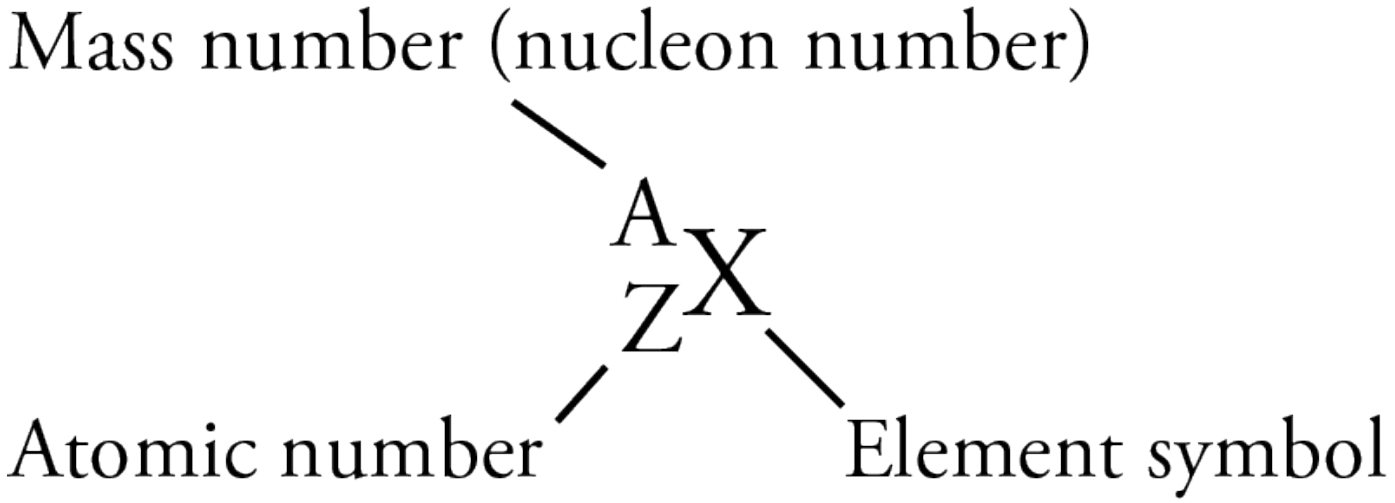
Nuclides

- ***Nuclide*** = a particular type of nucleus, characterized by a specific number of protons and neutrons and therefore a specific atomic number and nucleon number.
- ***Nucleon number*** or *mass number* = the number of ***nucleons*** (protons and neutrons) in the nucleus of a nuclide.

Nuclide Symbolism



Radioactive Iodine

- One of the products of the fission reaction of uranium atoms with 92 protons and 143 neutrons is iodine atoms with 53 protons and 78 neutrons.

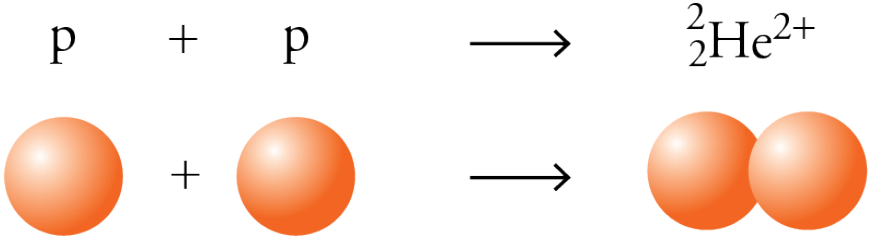
$^{235}_{92}\mathrm{U}$	$^{235}\mathrm{U}$	U-235	uranium-235
$^{131}_{53}\mathrm{I}$	$^{131}\mathrm{I}$	I-131	iodine-131

Two Forces in Nucleus

- ***Electromagnetic force*** = the force that causes opposite electrical charges to attract each other and like charges to repel each other.
- ***Strong force*** = the attractive force between nucleons (protons and neutrons).

Formation of a Helium Nucleus

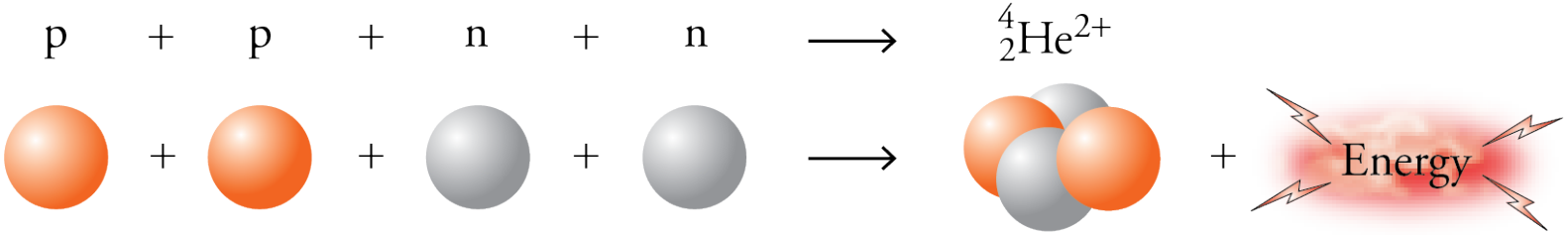
- Helium-2 with just two protons nucleus is unstable.

