N7 - Nuclear Chemistry

PART 1 - CONCEPTS

Introduction to Nuclear Chemistry

- The study of the structure of **atomic nuclei** and the **changes** they undergo.

Nuclear Atomic Symbols

You already know this, don't write

- A chemical symbol looks like…

mass #

$$^{14}_{6}\mathrm{C}$$

atomic #

Remember…to find # of neutrons, subtract mass # - atomic #

Chemical vs. Nuclear Reactions

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Atoms remain unchanged, although they may be rearranged	Atoms often converted into atoms of another element
Involve only valence electrons	May involve protons, neutrons, and electrons
Associated with small energy changes	Associated with large energy changes
Reaction rate influenced by temperature, particle size, concentration, etc.	Reaction rate is not influenced by temperature, particle size, concentration, etc.

Nuclear Reactions

Isotopes of one element are changed into isotopes of another element

- Contents of the **nucleus** change
- **Large** amounts of energy released

Uses of Nuclear Reactions

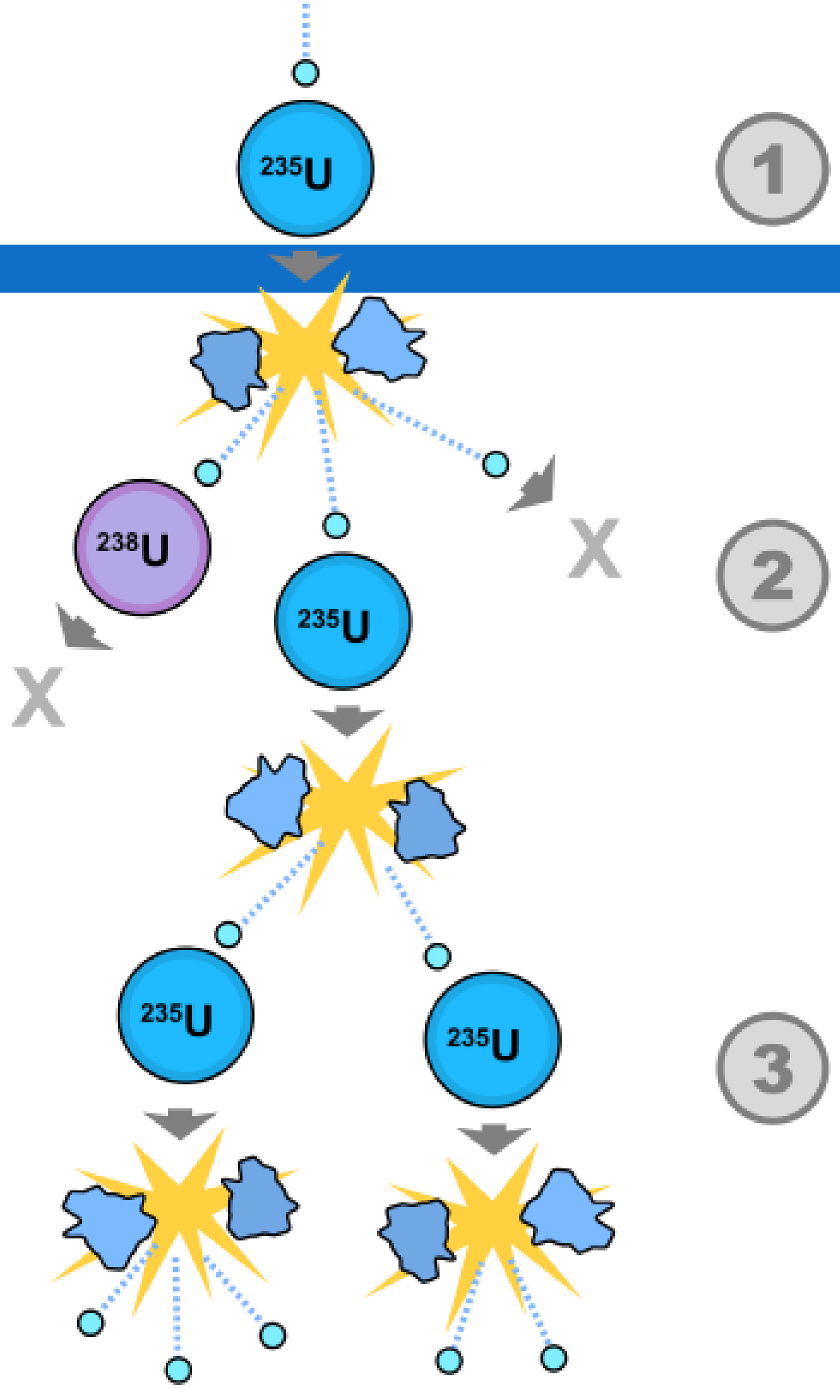
Uncontrolled reactions are dangerous, but when used properly they can be useful!

