TOPIC
12.1

Radioactivity

Why are some things radioactive, and others aren't?

Luckily for us, not everything is radioactive. Also luckily for us, some things are.

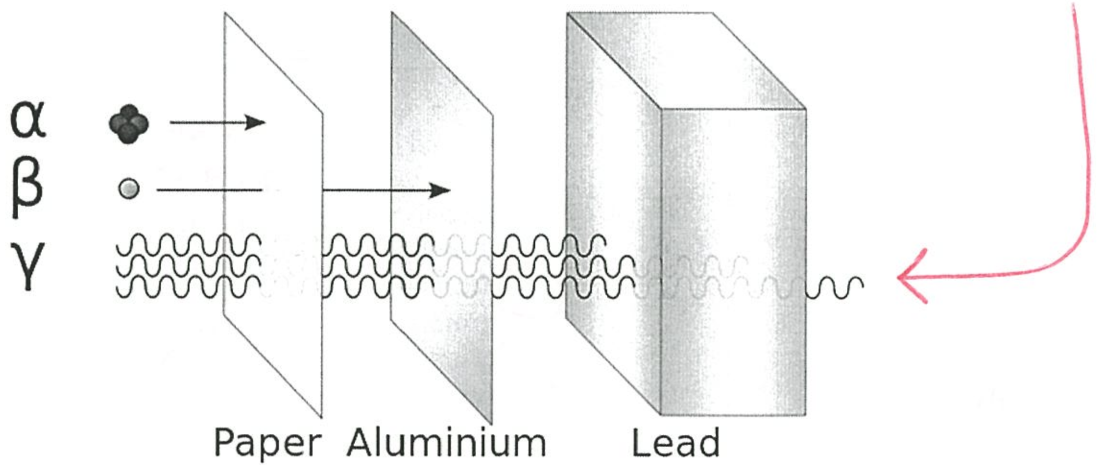
Radioactivity is a result of an **unstable** ratio of protons to neutrons in the nucleus.

Radioisotope: an isotope with an unstable nucleus that will spontaneously decay by emitting radiation

↑
Table N

There are different types of radiation, all tabulated on Reference Table O.

Type of Radiation	Symbol (with mass and charge)	Ability to pass through stuff – "**penetrating power**"
Alpha particle (α)	${}^{4}_{2}He$ or ${}^{4}_{2}\alpha$	low
Beta particle (β^-)	${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$	moderate
Positron (β^+)	${}^{0}_{+1}e$ or ${}^{0}_{+1}\beta$	moderate
Gamma ray (γ)	${}^{0}_{0}\gamma$	highest



TOPIC
12.2

Natural Transmutation/Decay Equations

How can we represent natural transmutation?

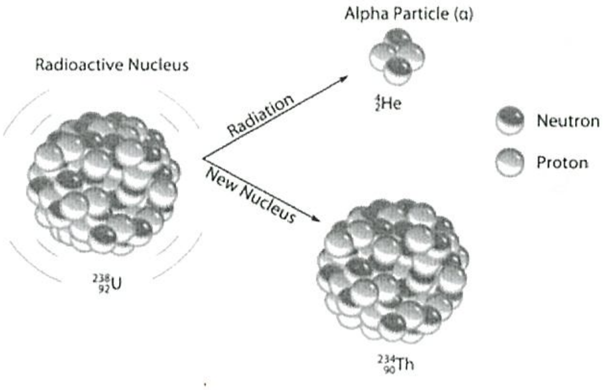
Radiation is the result of an unstable nucleus. In other words, when a nucleus is "unbalanced," it emits radiation in an effort to become more stable. But by doing so, the nucleus changes itself—transformed into something new! That's what we call…

Natural transmutation:

a nuclear reaction that converts one element into another element!

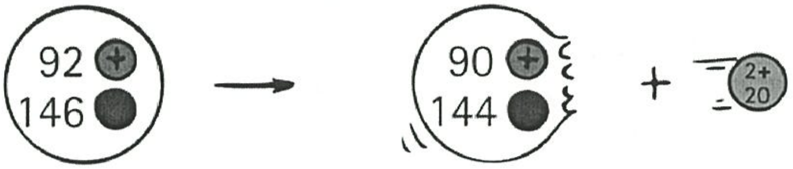
Radioisotope:

found on Table N



Natural transmutation is near always represented by a **decay equation**. They aren't chemical equations—but instead represent changes to the nucleus. Check out how they look:

$$^{238}_{92}U \overset{=}{\underset{=}{\longrightarrow}} {}^{234}_{90}Th + {}^{4}_{2}\alpha$$



