

Beta Decay Followed by Gamma Ray Emission

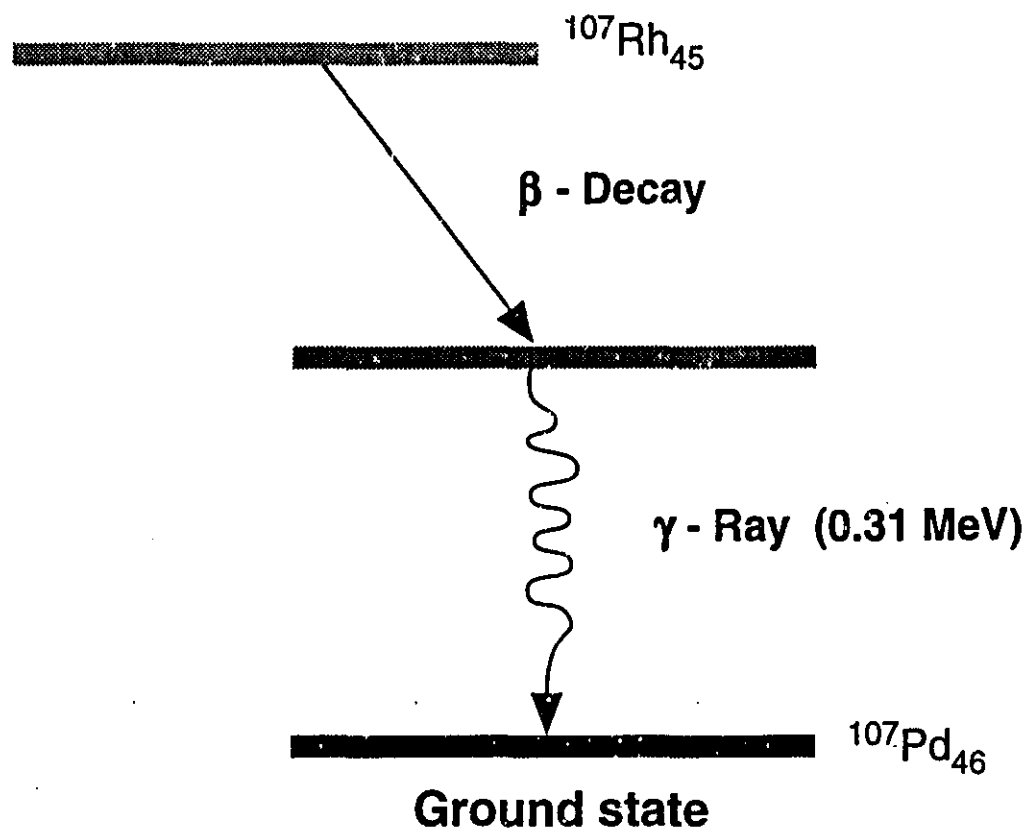
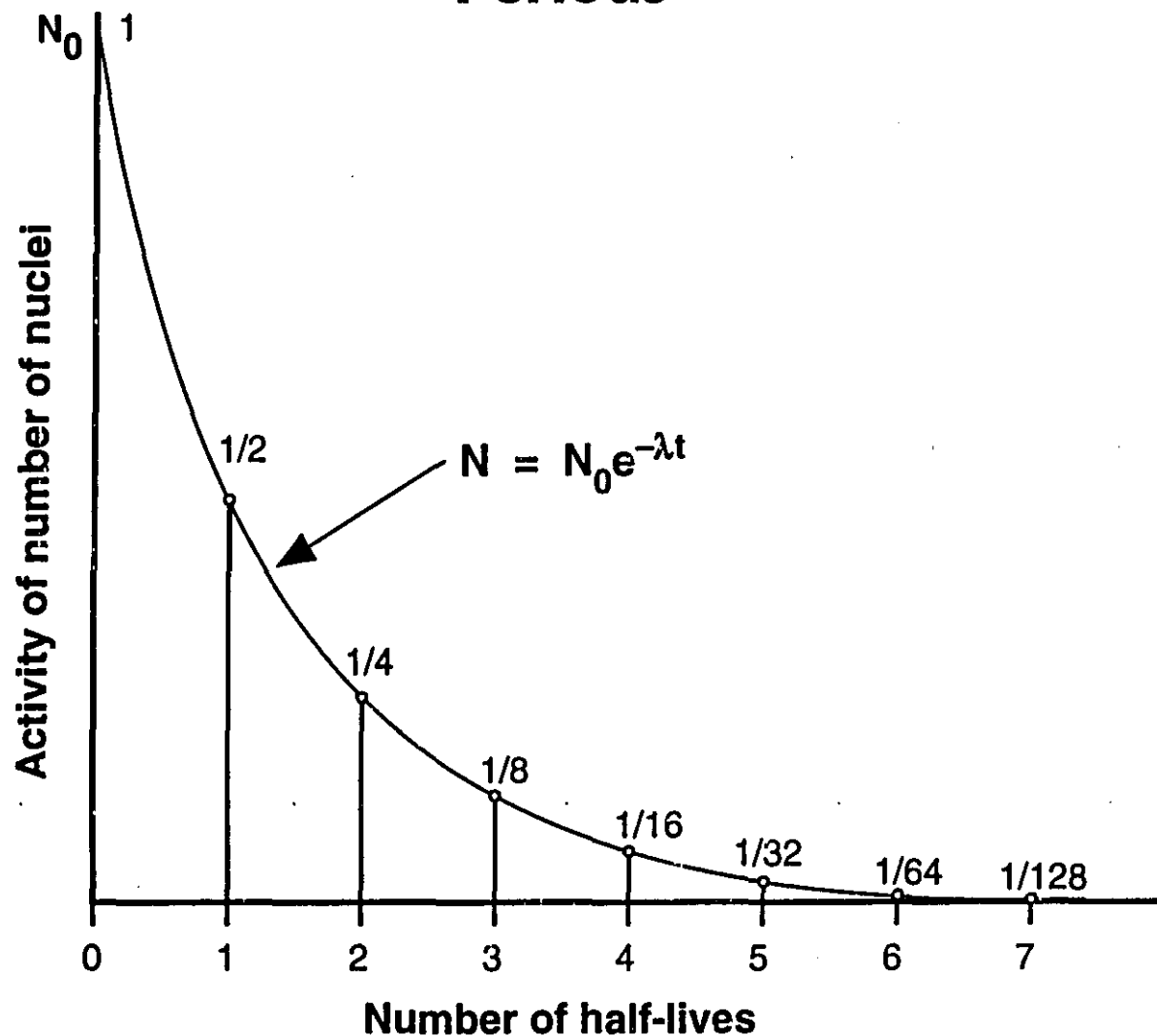