- Power plants
- Tracking chemical reactions and biological processes
- Radiation therapy for cancer
- Determining the age of dead plants/animals, or even rocks.

Nuclear Fission

- **Splitting of a nucleus**
- **Chain Rxn** – one released particle sets off another atom, keeps happening
- **Nuclear Reactor** – controlled situation, energy released slowly

Nuclear Fission



Nuclear Fission (don't need to write this)

- *1st controlled* nuclear reaction in December 1942.
- *1st uncontrolled* nuclear explosion occurred July 1945.
- **Examples** – atomic bomb, current nuclear power plants

Nuclear Fusion

- **Combining nuclei**
- **Doesn't normally happen** (+ and + repel)
- **Pros** – Inexpensive, no radioactive waste
- **Cons** – Hard to control, large startup energy
- **Examples** – stars, hydrogen bomb, future nuclear power plants

Nuclear Stability

Very Stable	Marginally Stable	Unstable/Radioactive

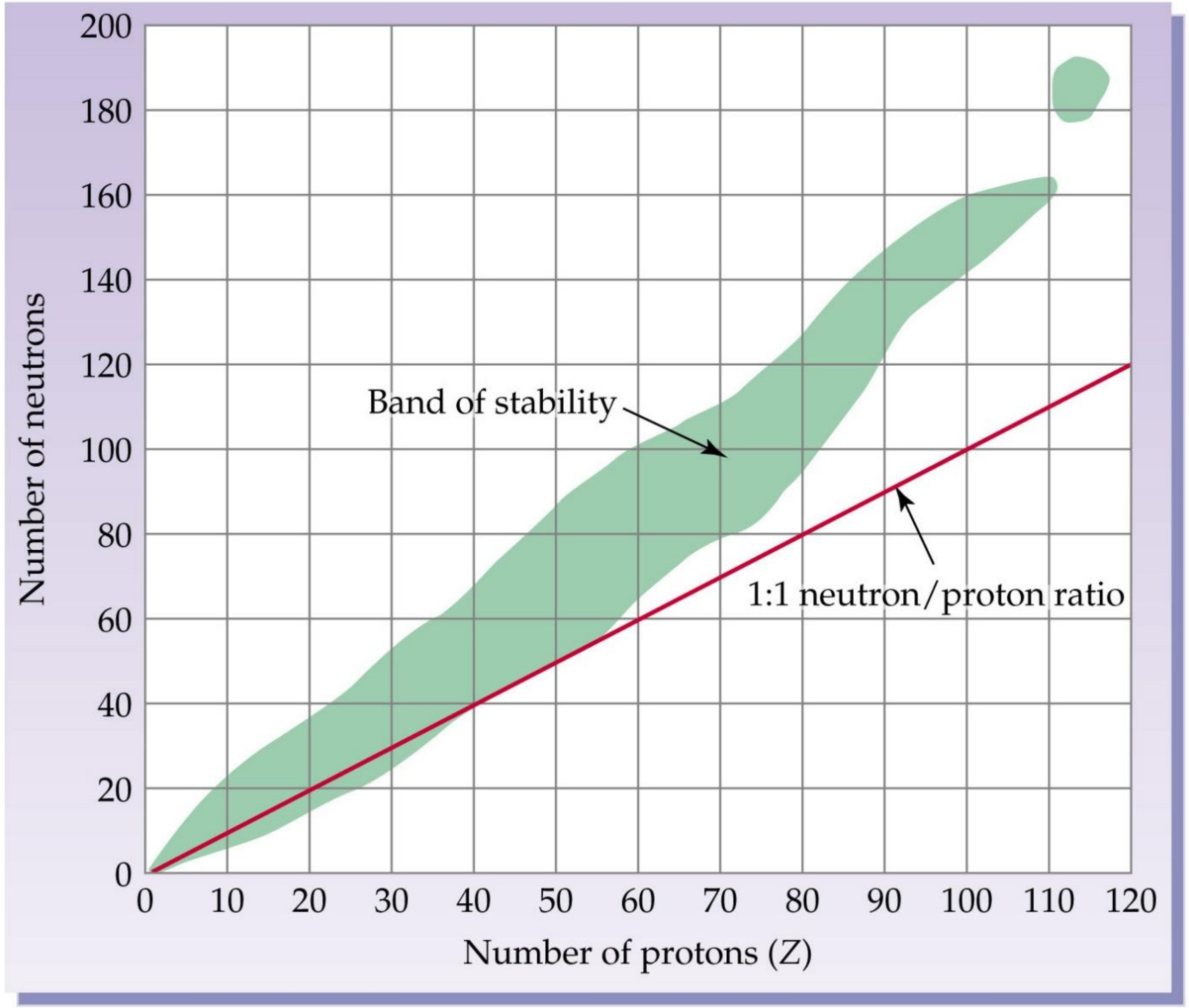
Nuclear Stability

Very Stable	Marginally Stable	Unstable/Radioactive
Atomic #s 1-20	**Atomic #s 21-82**	**Atomic #s > 82**
1:1 ratio Protons : Neutrons	**1:1.5 ratio** Protons : Neutrons	**> 1:1.5 ratio** Protons : Neutrons
Example: Carbon-12 6p : 6n	**Example:** Mercury-200 80p : 120n	**Example:** Uranium Plutonium

What keeps nuclei together?
Why do they fall apart?

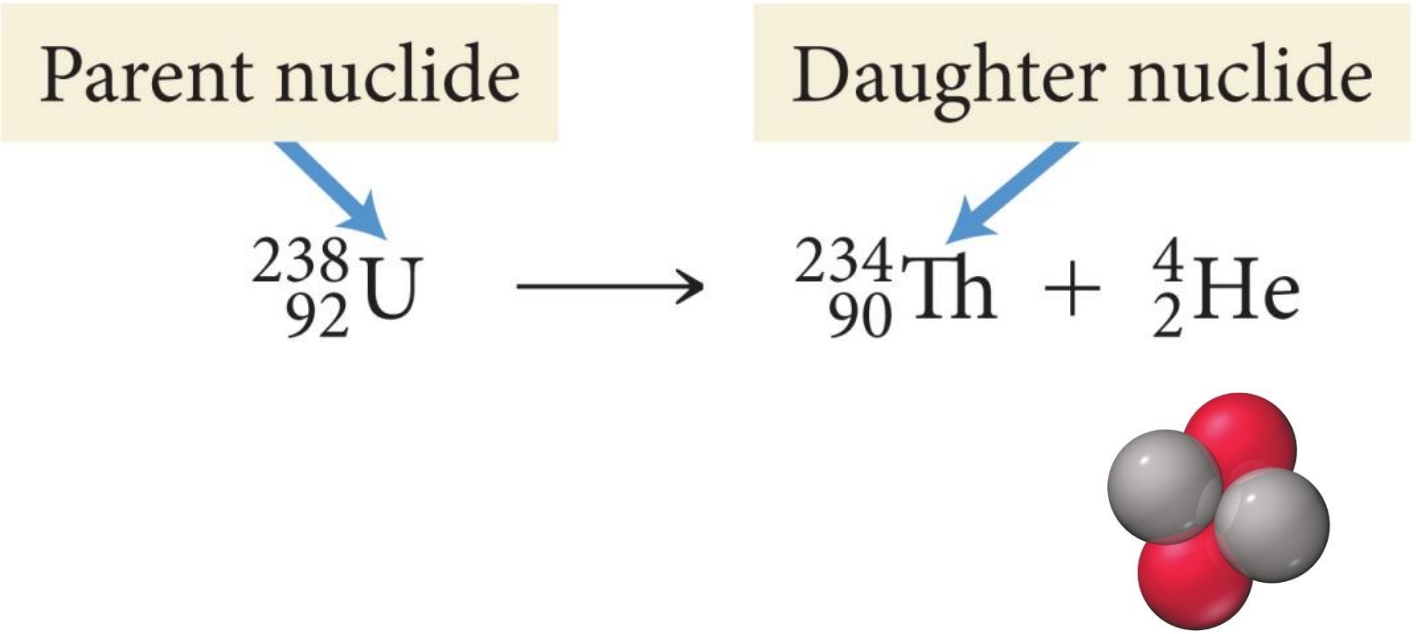
- **STRONG FORCE! –** Holds the nucleus together, even though the protons want to repel each other.
- **Too many neutrons? –** Strong force wont be strong enough, like a rubber band that is stretched too far…it will break!
  - **When it breaks, particles come flying out of the nucleus!**
- **Too many neutrons = radioactive!**

