Beta Decay Followed by Gamma Ray Emission

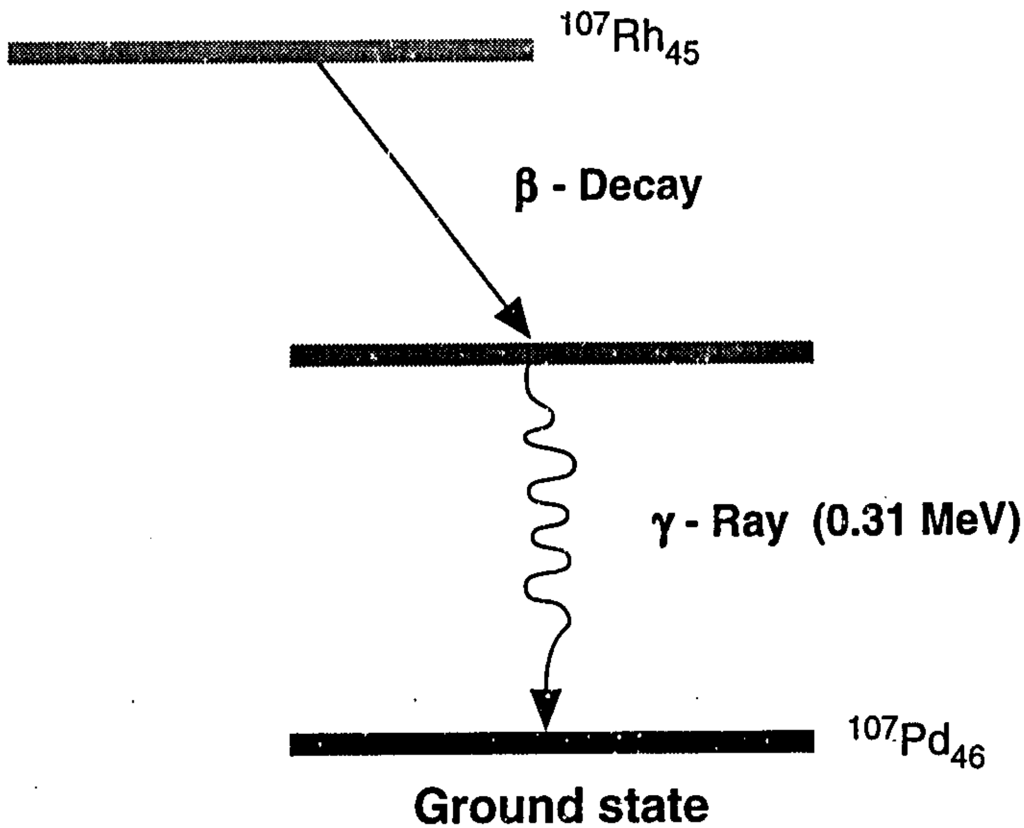


Fig. 1.2

Representation of Exponential Radioactive Decay in Terms of Half-life Periods

