RADIOACTIVITY / CANCER

1. some definitions
2. fundamentals of nuclear physics
3. types of decays : α β γ
4. we are radioactive /carbon 14 / alcohol
5. half-life / they don't age/radiocarbon dating
6. cloud chamber/ Geiger counter
7. the rem / radiation sickness
8. cancer versus radiation sickness
9. dirty bomb versus fossil fuel bombs
10. power from radioactivity
11. heat in earth and helium balloon
12. fusion and fission (intro to next chapter)
13. brief history

2. fundamentals of nuclear physics

The atomic nucleus consists of positively charged protons and neutral neutrons.

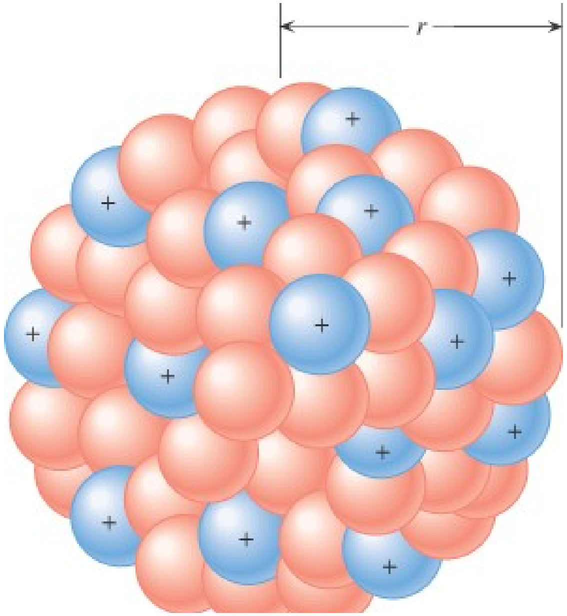
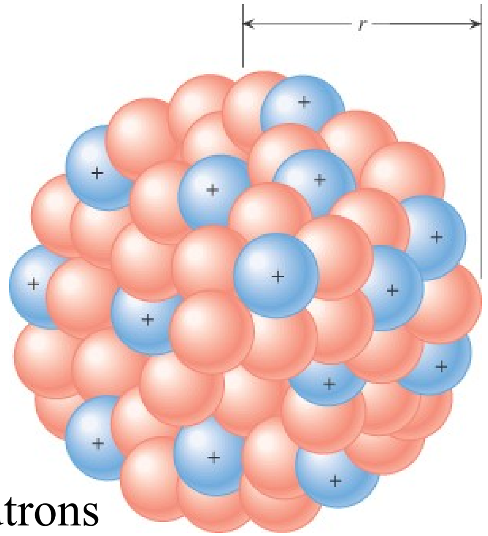


Table 31.1 Properties of Select Particles

Particle	Electric Charge (C)	Mass: Kilograms (kg)	Mass: Atomic Mass Units (u)
Electron	-1.60×10^{-19}	$9.109\,382 \times 10^{-31}$	$5.485\,799 \times 10^{-4}$
Proton	$+1.60 \times 10^{-19}$	$1.672\,622 \times 10^{-27}$	1.007 276
Neutron	0	$1.674\,927 \times 10^{-27}$	1.008 665
Hydrogen atom	0	$1.673\,534 \times 10^{-27}$	1.007 825

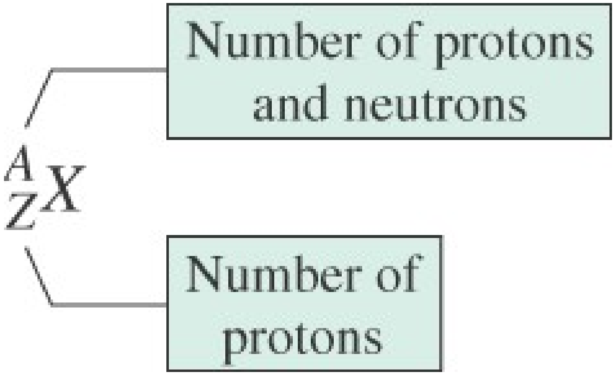
What's the ratio between the mass of the electron and the mass of the proton/neutron ?



atomic mass number A

atomic number Z

A number of
Protons and neutrons = number of protons + number of neutrons
N

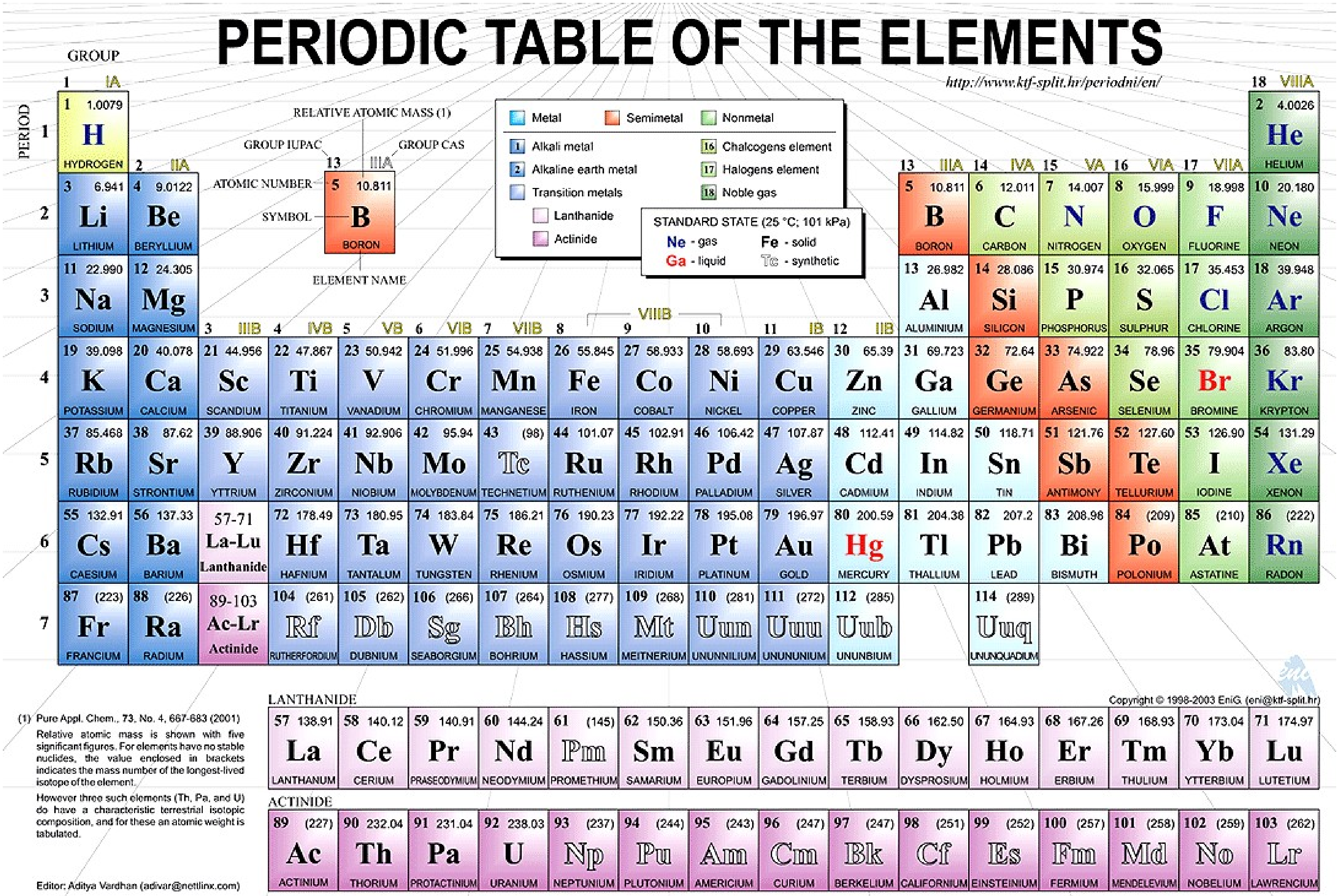


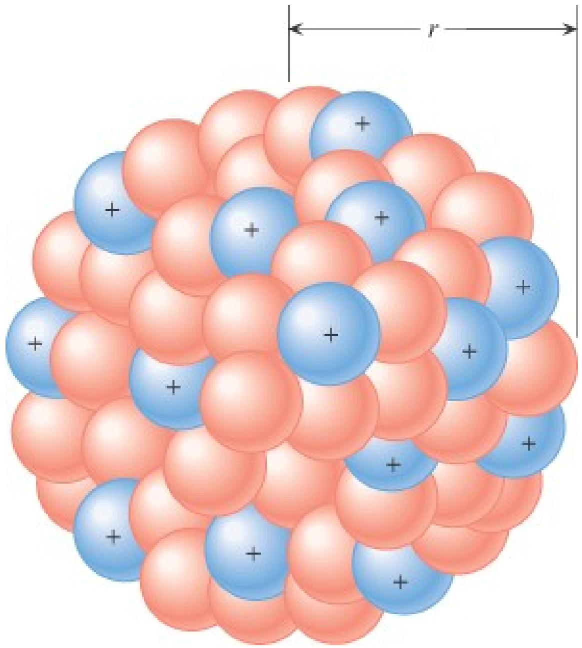
Nuclei that contain the same number of protons but a different number of neutrons are known as ***isotopes***.

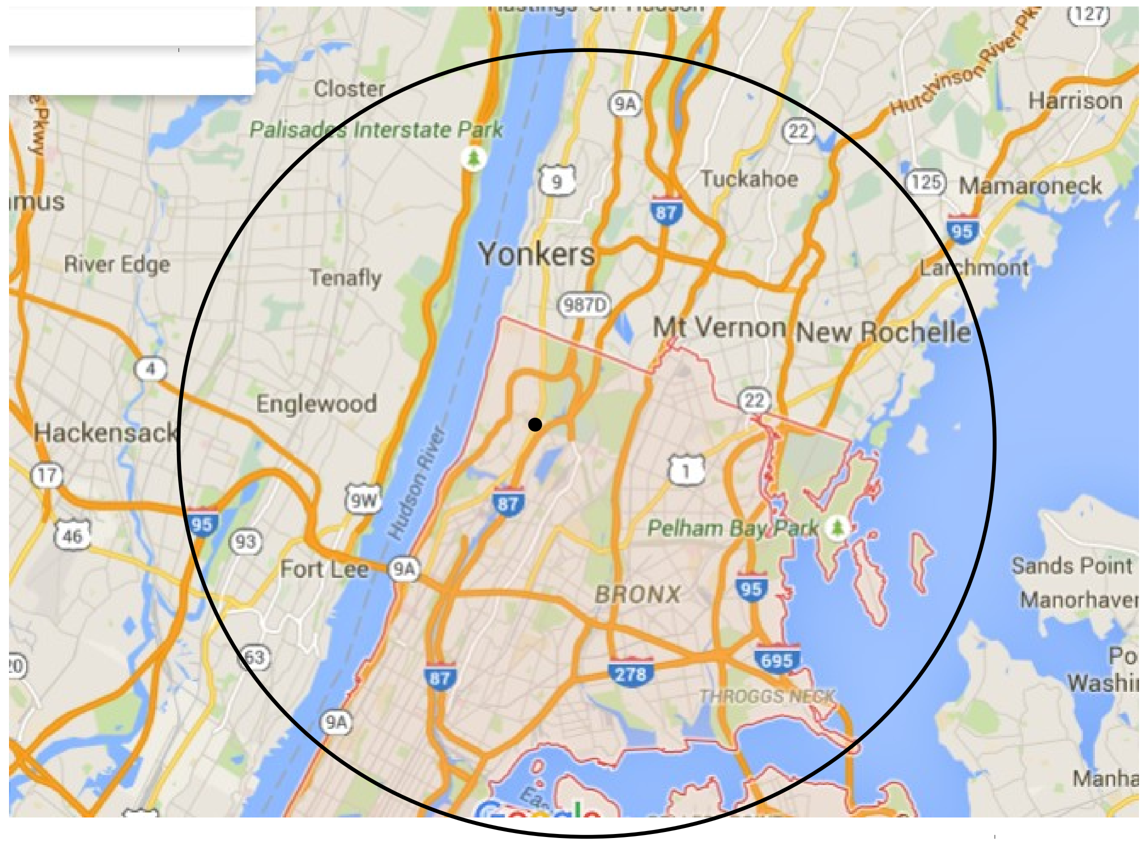
Check the interactive periodic table.
For carbon. Google carbon-12 carbon-13 carbon-11 carbon-14

http://www.ptable.com

https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html







The atom has a size of about 10^{-10} m.

