Quantum Mechanics: Blackbody radiation

Deductions from Planck's law

1. Rayleigh-Jeans law : low frequency or High wavelength

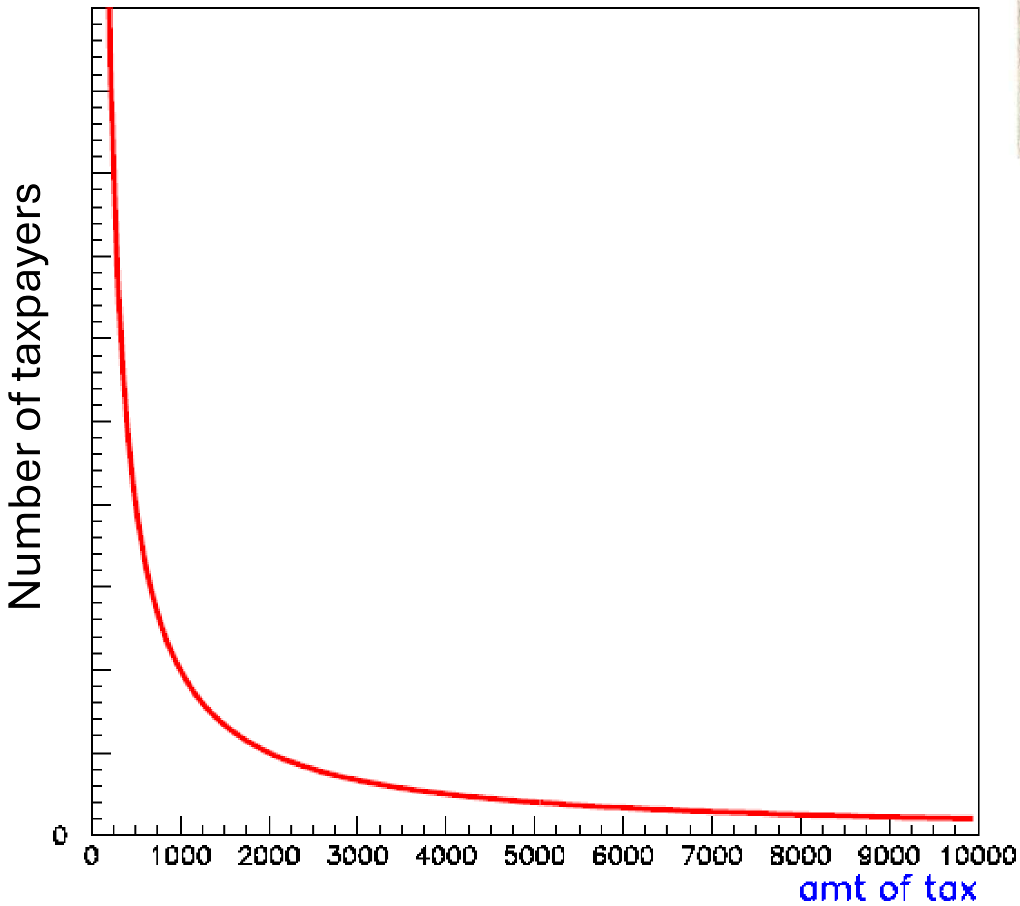
$$u_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}\left[\frac{1}{e^{\frac{hc}{\lambda kT}}-1}\right]d\lambda \quad \text{Planck's law}$$

