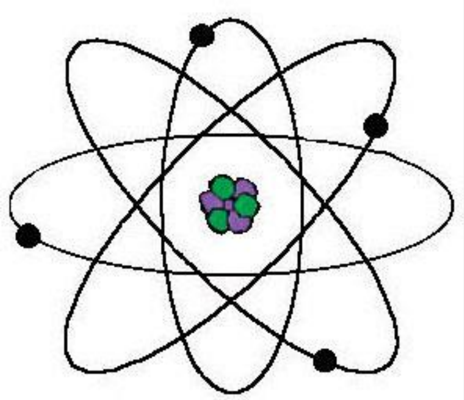
Chapter 10

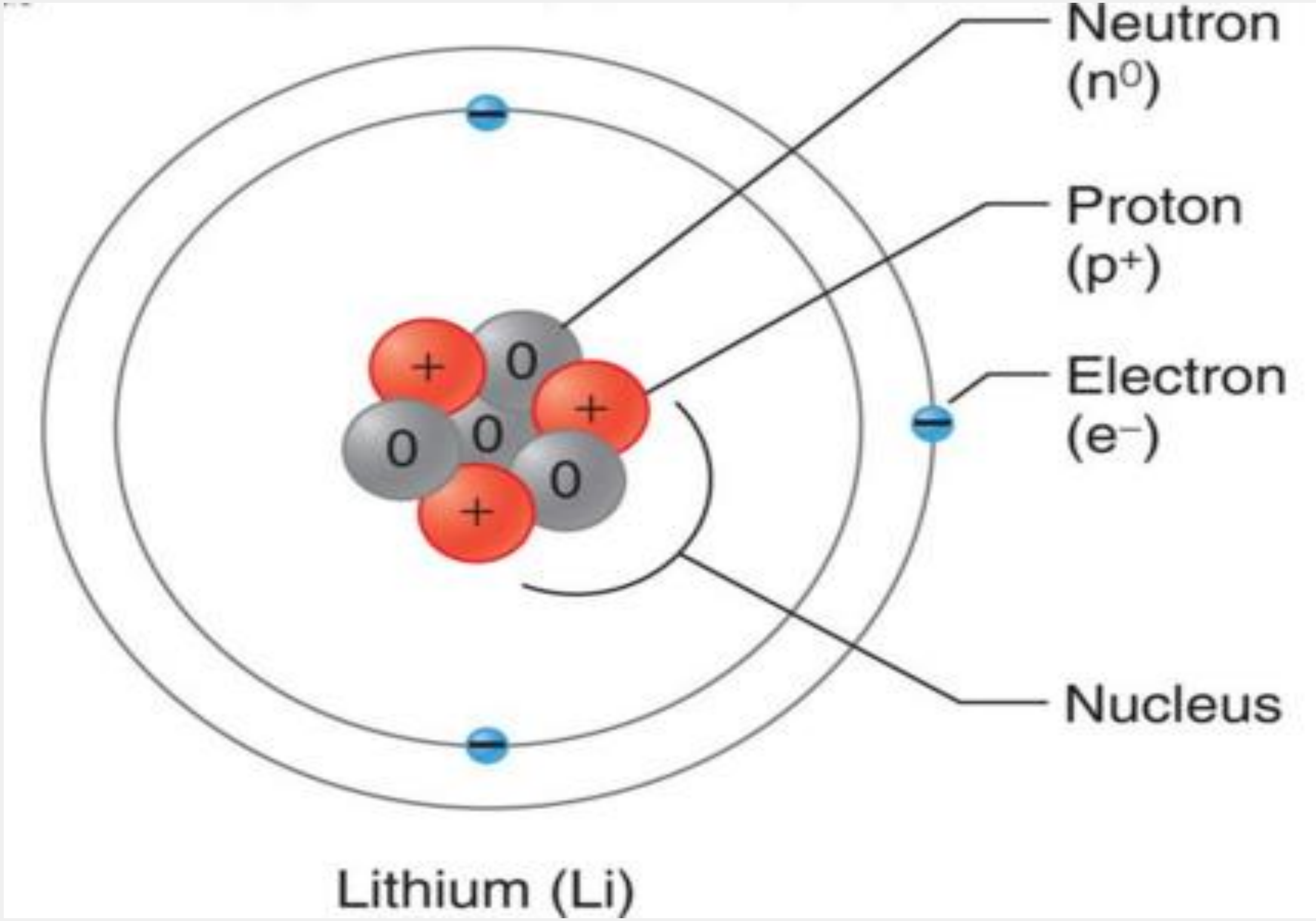


Nuclear Energy

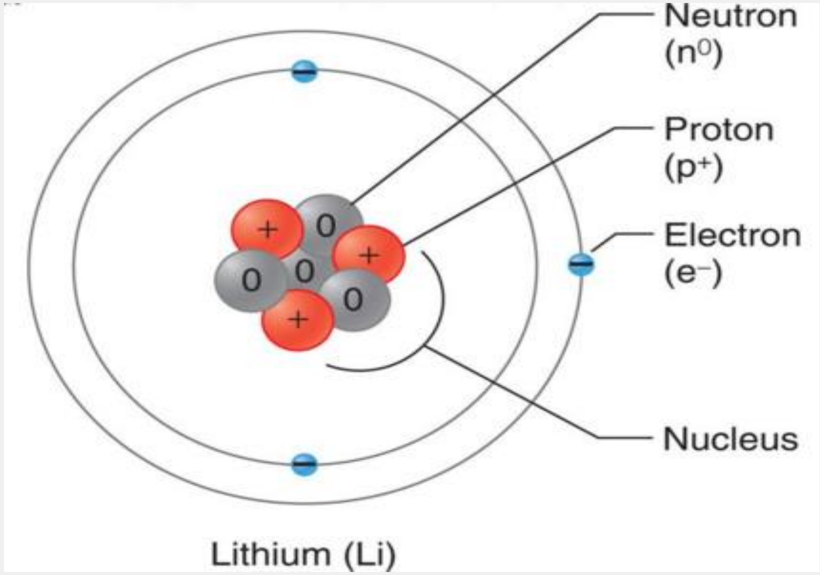
Focus Questions

1. Understand the powerful energy of nuclear force that holds protons and neutrons together in the nucleus of an atom.
2. Define radioactivity and write equations involving radioactive isotopes as they decay (specifically alpha and beta decay).
3. Explain and calculate the half-life of radioactive isotopes and how this relates to radioactive dating.

What's Wrong with this picture?



What's Wrong with this picture?



If "like" charges repel (*which they do*), how can protons exist in the same region of the atom without being repelled?

There must be a strong nuclear force that binds the protons together.

$$E = mc^2$$

Albert Einstein's theory of special relativity explains the strong nuclear force:

m → relativistic mass of a body

E → energy of motion (KE) of the body

c → the speed of light

Click on the following Link (Atomic Blast Action):

http://somup.com/cFX20qnjnh (4:48)

Matter can be turned into energy,

and energy into matter.

Matter can be turned into energy,
and energy into matter.

Background:

- Law of conservation of matter and energy → energy and/or matter cannot be created or destroyed.
- The total mass and energy of the universe is constant.

Modification:

- Matter and energy can be converted into each other.
- Mass and energy together are conserved.

In one kilogram of pure water, the mass of hydrogen atoms amounts to just slightly more than 111 grams, or 0.111 kg. (i.e. 0.2 pounds)

Calculating the energy in the hydrogen atom

$$E=mc^2$$

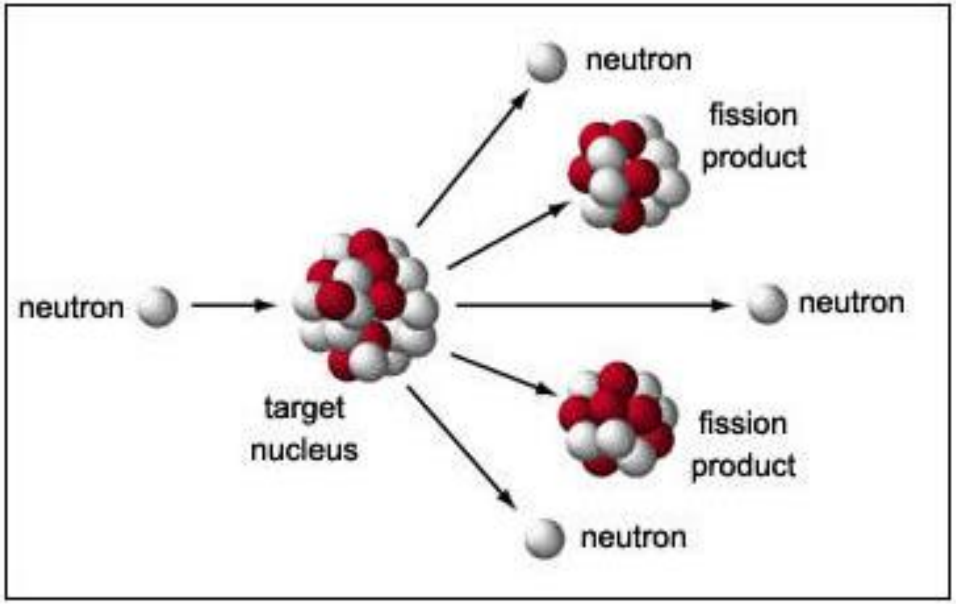
E = 0.111 kg x 300,000,000 m/s x 300,000,000 m/s

10,000,000,000,000,000 joules

Of Energy!!

