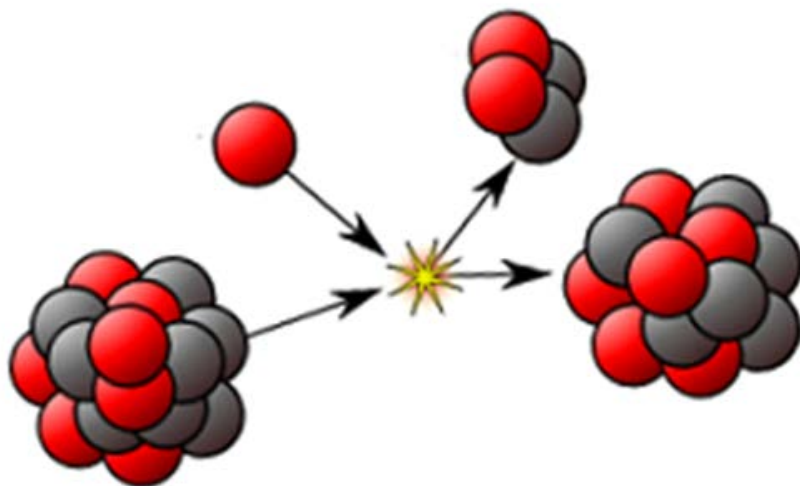


GENERAL CHEMISTRY

Nuclear Chemistry



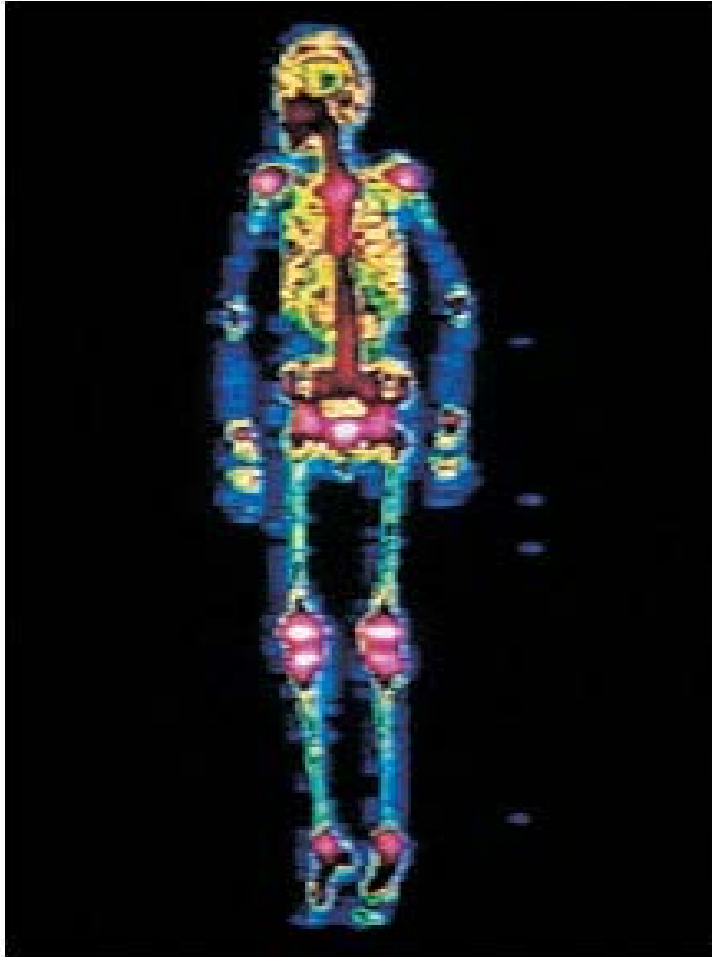


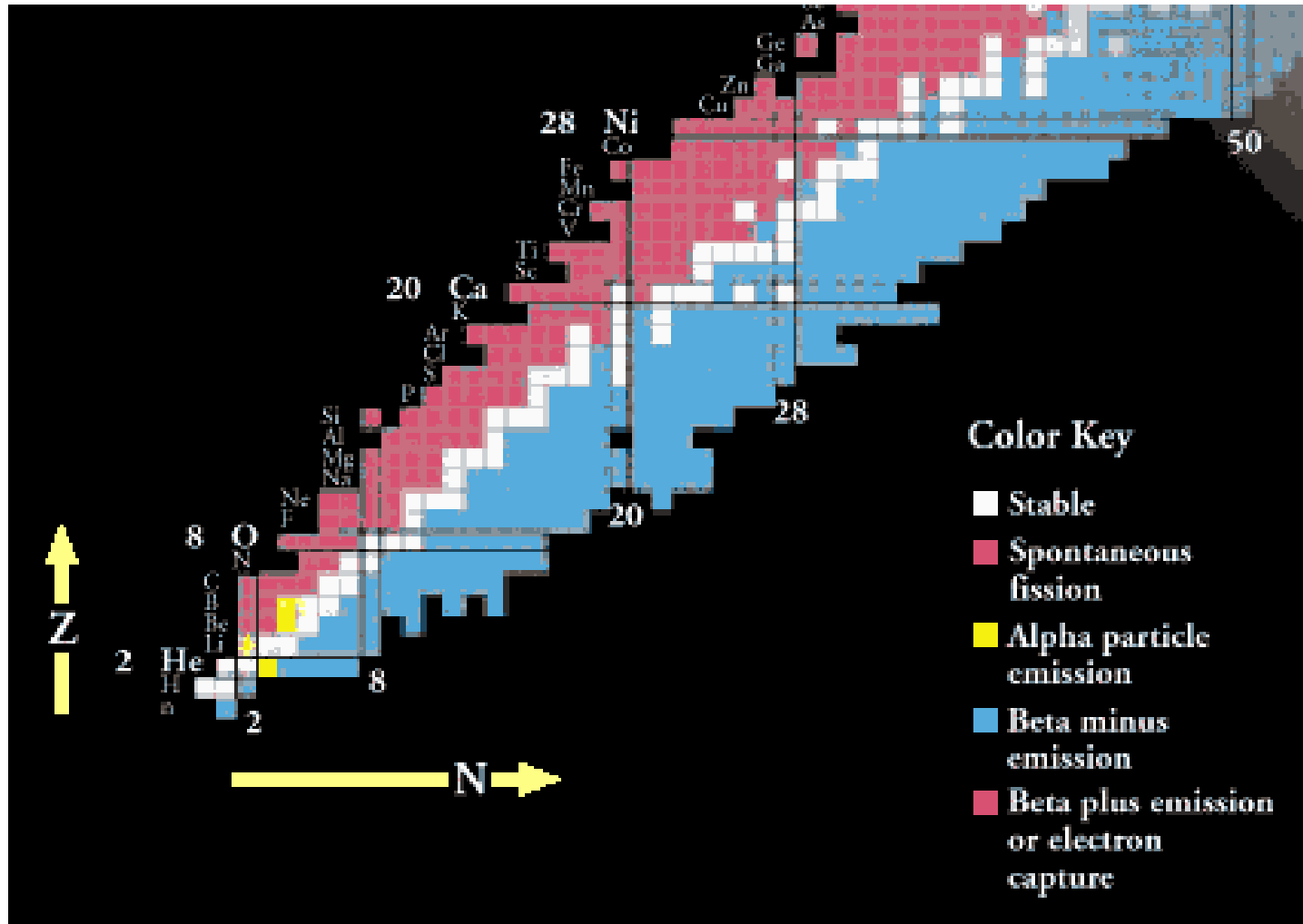
Image of a person's skeleton obtained using an excited form of technetium-99

