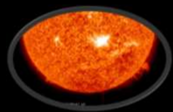
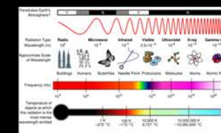


Chapter 10

Nuclear Changes

Nuclear Radiation

•**Radiation:** The process of emitting energy in the form of waves or particles.



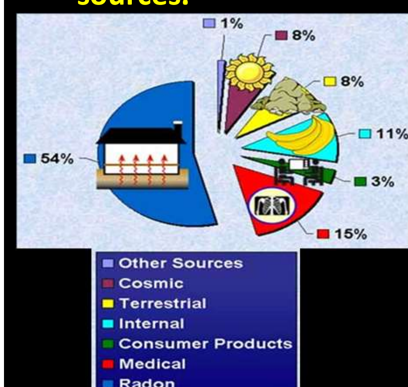
Where does radiation come from?

•The sun (solar) or radioactive isotopes of the elements (terrestrial).
•Produced when particles interact or decay.

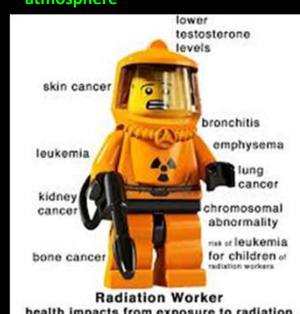
Radiation is going through you at this very moment!

Nuclear Radiation

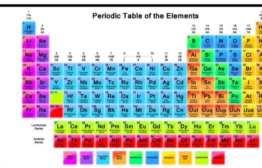
- Background radiation comes from several sources.



It is low-level radiation created by radioactive isotopes found in Earth's rocks, soils, and atmosphere



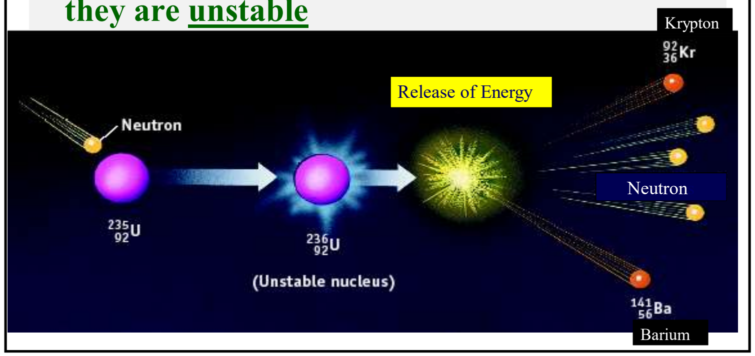
Nuclear Reactions



- Large, unstable atoms undergo nuclear reactions to become more stable
- There are 3 types of nuclear reactions:
  - ❖Fission
  - ❖Fusion
  - ❖Decay (alpha, beta, gamma)

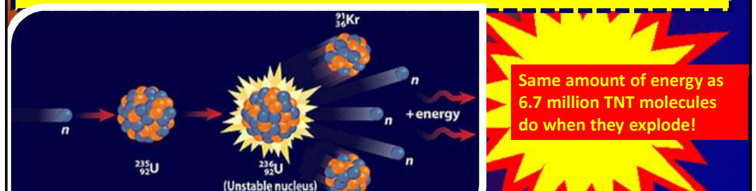
Nuclear Fission

- Fission is the splitting of atoms
- These are usually very large atoms, so that they are unstable



Nuclear Fission

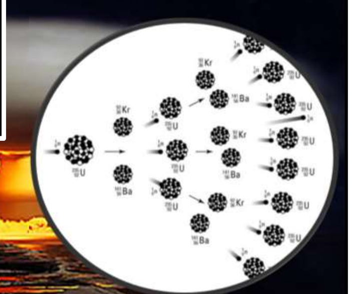
- Scientists shoot a larger nucleus (Uranium) with a neutron
  - Splits Uranium into two smaller atoms (Barium and Krypton)
  - Releases large amounts of energy and neutrons



$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{36}Kr + ^{143}_{56}Ba + ^{1}_{0}n + ^{1}_{0}n + ^{1}_{0}n$$

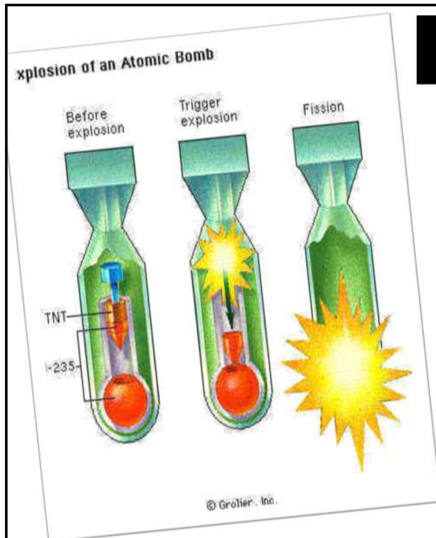
Nuclear Fission

- Nuclear chain reaction - the continuous series of nuclear fission due to neutrons dividing other nucleus from the same sample.



Used in the atomic bomb and nuclear power plants.

Mouse trap Video



How it works

- 2 or more masses of U-235 are surrounded by an explosive.
- The explosion forces the masses together to form a critical mass and a fission chain reaction occurs rapidly.
- Control rods are inserted that absorb neutrons.

