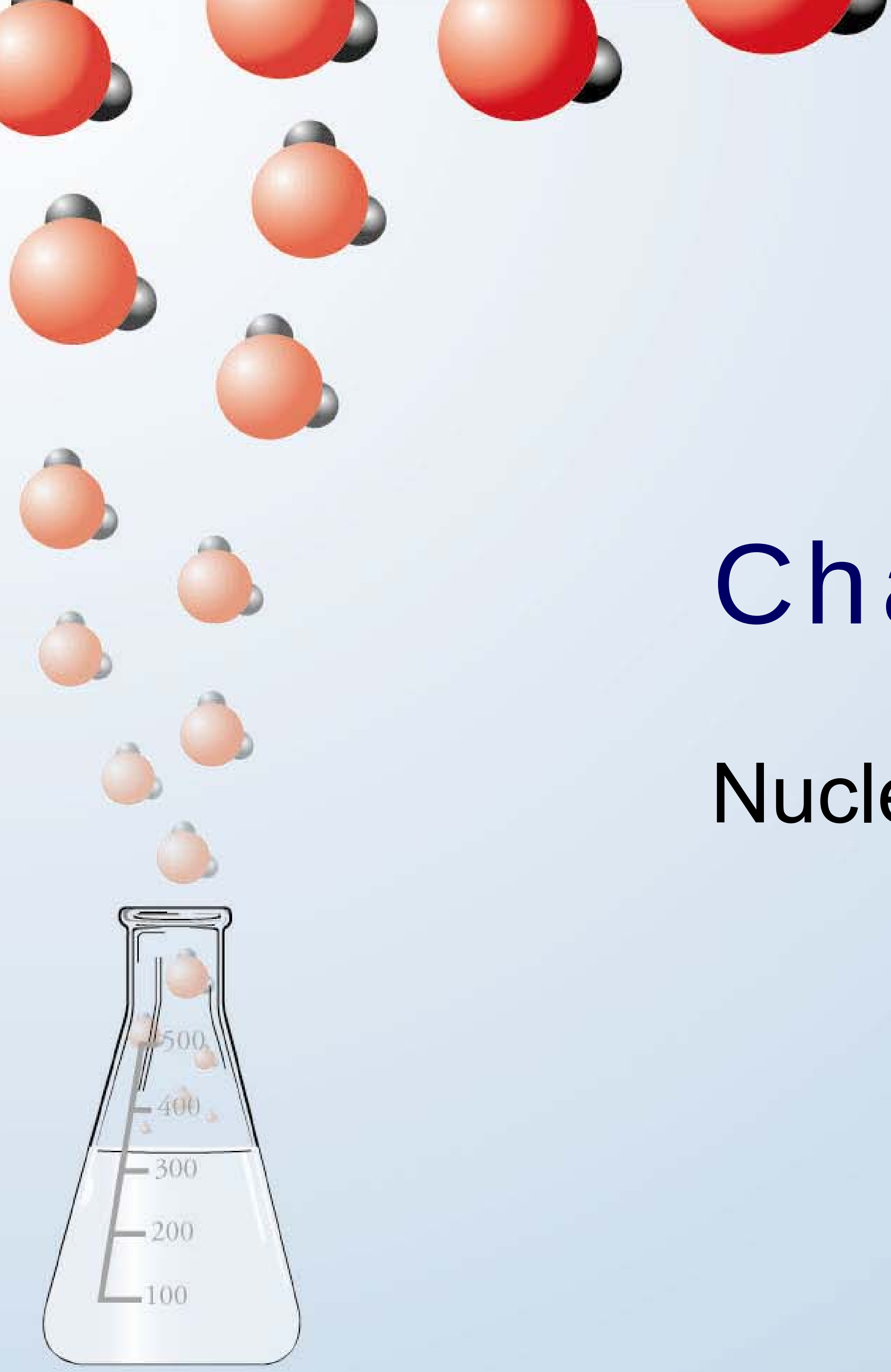
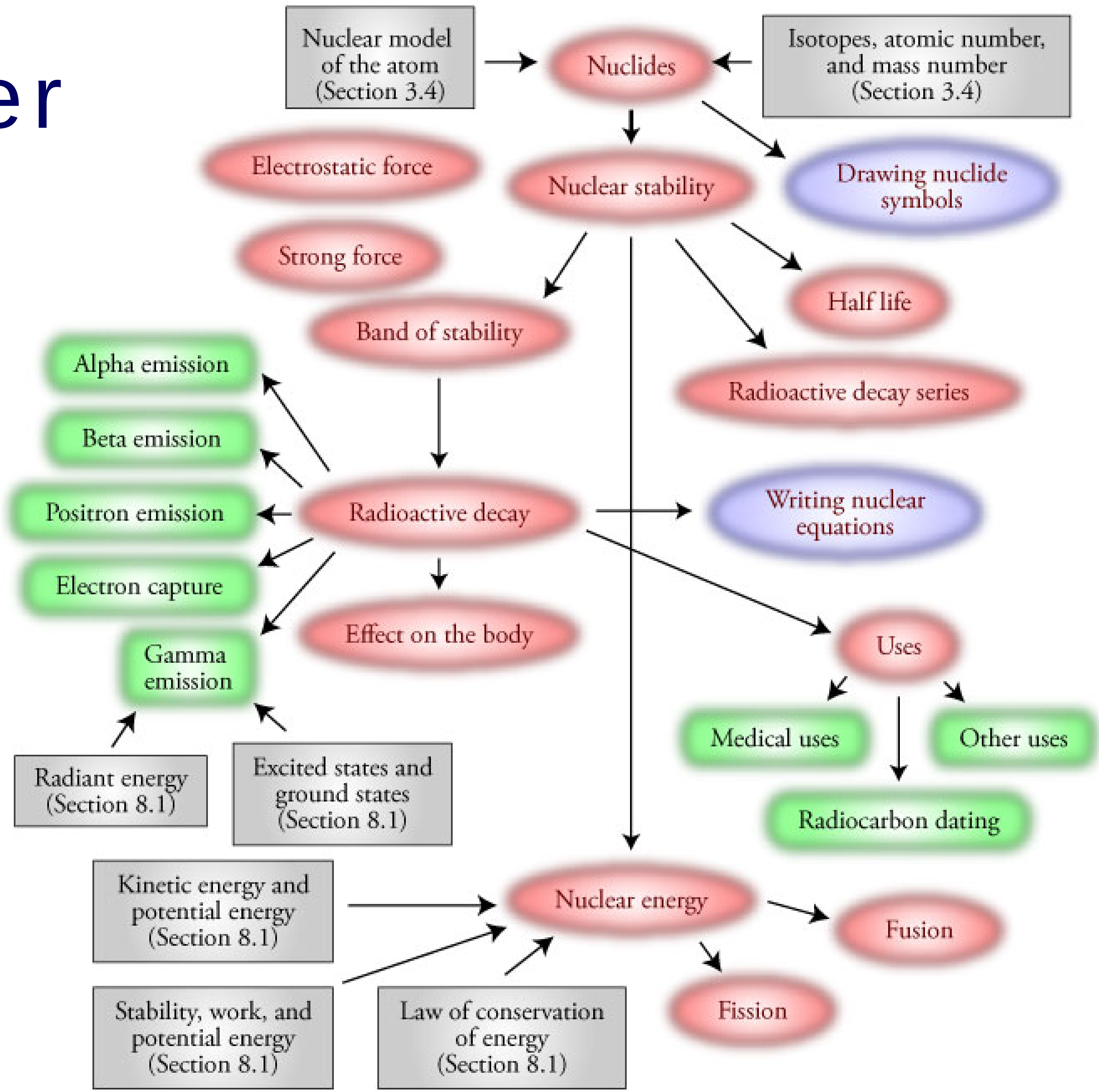