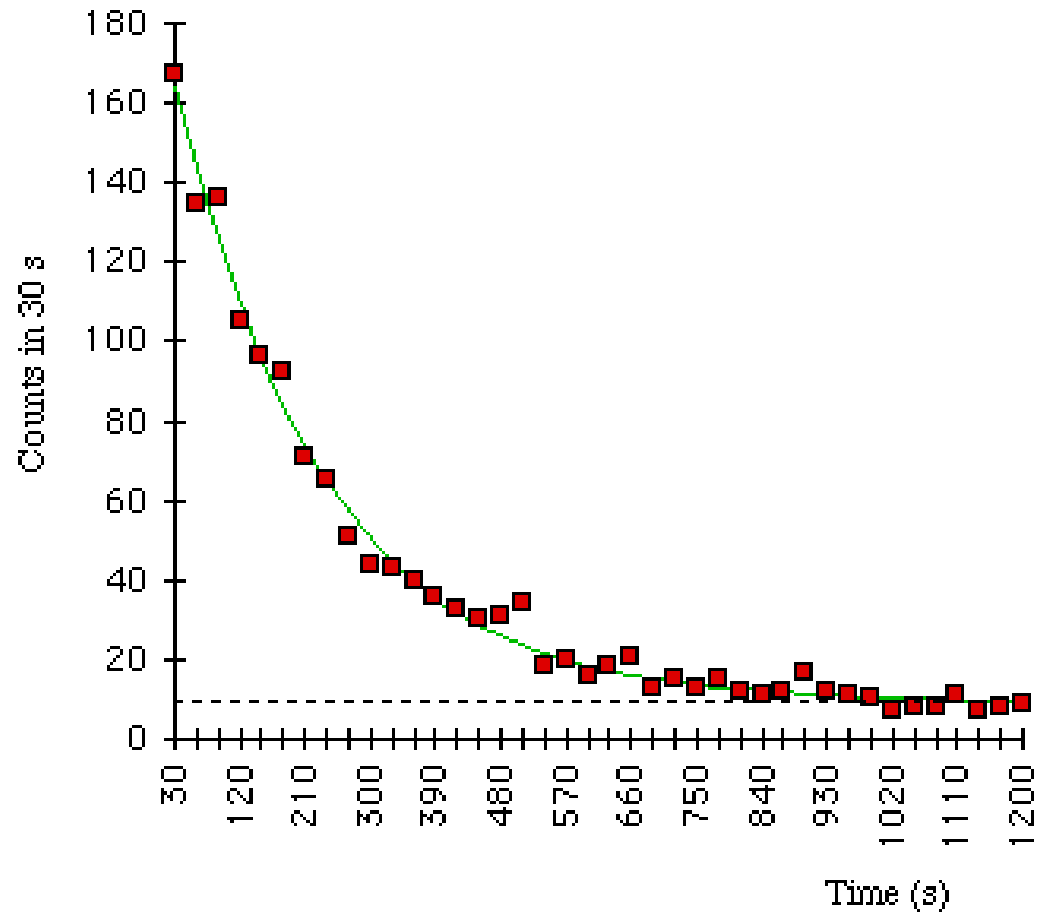
A technetium compound was injected into the body, where it concentrated in bone tissue. Gamma rays (similar to x rays) emitted by technetium were detected by special equipment to produce this image



Radioactivity and Nuclear Bombardment Reactions

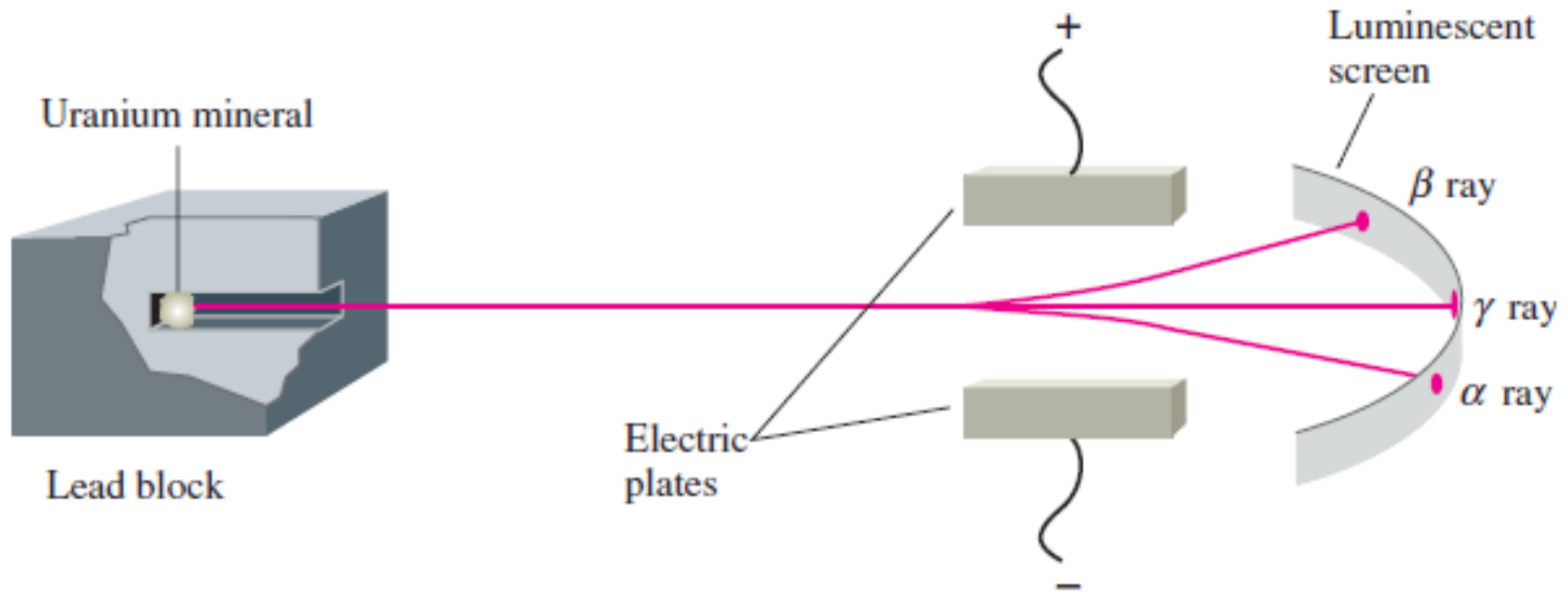
Radioactivity





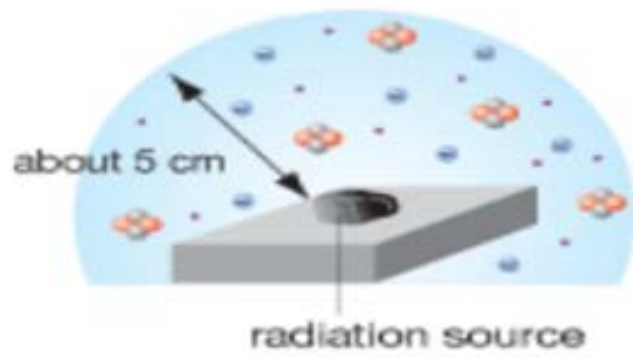
^{137}Ba decay data, counting numbers of decays observed in 30-second intervals. The best-fit exponential curve is shown. The points do not fall exactly because of statistical counting fluctuations.