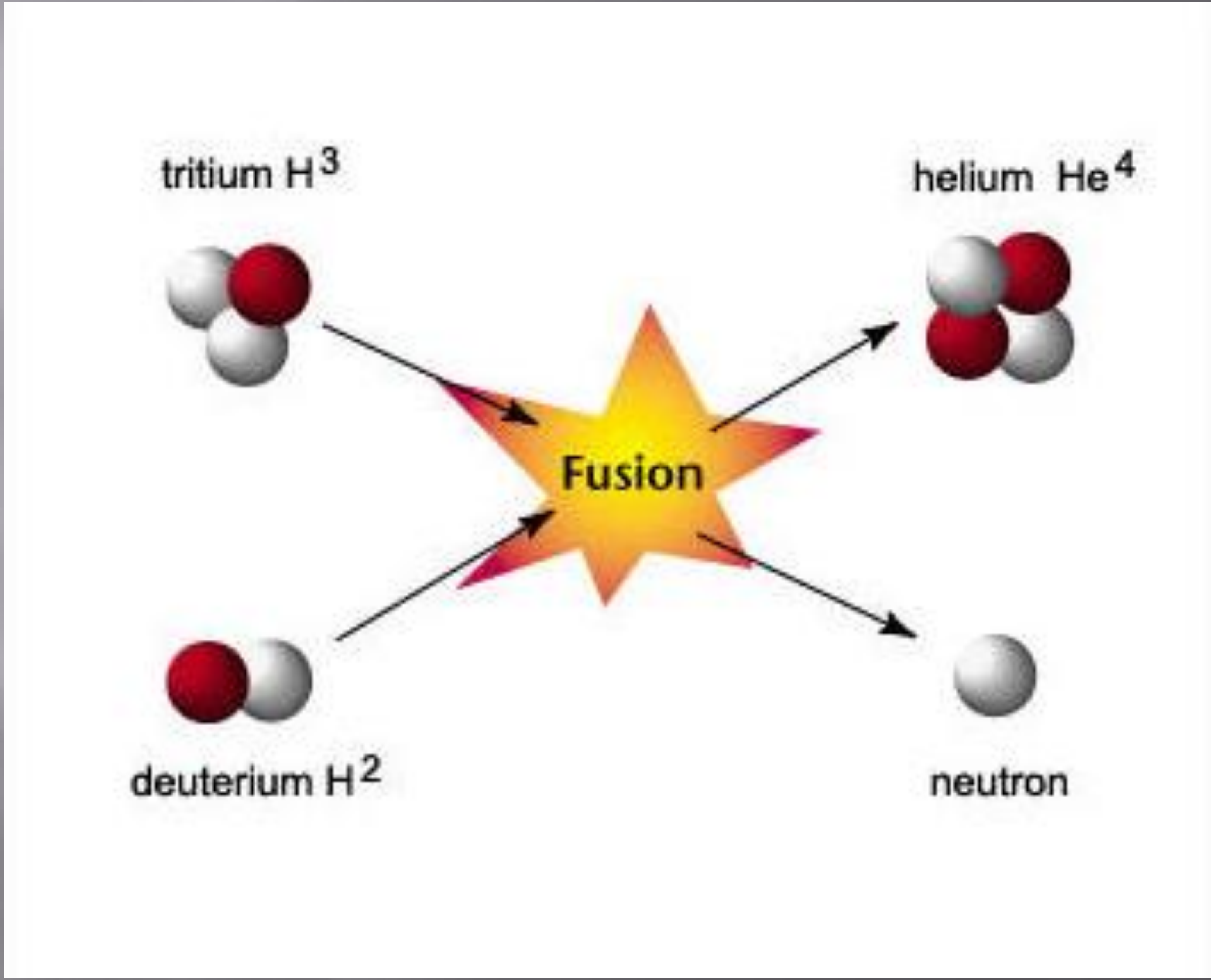
The **amount of energy** in 30 grams of **hydrogen** atoms is equivalent to burning hundreds of thousands of gallons of gasoline!

When a nucleus fissions, it splits into several smaller fragments. These fragments, or fission products, are about equal to half the original mass. Two or three neutrons are also emitted.



Nuclear Fission

The sum of the masses of these fragments is less than the original mass. This 'missing' mass (about 0.1 percent of the original mass) has been converted into energy according to Einstein's equation.



Nuclear Fusion

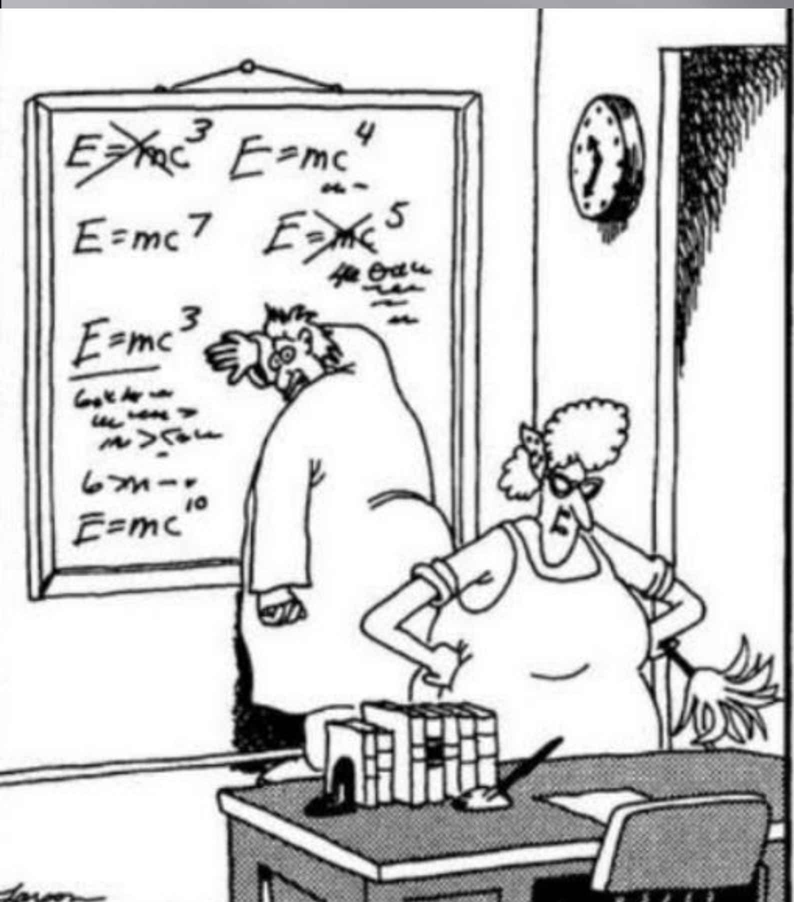
Two protons stuck together have less mass than two single separate protons!

When the protons are forced together, this extra mass is released ... as energy!

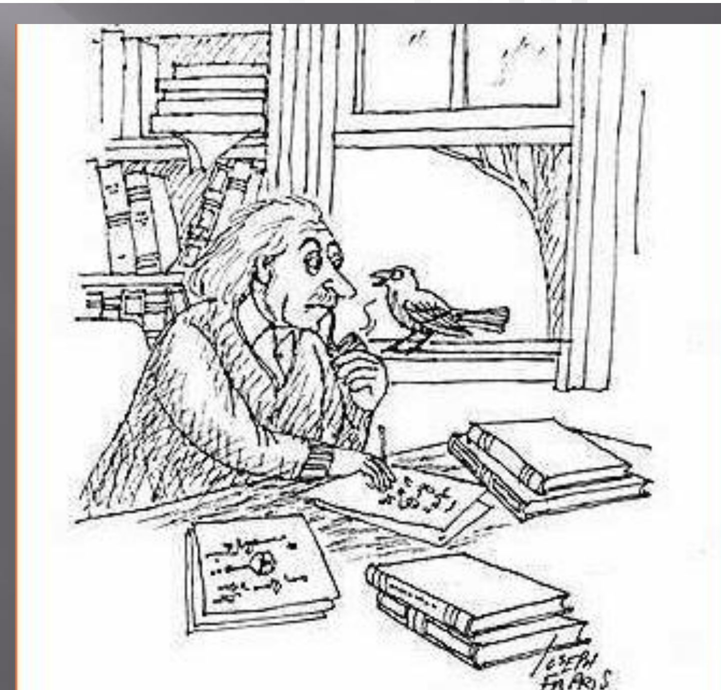
$$E=mc^2$$

Typically this amounts to about 0.7% of the total mass, converted to an amount of energy predictable using the formula.

$$E=mc^2$$



"Now that desk looks better. Everything's squared away, yessir, squaaaaaared away."