Chapter 18

Nuclear Chemistry

Chapter Map

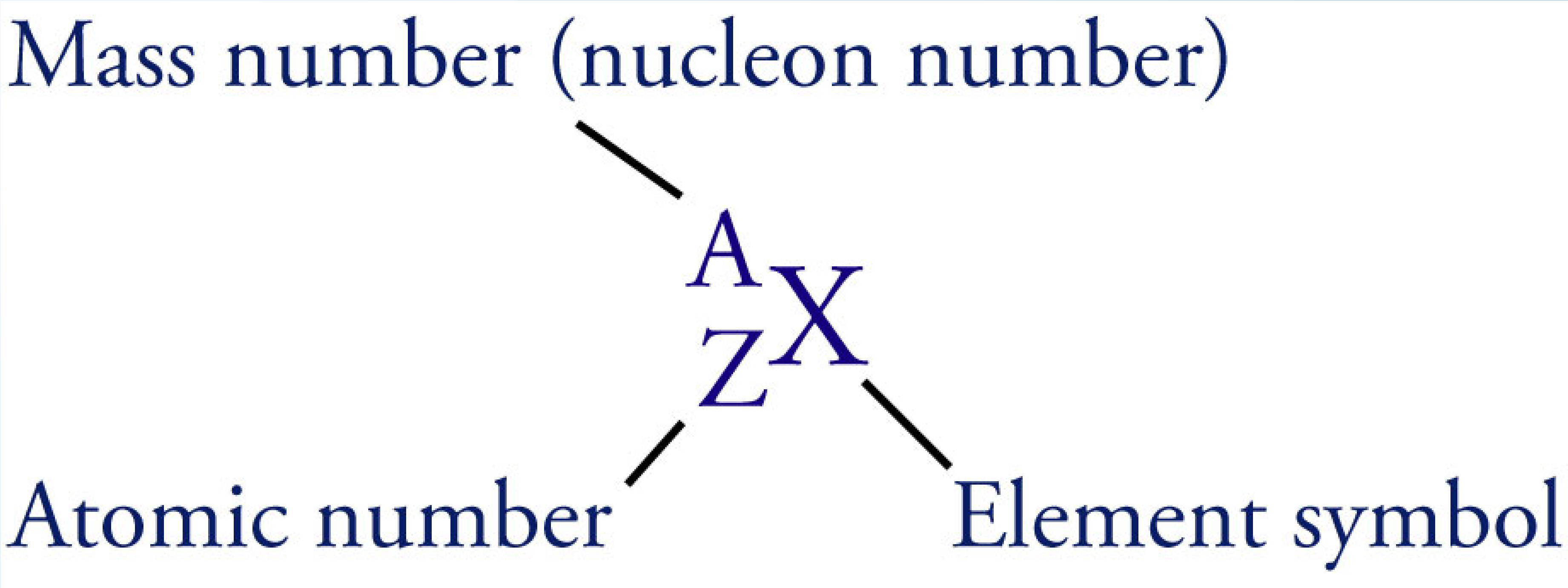


Nuclear model of the atom (Section 3.4)
Nuclides
Isotopes, atomic number, and mass number (Section 3.4)
Electrostatic force
Nuclear stability
Drawing nuclide symbols
Strong force
Half life
Band of stability
Radioactive decay series
Alpha emission
Beta emission
Positron emission
Radioactive decay
Writing nuclear equations
Electron capture
Effect on the body
Gamma emission
Uses
Medical uses
Other uses
Radiocarbon dating
Radiant energy (Section 8.1)
Excited states and ground states (Section 8.1)
Kinetic energy and potential energy (Section 8.1)
Nuclear energy
Fusion
Fission
Stability, work, and potential energy (Section 8.1)
Law of conservation of energy (Section 8.1)

Nuclides

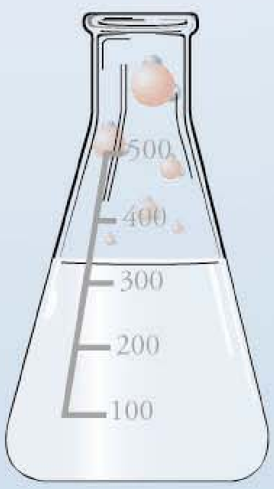
- ***Nuclide*** = a particular type of nucleus, characterized by a specific atomic number and nucleon number
- ***Nucleon number*** or *mass number* = the number of ***nucleons*** (protons and neutrons) in the nucleus of a nuclide.