Fig. 1.2

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



Binding Energy Per Nucleon

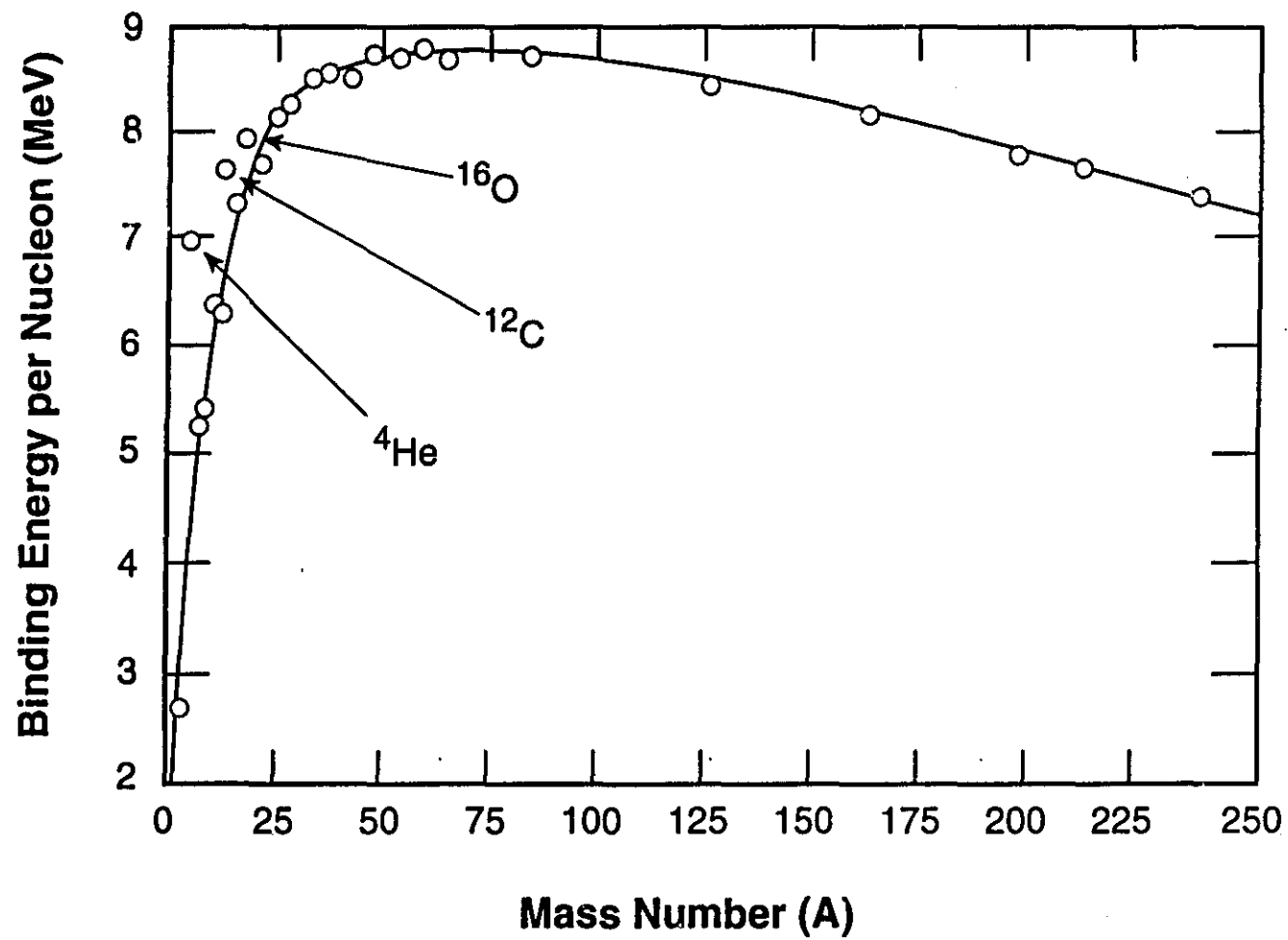
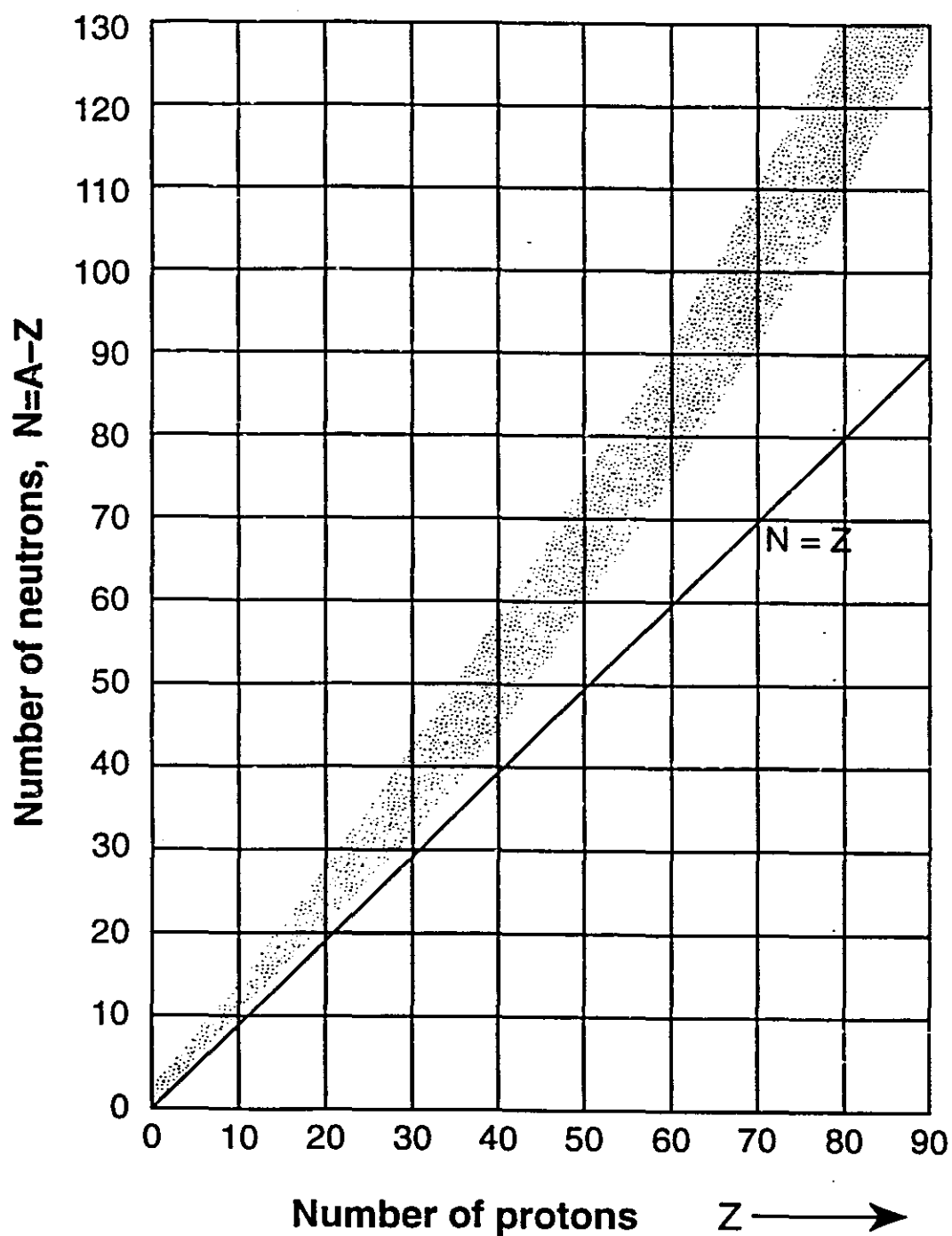
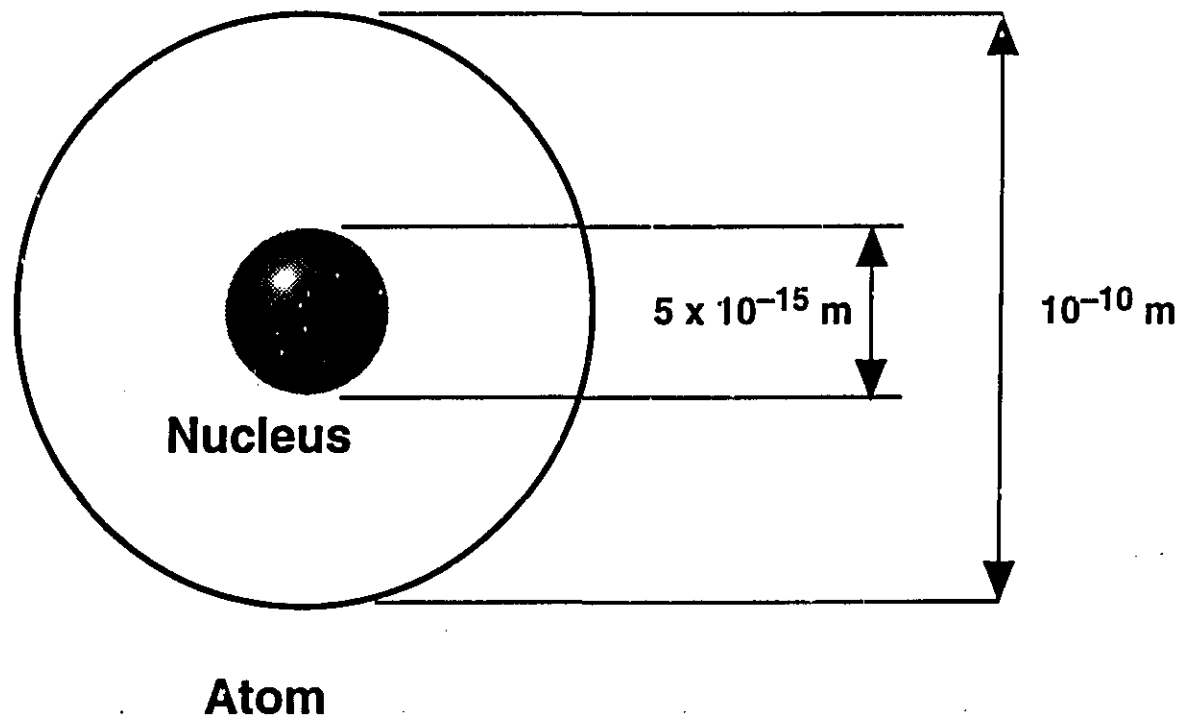


