Chapter: Nuclear Physics

Numerical with Hints:

1) Calculate the binding energy per nucleon of $_{26}Fe^{56}$. {Atomic mass of $_{26}Fe^{56}$ is 55.9349u and that of $_{1}H^{1}$ is 1.00783u and mass of $_{0}n^{1}$= 1.00867u and 1u=931MeV}.[2076,2070]

HINT: Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

$\Delta \mathbf{m}$ =(Zm_p+Nm_n) - M

where, Z = atomic number,

m_p = mass of proton ,

m_n = mass of neutron

N=number of neutron

BINDING ENERGY: $E_B=(\Delta m)$ X 931 Mev =....

BINDING ENERGY PER NUCLEON: $\overline{B.E.} = \frac{E_B}{A}$ = ...

2) Calculate the binding energy per nucleon of calcium nucleus ($_{20}Ca^{40}$).{ mass of $_{20}Ca^{40}$ is 39.962589u and that of proton($_{1}H^{1}$)is 1.007825u and mass of neutron($_{0}n^{1}$)= 1.008665u and 1u=931MeV.}[2076,]

HINT: Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

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

where, Z = atomic number,

m_p = mass of proton ,

m_n = mass of neutron

BINDING ENERGY: $E_B=(\Delta m)$ X 931 Mev =....

BINDING ENERGY PER NUCLEON: $\overline{B.E.} = \frac{E_B}{A}$ = ...

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3) A city requires 10^7 Watts of electrical power on the average. If this is to be supplied by a nuclear reactor of efficiency 20%. Using $_{92}U^{235}$ as the fuel source, calculate the amount of fuel required per day.(Energy released per fission $_{92}U^{235}$=200MeV)[2075]

HINT: $\eta\% = \frac{P_{out}}{P_{in}}$ and find P_{in}.

Again, Power (P_{in}) = $\frac{\text{total Energy released(E)}}{\text{time taken(t)}}$

$$P_{in} = \frac{\text{Number of atoms(N)X liberated energy(Q)}}{\text{time taken}}$$

Or, N X Q= P_{in} X t

Or, N=$\frac{P_{in}\text{ X t}}{Q}$ =

Now, $6.023\text{X}10^{23}$ atoms have mass of Uranium= 235gram

So, 1 atoms have mass of Uranium = $\frac{235}{6.023\text{ X }10^{23}}$ gram

∴ (N=...) atoms have mass of Uranium=$\frac{235}{6.023\text{ X }10^{23}}$ X N = ... gram

4) A nucleus of $_{92}U^{235}$ disintegrates according to $_{92}U^{235} \rightarrow {}_{90}Th^{234} + 2He^4$ Calculate

a) The total energy released in the disintegration process

b) The KE of the α-Particle, the nucleus at rest before disintegration.

(Mass of $_{92}U^{235}$ =$3.859\text{X}10^{-25}$Kg, Mass of $_{90}Th^{234}$ =$3.787\text{X}10^{-25}$Kg, Mass of $_2He^4$ =$6.648\text{X}10^{-27}$Kg) [2075,2067]

HINT:

Mass defect ($\Delta\mathbf{m}$)= Decrease of mass in reaction

=mass of reactant – mass of product

BINDING ENERGY or total energy : E_B=(Δm) X 931 Mev =....

b)K.E of the α-Particle=[$\frac{m_{Th}}{m_{Th}+m_{\alpha}}$]X E_B =....

(Since, α-particle is Helium).

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5) The Mass of $_{17}Cl^{35}$ is 34.9800amu. Calculate its binding energy and binding energy per nucleon. Mass of proton($_{1}H^{1}$)is 1.007825amu and mass of neutron($_{0}n^{1}$)= 1.008665amu and 1u=931MeV.[2074]

HINT: Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

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

where, Z = atomic number, m_p = mass of proton , m_n = mass of neutron

BINDING ENERGY: $E_B=(\Delta m\ )$ X 931 Mev =....

BINDING ENERGY PER NUCLEON: $\overline{B.E.} = \frac{E_B}{A}$ = ...

6) What will be the amount of energy released in the fusion of three alpha particles into a C^{12} nucleus if the mass of He^4 and C^{12} nuclei are respectively 4.00263amu and 12amu.[2073]

HINT: Given reaction, 3 X $_{2}He^{4} \rightarrow C^{12}$ + Q

Mass defect ($\Delta \mathbf{m}$)= Decrease of mass in reaction

=mass of reactant – mass of product

= 3 X 4.00263-12

=0.00789amu

BINDING ENERGY or energy released : $E_B=(\Delta m\ )$ X 931 Mev =....