Nuclide Symbolism

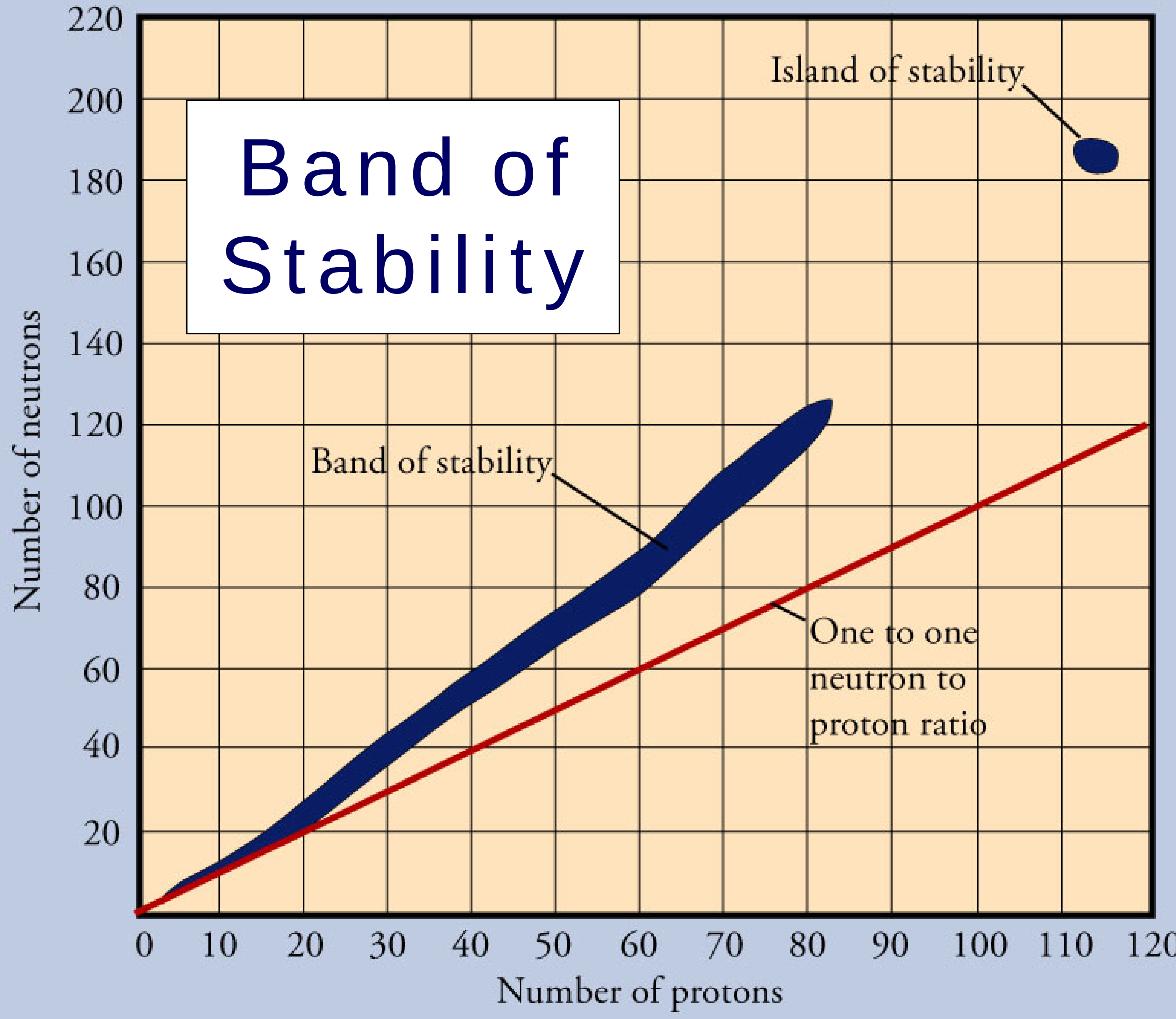


Nuclear Stability

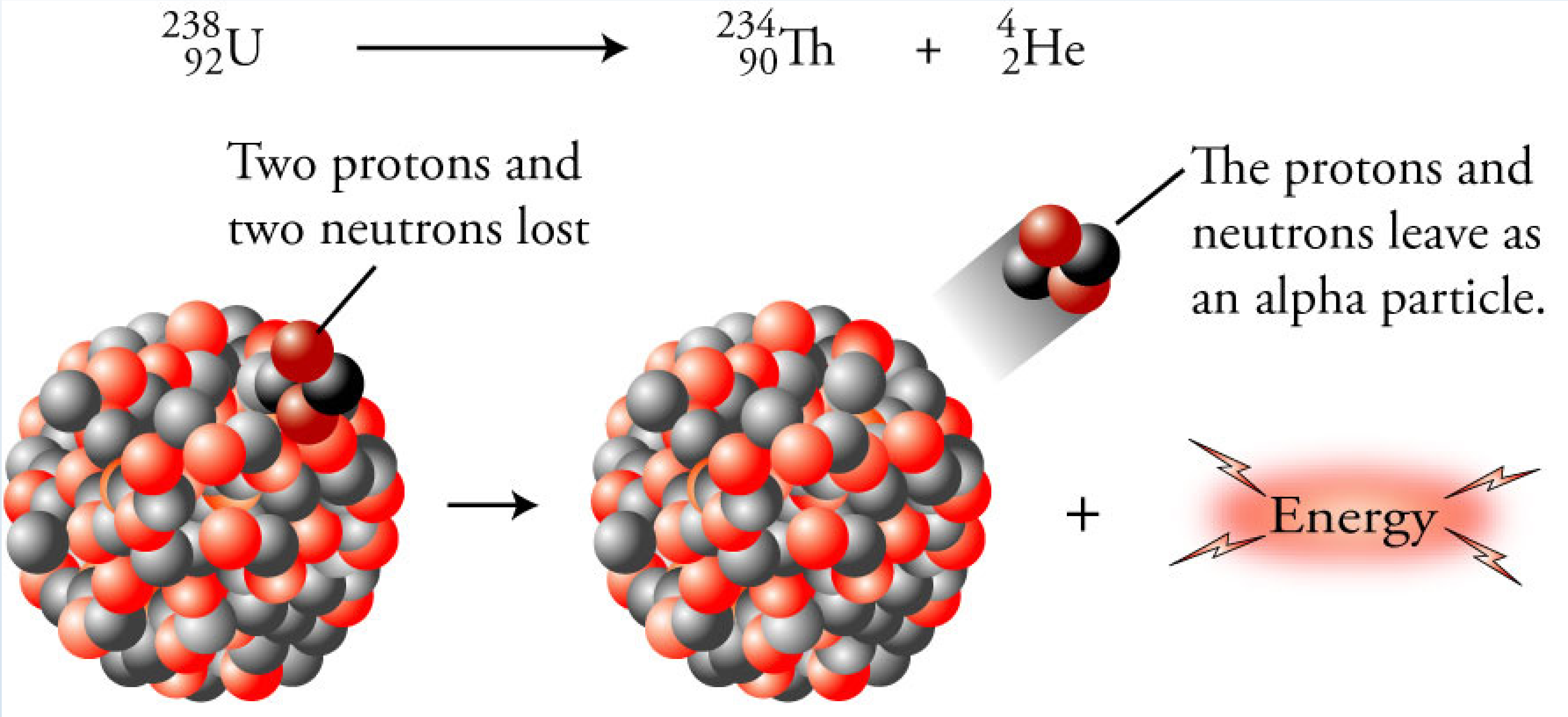
- ***Electrostatic force*** = the force that causes opposite electrical charges to attract each other.
- ***Strong force*** = the force between nucleons (protons and neutrons).
- Neutrons increase the attraction from the strong force without increasing electrostatic repulsion between nucleons.