Suppose the quantum were a Rs.1000 bill

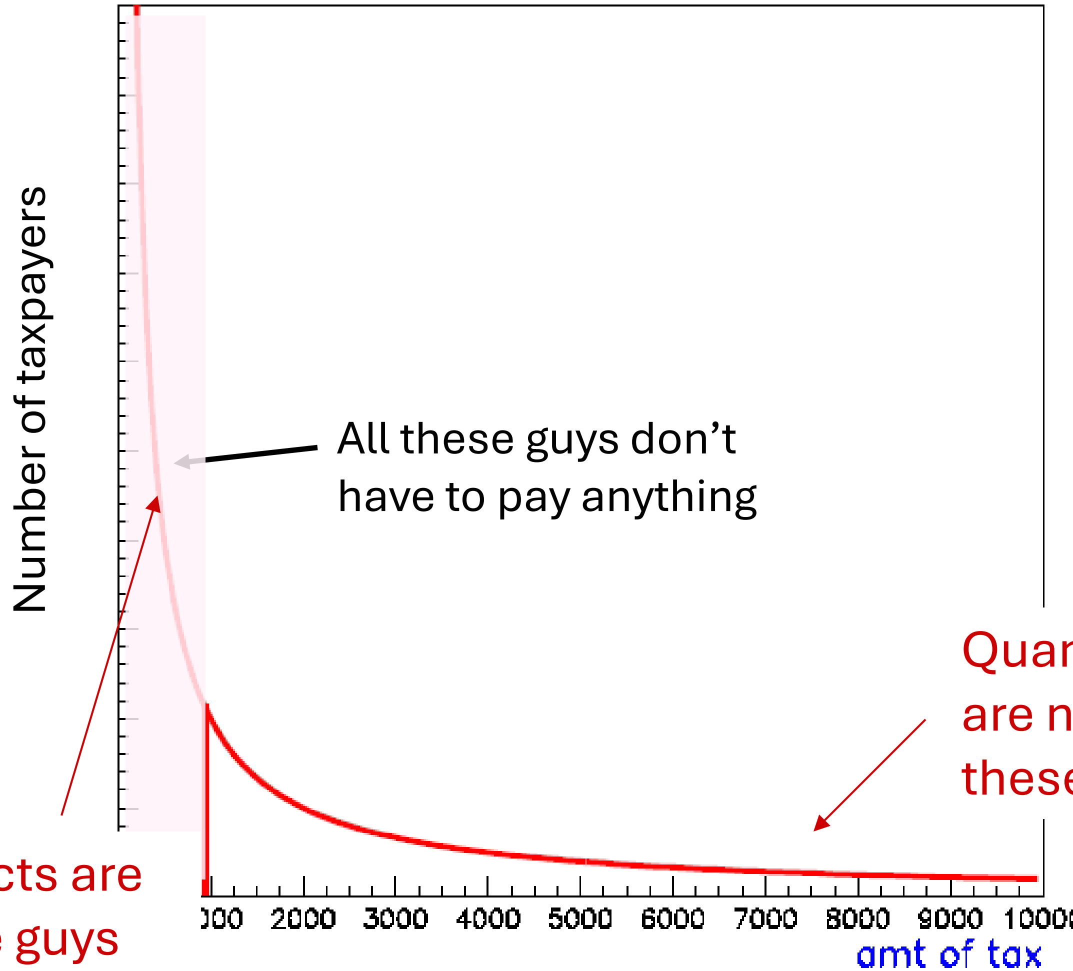
A quantum this large would have an enormous effect on “normal” transactions

The quantum of the Indian system

Indian Income tax with a Rs. 1 quantum



Indian Income tax with a Rs. 1000 quantum



Quantum effects are negligible to these taxpayers

Quantum effects are huge to these guys

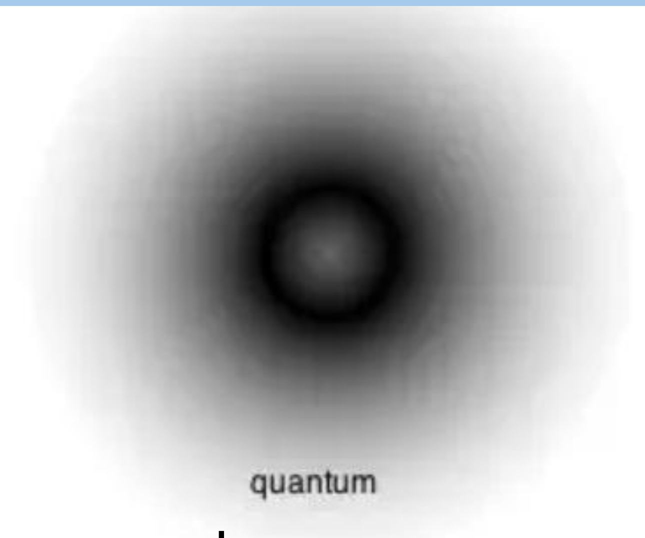
Quantum Mechanics: What have we learnt so far??