Fig. 1.4

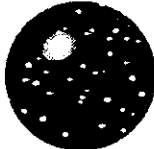
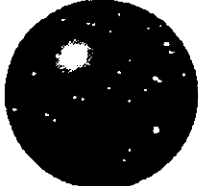
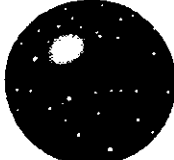
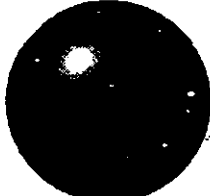
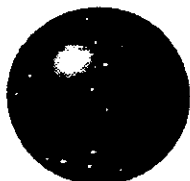
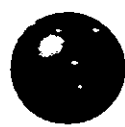
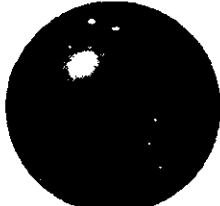
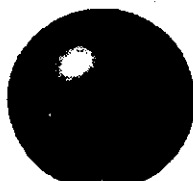
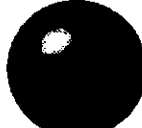
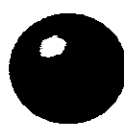
N/Z Ratios for the Stable Nuclides



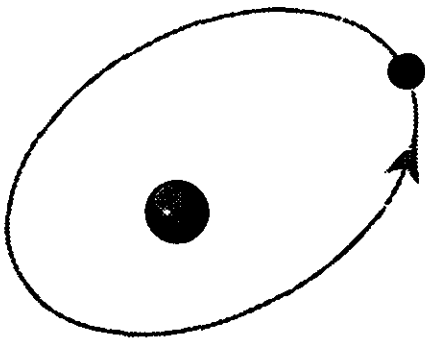
Atom and Nucleus



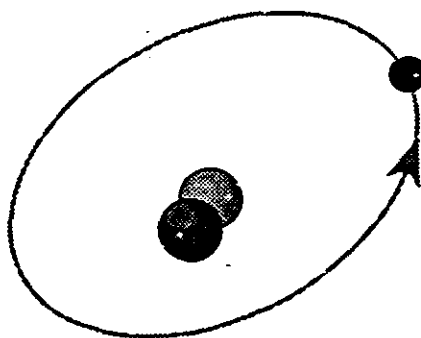
Atomic Radii ($\times 10^{-12}\text{m}$)