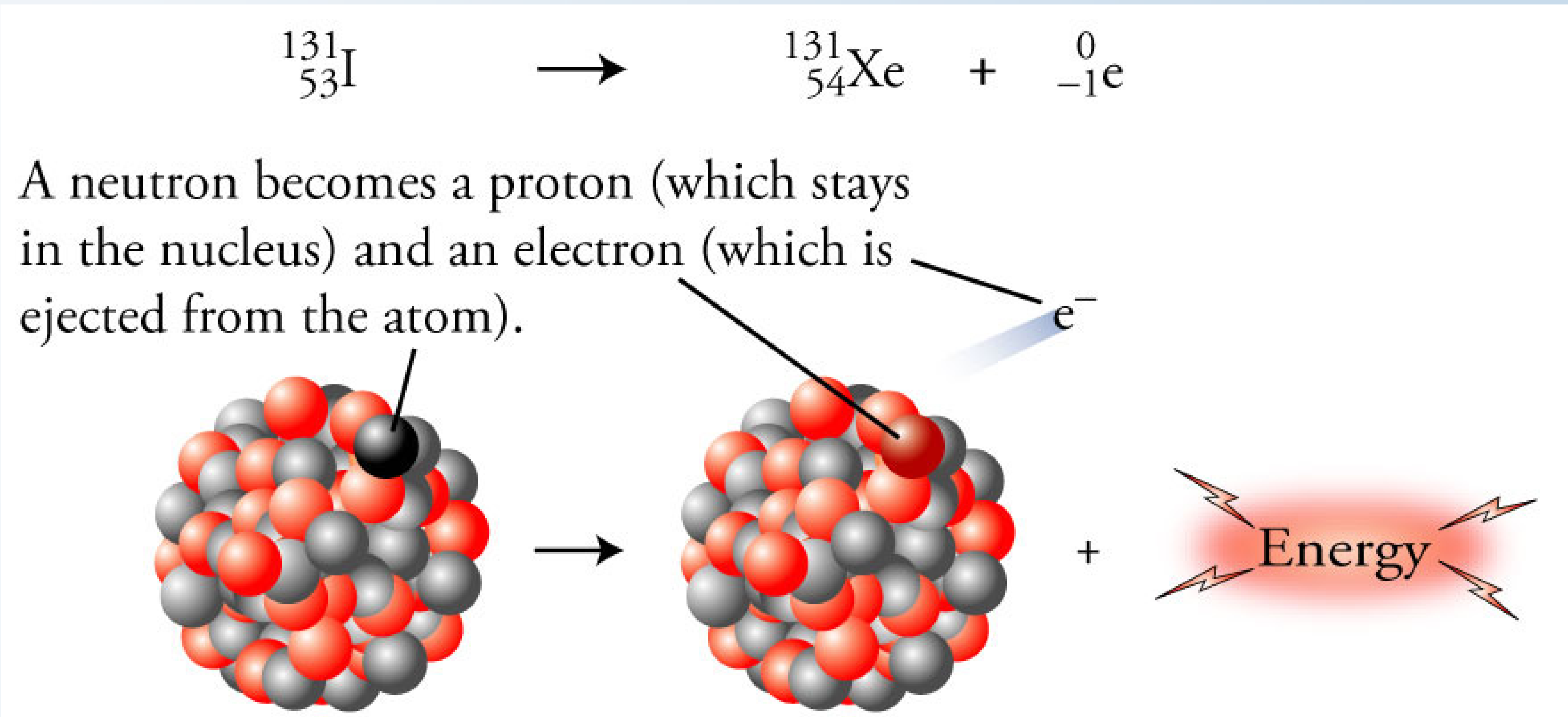
Band of Stability



Alpha Emission



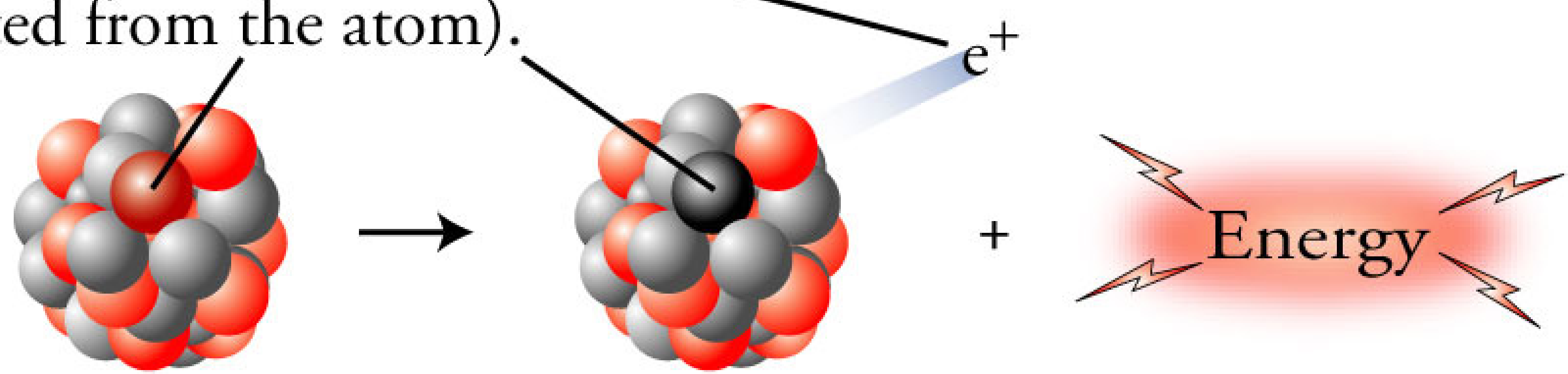
Beta Emission



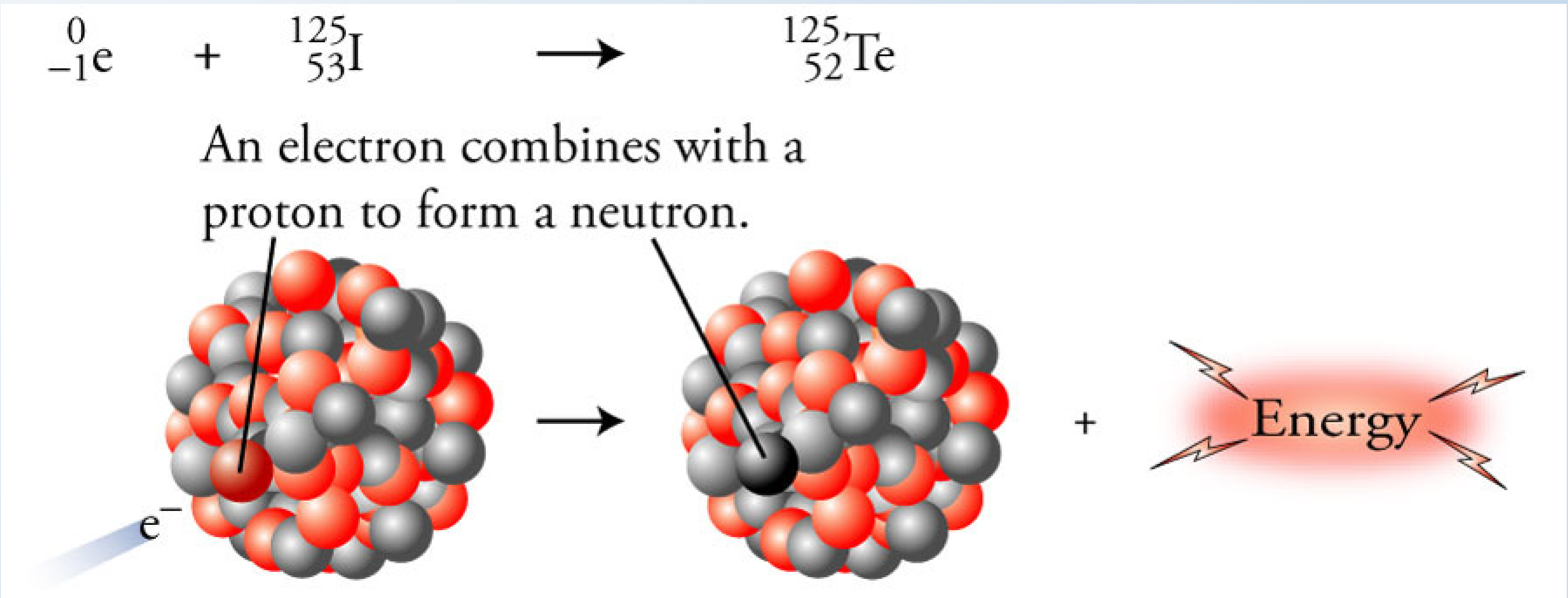
Positron Emission

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

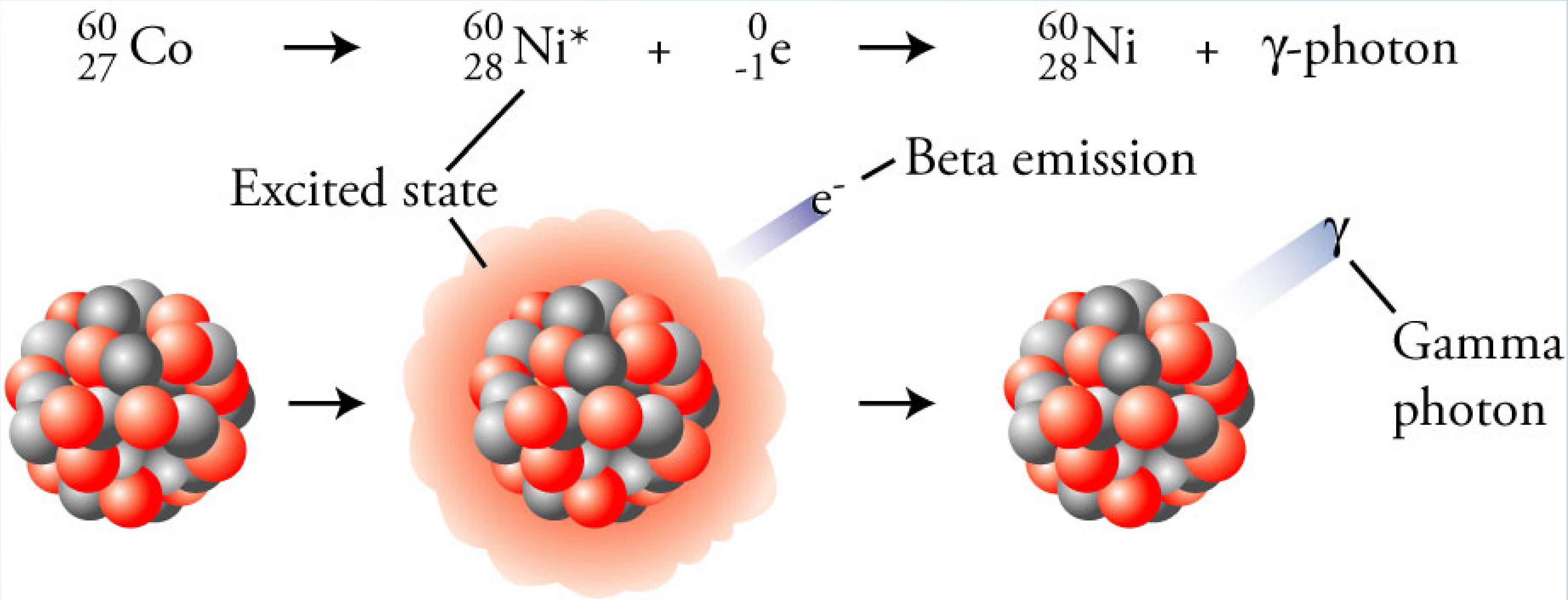
A proton becomes a neutron (which stays in the nucleus) and a positron (which is ejected from the atom).