- atomic structure,
- quantum mechanics,
- Compton effect
- photoelectric effect,
- Black body radiation
- Significance of quantum effects

Always be happy and grateful

Nuclear Physics: Objectives

- Already discussed about electron
- Next is nucleus
- Now we will discuss it
- Why it is important to study nuclear physics…examples



Ref.: Concepts of Modern Physics by Arthur Beiser.

Nuclear Physics: Objectives

- Few terms
- Radioactive decay
- Binding Energy
- Binding Energy per nucleon curve

Nuclear Physics

- Electron structure of the atom was understood before even the composition of its nucleus was known.

- Why it is so?

- Forces that hold nucleus together are stronger than electric forces.

- Thus, difficult to break a nucleus to find out what is inside.

- Changes in electron structure of an atom, such as those that occur when a photon is emitted or absorbed, involve energy of few eV.

- Changes in nuclear structure, involves energy in MeV range, 10^6 times greater.

Nuclear Physics

Terminology

$^{A}_{Z}X$

$A = Z + N$ (mass no.)

Z → atomic no.

- neutrons : N
- protons : Z
- electrons : Z in neutral atom
- atoms of same element have same atomic no. Z

Isotope : same element have different no. of neutrons N

$^{1}_{1}H$, hydrogen $^{2}_{1}H$, deuterium $^{3}_{1}H$, tritium

Nucleons : neutrons and protons together known as nucleon.

Isobar : same A, different Z $\quad ^{40}_{18}Ar \quad ^{40}_{20}Ca \quad ^{40}_{19}K$

