acting up to ~0.8 to 2 fm).
   b) They are charge-dependent.
   c) They exhibit a saturation property.
   d) They are attractive at distances > 0.8 fm and repulsive at distances < 0.8 fm.

3) The binding energy per nucleon is maximum for the nuclide: (CBSE 2026)
   a) $^{4}He_{2}$
   b) $^{56}Fe_{26}$
   c) $^{235}U_{92}$
   d) $^{14}N_{7}$

4) Which of the following pairs represents isotones:
   a) ${}_{1}^{3}H \text{ and } {}_{2}^{3}He$
   b) ${}_{80}^{198}Hg \text{ and } {}_{79}^{197}Au$
   c) ${}_{6}^{12}C \text{ and } {}_{6}^{14}C$
   d) ${}_{1}^{2}H \text{ and } {}_{1}^{3}H$

5) An element has binding energy 8 eV per nucleon. If it has a total binding energy of 128 eV, then the number of nucleons is
   a) 8
   b) 16
   c) 32
   d) 64

6) The potential energy of a pair of nucleons is plotted as a function of their separation r. The curve exhibits a minimum at r=0.8 fm. Which of the following correctly describes the nature of the nuclear force at different separations?

a) For r < 0.8 fm, the force is attractive; for r>0.8 fm, it is repulsive.
b) For r < 0.8 fm, the force is strongly repulsive; for r>0.8 fm, it is attractive.
c) The nuclear force is attractive for all separations r < 4 fm.
d) At r=0.8 fm, the nuclear force reaches its maximum attractive value.

7) The minimum energy required to separate all nucleons from a $^{-16}O_8$ nucleus (Atomic mass = 15.99493 u, m_p = 1.00727 u, m_n = 1.00866 u) is approximately:

a) 127.5 MeV
b) 7.98 MeV
c) 14.3 MeV
d) 200 MeV

8) If F_{pp}, F_{pn} and F_{nn} represent the magnitude of the strong nuclear force between proton-proton, proton-neutron, and neutron-neutron pairs at equal separation (r > 0.8 fm), then
a) $F_{pp} > F_{pn} > F_{nn}$
b) $F_{pp} = F_{pn} = F_{nn}$
c) $F_{pp} > F_{pn} = F_{nn}$
d) $F_{nn} > F_{pp} > F_{pn}$
9) Two nuclei have mass numbers in the ratio 1: 8. The ratio of their nuclear densities is:
a) 1:2
b) 1:8
c) 1:1
d) 8:1
10) The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for the helium nucleus. This implies that the helium nucleus is
a) Radioactive
b) Unstable
c) Easily fissionable
d) More stable nucleus than its neighbors

ASSERTION AND REASONING TYPE OF QUESTIONS (1 MARK):

DIRECTION: In the following questions, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:

a) Both A and R are true, and R is the correct explanation of A.
b) Both A and R are true, and R is not the correct explanation of A.
c) A is true, but R is false.
d) Both A and R are false

11) **Assertion (A):** The density of nuclear matter is independent of the size or mass number of the nucleus.
Reason (R): The volume of a nucleus is directly proportional to its mass number A.
12) **Assertion (A):** Nuclear forces are charge-independent.
Reason (R): The nuclear force between proton-proton, proton-neutron, and neutron-neutron is nearly equal.
13) **Assertion (A):** Thermonuclear fusion requires extremely high temperatures of the order of 10^8 K.
Reason (R): High kinetic energy is needed to overcome the strong electrostatic Coulomb repulsion between positively charged fusing nuclei.

VERY SHORT ANSWER TYPE OF QUESTIONS: (2 MARKS)

14) High kinetic energy is needed to overcome the strong electrostatic Coulomb repulsion between positively charged fusing nuclei. (CBSE 2022)
15) Two nuclei have mass numbers in the ratio 1: 27. (a) What is the ratio of their nuclear radii? (b) What is the ratio of their nuclear densities? (CBSE 2025)
16) Draw a labelled graph showing the potential energy of a pair of nucleons as a function of their separation r. Mark the equilibrium separation r_0 and state two characteristics of nuclear forces derived from this plot.
17) Define 'mass defect' and 'binding energy per nucleon'. Write the relation between mass defect in atomic mass units (u) and binding energy in MeV. (CBSE Gulf Region 2023)

SHORT ANSWER TYPE OF QUESTIONS (3 MARKS):