Separation of the radiation from a radioactive material (uranium mineral)



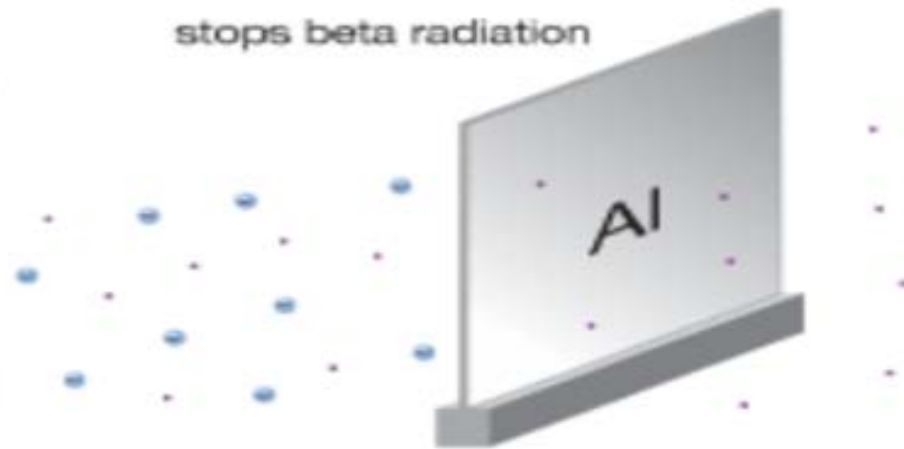
The radiation separates into alpha (α), beta (β), and gamma (γ) rays when it passes through an electric field.

alpha radiation through air

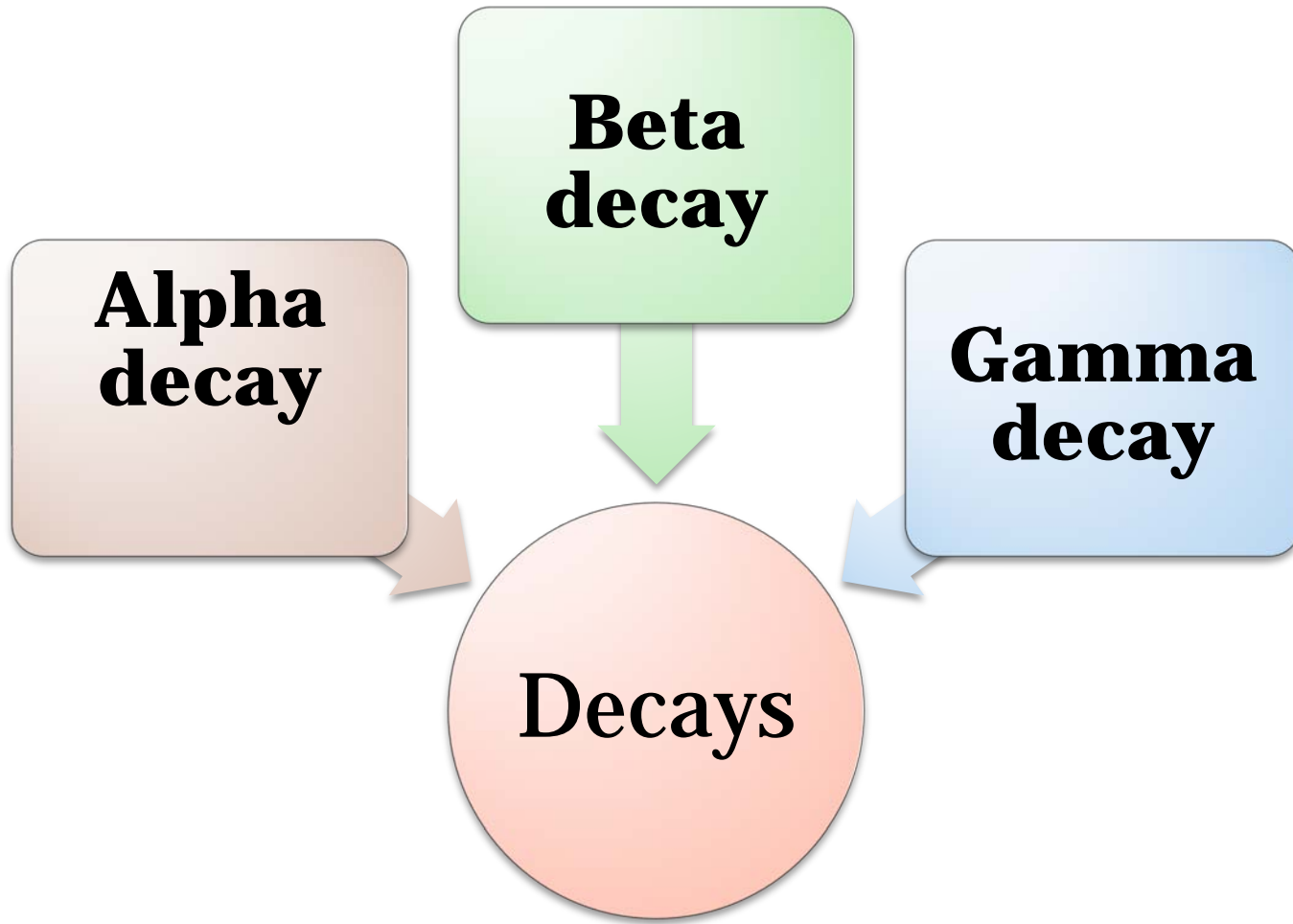


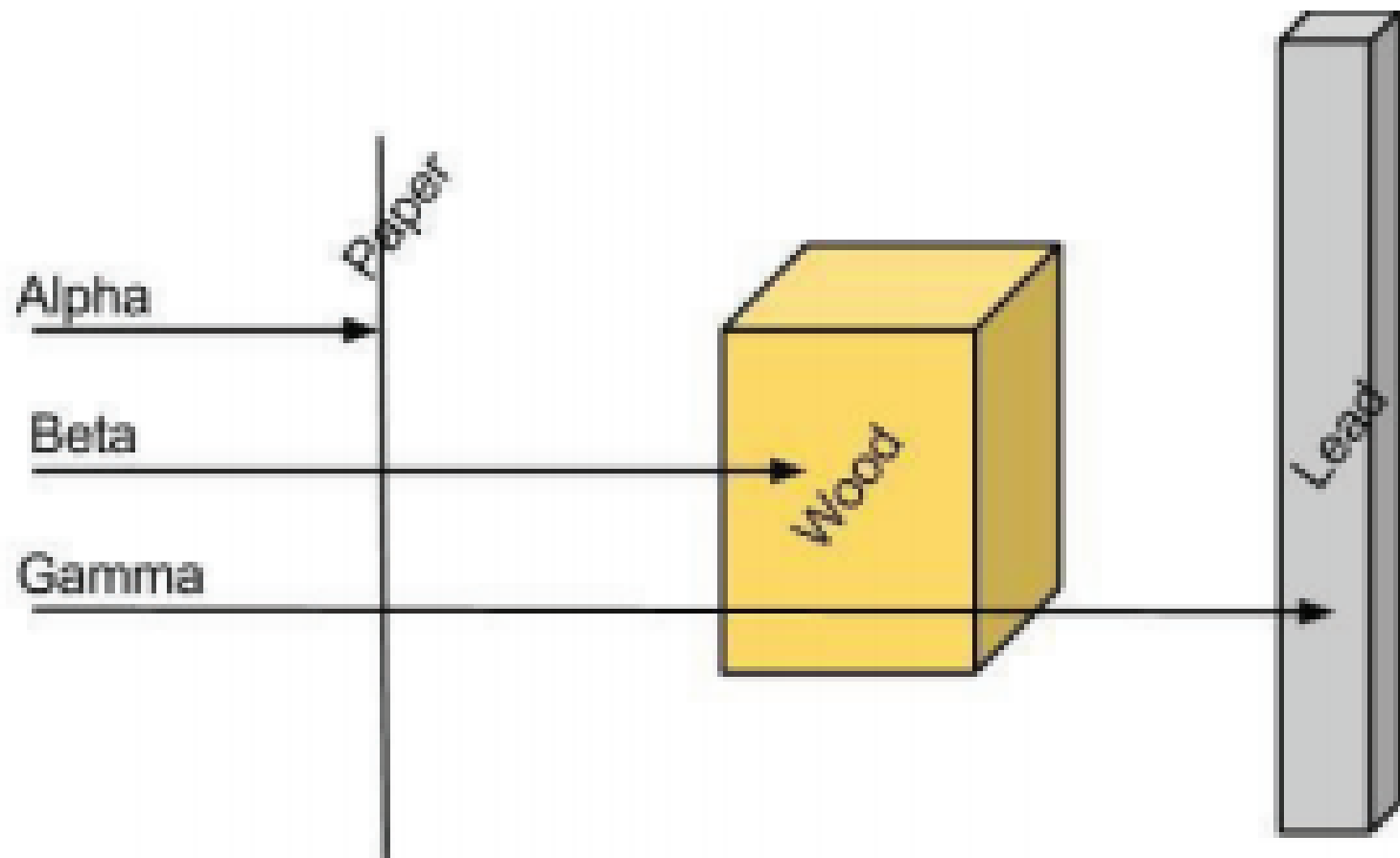
Alpha α 


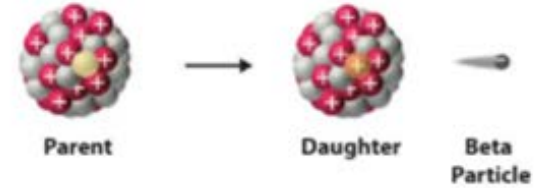
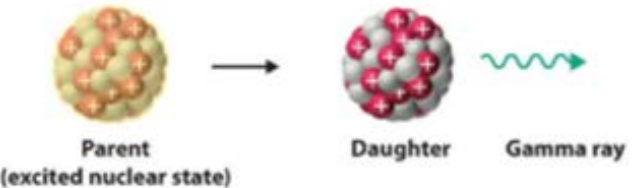
stops beta radiation