Isotone : nucleon with same N, diff. Z $\quad ^{14}_{6}C \quad ^{15}_{7}N$

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

$R_0 \simeq 1.2 \times 10^{-15}$ m

$\simeq$ **1.2** fm

Nuclear Physics

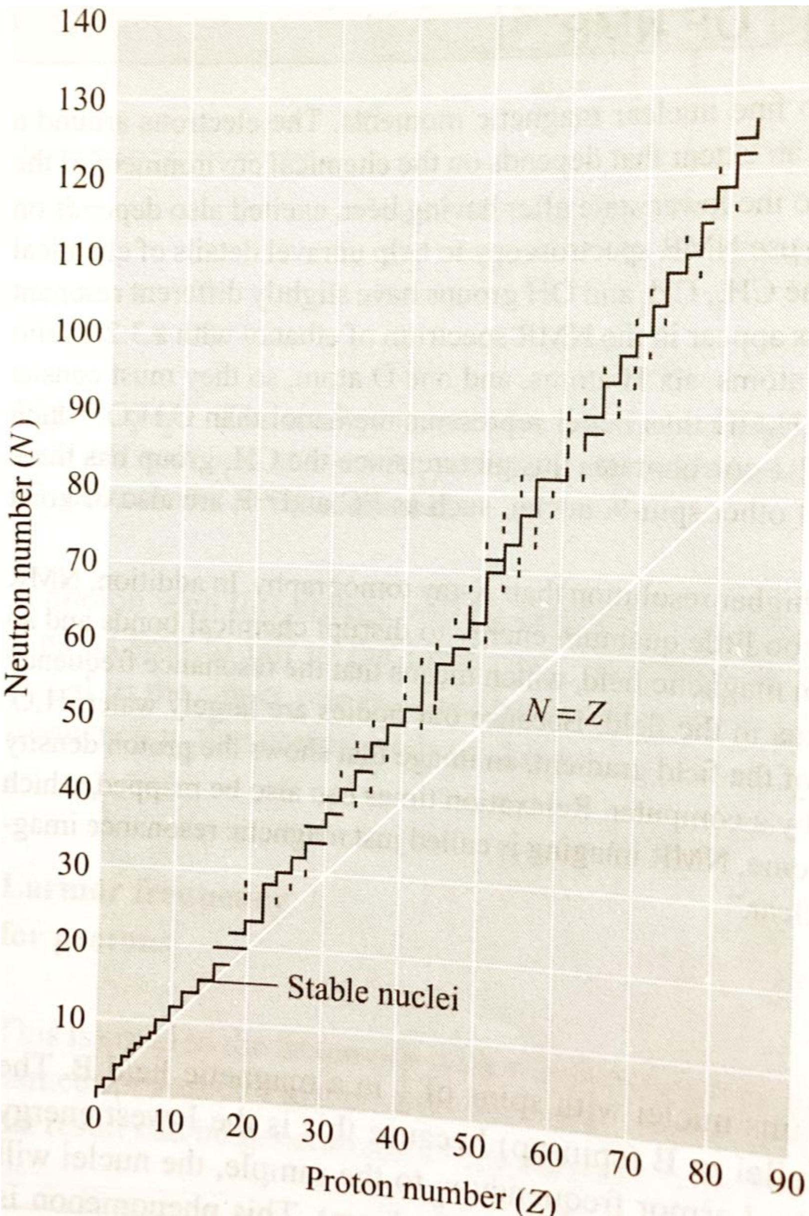
Atomic masses

Table 11.1 **Some Masses in Various Units**

Particle	Mass (kg)	Mass (u)	Mass (MeV/c^2)
Proton	1.6726×10^{-27}	1.007276	938.28
Neutron	1.6750×10^{-27}	1.008665	939.57
Electron	9.1095×10^{-31}	5.486×10^{-4}	0.511
${}^{1}_{1}H$ atom	1.6736×10^{-27}	1.007825	938.79

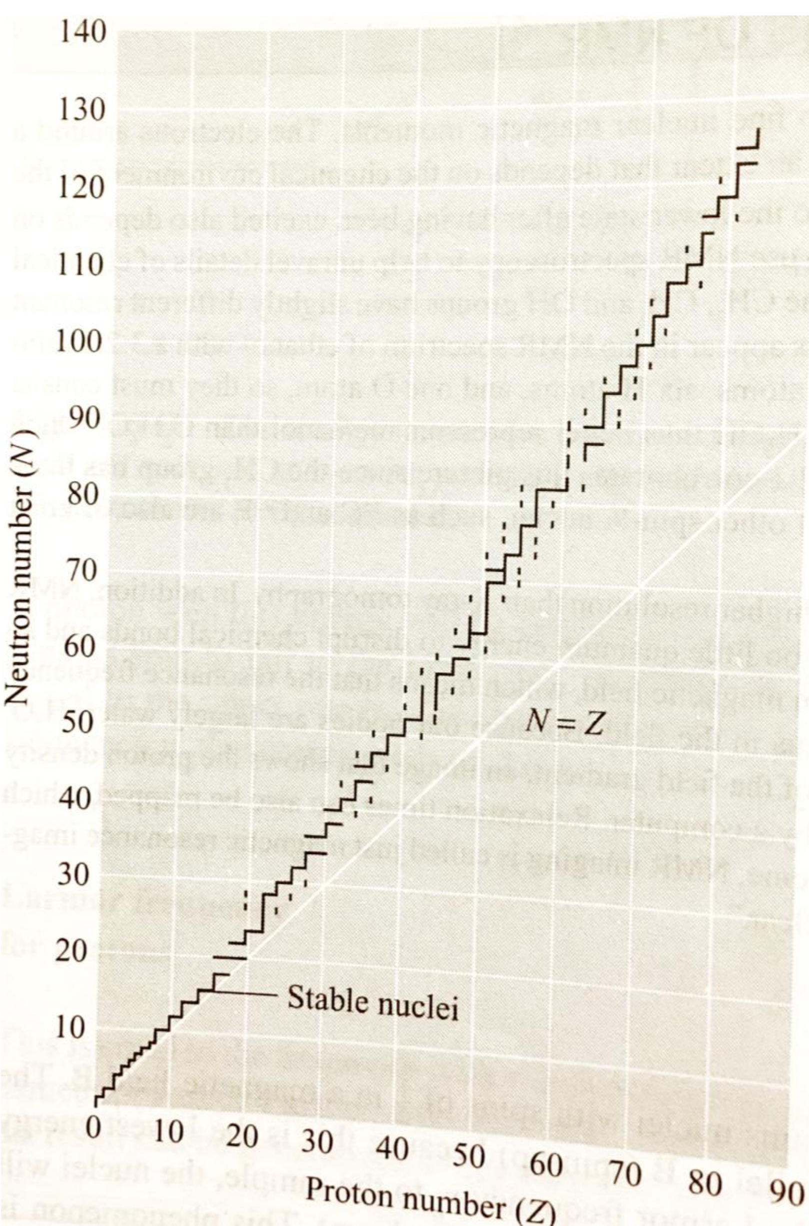
Nuclear Physics: Stable Nuclei?