Use Reference Table N & O to help you write the natural transmutation decay equations for the following radioisotopes:

atomic #

$^{222}_{86}Rn \rightarrow {}^{4}_{2}\alpha + {}^{218}_{84}Po$

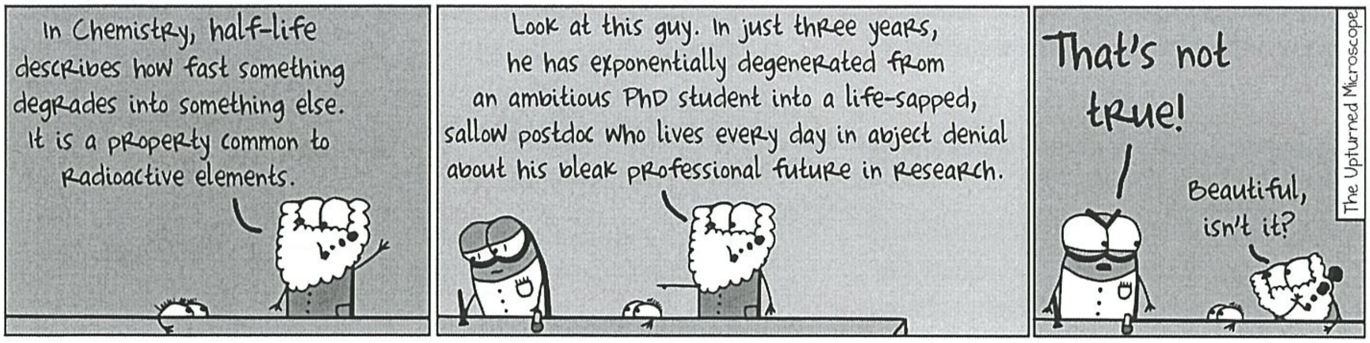
$^{42}_{19}K \rightarrow {}^{0}_{-1}\beta + {}^{42}_{20}Ca$

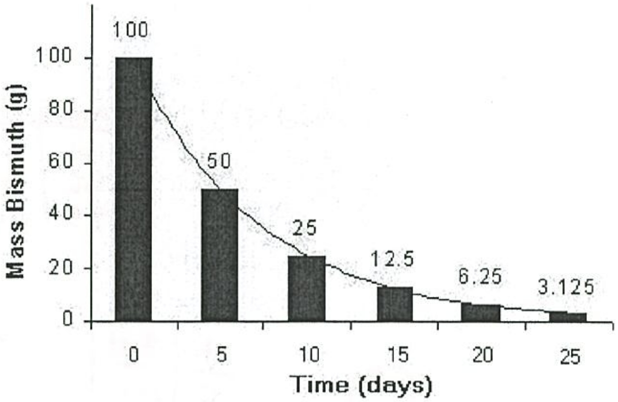
$^{37}_{20}Ca \rightarrow {}^{0}_{+1}e + {}^{37}_{19}K$

TOPIC
12.3

Half-Life

How quickly do radioactive isotopes decay?





What is happening in the graph to the left?

Every 5 days, the mass of Bismuth decreases by 50%

(HL)

Half Life: the amount of time it takes for a radioistope to lose ½ of its mass

"hat on wheels"

1. What mass of I – 131 remains 32 days after a 100 gram sample is obtained?

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

HL	Amt	Time
0	100	0
1	50	8
2	25	16
3	12.5	24
4	6.25	32

6.25g remains, the rest has decayed into Xe

2. Analysis of charred wood at a prehistoric campsite reveals that it contains ¼ of the amount of carbon – 14 that is found in living tissues. How old is the campsite?

HL	Amt	Time
0	1	0
1	½	5715
2	¼	11430

11,430 years old!

3. After decaying for 48 hours, 1/16 of the original mass of a radioisotope sample remains unchanged. What is the half-life of this radioisotope?