"Psst..e=mc^2."

Because other scientists were confirming his theories, Albert Einstein was able to see where an understanding of this formula would lead ...

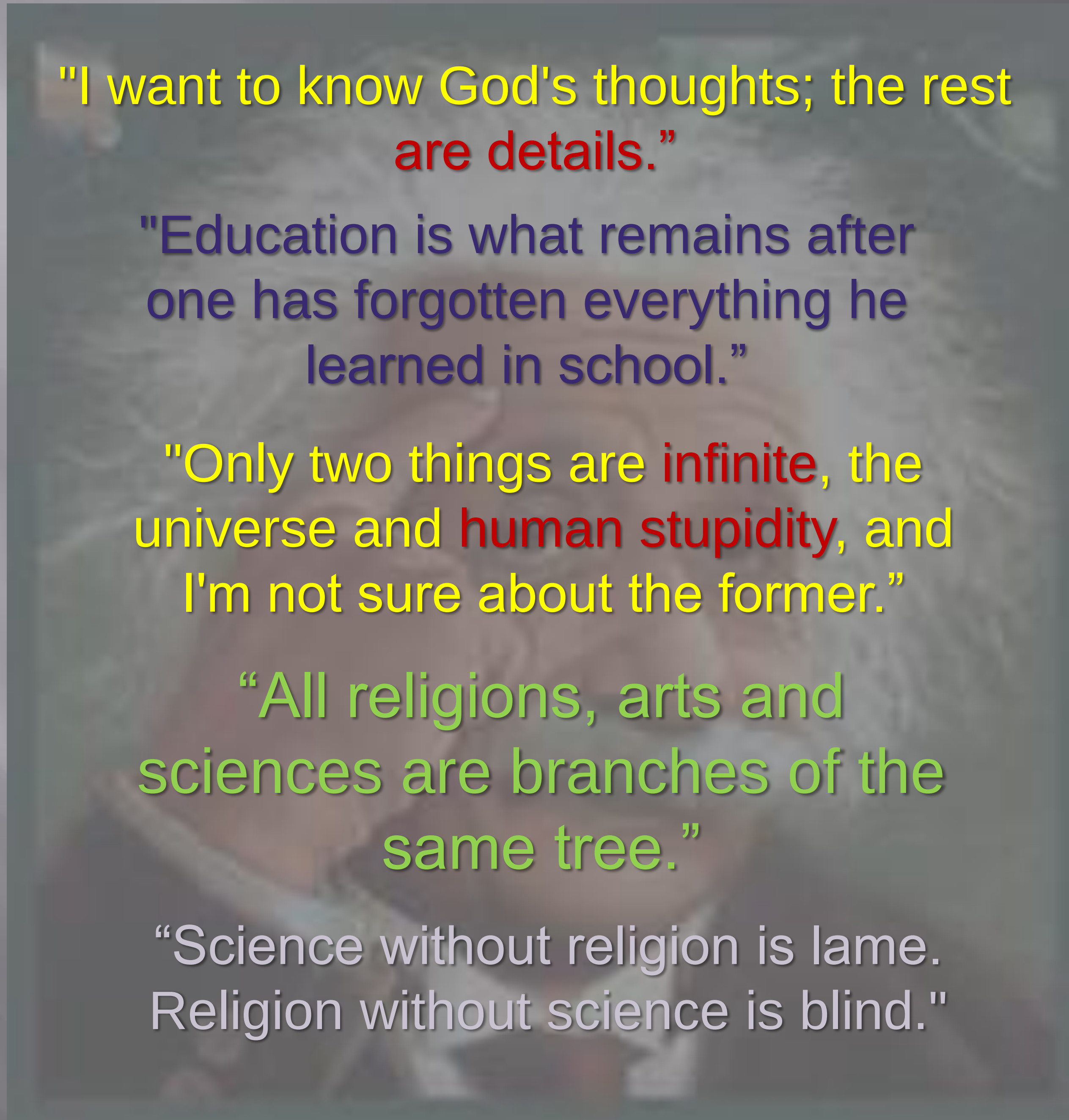
Although peaceful by nature and politics, he helped write a letter to the President of the United States, urging him to fund research into the development of an atomic bomb (The Manhattan Project) ... **before** the Nazis or Japan could develop their own first.

REGRETS

One of the most famous pacifists in history, and he had created the formula for weapons of mass destruction.

"Had I known that the Germans would not succeed in developing an atomic bomb, I would have done nothing."

Einstein



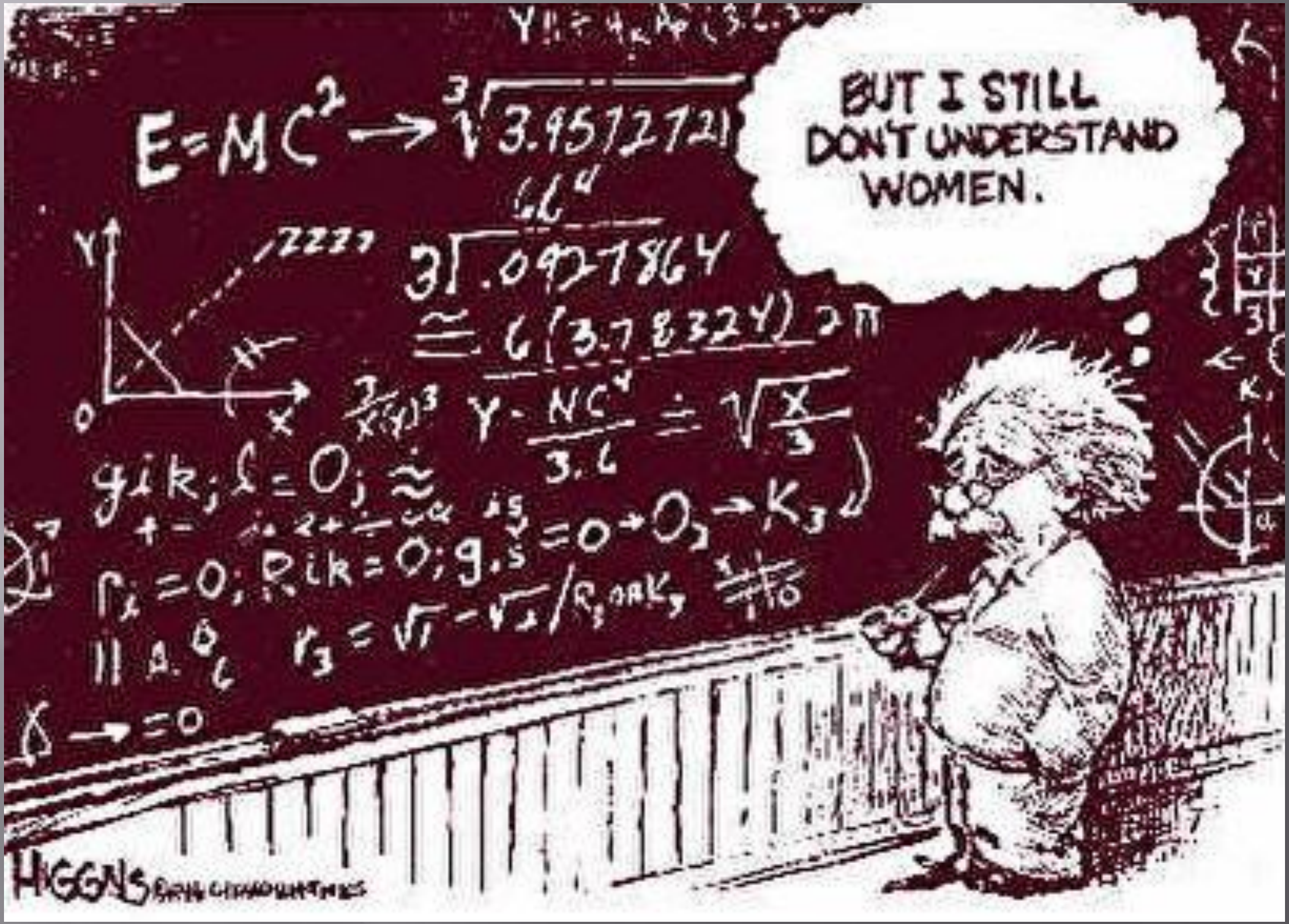
"I want to know God's thoughts; the rest are details."

"Education is what remains after one has forgotten everything he learned in school."

"Only two things are infinite, the universe and human stupidity, and I'm not sure about the former."

"All religions, arts and sciences are branches of the same tree."

"Science without religion is lame. Religion without science is blind."