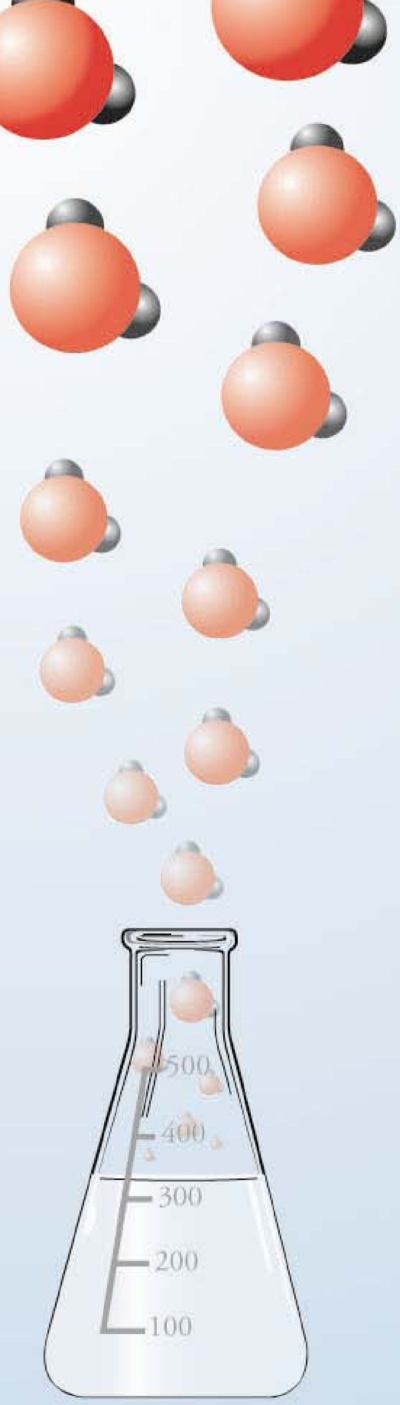


Electron Capture



Gamma Emission





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 (cont.)

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

Beta emission

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

Positron emission

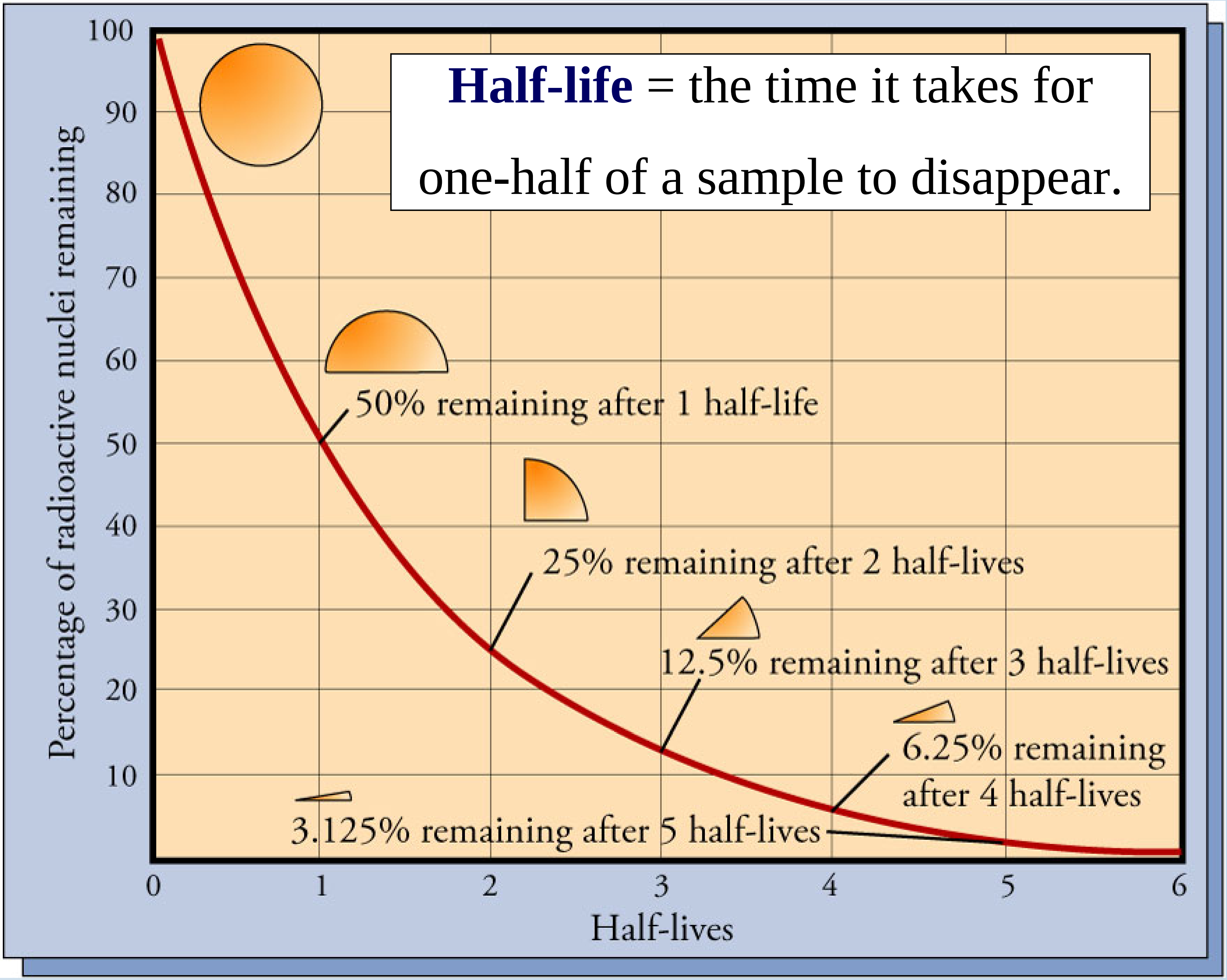
mass number	40		40 + 0	=	40
	$^{40}_{19}K$	$\longrightarrow$	$^{40}_{18}Ar + ^{0}_{+1}e$		
atomic number	19		18 + 1	=	19