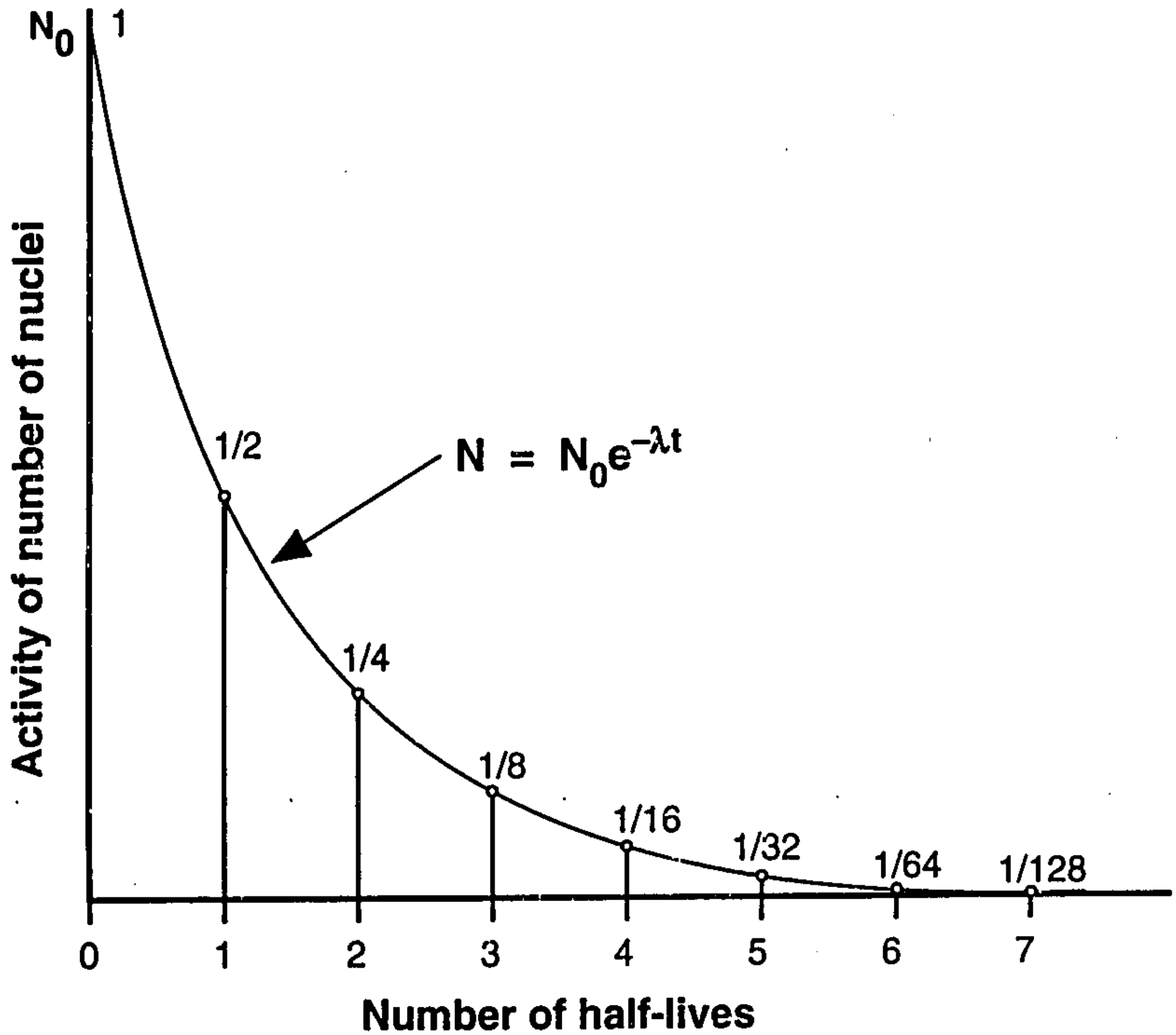


Fig. 1.3

Binding Energy Per Nucleon

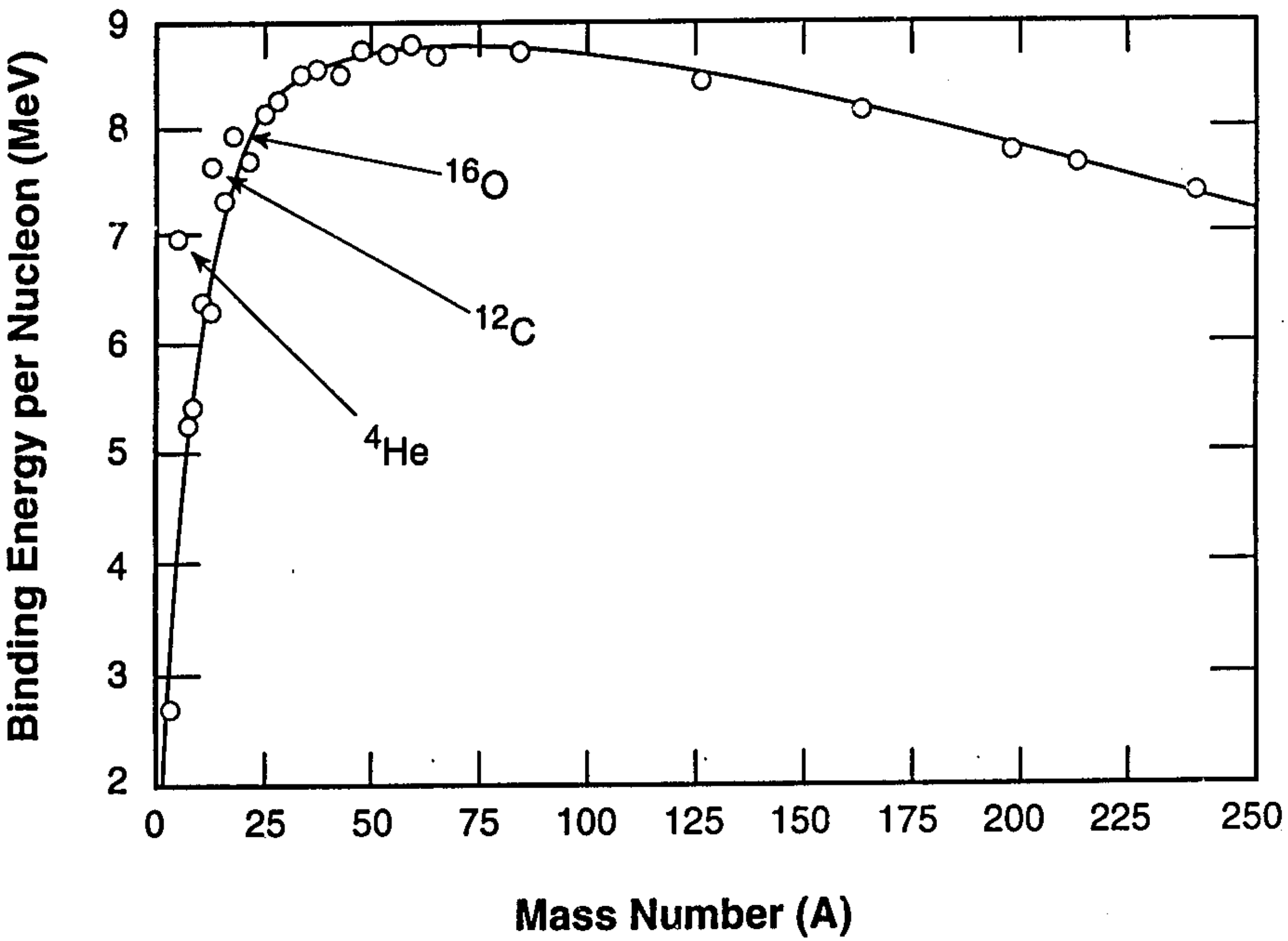
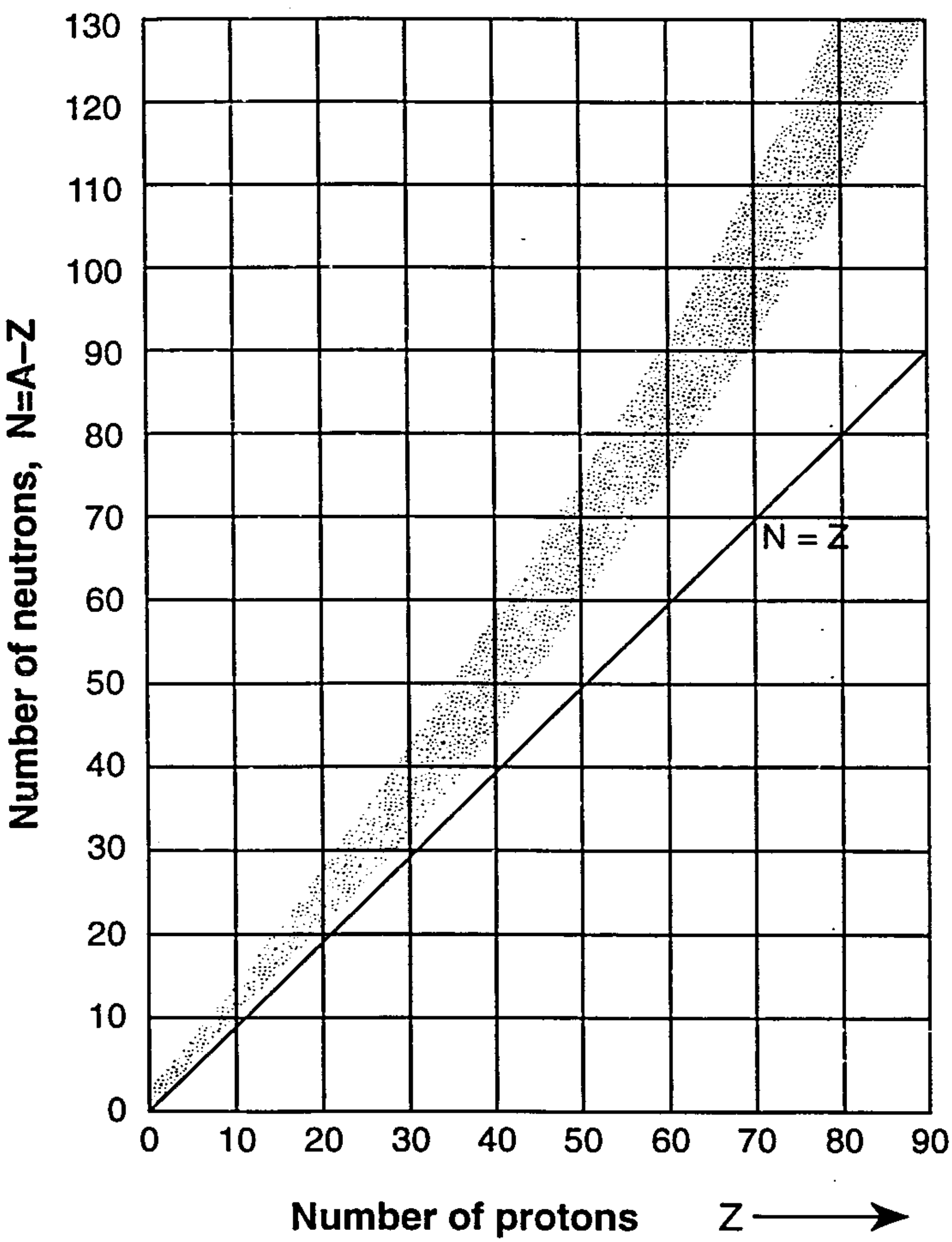
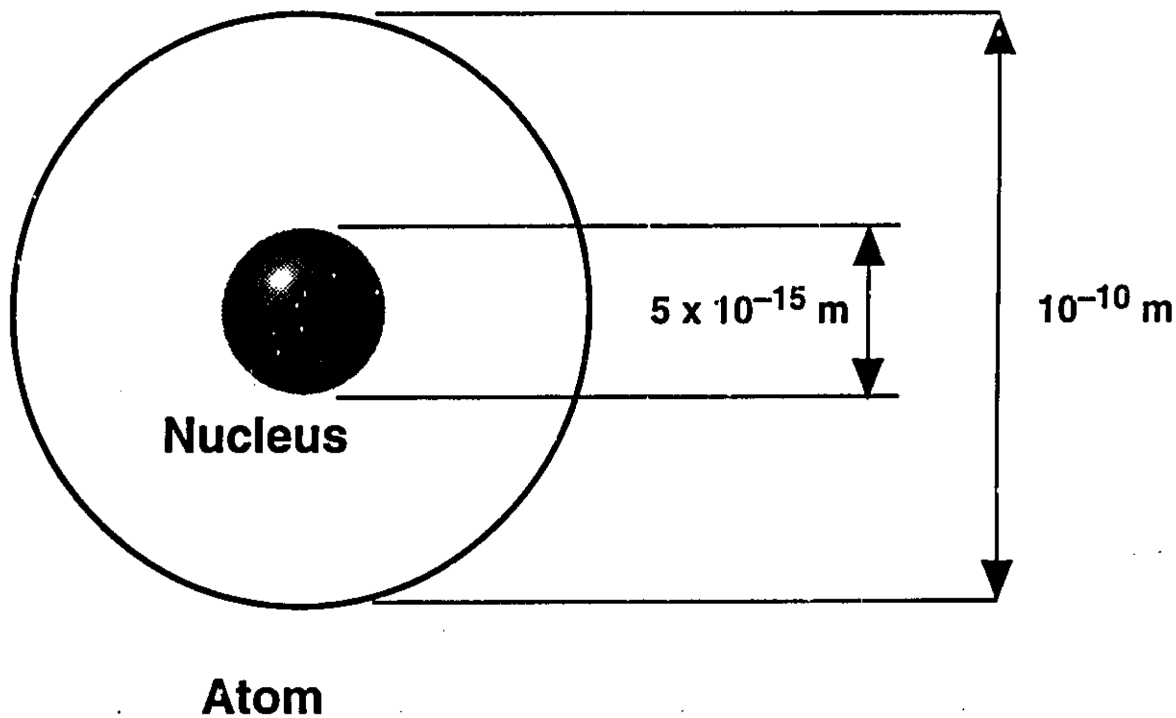