1A	2A	3A	4A	5A	6A	7A	8A
							
Li 152	Be 111	B 88	C 77	N 70	O 66	F 64	Ne 70
							
Na 186	Mg 160	Al 143	Si 117	P 110	S 104	Cl 99	Ar 94
							
K 231	Ca 197	Ga 122	Ge 122	As 121	Se 117	Br 114	Kr 109
							
Rb 244	Sr 215	In 162	Sn 140	Sb 140	Te 137	I 133	Xe 130
							
Cs 262	Ba 217	Tl 171	Pb 175	Bi 146	Po 150	At 140	Rn 140

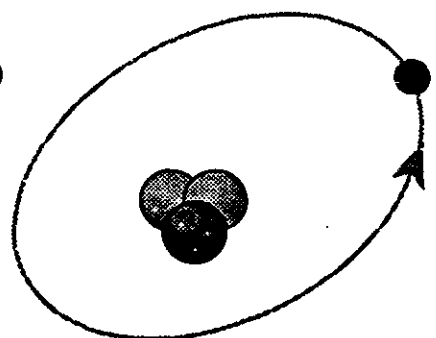
Atomic Structures



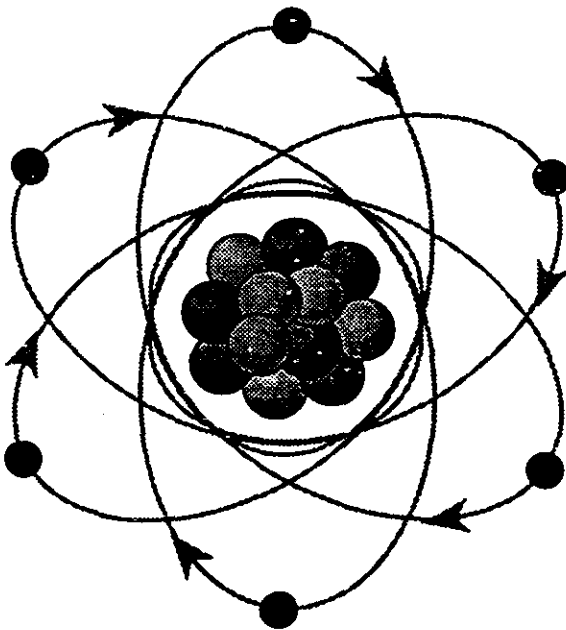
Hydrogen H¹



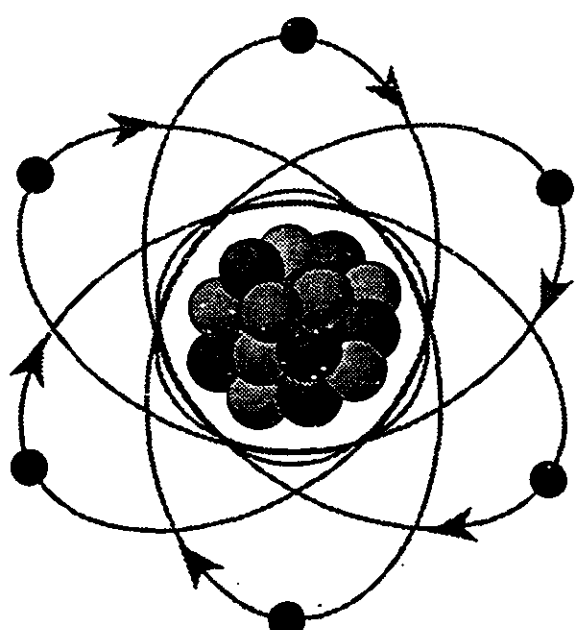
Deuterium H²



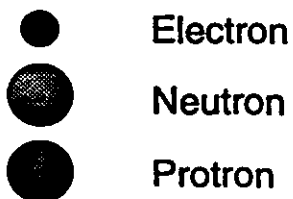
Tritium H³



Carbon-12



Carbon-14



Size of Nucleus

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

$$\begin{aligned} \text{For He } r &= (1.25 \times 10^{-15}) (4)^{1/3} \\ &= 1.25 \times 10^{-15} \times 1.587 \\ &= 1.98 \times 10^{-15} \\ &= 0.00198 \times 10^{-12} \text{m} \end{aligned}$$

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

$$\begin{aligned} \text{For U } r &= (1.25 \times 10^{-15}) (235)^{1/3} \\ &= 1.25 \times 10^{-15} \times 6.170 \\ &= 7.7 \times 10^{-15} \\ &= 0.0077 \times 10^{-12} \text{ m} \end{aligned}$$

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

$$\begin{aligned} \text{For H } r &= (1.25 \times 10^{-15}) (1)^{1/3} \\ &= 1.25 \times 10^{-15} \\ &= 0.00125 \times 10^{-12} \text{ m} \end{aligned}$$

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

Atomic Notation

Atomic Number Z

Atomic Mass Number A

Neutron Number N

$$A = N + Z$$

Chemical Symbol X

Isotope AX_Z

Hydrogen 1H_1

Deuterium 2H_1

Tritium 3H_1

Proton 1P_1

Neutron 1n_0

Masses and Charges of the Atomic Constituents

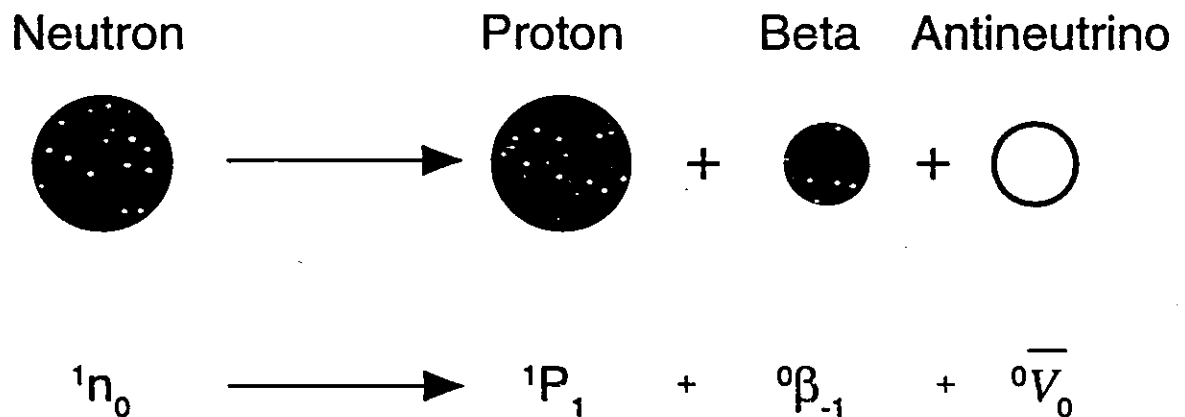
Particle	Mass (kg)	Charge (coulombs)
Proton	1.67265×10^{-27}	1.602×10^{-19} (positive)
Neutron	1.67495×10^{-27}	0
Electron	9.10953×10^{-31}	1.602×10^{-19} (negative)

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 (AX_z) = 12 [Mass (AX_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)