BUT I STILL DON'T UNDERSTAND WOMEN.
E=MC²

Lise MEITNER

A Jewish woman became the second woman to obtain a doctoral degree in physics at the University of Vienna in 1905. In 1907 she went to Berlin to attend lectures of Max Planck.

In 1926, Meitner became the first woman in Germany to assume a post of full professor in Physics, at the University of Berlin and became directly involved in research with German physicist Otto Hahn (1879-1968). Otto Frisch (Meitner's nephew) discovered "nuclear fission."

In 1933, Meitner was acting head of the Physics department of the Kaiser Wilhelm Institute for Chemistry when Hitler came into power. She was one of a very few allowed to stay under his anti-semitic regime.

In 1936, the duo discovered that uranium would successfully fission when bombarded by "moderated" (slowed down in "heavy" water) neutrons but **the discovery was not revealed in a publication**.

Lise MEITNER

As events changed in Nazi Germany, in 1938, Dr. Lise Meitner successfully escaped Germany to escape Hitler’s inevitable attack and went to Stockholm, Sweden.

She (along three other colleagues) confirmed Einstein's famous equation, $E = mc^2$, which explained the source of the tremendous releases of energy in nuclear fission.

In 1944, Hahn was awarded the Nobel Prize for Physics for his research into fission, but Meitner was ignored.

The Nobel "mistake," never acknowledged, was partly rectified in 1966, when Hahn, Meitner, and Strassmann were awarded the U.S. Fermi Prize.

Lise MEITNER

Significantly helped to confirm Einstein's $e = mc^2$ equation.

But Otto Hahn was given full credit when she fled from under the Nazi regime.

Element 109 would be given the official name meitnerium (Mt) in her honor as a consolation.

"When Einstein wrote about time and relativity, he must have been at a football game where the last 30 seconds took two hours."

Radioactive Decay

- **Radioactive decay**, also known as nuclear **decay** or **radioactivity**, is the process by which a nucleus of an unstable atom loses energy by emitting radiation.
- Radioactive decay occurs when a material spontaneously emits radiation — including alpha particles, beta particles, gamma rays.

Alpha Decay

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

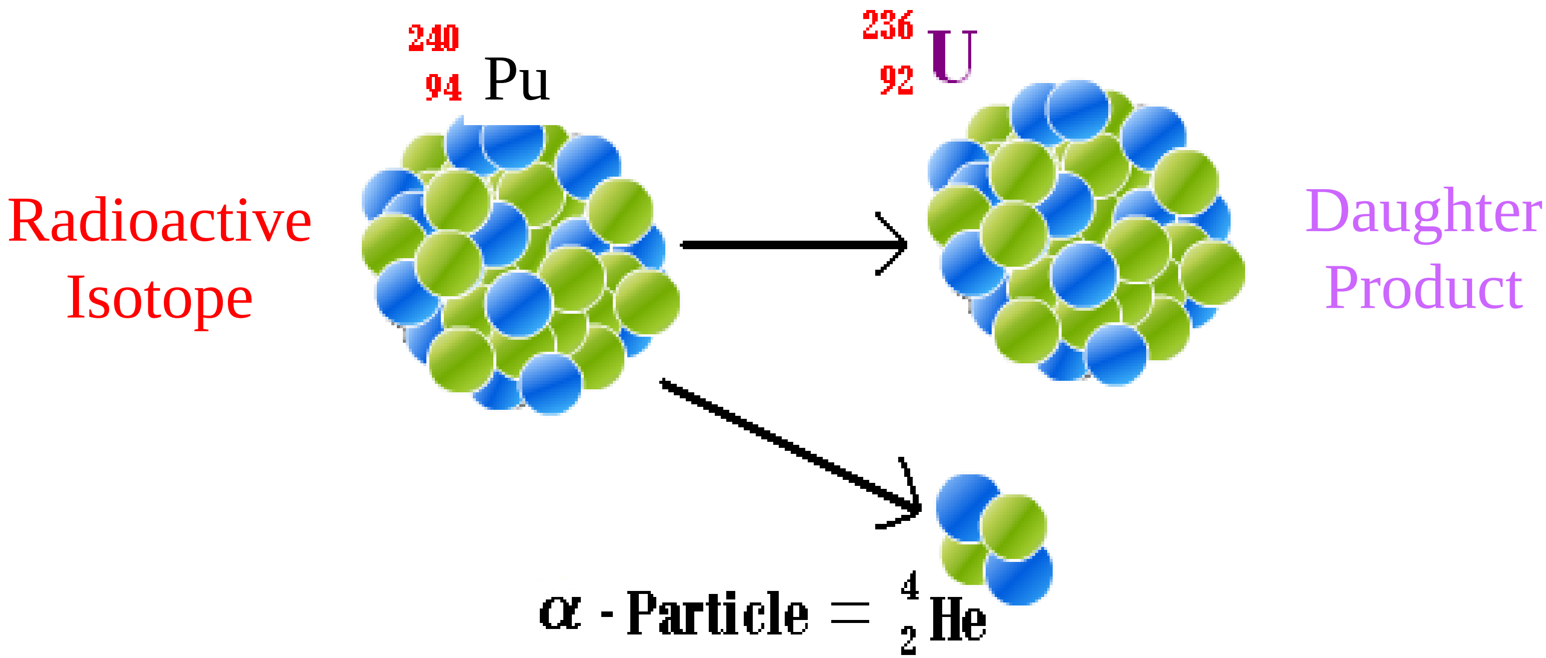
Radioactive Isotope

Daughter Product

Alpha Particle
α Particle

- A particle with two neutrons and two protons is ejected from the nucleus of a radioactive atom.
- The particle is identical to the nucleus of a helium atom.

Alpha Decay



Notice that the atomic mass & atomic number on each side of the arrow are equal.

Mass: 240 = 236 + 4

Atomic #: 94 = 92 + 2

Alpha Decay Transmutation

Fill in the atomic masses & atomic numbers on each side of the arrow. *Make sure they are equal on both sides.*

$$^{233}_{92}U \rightarrow {}^{229}_{\square}Th + {}^{\square}_{2}He$$

$$^{149}_{64}Gd \rightarrow {}^{\square}_{62}Sm + {}^{4}_{\square}He$$

$$^{\square}_{90}Th \rightarrow {}^{228}_{\square}Ra + {}^{4}_{2}He$$

$$^{175}_{\square}Pt \rightarrow {}^{4}_{2}He + {}^{\square}_{76}Os$$

$$^{\square}_{93}Np \rightarrow {}^{\square}_{\square}He + {}^{233}_{\square}Pa$$

Alpha Decay Transmutation

Fill in the atomic masses & atomic numbers on each side of the arrow. *Make sure they are equal on both sides.*

$$^{233}_{92}U \longrightarrow {}^{229}_{90}Th + {}^{4}_{2}He$$

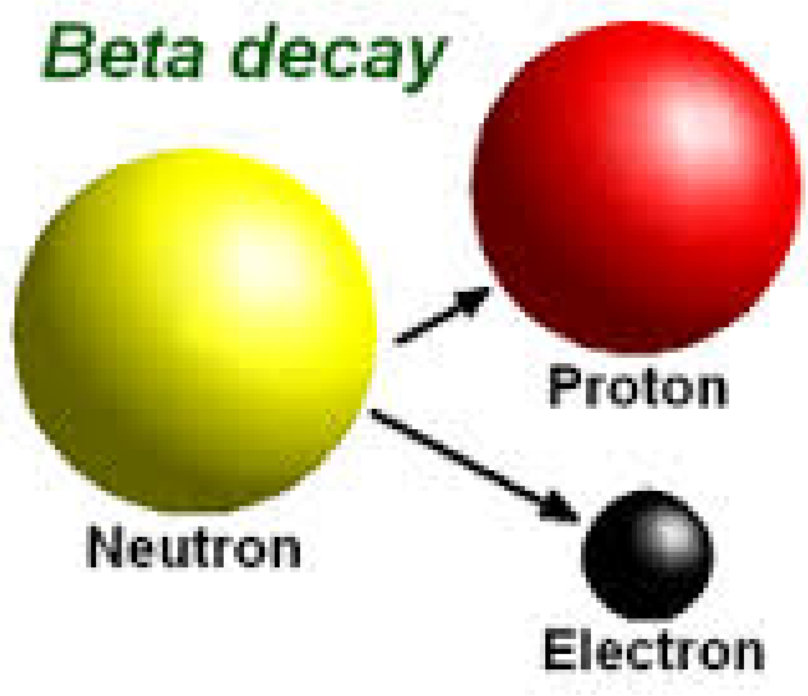
$$^{149}_{64}Gd \longrightarrow {}^{145}_{62}Sm + {}^{4}_{2}He$$

$$^{232}_{90}Th \longrightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$$