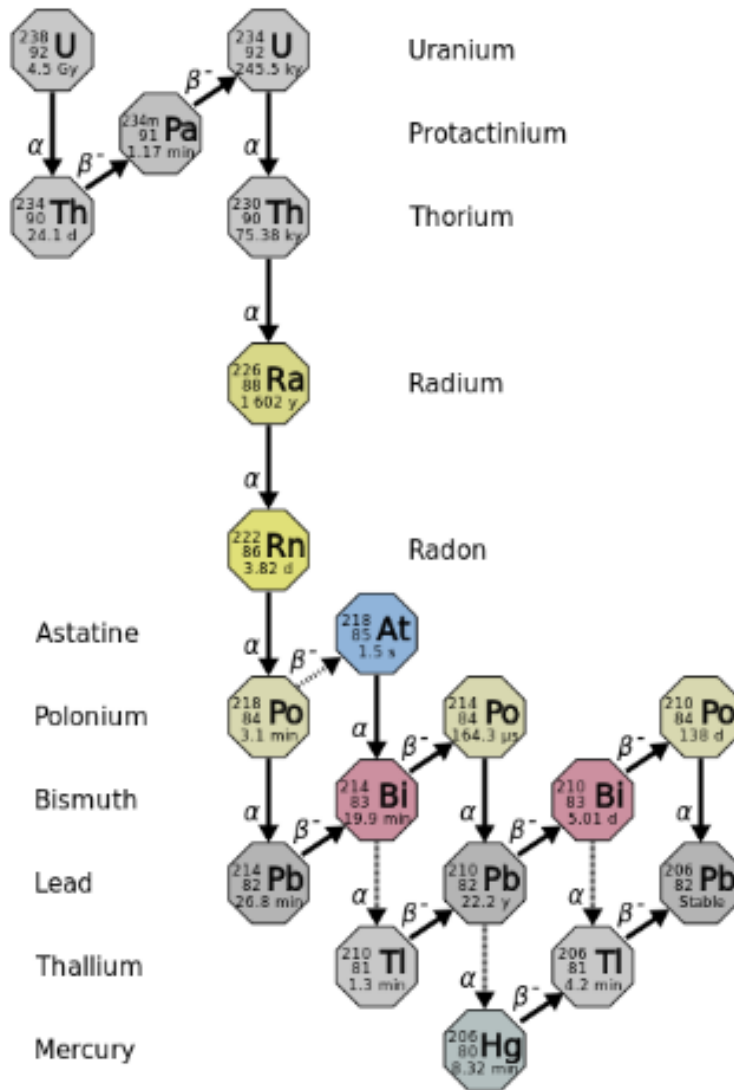


Beta β 





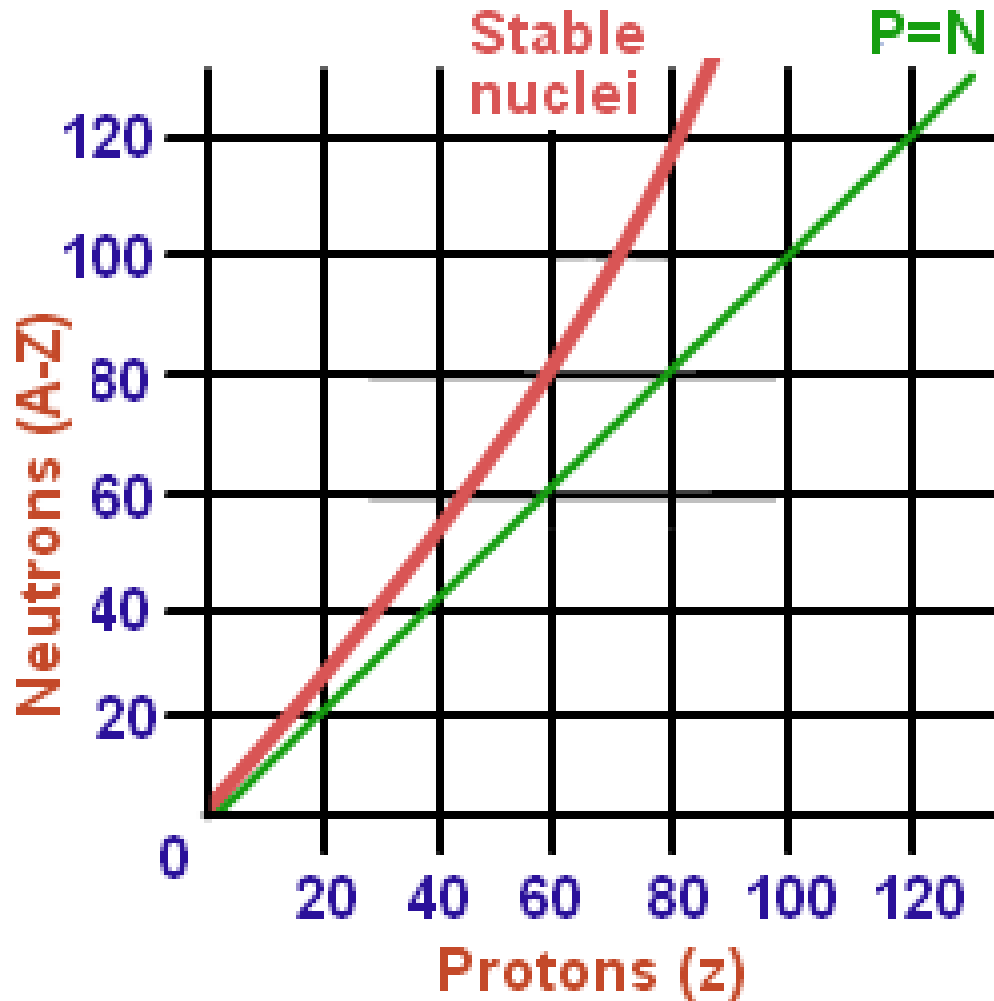
Decay Type	Radiation Emitted	Generic Equation	Model
Alpha decay	${}^4_2\alpha$	${}^A_ZX \longrightarrow {}^{A-4}_{Z-2}X' + {}^4_2\alpha$	 <p>Parent → Daughter + Alpha Particle</p>
Beta decay	${}^0_{-1}\beta$	${}^A_ZX \longrightarrow {}^A_{Z+1}X' + {}^0_{-1}\beta$	 <p>Parent → Daughter + Beta Particle</p>
Gamma emission	${}^0_0\gamma$	${}^A_ZX^* \xrightarrow{\text{Relaxation}} {}^A_ZX' + {}^0_0\gamma$	 <p>Parent (excited nuclear state) → Daughter + Gamma ray</p>