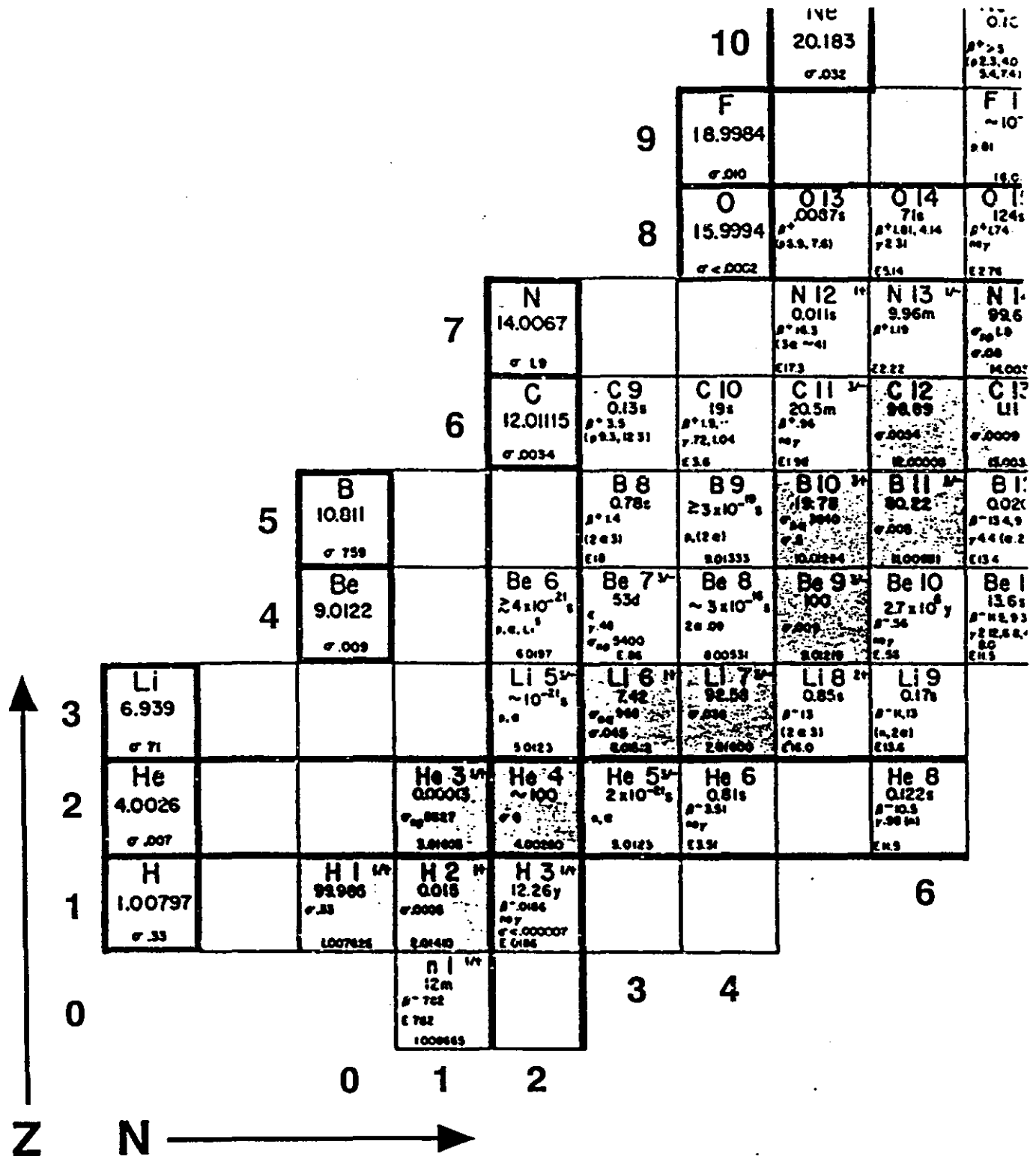
Neutron Decay

- Mass of Neutron = $1.67495 \times 10^{-27} \text{ kg}$
- Mass of Proton = $1.67265 \times 10^{-27} \text{ kg}$
- Mass of Electron = $0.00091 \times 10^{-27} \text{ kg}$
- Proton + Electron = $1.67356 \times 10^{-27} \text{ kg}$



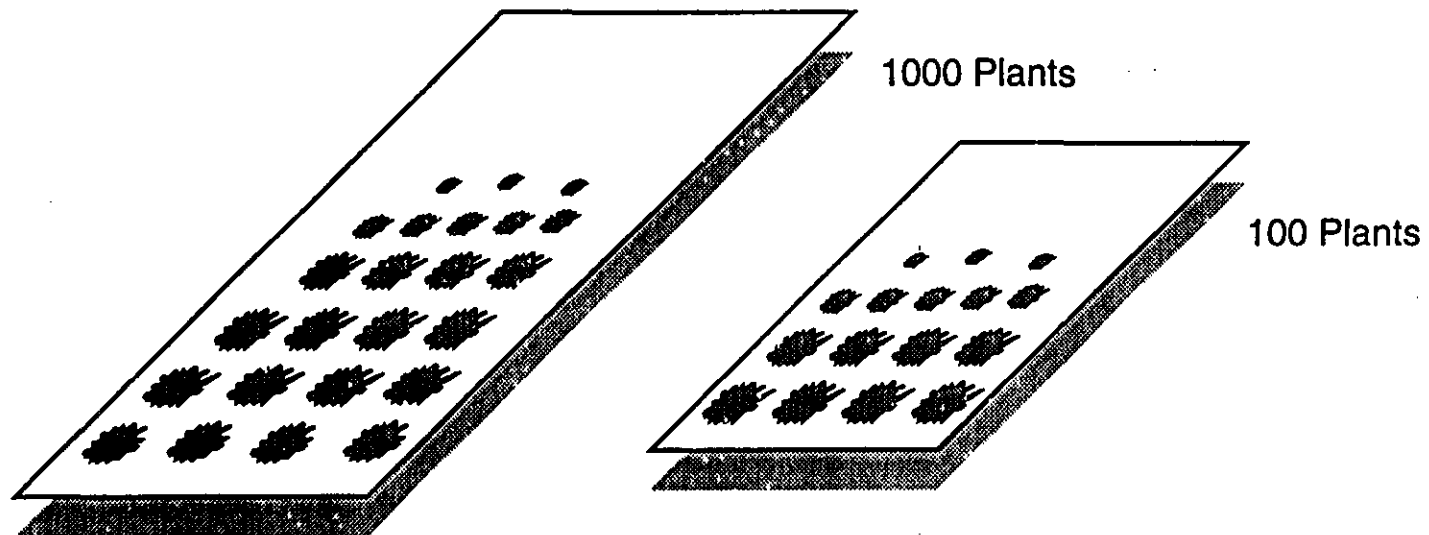
- Neutron Half-Life is 12 minutes
- What is the difference between an Electron and a Beta particle?

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

$$10^2 = 100$$

$$\text{Log}_{10} 100 = 2$$

$$10^1 = 10$$

$$\text{Log}_{10} 10 = 1$$

$$e^x = y$$

$$\text{Ln}_e y = x$$

$$e^1 = e$$

$$\text{Ln}_e e = 1$$

$$e^{-\lambda\tau} = y$$

$$\text{Ln}_e y = -\lambda\tau$$

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

$$\text{Ln}_e N_t/N_o = -\lambda\tau$$

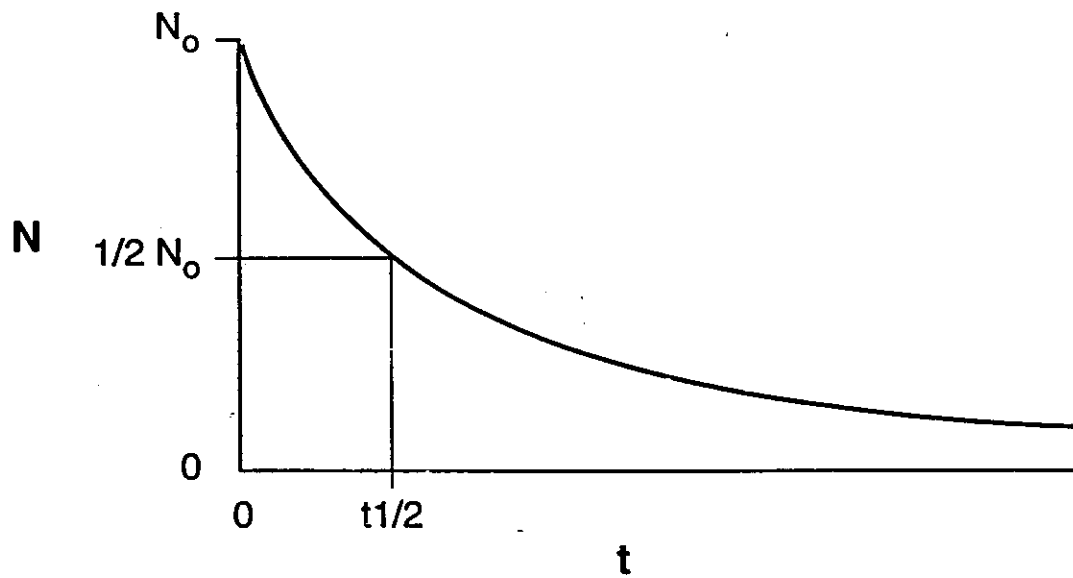
Solution For Decay Constant Equation

$$\text{Ln} N_t/N_o = -\lambda\tau$$

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

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

Half Life



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

$$N_t = N_0 e^{-\lambda t_{1/2}}$$

$$N_{t_{1/2}} = N_0 e^{-\lambda t_{1/2}}$$

But... $N_{t_{1/2}} = 1/2 N_0$

$$1/2 N_0 = N_0 e^{-\lambda t_{1/2}}$$

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

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

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

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

Mass-Energy Equivalence

- Mass of ^{12}C Atom $\equiv$ 12 Atomic Mass Units
 $1\text{u} = 1.660566 \times 10^{-27} \text{ kg}$
- Mass of Proton $= 1.0072765 \text{ u}$
- Mass of Neutron $= 1.0086650 \text{ u}$
- Mass of Electron $= 0.0005486 \text{ u}$