Electron capture

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

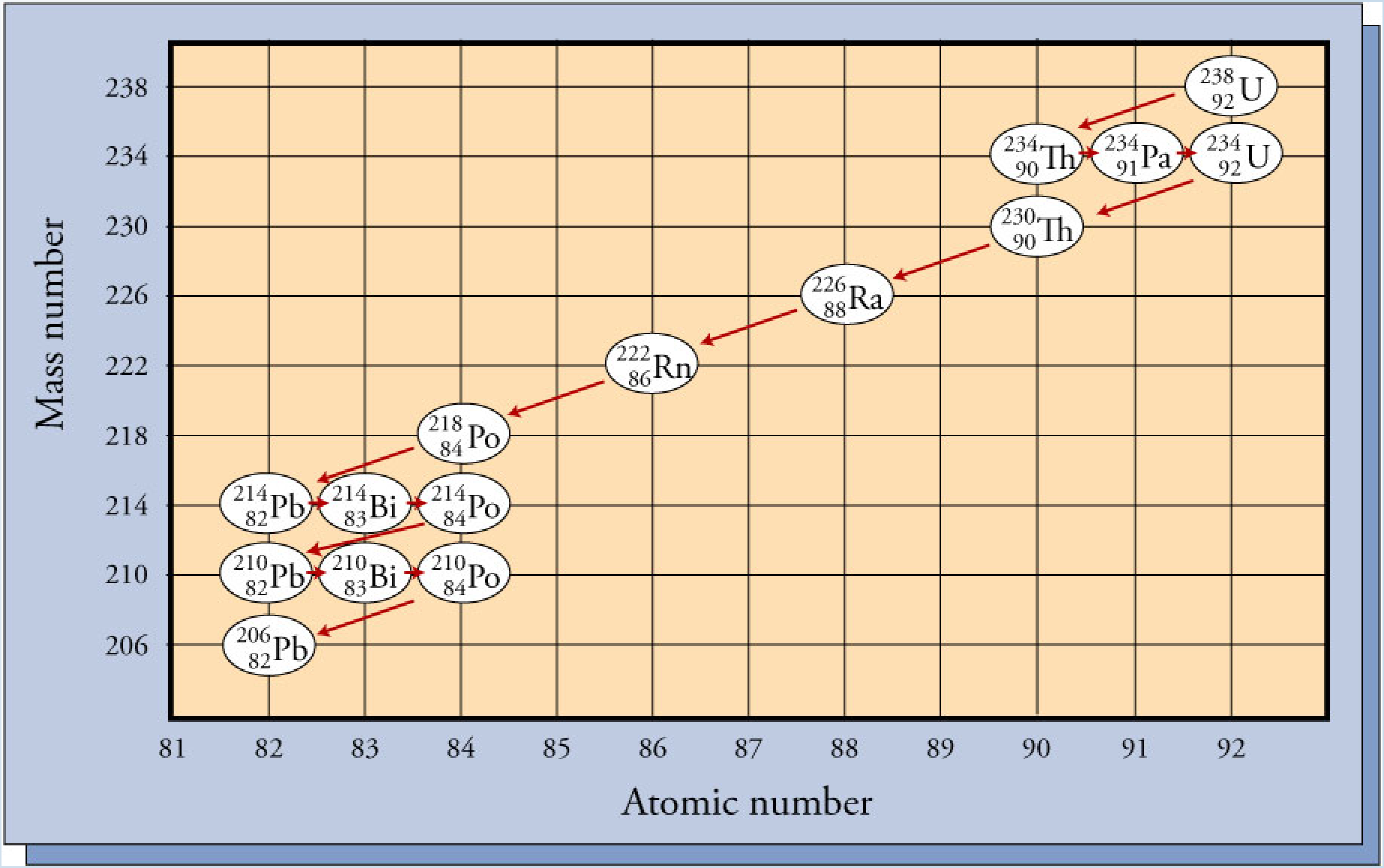
General Nuclear Equations

Alpha emission	${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$
Beta emission	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$
Positron emission	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$
Electron capture	${}^{0}_{-1}e + {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y$

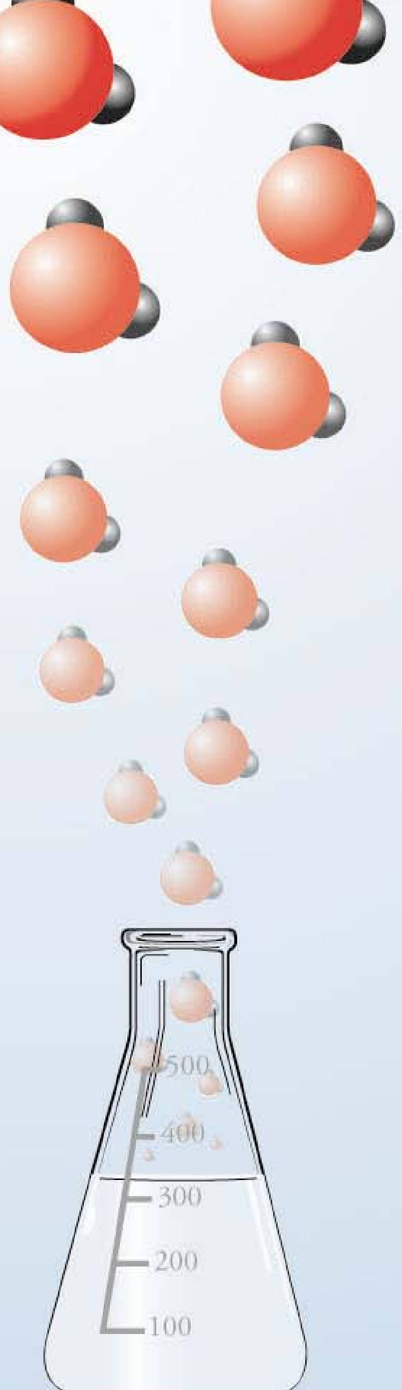


Half-life = the time it takes for one-half of a sample to disappear.
Percentage of radioactive nuclei remaining
100
90
80
70
60
50
40
30
20
10
50% remaining after 1 half-life
25% remaining after 2 half-lives
12.5% remaining after 3 half-lives
6.25% remaining after 4 half-lives
3.125% remaining after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

Radioactive Decay Series



Radiation Effect on Body



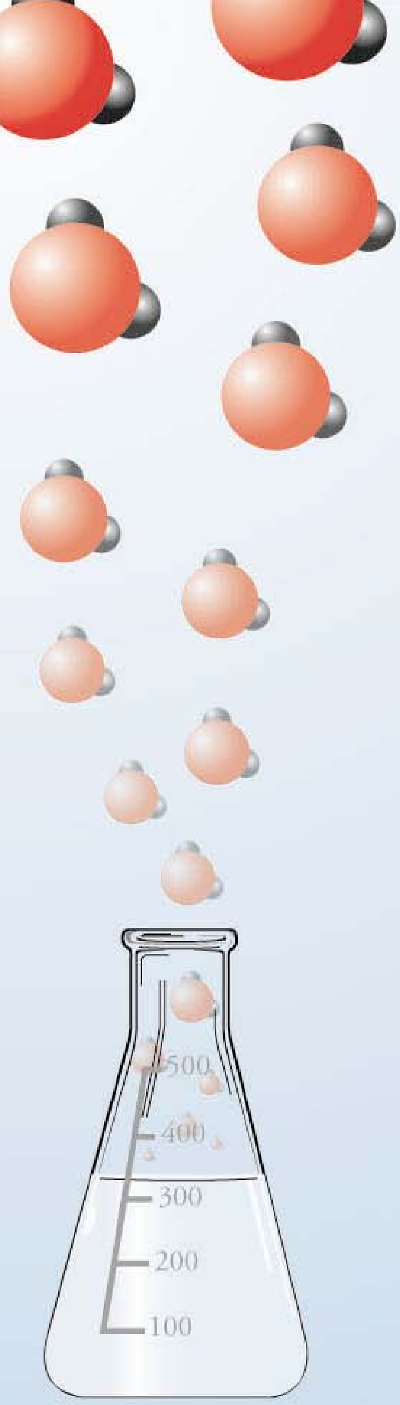
- Radioactive emissions ionize atoms and molecules. This also leads to free radicals (particles with unpaired electrons).