$$^{175}_{78}Pt \longrightarrow {}^{4}_{2}He + {}^{171}_{76}Os$$

$$^{237}_{93}Np \longrightarrow {}^{4}_{2}He + {}^{233}_{91}Pa$$

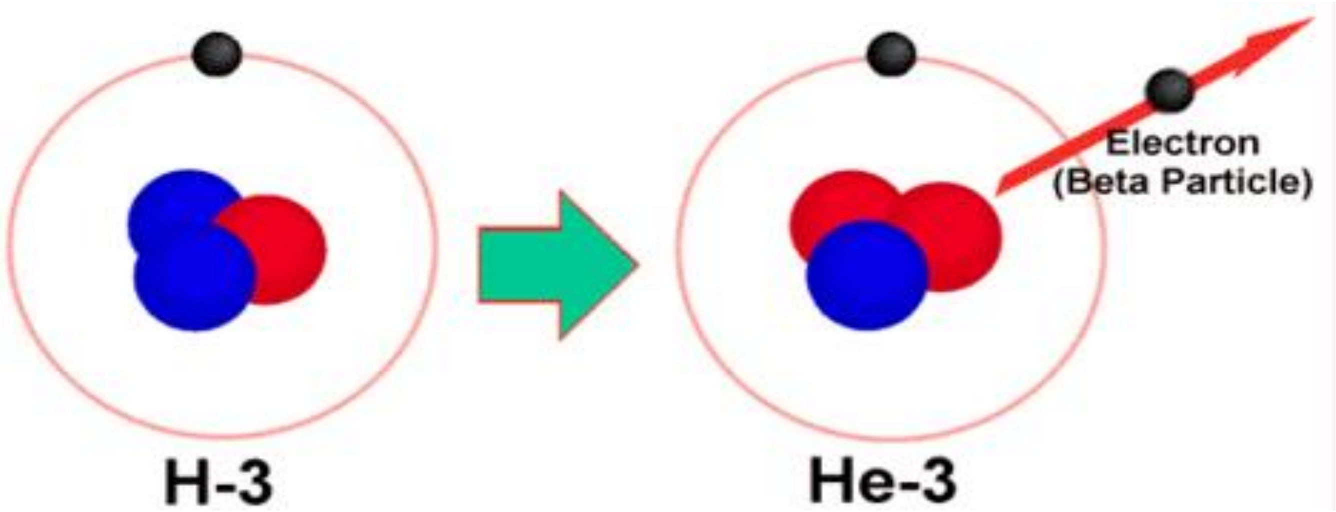
Beta Decay



A neutron in an atom's nucleus turns into a proton, an electron and an antineutrino.

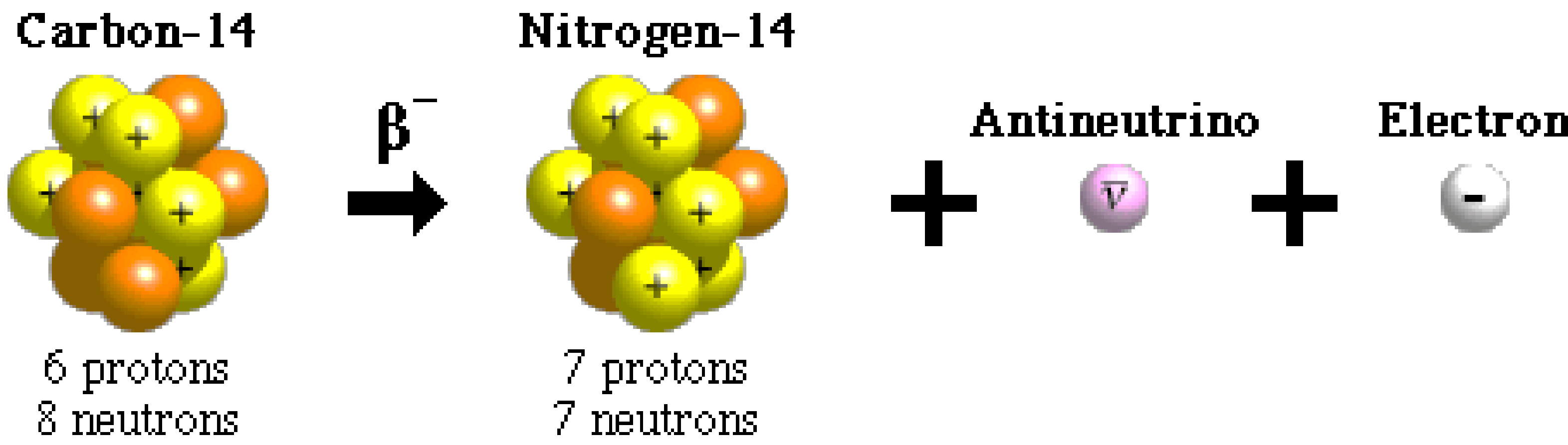
Beta Decay

- The electron and antineutrino fly away from the nucleus, which now has one more proton than it started with.
- Since an atom gains a proton during beta decay, it changes from one element to another (e.g. H to He).



Beta Decay

RadioIsotope Daughter Product



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

- Since an atom gains a proton during beta decay, it changes from one element to another (e.g. C to N).

Beta Decay Transmutation

Fill in the atomic masses & atomic numbers on each side of the arrow. *Make sure they are equal on both sides.*

$${}^{90}_{38}\mathrm{Sr} \longrightarrow {}^{\square}_{39}\mathrm{Y} + {}^{0}_{\square}\mathrm{e}$$

$${}^{\square}_{93}\mathrm{Np} \longrightarrow {}^{239}_{\square}\mathrm{Pu} + {}^{0}_{-1}\mathrm{e}$$

$${}^{247}_{95}\mathrm{Am} \longrightarrow {}^{\square}_{\square}\mathrm{Cm} + {}^{\square}_{-1}\mathrm{e}$$

$${}^{82}_{\square}\mathrm{Br} \longrightarrow {}^{\square}_{36}\mathrm{Kr} + {}^{0}_{-1}\mathrm{e}$$

$${}^{\square}_{43}\mathrm{Tc} \longrightarrow {}^{99}_{\square}\mathrm{Ru} + {}^{\square}_{\square}\mathrm{e}$$

Beta Decay Transmutation

Fill in the atomic masses & atomic numbers on each side of the arrow. *Make sure they are equal on both sides.*

$$^{90}_{38}Sr \longrightarrow {}^{90}_{39}Y + {}^{0}_{-1}e$$

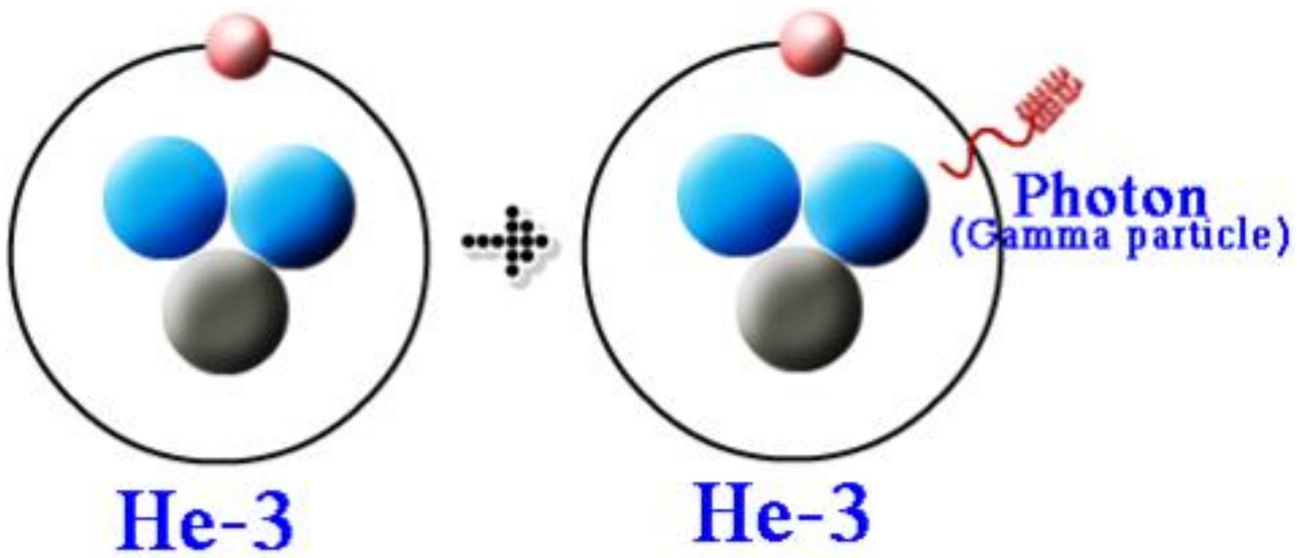
$$^{239}_{93}Np \longrightarrow {}^{239}_{94}Pu + {}^{0}_{-1}e$$