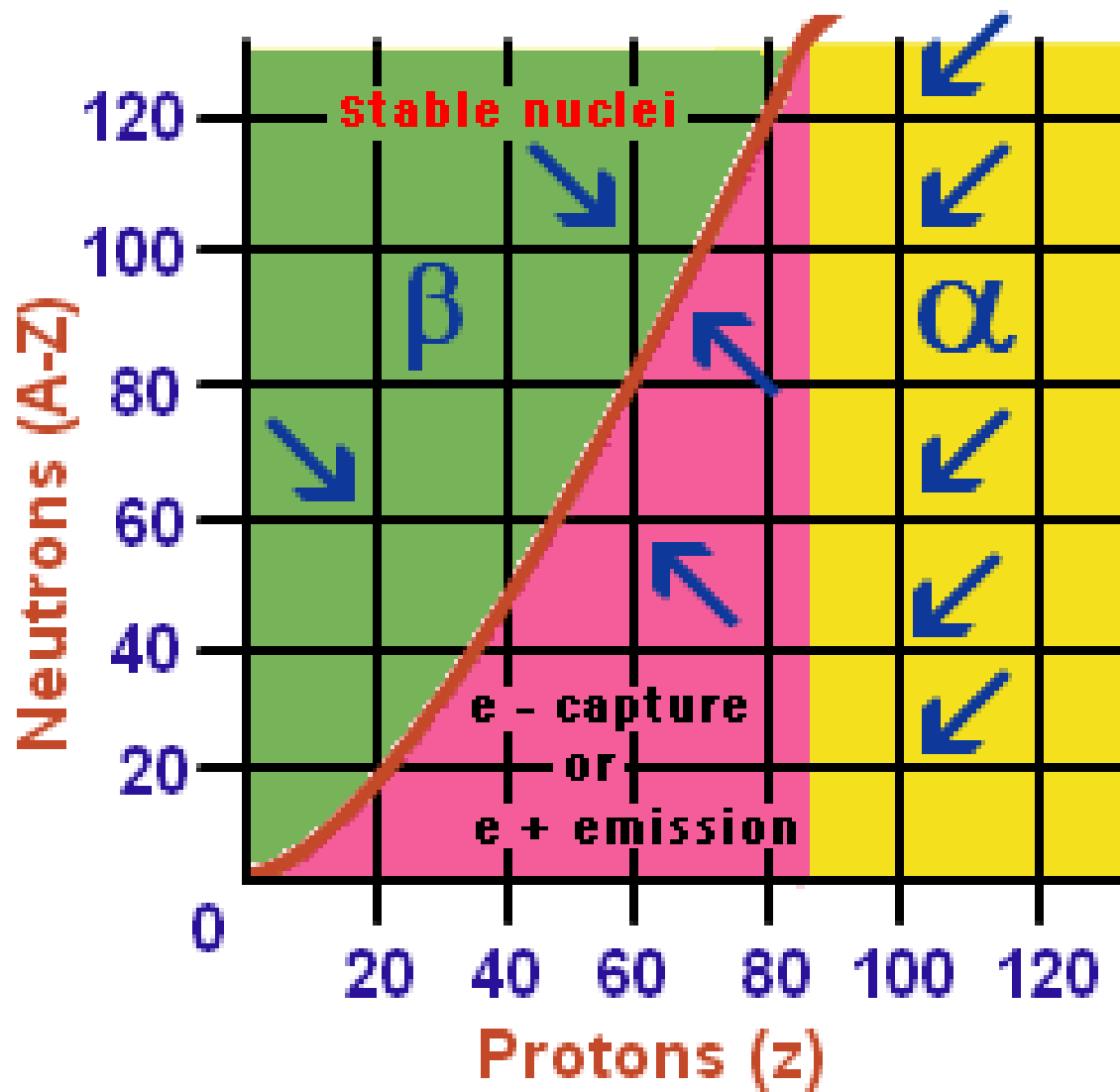


Decay Series

Nuclear Equations

Nuclear Stability

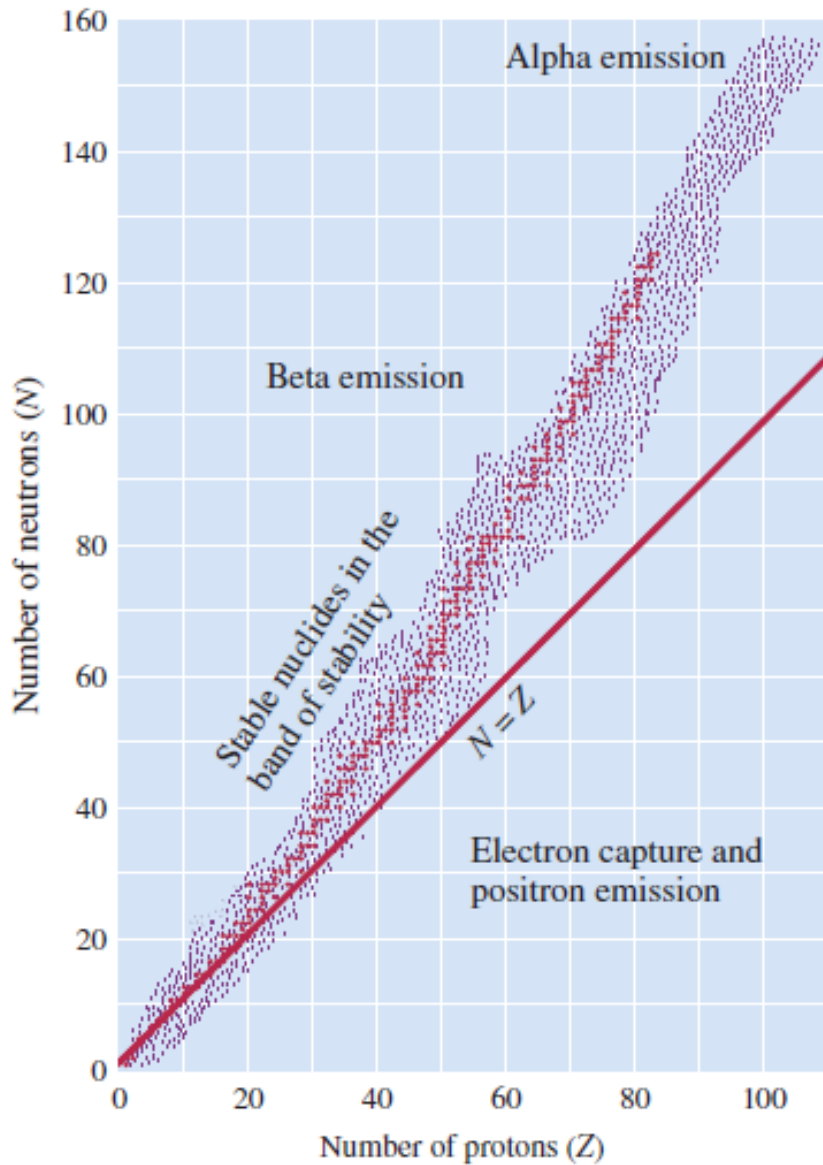




Number of Stable Isotopes with Even and Odd Numbers of Protons and Neutrons

	Number of Stable Isotopes			
	157	52	50	5
Number of protons	Even	Even	Odd	Odd
Number of neutrons	Even	Odd	Even	Odd

Evidence also points to the special stability of pairs of protons and pairs of neutrons, analogous to the stability of pairs of electrons in molecules.



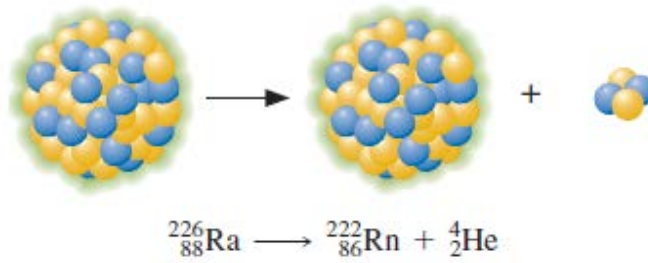
Band of stability

The stable nuclides, indicated by black dots, cluster in a band. Nuclides to the left of the band of stability usually decay by beta emission, whereas those to the right usually decay by positron emission or electron capture. Nuclides of $Z > 83$ often decay by alpha emission.