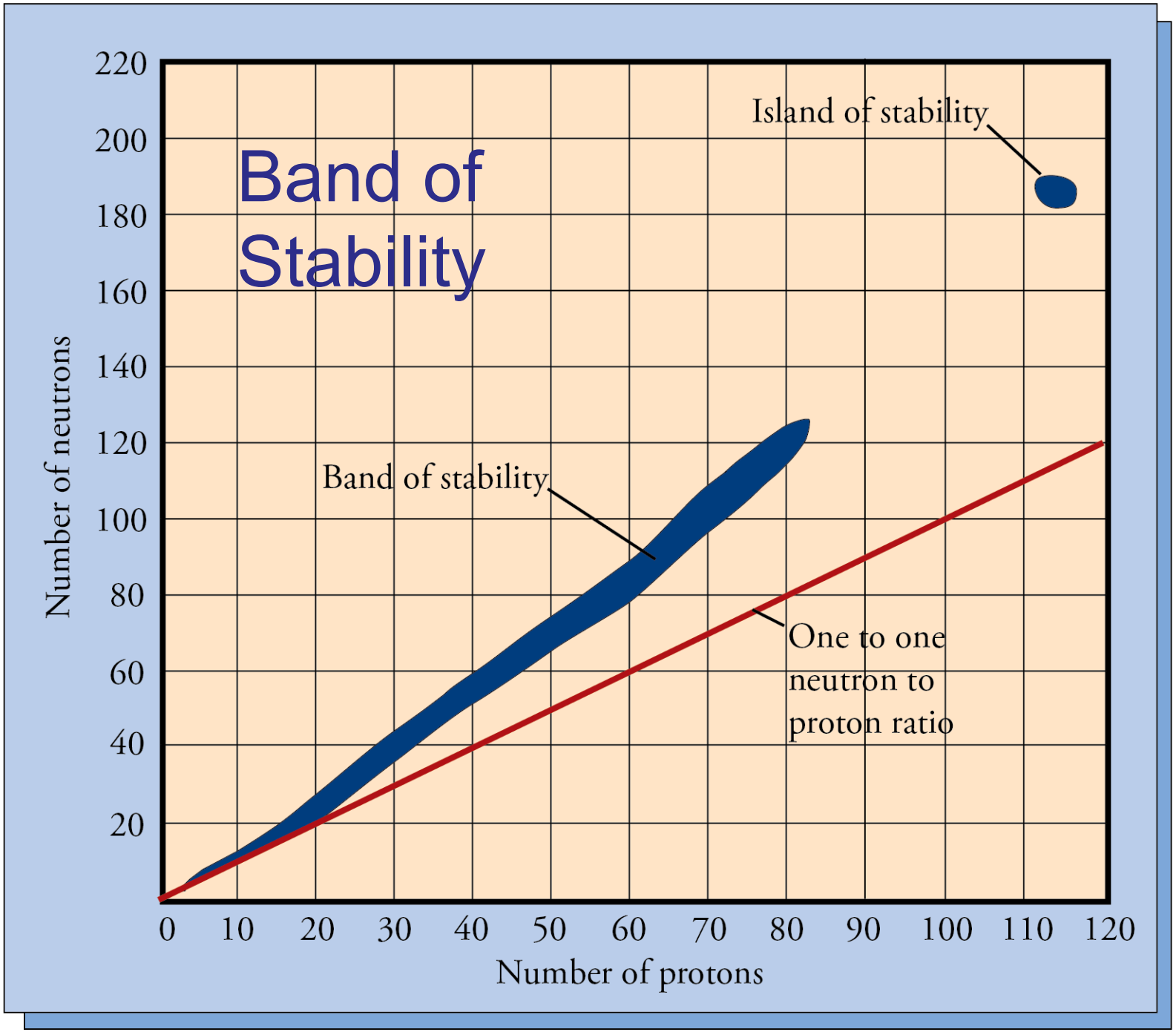


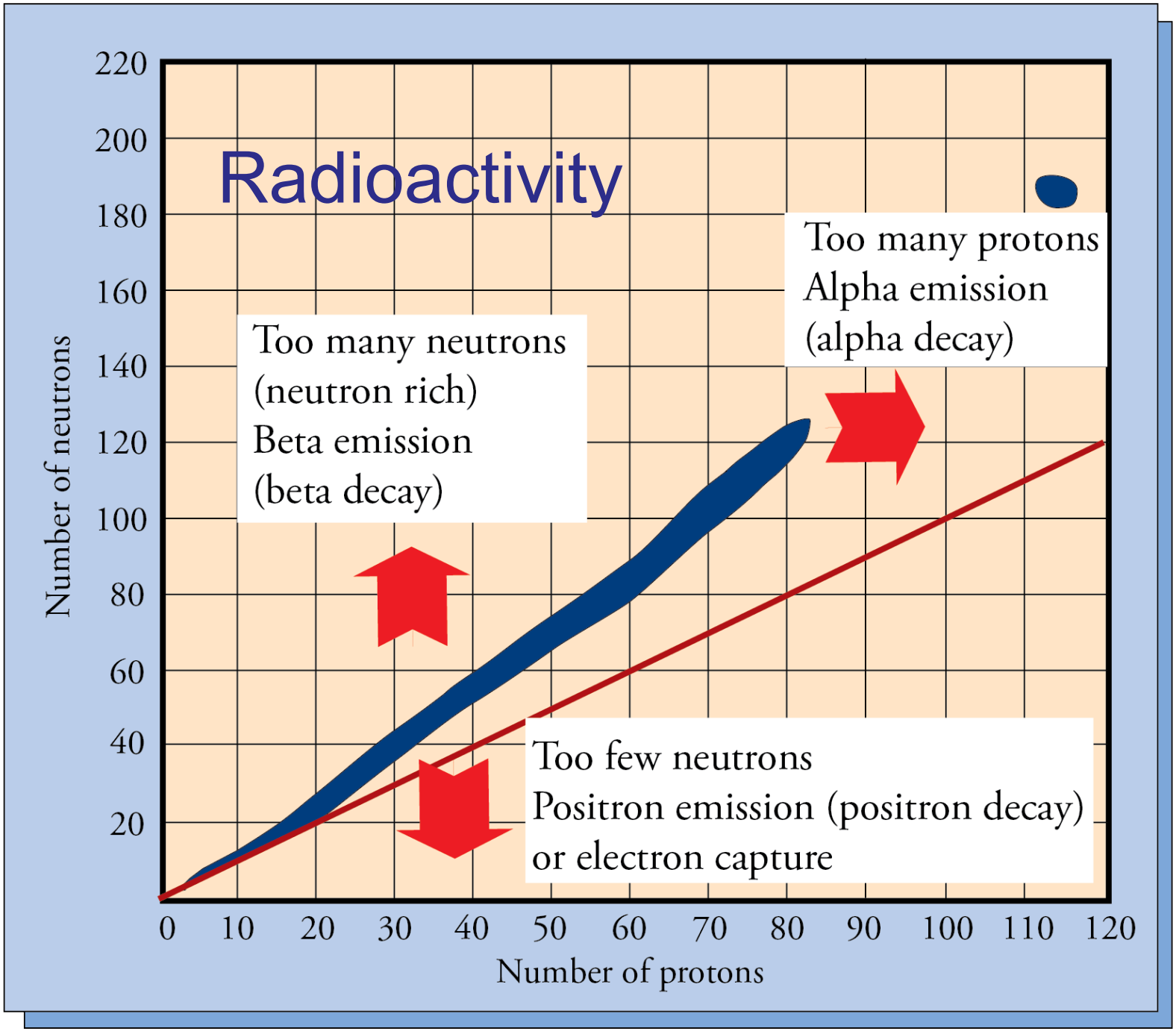
- The shorter the distance between the protons is, the stronger the electromagnetic repulsion between them.
- When they are close enough to form a helium nucleus, the strong force is not strong enough to overcome the electromagnetic repulsion, so the protons are pushed apart.