Fig. 1.4

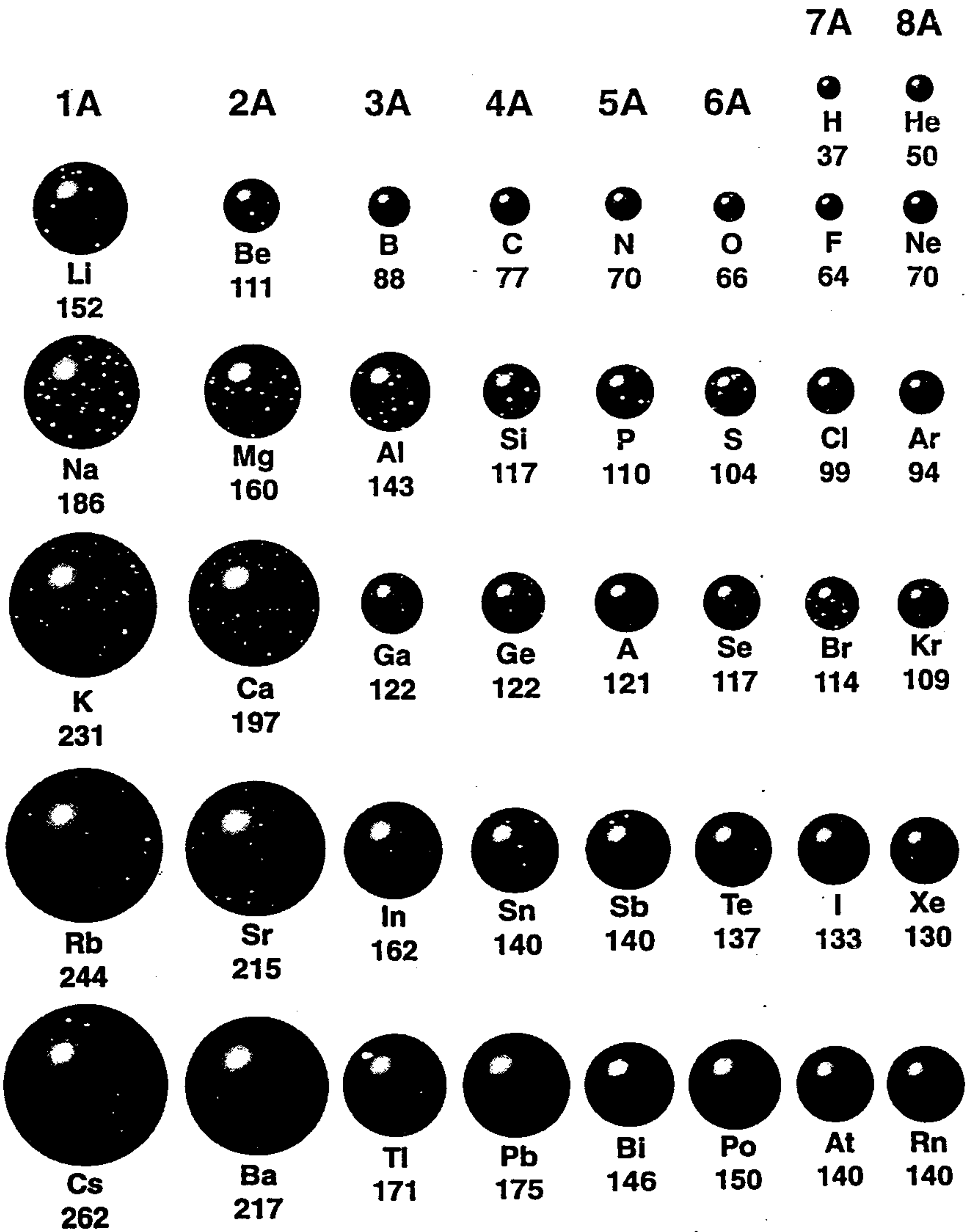
N/Z Ratios for the Stable Nuclides



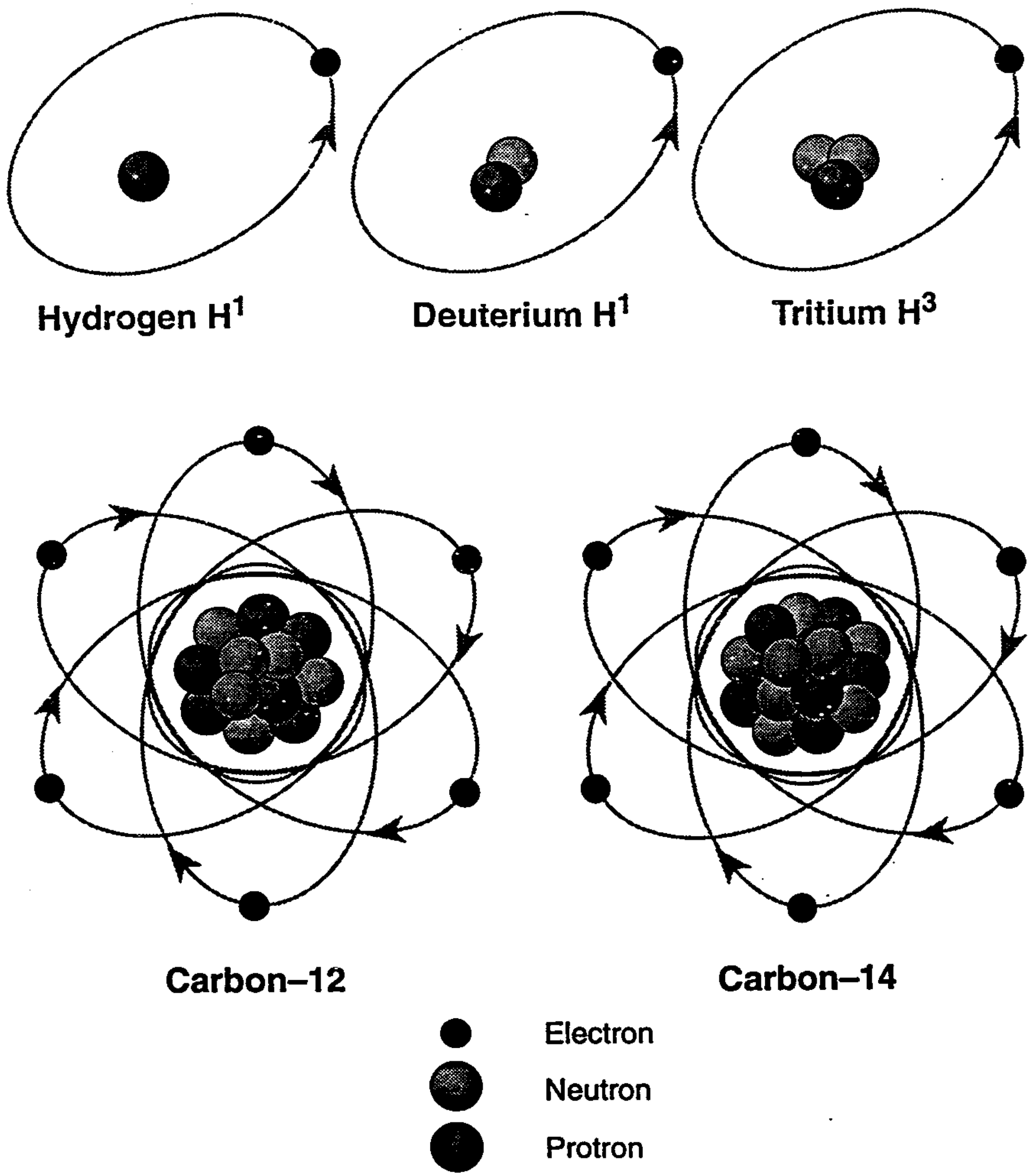
Atom and Nucleus



Atomic Radii (x 10^{-12}m)



Atomic Structures



Size of Nucleus

$\vartheta = (1.25 \times 10^{-15})(A^{1/3})\,m$

For He $\vartheta = (1.25 \times 10^{-15})(4)^{1/3}$

$= 1.25 \times 10^{-15} \times 1.587$

$= 1.98 \times 10^{-15}$

$= 0.00198 \times 10^{-12}\,m$

$d = 0.0040 \times 10^{-12}\,m$

For U $\vartheta = (1.25 \times 10^{-15})(235)^{1/3}$

$= 1.25 \times 10^{-15} \times 6.170$

$= 7.7 \times 10^{-15}$

$= 0.0077 \times 10^{-12}\,m$

$d = 0.0154 \times 10^{-12}\,m$

For H $\vartheta = (1.25 \times 10^{-15})(1)^{1/3}$

$= 1.25 \times 10^{-15}$

$= 0.00125 \times 10^{-12}\,m$

$d = 0.0125 \times 10^{-12}\,m$

Atomic Notation

Atomic Number	Z
Atomic Mass Number	A
Neutron Number	N

$$A = N + Z$$

Chemical Symbol	X
Isotope	$^{A}X_{Z}$
Hydrogen	$^{1}H_{1}$
Deuterium	$^{2}H_{1}$
Tritium	$^{3}H_{1}$