Band of Stability and Island of Stability



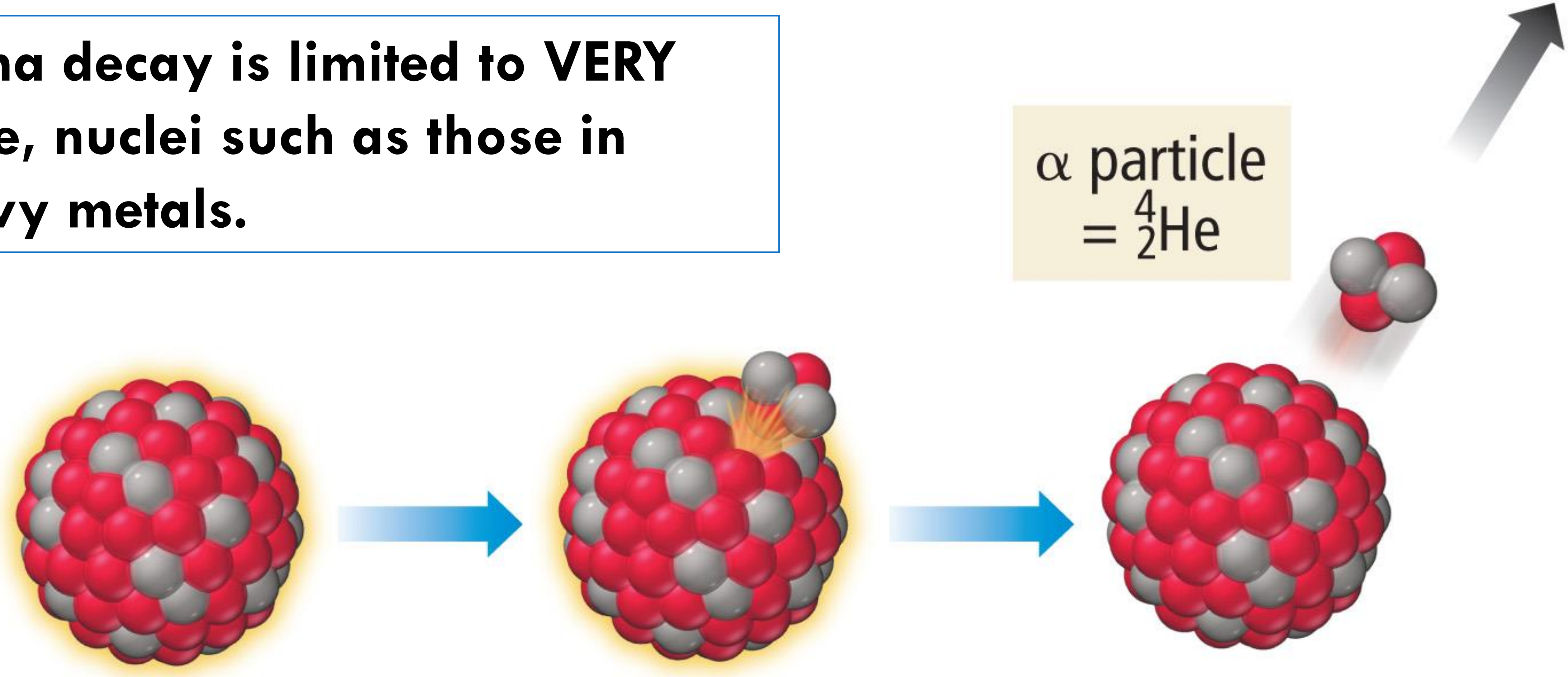
Type of Decay: Alpha Decay

- When an unstable nucleus emits a particle composed of two protons and two neutrons



Alpha Decay

Alpha decay is limited to VERY large, nuclei such as those in heavy metals.