Nuclear Stability

- Neutrons increase the attraction from the strong force without increasing electromagnetic repulsion between nucleons.
- Combining two neutrons with two protons increases the strong force enough to overcome the electromagnetic repulsion, making a stable helium nucleus.

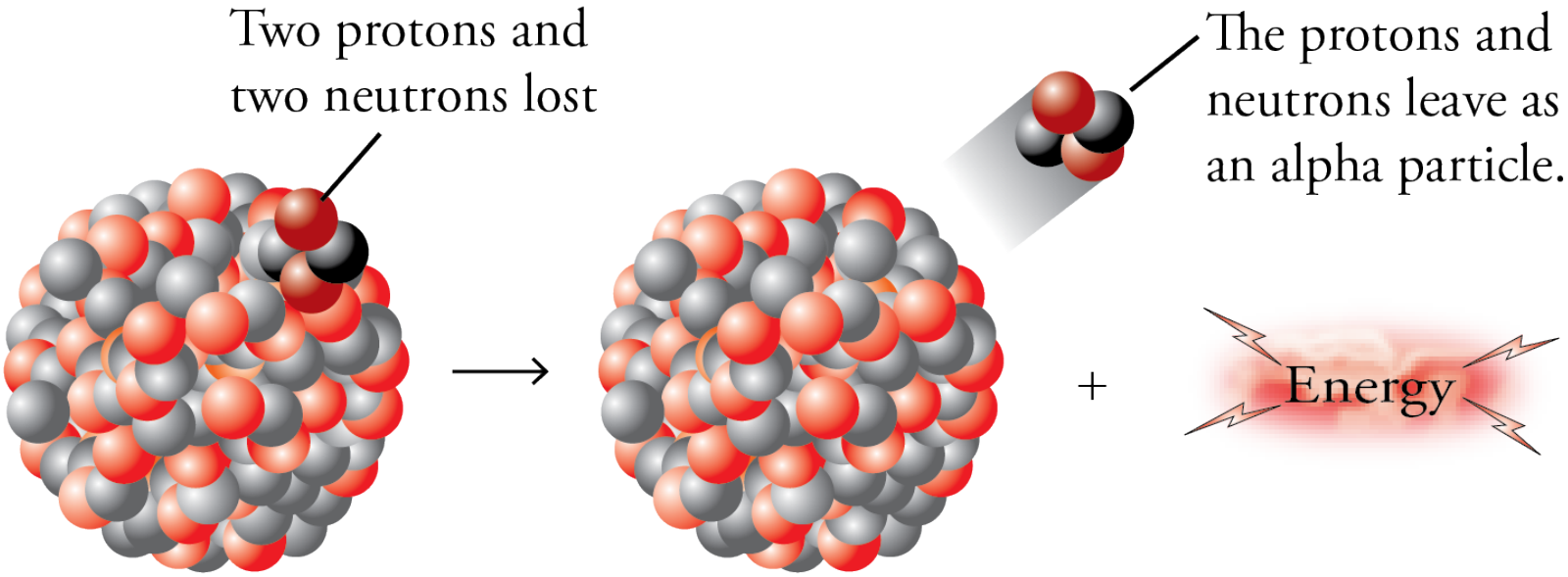



Band of Stability
Island of stability
Band of stability
One to one neutron to proton ratio
Number of neutrons
220
200
180
160
140
120
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100
110
120
Number of protons


Radioactivity
Too many protons
Alpha emission
(alpha decay)
Too many neutrons
(neutron rich)
Beta emission
(beta decay)
Too few neutrons
Positron emission (positron decay)
or electron capture
Number of neutrons
220
200
180
160
140
120
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100
110
120
Number of protons

Alpha Emission

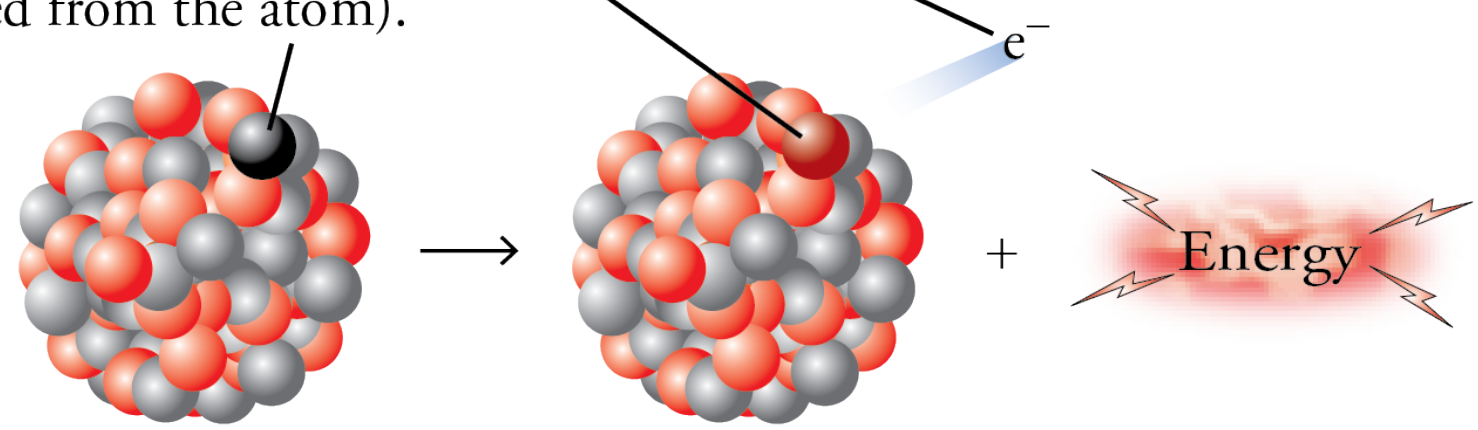
$$^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$