$$^{247}_{95}Am \longrightarrow {}^{247}_{96}Cm + {}^{0}_{-1}e$$

$$^{82}_{35}Br \longrightarrow {}^{82}_{36}Kr + {}^{0}_{-1}e$$

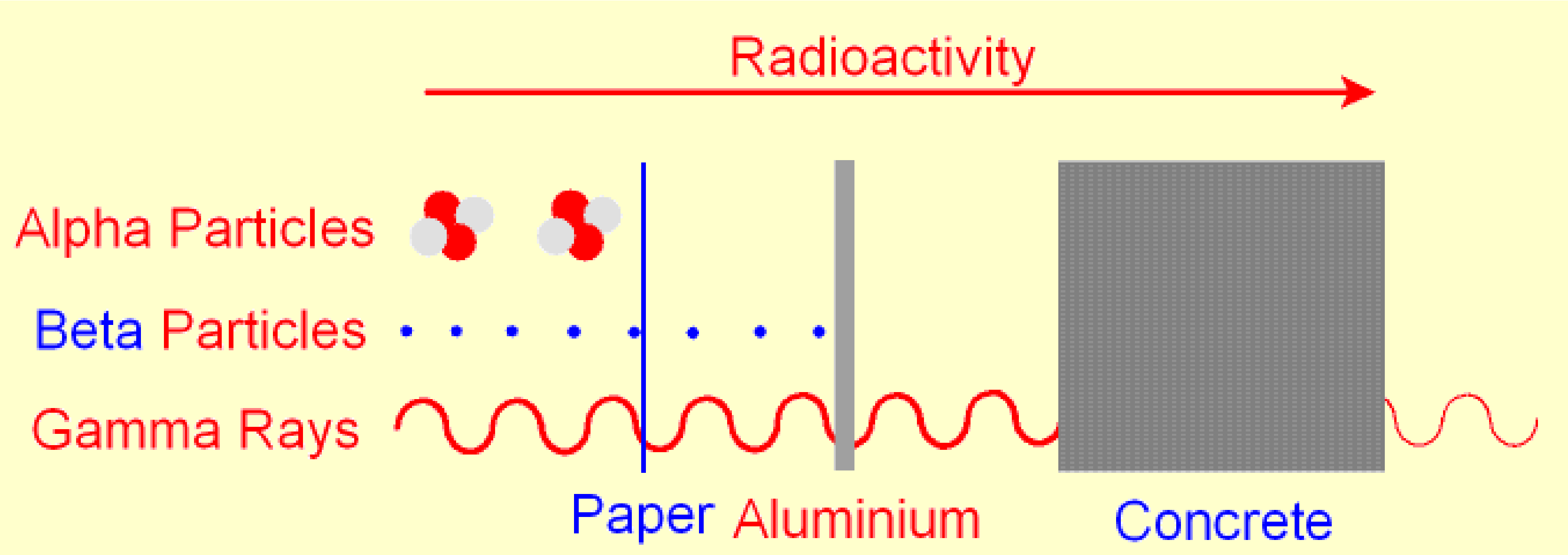
$$^{99}_{43}Tc \longrightarrow {}^{99}_{44}Ru + {}^{0}_{-1}e$$

Gamma Decay



- Gamma rays (e.g. photon) are NOT charged particles.
- They are HIGH energy electromagnetic radiation with 10,000 times more energy than visible light.

Penetration of Particles



- Gamma rays have no mass & can penetrate most substances except thick lead.
- Alpha particles can be stopped by paper.
- Beta particles have little mass, can penetrate more than alpha particles, but possess much lower energy than gamma rays.

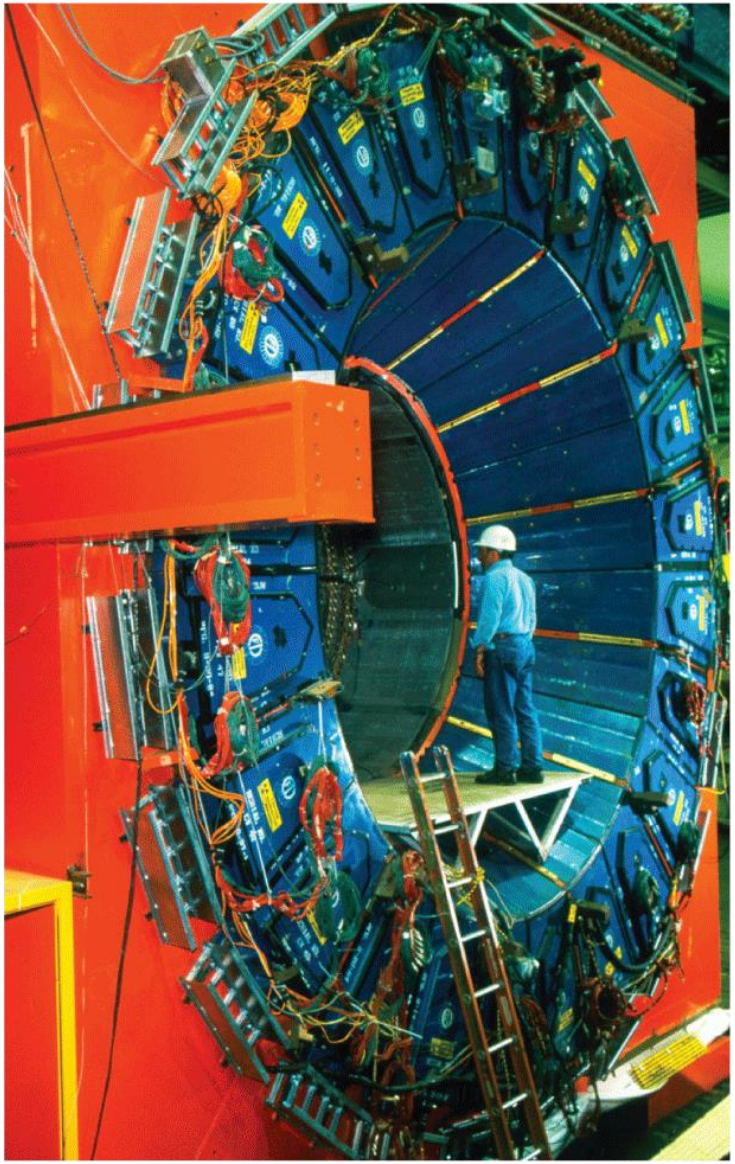
Particle Accelerators

Some transmutations require particles that are moving at extremely high speeds.

Particle accelerators cause charged particles to move very close to the speed of light.

The fast-moving particles collide with atomic nuclei.

Scientists have produced more than 3000 different isotopes.

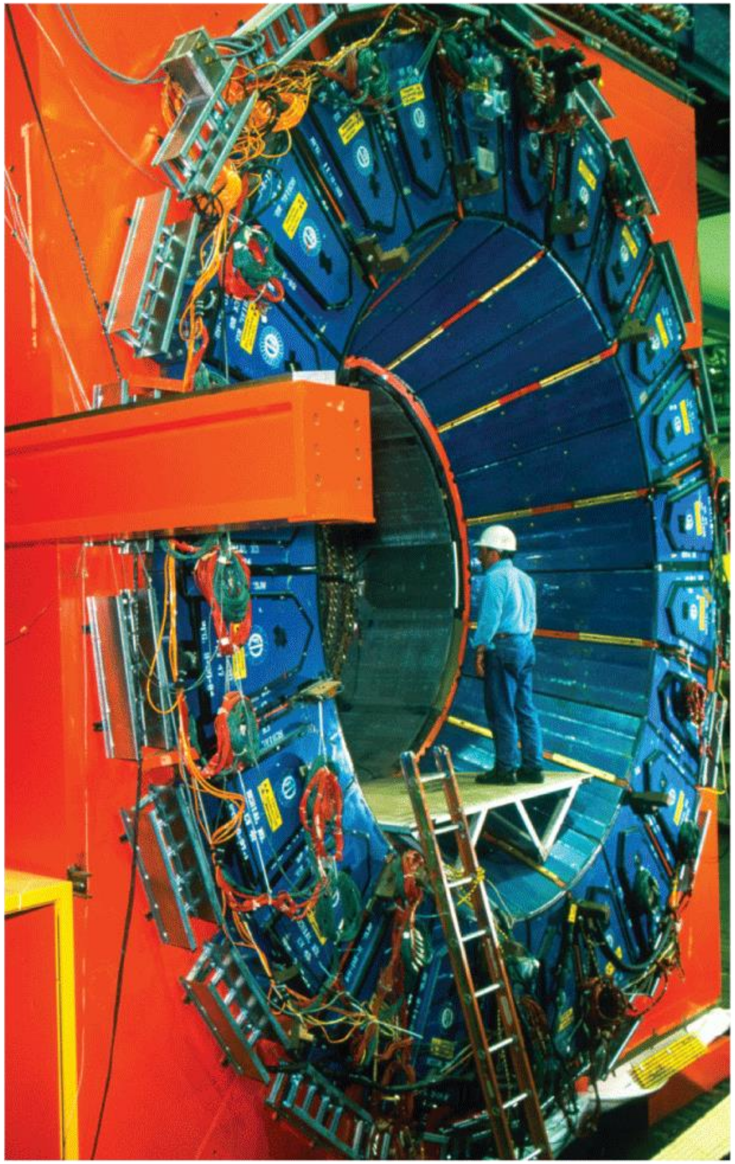


This particle detector records subatomic particles produced in the Tevatron, the most powerful particle accelerator in the world. (Fermilab in Batavia, Illinois.)