Fuel for Nuclear Fission

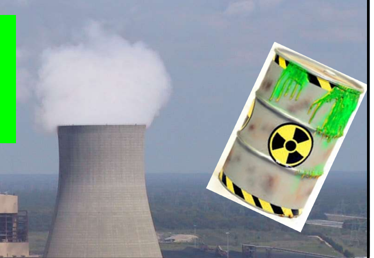
Uranium-235

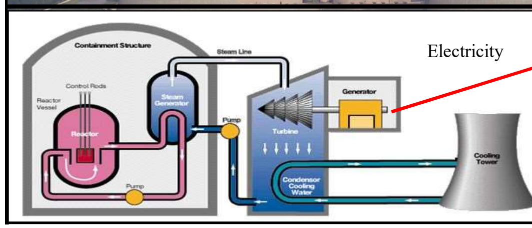
- Uranium is a slightly radioactive metal that occurs throughout the Earth's crust.
- It is about 500 times more abundant than gold and about as common as tin.
- It is present in most rocks and soils as well as in many rivers and in sea water.

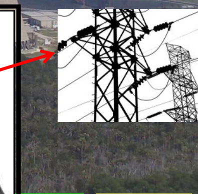
Uses of Nuclear Fission

Use in Nuclear Power Plants

- Energy is provide electrical energy to millions of homes and businesses.

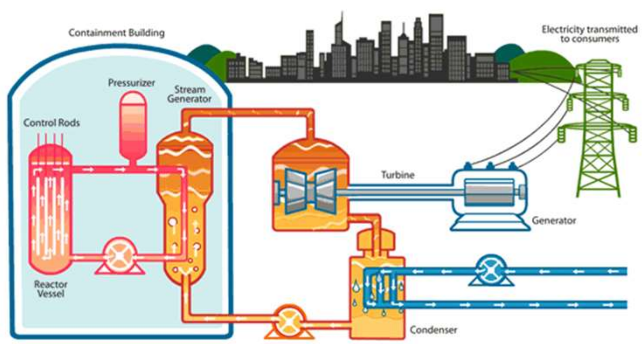




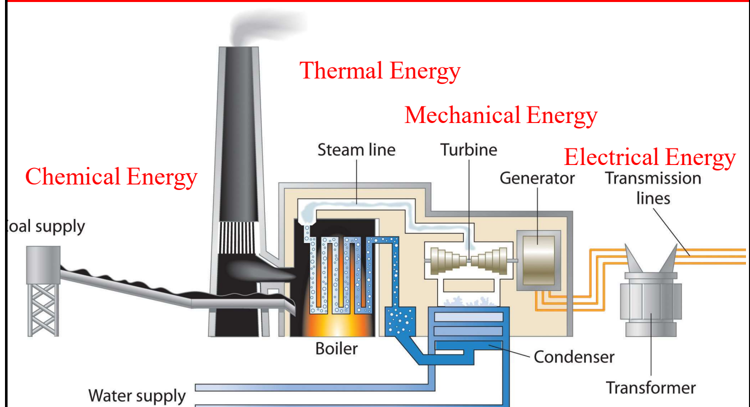


Video Animation

Nuclear Power Plant

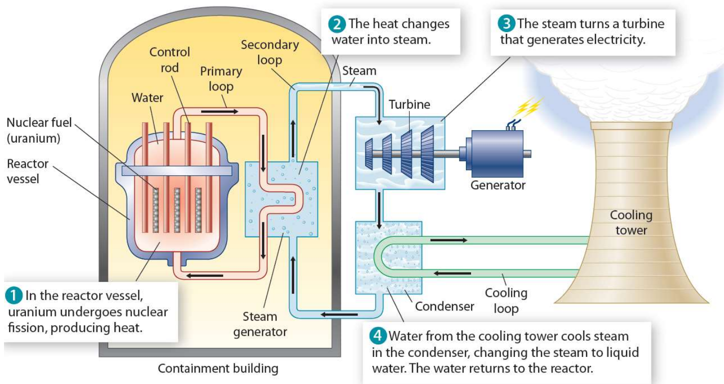


Uses of Nuclear Fission



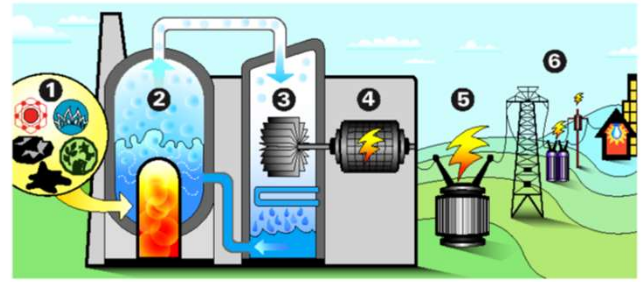
Coal Power Plant

Uses of Nuclear Fission



It converts **NUCLEAR ENERGY** into **THERMAL ENERGY** to **MECHANICAL ENERGY** then into **ELECTRICL ENERGY**.

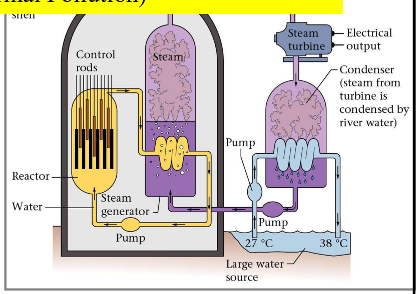
Uses of Nuclear Fission



1. Nuclear Energy
2. Thermal Energy
3. Mechanical Energy
4. Electrical Energy
5. Electrical Energy
6. Radiant Energy

Diagram of a nuclear power plant.