$$E = mc^2$$

$$\text{units (J)} = (\text{kg m}^2/\text{s}^2 = \text{Nm} = \text{J})$$

Energy Per Atomic Mass Unit

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

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

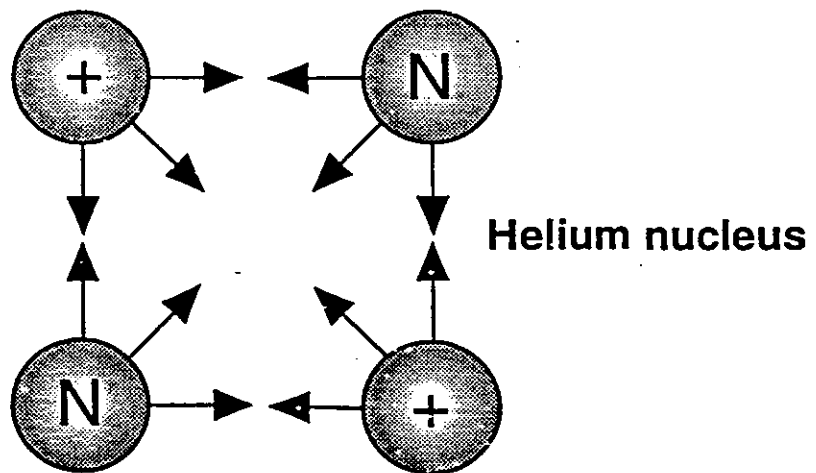
$$\text{but, } 1 \text{ eV} = 1.6022 \times 10^{-19} \text{ J}$$

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

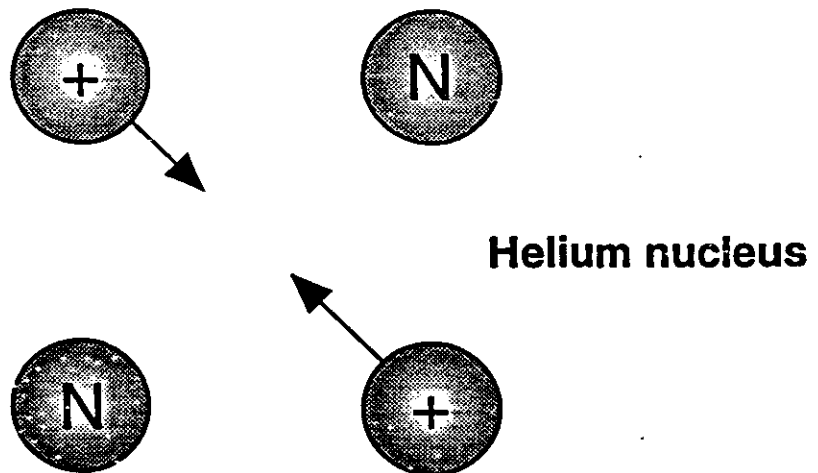
$$\text{Thus } E = 14.925 \times 10^{-11} / 1.6022 \times 10^{-13} \text{ MeV}$$

$$E = 931.5 \text{ MeV}$$

Force Characteristics

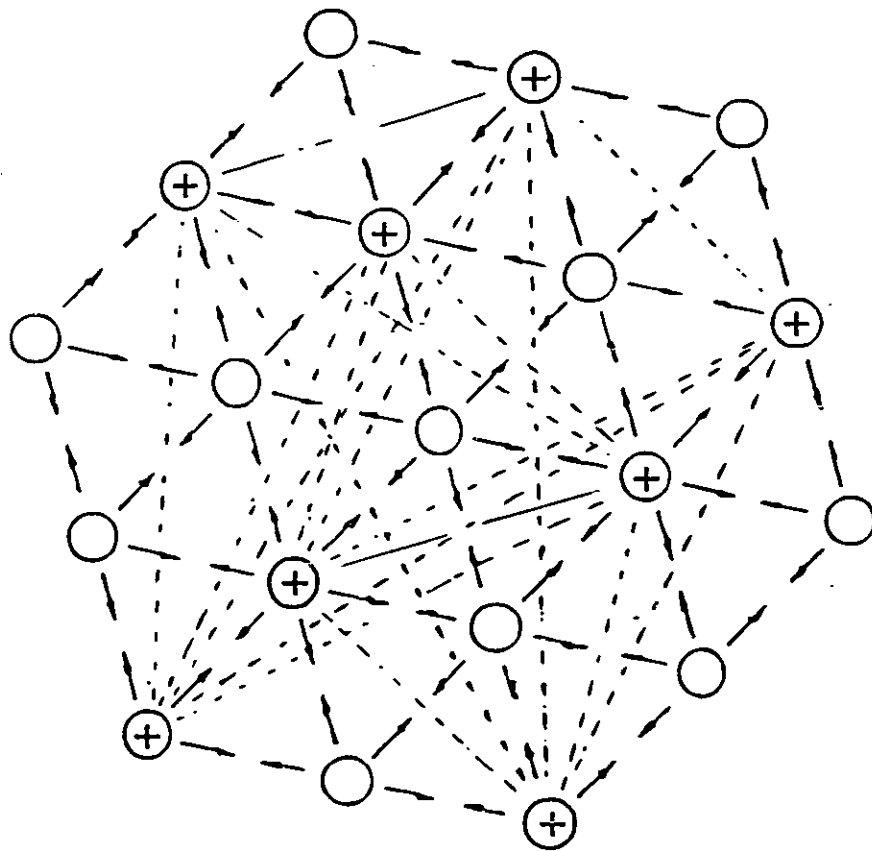


Nuclear forces



Electrostatic forces

Nuclear and Electrostatic Forces

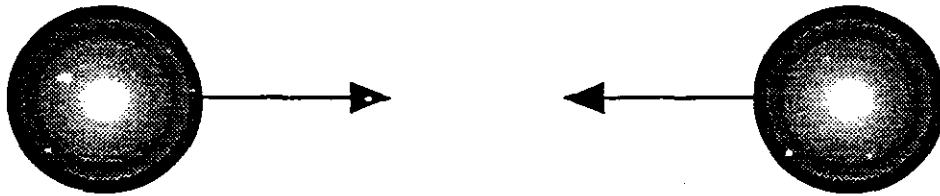


(Visual Model)

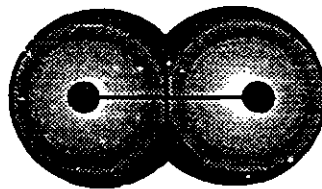
Mass Defect and Binding Energy

- * Mass of nucleus < sum of masses of nucleons
- * Mass Defect = Mass of Nucleons – Mass of Nucleus
$$\Delta m = (Zm_p + Nm_n - {}^A M_Z)$$
- * Binding Energy $\equiv$ 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
$$\text{B.E. (MeV)} = (Zm_p + Nm_n - {}^A M_Z) \times 931.5$$
- * B.E./Nucleon = B.E. Nucleus/A