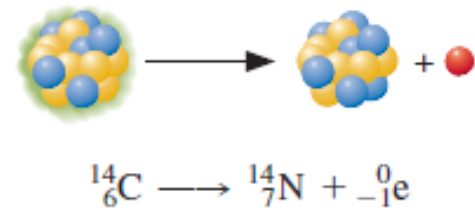
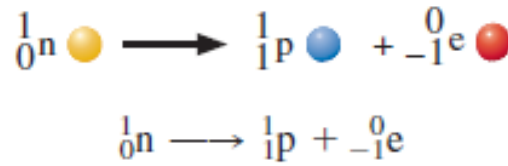
Types of Radioactive Decay

Type of Decay	Radiation	Equivalent Process	Resulting Nuclear Change		Usual Nuclear Condition
			Atomic Number	Mass Number	
Alpha emission (α)	${}^4_2\text{He}$	—	-2	-4	$Z > 83$
Beta emission (β)	${}^0_{-1}\text{e}$	${}^1_0\text{n} \longrightarrow {}^1_1\text{p} + {}^0_{-1}\text{e}$	+1	0	N/Z too large
Positron emission (β^+)	${}^0_1\text{e}$	${}^1_1\text{p} \longrightarrow {}^1_0\text{n} + {}^0_1\text{e}$	-1	0	N/Z too small
Electron capture (EC)	x rays	${}^1_1\text{p} + {}^0_{-1}\text{e} \longrightarrow {}^1_0\text{n}$	-1	0	N/Z too small
Gamma emission (γ)	${}^0_0\gamma$	—	0	0	Excited

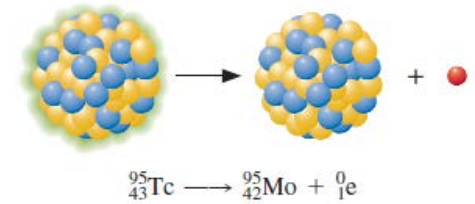
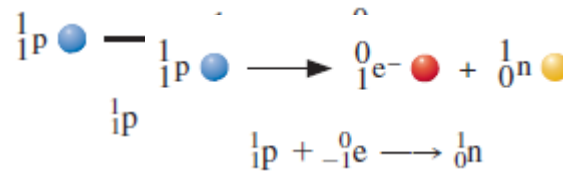
1. Alpha emission



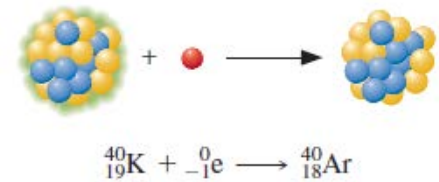
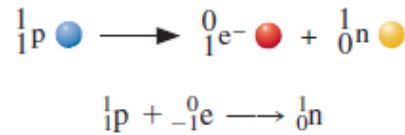
2. Beta emission



