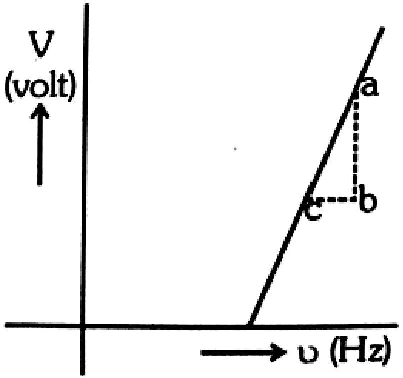
32nd Session: Modern Physics III
Classification of Nuclei

- Recap
- 2nd classification of nuclei
  - Binding energy & mass defect
  - Stable & unstable (radioactive) nuclei (2 important curves)
    - N v/s P
    - B.E. per Nucleon v/s A

Q. 1). In a photoelectric experiment the graph of frequency ν of incident light (in Hz) and stopping potential V (in volt) is shown in below. From figure the value of the Planck's constant is (e is the elementary charge)

(1) $e\frac{ab}{cb}$ ✓ (2) $e\frac{cb}{ab}$

(3) $e\frac{ac}{bc}$ (4) $e\frac{ac}{ab}$



$eV_s = h\nu - \phi$

$V_s = \frac{h}{e}\nu - \frac{\phi}{e}$

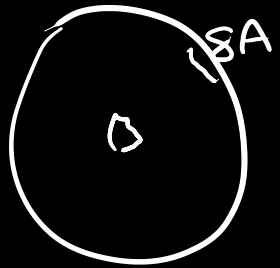
$\frac{h}{e} = \tan\theta = \text{slope} = \frac{ab}{cb}$

$h = e \cdot \frac{ab}{cb}$

Q. 2). A 500 W bulb is placed at the center of a perfectly black sphere of radius R = 1 metre. The approximate pressure experienced by the walls of the sphere as it absorbs all the photons emitted by the bulb is (take $4\pi = 12.6$)

(1) 1.3×10^{-7} N/m² ✓ (2) 2.5×10^{-7} N/m²

(3) 6.3×10^{-7} N/m² (3) 3.14×10^{-7} N/m²



$N_p = \frac{500}{4\pi(1)^2} \times \frac{\delta A\, \lambda}{hc}$

$\frac{\Delta p}{\Delta t} = \frac{h}{\lambda\, \Delta t}$

press = force/area

$= \frac{500}{4\pi c} = \frac{500}{12.6 \times 3 \times 10^8}$

$= 1.3 \times 10^{-7}$ N/m²

force $= N_p \times \frac{h}{\lambda}$

$= \frac{500}{4\pi} \times \frac{\delta A\, \lambda}{hc} \times \frac{h}{\lambda}$

Q. 3). A laser beam (λ = 633 nm) has an power of 3 mW. What will be the pressure exerted on a surface by this beam if the cross sectional area is 3 mm^2. (Assume perfect reflection and normal incidence)

(1) 6.6×10^{-3} N/m^2 ✓(2) 6.6×10^{-6} N/m^2

(3) 6.6×10^{-9} N/m^2 (4) 6.6 N/m^2

Steps (IAS)

1). Find (N_p) → normal area

2). ΔP for each photon

3). Force = $N_p \times \Delta P$ → components or not.

4. vector add^n.

5). press = Force / normal area.

$$\text{pressure} = \frac{3\times10^{-3}\,\lambda}{hc} \times \frac{2h}{\lambda} \times \frac{1}{3\times10^{-6}} = 6.6\times10^{-6}\ N/m^2$$

Q. 4). The electron of a hydrogen atom revolves round the proton in a circular n^{th} orbit of radius $r_n = \frac{\varepsilon_0 n^2 h^2}{(\pi m e^2)}$ with a speed $v_n = \frac{e^2}{2\varepsilon_0 nh}$. The current due to the circulating charge is proportional to