18) Draw the graph showing the variation of binding energy per nucleon (E_{bn}) with mass number A (for $1 \leq A \leq 240$). State any two main features of this curve and explain how it accounts for the release of energy in (i) Nuclear Fission and (ii) Nuclear Fusion. (CBSE 2026)
19) The atomic mass of nitrogen-14 is 14.00307 u. Given that the mass of a hydrogen atom is 1.007825 u and the mass of a neutron is 1.008665 u, calculate:
(a) The mass defect of the nitrogen-14 nucleus.
(b) The total binding energy of the nucleus.
(c) The binding energy per nucleon. (CBSE 2025)
20) Write the complete set of nuclear reactions for the proton-proton (p-p) cycle taking place in the core of the Sun. Calculate the net energy released when 4 hydrogen nuclei fuse into a $^4He_2$ nucleus. (CBSE Gulf Region 2024)
21) Distinguish between nuclear fission and nuclear fusion with suitable examples. Why is controlled fusion much more difficult to achieve in a laboratory than controlled fission? (CBSE 2023)

LONG ANSWER TYPE OF QUESTIONS (5 MARKS):

22) (a) Calculate the total amount of energy (in Joules and MeV) released when 1 kg of ^{235}U undergoes complete fission. Assume the energy released per fission event is 200 MeV.
(Avogadro's Number $N_A = 6.023 \times 10^{23}$ mol^{-1}).
(b) How long can a 100 W electric bulb remain illuminated using this 1 kg of ^{235}U fuel?

23) Two deuterium nuclei approach each other during a nuclear fusion reaction. Each deuterium nucleus has a radius of 2 fm and carries a charge of +e.
(a) Calculate the distance between their centres when they are just in contact.
(b) Calculate the electrostatic potential energy between the two nuclei at this separation.
24) (a) Calculate the binding energy of an alpha-particle in MeV.
(b) The nuclear mass of $^{56}_{26}Fe$ is 55.85 amu. Calculate its nuclear density.

CASE STUDY TYPE OF QUESTIONS (4 MARKS):

25) The binding energy per nucleon, E_{bn}, is the average energy required to remove one nucleon from a nucleus. It indicates how tightly the protons and neutrons are held together: a larger E_{bn} generally means a more tightly bound and more stable nucleus.
When E_{bn} is plotted against mass number A, the curve rises very steeply for light nuclei, reaches a broad maximum of about 8.8 MeV per nucleon near iron-56, and then gradually declines for heavier nuclei. Uranium-238 has an E_{bn} of about 7.6 MeV per nucleon. This fall occurs because, in very large nuclei, the repulsive electric force between many protons increasingly weakens the net binding effect of the strong nuclear force.

The shape of this curve explains why energy is released in both **nuclear fusion** and **nuclear fission**. Fusion combines light nuclei, moving products toward the peak of the curve and increasing binding energy per nucleon. Fission splits a heavy nucleus into intermediate-mass fragments, which are more tightly bound than the original heavy nucleus. In both cases, the final products have greater binding energy per nucleon, so the difference appears as released energy according to $E=\Delta mc^2$.

i. Why does fission of uranium release energy even though the fission fragments have a larger total number of nucleons than a single light nucleus?
   a) Because the fragments have lower total mass than the original nucleus
   b) Because the fragments have a higher binding energy per nucleon than uranium
   c) Because fission creates additional protons
   d) Because uranium nuclei contain no binding energy

ii. Why is iron-56 near the peak of the binding-energy curve rather than the heaviest element?
   a) It has the greatest total binding energy of all nuclei
   b) Beyond iron, increasing proton repulsion reduces binding energy per nucleon
   c) Iron has no neutrons
   d) Heavy nuclei cannot undergo any nuclear reactions

iii. Thermonuclear fusion between light nuclei requires temperatures of the order of 10^7-10^9 K because:
   a) High temperatures are required to convert protons into neutrons via beta decay.
   b) Nuclei need sufficient kinetic energy to overcome the repulsive electrostatic Coulomb barrier between positive charges.
   c) The strong nuclear force becomes repulsive at high temperatures.
   d) Gravitational contraction stops functioning at lower temperatures.

iv. During nuclear fusion of two light nuclei into a heavier nucleus, the binding energy per nucleon of the product nucleus is:
   a) Less than that of the reactants
   b) Greater than that of the reactants
   c) Equal to that of the reactants
   d) Zero

OR

Heavy nuclei undergo fission while light nuclei undergo fusion because (CBSE 2022)

a) Both processes lead to nuclei with lower binding energy per nucleon.
b) Both processes lead to nuclei with higher binding energy per nucleon.
c) Mass defect is negative in both cases.
d) Nuclear density increases in both cases.