Beta Emission

$$^{131}_{53}\mathrm{I} \longrightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e}$$

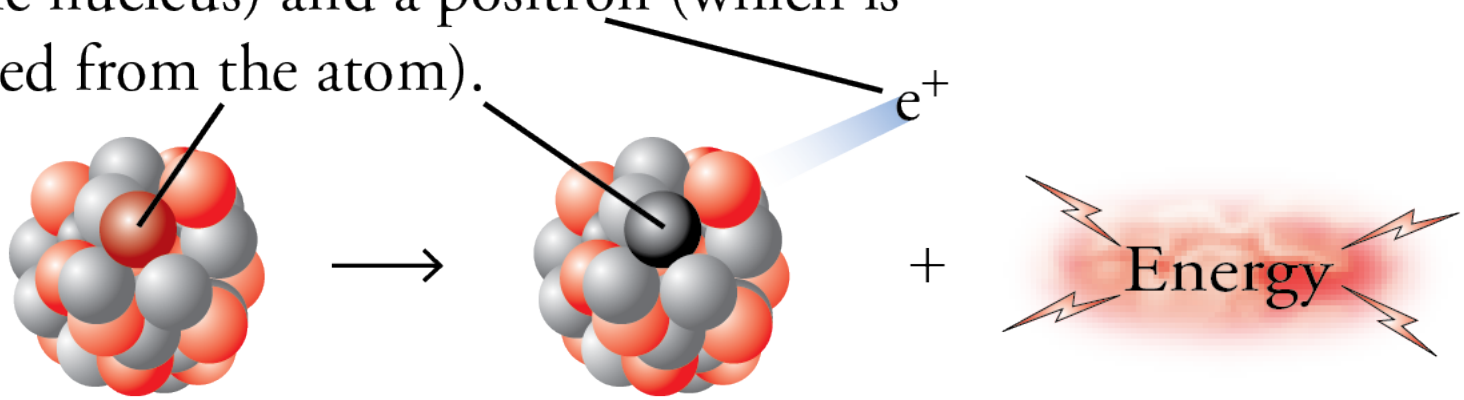
A neutron becomes a proton (which stays in the nucleus) and an electron (which is ejected from the atom).



Positron Emission

$$^{40}_{19}\mathrm{K} \longrightarrow {}^{40}_{18}\mathrm{Ar} + {}^{0}_{+1}\mathrm{e}$$

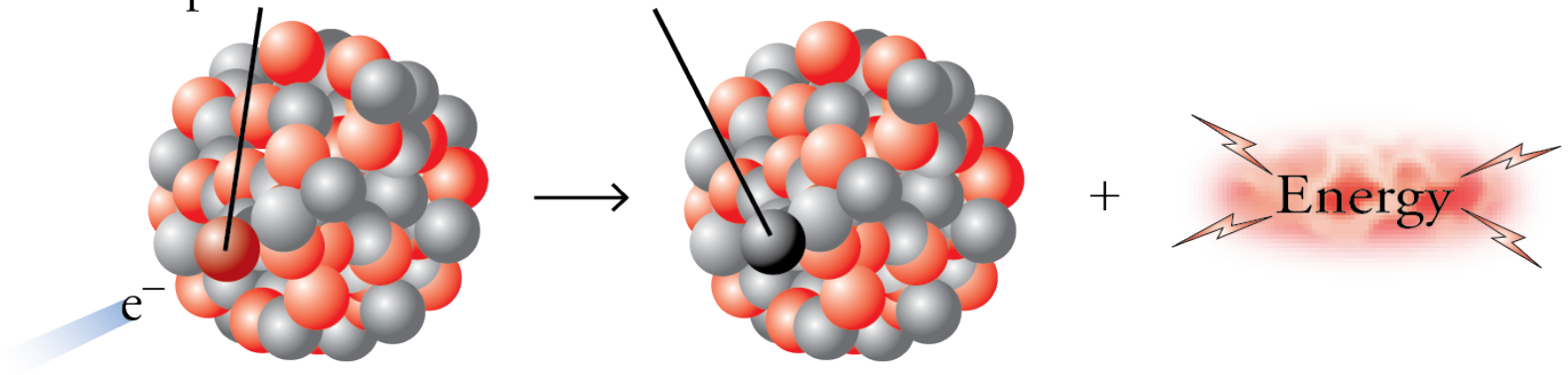
A proton becomes a neutron (which stays in the nucleus) and a positron (which is ejected from the atom).