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

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

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

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

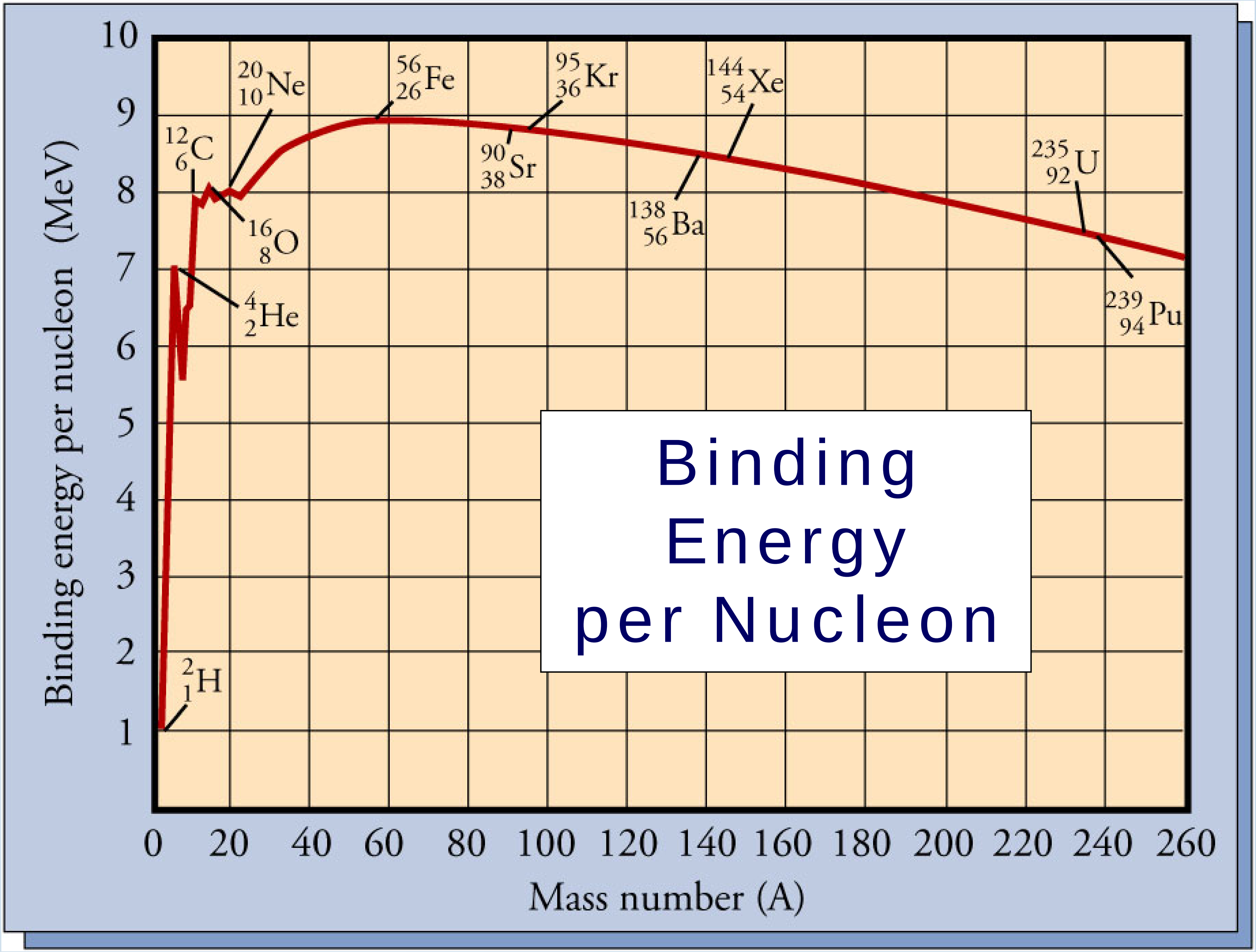


Uses for Radioactive Nuclides

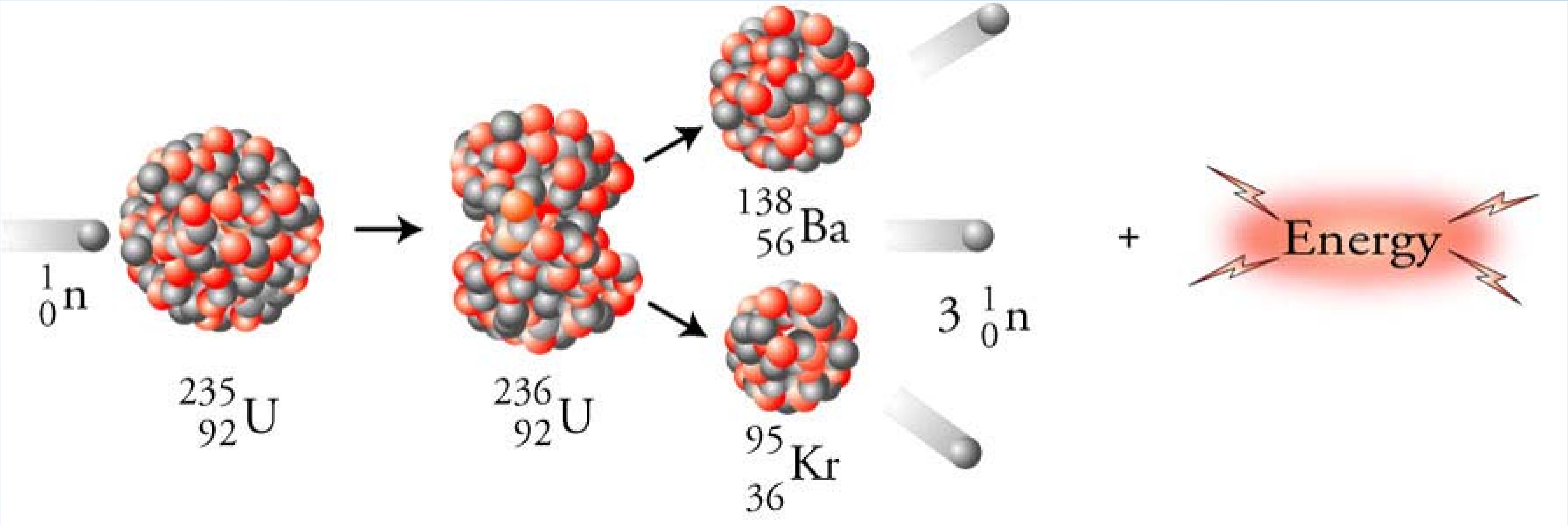
- Cancer radiation treatment
- Computer imaging techniques
- Radiocarbon dating
- Smoke detectors
- Food irradiation
- Radioactive tracers