Proton	$^{1}P_{1}$
Neutron	$^{1}n_{0}$

Masses and Charges of the Atomic Constituents

Particle	Mass (kg)	Charge (coulumbs)
Proton	1.67265×10^{-27}	1.602×10^{-19} (psitive)
Neutron	1.67495×10^{-27}	0
Electron	9.10953×10^{-31}	1.602×10^{-19} (negative)

Atomic Mass Scale

* Atomic mass is based on Carbon-12 **Atom**

* Atomic mass of Carbon-12 **Atom** is exactly 12

* Atomic masses of other elements are given relative to Carbon-12

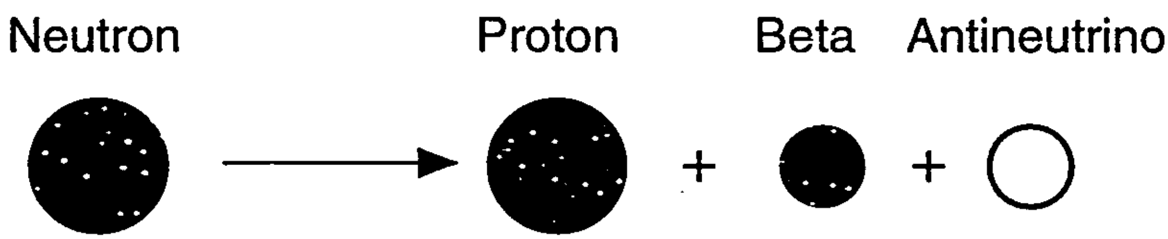
* Atomic Mass ($^{A}X_{Z}$) = 12 [Mass ($^{A}X_{Z}$)/Mass (^{12}C)]

* Atomic Masses are given in the chart of nuclides. Note that the atomic mass includes the mass of the electrons

* When determining the mass of the nucleus only, the mass of the electrons must be subtracted (or cancelled)

Neutron Decay

- Mass of Neutron = 1.67495×10^{-27}kg
- Mass of Protron = 1.67265×10^{-27} kg
- Mass of Electron = 0.00091×10^{-27} kg
- Proton + Electron = 1.67356×10^{-27} kg