Alpha radiation

Composition	Symbol	Charge	Mass
helium nuclei	${}^{4}_{2}He$, α	+2	4amu
Shielding	**Approx. Energy**	**Penetrating power**	
Paper, clothing	5 MeV	Low 0.05mm body tissue	

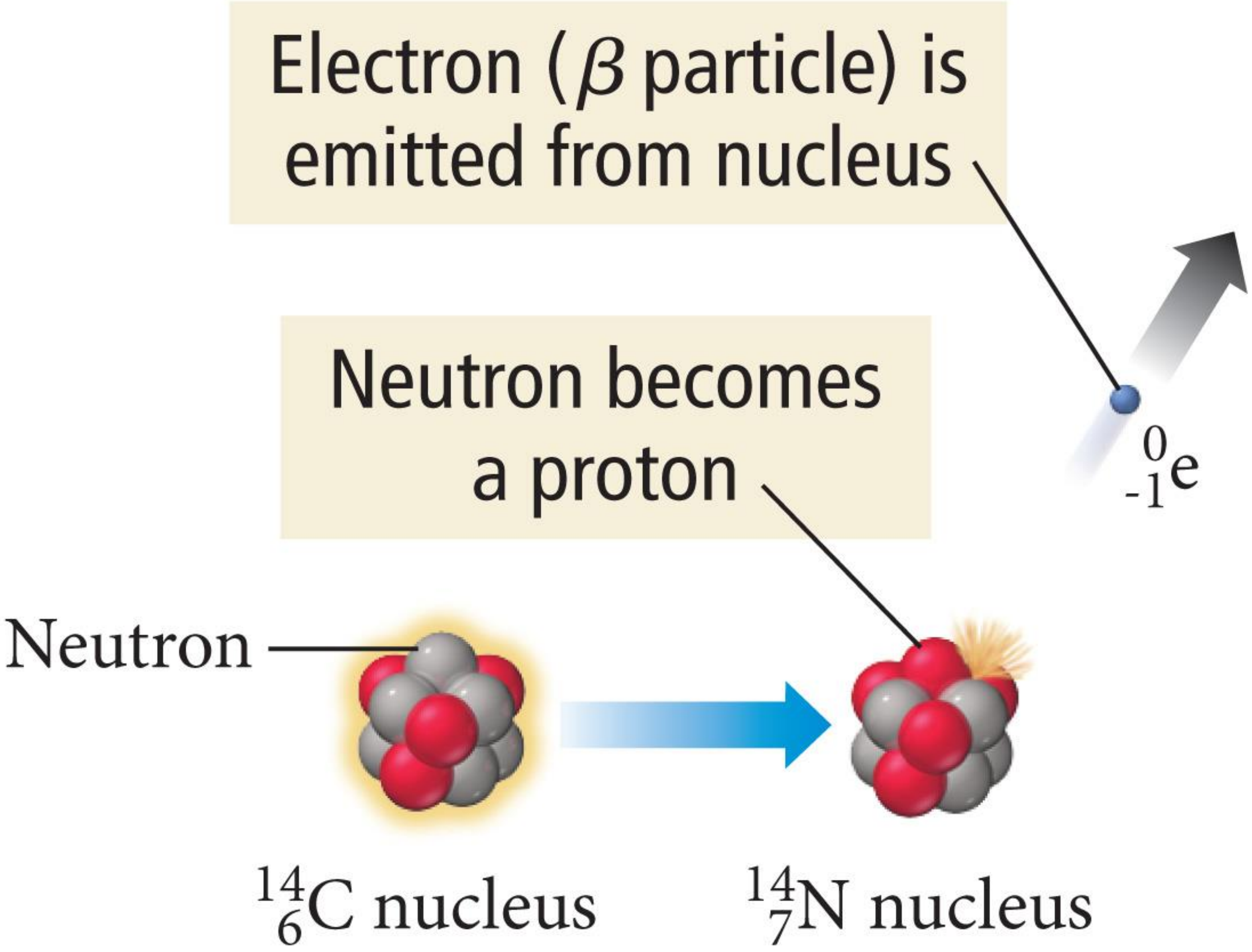
Type of Decay - Beta Decay

- When an unstable nucleus emits an electron

$$^{228}_{88}\mathrm{Ra} \longrightarrow {}^{228}_{89}\mathrm{Ac} + {}^{0}_{-1}\mathrm{e}$$

Beta Decay

Beta decay converts a neutron into a proton.