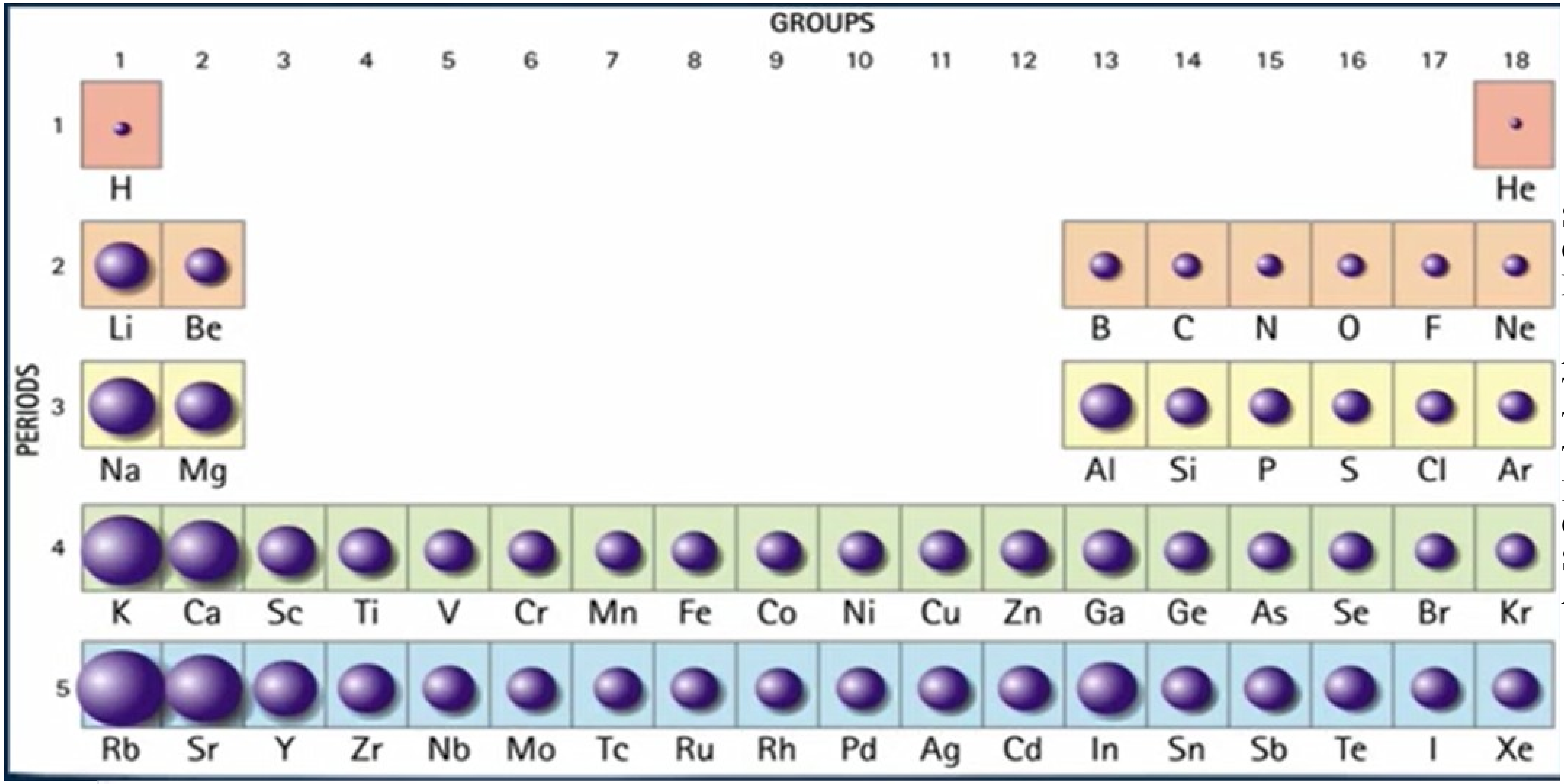
If the size of the nucleus is about 10^{-15}m

If the nucleus was a basketball at Manhattan College
The electrons are 7.5 miles away.

What is the ratio ?

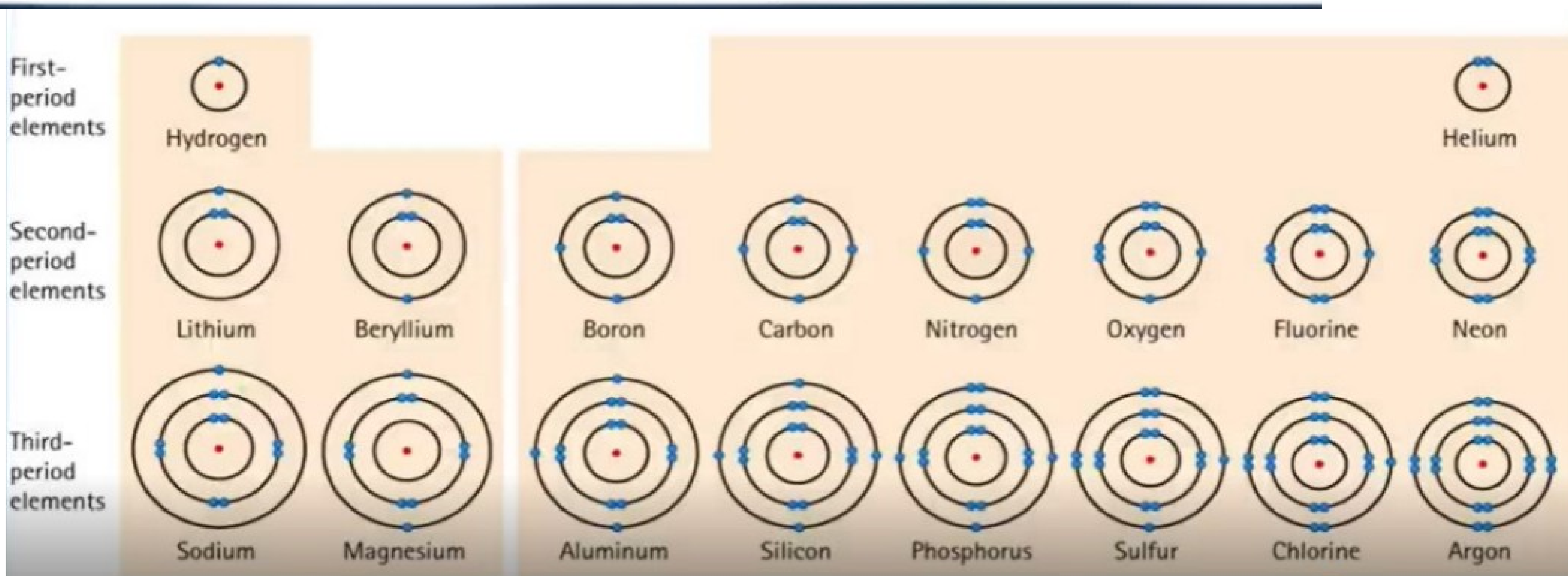
It the nucleus is 1mm (ant) then the size of the atom is about ________ mm = _____m (divide by 1000. 1m = 1 yard about). It's the ratio between a grape seed and A baseball stadium !!!

A lot of space. (the space is filled by electron waves)



Source:
Conceptual Physics
Hewitt

Along a line as you increase
The number of electrons on
The outer shell the pull between
The nucleus and the electrons
Increases and bringing the electrons
Closer to nucleus.
Size decreases. From one line to
Another another shell is added.



The number of protons define the element. The number of neutrons Can vary. Elements have isotopes.

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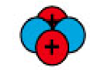
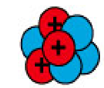
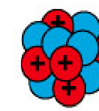
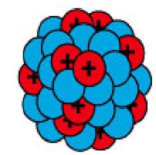
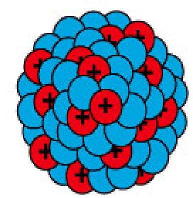
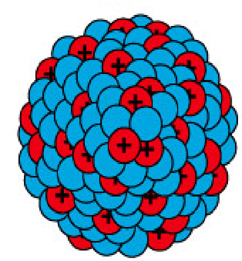
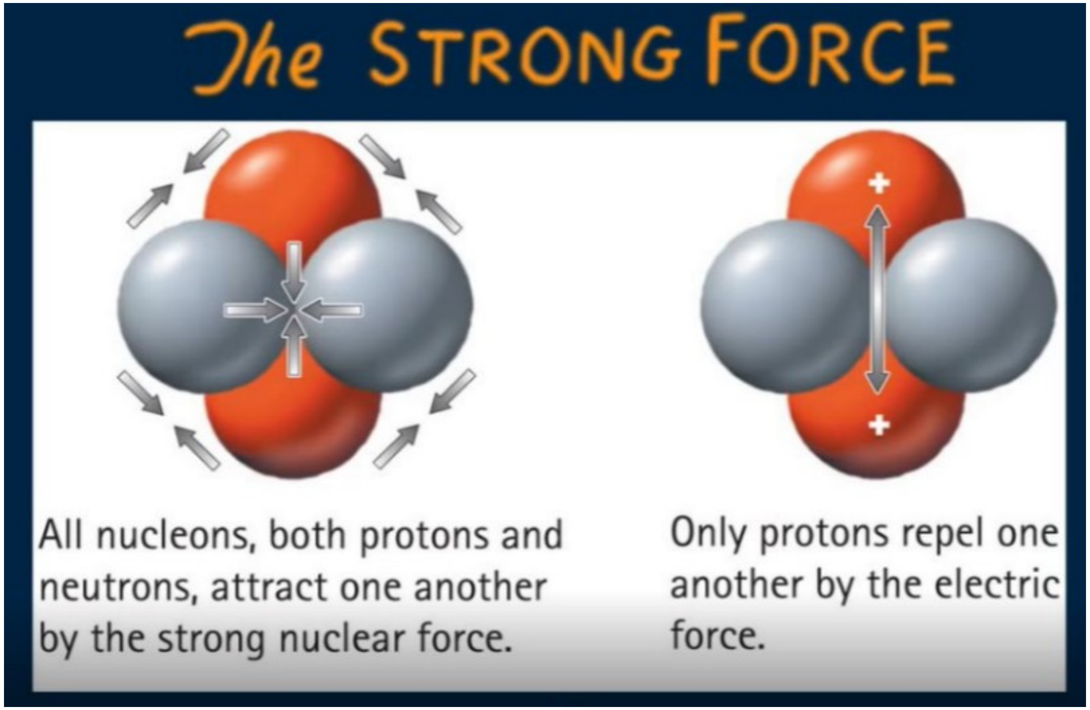
Isotope	Symbol	Number of protons	Number of neutrons	Relative size
Helium-4	$_{2}He^{4}$	2	2	
Beryllium-9	$_{4}Be^{9}$	4	5	
Nitrogen-14	$_{7}N^{14}$	7	7	
Chlorine-37	$_{17}Cl^{37}$	17	20	
Iron-56	$_{26}Fe^{56}$	26	30	
Uranium-238	$_{92}U^{238}$	92	146	

31.2 *The Strong Nuclear Force and the Stability of the Nucleus*

The mutual repulsion of the protons tends to push the nucleus apart.