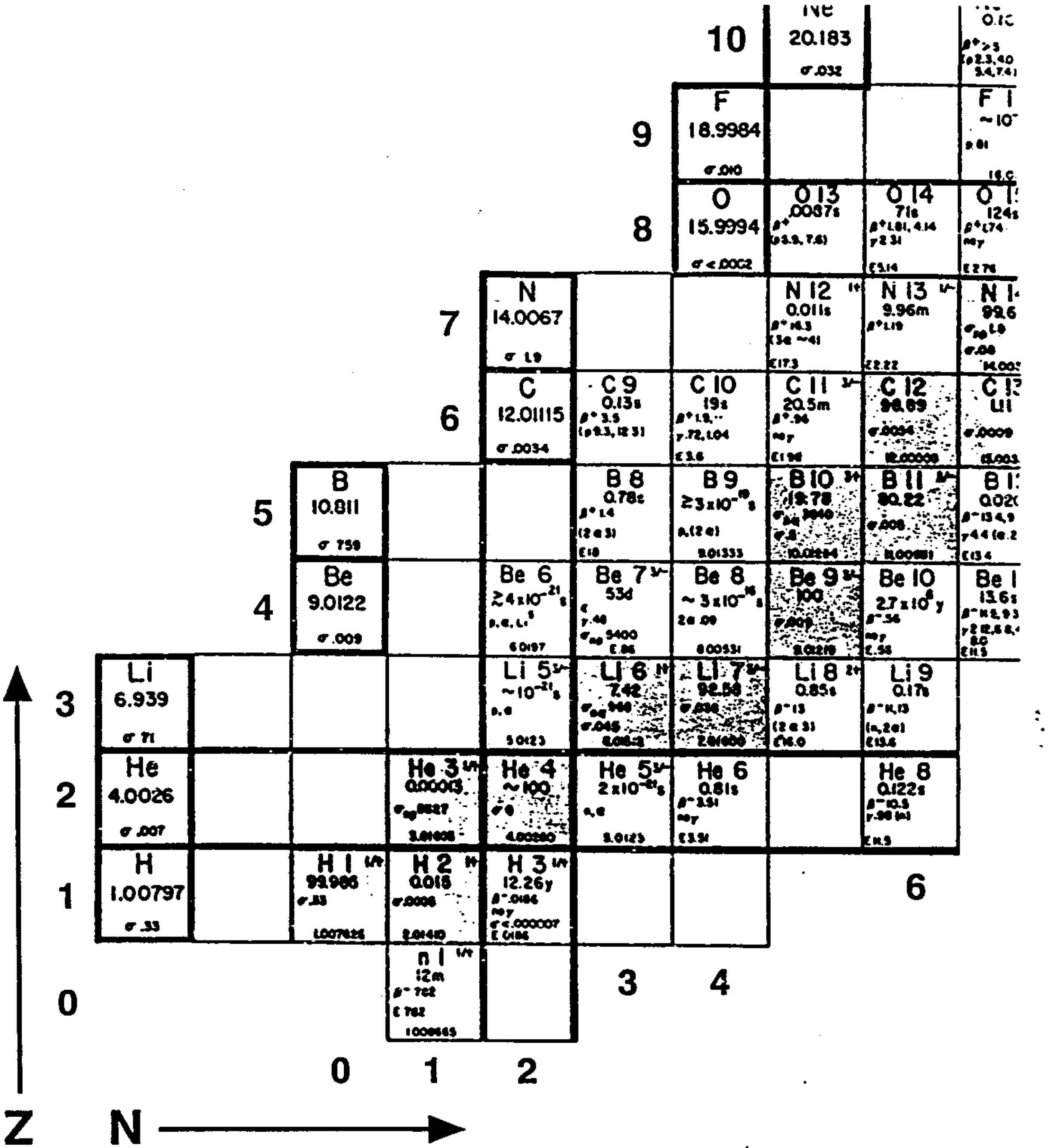


$$^{1}n_{0} \longrightarrow {}^{1}P_{1} + {}^{0}\beta_{-1} + {}^{0}\overline{V}_{0}$$

- Neutron Half-Life is 12 minutes

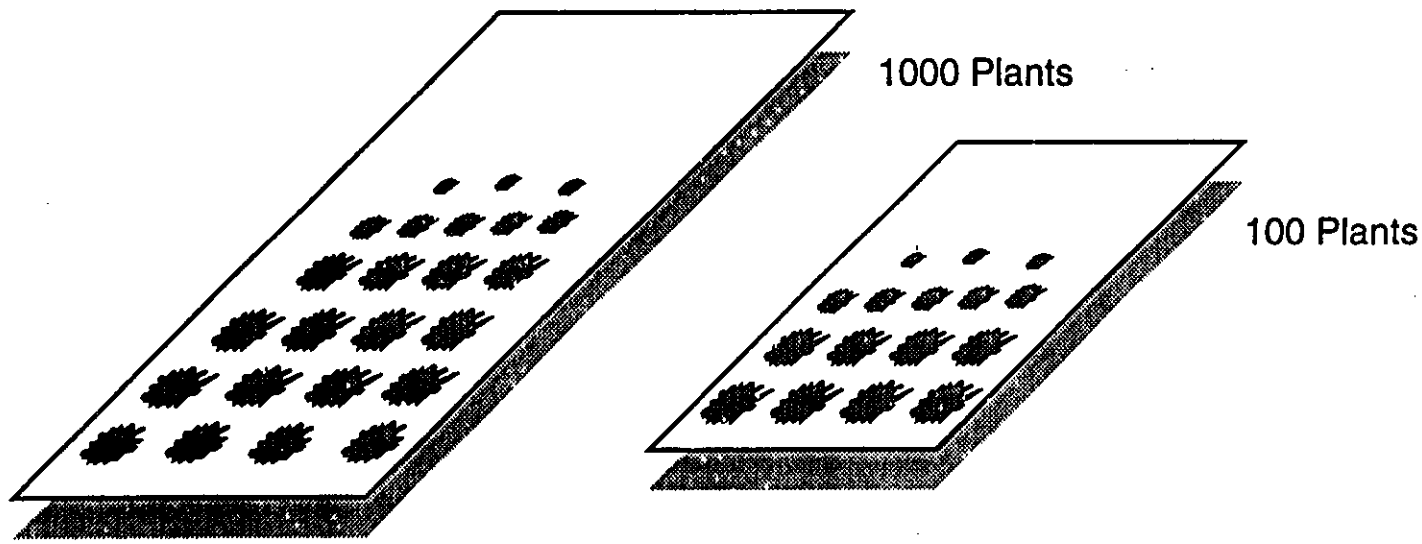
- What is the difference between an Electron and a Beta article?

Nuclide Chart



Events Proportional to Number

Flowers opening (daily)



Death rate (yearly)

Death rate in Canada with 25 000 000 people? =

Death rate in St. John with 100 000 people? =

Exponential Representation

General Notation

$10^2 = 100$		$Log_{10}100 = 2$	
$10^1 = 10$		$Log_{10}10 = 1$	
$e^x = y$		$Ln_e y = x$	
$e^1 = e$		$Ln_e e = 1$	
$e^{-\lambda\tau} = y$		$Ln_e y = -\lambda\tau$	
$e^{-\lambda\tau} = N_t/N_o$		$Ln_e N_t/N_o = -\lambda\tau$	

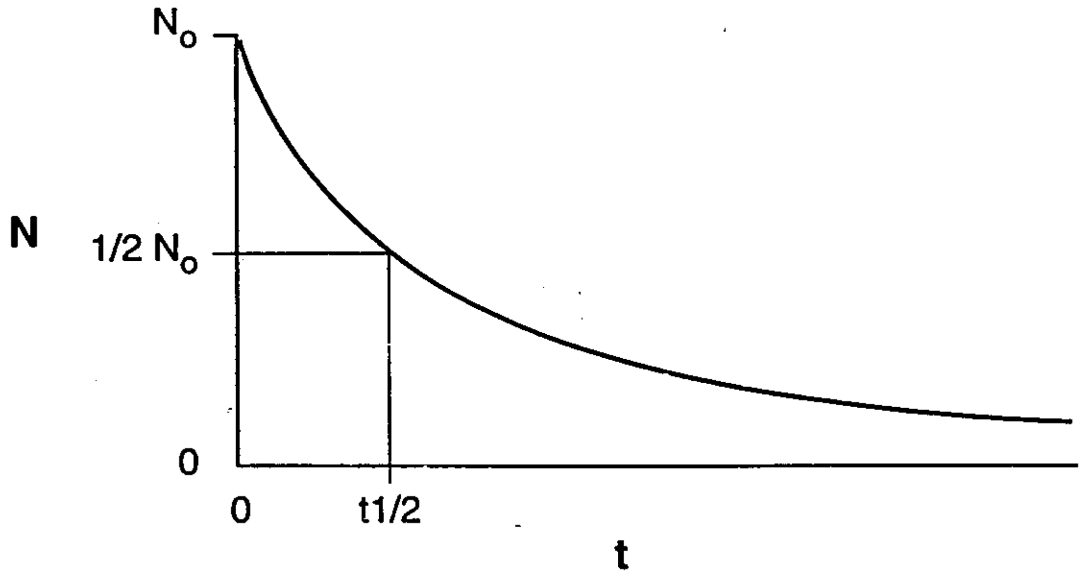
Solution For Decay Constant Equation

$$LnN_t/N_o = -\lambda\tau$$

$$N_t/N_o = e^{-\lambda\tau}$$

$$N_t = M_0 e^{-\lambda\tau}$$

Half Life



Half life is time for number to decay to half of the initial value

$$N_t = N_o e^{-\lambda t_{1/2}}$$

$$N_{t_{1/2}} = N_o e^{-\lambda t_{1/2}}$$

But... $$N_{t_{1/2}} = 1/2\ N_o$$

$$1/2\ N_o = N_o e^{-\lambda t_{1/2}}$$

$$2 = e^{-\lambda t_{1/2}}$$

$$Ln_e 2 = \lambda t_{1/2}\ \ Ln_e e$$

$$0.693 = \lambda t_{1/2}$$

$$t_{1/2} = \frac{0.693}{\lambda}$$

Mass-Energy Equivalence

- Mass of 12C Atom ≡ 12 Atomic Mass Units
  $1\upsilon = 1.660566 \times 10^{-27}$ kg