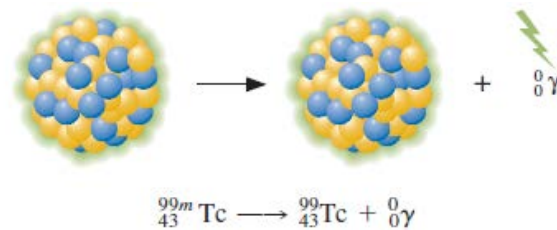
3. Positron emission



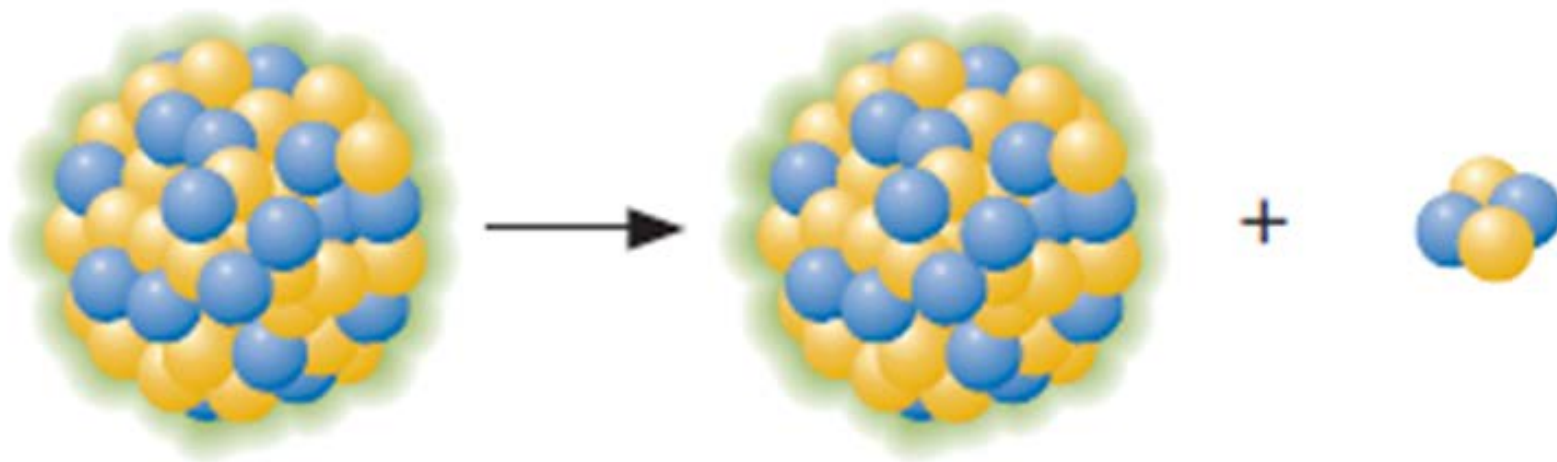
4. Electron capture



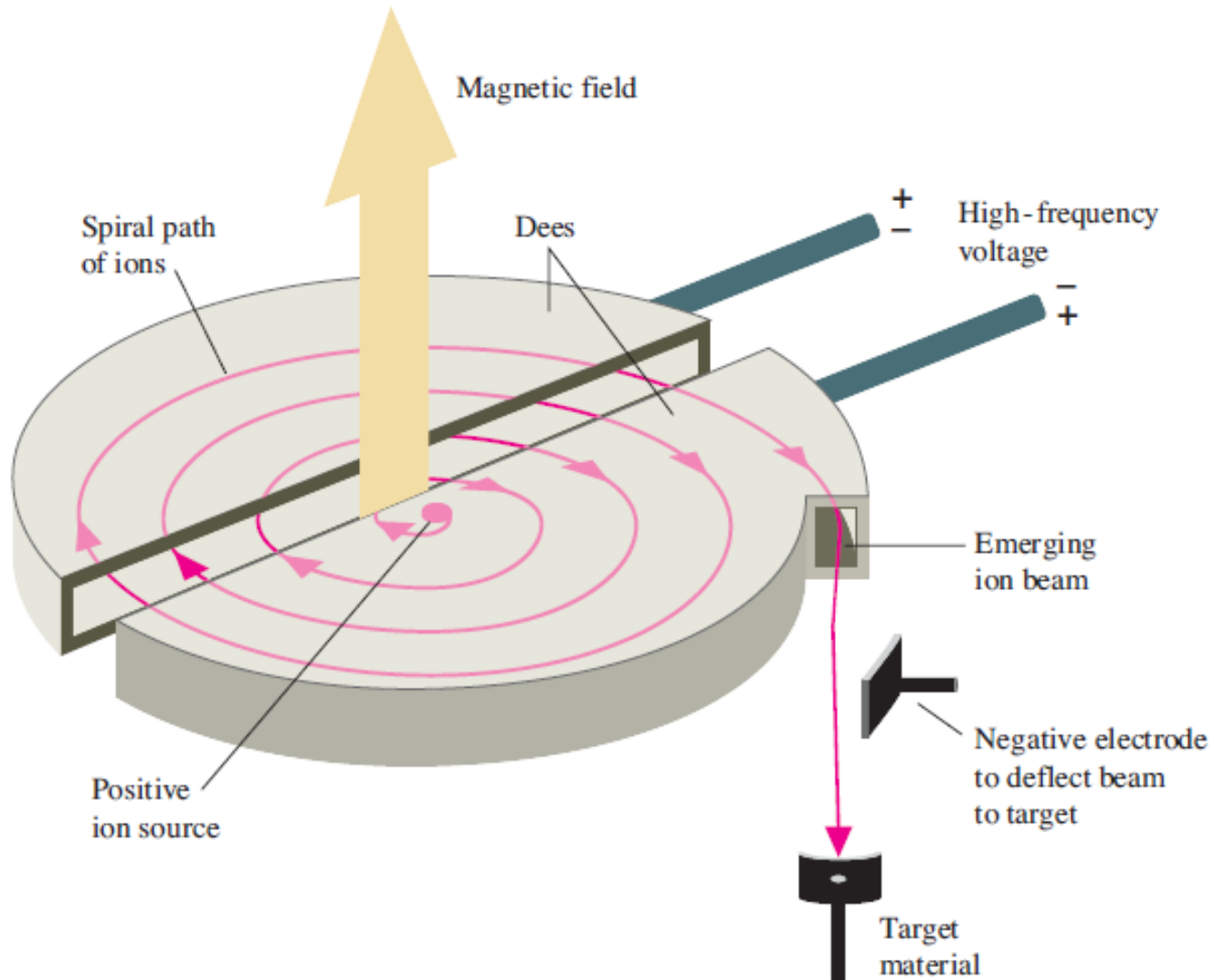
5. Gamma emission



We can write an equation for the nuclear reaction corresponding to the decay of uranium-238 much as we would write an equation for a chemical reaction.



Nuclear Bombardment Reactions

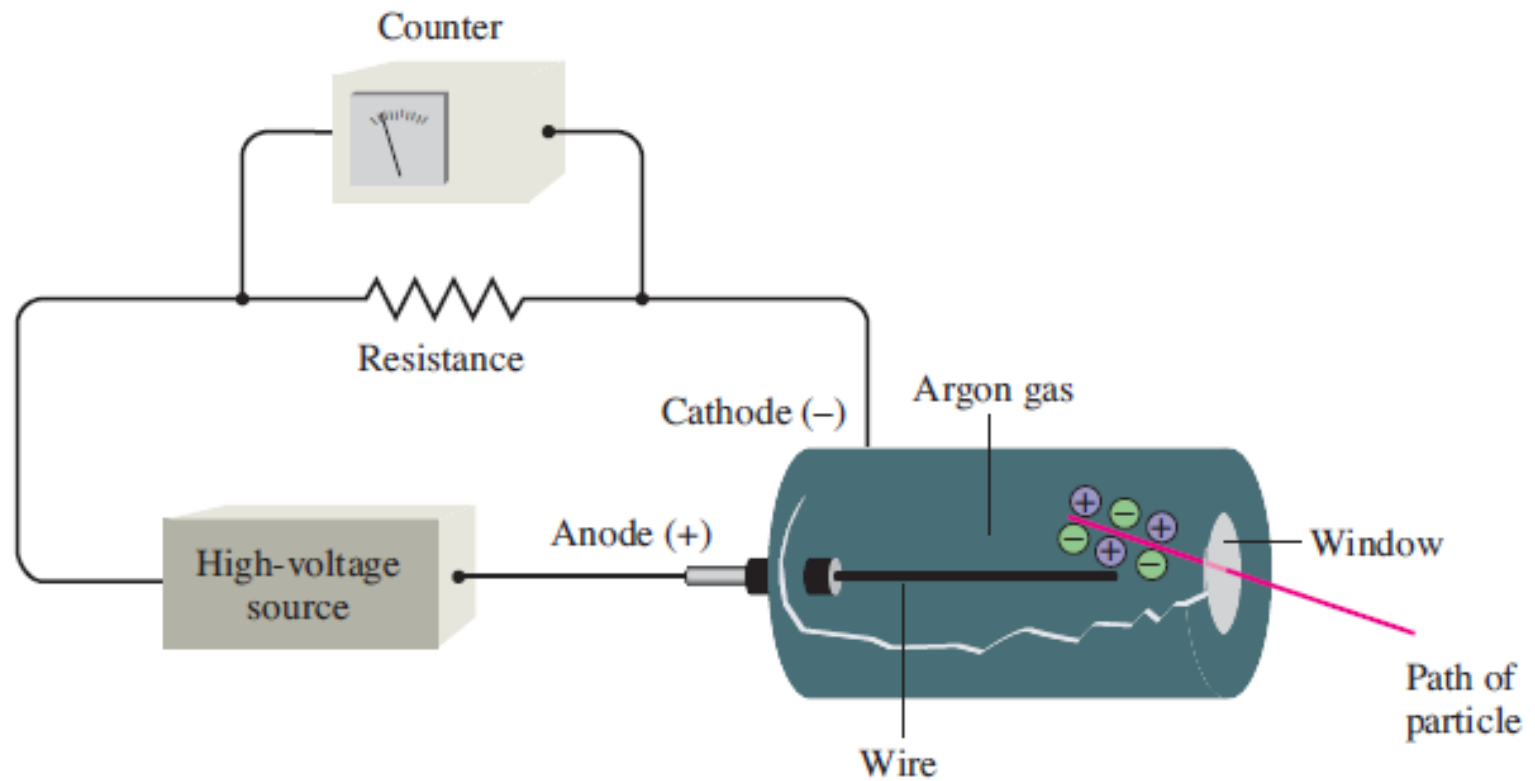




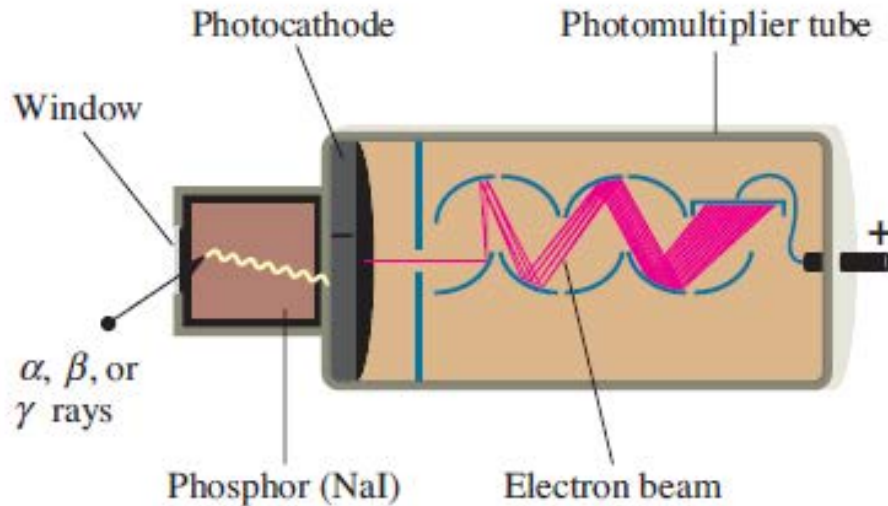
Radiations and Matter: Detection and Biological Effects