Beta radiation

Composition	Symbol	Charge	Mass
Same as an electron	e^-, β	-1	1/1837th (basically 0)
Shielding	**Approx. Energy**	**Penetrating power**	
Aluminum foil	0.05-1MeV	Moderate 4mm body tissue	

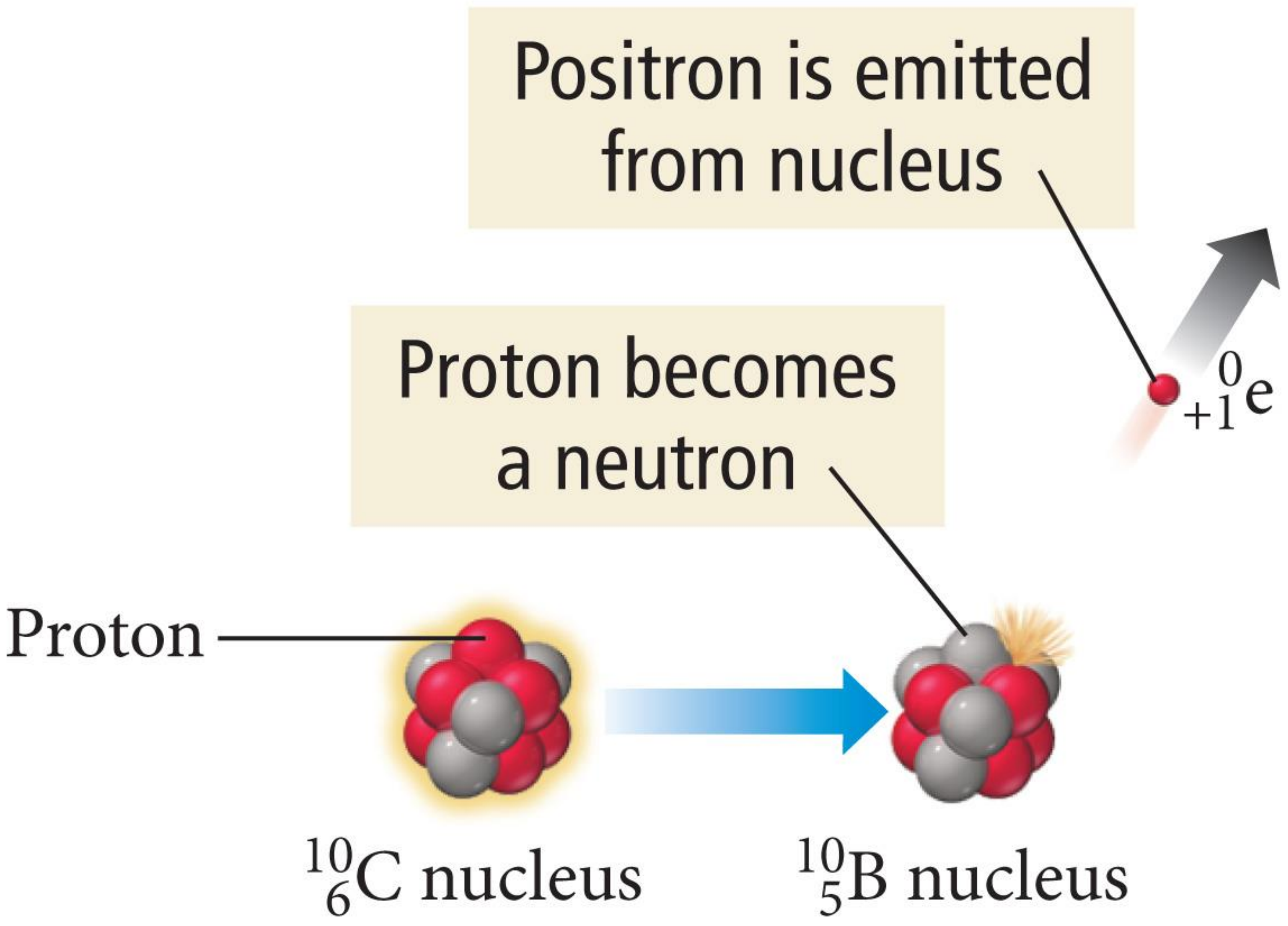
Type of Decay - Positron Emission

- Like a beta particle, but has a charge of +1

$$^{30}_{15}\mathrm{P} \longrightarrow {}^{30}_{14}\mathrm{Si} + {}^{0}_{+1}\mathrm{e}$$

Positron Emission

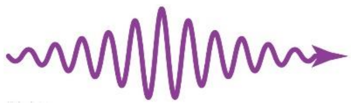
Positrons result from a proton changing into a neutron.



Type of Decay - Gamma Emission

- High energy photons.
- No loss of particles from the nucleus
- Usually after the nucleus undergoes some other type of decay and the remaining particles rearrange

$$^{238}_{92}U^{*} \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He + {}^{0}_{0}\gamma$$



Gamma radiation

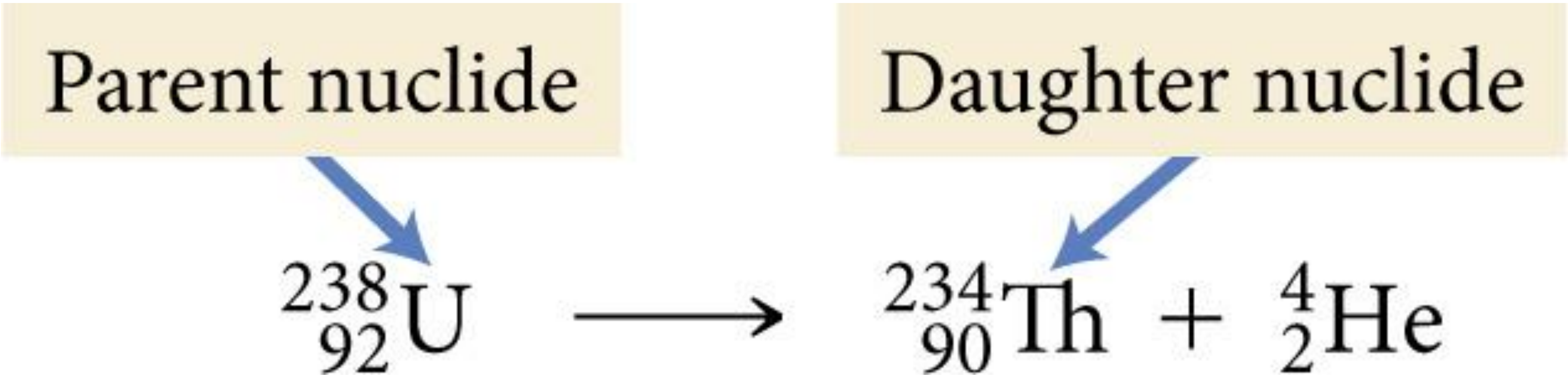
Composition	Symbol	Charge	Mass
High energy electromagnetic radiation	γ	0	0

Shielding	Approx. Energy	Penetrating power
Lead, Concrete	1MeV	High Penetrates easily

PART 2 –BALANCED NUCLEAR EQUATIONS

Nuclear Equations

- Mass numbers and atomic numbers are **conserved**.
- We can use this fact to determine the identity of a daughter nuclide if we know the parent and type of decay.



Example 1: Write the nuclear equation for the radioactive decay of polonium – 210 by alpha emission.

Step 1: Write the element that you are starting with.

Mass #

$$^{210}_{84}Po$$

Atomic #

Example 1: Write the nuclear equation for the radioactive decay of polonium – 210 by alpha emission.

Step 2: Draw the arrow.

Mass #

$$^{210}_{84}\mathrm{Po} \rightarrow$$

Atomic #

Example 1: Write the nuclear equation for the radioactive decay of polonium – 210 by alpha emission.