ANSWER KEY	
1	b)2:3
2	b)They are charge-dependent
3	b)$^{56}Fe_{26}$
4	b)$^{198}_{80}Hg\ and\ ^{197}_{79}Au$
5	a)16
6	b)For r < 0.8 fm, the force is strongly repulsive; for r>0.8 fm, it is attractive.
7	a)127.5 MeV.
8	(b) Fpp = Fpn = Fnn
9	(c) 1: 1
10	(d) More stable nucleus than its neighbours.

11	a)Both A and R are true, and R is the correct explanation of A.
12	a)Both A and R are true, and R is the correct explanation of A.
13	a)Both A and R are true, and R is the correct explanation of A.
14	Both nuclei taking part in fusion are positively charged. Hence, they experience electrostatic (Coulomb) repulsion. They must approach within a distance of a few femtometres, where the attractive strong nuclear force becomes effective. High kinetic energy, obtained by heating the fuel to an extremely high temperature, helps the nuclei overcome the Coulomb barrier and come sufficiently close for fusion.
15	$$R = R_0 A^{1/3}$$ $$\frac{R_1}{R_2} = \left(\frac{8}{216}\right)^{1/3}$$ $$= \frac{2}{6}$$ $$\boxed{R_1 : R_2 = 1 : 3}$$ **Ratio of nuclear densities:** Nuclear density is approximately independent of mass number. $$\boxed{\rho_1 : \rho_2 = 1 : 1}$$
16	The nuclear potential energy curve has the following features: 1. At very small distances, the potential energy increases sharply, indicating a strong repulsive force. 2. At intermediate distances, the potential energy is negative, indicating an attractive nuclear force. 3. At large distances, the potential energy approaches zero because the nuclear force is short-ranged. The potential energy is minimum at the equilibrium separation, approximately 0.8 fm. At this point, the net force is zero.

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Mass defect: The difference between the total mass of the individual nucleons and the actual mass of the nucleus is called mass defect.

For a nucleus containing Z protons and $A - Z$ neutrons:

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

where M is the mass of the nucleus.

Binding energy: The energy required to separate a nucleus completely into its individual nucleons is called binding energy.

$$BE = \Delta mc^2$$

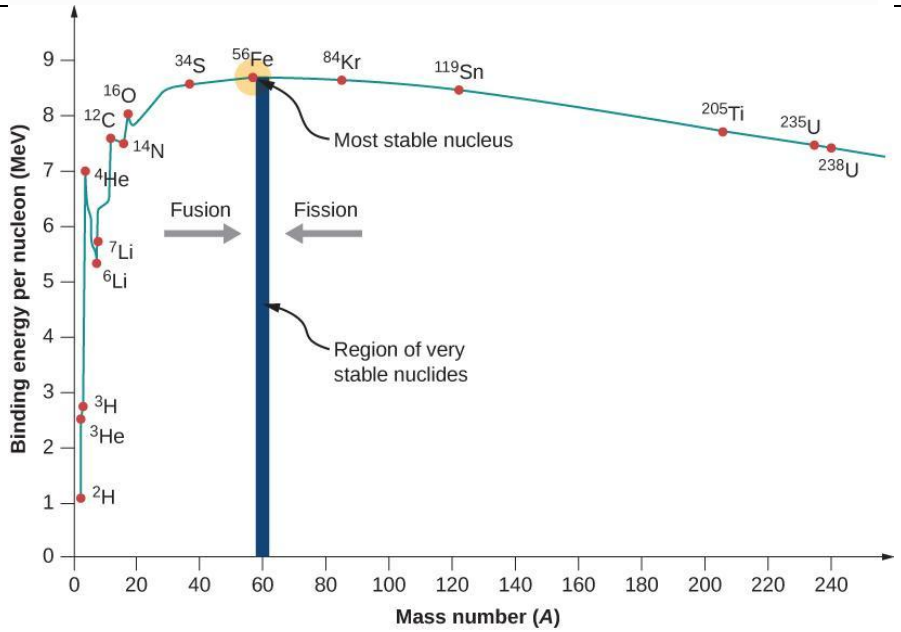
When mass defect is expressed in atomic mass units:

$$BE = \Delta m \times 931.5\ MeV$$

Binding energy per nucleon:

$$BE/A = \frac{\text{Total binding energy}}{\text{Mass number}}$$

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The binding energy per nucleon curve shows the variation of binding energy per nucleon with mass number.