Issues
- Uranium-235 is nonrenewable
- High levels of exposure cause radiation sickness.
- Storage of radiation toxic waste.
- High risk of meltdown.
- Cooling of water (Thermal Pollution)

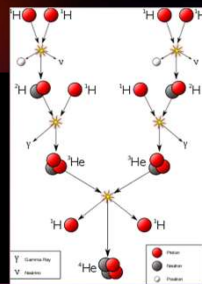


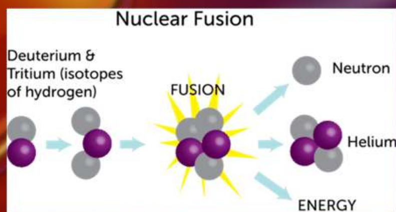
Draw the process of Nuclear Fission

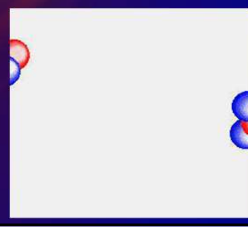
$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{36}Kr + ^{143}_{56}Ba + ^{1}_{0}n + ^{1}_{0}n + ^{1}_{0}n$$

Nuclear Fusion

☞Two nuclei of (Hydrogens) which are very abundant combine to form a nucleus of larger mass (Helium) which is harmless.







Nuclear Fusion

small nuclei combine to form large nuclei

$$^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n + \text{Energy}$$

Deuterium Tritium Helium neutron

This goes in your notes and memorize

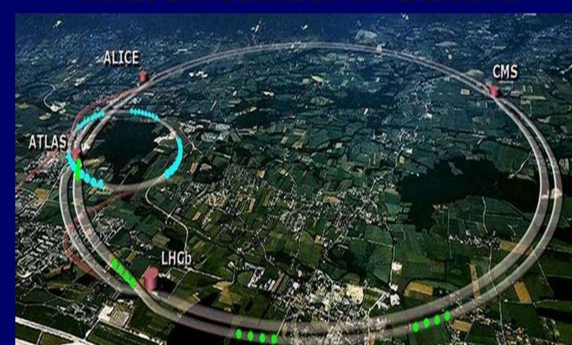
Nuclear Fusion

- The energy released from fusion is 3-4 times greater than the energy released from fission.

Occurs in:
- The sun and other stars.
- Humans are still unsuccessful.

(Unless you are Tony Starks)

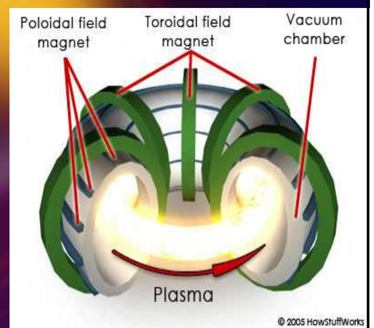
Aerial View of the Large Hadron Collider in Geneva



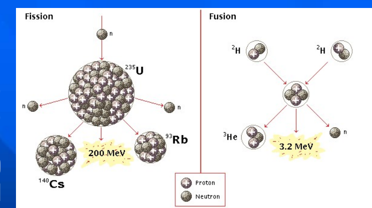
Why aren't we using Fusion instead of Fission?

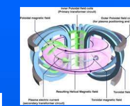
Negative
Only one HUGE Problem
- Can't control temperatures required to sustain.
- 100 million Kelvin and no manmade container can hold it without melting

Positives
- Huge amount of energy produced.
- No harmful waste
- No possible runaway reactions.
- Hydrogen is abundant (Fuel)



Fission vs. Fusion





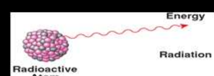
FISSION
1. ^{235}U is limited
2. danger of meltdown
3. toxic waste
4. thermal pollution

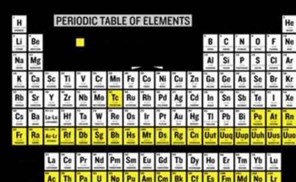
FUSION
1. fuel is abundant (Hydrogen)
2. no danger of meltdown
3. no toxic waste (Helium)
4. not yet sustainable

Nuclear Radiation

Radioactivity

- This is the process of nuclei decaying and emitting matter and energy.



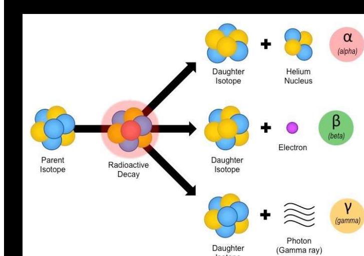


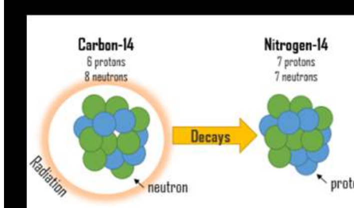
- Nuclei with more than 83 proton are radioactive.
- They are unstable, so they emit energy to stabilize.

Isotopes

- What's an isotope?
- Certain isotopes are "unstable" and decay to lighter isotopes or different elements.

Carbon-14 is used is Radioisotope Dating





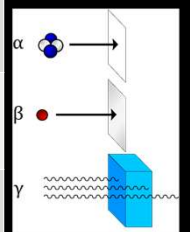
Nuclear Radiation

Video

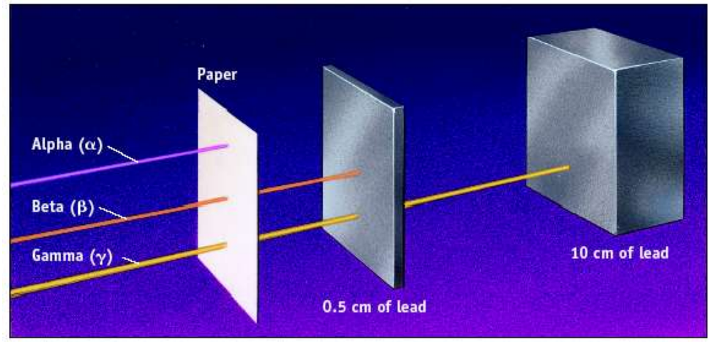
3 Types of Nuclear Radiation emitted

Types of radiation Video

Radiation type	Form	Symbol	Mass (kg)	Charge
1.Alpha particles (α)	Particle	$^{4}_{2}He$	6.646 x 10 $^{-27}$ Heaviest	+2
2.Beta particles (β)	Particle	$^{0}_{-1}e$	9.109 x 10 $^{-31}$ Less Heavy	-1,(+1)
3.Gamma -rays (γ)	Electromagnetic Wave (Energy)	$^{0}_{0}\gamma$	No Mass	0