Binding Energy

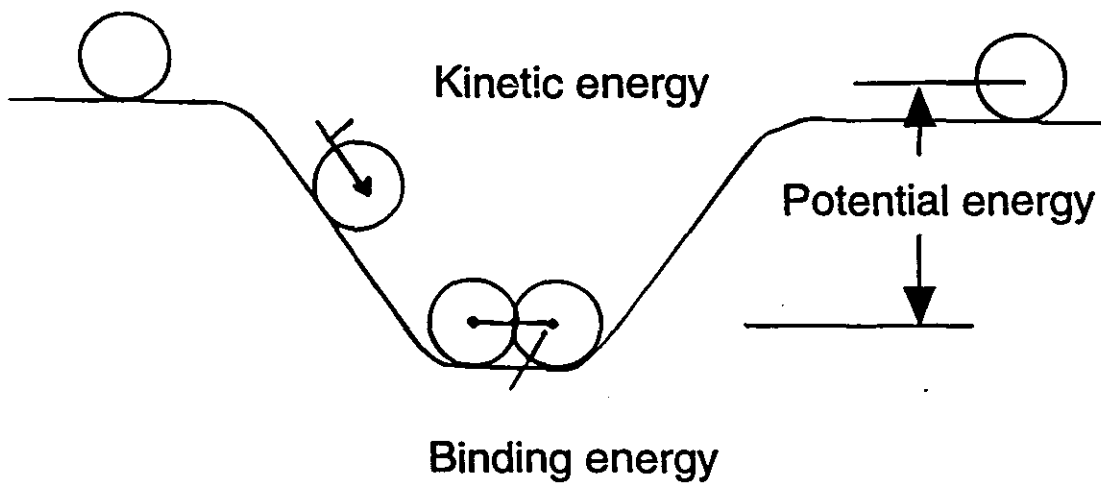


Force of attraction between nucleons

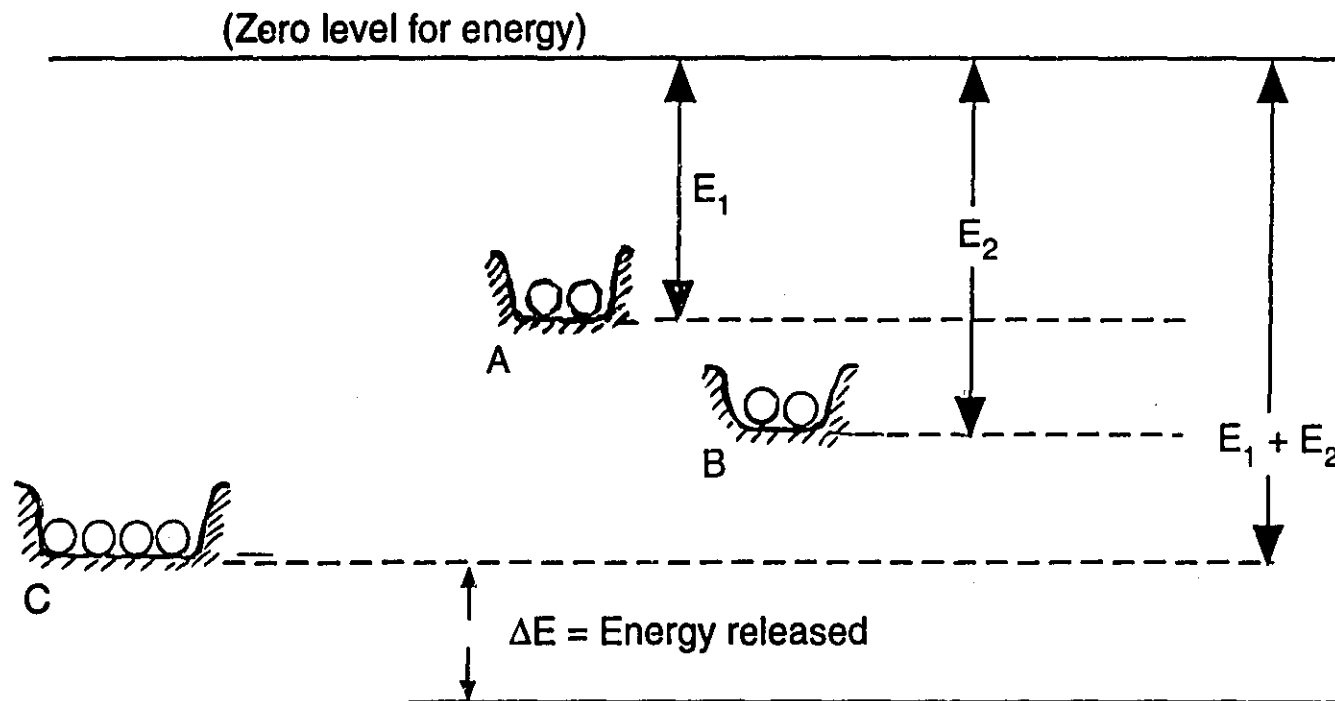


Work done by force = Binding energy (MeV)

