INDIAN SCHOOL AL WADI AL KABIR		
CLASS: XII	DEPARTMENT: SCIENCE (2024-25) SUBJECT: PHYSICS	DATE: 04/11/2024
WORKSHEET NO: 13 WITH ANSWERS	TOPIC NUCLEI	NOTE: A4 FILE FORMAT
CLASS & SEC:	NAME OF THE STUDENT:	ROLL NO.

Multiple choice type questions;

ANSWERS OF MCQs; -(1). (D), 2. (A), 3. (D), 4. (C), 5. (A),6. (C)

1. A proton and an alpha particle having equal velocities approach a target nucleus. They come momentarily to rest and then reverse their directions. The ratio of the distance of closest approach of the proton to that of the alpha particle will be:
   (A) $\frac{1}{2}$ (B) 2 (C) $\frac{1}{4}$ (D) 4
2. The potential energy between two nucleons inside a nucleus is minimum at a distance of about
   (A) 0.8 fm (B) 1.6 fm (C) 2.0 fm (D) 2.8 fm
3. The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for helium nucleus. This implies that helium nucleus is
   (A) radioactive (B) unstable
   (C) easily fissionable (D) The more stable nucleus than its neighbors.
4. Which of the following statements is not true for nuclear forces?
   (A) They are stronger than Coulomb forces.
   (B) They have about the same magnitude for different pairs of nucleons.
   (C) They are always attractive.
   (D) They saturate as the separation between two nucleons increases.
5. The difference in mass of ^{7}X nucleus and total mass of its constituent nucleons is 21·00 u. The binding energy per nucleon for this nucleus is equal to the energy equivalent of:
   (A) 3 u (B) 3·5 u (C) 7 u (D) 21 u
6. The ratio of the nuclear density of two nuclei having mass numbers 64 and 125 is.
   (A) $\frac{64}{125}$ (B) $\frac{5}{4}$ (C) $\frac{4}{5}$ (D) 1

Assertion and Reason type questions;

DIRECTIONS. In each of the following questions, read the two statements and choose if

(A) both Assertion and Reason are true and the Reason is correct explanation of the Assertion.
(B) both Assertion and Reason are true, but the Reason is not a correct explanation of the Assertion.
(C) Assertion is true and Reason is false.
(D) both, Assertion and Reason are false.

1. Assertion: α-particle is a helium nucleus.
   Reason: In α-decay, mass number as well as atomic number of the daughter is more than that of parent.
   (a) A (b) B (c) C (d) D
2. Assertion: Isotopes of an element can be separated by using a mass spectrometer.
   Reason: Separation of isotopes is possible because of difference in electron numbers of isotopes.
   (a) A (b) B (c) C (d) D
3. Assertion: If a heavy nucleus is split into two medium sized parts, each of new nucleus will have more binding energy per nucleon than original nucleus.

Reason: Joining two light nuclei together to give a single nucleus of medium size means more binding energy per nucleon in new nucleus.

(a) A (b) B (c) C (d) D

4. Assertion: Density of nuclear matter is same for all nuclei

Reason: Density has nothing to do with mass and size of nucleus.

(a) A (b) B (c) C (d) D

5. Assertion: 1 amu = 933 MeV

Reason: It follows from E = mc2

(a) A (b) B (c) C (d) D

6. Assertion: Nuclei of isobars atoms have same size.

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

(a) A (b) B (c) C (d) D

7. Assertion (A): The nucleus ${}^{7}_{3}X$ is more stable than the nucleus ${}^{4}_{3}Y$.

Reason (R): ${}^{7}_{3}X$ contains a greater number of protons.

(a) A (b) B (c) C (d) D

1.(c), 2. (c), 3. (b),4. (c),5. (c), 6. (a), 7. (C).

SHORT ANSWER TYPE QUESTIONS: (2/3 marks)

1. Obtain the binding energy (in MeV) of a nitrogen nucleus (${}_7N^{14}$).

Given, $m({}_7N^{14}) = 14.00307$ u.

$$\Delta m = (7m_p + 7m_n - m_N)$$
$$\Delta m = (7 \times 1.007825 + 7 \times 1.008665 - 14.00307) = 0.11236\ u$$
$$1\ u = 931.5\ MeV/c^2$$
$$E_b = 0.11236 \times 931.5 = 104.66334\ MeV$$

2. Obtain the binding energy of the nuclei ${}_{26}Fe^{56}$ and ${}_{83}Bi^{209}$ in units of MeV from the following data: m (${}_{26}Fe^{56}$) = 55.934939 u, m(${}_{83}Bi^{209}$) = 208.980388 u.