Particle Accelerators

Scientists also conduct collision experiments in order to study nuclear structure.

- More than 200 different subatomic particles have been detected.
- A **quark** is a subatomic particle theorized to be among the basic units of matter.
- According to the current model of the atom, protons and neutrons are made up of quarks.



Radioactive Isotopes (RadioIsotopes)

- Radiometric isotopes are used in industry, medicine, and to determine the age of rocks & formerly living organisms.
- Carbon dating is used for formerly living organisms (trees, bones).

Radioactive Isotope	Industrial Applications
Americium-241	For uniform thickness when rolling steel and paper, determine location of oil wells
Sodium-24	Oil well studies and to locate leaks in pipe lines
Iridium-192	Test integrity of boilers and aircraft parts
Uranium-235	Nuclear power plant and naval propulsion systems fuel, production of fluorescent glassware and colored wall tiles
Californium-252	Determine moisture content of soil – important for road construction and building industries

Radioactive Isotopes (RadioIsotopes)

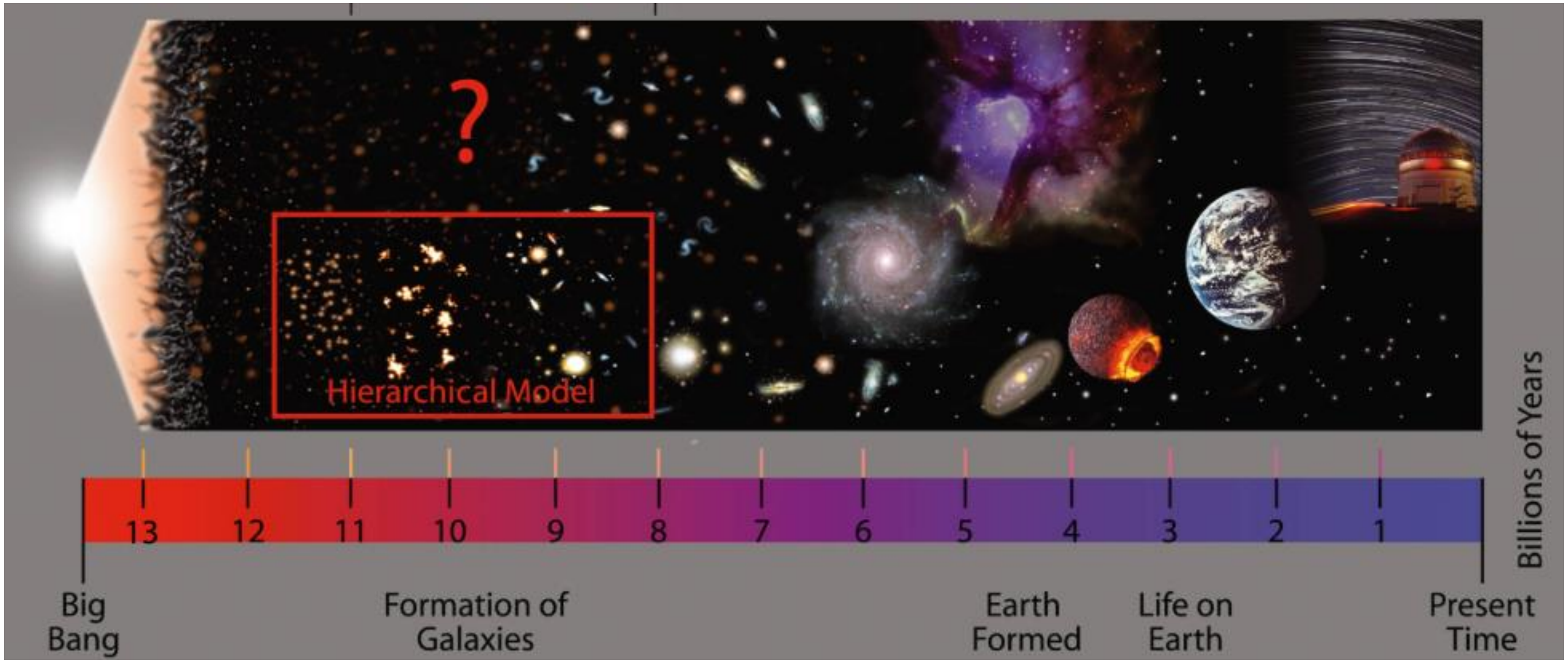
Cobalt-60 is extensively used in treating cancer.

Iodine-131 is used to locate brain tumors, measure cardiac output, and determine liver and thyroid activity.

Radioactive Isotope	Applications in Medicine
Cobalt-60	Radiation therapy to prevent cancer
Iodine-131	Locate brain tumors, monitor cardiac, liver and thyroid activity
Carbon-14	Study metabolism changes for patients with diabetes, gout and anemia
Carbon-11	Tagged onto glucose to monitor organs during a PET scan
Sodium-24	Study blood circulation
Thallium-201	Determine damage in heart tissue, detection of tumors
Technetium-99m	Locate brain tumors and damaged heart cells, radiotracer in medical diagnostics (imaging of organs and blood flow studies)

Radioactive Dating

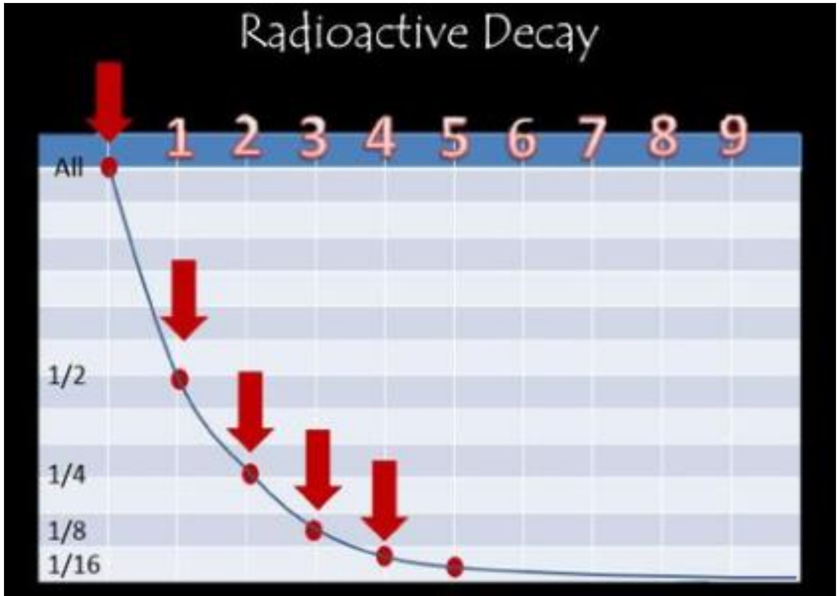
According to the Theory of Evolution, the universe is over 13 Billion years old and our Earth is considered 4.5 Billion years old all based on radioactive dating. Fact or Fiction?



Radioactive Dating

Three assumptions of Radioactive dating:

1) The original amount of both mother and daughter elements is known.
2) The sample has remained in a closed system.
3) The rate of decay has remained constant throughout the past.



Radioisotopes are only reliable to 2-3 half-lives, not indefinitely.

Radioactive Dating

Addressing the assumptions of Radioactive dating:

1) Ensuring that any one of the assumptions is met is difficult at best, if not impossible.
2) Many dates have changed due to different procedures or materials used.
3) Emotion, reasoning, and bias dominate this topic on the part of Christians and evolutionists.

"As we overthrow reasonings and every high thing rising up against the knowledge of God …"

2 Corinthians 10:5

Radioactive Dating

Although evolutionists claim “absolute age” based on dating, we certainly cannot know precise dates, especially over 100’s, 1000’s, millions, and billions of years.

Some things to consider:

1) People often believe what they were taught even if it is proven false (e.g. prejudice).
2) Historians cannot even decide on exact dates within the past 6,000 years. How can scientists be so sure of millions of years ago?
3) We should not reject the fossil record, but neither should we compromise the Bible.

