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Nucleus ↦ Atomic nucleus is made up of +vely charged protons and ~~neutron~~ neutrons.

$$m_p = 1.6726 \times 10^{-27} Kg = 1835\ m_e$$

and $$m_n = 1.6749 \times 10^{-27} Kg = 1839\ m_e$$

m_p is almost equal to m_n.

① Nucleons ↦ Protons and neutrons present in the nucleus of an atom are called nucleons.

② Atomic number ↦ The number of protons present in the nucleus of an atom is called atomic number of the ~~nucleus~~ element.

In a $_ZX^A$ nucleus of X element

Z = no. of protons = no. of electrons in a neutral atom
= Atomic number of the X element.

e.g in $_6C^{12}$, 6 is the atomic number of carbon.

③ Mass number ↦ The total number of nucleons prensent in the nucleus of an atom is called mass number of the element.

In $_ZX^A$ ~~atom~~ nucleus of X element

A = no. of nucleon = no. of protons + no. of neutrons
= Mass number of X element.

∴ $A - Z$ = no. of neutrons.

~~$m(1.6\times10^{-27})$~~

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e.g in $_{17}Cl^{35}$, 35 is the mass number the cl

and $35-17=18$ = no. of neutrons.

4. Also in gold nucleus represented by $_{79}Au^{197}$

no. of protons = 97

∴ ~~Mass~~ Atomic number = 97.

No. of nucleons = 197

∴ Mass number = 197

and no. of neutrons = $A-Z = 197-79 = 118$.

Isotopes ↦ The atom of an element which have sam atomic number but different mass number are called isotopes.

They exhibit almost same chemical properties

e.g. isotopes of hydrogen are $_1H^1$ (protium)

$_1H^2$ (deuterium)

$_1H^3$ (tritium)

and isotopes of carbon are $_6C^{11}$, $_6C^{12}$, $_6C^{13}$, $_6C^{14}$.

Isobars ↦ The atoms of the different elements which have different atomic numbers but same mass num are called isobars.

Since these elements contain different no. of electrons therefore they exhibit diff. chemical propertie

eg $_1H^3$ and $_2He^3$

$_{17}Cl^{37}$ and $_{16}S^{37}$ or $_{20}Ca^{40}$ and $_{18}Ar^{40}$.

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Isotones ↦ The nuclides having same number of neutrons are called isotones.

eg $_{17}Cl^{37}$ and $_{19}K^{39}$ $(A-Z=20)$

and $_{80}Hg^{198}$ and $_{79}Pu^{197}$ $(A-Z=118)$

Isomers ↦

These are the nuclei with same atomic number and same mass number but existing in different energy states.

eg. a nucleus in ground ~~sat~~ state and same nucleus in metastable excited state are isomers.

eg. $_{28}Ni^{60}$ in ground state and $_{28}Ni^{60}$ in excited state are isomers.

Atomic mass unit ↦ One amu is d/a the $\frac{1}{12}$th of mass of $_6C^{12}$ atom.

ie $1\ amu = \frac{1}{12} \times$ mass of $_6C^{12}$ atom

$\therefore$ $1\ amu = 1.66 \times 10^{-27}\ kg$

This unit is used to measure the masses of atomic particles.

$m_p = 1.6726 \times 10^{-27}\ kg = 1.0073\ amu$

$m_n = 1.6749 \times 10^{-27}\ kg = 1.0086\ amu$

$m_H = 1.0078\ amu$ $(\because m_p + m_e = m_H)$

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Electron volt ↦ Energy possessed by an electron, whe[n] it is accelerated by applying a potential differ[ence] of one volt is called 1 electron volt (or 1eV

ie $1eV = 1e \times 1V$

$= 1.6 \times 10^{-19} C \times 1V$

$= 1.6 \times 10^{-19} CV$

$$\Rightarrow \boxed{1eV = 1.6 \times 10^{-19} J}$$

and $1 MeV = 1.6 \times 10^{-13} J$.

Relation b/w amu and MeV ↦ According to Einste[in's] mass energy relationship

$$E = mc^2$$

ie m unit of mass can produce E unit of ene[rgy]

If $m = 1 amu = 1.66 \times 10^{-27} Kg$

then $E = 1.66 \times 10^{-27} Kg \times (3 \times 10^{8} ms^{-1})^2$

$= 1.66 \times 10^{-27} \times 9 \times 10^{16} Kg m^2 s^{-2}$

$= 14.94 \times 10^{-11} J$

$= \frac{14.94 \times 10^{-11}}{1.6 \times 10^{-13}} MeV$

$E = 931 MeV$.

ie 1 amu of mass can produce 931 MeV of energy

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Nuclear size ↦ Surface of nucleus is not a well defined boundaries. However Rutherford scattering experiment helps us to estimate the size of the nucleus.