- Mass of Proton = $1.0072765\ \upsilon$
- Mass of Neutron = $1.0086650\ \upsilon$
- Mass of Electron = $0.0005486\ \upsilon$

$$E = mc^2$$

units (J) = (kg m²/5² = Nm = J)

Energy Per Atomic Mass Unit

$$E = 1.660566 \times 10^{-27} \times (2.998 \times 10^{8})^2$$

$$E = 14.925 \times 10^{-11}\ J$$

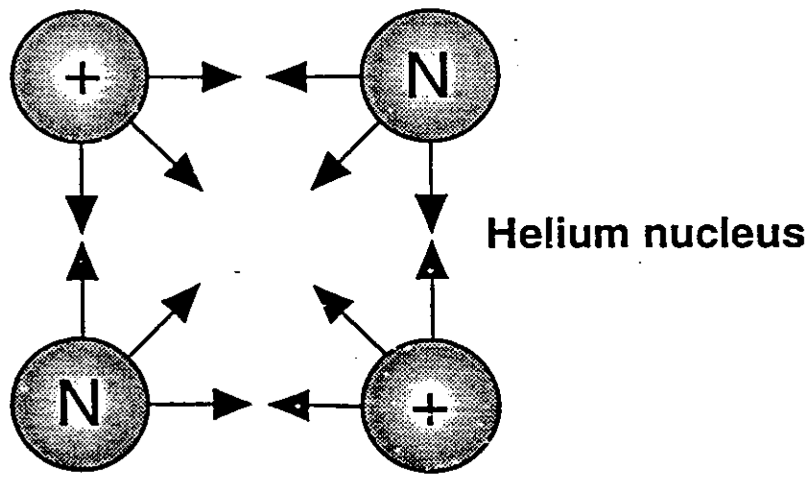
but, $1\ eV = 1.6022 \times 10^{-19}$ J

$$\therefore 1 MeV = 1.6022 \times 10^{-13}\ J$$

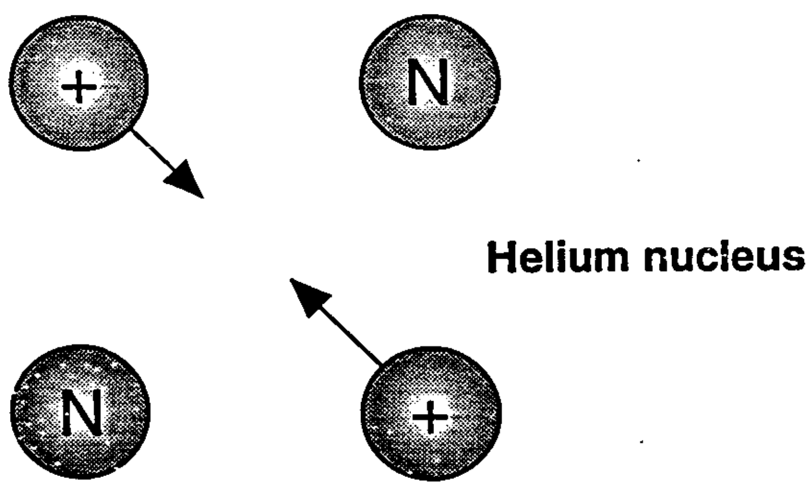
Thus $E = 14.925 \times 10^{-11} / 1.6022 \times 10^{-13}$ MeV

$$E = 931.5\ MeV$$

Force Characteristics

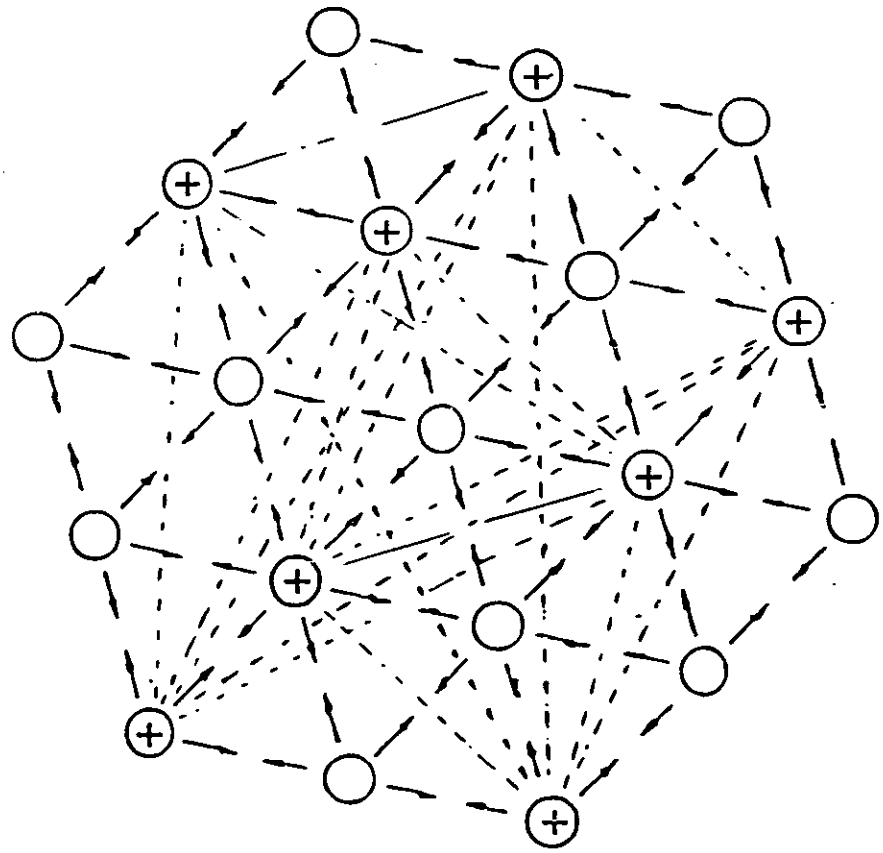


Nuclear forces



Electrostatic forces

Nuclear and Electrostatic Forces



(Visual Model)

Mass Defect and Binding Energy

* Mass of nucleus < sum of masses of nucleons

* Mass Defect = Mass of Nucleons – Mass of Nucleus

$$Dm = (Zm_p + Nm_N - {}^{A}M_Z)$$

* Binding Energy ≡ Mass Defect

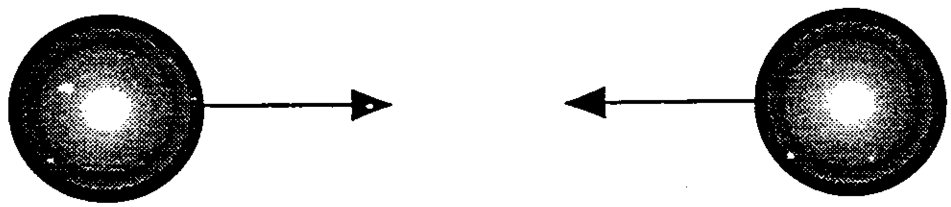
$$E = mc^2$$

* B.E. (Joules) = $(Zm_p + Nm_n - {}^{A}M_Z) \times c^2$
(with masses in kg)

