Sub-Atomic Particles and Isotopes

	Mass	Charge	Location
proton	~ 1	$+1$	Nucleus
neutron	~ 1	0	Nucleus
electron	~ 0	-1	Outside

Sample Isotopes	#protons	#neutrons	#electrons
${}^{13}_{6}C$	6	7	6
${}^{17}\mathrm{O}^{-2}$	8	9	10
${}^{235}_{92}U^{+2}$	92	143	90

Elemental Symbols

$${}^{A}_{Z}X^{\pm q}$$

- A: Mass number = #protons + #neutrons
- Z: Atomic number = #protons
- X: Elemental symbol
- q: ionic charge

First Order Kinetics: *The following equations show the mathematical basis for the kinetic theory used for radioactive decay. You are NOT responsible for this.*

$$\text{rate} = \text{k[A]}$$

$$\frac{-dA}{dt} = \text{k[A]}$$

$$\int \frac{1}{A} dA = -\int k\, dt$$

$$\ln([A]) - \ln([A_0]) = \text{-kt}$$

$$\ln\left(\frac{[A]}{[A_0]}\right) = \text{-kt}$$

After 1 half-life:

$$\text{t} = \text{t}_{1/2} \qquad [\text{A}] = \tfrac{1}{2}[\text{A}_0]$$

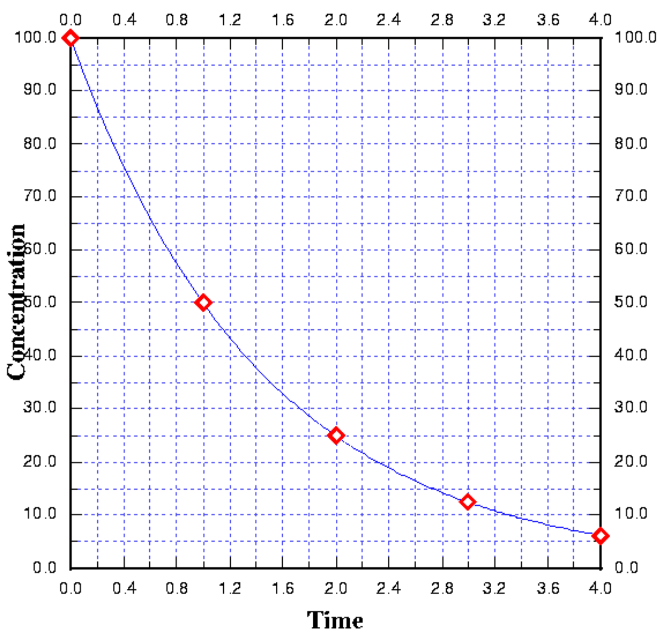
$$\ln\left(\frac{[A]}{[A_0]}\right) = \text{-kt}$$

$$\ln\left(\frac{\frac{1}{2}[A_0]}{[A_0]}\right) = \ln\left(\tfrac{1}{2}\right) = -0.693 = \text{-kt}_{1/2}$$

$$\text{t}_{1/2} = \frac{0.693}{k} \quad \text{(constant value)}$$

The Half-life of a radioactive isotope is a constant and does NOT depend on the amount of material present. The half-live indicates how long it will take for half of any sample to decay.

Radioactive Decay



Time	0	1	2	3	4
Concentration	100%	50%	25%	12.5%	6.25%

Selected Radioactive Nucleotides

Isotope	**Half-Life**	**Uses**
^{238}U	4.5 billion years	Nuclear fuel
^{239}Pu	24,400 years	Nuclear byproduct
^{90}Sr	28.9 years	Nuclear fallout
^{14}C	5730 years	Carbon dating
^{222}Rn	3.8 days	Radon
^{241}Am	432.2 years	Smoke Detectors
^{59}Fe	44.5 days	Medical
^{99m}Tc	6.0 hours	Medical

Source of Energy

$$E = mc^2$$

If m = 1.00 g, $E \simeq 10^{14}$ Joules
In nuclear reaction, very small changes in mass occur.

$$\begin{array}{cccc} {}^{238}_{92}U & \longrightarrow & {}^{234}_{90}Th & + \quad {}^{4}_{2}He \\ 238.0003 & & 233.9942 & \quad 4.0015 \\ \hline 238.0003 & & 237.9957 & \\ \multicolumn{4}{c}{\text{mass lost} = 0.0046} \end{array}$$

For this example, 238 grams of ^{238}U will produce 4×10^{11}J.
Over 8 million grams of gasoline would have to be burned to produce this much energy.

Nuclear Decay Products

Particle	Composition	Description
Alpha, α	${}^{4}_{2}He^{+2}$	Helium nucleus
Beta, β	${}^{0}_{-1}e^{-1}$	Electron
Gamma, γ	${}^{0}_{0}\gamma$	Energy
Neutron, n	${}^{1}_{0}n$	Neutron

Balancing Reactions

$$\begin{array}{ccccccccc} {}^{235}_{92}U & + & {}^{1}_{0}n & \longrightarrow & {}^{92}_{36}Kr & + & {}^{141}_{56}Ba & + & 3\,{}^{1}_{0}n \\ \hline 92\text{ p} & & 0\text{ p} & & 36\text{ p} & & 56\text{ p} & & 0\text{ p} \\ 143\text{ n} & & 1\text{ n} & & 56\text{ n} & & 85\text{ n} & & 3\text{ n} \\ 235 & & 1 & & & & 141 & & 3 \end{array}$$

92 protons, 144 neutrons

Nuclear Uses

- Smoke Detectors
- Nuclear Energy
- Nuclear Weapons
- Medical Diagnosis and Treatment
- Nuclear Fusion ??