It was found out experimentally that volume of the nucleus is directly proportional to its mass number

ie $\frac{4}{3}\pi R^3 \propto A$

$\Rightarrow \quad R^3 \propto A$

$\Rightarrow \quad R \propto A^{1/3}$

$\Rightarrow \quad R = R_0 A^{1/3}$

where $R_0 = 1.2 \times 10^{-15} m = 1.2 \; fm = \text{Const.}$

Thus radius of the nucleus is directly proportional to cube root of mass number.

Nuclear density ↦ ~~we know that~~ Let m is the avg. mass of the nucleon of $_Z X^A$ nucleus of radius R.

Thus Density of nucleus = $\frac{\text{Mass of the nucleus}}{\text{Volume of the nucleus}}$

ie $\rho = \frac{mA}{\frac{4}{3}\pi R^3}$

$\frac{10^{-27}}{10^{-45}}$ 10^{45-27} 18 10^{18}

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$$= \frac{mA}{\frac{4}{3}\pi (R_0 A^{1/3})^3}$$

$$= \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$\Rightarrow \rho = \frac{3m}{4\pi R_0^3} = \text{Const}.$$

ie density of nucleus is independent of the mass number of the nucleus. ie density of hydrogen nucleus and density of iron nucleus is same.

ie Two identical boxes one containing hydrogen nuclei and other containing iron nuclei will have same mass.

On substituting the standard values

$$\rho = 2.3 \times 10^{17}\ Kg\ m^{-3}$$ (Very high in comparison to density of water ie $1.0 \times 10^3\ Kg\ m^{-3}$)

Nuclear force ↦ The strong interaction b/w the nucleons present inside the nucleus is called nuclear force

properties of nuclear force ↦

① It is strongest force in nature. This force binds the nucleons together in the nucleus despite of the electrostatic force of repulsion b/w the protons

$$F_N : F_{ES} : F_{week} : F_G = 10^{38} : 10^{36} : 10^{25} : 1$$

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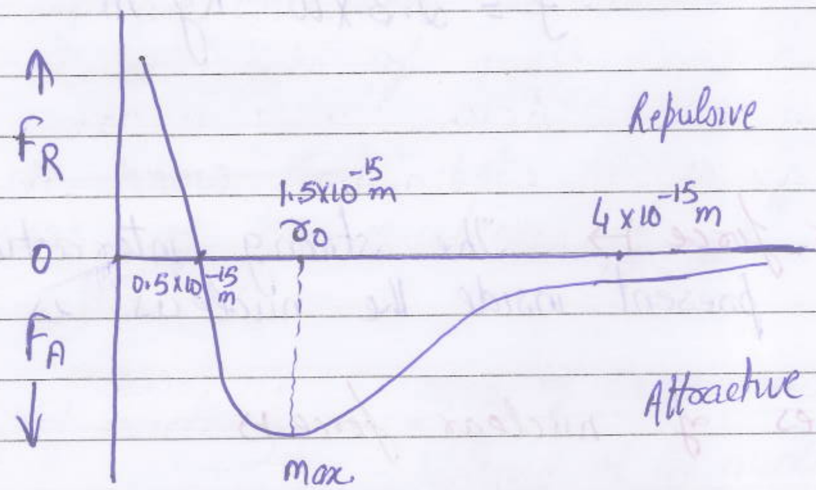
(2) Nuclear forces are short range forces. ie these forces act only if the distance b/w nucleon is very-very small.

3. Nuclear forces are independent of the charge on the nucleon ie nuclear force b/w p and p, n and n or n and p is same provided the distance b/w them is same.

4. Cause of these forces is exchange of elementary particle π-meson b/w the nucleons.

5. Nuclear forces are non central force ie it does not act along the line joining the centres of two nucleons.

6. Nuclear force varies with distance b/w the nucleons as shown in the graph.



For a distance more than 4×10^{-15} m $= 4$ fm nuclear force is almost zero (ie short range force)

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Mass Defect and packing fraction ↦

It is found that mass of the stable nucleus is always less than the sum of the mass of its constituent nucleons.

The difference b/w the sum of rest mass of the nucleons present in the nucleus and actual mass of nucleus is called mass defect.
It is denoted by Δm.