Electron Capture

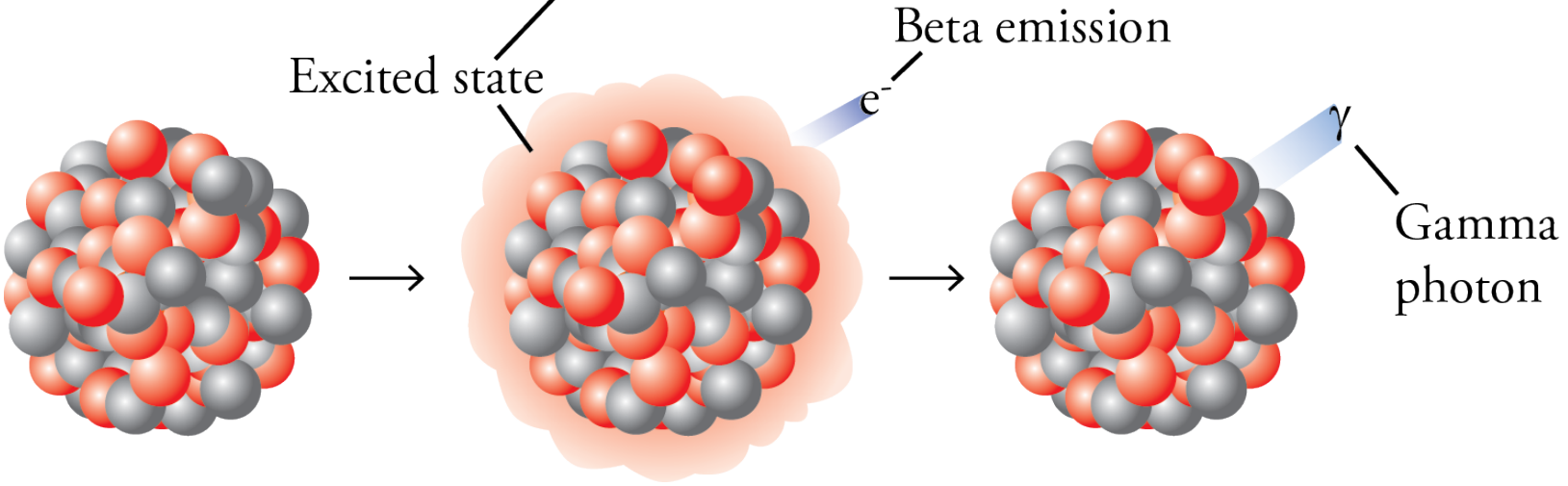
$$ {}^{0}_{-1}e + {}^{125}_{53}I \longrightarrow {}^{125}_{52}Te $$

An electron combines with a proton to form a neutron.



Gamma Emission

$$^{137}_{55}\mathrm{Cs} \longrightarrow {}^{137}_{56}\mathrm{Ba}^{*} + {}^{0}_{-1}\mathrm{e} \longrightarrow {}^{137}_{56}\mathrm{Ba} + \gamma\text{-photon}$$



Nuclear Reactions

- Nuclear reactions involve changes in the nucleus, whereas chemical reactions involve the loss, gain, and sharing of electrons.
- Different isotopes of the same element may undergo very different nuclear reactions, even though an element's isotopes all share the same chemical characteristics.

Nuclear Reactions (2)

- Unlike chemical reactions, the rates of nuclear reactions are unaffected by temperature, pressure, and the presence of other atoms to which the radioactive atom may be bonded.
- Nuclear reactions, in general, give off much more energy than chemical reactions.

Nuclear Equations

Alpha emission

mass number	238			234	+	4	=	238
	$^{238}_{92}\mathrm{U}$	$\longrightarrow$		$^{234}_{90}\mathrm{Th}$	+	$^{4}_{2}\mathrm{He}$		
atomic number	92			90	+	2	=	92

Beta emission

mass number	131			131	+	0	=	131
	$^{131}_{53}\mathrm{I}$	$\longrightarrow$		$^{131}_{54}\mathrm{Xe}$	+	$^{0}_{-1}\mathrm{e}$		
atomic number	53			54	+	(−1)	=	53

Positron emission

mass number	40			40	+	0	=	40
	$^{40}_{19}\mathrm{K}$	$\longrightarrow$		$^{40}_{18}\mathrm{Ar}$	+	$^{0}_{+1}\mathrm{e}$		
atomic number	19			18	+	1	=	19

Electron capture

mass number	0	+	125	=	125			125		
	$^{0}_{-1}\mathrm{e}$	+	$^{125}_{53}\mathrm{I}$			$\longrightarrow$		$^{125}_{52}\mathrm{Te}$		
atomic number	−1	+	53	=	52			52		