- **What then, holds the nucleus together?**

- **What are the 4 fundamental forces Of nature ?**



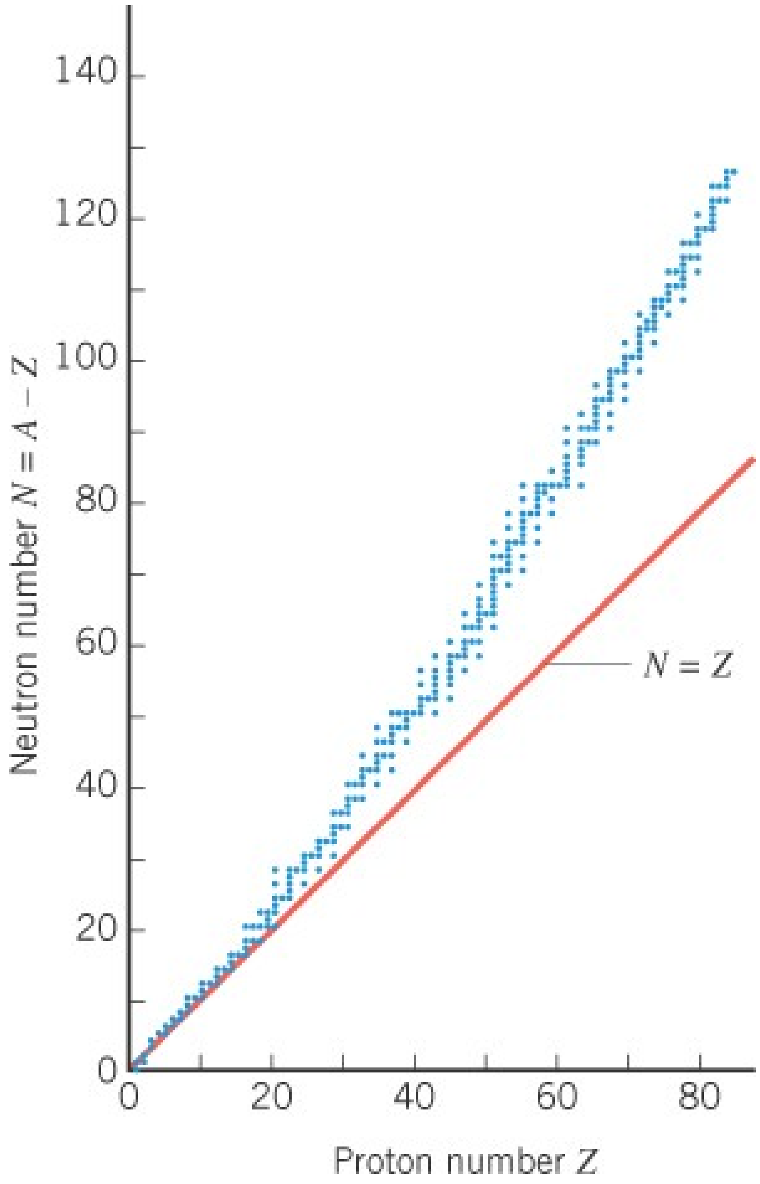
Source: Hewitt – conceptual Physics

Inside the nucleus :
The **strong nuclear force** is 100 times larger than the **electromagnetic force**.
The **weak force** is 100,000 times weaker than the strong force.
The **gravitational force** is 10^{-43} times the **electromagnetic force**.

Outside the nucleus:
The strong and the weak forces are 0.

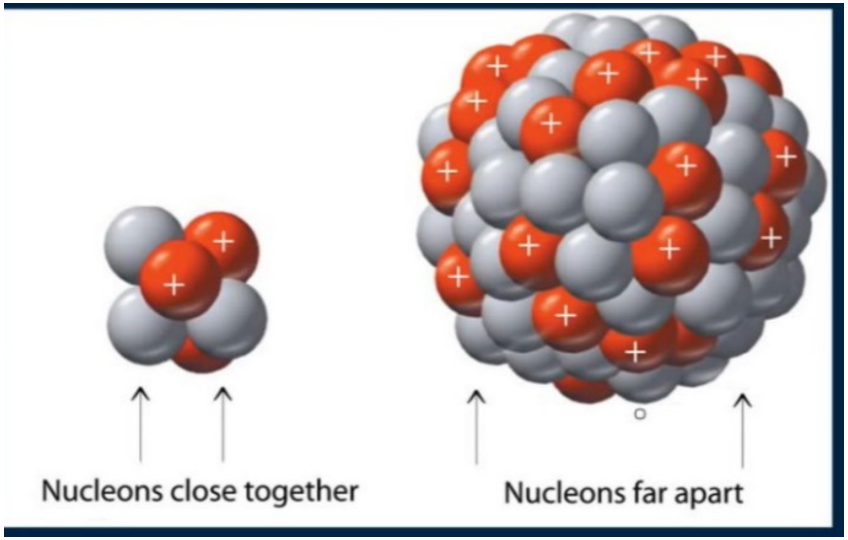
But a chemical explosion (TNT) generates 1 million times less than a nuclear explosion.

31.2 The Strong Nuclear Force and the Stability of the Nucleus



As nuclei get larger, more neutrons are required for stability.

The neutrons act like glue without adding more repulsive force.



Source: Hewitt – conceptual Physics

ISOTOPES

- Each element has a given number of protons, but can have different numbers of neutrons.
- Each different possible “type” of atom is called an **isotope**.
  - **Isotopes** of a given element have the same number of protons in the nucleus but a different number of neutrons.
- Different isotopes have essentially the same atomic properties but different nuclear properties.

The nucleus, cont'd

- Most of the 114 different elements have several isotopes.
  - Some have only a few: hydrogen has 3
  - Others have many: iodine, mercury and silver have more than 20
- More than 2,500 different isotopes have been identified and studied.
  - Only about 300 of these occur naturally.

The nucleus, cont'd

- The different isotopes of carbon are carbon-12, carbon-13, and carbon-14.
- The different isotopes of hydrogen have special names:
  - hydrogen-2 is called deuterium.
  - hydrogen-3 is called tritium.
- Isotopes play no role in chemical reactions.
- They are pivotal for understanding nuclear reactions.

The nucleus, cont'd

- We use a special notation to represent each isotope.
  - The element's chemical symbol is used.
  - A subscript to the left of the chemical symbol represents the atom's atomic number *Z*.
  - A superscript to the left of the chemical symbol represents the atom's atomic mass *A*.

Helium-4 $^{4}_{2}He$

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

Carbon-12 $^{12}_{6}C$

Uranium-235 $^{235}_{92}U$

Isotopes with unstable nuclei are called **radioisotopes**.

- The majority of all isotopes are radioactive.
-

  In medical field the radioactive substances (made using induced radioactivity) are called radionuclide or radiopharmaceuticals.

notation

- We use a similar notation for atomic particles.

Neutron	$^{1}_{0}n$
Proton	$^{1}_{1}p$
Electron	$^{0}_{-1}e$

- The superscript is the mass in atomic units.
  - Zero for the electron since it is so small
- The subscript is the electric charge.

1) Use the periodic table (slide2).
The element chlorine has ___________- protons and _______ electrons
The table shows that Cl-35 is the most common isotope. It contains __________ neutrons.
Chlorine has 24 isotopes. From Cl-28 to Cl-51 .
So the number of neutrons can vary from _______ to ________.
(remember the number of protons stays the same!)

2) An element has 3 protons and 4 neutrons in its nucleus.
What is the notation to identify this element ?

3) If the atomic number of a neutral element is 35 and contains 40 neutrons.
what is the element and its notation?

4) What is the charge on a particle that contains 9 protons, 10 neutrons and 7 electrons ?
What is the notation?

5) There are 3 isotopes O-16, O-17 and O-18.
How many protons/neutrons these isotopes contain?
Which one is the most common?

6) Ammonia NH_3 is made all around the world. What make up this molecule?

7) Which of the following particles has the smallest mass ?
A) neutron B) electron C) proton D) hydrogen atom

8) All isotopes of neutral atoms of sodium have :
______ protons ________ neutrons ___________ electrons

8) All isotopes of neutral atoms of sodium have :
_____ protons _______ neutrons __________ electrons

9) Determine the nuclear composition of the following isotopes:
A) carbon 14 B) calcium 45 C) silver 108 D) radon 225 E) plutonium 242

10) An atomic species is represented as Ir -190 . State the number of electrons in the rings, neutrons in the nucleus
Protons in the nucleus.