Consider a ${}_{Z}X^{A}$ nucleus having mass M_N and Z protons each of mass m_p and $(A-Z)$ neutrons each of mass m_n then mass defect is

$$\Delta m = Z m_p + (A-Z) m_n - M_N.$$

or
$$\Delta m = Z m_p + Z m_e + (A-Z) m_n - M_N - Z m_e$$
$$= Z M_H + (A-Z) m_n - M_X$$

(where $m_p + m_e = M_H$ = m... and $M_N + Z m_e = M_X$ = mass ...)

Packing fraction ↦

Mass defect per nucleon of the nucleus is called its packing fraction.

ie Packing fraction of nucleus $= \frac{\Delta m}{A}$.

O → m + ε

O+ε → m

for nuclei having mass number < 20 and > 200, packing fraction (or mass defect is -ve) and such nuclei are unstable nuclei

w/a for nuclei having mass number > 20 and < 200, packing fraction (or mass defect) is +ve and such nuclei are stable nuclei..

Binding Energy and Binding energy per nucleon ↦

To form a nucleus ie bringing the nucleons together in the nucleus, some work has to be done against the electrostatic force of repulsion.

This energy required to bind all the nucleons together in the nucleus is called binding energy.

On the contrary, similar amount of energy is required to break up the nucleus into its constituent nucleons and place them at infinite distance from each other, so that they may not interaction with each other.

Thus binding energy may also be defined as the energy required to split up the nucleus into its constituent nucleon and separate them to such a large distance so that they may not interact with each other.

We know that for a stable nucleus sum of the masses of ~~nucleus is~~ nucleons is always more than mass of stable nucleus. It is because some part of the mass of the nucleons get converted into binding energy which holds the nucleons together in the nucleus.

from Einstein's mass energy relationship.

$B.E = \text{mass defect} \times c^2$

ie $\boxed{B.E = \Delta m c^2}$

$$\boxed{B.E = [Zm_p + (A-Z)m_n - M_N]\, c^2}$$

or. $B.E = [Zm_p + Zm_e + (A-Z)m_n - M_N - Zm_e]\, c^2$

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$$\Rightarrow B.E = [Z(m_p + m_e) + (A-Z)m_n - (M_N + m_e)]c^2$$

$$\Rightarrow \boxed{B.E = [ZM_H + (A-Z)m_n - M_X]c^2}$$

where $M_H = m_p + m_e$ = mass of hydrogen atom

and $M_X = M_N + Zm_e$ = " " X atom.

Binding energy per nucleon ↦ The energy required to remove first nucleon from the nucleus is not same as that of removing 2nd or so on.

Thus avg. energy required to extract one nucleon from the nucleus is called binding energy per nucleon.

Mathematically.

$$B.E. \text{ per nucleon} = \frac{B.E}{\text{number of nucleon}}$$

$$= \frac{[ZM_H + (A-Z)m_n - M_X]c^2}{A}.$$

B.E. Curve ↦

The graph b/w B.E per nucleon of the nucleus and mass number is called B.E. Curve.