7) The Mass of the nucleus of the isotope Lithium ($_{3}Li^{7}$) is 7.014351u. Find its binding energy and binding energy per nucleon. (. Mass of proton($_{1}H^{1}$)is 1.007825u and mass of neutron($_{0}n^{1}$)= 1.008665u and 1u=931MeV.[2072supp,2069]

HINT: Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

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

where, Z = atomic number, m_p = mass of proton , m_n = mass of neutron

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BINDING ENERGY: $E_B=(\Delta m\ )$ X 931 Mev =....

BINDING ENERGY PER NUCLEON: $\overline{\text{B. E.}}\ =\frac{E_B}{A}$ = ...

8) $_{28}Ni^{62}$ may be described as the most strongly bound nucleus because it has the highest BE per nucleon. Its neutral atomic mass is 61.928349amu. Find its mass defect, its total binding energy and binding energy per nucleon. Mass of proton($_1H^1$)is 1.007825amu and mass of neutron($_0n^1$)= 1.008665amu and 1u=931.5MeV.[2072]

HINT: Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

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

where, Z = atomic number, m_p = mass of proton , m_n = mass of neutron

BINDING ENERGY: $E_B=(\Delta m\ )$ X 931 Mev =....

BINDING ENERGY PER NUCLEON: $\overline{\text{B. E.}}\ =\frac{E_B}{A}$ = ...

9) Calculate the binding energy per nucleon for a helium nucleus. Mass of Helium nucleus=4.001509amu, Mass of proton($_1H^1$)is 1.007825amu and mass of neutron($_0n^1$)= 1.008665amu and 1u=931MeV.[2071]

HINT: Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

$\mathbf{\Delta m}$ ={Zm_p+(N)m_n} - M

where, Z = atomic number, m_p = mass of proton , m_n = mass of neutron

BINDING ENERGY: $E_B=(\Delta m\ )$ X 931 Mev =....

BINDING ENERGY PER NUCLEON: $\overline{\text{B. E.}}\ =\frac{E_B}{A}$ = ...

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10) The most common isotope of Uranium $_{92}U^{235}$ has atomic mass 238.050783u. Calculate the mass defect, binding energy and binding energy per nucleon. Mass of proton($_1H^1$)is 1.007825amu and mass of neutron($_0n^1$)= 1.008665amu and 1u=931.5MeV.[2070supp]

HINT: Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

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

where, Z = atomic number, m_p = mass of proton , m_n = mass of neutron

BINDING ENERGY: $E_B=(\Delta m\ )$ X 931 Mev =....

BINDING ENERGY PER NUCLEON: $\overline{B.E.} = \frac{E_B}{A}$ = ...

11) Assuming that about 200MeV energy is released per fission of $_{92}U^{235}$ nuclei. What would be the mass of U^{235} consumed per day in the fission reactor of power 1MW approximately?[2068old]

HINT: Power produced = $\frac{\text{total Energy released(E)}}{\text{time taken(t)}}$

$$P = \frac{\text{Number of atoms(N)X liberated energy(Q)}}{\text{time taken}}$$

Or, N X Q= P X t

$$\text{Or, } N=\frac{P\ X\ t}{Q}$$

$$=\frac{(1MW)X\ (1\ day)}{(200MeV)}$$

$$= \frac{(1\ X\ 1000000W)X\ (86400sec)}{3.2\ x\ 10^{-11}J}$$

= 2.7 x 10^{21} atoms

Now, 6.023X10^{23} atoms have mass of Uranium= 235gram

So, 1 atoms have mass of Uranium = $\frac{235}{6.023\ X\ 10^{23}}$ gram

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$\therefore$ 2.7 X 10^{21} atoms have mass of Uranium$=\frac{235}{6.023 \text{ X } 10^{23}}$ X 2.7 X 10^{21}

=1.05gram.

12) The energy liberated in the fission of a single Uranium -235 atom is 3.2X10^{-11}J. Calculate the power production corresponding to the fission of 1.5Kg of Uranium per day.[2064]

HINT: Here, 235 gm of Uranium contains= 6.023X10^{23}atoms

So 1 gm of Uranium contains$=\frac{6.023 \text{ X } 10^{23}}{235}$ atoms

$\therefore$ 1.5Kg(i.e.1500gm) Uranium contains = $\frac{6.023 \text{ X } 10^{23}}{235}$ X 1500 atoms = N

Power produced = $\frac{\text{total Energy released}}{\text{time taken}}$

$= \frac{\text{Number of atoms(N)X liberated energy(Q)}}{\text{time taken}}$

Where, Q= energy liberated by fission of U^{235} atom= 3.2X10^{-11}J

13) The energy liberated in the fission of a single Uranium -235 atom is 3.2X10^{-11}J. Calculate the power production corresponding to the fission of 1Kg of Uranium per day. Assume Avogadro constant as 6.02x10^{23}mole^{-1}. [2054]