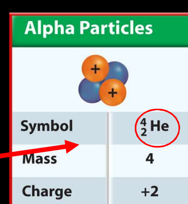
Penetrating Ability



Nuclear Radiation

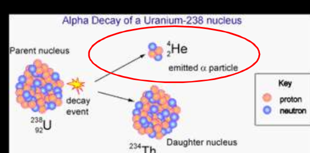
Alpha Particles

- Emitted from decaying nucleus.
- Alpha particle =helium nucleus (2 protons and 2 neutrons)
  - Atomic mass of 4 & charge of +2
- New element: decreased by an atomic number by 2 and mass number by 4



Alpha Particles

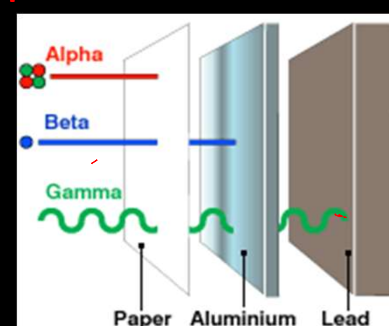
Symbol	$^{4}_{2}He$
Mass	4
Charge	+2



Nuclear Radiation

Alpha Particles

- Most massive compared to others
- The least penetrating form of nuclear radiation.
- Can be stopped by a sheet of paper.



Note: This is the atomic weight, which is the number of protons plus neutrons

Alpha Particles (α)

Radium R^{226} → Radon Rn^{222} + ^{4}He α

88 protons, 138 neutrons → 86 protons, 136 neutrons + 2 protons, 2 neutrons

The **alpha-particle** (α) is a **Helium nucleus**.

It's the same as the element Helium, with the electrons stripped off !

Alpha Decay Practice

$$^{210}_{84}Po \rightarrow \,^{\_}_{\_}\,\_\_ + \,^{\_}_{\_}\,\_\_$$

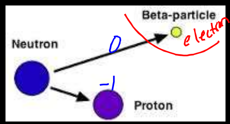
$$^{222}_{86}Rn \rightarrow \,^{\_}_{\_}\,\_\_ + \,^{\_}_{\_}\,\_\_$$

$$^{255}_{\_}Rf \rightarrow \,^{4}_{2}\alpha + \,^{\_}_{\_}\,\_\_$$

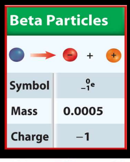
Nuclear Radiation

Beta Particles

- A neutron decays into a proton
- Emits a fast moving electron (beta particle).



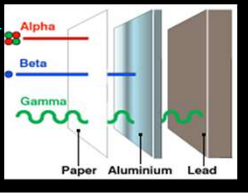
$^{0}_{-1}e$



- May be positively charged (+), positrons

$^{0}_{+1}e$

- Not as massive as alpha particles, so they can pass through thicker substances



Beta Particles (b)

Carbon C^{14} → Nitrogen N^{14} + e^-

Atomic mass stays the same

Atomic Number Changes

6 protons, 8 neutrons → 7 protons, 7 neutrons + electron (beta-particle)

Neutron decays into a proton and emits an electron.

Because the atom now has one more proton, it becomes the element with an atomic number (proton number) one greater than that of the original element.

The mass number of the new element is the same because the total number of protons and neutrons does not change during beta decay

Beta Decay Practice

$$^{90}_{38}\text{Sr} \rightarrow \,^{\_\_}_{\_\_}\_\_\_ + \,^{\_\_}_{\_\_}\_\_\_$$

$$^{40}_{19}\text{K} \rightarrow \,^{\_\_}_{\_\_}\_\_\_ + \,^{\_\_}_{\_\_}\_\_\_$$

$$\_\_\_ \rightarrow \,^{0}_{-1}\text{e} + \,^{52}_{23}\text{V}$$

Try this!!

Identify the type of radiation?

A

$$^{234}_{90}\text{Th} \rightarrow \,^{234}_{91}\text{Pa} + \,^{0}_{-1}\text{e}$$

Beta particle

B

$$^{222}_{88}\text{Ra} \rightarrow \,^{4}_{2}\text{He} + \,^{218}_{86}\text{Rn}$$

Alpha particle

C

$$^{230}_{90}\text{Th} \rightarrow \,^{4}_{2}\text{He} + \,^{226}_{88}\text{Ra}$$

Alpha particle

D

$$^{38}_{19}\text{K} \rightarrow \,^{38}_{18}\text{Ar} + \,^{0}_{+1}\text{e}$$

Beta particle(Positron)

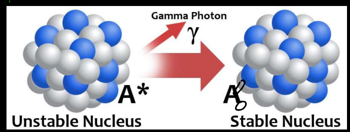
There are multiple decay paths for isotopes, and some isotopes decay faster than others. Below is a table showing one decay path for Uranium-238.