11) the neutral element magnesium Mg 24 has ___ protons, ____ electrons , ___ neutrons

12) Refer to slide 2. The mass of an atomic nucleon (proton or neutron) is nearly
A) twice the mass of an electron B) four times C) a thousand D) two thousand

13) An atom with an unbalanced number of electrons to protons is an _______

14) The atomic number of a nucleus is the same as the number of its: A) protons B) neutrons C) nucleons

15) The atomic mass of a nucleus is the same as the number of of its: A) protons B) neutrons C) nucleons

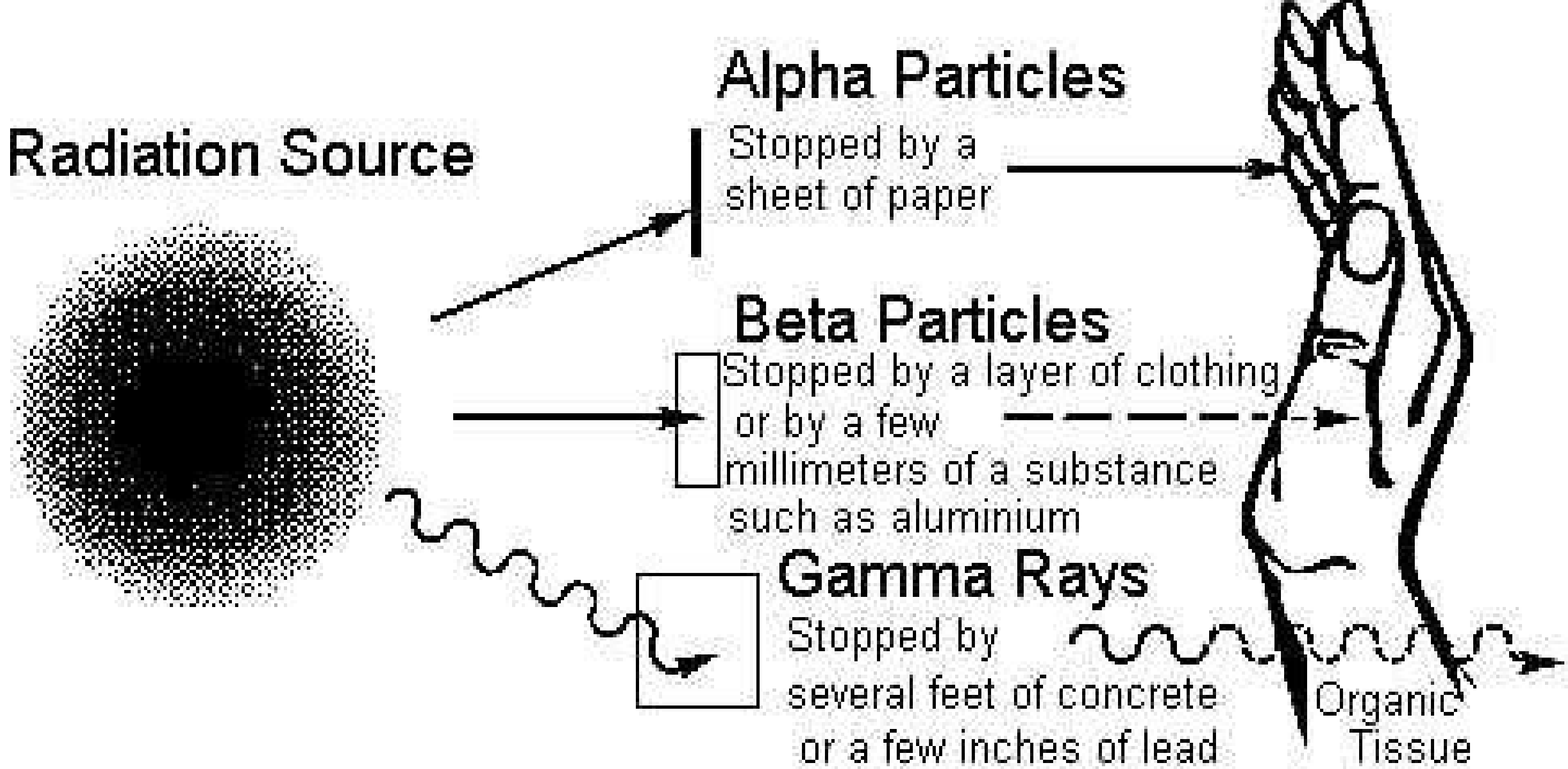
16) Deuterium and tritium as both: A) forms of hydrogen B) isotopes of the same elements C) neither of these D) both of these..

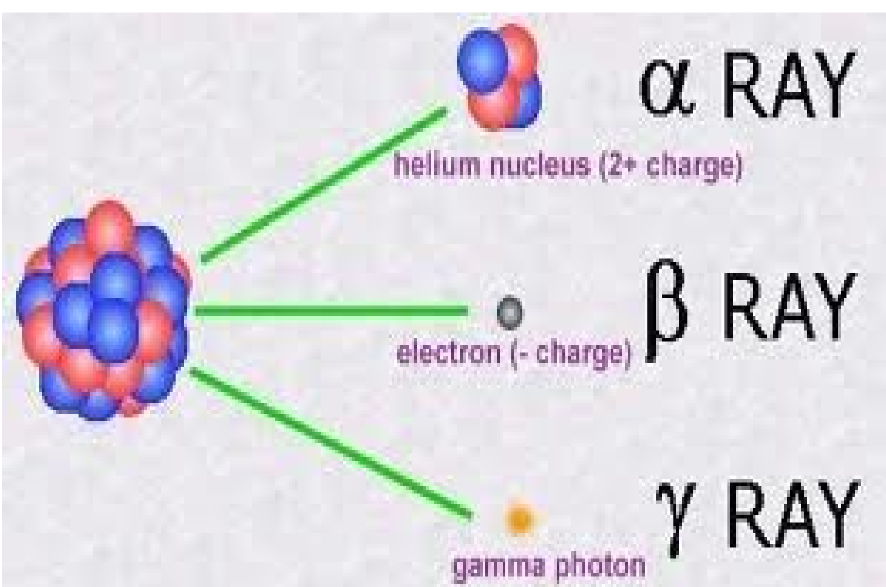
17) Different isotopes of an element have different numbers of A)protons B) neutrinos C) photons D) neutrons E) none of these

18) electric force within an atomic nucleus tend to: A) hold it together B) push it apart C) IDK

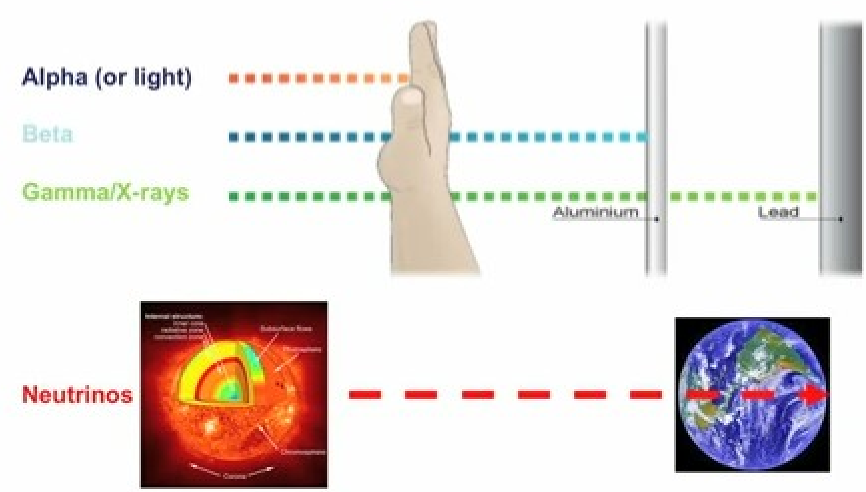
19) Generally speaking, the larger a nucleus, the greater its:A) stability B) instability C) neither

20)





Neutrinos go through anything (almost)

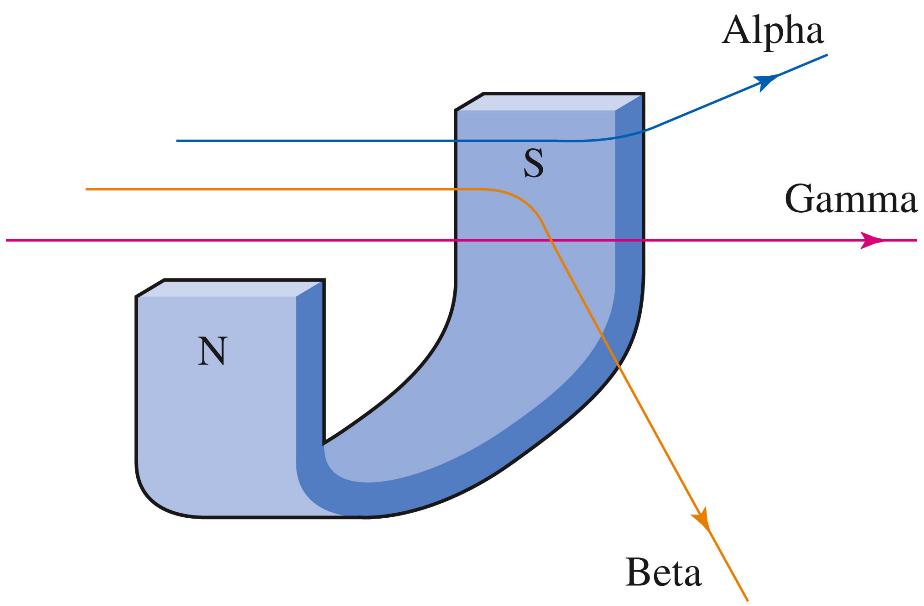


Radioactivity

- There are three types of nuclear radiation:
  - **alpha radiation** (α) are made of helium nuclei.
    - Two protons and two neutrons
    - Has a positive electric charge
  - **beta radiation** (β) are made of high energy electrons.
    - Has a negative electric charge
  - **gamma radiation** (γ) is EM radiation
    - Has no electric charge

Radioactivity, cont'd

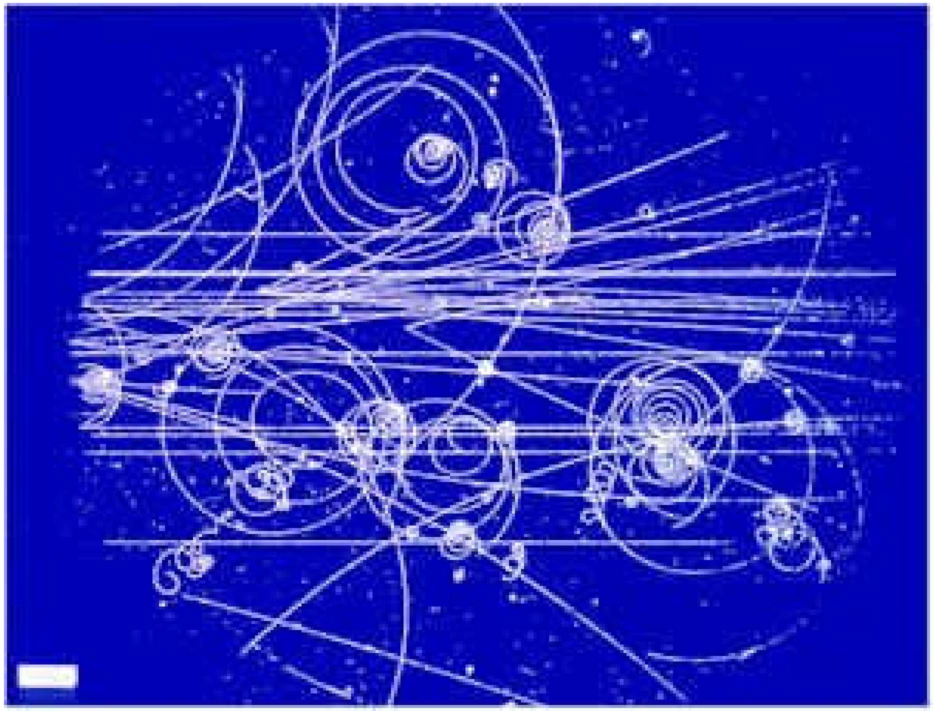
- The type of radiation can be determined by passing it through a magnetic field.
- Since each type has a different electric charge, they are deflected differently by the magnet.