HL	Amt	Time
0	1	0
1	½	12
2	¼	24
3	⅛	36
4	1/16	48

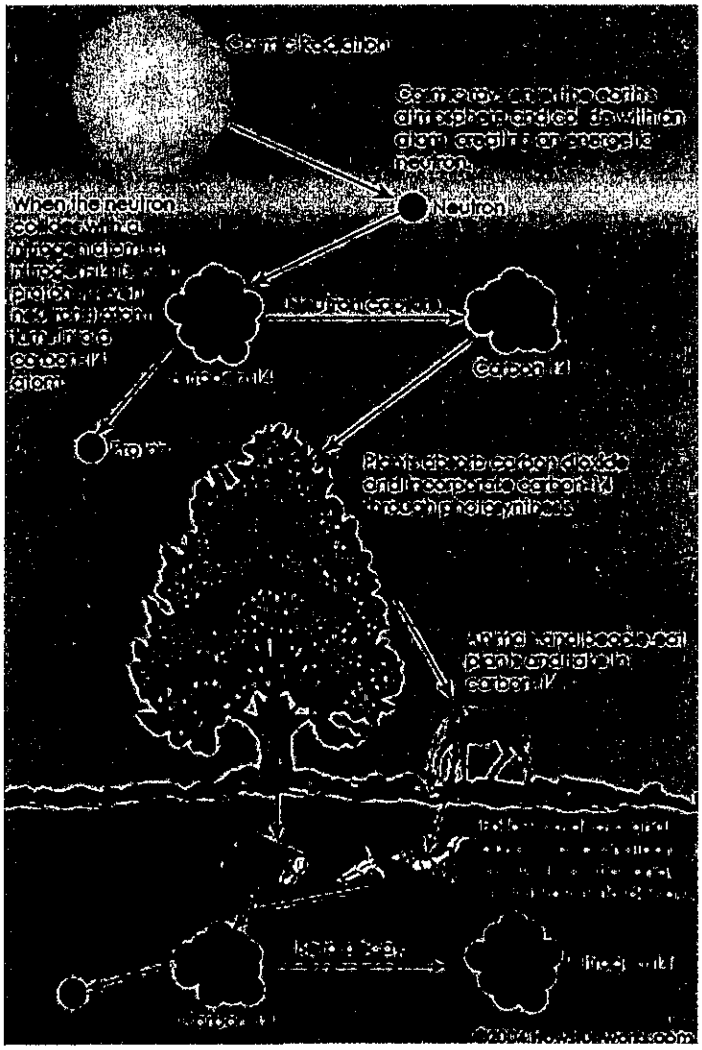
$\frac{48 \text{ hrs}}{4 \text{ half lives}} = 12 \text{ hr}/1 \text{ HL}$

$\boxed{12 \text{ hours}}$

TOPIC
12.4

Useful Isotopes

How can radioisotopes benefit society?



Uses of Radioisotopes

Dating

Carbon – 14 (C – 14) is measured in dead organism to find out when it was last alive based on its ½ life

Uranium – 238 is used to date geological formations → decays to lead - 206

Medical

Certain radioisotopes are useful because they have Short half-lives and thus are quickly removed from the body

- Iodine – 131 : used to detect & treat thyroid disorders
- Cobalt – 60: emits gamma rays that can destroy Cancer cells
- Technetium – 99: detects Cancerous tumors

Risks

Large amounts of radiation given off by isotopes can cause serious illness and death and environmental damage

Assignment #4:

1. Which radioisotope is used in dating geological formations?

   A) I-131 [✓ B) U-238]
   C) Ca-37 D) Fr-220

2. Which radioisotope is used for diagnosing thyroid disorders?

   A) U-238 B) Pb-206
   [✓ C) I-131] D) Co-60

3. Which isotope is used to treat cancer?

   A) C-14 B) U-238
   [✓ C) Co-60] D) Pb-206

4. Cobalt-60 and iodine-131 are radioactive isotopes that are used in

   A) dating geologic formations
   B) industrial measurements
   [✓ C) medical procedures]
   D) nuclear power

5. Which nuclide is paired with a specific use of that nuclide?

   A) carbon-14, treatment of cancer
   B) cobalt-60, dating of rock formations
   [✓ C) iodine-131, treatment of thyroid disorders]
   D) uranium-238, dating of once-living organisms

6. Radioisotopes used for medical diagnosis must have

   A) long half-lives and be quickly eliminated by the body
   B) long half-lives and be slowly eliminated by the body
   [✓ C) short half-lives and be quickly eliminated by the body]
   D) short half-lives and be slowly eliminated by the body

7. A radioisotope which is sometimes used by doctors to pinpoint a brain tumor is

   A) carbon-12 B) lead-206
   [✓ C) technetium-99] D) uranium-238

8. Iodine-131 is used for diagnosing thyroid disorders because it is absorbed by the thyroid gland and

   [✓ A) has a very short half-life]
   B) has a very long half-life
   C) emits alpha radiation
   D) emits gamma radiation