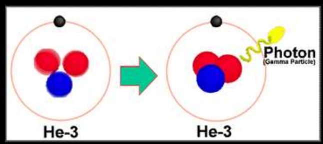
Isotope	Half-Life	Decay Mode
Uranium-238	4.5 billion years	alpha
Thorium-234	24.1 days	beta
Protactinium-234	1 minute	beta
Uranium-234	245,000 years	alpha
Thorium-230	76,000 years	alpha
Radium-226	1,600 years	alpha
Radon-222	3.8 days	alpha
Polonium-218	3.0 minutes	alpha
Lead-214	27 minutes	beta
Bismuth-214	20 minutes	beta
Polonium-214	<1 second	alpha
Lead-210	22.3 years	beta
Bismuth-210	5 days	beta
Polonium-210	138.4 days	beta
Lead-206	stable	

Nuclear Radiation

Gamma Rays

- It is an electromagnetic radiation (Energy).
- The element stays the same, it just loses energy





Gamma Ray=High Energy Photon

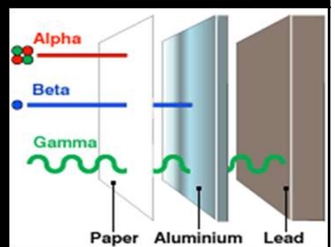
Happens in with Beta or Alpha emissions. Rather than emit another particle, excess energy is given off in gamma rays.

Nuclear Radiation

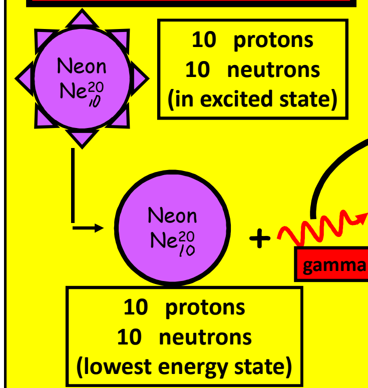
Gamma Rays

- They have no mass and no charge and travel at the speed of light.
- The most penetrating form of nuclear radiation.
- Lead and concrete, are required to stop gamma rays.
- Most dangerous to humans.

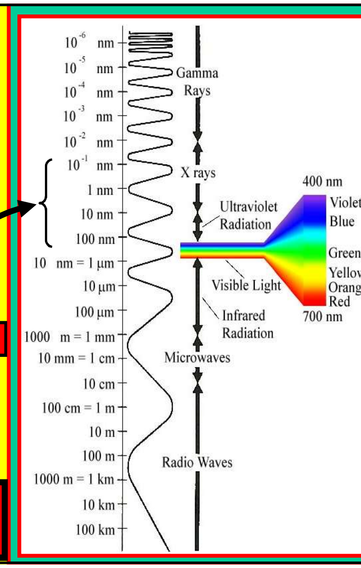
Gamma Rays	
Symbol	γ
Mass	0
Charge	0



Gamma Rays



The gamma from nuclear decay is in the X-ray/ Gamma ray part of the EM spectrum (very energetic!)



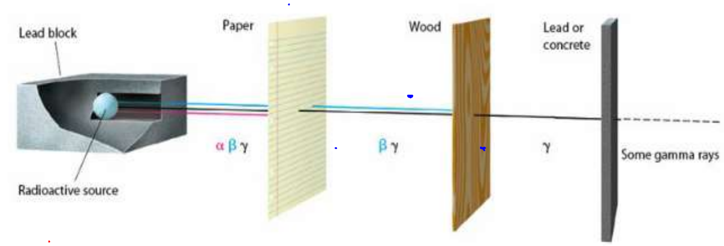
Gamma Decay Practice

$$^{148}_{64}Gd \rightarrow {}^{0}_{0}Y + {}^{\_\_}_{\_\_}\_\_\_\_$$

$$^{210}_{83}Bi \rightarrow {}^{\_\_}_{\_\_}\_\_\_\_ + {}^{\_\_}_{\_\_}\_\_\_\_$$

Alpha particles are the least penetrating.

Gamma rays are the most penetrating.



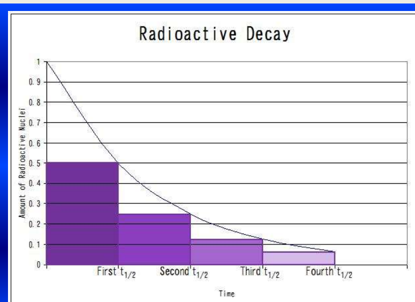
Radioactive Decay Rates

Half-Life

The **TIME** required for ½ of the nuclei in a given radioactive sample to decay.

- **The nucleus left after the isotope decays is called the daughter nucleus.**
- Each element decays into a new element

C14 decays into N14



Radioactive Decay Rates

- **You just won $1,000, but…**
- **…you can only spend half of it in month 1…**
- **…half of the remainder in month 2, etc.**
- **After how many months would you be left with less than $1?**
- **What is the half life for this prize?**

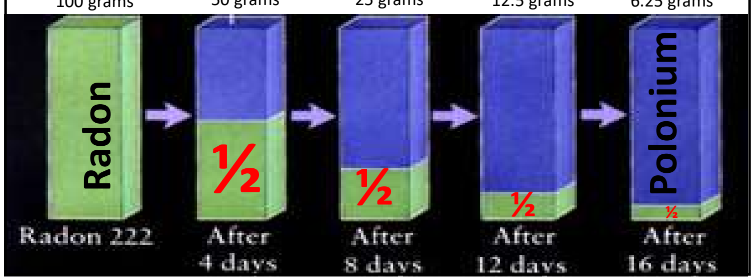
Half live	Time	Amount
0	0 months	1,000
1	1 month	500
2	2 months	250
3	3 months	125
4	4 months	62.5
5	5 months	31.25
6	6 months	15.625
7	7 months	7.8125
8	8 months	3.906
9	9 months	1.953
10	10 months	0.976
11		

Radioactive Decay Rates

- **The "half-life" is the *TIME* it takes for *half the atoms* of a radioactive substance to decay.**

