Carbon Dating

- Fraction of C-14 to C-12 is constant in the atmosphere
- Fraction of C-14 to C-12 is constant in living tissue
- No new C-14 absorbed by dead tissue
- Fraction of C-14 reveals age

$$\frac{N}{N_0} = 2^{-t/T_{1/2}} \qquad T_{1/2} = 5730 \text{ years}$$

Heisenberg Uncertainty Principle

Δx = the uncertainty in position of a particle

Δp = the uncertainty in the momentum of a particle

$$\Rightarrow \Delta x \Delta p \geq \frac{\hbar}{2} \qquad \hbar = \frac{h}{2\pi}$$

Nuclear Decay

1) Alpha Decay

$$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He$$

parent nucleus

daughter nucleus

alpha particle

eg. $$^{238}_{92}U \rightarrow \, ^{234}_{90}Th + \, ^{4}_{2}He$$

h.l. $= 4.5 \times 10^{9}$ years

$^{222}_{86}Rn \rightarrow ^{218}_{84}Po + ^{4}_{2}He$ h.l. = 3.82 days

$^{218}_{84}Po \rightarrow ^{214}_{82}Pb + ^{4}_{2}He$.   hl = 3.1 min

$^{226}_{88}Ra \rightarrow ^{226}_{86}Rn + ^{4}_{2}He$ hl = 1.6×10^3 yr

2) Beta Decay

Beta-: $^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e^{-} + \bar{\nu}$

Beta+: $^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e^{+} + \nu$

within nucleus

$n \rightarrow p + e^{-} + \bar{\nu}$

$p \rightarrow n + e^{+} + \nu$

Beta decay examples

$$^{14}_{6}C \rightarrow ^{14}_{7}N + e^- + \bar{\nu}$$

$$^{12}_{7}N \rightarrow ^{12}_{6}C + e^+ + \nu$$

3) Electron Capture

$$^{A}_{Z}X + e^- \rightarrow ^{A}_{Z-1}Y + \nu$$

Proton rich nucleus captures inner electron

4) Gamma Decay

- Quantum Mechnics $\Rightarrow$ nuclei can have discrete energy levels (just like atoms)
- Transition from an excited state to a state of lower energy $\Rightarrow$ photon emitted

$$\underbrace{{}^{A}_{Z}X^{*}}_{\text{excied nucl}} \longrightarrow \underbrace{{}^{A}_{Z}X}_{\text{de-excited nucleus}} + \underbrace{\gamma}_{\text{gamma ray photon}}$$

Nuclear Reactions

result of collisions between nuclei

$$a + X \rightarrow Y + b$$

Reactants = $\{a, X\}$
Products = $\{Y, b\}$

e.g. $^{4}_{2}He + ^{14}_{7}N \rightarrow ^{17}_{8}O + ^{1}_{1}H$

Reaction Energy Q

$$Q = (\text{Mass of Reactants} - \text{Mass of Products}) \times c^2$$

mass deficit = mass converted to energy in a nuclear reaction

= Mass of reacts - Mass of products

Reaction energy = $(\text{mass deficit})c^2 = Q$

$E = mc^2$

$Q > 0 \Rightarrow$ exothermic reaction (energ released)

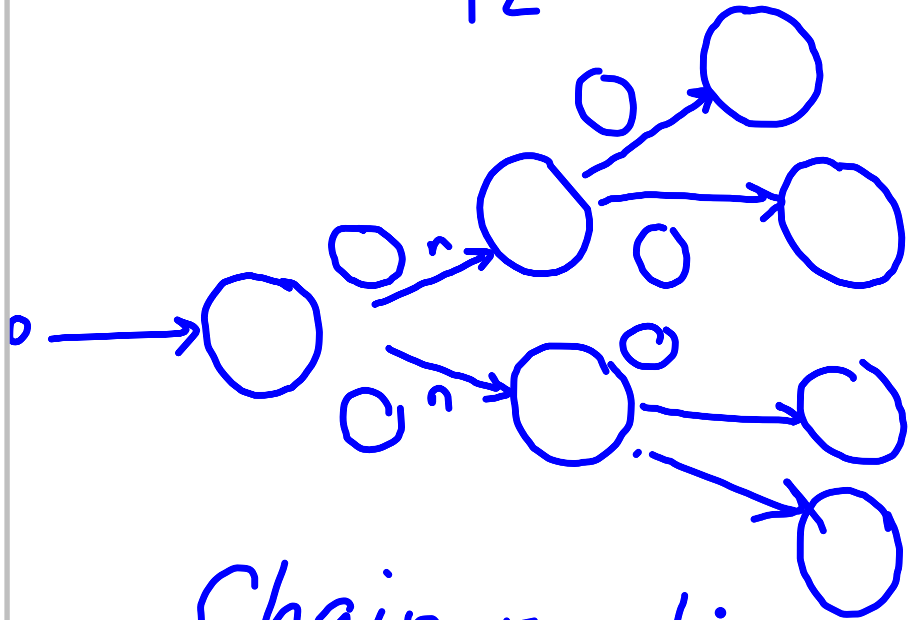
$Q < 0 \Rightarrow$ endothermic reaction (energy absorbed)

Nuclear Fission

- neutron hits large unstable nucleus
- Nucleus splits into
  1) Two large fragments (nuclei)
  2) Two or 3 energetic neutrons
  3) gamma rays

example

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{94}_{36}Kr + {}^{139}_{56}Ba + 2\,{}^{1}_{0}n + \gamma$$



atomic bomb

γ

Chain reaction