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Binding energy per nucleons ($E_{b/n}$): Binding energy divided by the total number of nucleons in the nucleus.

Binding energy per nucleons ($E_{b/n}$) = Binding energy/Atomic mass

The atomic mass unit (amu), is defined as 1/12th of the mass of carbon (^{12}C) atom.

Thus, 1 a.m.u. = 1.66×10^{-27} kg

Energy Equivalent to 1 amu= mc^2 = (1.66×10^{-27} Kg) x (3×10^{-8} m/s)^2 = 1.49×10^{10} J

(since 1.6×10^{-19} J = 1eV)

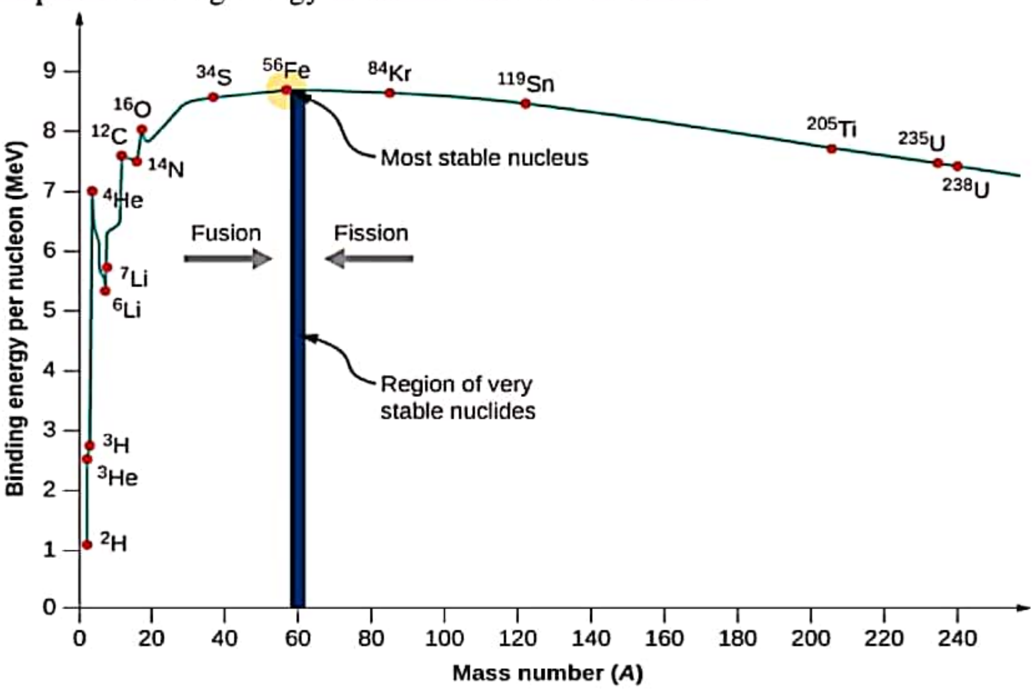
Therfore, 1.5×10^{10} J = 1.5×10^{10} / 1.6×10^{-19} eV = 0.93125×10^{9} eV

(Since 10^6 eV = 1 MeV)

Therfore, 0.93125×10^{9} eV = 931.25×10^{6} eV = 931.25 MeV

Thus 1 amu of mass = 931.25 MeV

There is a plot of binding energy vs atomic mass shown below:



Conclusions from this graph:

(i) The binding energy per nucleon ($E_{b/n}$) is independent of the atomic number for nuclei of middle mass number (30 < A < 170). The curve has a maximum of about 8.75 MeV for Iron having atomic mass 56 i.e. iron has most stable nucleus.

(ii) Binding energy per nucleon is lower for both light nuclei (A<30) and heavy nuclei (A>170).

(iii) A heavy nucleus, like an atom having atomic mass 240, has lower binding energy per nucleon compared to that of a nucleus with an atom having atomic mass 120. Thus if a nucleus A = 240 breaks into two A = 120 nuclei, nucleons get more tightly bound. This implies energy would be released in the process.

(iv) When two very light nuclei ($A \leq 10$) combine to form a heavier nucleus the binding energy per nucleon of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. This means that the final system is more tightly bound than the initial system. Again energy would be released in such a process of fusion.

Solution of previous lecture notes:

Q1: Answers (a) The $^{16}_{8}O$ contains 8 protons and 8 neutrons (even-even) and the $^{17}_{8}O$ contains 8 protons and 9 neutrons (even-odd). Therefore, $^{17}_{8}O$ is radioactive (b) The $^{35}_{17}Cl$ has 17 protons and 18 neutrons (odd-even) and the $^{36}_{17}Cl$ has 17 protons and 19 neutrons (odd-odd). Therefore, $^{36}_{17}Cl$ is radioactive. (c) The $^{20}_{10}Ne$ contains 10 protons and 10 neutrons (even-even) and the $^{17}_{10}Ne$ contains 10 protons and 7 neutrons (even-odd). Therefore, $^{17}_{10}Ne$ is radioactive. (d) The $^{40}_{20}Ca$ contains 20 protons and 20 neutrons (even-even) and the $^{45}_{20}Ca$ contains 20 protons and 25 neutrons (even-odd). Therefore, $^{45}_{20}Ca$ is radioactive.

Q2: Calculate Δm & binding energy of $^{75}_{33}As$. The mass of one proton, one neutron & one electron & atomic mass of $^{75}_{33}As$ is 1.0073 amu, 1.0087 amu & 0.0055 amu and 74.9216 amu respectively

Ans. $^{75}_{33}As$ has 33 protons, 33elecrons & (75-33)= 42 neutrons

Mass of nucleus (Actual) = Atomic Mass-Mass of 33 electrons

$= 74.9216 - 33\times0.00055 = 74.9216 - 0.01815 = 74.90345$ amu

Mass of nucleus (calculated) = mass of 33protons + mass of 42neutrons

$= 33\times1.0073+42\times1.0087 = 33.2409 +42.3654 = 75.6063$ amu

$\Delta m = 75.6063 - 74.90345 = 0.70285$ amu

Binding energy = $\Delta m\times931$ MeV = $0.70285\times931 = 654.35$ MeV

Q3: Calculate the Δm & binding energy of $_2He^4$. Its actual atomic mass is 4.0039 amu. The mass of one n & one p together is 2.0165 amu. mass one electron=0.0005486amu

Ans. $_2He^4$ has 2 protons, 2 electrons & 2 neutons

Mass of Nucleus = Atomic mass-mass of 2e = $4.0039 - 2\times0.0005486 = 4.0028$ amu

Mass of nucleus (Calculated) = mass of 2p +mass of 2nn= 2(mass of P+mass of n)

$= 2\times2.0165 = 4.033$ amu

Mass defect (Δm) = 4.033 amu- 4.0028 amu = 0.0302 amu

Binding energy = $\Delta m\times931$ MeV = $0.0302\times931 = 28.12$ MeV.

Q4: Binding energy per nucleon for an element is 7.14 MeV. If the binding energy of the element is 28.6MeV. Calculate the number of nucleons in the nucleus.

Ans. Binding energy = 28.6MeV, Binding Energy per Nucleon = 7.14MeV

No. of nucleons = 28.6 MeV/7.14MeV = 4

Q5: Binding energy of an element is 64 MeV. Binding energy per nucleon is 6.39 MeV. What is the total number of neutrons and protons in the nucleus?

Ans. Binding energy = 64MeV, Binding energy per nucleon = 6.39 MeV

No. of Nucleons = 64MeV/6.39 MeV= 10

No. of nucleons = No. of Protons + No. of Neutrons

So, Total no. of neutrons & protons = 10