Radioactive decay

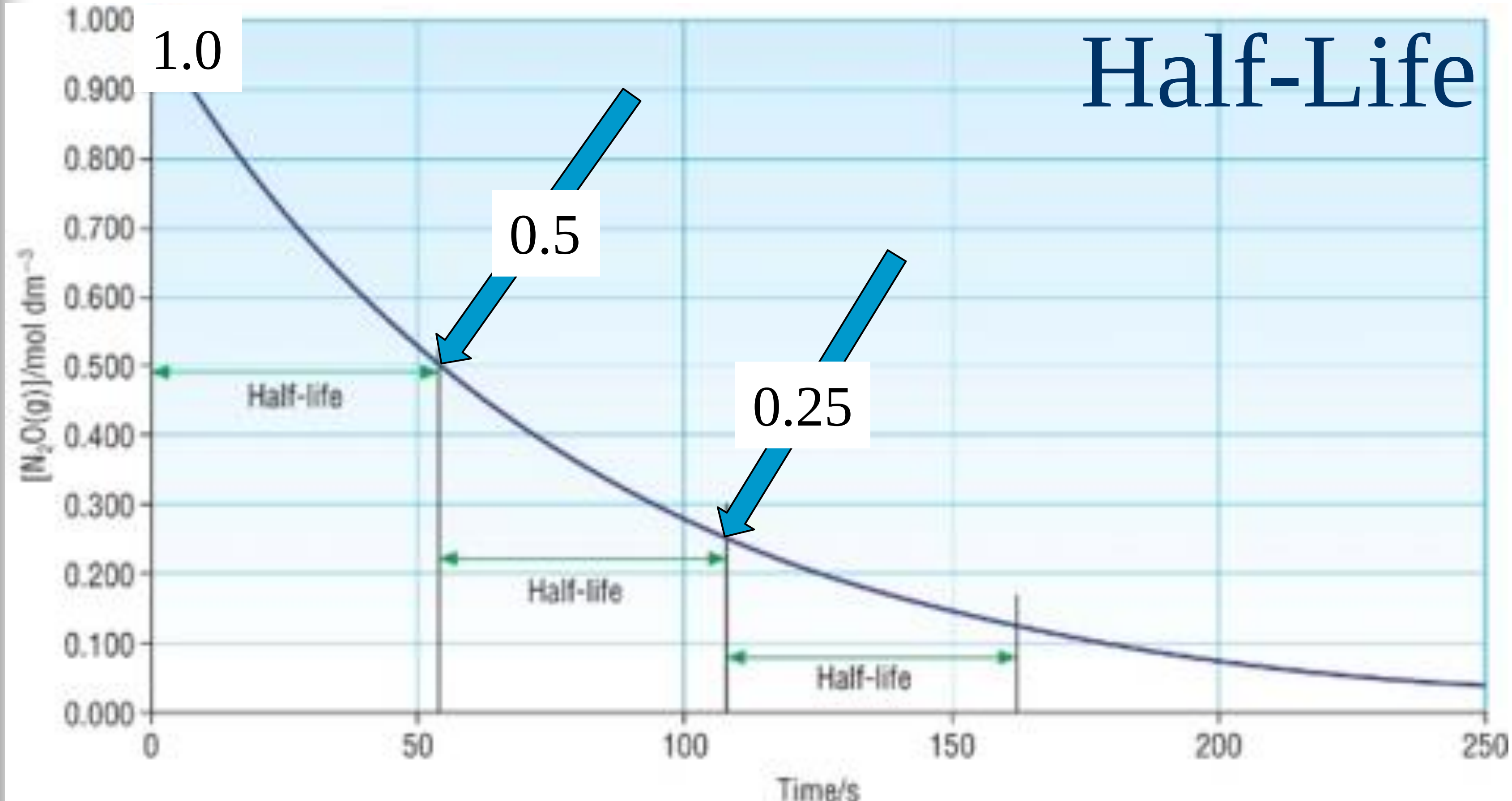
- Radioactive isotopes are used based on the decay of specific atomic nuclei.
- The moment in time at which a particular nucleus decays is unpredictable.
- However, a collection of atoms of a radioactive nuclide decays exponentially at a rate described by half-life.
- Half-life is usually given in units of years.

Half-Life

- Measures the rate of decay of a radioactive isotope

- The time it takes for ½ of an original quantity of a radioactive element to decay into another element.

Half-Life



Half-life is the time it takes for a radioactive isotope to half its amount.

Reliability greatly decreases with each half-life. After 2-3 half lives, the dating of a sample is relatively unreliable.

Half-Life Example

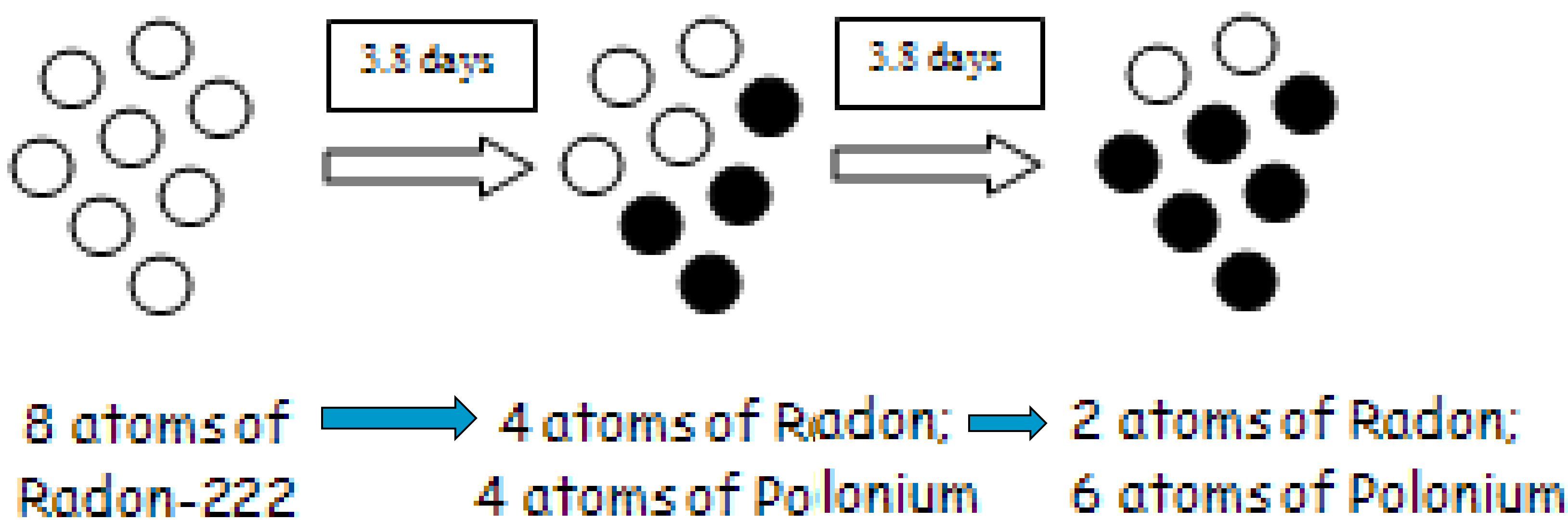
- Radium-226 has a ½ life of 1,620 years
- This means ½ of a sample of radium will change into other elements after 1,620 years
- After another 1,620 years (*3240 years total*), ½ the remaining radium will decay (leaving ¼ the original amount)

Half-Life

- The shorter the half-life of an element, the faster it decays
- The more radioactivity it gives off

Half-Life Example

A sample of 8 atoms of Radon-222 has a ½ life of 3.8 days



Dangers of Radioactive Decay

- **A feared and negative effect of radiation is cancer due to mutations.**
  - **Alpha, beta, and gamma particles penetrate to our cells**
- Radiation also causes burns, hair loss, alter chemical reactions in the body, and many other severe side effects.

Dangers of Radioactive Decay

- The Chernobyl disaster was the worst nuclear power plant accident in history in terms of cost and casualties.
- Used graphite instead of heavy water as its coolant and neutron moderator.
- Gives nuclear energy a "bad" name based on fear.

Half-Life Example

TRY IT

Carbon-14 has a ½ life of 5,730 years. If a fossil has 1/8 of its original carbon-14, how old is it?

Half-Life Example

TRY IT

Carbon-14 has a ½ life of 5,730 years. If a fossil has 1/8 of its original carbon-14, how old is it?

- Each half-life took 5,730 years and there were three half-lives.
- So, 5,730 x 3 = **17,190 years old**
- **Now → 5730 yrs → 11,460 yrs → 17,190 yrs**

Half-Life Example

TRY IT

The half-life of Zn-71 is 2.4 minutes. If one had 100.0 g at the beginning, how many grams would be left after 7.2 minutes has elapsed?

Half-Life Example

TRY IT

The half-life of Zn-71 is 2.4 minutes. If one had 100.0 g at the beginning, how many grams would be left after 7.2 minutes has elapsed?

7.2 / 2.4 = 3 half-lives

100.0 g → 50.0 g → 25.0 g → ***12.5 g***

$y = a\,(1/2)^t$ **$y = (100\text{ g})\,(1/2)^3$**

$X = 100\text{ g}^{(1/8)}$ = **12.5 g**