HINT: Here, 235 gm of Uranium contains= 6.023X10^{23}atoms

So 1 gm of Uranium contains$=\frac{6.023 \text{ X } 10^{23}}{235}$ atoms

$\therefore$ 1Kg(i.e.1000gm) Uranium contains = $\frac{6.023 \text{ X } 10^{23}}{235}$ X 1000 atoms = N

Power produced = $\frac{\text{total Energy released}}{\text{time taken}}$

$= \frac{\text{Number of atoms(N)X liberated energy(Q)}}{\text{time taken}}$

Where, Q= energy liberated by fission of U^{235} atom= 3.2X10^{-11}J

14) The energy liberated in the fission of single uranium-235 atom is 3.2x10^{-11}J. Calculate the power production corresponding to the

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fission of 1g of uranium per day. Assume Avogadro constant as $6.02 \times 10^{23} mole^{-1}$.[2073supp,2072,2070supp,2068]

HINT: Here, 235 gm of Uranium contains= $6.023 X 10^{23}$ atoms

So 1 gm of Uranium contains= $\frac{6.023 \text{ X } 10^{23}}{235}$ atoms = N.

Power produced = $\frac{\text{total Energy released}}{\text{time taken}}$

$= \frac{\text{Number of atoms(N)X liberated energy(Q)}}{\text{time taken}}$

Where, Q= energy liberated by fission of U^{235} atom= $3.2X10^{-11}$J

15) The energy released by fission of one U^{235} atom is 200MeV. Calculate the energy released in KWH, when one gram of uranium undergoes fission.[2071]

HINT: Here, 235 gm of Uranium contains= $6.023X10^{23}$atoms

So 1 gm of Uranium contains= $\frac{6.023 \text{ X } 10^{23}}{235}$ atoms = N.

Total energy released (E)= N X Q

Where, Q= energy liberated by fission of U^{235} atom= 200MeV= $3.2X10^{-11}$J

16) Calculate the speed of a particle if the mass of it is equal to 5 times its rest mass.[2052]

Hint: From the relativistic formula for the variation of mass with velocity is given as

$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ and find v.

(Here, $c=3 \text{ X} 10^8$m/s and $m=5m_0$ where m_0 is rest mass of particle)

17) Calculate the Q-value of the reaction and mention the type of reaction(endothermic or exothermic) Mass of proton(${}_1H^1$)is

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1.00814amu and mass of Helium($_2He^4$)= 4.00377amu, Mass of Nitrogen($_7N^{14}$)is 14.00783amu and mass of Oxygen($_8O^{16}$)= 4.00377amu [2052]

HINT: Given reaction, $_7N^{14} + {}_2He^4 \rightarrow {}_8O^{17} + {}_1H^1 +$ Q

Mass defect (Δm)= Decrease of mass in reaction=

=mass of reactant – mass of product

= 3 X 4.00263-12

=0.00789amu

BINDING ENERGY or Q-value of reaction: E_B=(Δm) X 931 Mev =....

Here, Q-value is negative so the reaction is endothermic.

SHORT QUESTIONS

1) Define Mass defect, Packing fraction, binding Energy and Binding Energy per Nucleon of a nucleus.
2) Write the significance of Binding energy per nucleon.
3) All nuclei have nearly the same density. Why?
4) Does nucleus contain the electrons? Explain.
5) Does the nucleus contain the protons? Explain.
6) Neutron is considered the most effective bombarding particle in a nuclear reaction. Why?
7) A nucleus consists of positively charged particle protons and electrically neutral neutrons in a small volume. How can this be possible as the like charges repel each other?
8) Why is the mass of a nucleus slightly less than the mass of constituent nucleons?
9) Define Atomic mass unit (amu). Hence convert the mass of a neutron, (1840 MeV),into amu where M_e is the mass of an electron.
10) By what factor must the mass number of a nucleus increase to double its volume?

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11) Diameter of Al^{27} nucleus is D_{Al}. How can one express the diameter of Cu^{64}in terms of D_{Cu}? Explain.
12) What does the energy balance (Q-value) of a nuclear reaction signify? Explain.
13) Why does a mountain of Uranium not explode as a bomb?
14) Write difference between nuclear fission and nuclear fusion.
15) Distinguish between isotopes and isobar?
16) Explain Binding energy in terms of Packing fraction.
17) What is meant by Chain reaction?
18) Write down the representative nuclear fission and fusion reactions.

LONG QUESTIONS:

1) Define mass Defect, Binding Energy and Binding Energy per Nucleon. Explain the Binding energy curve with neat and clean Diagram and write its significance?
2) Write the differences between Nuclear Fusion & Nuclear Fission? Explain the Production of energy in the Sun.
3) What is nuclear fusion? How energy is released in nuclear fusion reaction? Explain with examples
4) What is nuclear fission? How energy is released in nuclear fission reaction? Explain with examples.
5) State and explain Einstein's mass energy relation with example. Write its significance.
6) Discuss the important properties (size, charge, mass and density) of Nuclei.

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