CLOUD CHAMBER
See animation/video

The chamber is filled with water vapor (or alcohol) ready to become Liquid. The ray leaves a streak of fine droplets on its way.
It ionizes on its way the molecule of gas , the molecule become ions.
The gas form droplets on these ions.

supersaturated vapor that condenses to tiny liquid droplets around ions produced by the passage of energetic charged particles, such as alpha particles, beta particles, or protons

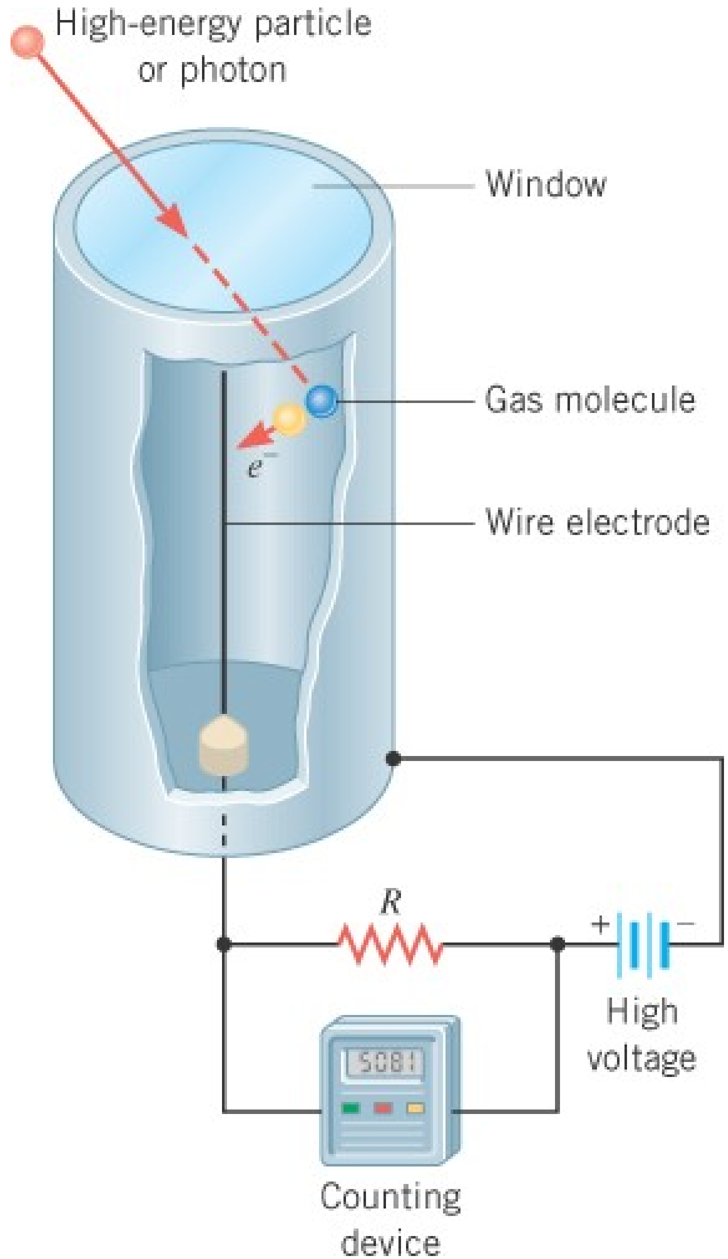


See video

http://www.thenakedscientists.com/HTML/content/kitchenscience/exp/cloud-chamber/

31.9 Radiation Detectors

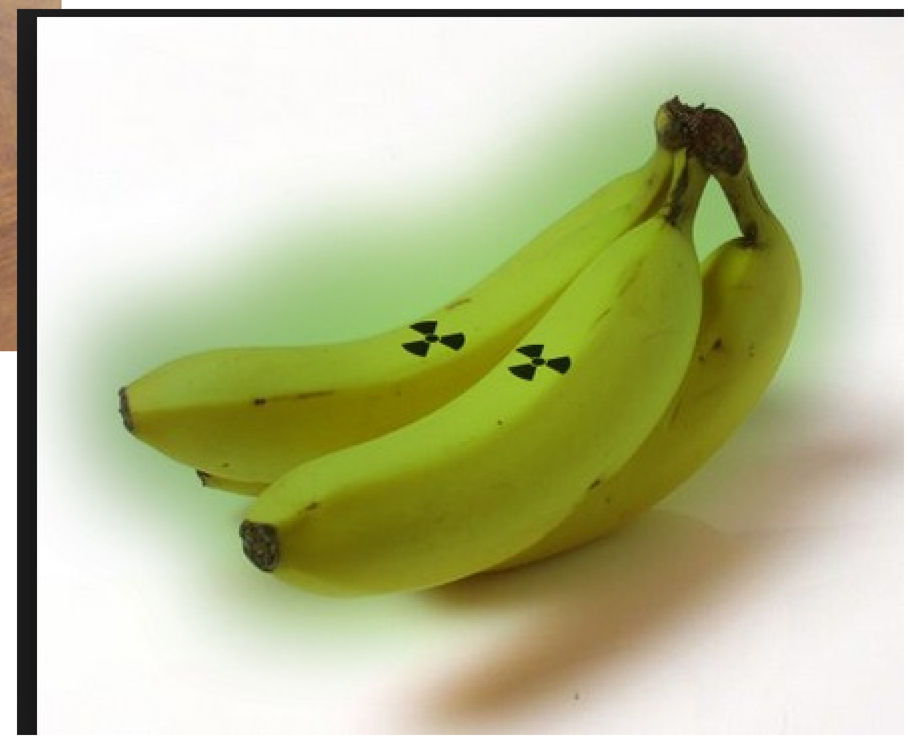
A Geiger counter



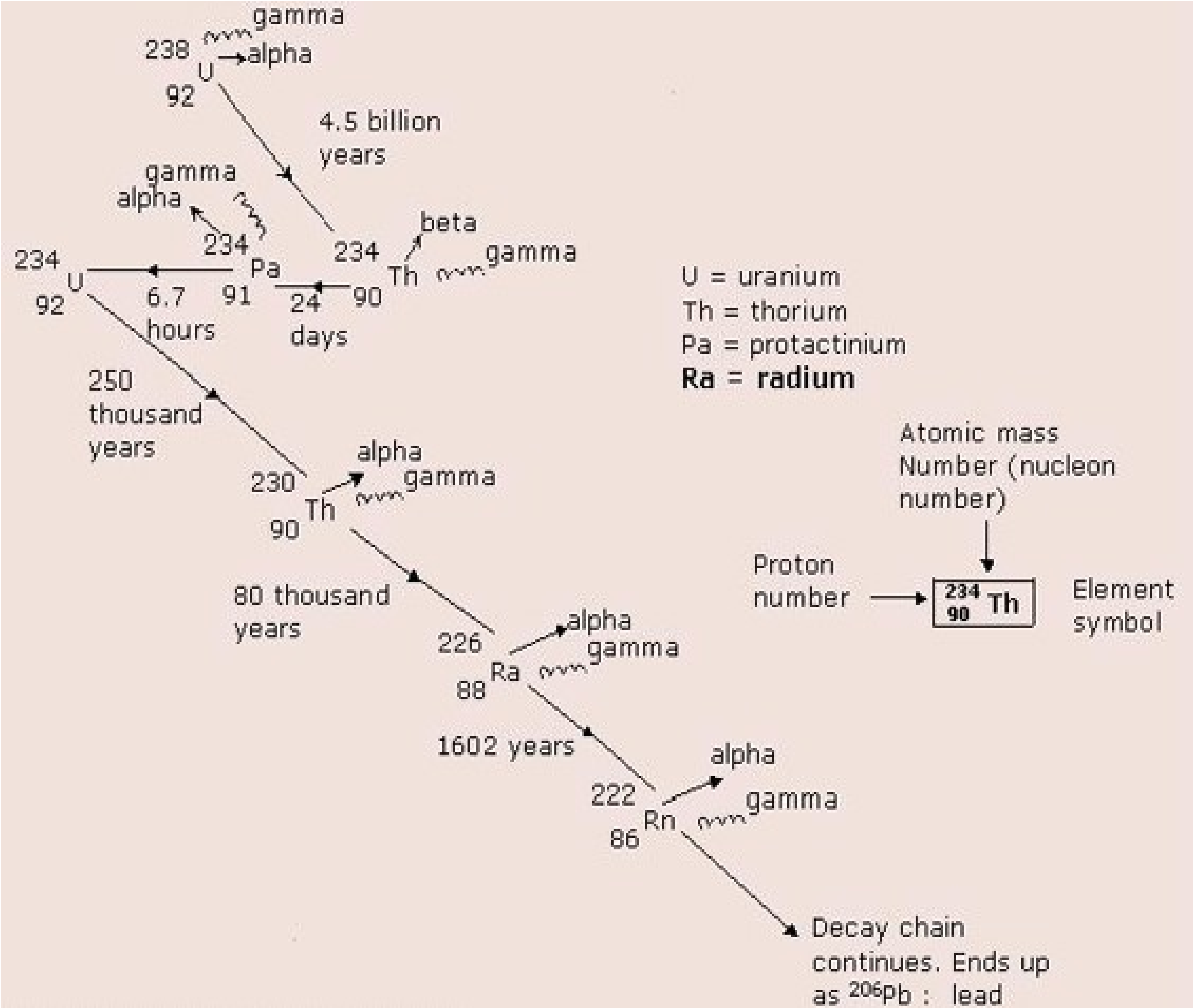
SEE VIDEO

Source: Cutnell and Johnson

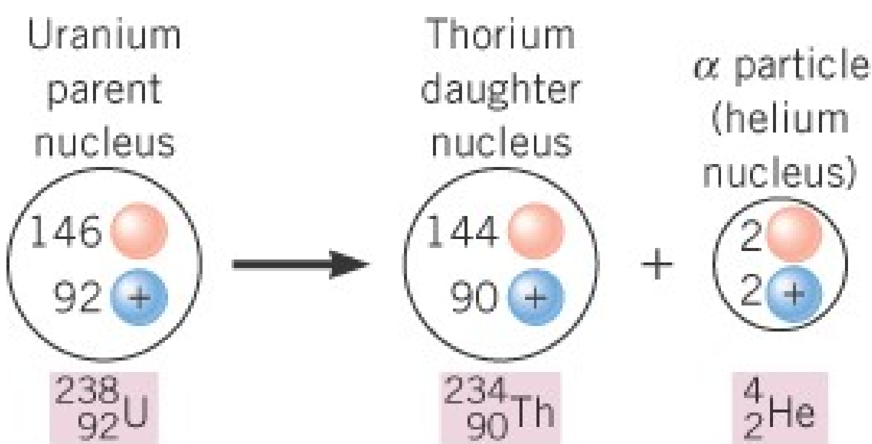
http://depletedcranium.com/if-uranium-is-not-so-radioactive-why-does-it-peg-a-geiger-counter/