Electron, proton and neutron- all are fermions and have spin ½.



Nuclear Physics: Stable Nuclei?

Electron, proton and neutron- all are fermions and have spin ½.



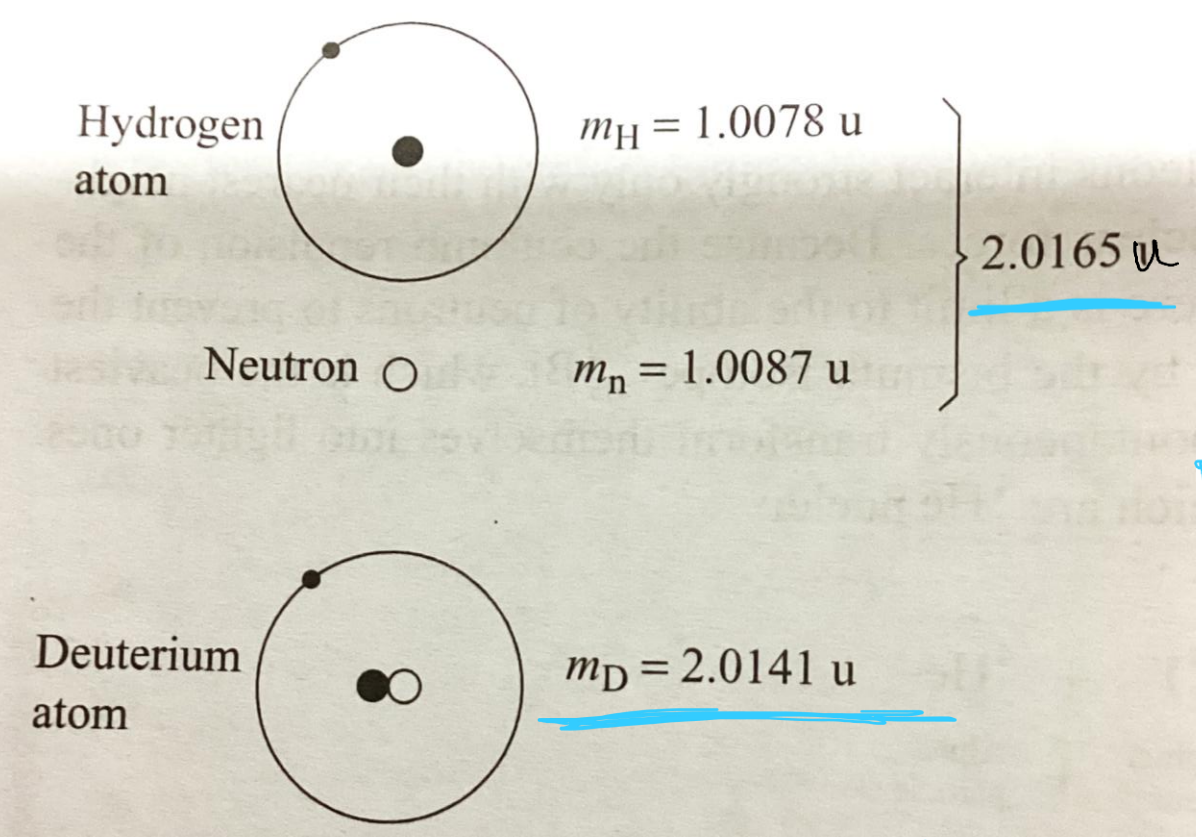
Why some combination of neutron and proton are more favorable?