Ex: 100 grams of Radon. Half life of 4 days

Start	1 half life	2 half life	3 half life	4 half life
100 grams	50 grams	25 grams	12.5 grams	6.25 grams



Example of Radioactive Decay

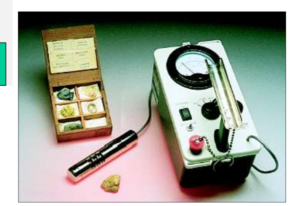
For example: Ra-234 has a half-life of 3.6 days

If you start with 50 grams of Ra-234

After 3.6 days >

After 7.2 days >

After 10.8 days >



Half-Life Math Problem

•For example, suppose we had 20,000 atoms of a radioactive substance. If the half-life is 1 hour, how many atoms of that substance would be left after:

Half-lives	#atoms remaining	% of atoms remaining	Time	Fraction
0	20,000	100%	0 hours	1/1
1	10,000	50%	1 hour	1/2
2	5,000	25%	2 hours	1/4
3	2,500	12.5%	3 hours	1/8

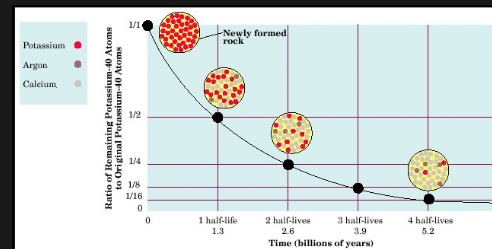
Radioactive Half-Life

- Figuring out Half-life on a graph

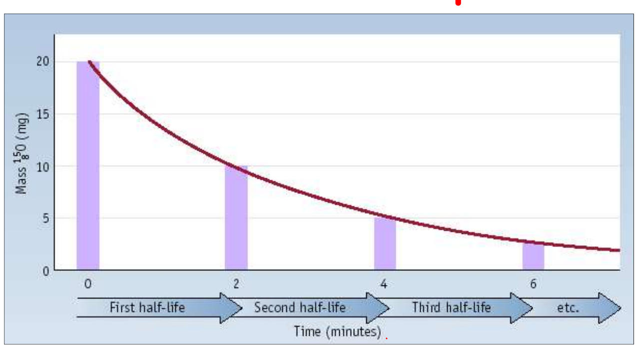
1st Look at your Y-axis and find your amount.

2nd Figure out what is half of your original amount.

3rd Look at your X-axis and find out how much time it took.



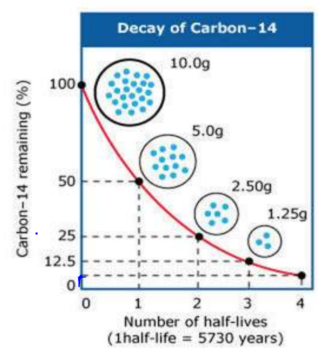
Half-Life in Graphs



Decay of 20.0 mg of oxygen-15.
What remains after 3 half-lives? After 5 half-lives?

Radioactive Decay of Carbon-14

C^{14} decays into N^{14}



1. How many half-lives did it take to only have 12.5% remaining of your original amount of Carbon-14?

3 Half-life's

2. What is the half-life of Carbon-14?

Half-life is 5730 years

2. How long did it take for 10 grams of Carbon-14 to decay to only 1.25 grams ?

171,190 years

Radioactive Half-Life Practice Problems

1. How many grams of iodine 131 (half life- 5 days) would be left after 20 days if you start with 25 grams?

Answer: 1.56 g

The half life is			5 days
Number of half-lives passed	Amount of Matter		Time
0	Started with	25 g	0 { days}
1	How Much is left	12.5g	5 days
2	How Much is left	6.25 g	10 days
3	How Much is left	3.12 g	15 days
4	How Much is left	1.56 g	20 days
5	How Much is left		

2. How long will it take 600 grams of Plutonium 239 (half life 24,000 years) to decay to 18.75 grams?

120,000 yrs

The half life is			24,000 yrs
Number of half-lives passed	Amount of Matter		Time
0	Started with	600 g	0 yrs
1	How Much is left	300 g	24,000 yrs
2	How Much is left	150 g	48,000 yrs
3	How Much is left	75 g	72,000 yrs
4	How Much is left	37.5 g	96,000 yrs
5	How Much is left	18.75 g	120,000 yrs

3. K-42 has a half-life of 15.5 hrs. If 13.125g of K-42 remains undecayed after 62.0 hours, what was the original sample size?

210 g

The half life is			15.5 hrs
Number of half-lives passed	Amount of Matter		Time
0	Started with	210 g	0 hrs
1	How Much is left	105 g	15.5 hrs
2	How Much is left	52.5 g	31 hrs
3	How Much is left	26.25 g	46.5 hrs
4	How Much is left	13.125 g	62 hrs
5	How Much is left		

Half-Life Calculation #1

Thallium-208 has a half-life of 3 min. How long will it take for 120.0 g to decay to 7.50 g?

12 minutes

Half Life	Time	Mass

Half-Life Calculation #2

An isotope of cesium (cesium-137 has a half -life of 30 years. If 20 mg of cesium-137 disintegrates over a period of 90 years, how many mg of cesium-137 would remain?

2.5 mg

# Half Life	Time	Mass

Half-Life Calculation #3

If 60 g of Lithium-9 has a half-life of 100 years, how long will it take for lithium-9 to decay to 15 g?

200 years

Half Life	Time (in) yrs	Mass

Half-Life Calculation #4

- You have 400 mg of a radioisotope with a half-life of 5 minutes. How much will be left after 30 minutes?

6.25 mg

Half Life	Time	Mass

Half-Life Calculation #5

- Suppose you have a 100 mg sample of Au-191, which has a half-life of 3.4 hours. How much will remain after 10.2 hours?