(1) e^2 (2) e^3

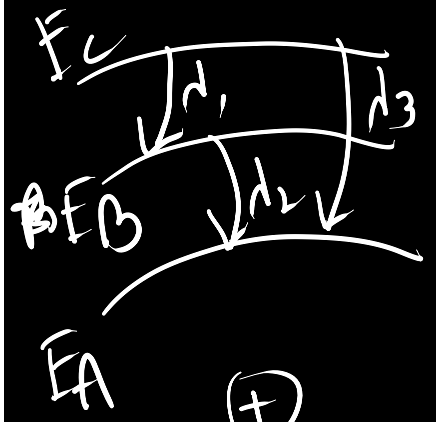
(3) e^5 ✓ (4) e^6

$$i = \frac{e}{T} = \frac{e v_n}{2\pi r_n} \propto \frac{e \cdot e^2 \times e^2}{1} \propto e^5$$

Q. 5). Energy levels A, B and C of a certain atom correspond to increasing values of energy i.e. $E_A < E_B < E_C$. If λ_1, λ_2, and λ_3 are wave lengths of radiations corresponding to transitions C to B, B to A and C to A respectively, which of the following relations is correct :-

(1) $\lambda_3 = \lambda_1 + \lambda_2$ ✓(2) $\lambda_3 = \dfrac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

(3) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (4) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$



$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

$$\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$$

Q. 6). Electrons of mass m with de-Broglie wavelength λ fall on the target in an X-ray tube. The cutoff wavelength (λ_0) of the emitted X-ray is :-

(A) $\lambda_0 = \dfrac{2m^2c^2\lambda^3}{h^2}$

(2) $\lambda_0 = \lambda$

(3) $\lambda_0 = \dfrac{2mc\lambda^2}{h}$ ✓

(4) $\lambda_0 = \dfrac{2h}{mc}$

$$\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2mk}} \Rightarrow k = \frac{h^2}{2m\lambda_e^2} = \frac{hc}{\lambda_0}$$

$$\lambda_0 = \frac{hc \cdot 2m\lambda_e^2}{h^2} = \frac{2mc\lambda_e^2}{h}$$

Q. 7). For production of characteristics K_β X-rays, the electron transition will be :-

(1) n = 2 to n = 1 (2) n = 3 to n = 2

(3) n = 3 to n = 1 (4) n = 4 to n = 2

Q. 8). if voltage of X-ray tube is doubled then intensity of X-rays will :-

(1) Halved
(2) Remains constant
(3) Doubled
(4) Quadrupled

Q. 9). 20 kV potential is applied across X-ray tube, the minimum wavelength of X-ray emitted will be :-

(1) 0.62 Å ✓ (2) 0.37 Å

(3) 1.62 Å (4) 1.31 Å

$$20\,kV \times e = \frac{hc}{\lambda}$$

$$\lambda = \frac{12400}{20 \times 1000} = 0.62\,Å$$

Q. 10). Lattice constant of a crystal is 3×10^{-8} cm and glance angle of X-ray is 30^0 for first order diffraction, then the value of λ will be :-

(1) 6×10^{-8} cm
(2) 3×10^{-8} cm ✓
(3) 1.5×10^{-8} cm
(4) 10^{-8} cm

Lattice constant ⟷ inter-planar dist.