Analogy with potential and kinetic energy



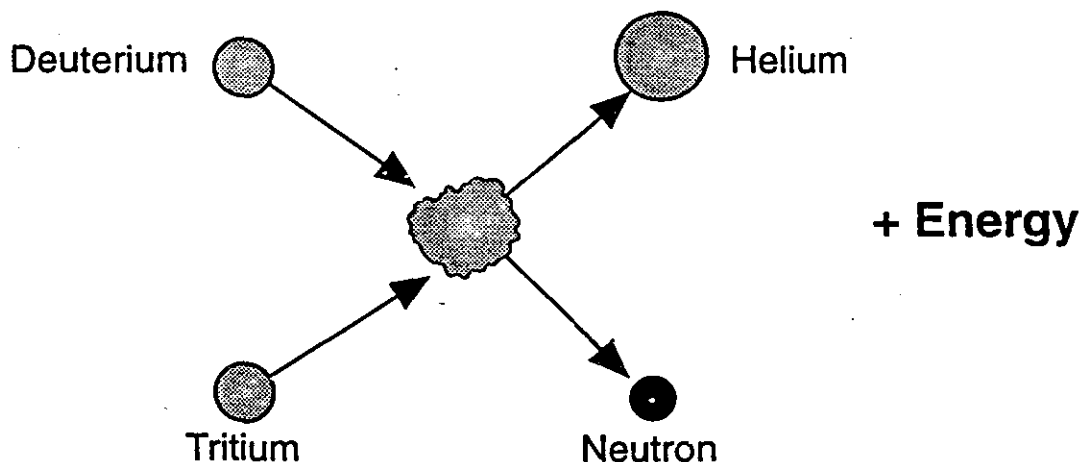
Energy Release in Fission



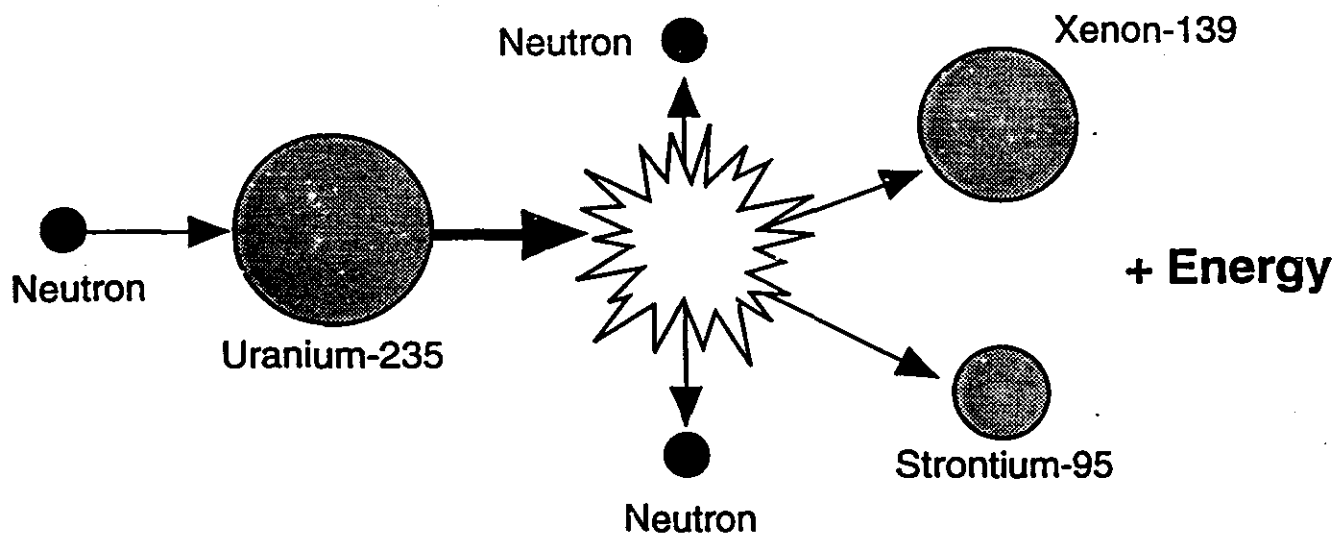
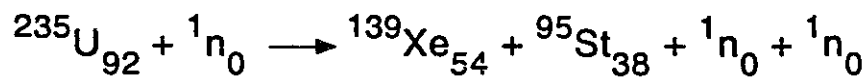
Very heavy nucleus (C) has lower binding energy per nucleon than middle-mass nuclei (A,B) when a very heavy nucleus fissions to become two middle-mass nuclei, the surplus energy ΔE is released

Fusion and Fission

Fusion



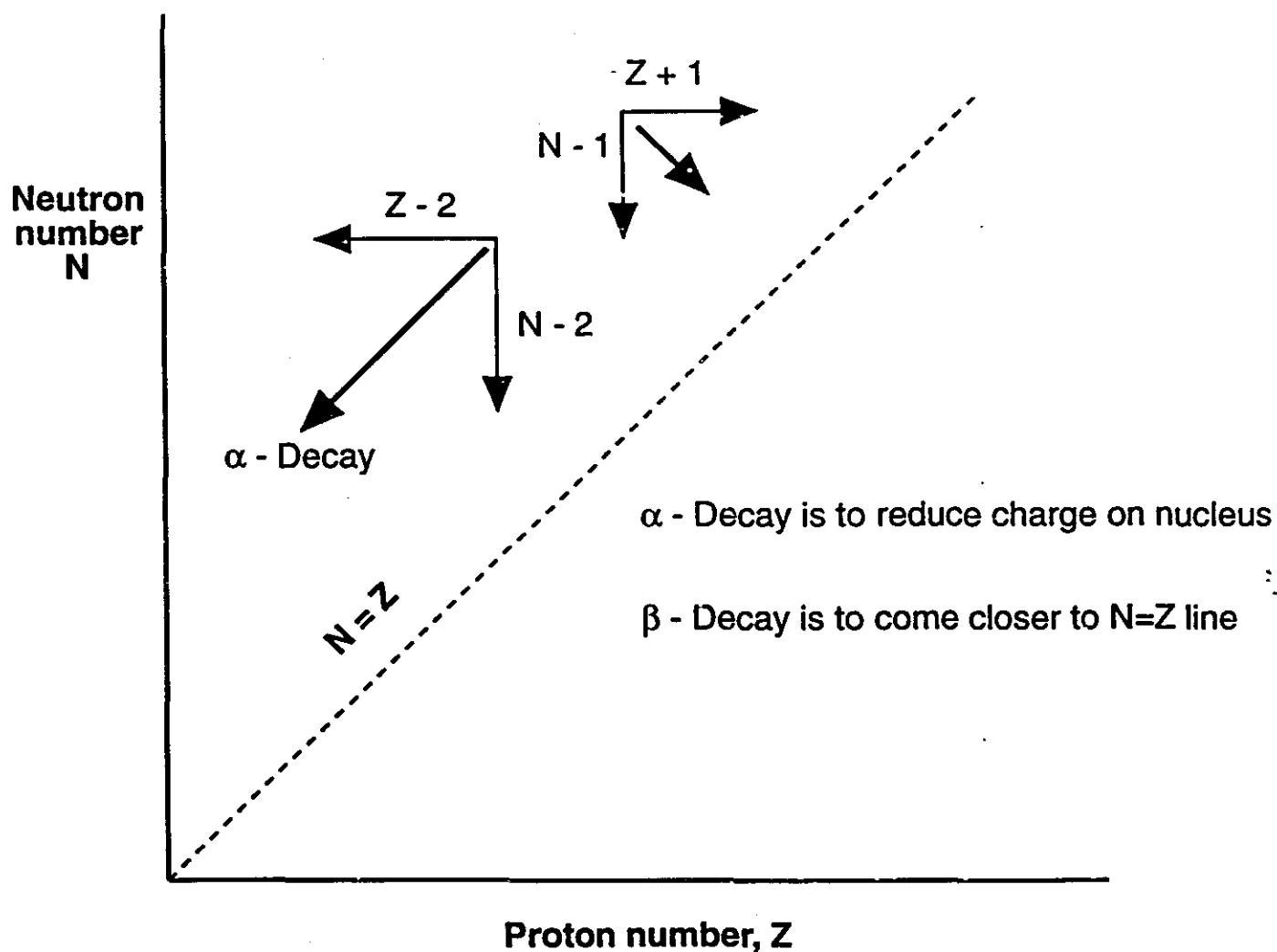
Fission



Alpha and Beta Decay

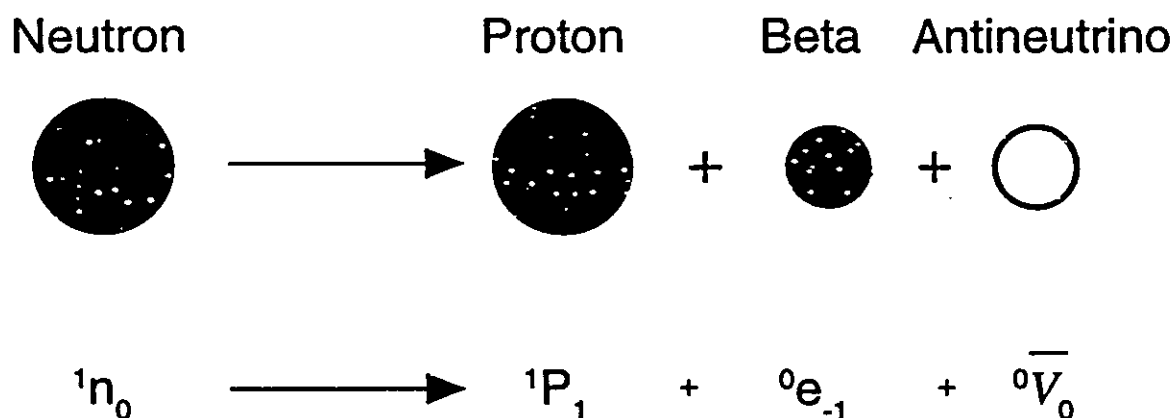


(Neutron $\longrightarrow$ Proton + Electron)



Neutron Decay

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