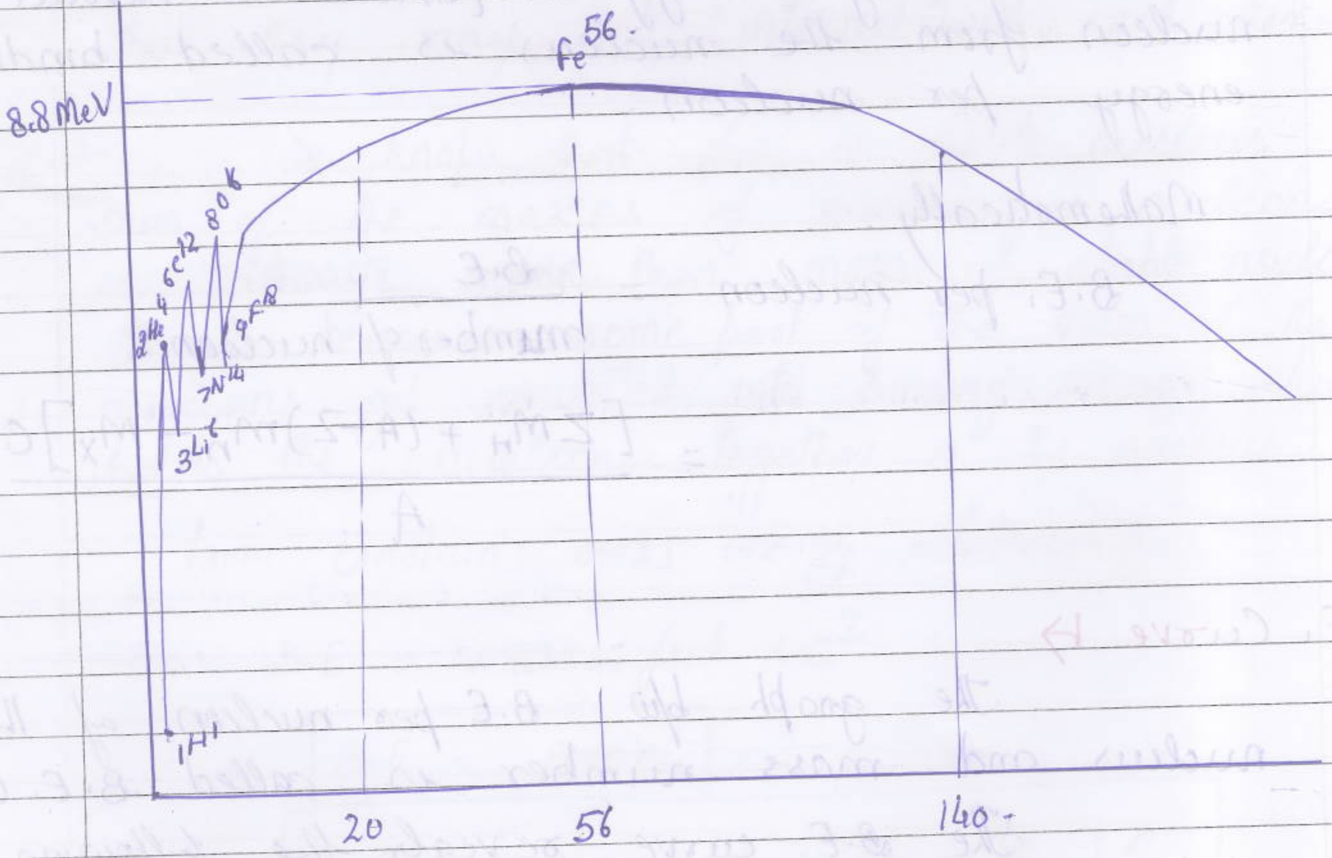
The B.E curve reveals the following facts

① The B.E/nucleon for smaller or light nuclei is small. ie light nuclei are comparatively less stable

2. We get certain peaks in the B.E curve for $_2He^4$, $_6C^{12}$ $_8O^{16}$. It shows that these nuclei are comparitively more stable than their neighbouring nuclei

3. B.E. curve is almost flat for mass numbers b/w 20 to 140. However B.E per nucleon for Fe^{56} is maximum (8.8 MeV). Thus we can say that iron is most stable element.

4. B.E./nucleon ~~decto~~ decreases gradually for mass numbers above 140. Thus these nuclei are again unstable and emit elementary particles.



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Ques ↦ How B.E curve can be used to explain the phenomena of nuclear fission or fusion.

Ans ↦ from the B.E curve it is clear that B.E per nucleon of the heavier nuclei like U^{235} is very small as compared to B.E per nucleon for Ba^{141} or Kr^{92}. Thus in order to attain more stablity U^{235} splits up into Ba^{141} and Kr^{92}.

Similarly B.E per nucleon of ${}_1H^1$ is very small as compared to that of ${}_2He^4$. Thus in order to attain more B.E and hence more stability ${}_1H^1$ nuclei fuse together to give ${}_2He^4$ nucleus.

Ques ↦ Calculate the mass defect, P.F, B.E and B.E per nucleon of ${}_{20}Ca^{40}$.

Given $m_p =$ ~~1.008620~~ 1.007825 amu.

$m_n = 1.008665$ amu.

and $M_{Ca} = 39.962589$ amu.

Ans ↦ We know that ${}_{20}Ca^{40}$ contains 20 protons and 20 neut

$\therefore$ Sum of masses of nucleons $= Zm_p + (A-Z)m_n$

$= 20 \times 1.007825 + 20 \times 1.008665$

$= 20.1565 + 20.1733$

$= 40.3298$ amu.

Actual mass of ${}_{20}Ca^{40}$ nucleus, $M_{Ca} = 39.962589$ amu.

Thus mass defect, $\Delta m = 40.3298 - 39.962589$

$= 0.367211$ amu.

$\therefore$ Packing fraction $= \frac{\Delta m}{A} = \frac{0.367211}{40} = 0.009180275$ amu

$\therefore B.E = \left(\Delta m_{\text{in amu}}\right) \times 931$ MeV ($\because$ 1 amu produces 931 MeV of ene

$= 0.367211 \times 931$ MeV.

$= 341.87$ MeV.

$\therefore$ B.E per nucleon $= \frac{341.87}{40}$ MeV

$= 8.547$ MeV.

$Q = BE_P - BE_R$

$Q = (M_R - M_P)c^2 \times 931$