$$2d \sin\theta = n\lambda$$

$$2 \times 3 \times 10^{-8} \sin 30^\circ = 1 \times \lambda$$

$$\lambda = 3 \times 10^{-8} \text{ cm}$$

1	2	3	4	5	6	7	8	9	10
1	1	2	3	2	3	3	2	1	2

2^{nd} Classification (based on stability): Chart of nuclides

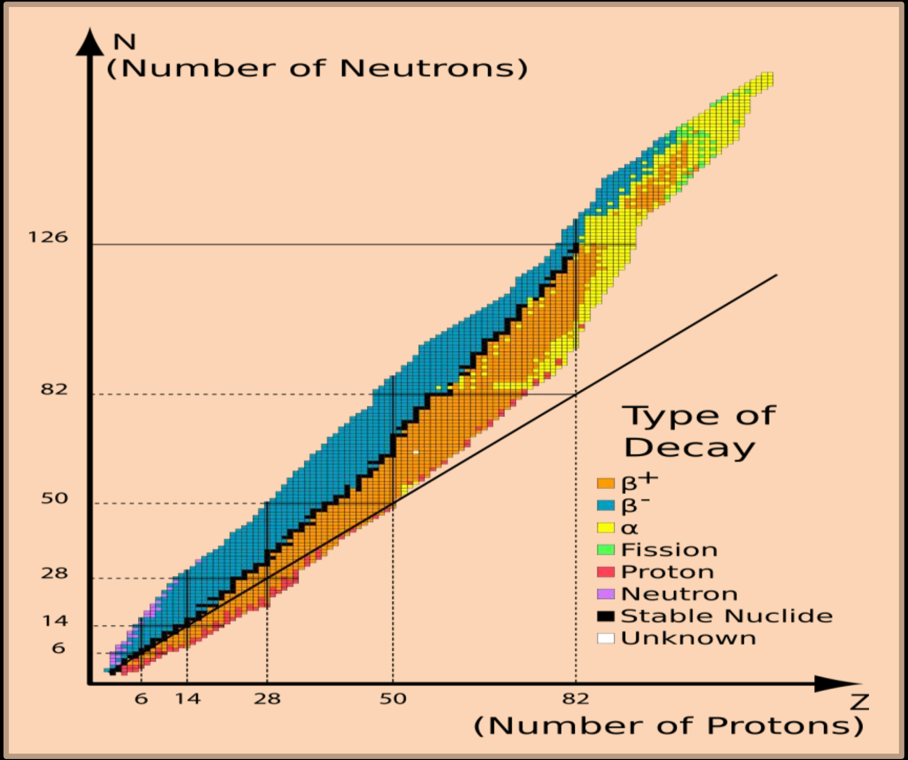


Chart of Nuclides

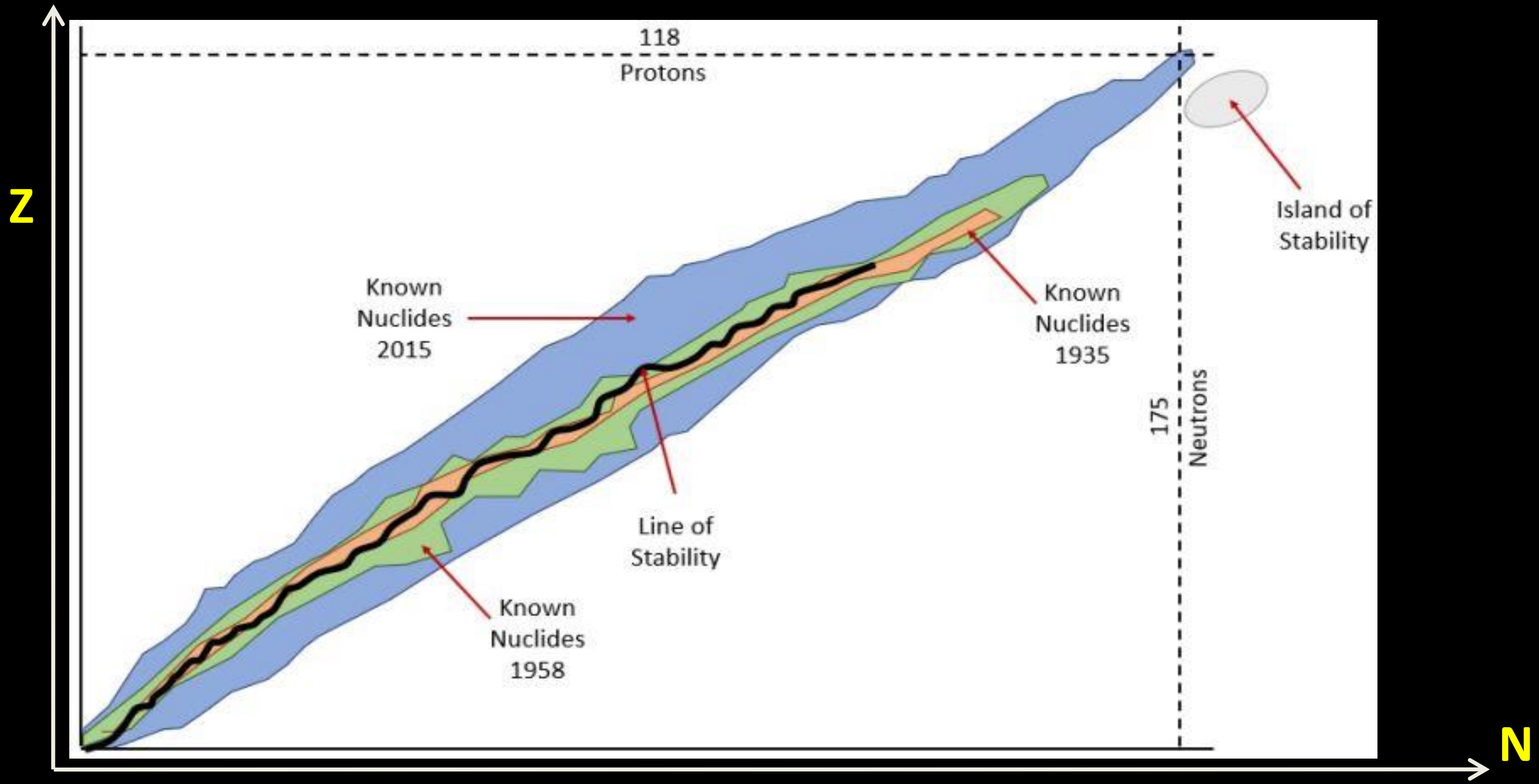
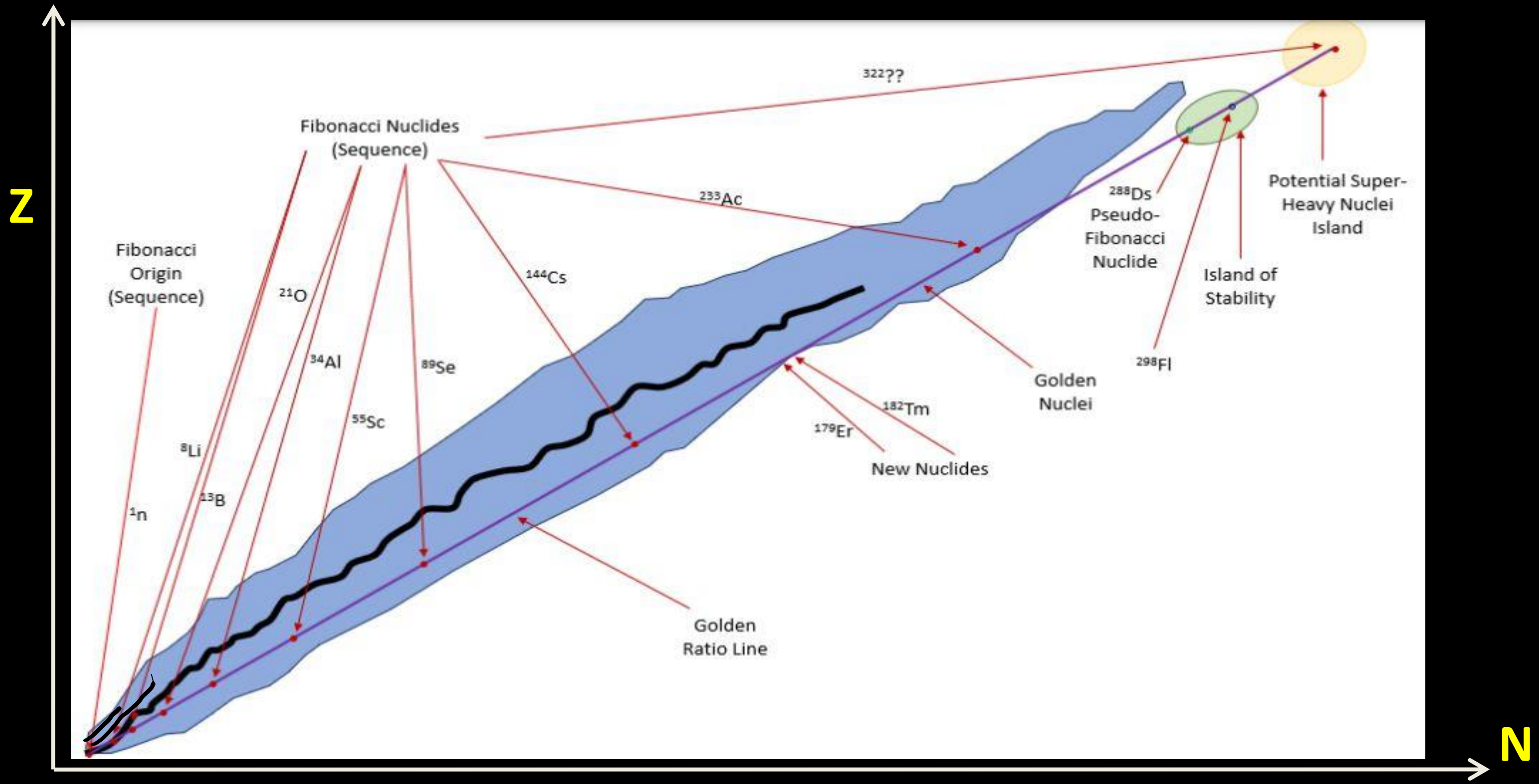
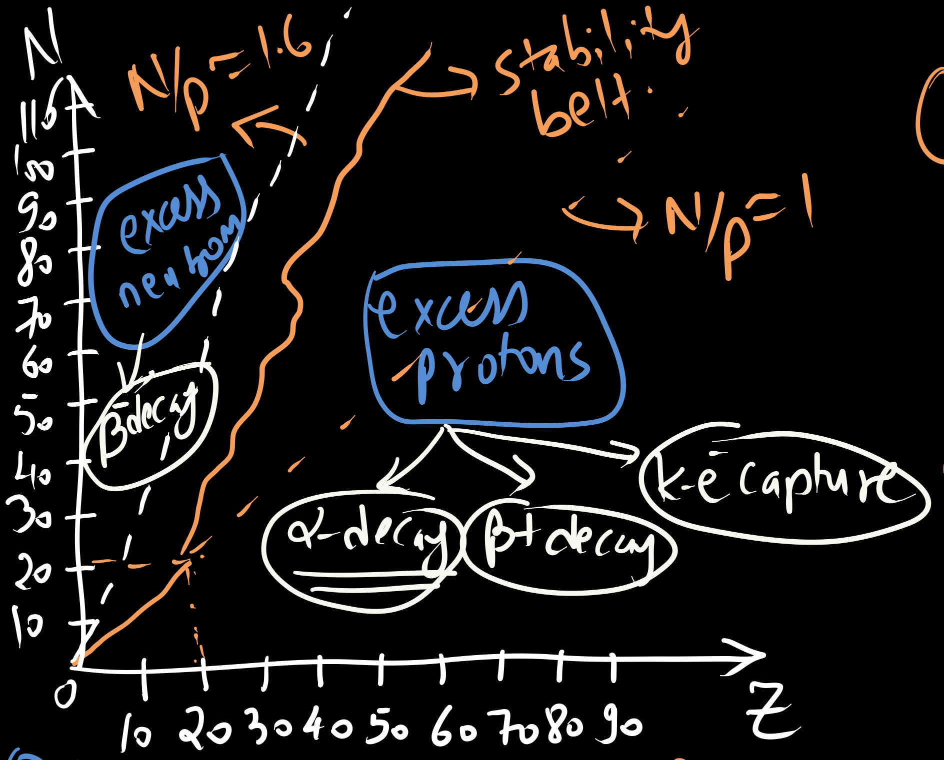