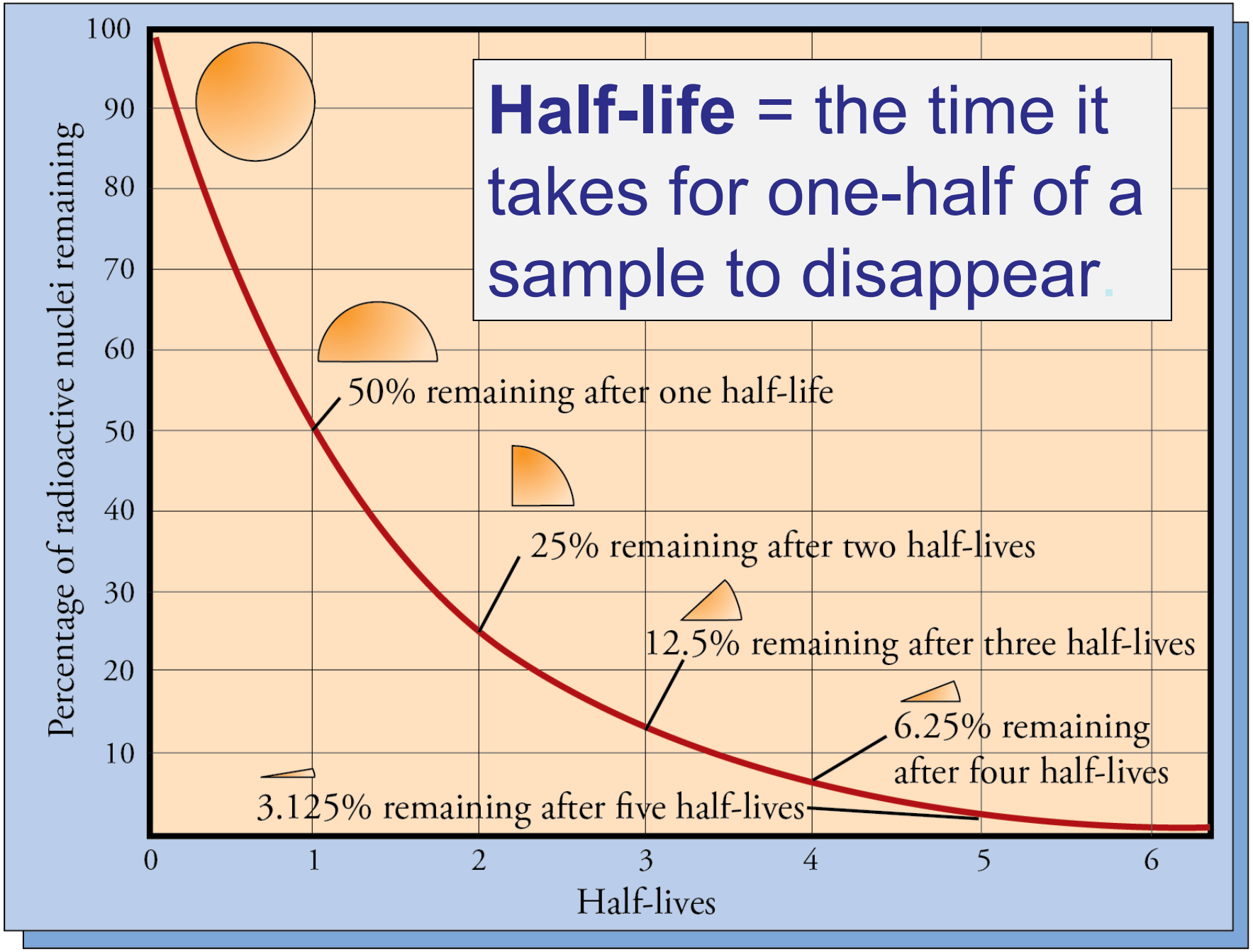
General Nuclear Equations

Alpha emission $\quad {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$

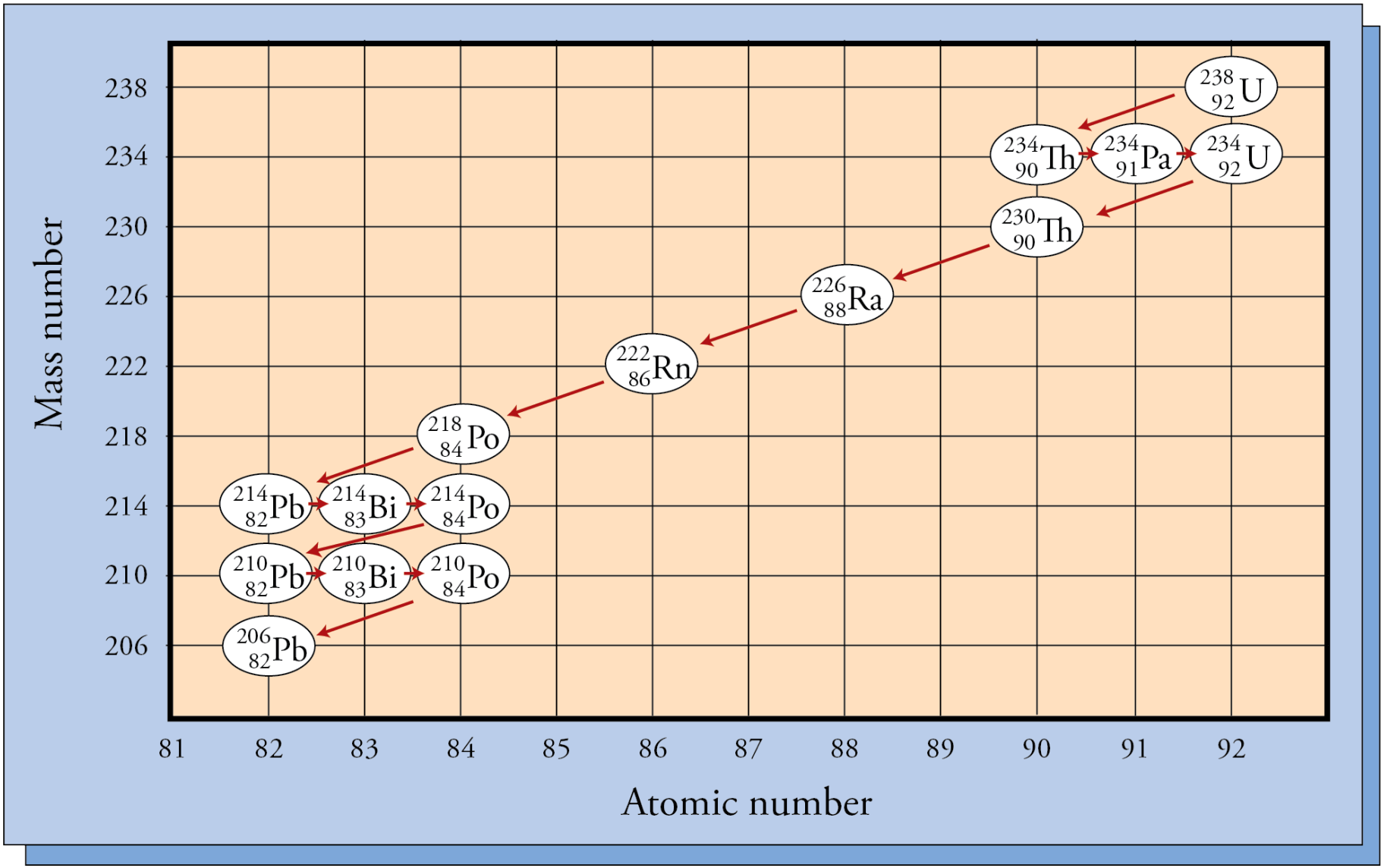
Beta emission $\quad {}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$