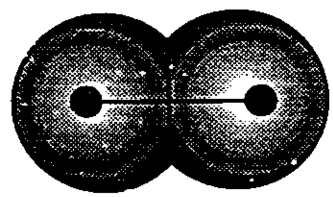
* If masses in μ, B.E. in MeV is
B.E. (MeV) = $(Zm_p + Nm_N - {}^{A}M_Z) \times 931.5$

* B.E./Nucleon = B.E. Nucleus/A

Binding Energy

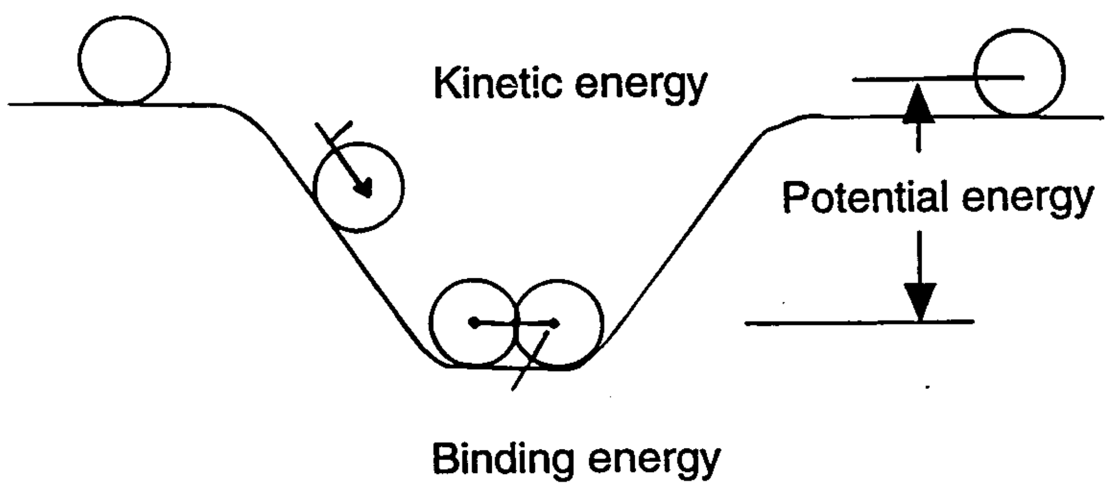


Force of attraction between nucleons

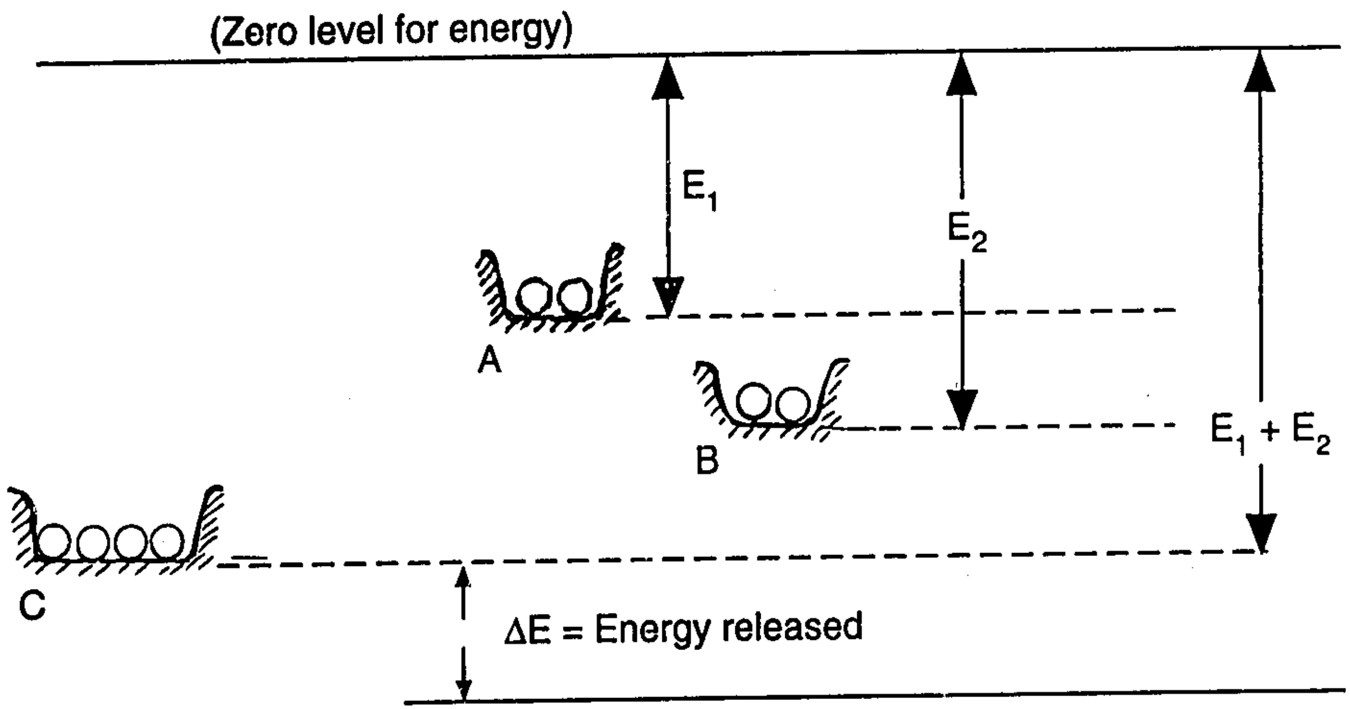


Work done by force = Binding energy (MeV)

Analogy with potential and kinetic energy



Energy Release in Fission

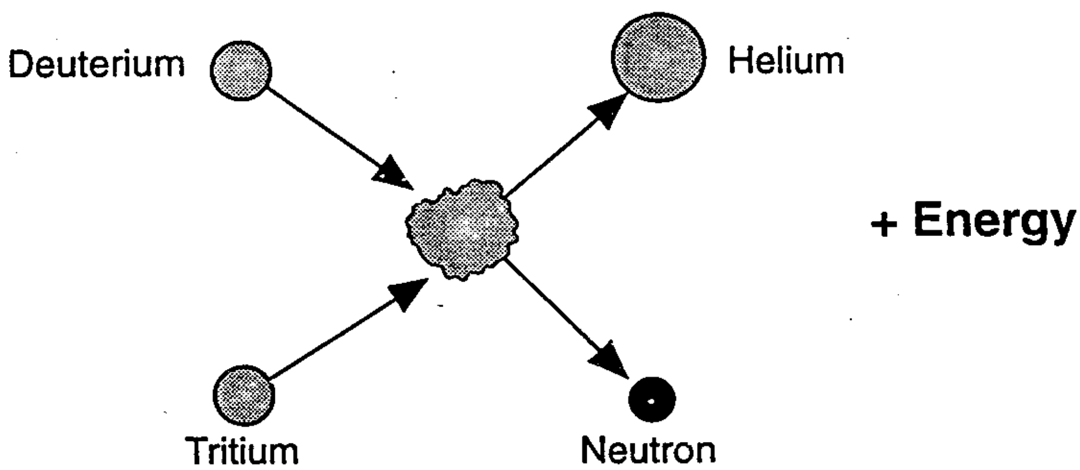


Very heavy nucleus (C) has lower binding energy per nucleon than middle-mass nuclei (A,B) when a very heavy nucleus fissions to become two middle-mass nuclei, the surplus energy ΔE is released