Chart of Nuclides: Golden Ratio line





① For $Z < 20$

stable nuclei have $n/p \simeq 1$

$^{4}_{2}He$ $^{12}_{6}C$ $^{14}_{7}N$ $^{16}_{8}O$ $^{23}_{11}Na$ $^{24}_{12}Mg$ $^{40}_{20}Ca$

$p \to 2$ $p \to 6$ $p \to 7$ $p \to 8$ $p \to 11$ $p \to 12$ $p \to 20$

$n \to 2$ $n \to 6$ $n \to 7$ $n \to 8$ $n \to 12$ $n \to 12$ $n \to 20$

$12/11 = 1.09$

$^{1}_{1}H$ $^{3}_{2}He$ $^{9}_{4}Be$ $^{7}_{3}Li$

$p \to 1$ $p \to 2$ $p \to 4$ $p \to 3$

$n \to 0$ $n \to 1$ $n \to 5$ $n \to 4$

0.5 $n/p = 5/4 = 1.25$ $n/p = 4/3 = 1.33$

② for $Z > 20$.

stable nuclei have $1 < n/p < 1.618$

last stable nucleus $\to {}^{209}_{83}Bi$

$^{56}_{26}Fe$ $p \to 26$, $n \to 30$

$^{108}_{47}Ag$ $p \to 47$, $n \to 61$

③ An unstable nucleus disintegrates to become stable by changing its (n/p) ratio.