Features of the curve:

1. For light nuclei, binding energy per nucleon increases rapidly with increasing mass number.
2. It reaches a maximum value of approximately 8.8 MeV near the iron-nickel region, around mass number 56.
3. For heavier nuclei, binding energy per nucleon decreases gradually.

	(i) Nuclear fusion: Two light nuclei combine to form a heavier nucleus nearer the peak. The product has a greater binding energy per nucleon; its total binding energy increases and the mass of the products is less than the total initial mass. The mass difference is released as energy, $E = \Delta mc^2$. (ii) Nuclear fission: A very heavy nucleus splits into two medium-mass nuclei nearer the peak. The fission fragments have greater binding energy per nucleon than the original heavy nucleus. The increase in total binding energy appears as released energy.
19	• Atomic mass of nitrogen-14 = 14.00307 u • Mass of proton = 1.007276 u • Mass of neutron = 1.008665 u • Atomic number $Z = 7$ • Mass number $A = 14$ • Mass of electron = 0.0005486 u **Step 1: Calculate the mass of the nitrogen nucleus.** $$M_{\text{nucleus}} = 14.00307 - 7(0.0005486)$$ $$= 14.00307 - 0.0038402$$ $$M_{\text{nucleus}} = 13.9992298\ u$$ **Step 2: Calculate the total mass of individual nucleons.** $$M = 7m_p + 7m_n$$ $$= 7(1.007276) + 7(1.008665)$$ $$= 7.050932 + 7.060655$$ $$M = 14.111587\ u$$ **Step 3: Calculate mass defect.** $$\Delta m = 14.111587 - 13.9992298$$ $$\boxed{\Delta m = 0.1123572\ u}$$

	Step 4: Calculate total binding energy. $$BE = 0.1123572 \times 931.5$$ $$BE \approx 104.66\ MeV$$ **Step 5: Calculate binding energy per nucleon.** $$BE/A = \frac{104.66}{14}$$ $$\boxed{BE/A \approx 7.48\ MeV}$$
20	The proton-proton cycle is an important nuclear fusion process through which stars like the Sun produce energy. The reactions involved in the proton-proton cycle are: **Step 1: Formation of deuterium** $$^1H + ^1H \rightarrow ^2H + e^+ + \nu_e$$ This reaction occurs twice. **Step 2: Formation of helium-3** $$^2H + ^1H \rightarrow ^3He + \gamma$$ This reaction also occurs twice. **Step 3: Formation of helium-4** $$^3He + ^3He \rightarrow ^4He + ^1H + ^1H$$ **Overall reaction:** $$4\,^1H \rightarrow ^4He + 2e^+ + 2\nu_e + \text{Energy}$$ Approximately 26.7 MeV of energy is released per helium-4 nucleus formed, including the energy associated with positron annihilation. A small fraction is carried away by neutrinos.

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Nuclear fission	Nuclear fusion
A heavy nucleus splits into two or more lighter nuclei.	Two light nuclei combine to form a heavier nucleus.
It can be initiated by bombarding suitable nuclei with neutrons.	It requires very high temperatures and suitable conditions.
It releases energy because the products have higher binding energy per nucleon.	It releases energy when light nuclei combine towards greater binding energy per nucleon.
Example: Fission of uranium-235.	Example: Fusion of deuterium and tritium.

Example of fission:

$$^{235}U +^{1} n \rightarrow \text{Fission fragments} + \text{neutrons} + \text{Energy}$$

Example of fusion:

$$^{2}H +^{3} H \rightarrow^{4} He +^{1} n + 17.6\ MeV$$

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Given:

- Mass of uranium = 1 kg = 1000 g
- Molar mass of uranium-235 = 235 g/mol
- Energy released per fission = 200 MeV
- Power of bulb = 100 W
- Avogadro's number = 6.023×10^{23}
- $1\,MeV = 1.602 \times 10^{-13}\,J$

Step 1: Calculate the number of moles of uranium-235.

$$n = \frac{\text{Given mass}}{\text{Molar mass}}$$

$$n = \frac{1000}{235}$$

$$n = 4.2553\ mol$$

Step 2: Calculate the total number of uranium nuclei.

$$N = nN_A$$

$$N = 4.2553 \times 6.023 \times 10^{23}$$

$$N = 2.563 \times 10^{24}$$

Step 3: Calculate the total energy released.