Step 3: Write the alpha particle.

Mass #

$$^{210}_{84}Po \rightarrow \, ^{4}_{2}He$$

Atomic #

<u>Example 1</u>: Write the nuclear equation for the radioactive decay of polonium – 210 by alpha emission.

Step 4: Determine other product (ensuring everything is balanced).

Mass #

$$^{210}_{84}\text{Po} \rightarrow {}^{4}_{2}\text{He} + {}^{206}_{82}\text{Pb}$$

Atomic #

Example 2: **Write the nuclear equation for the radioactive decay of radium – 226 by alpha emission.**

Step 1: Write the element that you are starting with.

Mass #

$^{226}_{88}Ra$

Atomic #

<u>Example 2:</u> Write the nuclear equation for the radioactive decay of radium – 226 by alpha emission.

Step 2: Draw the arrow.

Mass #

$$^{226}_{88}\mathrm{Ra} \rightarrow$$

Atomic #

<u>Example 2:</u> Write the nuclear equation for the radioactive decay of radium – 226 by alpha emission.

Step 3: Write the alpha particle.

Mass #

$$^{226}_{88}Ra \rightarrow {}^{4}_{2}He$$

Atomic #

<u>Example 2:</u> Write the nuclear equation for the radioactive decay of radium – 226 by alpha emission.

Step 4: Determine other product (ensuring everything is balanced).

Mass #

$$^{226}_{88}\mathrm{Ra} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{222}_{86}\mathrm{Rn}$$

Atomic #

<u>Example 3:</u> Write the nuclear equation for the radioactive decay of zirconium – 97 by beta decay.

Step 1: Write the element that you are starting with.

Mass #

$$^{97}_{40}Zr$$

Atomic #

Example 3: Write the nuclear equation for the radioactive decay of zirconium – 97 by beta decay.

Step 2: Draw the arrow.

Mass #

$$^{97}_{40}Zr \rightarrow$$

Atomic #

Example 3: Write the nuclear equation for the radioactive decay of zirconium – 97 by beta decay.

Step 3: Write the beta particle.

Mass #

$$^{97}_{40}Zr \rightarrow \; ^{0}_{-1}e$$

Atomic #

Example 3: Write the nuclear equation for the radioactive decay of zirconium – 97 by beta decay.

Step 4: Determine other product (ensuring everything is balanced).

Mass #

$$^{97}_{40}Zr \rightarrow ^{0}_{-1}e + ^{97}_{41}Nb$$

Atomic #

Example 4: What type of decay is it when carbon – 14 turns into nitrogen – 14 ?

Step 1: Write the element that you are starting with.

Mass #

$$^{14}_{6}C$$

Atomic #

Example 4: What type of decay is it when carbon – 14 turns into nitrogen – 14 ?

•

Step 2: Draw the arrow.

Mass #

$$^{14}_{6}\mathrm{C} \longrightarrow$$

Atomic #

Example 4: What type of decay is it when carbon – 14 turns into nitrogen – 14 ?

•

Step 3: Write the daughter product this time!

Mass #

$$^{14}_{6}C \rightarrow \qquad ^{14}_{7}N$$

Atomic #

Example 4: What type of decay is it when carbon – 14 turns into nitrogen – 14 ?

Step 4: Determine other product (ensuring everything is balanced).

Mass #

$$^{14}_{6}C \rightarrow {}^{0}_{-1}e + {}^{14}_{7}N$$

Atomic #

Sometimes lots of parts! Still just adding/subtracting!

(2 x 1) + 235 = **237**

(3 x 0) + 237 = **237**

$$2\,{}^{1}_{0}n + {}^{235}_{92}U \rightarrow 3\,{}^{0}_{-1}e + {}^{237}_{95}Am$$

(2 x 0) + 92= **92**

(3 x -1) + 95 = **92**

By the way…This is called "neutron bombardment"

Sometimes lots of parts! Still just adding/subtracting!

0 + 218 = **218**

218 + 0 = **218**

$$_{-1}^{0}e + _{85}^{218}At \rightarrow _{84}^{218}Po + \gamma_{0}^{0}$$

(-1) + 85= **84**

84 + 0 = **84**

By the way…This is called “electron capture”