12.5 mg

Half Life	Time	Mass

Half-Life Calculation # 6

- Cobalt-60 is a radioactive isotope used in cancer treatment. Co-60 has a half-life of 5 years. If a hospital starts with a 1000 mg supply, how many mg will need to be purchased after 10 years to replenish the original supply?

750 mg

Half Life	Time	Mass

Half-Life Calculation # 7

- A radioisotope has a half-life of 1 hour. If you began with a 100 g sample of the element at noon, how much remains at 3 PM? At 6 PM? At 10 PM?

3pm=12.5 g

6 pm=1.5625 g

10pm=0.09765625 g

Half-Life Calculation # 8

- How many half-lives have passed if 255 g of Co-60 remain from a sample of 8160 g?

5 half-lives

Half Life	Time	Mass

Half-Life Calculation # 9

- Suppose you have a sample containing 400 nuclei of a radioisotope. If only 25 nuclei remain after one hour, what is the half-life of the isotope?

15 minutes

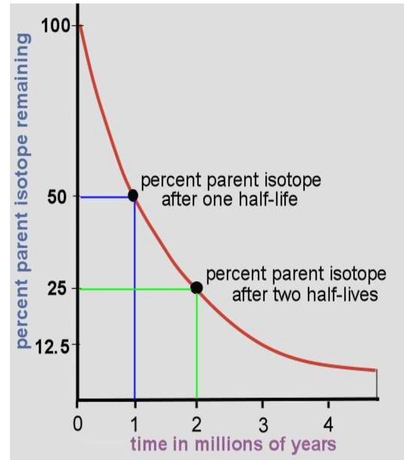
Half Life	Time	Mass

Half-Life Calculation # 10

- If a radioactive element has diminished by 7/8 of its original amount in 30 seconds, what is its half-life?

10 seconds

Half Life	Time	Mass



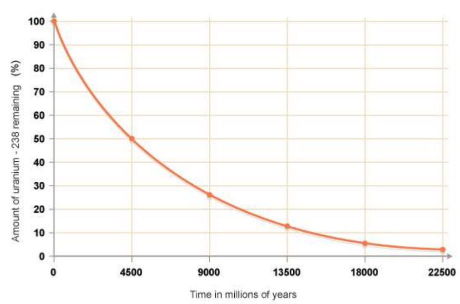
What is the half life represented in this graph?

1 million years

Radioactive Decay of a Sample of Uranium-238

You Try

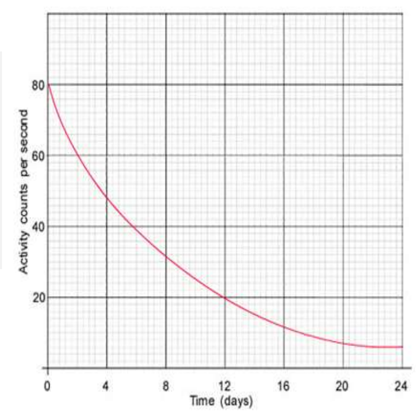
1. How many half-lives does it take for Uranium-238 to decay to only 12.5%?
2. How long did it take for Uranium-238 to decay to 6.25%?
3. How much Uranium-238 is still left over after 4500 million years?
4. In fraction form, how much of the original sample of Uranium-238 is still left over after 22,500 million years?



Half life Graph Practice

- What is the half-life of the isotope represented in this graph?

6 days



Radioactive Decay Worksheet

A — Which of the following is an example of nuclear fusion?
- A. Hydrogen-1 and Hydroen-2 combine to form helium-3.
- B. Polonium-210 decays into lead-206 and an alpha particle.
- C. Carbon-14 breaks down into a beta particle and nitrogen-14.
- D. Uranium-235 and a neutron produce barium-141, krypton-92, and three neutrons.

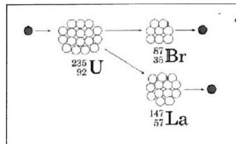
C — Which of the following statements accurately describes alpha particles in terms of charge and mass?
- A. Alpha particles are positively charged and less massive than beta particles.
- B. Alpha particles are negatively charged and less massive than beta particles.
- C. Alpha particles are positively charged and more massive than beta particles.
- D. Alpha particles are negatively charged and more massive than beta particles.

D — Which of the following statements applies to a nuclear fission reaction?
- A. The reaction has no commercial applications.
- B. The reaction takes place only at very high temperatures.
- C. The reaction produces only shortlived radioactive waste.
- D. The reaction releases large amounts of energy when nuclei split apart.

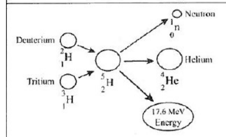
B — Bismuth-210 decays directly to polonium-210. Which of the following must be emitted during this radioactive decay?
- A. Alpha particle
- B. Beta particle
- C. Neutron
- D. Proton

A — Which of the following statements best describes a difference between nuclear fission and nuclear fusion reactions?
- A. Nuclei split during fission and combine during fusion.
- B. Fission forms heavier elements, and fusion forms lighter elements.
- C. Fission generates potential energy, and fusion generates kinetic energy.
- D. Nuclei gain electrons during fission and release electrons during fusion.

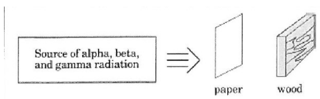
Radioactive Decay Worksheet



- Neutron goes into Uranium-235.
- U-235 splits (fission) to produce 2 smaller atoms (Barium and Krpton) and 3 neutrons



- Two Hydrogen isotopes fuse to create a Helium atom.
- One neutron is also released
- A lot of energy is released during the process of fusion.