- Not all combinations of neutrons and protons form stable nuclei.
- Light nuclei (A<20) contain approx. equal no. of protons and neutrons.
- Neutrons are filled in nuclear energy levels similar to electron.
- Proton are positively charged and repel each other.
- Neutrons produce only attractive forces.
- Repulsive forces become greater when Z>10, so more no. of neutrons are required to form stable nucleus.

Nuclear Physics: Binding Energy

Binding energy: Missing energy that keeps a nucleus together.

How to calculate mass of deuterium? $^{2}_{1}H \longrightarrow$ 1 neutron + 1 proton



measured mass is 0.002388 u less than combined mass of $^{1}_{1}H$ and a neutron.

$\Delta E = mc^2$

$= 0.00238 \times 931.5$

$\boxed{\Delta E = 2.24 \text{ MeV}}$

this energy is same energy which is reqd. to break apart deuterium nucleus into separate neutron and proton.

Nuclear Physics: Binding Energy

This missing energy is termed as BINDING ENERGY

${}^{A}_{Z}X \qquad N = A - Z$

$$\boxed{E_b = \left[Z\,m({}^{1}_{1}H) + N\,m(n) - m({}^{A}_{Z}X)\right](931.5\ \text{MeV}/u)}$$

Q. Calculate binding energy of ${}^{20}_{10}Ne$.

$$E_b = \left[10(1.007825\ ) + 10(1.008665) - 20\right](931.5)\ \text{MeV}$$

Nuclear Physics: Binding Energy

This missing energy is termed as **BINDING ENERGY**

${}^{A}_{Z}X \qquad N = A - Z$

$$\boxed{E_b = \left[Z\,m({}^{1}_{1}H) + N\,m(n) - m({}^{A}_{Z}X)\right](931.5\ \text{MeV}/u)}$$