Energy released per fission:

$$E = 200\,MeV$$

Total energy:

$$E_{\text{total}} = N \times 200$$

$$= 2.563 \times 10^{24} \times 200$$

$$= 5.126 \times 10^{26}\,MeV$$

Converting into joules:

$$E_{\text{total}} = 5.126 \times 10^{26} \times 1.602 \times 10^{-13}$$

$$\boxed{E_{\text{total}} \approx 8.21 \times 10^{13}\,J}$$

Step 4: Calculate the time for which the bulb can glow.

$$P = \frac{E}{t}$$

$$t = \frac{E}{P}$$

$$t = \frac{8.21 \times 10^{13}}{100}$$

Converting into years:

$$t = \frac{8.21 \times 10^{11}}{365 \times 24 \times 3600}$$

$$\boxed{t \approx 2.60 \times 10^{4}\ \text{years}}$$

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Given:

- Radius of each deuterium nucleus = 2 fm
- Charge of each nucleus = $+e$
- $e = 1.6 \times 10^{-19}\, C$
- Coulomb constant $k = 9 \times 10^{9}\, Nm^2/C^2$
- Boltzmann constant $k_B = 1.38 \times 10^{-23}\, J/K$

Step 1: Calculate the distance of closest approach.

At contact, the distance between the centres of the two nuclei is equal to the sum of their radii.

$$r = 2 + 2 = 4\, fm$$

$$r = 4 \times 10^{-15}\, m$$

Substituting:

$$U = \frac{9 \times 10^{9}(1.6 \times 10^{-19})^2}{4 \times 10^{-15}}$$

$$U = \frac{9 \times 10^{9} \times 2.56 \times 10^{-38}}{4 \times 10^{-15}}$$

$$\boxed{U = 5.76 \times 10^{-14}\, J}$$

In MeV:

$$U = \frac{5.76 \times 10^{-14}}{1.602 \times 10^{-13}}$$

$$\boxed{U \approx 0.36\, MeV}$$

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- Mass of proton = 1.007276 u
- Mass of neutron = 1.008665 u
- Mass of alpha particle = 4.001506 u

An alpha particle contains two protons and two neutrons.

Step 1: Calculate the total mass of the individual nucleons.

$$M = 2m_p + 2m_n$$

$$= 2(1.007276) + 2(1.008665)$$

$$= 2.014552 + 2.017330$$

$$M = 4.031882\,u$$

Step 2: Calculate the mass defect.

$$\Delta m = 4.031882 - 4.001506$$

$$\boxed{\Delta m = 0.030376\,u}$$

Step 3: Calculate the binding energy.

$$BE = \Delta m \times 931.5$$

$$= 0.030376 \times 931.5$$

$$\boxed{BE \approx 28.3\,MeV}$$

Given:

- Mass number $A = 56$
- Mass of nucleus $\approx 55.85\,u$
- $1\,u = 1.66 \times 10^{-27}\,kg$
- $R_0 = 1.2 \times 10^{-15}\,m$

Step 1: Calculate the nuclear radius.

$$R = R_0 A^{1/3}$$

$$R = 1.2 \times 10^{-15} \times 56^{1/3}$$

$$\boxed{R \approx 4.59 \times 10^{-15}\,m}$$

Step 2: Calculate the mass of the nucleus.

$$m = 55.85 \times 1.66 \times 10^{-27}$$

$$\boxed{m = 9.27 \times 10^{-26}\,kg}$$

Step 3: Calculate the volume of the nucleus.

$$V = \frac{4}{3}\pi R^3$$

$$V = \frac{4}{3}\pi (4.59 \times 10^{-15})^3$$

$$\boxed{V \approx 4.05 \times 10^{-43}\,m^3}$$

Step 4: Calculate nuclear density.

$$\rho = \frac{m}{V}$$

$$\rho = \frac{9.27 \times 10^{-26}}{4.05 \times 10^{-43}}$$

$$\boxed{\rho \approx 2.29 \times 10^{17}\,kg/m^3}$$

25	i. b) Because the fragments have a higher binding energy per nucleon than uranium.

	ii. b) Beyond iron, increasing proton repulsion reduces binding energy per nucleon. iii. b) Nuclei need sufficient kinetic energy to overcome the repulsive electrostatic Coulomb barrier between positive charges. iv. b) Greater than that of the reactants. OR b) Both processes lead to nuclei with higher binding energy per nucleon.

Prepared by: *Ms Vivette Lasrado*	*Checked by:* *HOD Science*