Positron emission $\quad {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$

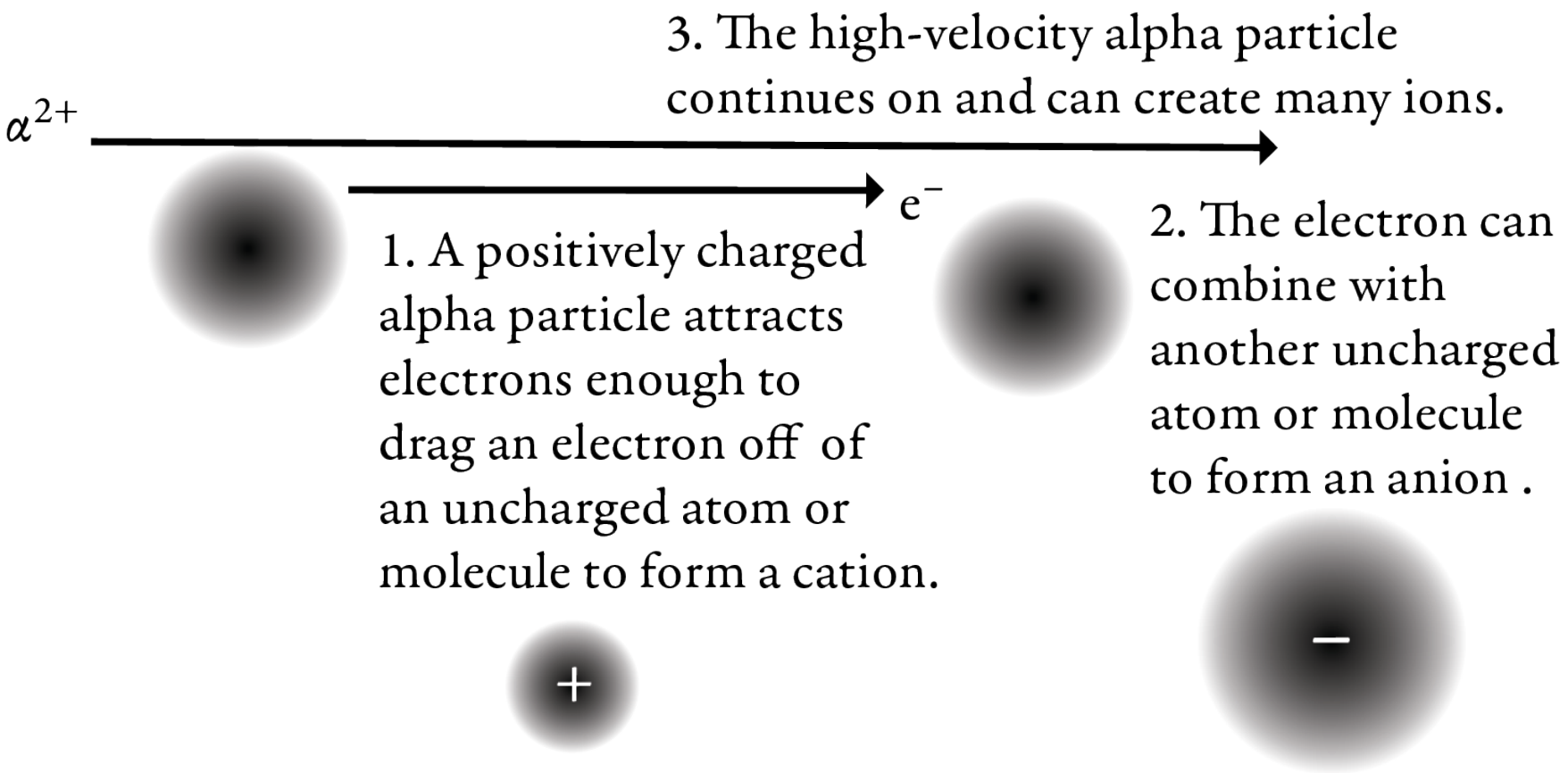
Electron capture $\quad {}^{0}_{-1}e + {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y$


Half-life = the time it takes for one-half of a sample to disappear.
Percentage of radioactive nuclei remaining
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Half-lives
50% remaining after one half-life
25% remaining after two half-lives
12.5% remaining after three half-lives
6.25% remaining after four half-lives
3.125% remaining after five half-lives