- Alpha particle is heaviest, so it is stopped by paper
- Beta particle is not as heavy so it goes through paper, but stopped by wood.
- Gamma passes both since it doesn't have any mass

Radioactive Decay Worksheet

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

$^{42}_{19}K \rightarrow {}^{4}_{2}He + {}^{38}_{17}Cl$ — Alpha

$^{238}_{92}U \rightarrow {}^{0}_{-1}e + {}^{238}_{93}Np$ — Beta

$^{152}_{63}Eu \rightarrow {}^{4}_{2}He + {}^{148}_{61}Pm$ — Alpha

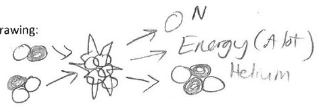
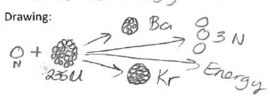
Radioactive Decay Worksheet

$^{251}_{98}Cf \rightarrow {}^{0}_{-1}e + {}^{251}_{99}Es$ — Beta

$^{252}_{99}Es \rightarrow {}^{0}_{0}\gamma + {}^{252}_{99}Es$ — Gamma

More Energy — Less Energy

Mixed Radioactivity Review Problems

Fusion	Fission
What happens to the nucleus?: 2 small nuclei combine to produce a single nucleus with a higher mass.	What happens to the nucleus?: Nucleus splits into two smaller nuclei.
Where/How is it used? Sun + other star	Where/How is it used? - Atomic Bomb - Nuclear power plants - Used for energy to produce electricity
Drawing: 	Drawing: 
Sample Nuclear Equation: ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}N$ + Energy	Sample Nuclear Equation: ${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}N$ + Energy

Mixed Radioactivity Review Problems

2. Use your notes to complete the table below. Be as specific about each type of Nuclear Decay as possible.

Decay Types	What is lost from the atom?	Symbol	What is the charge of this radiation?	What happens to the atom's atomic #?	What happens to the atom's mass #?
Alpha	2 protons 2 neutrons	${}^{4}_{2}He$	+2	decrease by 2	decreases by 4
Beta	electron	${}^{0}_{-1}e$	−1	increases by 1	stays the same
Gamma	Energy	${}^{0}_{0}\gamma$	0	stays the same	stays the same

Mixed Radioactivity Review Problems

3. What type of decay is represented by the following equations? Fill in the missing parts.

a. Gamma — ${}^{14}_{?}N \rightarrow {}^{14}_{?}N + ? \longrightarrow$ ${}^{0}_{0}\gamma$

b. Alpha — ${}^{238}_{92}U \longrightarrow {}^{234}_{90}Th + ? \longrightarrow$ ${}^{4}_{2}He$

c. Beta — ${}^{14}_{6}C \longrightarrow {}^{14}_{7}N + ? \longrightarrow$ ${}^{0}_{-1}e$

Mixed Radioactivity Review Problems

Half-life Question & **WORK**
Radon-222 is a radioactive gas with a half-life of 3.82 days. **How long** will it take for one sixteenth of a sample of Radon-222 to decay?
Uranium-238 decays very slowly, with a half-life of 4.47 billion years. **What percentage** of a sample of Uranium -238 would remain after 13.4 billion years?

Half-life Question & **WORK**	Final Answer
Radon-222 is a radioactive gas with a half-life of 3.82 days. **How long** will it take for ~~fifteen~~ 1/16 ~~sixteenths~~ of a sample of Radon-222 to decay?	15.28 days
Uranium-238 decays very slowly, with a half-life of 4.47 billion years. **What percentage** of a sample of Uranium -238 would remain after 13.4 billion years?	12.5 %

HL	Time	Amount
0	0	1
1	3.82 day	1/2
2	7.64	1/4
3	11.46	1/8
4	15.28	1/16

HL	T	Amount
0	0	100%
1	4.47B	50%
2	8.94B	25%
3	13.41B	12.5%

Mixed Radioactivity Review Problems

A sample of Strontium-90 is found to have decayed to one-sixteenth of its original amount after 87.3 years. **What is the half-life** of strontium-90?

The ratio of Carbon-14 to Carbon-12 in a prehistoric wooden artifact is measured to be 6.25% of the ratio measured in a fresh sample of wood from the same region. The half-life of carbon-14 is 5715 years. Determine its age.

A sample of Strontium-90 is found to have decayed to one-sixteenth of its original amount after 87.3 years. **What is the half-life** of strontium-90?

HL	T	Amount
0	0	1
1		1/2
2		1/4
3		1/8
4	87.3yr	1/16

$\frac{87.3 \text{ yrs}}{4 \text{ Half lives}}$

21.825 yrs

The ratio of Carbon-14 to Carbon-12 in a prehistoric wooden artifact is measured to be 6.25% of the ratio measured in a fresh sample of wood from the same region. The half-life of carbon-14 is 5715 years. Determine its age.

HL	T	Amount
0	0	100%
1	5,715	50%
2	11,430	25%
3	17,145	12.5%
4	22,860	6.25%

22,860 yrs

Mixed Radioactivity Review Problems

Radioactive Decay

alpha decay occurs for each of the nuclei given below. Complete the equation for each:

$^{212}_{84}Po \rightarrow {}^{4}_{2}He + {}^{208}_{82}Pb$

$^{232}_{92}U \rightarrow {}^{4}_{2}He + {}^{228}_{90}Th$

$^{248}_{94}Pu \rightarrow {}^{4}_{2}He + {}^{244}_{92}U$

Mixed Radioactivity Review Problems

beta decay occurs for each of the following nuclei below. Complete the equation for each:

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

$^{212}_{82}Pb \rightarrow {}^{212}_{83}Bi + {}^{0}_{-1}e$

$^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}_{-1}e$