$$\Delta m = (26m_p + 30m_n - m_N)$$
$$\Delta m = (26 \times 1.007825 + 30 \times 1.008665 - 55.934939)\ u$$
$$= (26.20345u + 30.25995 -55.934939) = 0.\ 528461\ u$$
$$1\ u = 931.5\ MeV/c^2$$
$$E_b = 0.\ 528461 \times 931.5 = 492.2614215\ MeV$$

$$\Delta m = (83m_p + 126m_n - m_N)$$
$$\Delta m = (83 \times 1.007825 + 126 \times 1.008665 - 208.980388)\ u$$
$$= (83.649475 + 127.09179 - 208.980388) = 1.760877\ u$$
$$1\ u = 931.5\ MeV/c^2$$
$$E_b = 1.760877 \times 931.5 = 1{,}640.2569255\ MeV$$

3. 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 $_{29}Cu^{63}$ atoms (of mass 62.92960 u).

$$\text{Number of atoms; } N = \frac{6.023 \times 10^{23} \times 3}{63} = 2.868 \times 10^{22} \text{ atoms.}$$

It has 29 protons and 34(63− 29) neutrons

$$\Delta m' = 29 \times 1.007825 + 34 \times 1.008665 - 62.9296 = 0.591935 \text{ u}$$

$$\text{Mass defect of all atoms} = \Delta m = 0.591935 \times 2.868 \times 10^{22} = 1.69766958 \times 10^{22} \text{ u}$$

$$\text{But } 1 \text{ u} = 931.5 \text{ MeV}/c^2$$

$$\therefore \Delta m = 1.69766958 \times 10^{22} \times 931.5 \text{ MeV}/c^2$$

$$E_b = \Delta mc^2 = 1.69766958 \times 10^{22} \times 931.5 \text{ MeV} = 1.581 \times 10^{25} \text{ MeV} = 2.5296 \times 10^{12} \text{ J}$$

4. Obtain approximately the ratio of the nuclear radii of the gold isotope, $_{79}Au^{197}$ and the silver isotope $_{47}g^{107}$.

$$\text{As we know } R = R_0 A^{\frac{1}{3}}$$

$$\frac{R_{gold}}{R_{silver}} = \left(\frac{A_{gold}}{A_{silver}}\right)^{\frac{1}{3}} = \left(\frac{197}{107}\right)^{\frac{1}{3}} = 1.2256.$$

5. The Q value of a nuclear reaction $A + b \rightarrow C + d$ is defined by $Q = [\, m_A + m_b - m_C - m_d]c^2$ where the masses refer to the respective nuclei. Determine from the given data the Q-value of the following reactions and state whether the reactions are exothermic or endothermic.
[m ($_1H^1$) = 1.007825u, m ($_1H^2$) = 2.014102 u, m ($_1H^3$) = 3.016049 u, m ($_6C^{12}$) = 12.000000 u, m ($_{10}Ne^{20}$) = 19.992439 u, m ($_2He^4$) = 4.002603 u]

(i) $_1H^1 + {_1H^3} \rightarrow {_1H^2} + {_1H^2}$ (ii) $_6C^{12} + {_6C^{12}} \rightarrow {_{10}Ne^{20}} + {_2He^4}$

$$\text{(i) } \Delta m = [m\,(_1H^1) + m\,(_1H^3) - 2\,m\,(_1H^2)]$$

$$= (1.007825 + 3.016049 - 2 \times 2.014102) \text{ u} = -0.00433 \text{ u}$$

$$E = \Delta m \times 931.25 \text{ MeV} = -0.00433 \times 931.25 \text{ MeV} = -4.0323125 \text{ MeV. (endothermic)}$$

$$\text{(ii) } \Delta m = [2\,m(_6C^{12}) - \{m(_{10}Nc^{20}) + m(_2Hc^4)\}]$$

$$= (2 \times 12.000000 - \{19.992439 + 4.002603\}) = (2 \times 12.000000 - 23.995042) = 0.004958$$

$$E = \Delta m \times 931.25 \text{ MeV} = 0.004958 \times 931.25 \text{ MeV} = 4.6171375 \text{ MeV. (exothermic)}$$

6. Suppose, we think of fission of a $_{26}Fe^{56}$ nucleus into two equal fragments, $_{13}Al^{28}$. Is the fission energetically possible? Argue by working out *Q* of the process.

Given *m* ($_{26}Fe^{56}$) = 55.93494 u and *m* ($_{13}Al^{28}$) = 27.98191 u.

$$_{26}Fe^{56} \rightarrow {}_{13}Al^{28} + {}_{13}Al^{28} + Q$$

$$(i)\ \Delta m = [m\,(_{26}Fe^{56}) - 2\,m\,(_{13}Al^{28})]$$

$$\Delta m = [55.93494\ u - 2 \times 27.98191\ u] = [55.93494\ u - 55.96382 u] = -\ 0.02888\ u$$

$$E = \Delta m \times 931.25\ MeV = -\ 0.02888 \times 931.25\ MeV$$

$$E = -\ 26.8945\ MeV\ [Q = -ve,\ \text{not possible energetically}]$$

For fission Q = +ve.

7. The fission properties of $_{94}Pu^{239}$ are very similar to those of $_{92}U^{235}$. The average energy released per fission is 180 MeV. How much energy, in MeV, is released if all the atoms in 1 kg of pure $_{94}Pu^{239}$ undergo fission?