Fusion and Fission

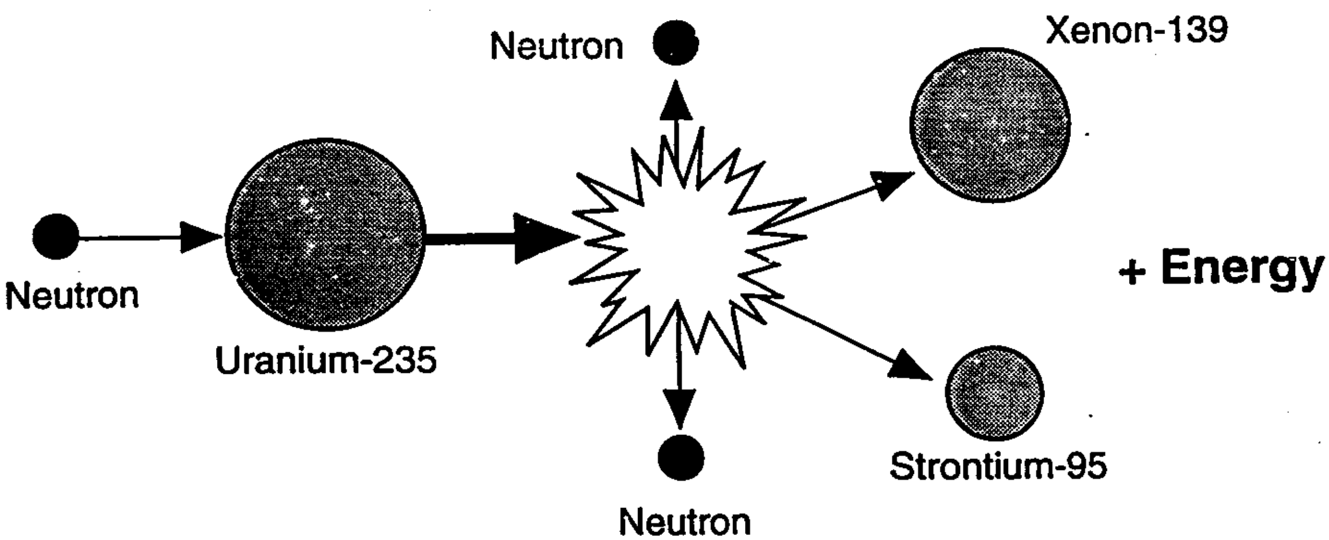
Fusion

$$^{2}H_{1} + ^{3}H_{1} \longrightarrow ^{4}He_{2} + ^{1}n_{0}$$



Fission

$$^{235}U_{92} + ^{1}n_{0} \longrightarrow ^{139}Xe_{54} + ^{95}St_{38} + ^{1}n_{0} + ^{1}n_{0}$$

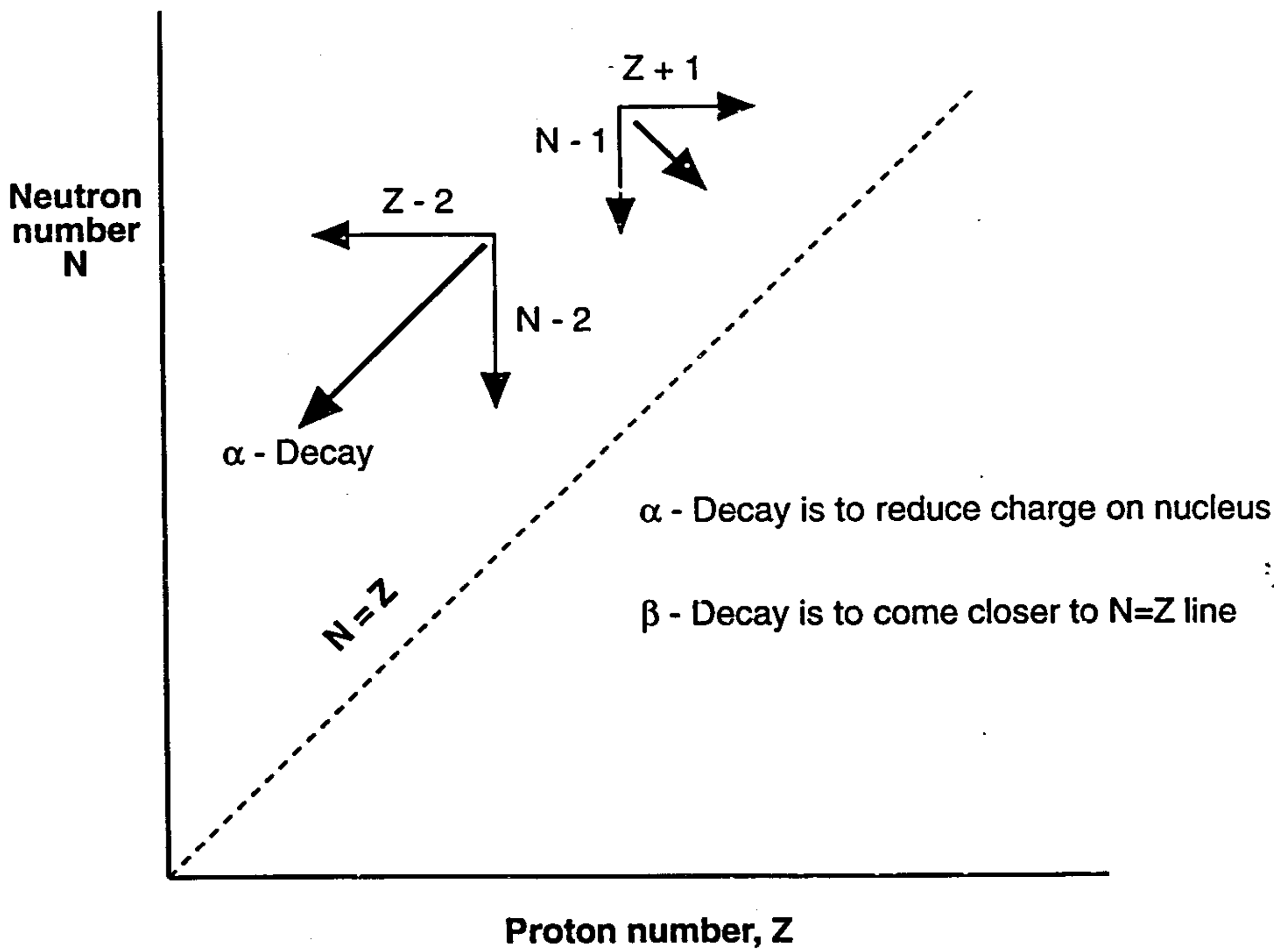


Alpha and Beta Decay

Alpha decay: $^{A}X_{Z} \longrightarrow {}^{A-4}Y_{Z-2}\ (N-2) + {}^{4}\alpha_{2}$

Beta decay: $^{A}X_{Z} \longrightarrow {}^{A}Y_{Z+1}\ (N-1) + {}^{0}e_{-1}$

(Neutron ⟶ Proton + Electron)



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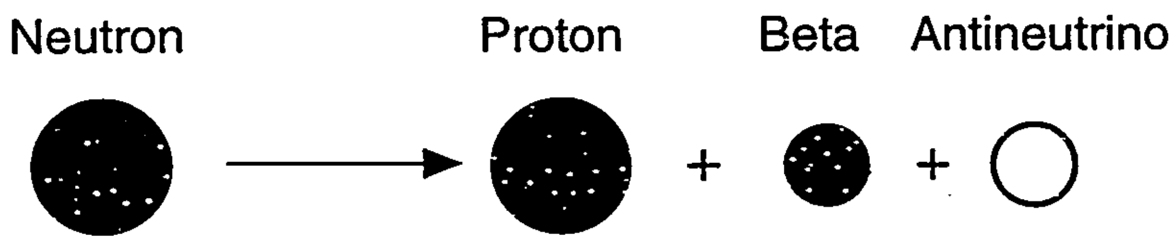

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