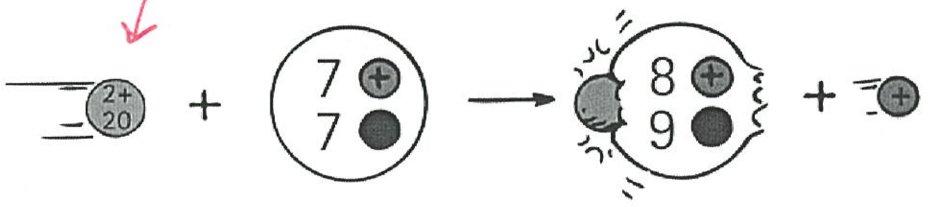
TOPIC 12.5

Artificial Transmutation

How can we manipulate the nuclei of atoms?

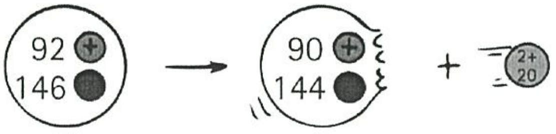
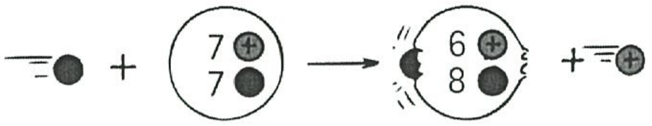
All right. So radioactive isotopes can release particles and, ultimately, change their identities. Soooo…can we *make* a nucleus change? Sort of.

Artificial transmutation: "man made" nuclear reaction caused by hitting a nucleus w/ a high energy particle



$$^{4}_{2}\mathrm{He} + {}^{14}_{7}\mathrm{N} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$$

Let's just take a second to compare natural and artificial transmutation.

Natural Transmutation	Artificial Transmutation
 $^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$	 $^{1}_{0}n + {}^{14}_{7}\mathrm{N} \rightarrow {}^{14}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H}$
1 reactant, 2 products spontaneous new element is formed	2 reactants, 2 products nonspontaneous new element is formed

TOPIC
12.6

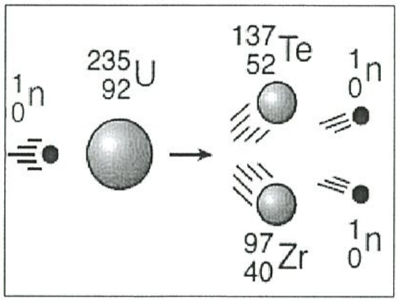
Fission and Fusion

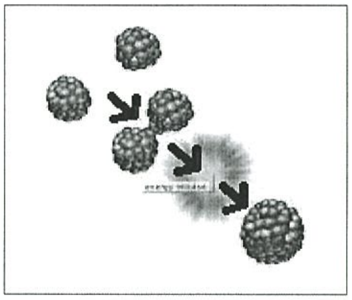
How can we harness the power of nuclear change?

Perhaps the most well-known nuclear reactions are: fission and fusion. If your life is dependent on the sun continuing to burn, or you are aware of the existence of nuclear power plants or nuclear weapons, fission and fusion have already been a part of your life.

Fission is the DIVISION of atoms

Fusion is the UNION of atoms





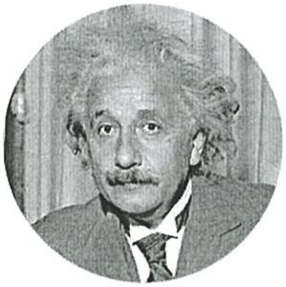
236 = 94 + x

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{38}Sr + \underline{^{142}_{54}Xe} + 2^{1}_{0}n + \text{energy}$

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3\,\underline{^{1}_{0}n} + \text{energy}$

$^{2}_{1}H + ^{2}_{1}H \rightarrow \underline{^{4}_{2}He}$

$^{2}_{1}H + ^{3}_{1}H \rightarrow \underline{^{4}_{2}He} + ^{1}_{0}n$



$E = mc^2$

Fission and fusion reactions convert small amounts of Mass into large amounts of Energy.

REWARDS	RISKS	REWARDS	RISKS
- nuclear power plants provide cleaner energy than fossil fuels - A LOT of energy can be produced	- nuclear waste is radioactive and difficult to store / get rid of - accidents can release harmful waste into air & H_2O	- 4x more energy than fission - no long lived nuclear waste	- costly