Radiation Counters

A Geiger counter



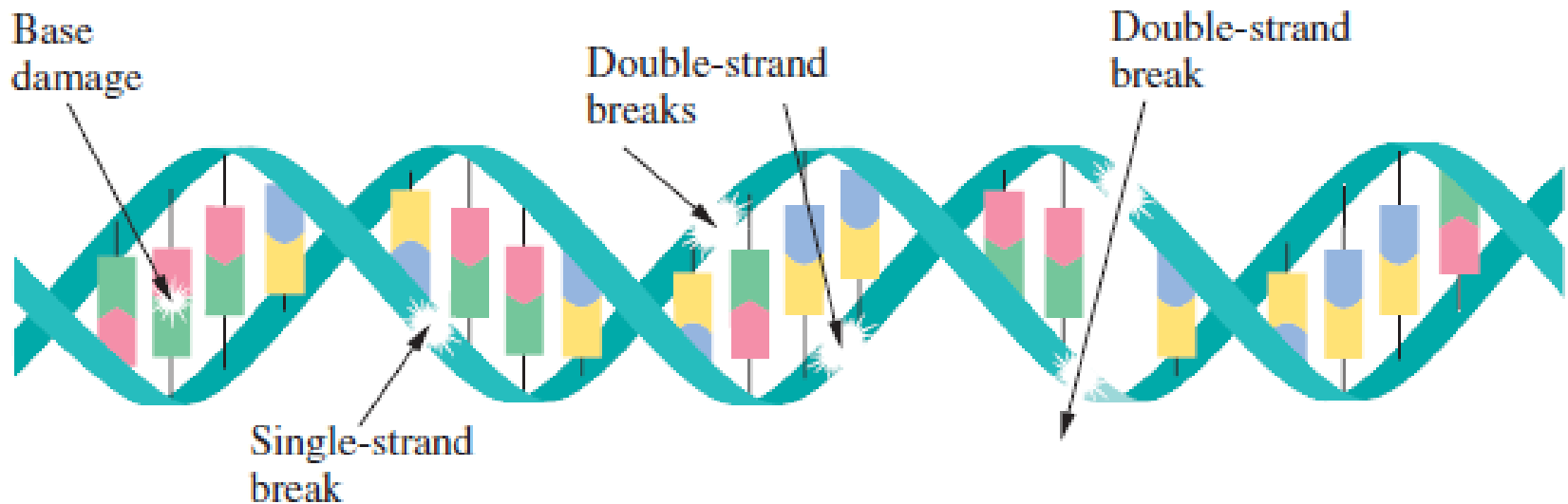
A scintillation counter probe



Left: Radiation passes through the window into a phosphor (here, NaI). Flashes of light from the phosphor fall on the photocathode, which ejects electrons by the photoelectric effect. The electrons are accelerated to electrodes of increasing positive voltage, each electrode ejecting more electrons, so that the original signal is magnified. Right: Photograph of a scintillation probe (the window is on the left).

Biological Effects and Radiation Dosage

Examples of damage to DNA from nuclear radiation



Damaged DNA can prevent cells from properly functioning and increase the likelihood of tumors.

Rate of Radioactive Decay

Rate of Radioactive Decay and Half-Life

The rate of radioactive decay—that is, the number of nuclei disintegrating per unit time—is found to be proportional to the number of radioactive nuclei in the sample. You can express this rate mathematically as

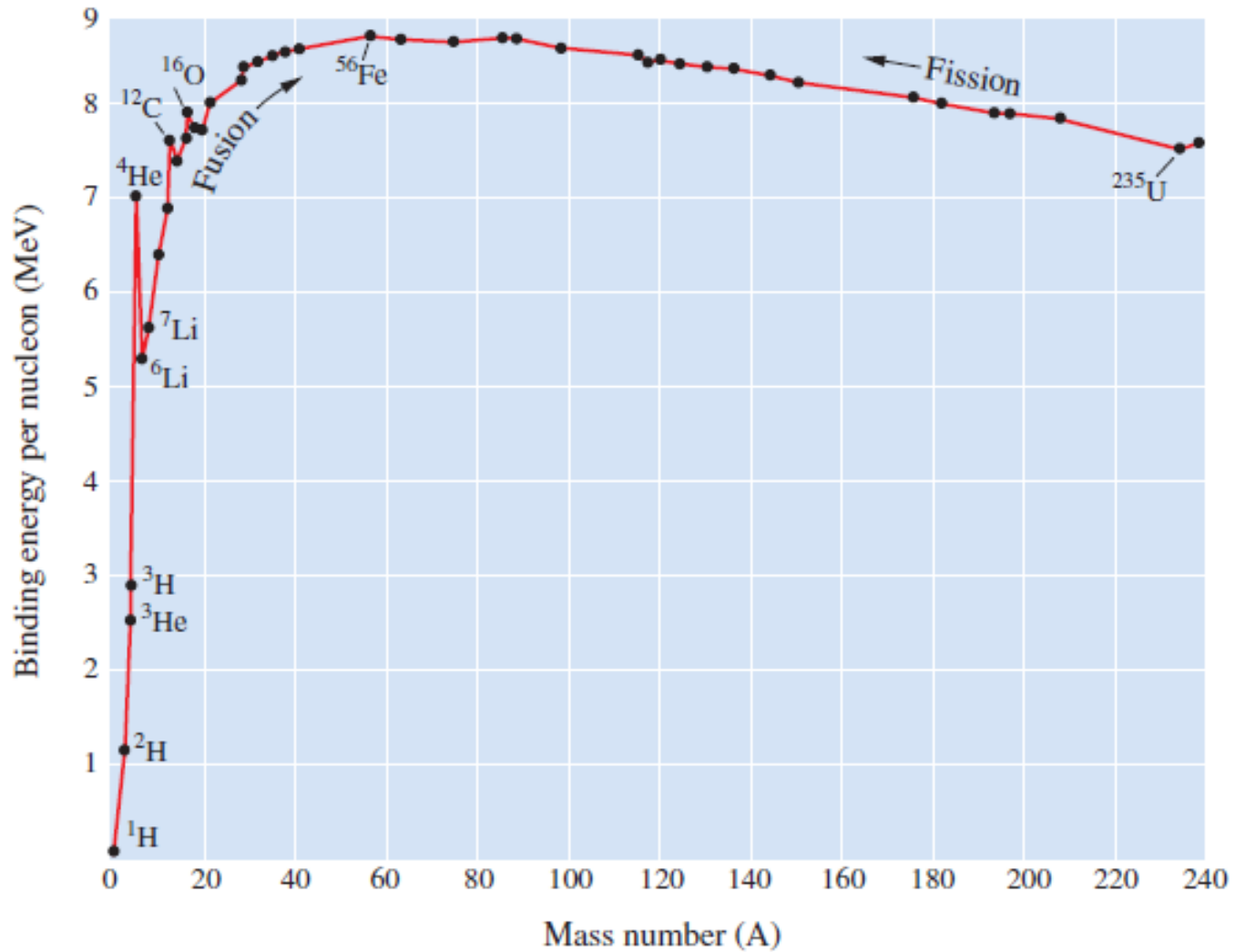
$$\text{Rate} = kN_t$$

Here N_t is the number of radioactive nuclei at time t , and k is the **radioactive decay constant**, or rate constant for radioactive decay. This rate constant is a characteristic of the radioactive nuclide, each nuclide having a different value.

Masses of Some Elements and Other Particles

Symbol	Z	A	Mass (amu)	Symbol	Z	A	Mass (amu)
e ⁻	-1	0	0.000549	Co	27	59	58.93320
n	0	1	1.008665	Ni	28	58	57.93534
p	1	1	1.00728		28	60	59.93079
H	1	1	1.00783	Pb	82	206	205.97444
	1	2	2.01400		82	207	206.97587
	1	3	3.01605		82	208	207.97663
He	2	3	3.01603	Po	84	208	207.98122
	2	4	4.00260		84	210	209.98285
Li	3	6	6.01512	Rn	86	222	222.01757
	3	7	7.01600	Ra	88	226	226.02540
Be	4	9	9.01218	Th	90	230	230.03313
B	5	10	10.01294		90	234	234.03660
	5	11	11.00931	Pa	91	234	234.04330
C	6	12	12.00000	U	92	233	233.03963
	6	13	13.00336		92	234	234.04095
O	8	16	15.99492		92	235	235.04392
Cr	24	52	51.94051		92	238	238.05078
Fe	26	56	55.93494	Pu	94	239	239.05216

Nuclear Binding Energy



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