Q. Calculate binding energy of ${}^{20}_{10}Ne$.

$$E_b = [10(1.007825) + 10(1.008665) - 20](931.5)\ \text{MeV}$$

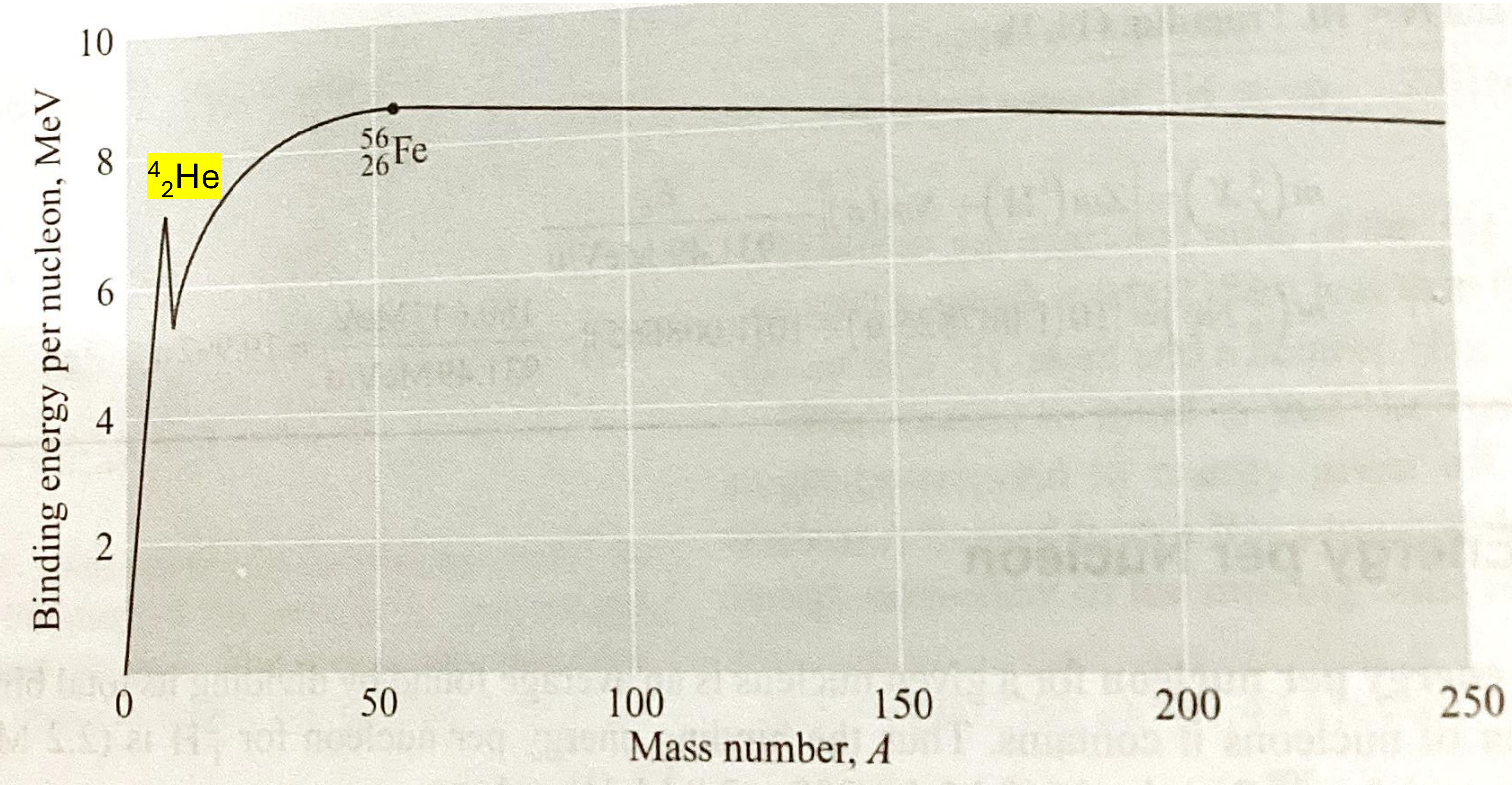
$$E_b = 160.647\ \text{MeV}$$

Binding energy per nucleon

- ${}^{2}_{1}H = \dfrac{2.2\ \text{MeV}}{2} = 1.1\ \text{MeV/nucleon}$

Nuclear Physics: Binding energy per nucleon

- **Strong interaction in nucleus**
- Electromagnetic interaction between charge particles
- Gravitational interaction everywhere



- While attractive forces that nucleons exert upon one another are very strong, their range is short.
- Up to a separation of about 3fm, the nuclear attraction between two protons is about 100 times stronger than electric repulsion between them.
- Nuclear interaction between proton and proton, between proton and neutron and between neutron and neutron appear to be identical.

Nuclear Physics: Liquid drop model

- At a first approximation, we can think of each nucleon in a nucleus as interacting solely with its nearest neighbors.
- Analogy with liquid was proposed by George Gamow in 1929 and developed in detail by C.F. von Weizsacker in 1935.
- Assume energy associated with each nucleon-nucleon bond has some value U.
- This value is actually negative since attractive forces are involved, but usually written as positive for convenience.

each bond is shared by two nucleons, each has a binding energy of $\frac{1}{2}U$.

assembly of nucleons packed together into smallest volume each sphere is surrounded by 12 other spheres.

(volume energy) $E_v = 12 \times \frac{1}{2} U(A) = 6U(A) = 6UA$

if all "A" nucleons in a nucleus were in its interior

(volume energy) $E_v = a_1 A$ —— (1)