https://www.youtube.com/watch?v=v8wKbpsw-OE Go to 0:33

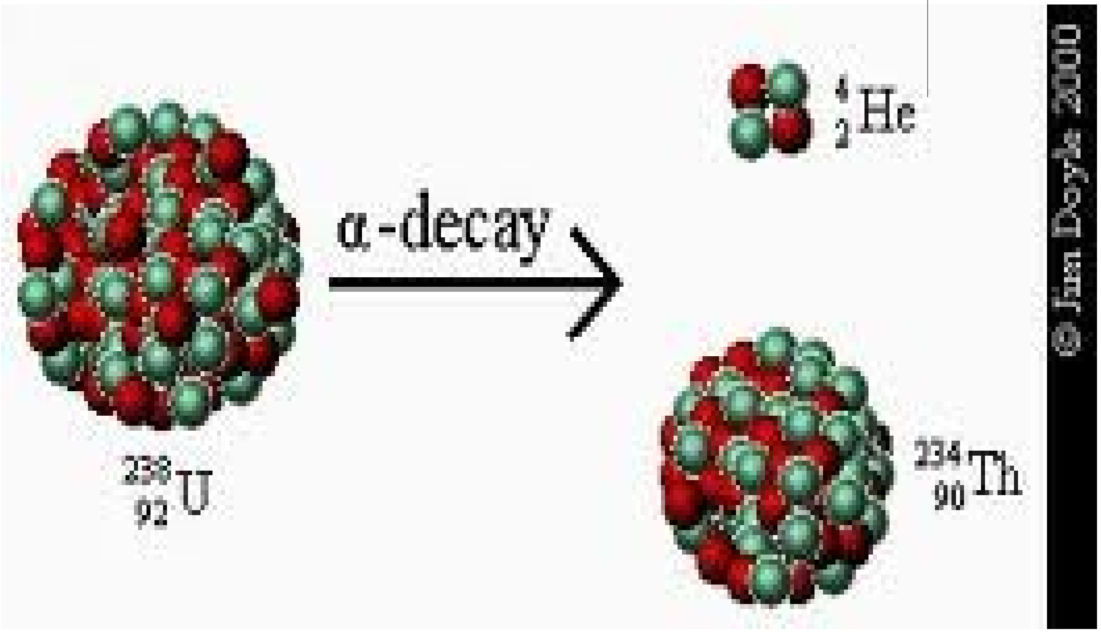

gamma
238
U
92
alpha
4.5 billion years
gamma
alpha
234
Pa
91
234
Th
90
beta
gamma
234
U
92
6.7 hours
24 days
U = uranium
Th = thorium
Pa = protactinium
Ra = radium
250 thousand years
230
Th
90
alpha
gamma
Atomic mass Number (nucleon number)
Proton number
234
90
Th
Element symbol
80 thousand years
226
Ra
88
alpha
gamma
1602 years
222
Rn
86
alpha
gamma
Decay chain continues. Ends up as 206Pb : lead

α DECAY



Up !

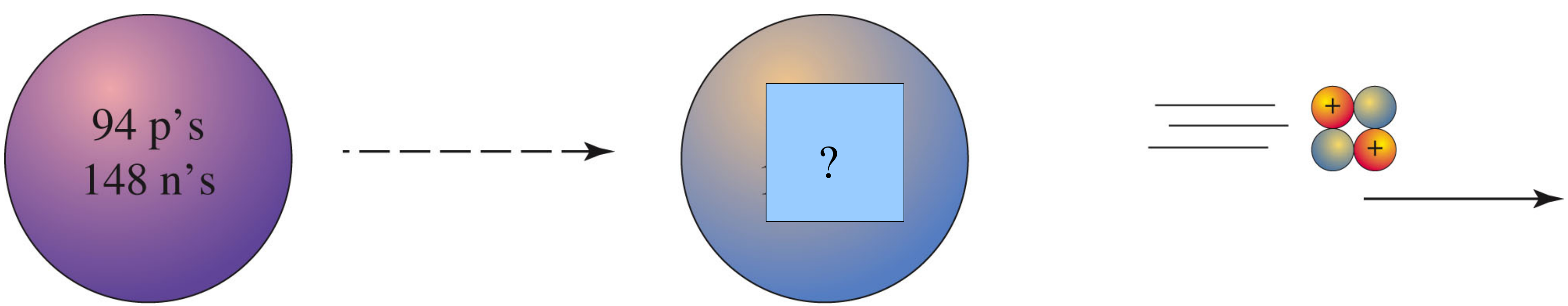
$$ {}^{A}_{Z}P \rightarrow {}^{A-4}_{Z-2}D + {}^{4}_{2}He $$



The energy is in the **kinetic Energy** of the **helium nucleus (alpha)**.
The nuclei will slow down and
Combine with 2 electrons
To make a helium atom.

Alpha decay, cont'd

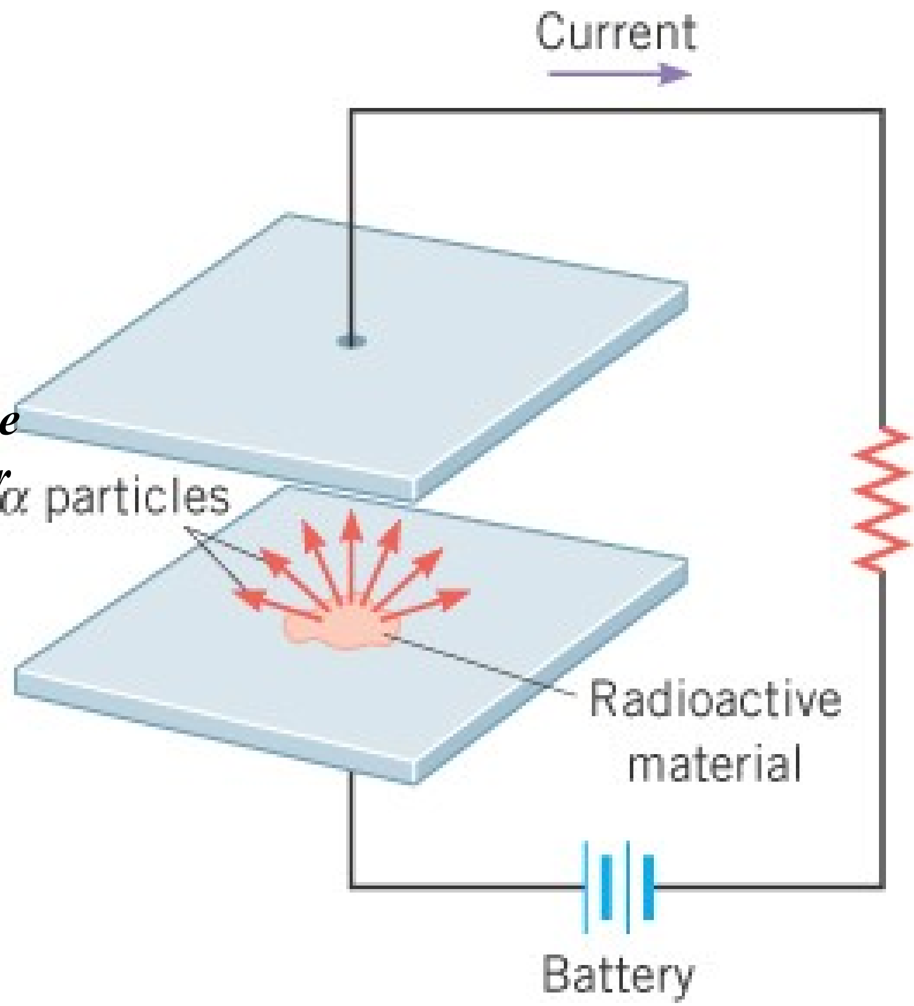
- Here is a diagram illustrating alpha decay.
  - We start with an unstable plutonium nucleus.
  - We obtain:
    - a uranium nucleus, and
    - an alpha particle

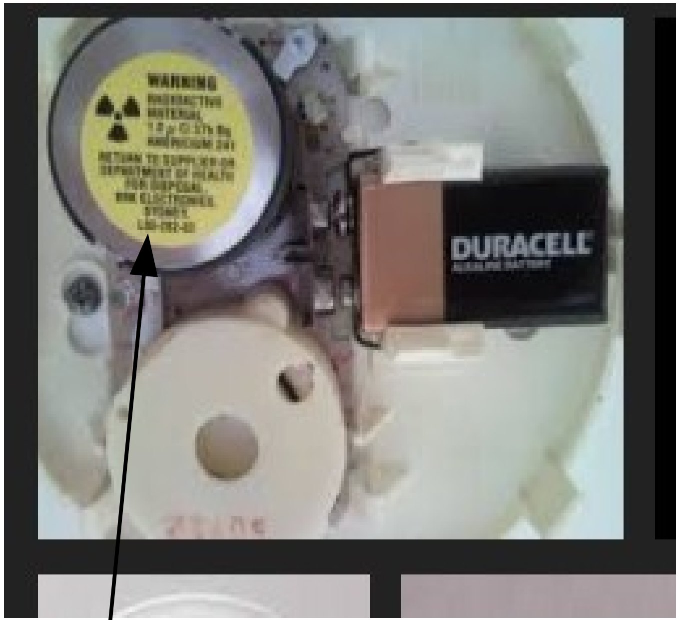


$^{242}_{94}\mathrm{Pu} \dashrightarrow \boxed{?} + {}^{4}_{2}\mathrm{He}$

31.4 *Radioactivity*

A smoke detector





americium

The alpha particles
Break the molecules of air into negative part and positive part. They are ionized.
The current can go through . If smoke between the 2 plates, the electrons attach to the smoke particles, the current can't get through. The smoke detector triggers the alarm.

Poisoning of the previous FSB (new KGB) officer : **Alexander Litvinenko**

Litvinenko described Vladimir Putin's rise to power as a coup d'état organized by the FSB

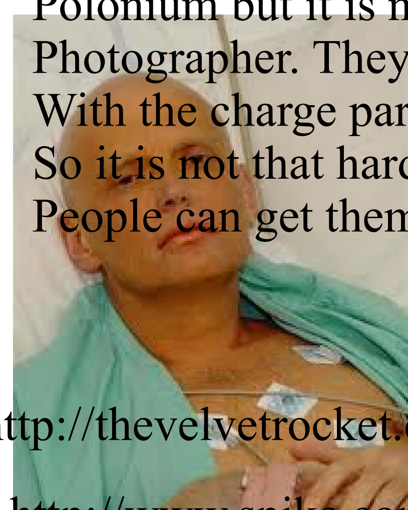
http://en.wikipedia.org/wiki/Poisoning_of_Alexander_Litvinenko

2006 – died in a few weeks of radiation illness. The particles messed up his chemistry.

He was poisoned with polonium 210. It's an alpha decay.
It's not dangerous when handled because the alpha particles are stopped by the
Dead layers of the skin. But if polonium is absorbed, there is no layer to
Protect the blood and vital organ.

The people who poisoned him could have used arsenic but they wanted to make a point.
Maybe a punishment for writing books that denounced what the FSB did.

Media said only the government can have access to the radioactive material
Polonium but it is no true. Polonium is found on special brushes used by
Photographer. They use the brush to uncharged the films. The alpha particles combine
With the charge particles. The author of the book could order them from the internet.
So it is not that hard to get. The polonium is inside a plastic capsule but skilled
People can get them.



http://thevelvetrocket.com/2010/10/03/alexander-litvinenkos-grave-in-highgate-cemetery/

http://www.spike.com/video-clips/sge3ct/1000-ways-to-die-red-scare

Alexander Litvinenko's Grave In Highgate Cemetery

Posted on October 3, 2010 *by* JUSTIN AMES   Leave a comment

London's Highgate Cemetery has a number of interesting figures buried on its grounds, including Karl Marx and various relatives of mine.

One very interesting (at least to me) recent arrival is that of Alexander Litvinenko. Remember the Alexander Litvinenko story?