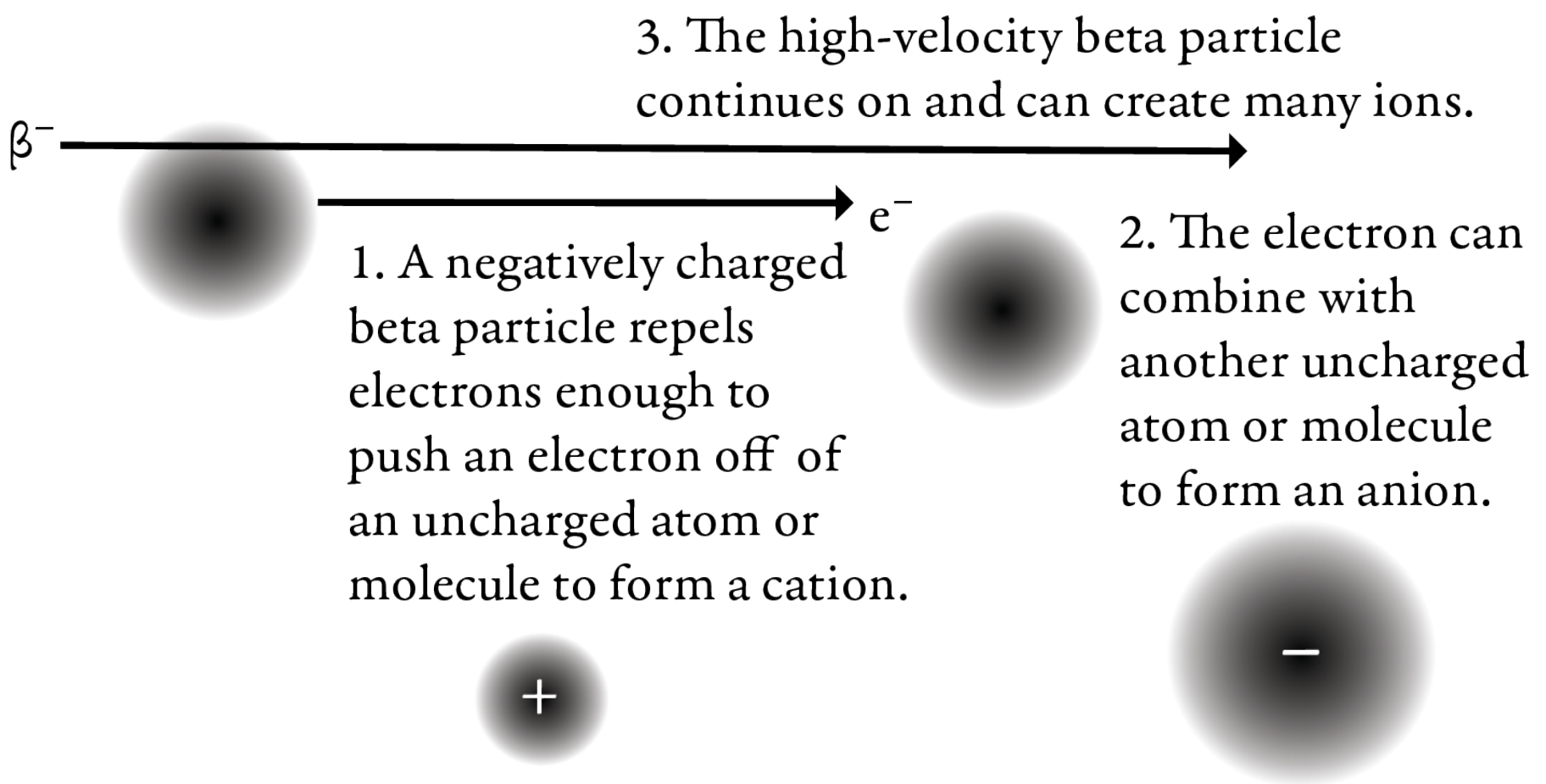
Radioactive Decay Series



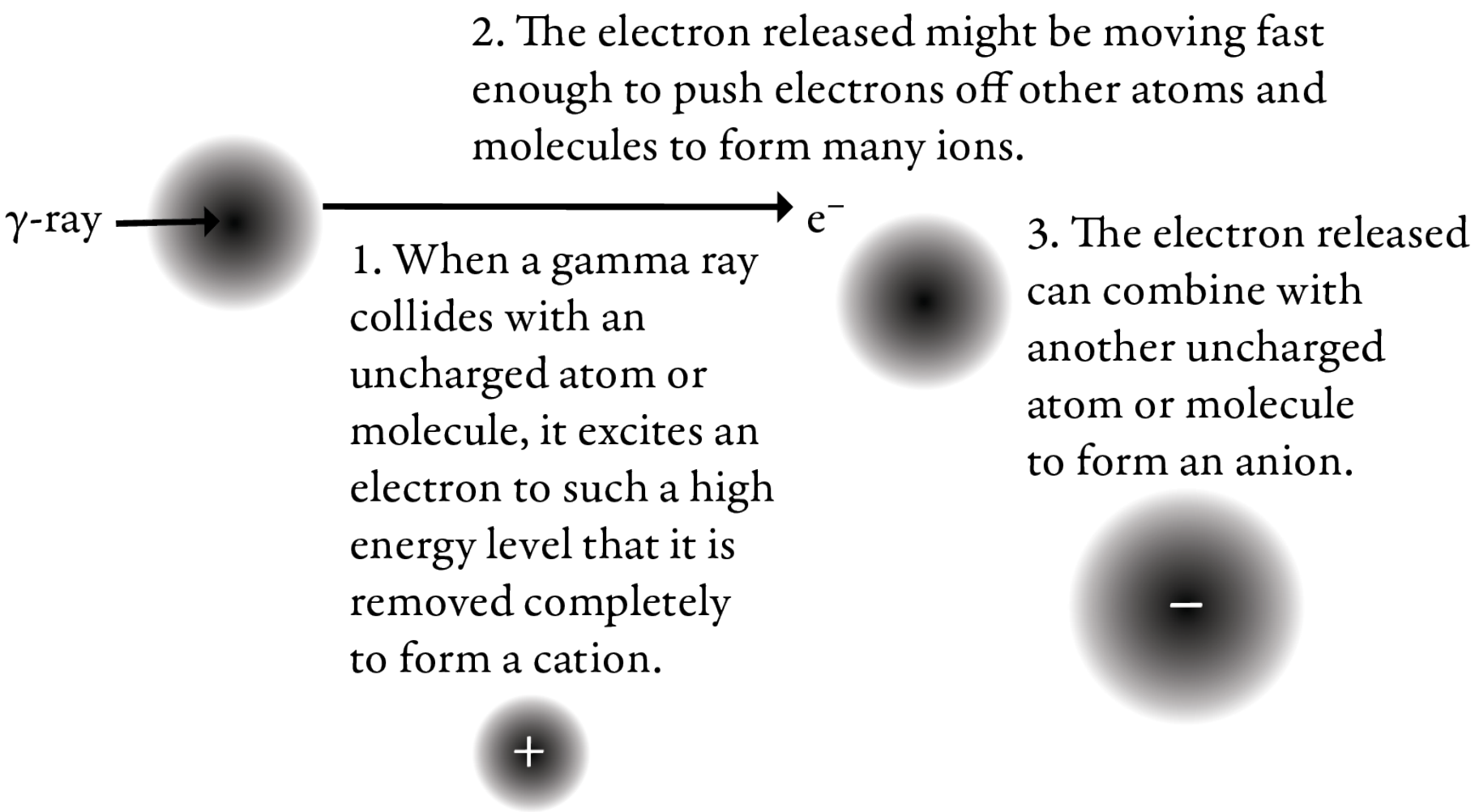
Ionization by Alpha Particles



Ionization by Beta Particles



Ionization by Gamma Rays



Radiation Effect on Body

- As the radioactive emissions ionize atoms and molecules, such as water molecules, they also form highly reactive free radicals, which are particles with unpaired electrons.

$$H_2O \rightarrow H_2O^{\bullet +} + e^-$$

$$H_2O^{\bullet +} + H_2O \rightarrow H_3O^+ + {\bullet}OH$$

$$H_2O + e^- \rightarrow H^{\bullet} + OH^-$$

- These reactive particles react with important substances in the body, leading to immediate damage and delayed problems, such as cancer.

Penetration by Radioactive Emissions

- There is an animation that will provide a review of radioactivity at the following web address.
- A portion of this animation describes the relative penetrating ability of alpha particles, beta particles, and gamma photons.

https://preparatorychemistry.com/radioactivity_Canvas.html