Number of atoms in 1 kg of pure $_{94}Pu^{239}$

$$N = \frac{1000 \times 6.023 \times 10^{23}}{239} = 2.54 \times 10^{24}\ \text{atoms.}$$

$$\text{Energy released.} 180 \times MeV \times 2.54 \times 10^{24} = 4.536 \times 10^{26}\ MeV.$$

8. How long can an electric lamp of 100W be kept glowing by fusion of 2.0 kg of deuterium? Take the fusion reaction as $_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + n + 3.27$ MeV.

Number of atoms in 2 kg of pure deuterium

$$N = \frac{2000 \times 6.023 \times 10^{23}}{2} = 6.023 \times 10^{26}\ \text{atoms.}$$

When two atoms of deuterium fuse, 3.27 MeV energy is released.

$$\text{Total Energy} = \frac{3.27}{2} \times 6.023 \times 10^{26}\ MeV = \frac{3.27}{2} \times 6.023 \times 10^{26} \times 1.6 \times 10^{-13}\ J = 15.6 \times 10^{13}\ J$$

$$P = 100\ W = 100\ J/s$$

$$\text{The total time} = \frac{15.6 \times 10^{13}\ J}{100\ J/s} = 15.6 \times 10^{11}\ s = 4.9 \times 10^{4}\ yrs.$$

9. Calculate the height of the potential barrier for a head on collision of two deuterons. (Hint: The height of the potential barrier is given by the Coulomb repulsion between the two deuterons when they just touch each other. Assume that they can be taken as hard spheres of radius 2.0 fm.)

$$d = 2\ fm + 2\ fm = 4 \times 10^{-15}\ m$$

$$\text{Potential energy of the two-deuteron system: } V = \frac{1}{4\pi\varepsilon_o}\frac{e \times e}{d}$$

$$V = 9 \times 10^9 \times \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{4 \times 10^{-15}}\ J = 9 \times 10^9 \times \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{4 \times 10^{-15} \times 1.6 \times 10^{-19}}\ eV = 360\ KeV.$$

10. From the relation $R = R_0A^{1/3}$, where R_0 is a constant and A is the mass number of a nucleus, show that the nuclear matter density is nearly constant (i.e. independent of A).

mass of nucleus = mA, where A is the mass number of the element

$$\text{Volume of nucleus} = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi\,(R_0\,A^{1/3})^3 = \frac{4}{3}\pi R_0^{\,3}A$$

$$\text{density} = \frac{\text{mass of nucleus}}{\text{volume of nucleus}} = \frac{mA}{\frac{4}{3}\pi R_0^3 A} = \frac{3m}{4\pi R_0^3}.$$

m and R_o are constant, $\rho = 2.29 \times 10^{17}\ kg/m^3$. Is constant for all nuclei.

Case- study based questions: -

1. When subatomic particles undergo reactions, energy is conserved, but mass is not necessarily conserved. However, a particle's mass "contributes" to its total energy, in accordance with Einstein's famous equation, $E = mc^2$. In this equation, E denotes the energy carried by a particle because of its mass. The particle can also have additional energy due to its motion and its interactions with other particles. Consider a neutron at rest and well separated from other particles. It decays into a proton, an electron and an undetected third particle as given here: Neutron → proton + electron + ???

The given table summarizes some data from a single neutron decay. Electron volt is a unit of energy. Column 2 shows the rest mass of the particle times the speed of light squared.

Particle	Mass x c^2 (Me V)	Kinetic energy (MeV)
Neutron	940.97	0.00
Proton	939.67	0.01
Electron	0.51	0.39

(i) From the given table, which properties of the undetected third particle can be calculated?

(a) Total energy, but not kinetic energy (b) Kinetic energy, but not total energy

(c) Both total energy and kinetic energy (d) Neither total energy nor kinetic energy

(ii) Assuming the table contains no major errors, what can we conclude about the (mc^2) of the undetected third particle?

(a) It is 0.79 MeV (b) It is 0.39 MeV

(c) It is less than or equal to 0.79 MeV; but we cannot be more precise.

(d) It is less than or equal to 0.40 MeV; but we cannot be more precise.

(iii) Could this reaction occur? ***Proton → neutron + other particles***

(a) Yes, if the other particles have much more kinetic energy than mass energy.

(b) Yes, but only if the proton has potential energy (due to interactions with other particles).

(c) No, because a neutron is more massive than a proton.

(d) No, because a proton is positively charged while a neutron is electrically neutral.

(iv) How much mass has to be converted into energy to produce electric power of 500 MW for one hour?

(a) 2×10^{-5} kg (b) 1×10^{-5} kg (c) 3×10^{-5} kg (d) 4×10^{-5} kg

Or

The equivalent energy of 1 g of substance is

(a) 9×10^{13}J (b) 6×10^{12}J (c) 3×10^{13}J (d) 6×10^{13}J

Answers: - (i) a (ii) d (iii) b (iv) a (iv) Or a

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