We were advised that his body was still so radioactive that he had to be buried in a special coffin:

1) The isotope radium-226 undergoes alpha decay. Write the reaction equations, and determine the identity of the daughter nucleus.

2) Write the equation for the alpha decay of thorium-230

3) write the alpha decay of uranium 238

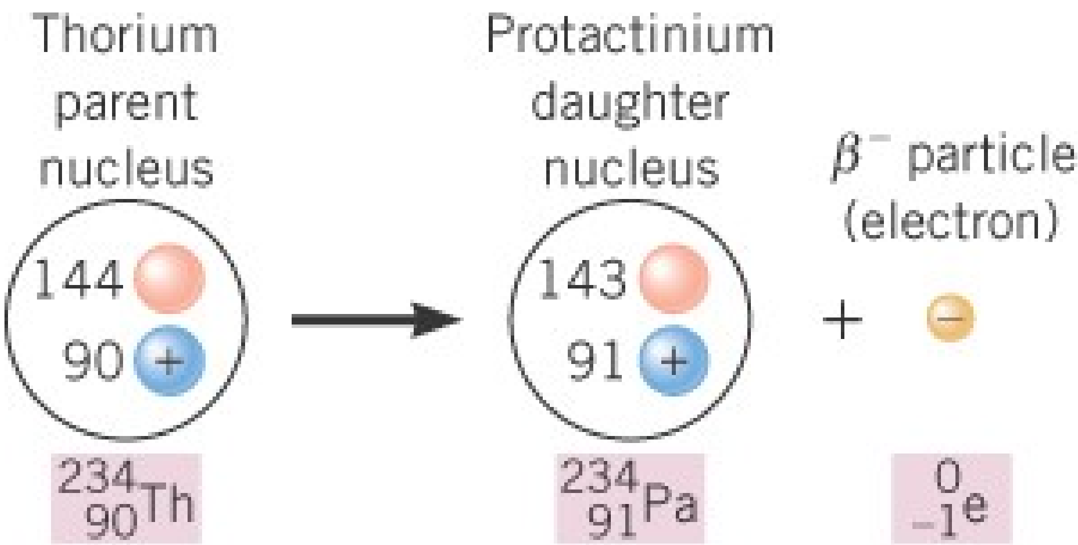
5) Home smoke detectors contain a small radioactive sample of americium 241 . What is the

Daughter nucleus of the alpha decay ?

7)The isotope polonium 210 undergoes alpha decay. Write the reaction equation, and determine the identity of the daughter nucleus

6) The isotope plutonium 239 undergoes alpha decay. Write the equation and determine the identity of the daughter nucleus.

β DECAY



$$^{A}_{Z}P \rightarrow \, ^{A}_{Z+1}D + \, ^{0}_{-1}e$$

The neutron becomes a proton , the weak force makes this change happens.
Its possible because the neutron has more mass than proton.
Energy is released. The energy is in the kinetic energy of the electron.
The electron slow down and attach to an atom or molecules.
When this happen , you can get a glow. Like in TV. (electrons lose Their energy by glowing) or inside the nuclear power plant.

The neutron has more mass than the proton so energy is released.

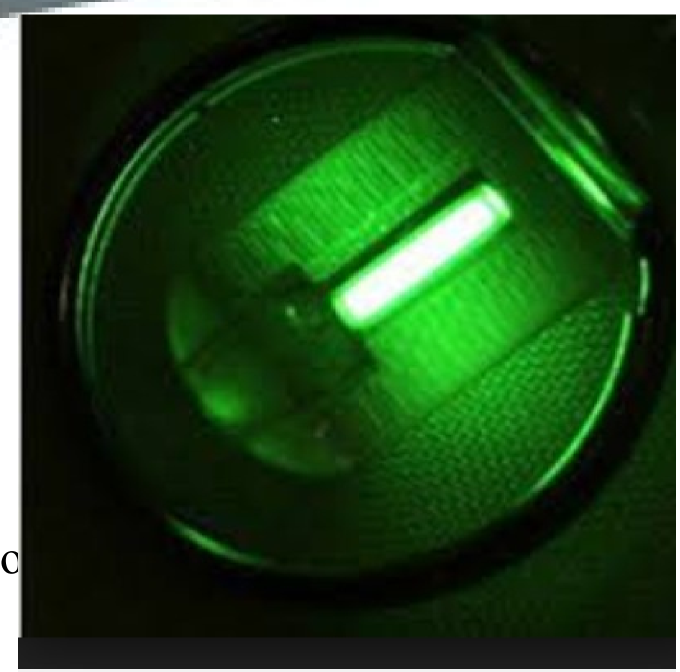
Beta decay, cont'd

- The emission of an beta particle:
  - Keeps the atomic mass the same, but changes the type of nucleons

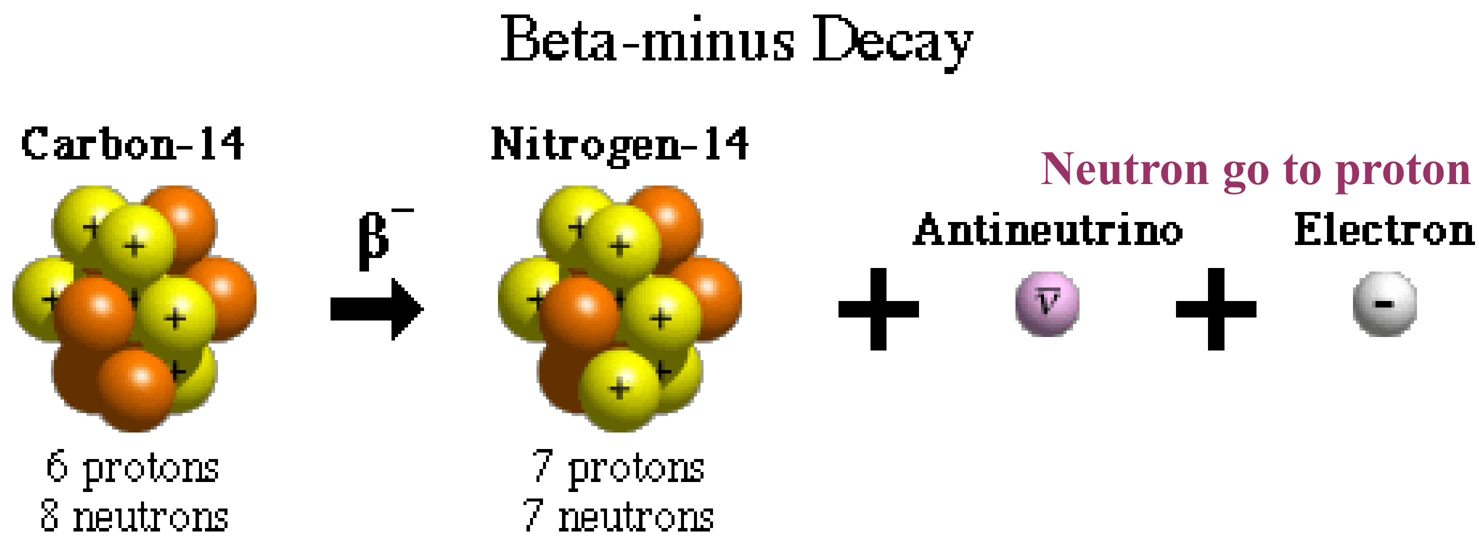
    stability is increases by increasing the nuclear charge. (alpha decreases it)
  - This is done by converting a neutron to a proton and an electron. The electron is ejected. The proton stays in the nucleus.
  - A gamma ray may or may not come off also, but there is always another particle called a neutrino (actually anti neutrino).

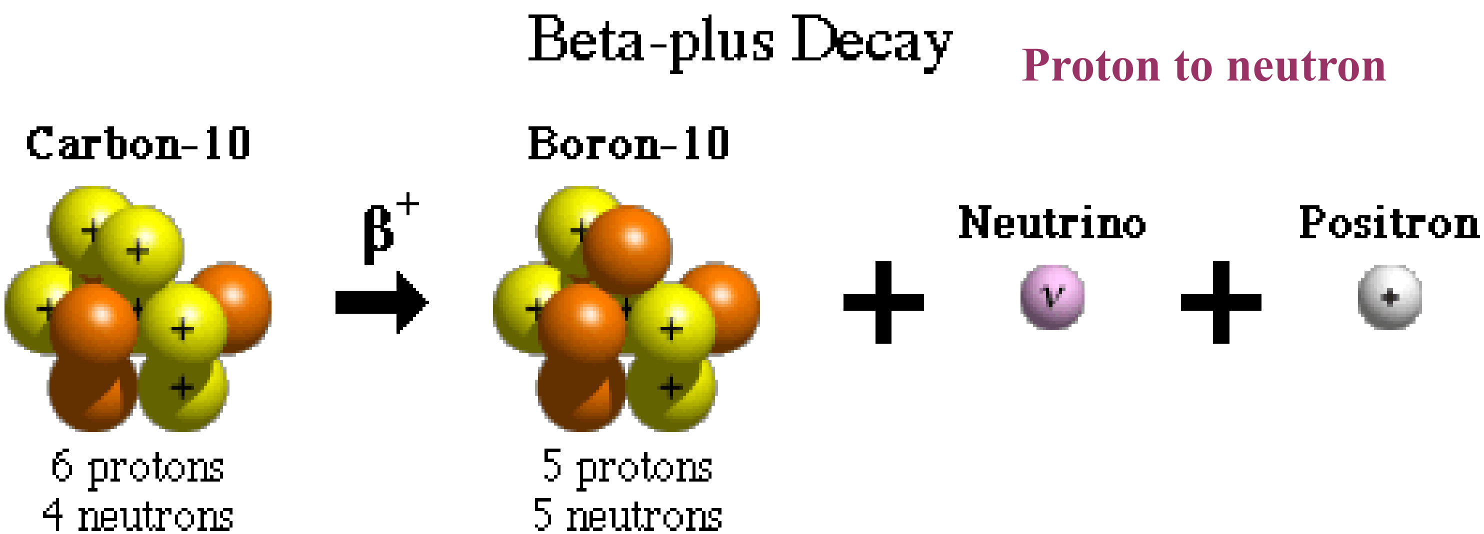
example of beta decays: The watches using tritium (or EXIT signs)
They glow in the dark. The beta particles are absorbed by phosphorus and emit light.

Electrons use their energy = radiation = glowing.



http://en.wikipedia.org/wiki/Tritium_illuminatic



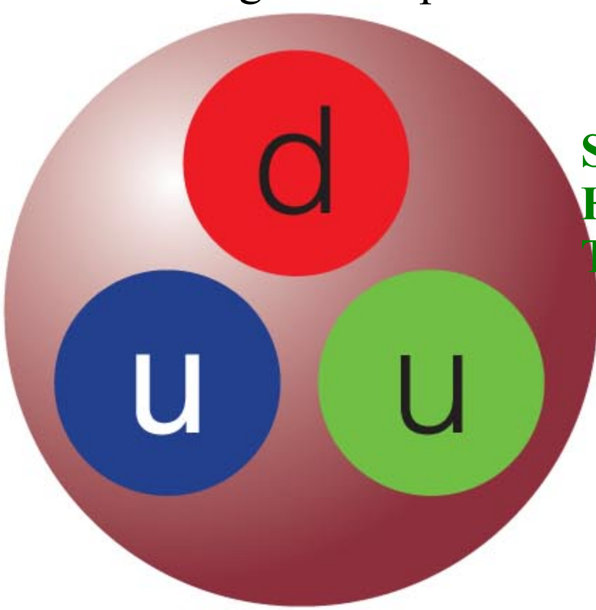


Proton go to neutron Like in stars. It can't happen spontaneously because neutron has more energy than proton. You need to put in Energy for the reaction to happen. High temperature make it possible like in massive stars. It also happens in medium stars thanks to the "tunneling effect" . This is a strange quantum mechanics phenomenon.
Proton " borrows" energy from vacuum to overcome an energy barrier.