Nuclear Energy

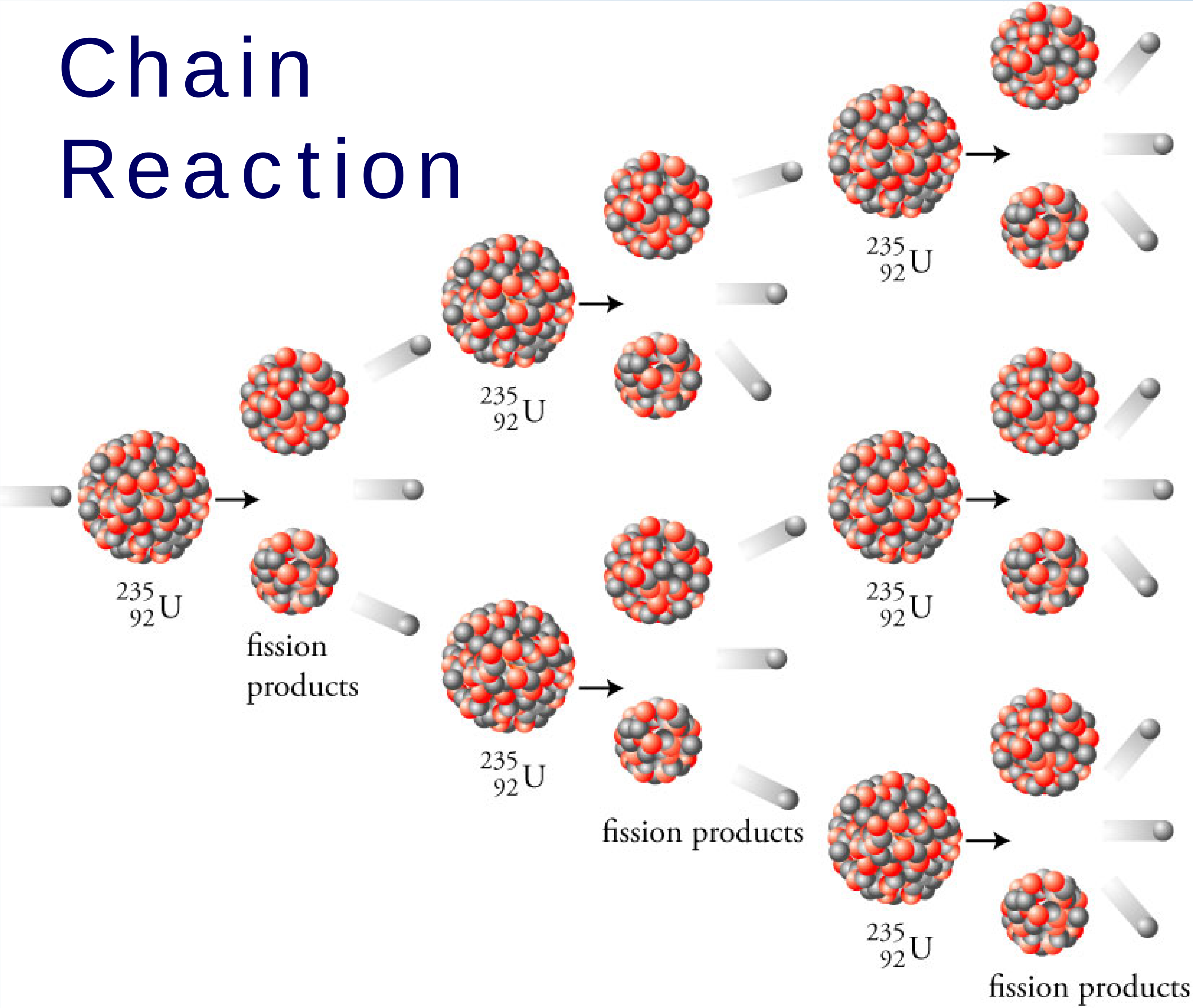
- ***Binding energy*** = the amount of energy released when a nucleus is formed.
- Binding energy per nucleon generally increases from small atoms to atoms with a mass number around 56. Thus fusing small atoms to form medium-sized atoms (***nuclear fusion***) releases energy.
- Binding energy per nucleon generally decreases from atoms with a mass number around 56 to larger atoms. Thus splitting large atoms to form medium-sized atoms (***nuclear fission***) also releases energy.

Binding Energy per Nucleon
Binding energy per nucleon (MeV)
Mass number (A)
10
9
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
140
160
180
200
220
240
260
$^{2}_{1}H$
$^{4}_{2}He$
$^{12}_{6}C$
$^{16}_{8}O$
$^{20}_{10}Ne$
$^{56}_{26}Fe$
$^{90}_{38}Sr$
$^{95}_{36}Kr$
$^{138}_{56}Ba$
$^{144}_{54}Xe$
$^{235}_{92}U$
$^{239}_{94}Pu$

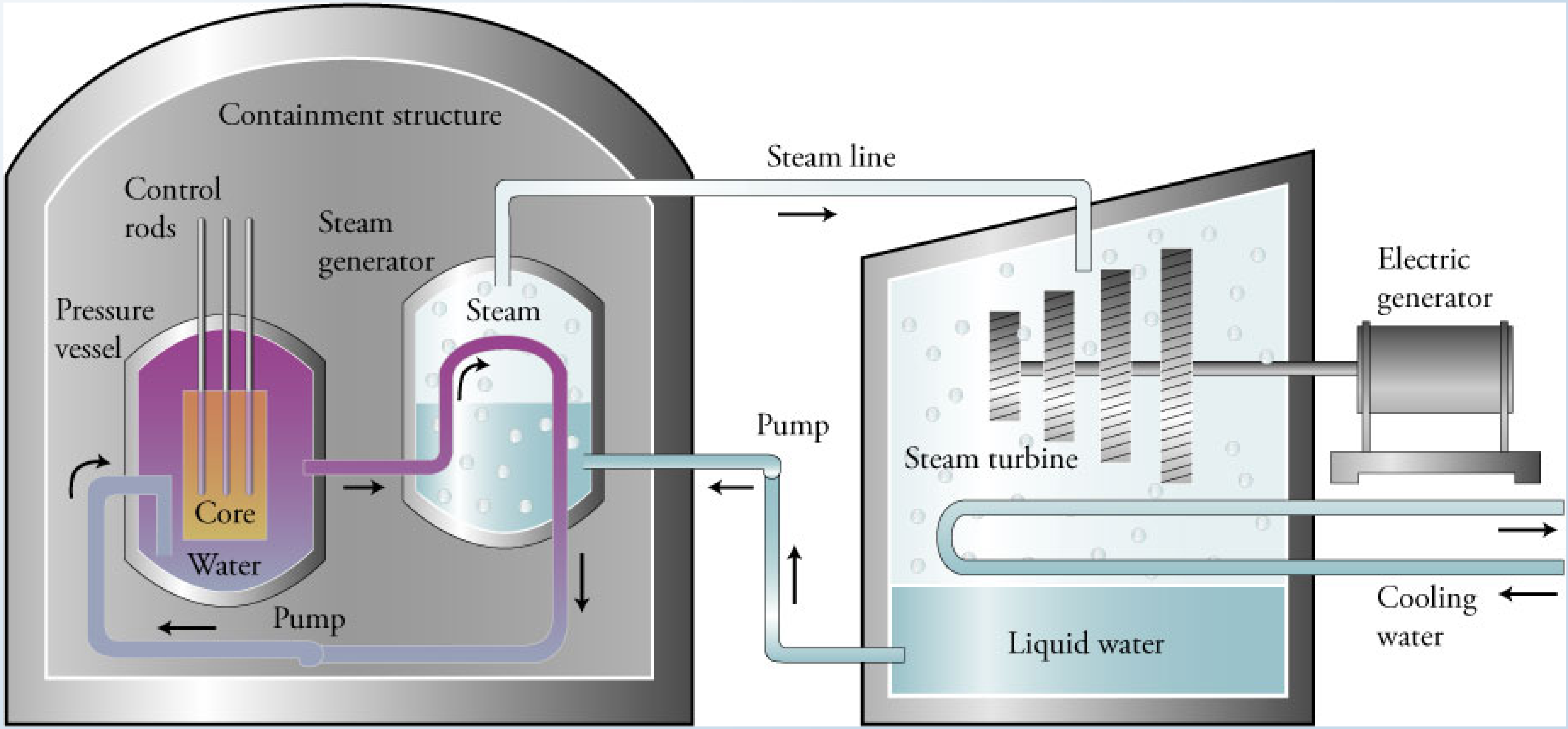
Nuclear Fission



Chain Reaction



Nuclear Reactor



Nuclear Fusion Powers the Sun