How a proton can change into a neutron or a neutron into a proton ? It is an identity crisis ?

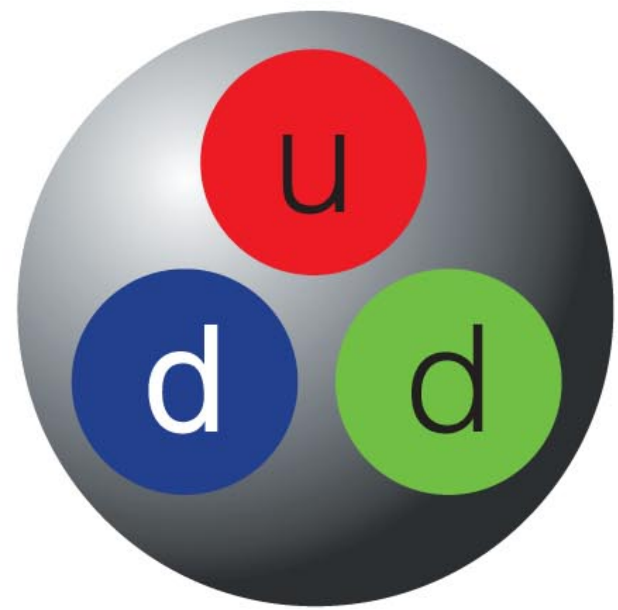
Protons and neutrons are made of smaller particles called quarks.
2 kinds of quarks make up the protons/neutrons: up quark and down quark.

Charge of up quark = 2/3 charge of down quark = -1/3
Find the charge of the proton and the neutron if this is the case.



PROTON

So what do you think Happen when proton Transforms to neutron?



NEUTRON

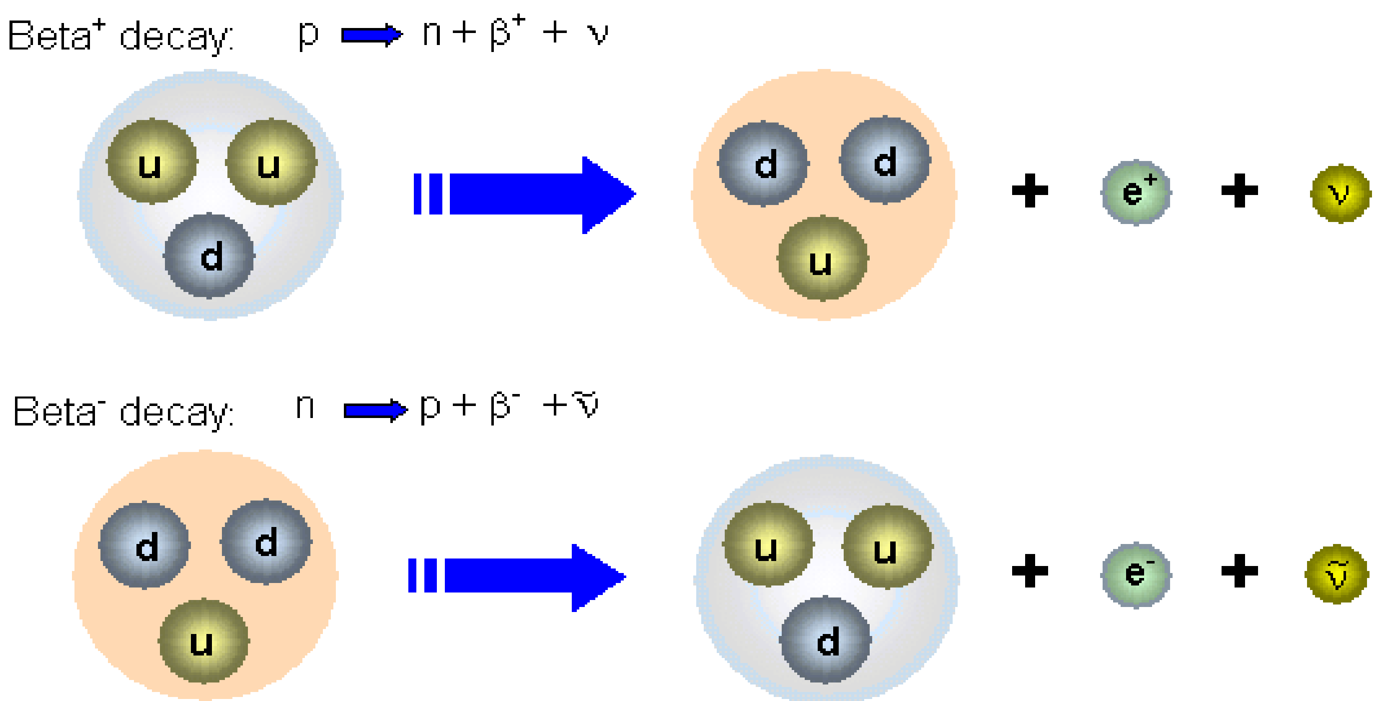
Watch movie about Quark

**Quark was hypothesized by Murray Gell Mann and later confirmed by experience.
The name comes from the book by James Joyce Finnegan's Wake.**

How a proton can change into a neutron or
A neutron into a proton ?
It is an identity crisis ?

Has to do with the building blocks of protons and neutrons = quarks.
Up quark and change into a down quark and the other way around.

The vector of change is the weak nuclear force !



More on quarks: http://www.schoolphysics.co.uk/age16-19/Nuclear%20physics/Nuclear%20structure/text/Quarks_/index.html

2) The isotope helium 6 undergoes beta decay. Write the equation, and determine the identity of the daughter nucleus.

3) The isotope silver 100 undergoes beta decay. Write the equation, and determine the identity of the daughter nucleus.

4) the nuclide carbon-14 undergoes beta(-) decay and forms an isotope of nitrogen N.
Write the nuclear equation for this process.

5) Neon-19 undergoes a beta(+) decay. Write the equation for it and find the isotope the Neon
Turns into .

6) The nuclide P(32,15) undergoes a beta(-) decay. Write a balance nuclear equation that illustrates this process.

γ DECAY

$$^{A}_{Z}\mathrm{P}^{*} \rightarrow \ ^{A}_{Z}\mathrm{P} + \gamma$$

excited energy state

lower energy state

Gamma rays are not easily absorbed by matter as easily as beta rays or alpha rays
But they can break down atoms and you get secondary radiation.
Usually very damaging.

Gamma decay

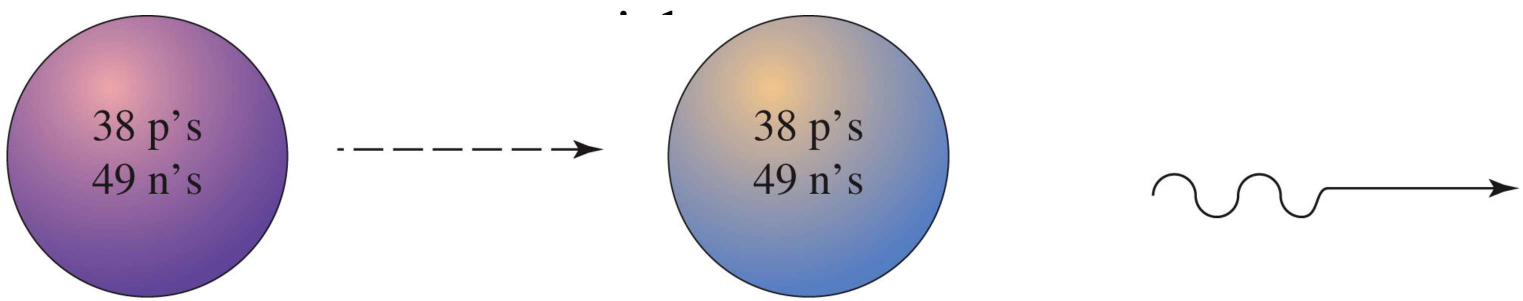
- Gamma decay occurs when an excited nucleus ejects a gamma particle.
  - Recall that an gamma particle is just a photon in the gamma ray part of the EM spectrum.

$$\text{gamma particle}: \quad \gamma$$

- The nucleus does not contain any photons.
  - This decay is similar to an excited atom emitting a photon.

Gamma decay, cont'd

- Here is a diagram illustrating gamma decay.
  - We start with an excited strontium nucleus.
  - We obtain:
    - a strontium nucleus in a lower energy level, and



$${}^{87}_{38}\mathrm{Sr}^{*} \dashrightarrow {}^{87}_{38}\mathrm{Sr} + \gamma$$

Gamma decay, cont'd

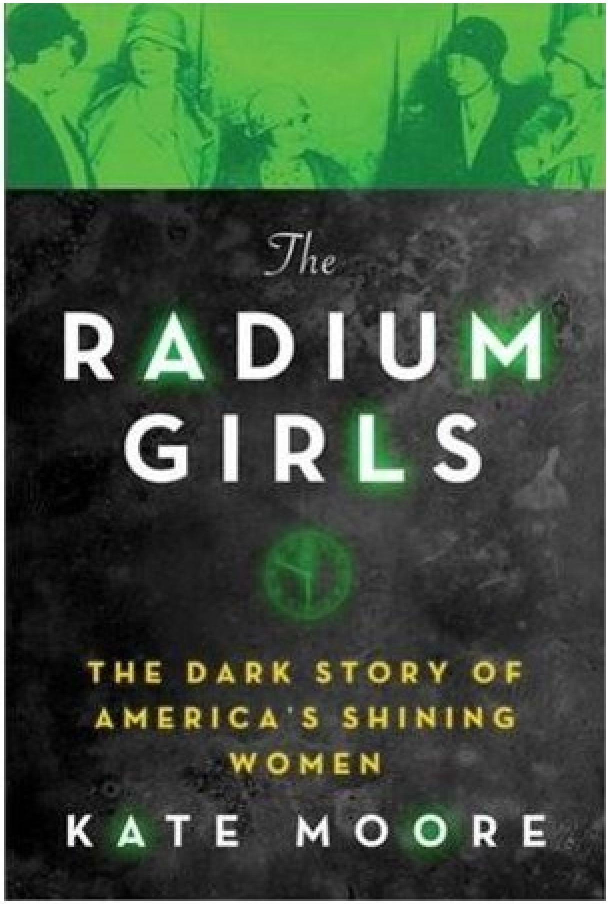
- Gamma decay results in no change of the nuclear mass.
  - It is simple the emission of a photon due to the nucleus being in an excited state.
- The ejected gamma particle passes easily through almost all matter.
  - A brick of lead provides a reasonably good shield against gamma particles.

The old radium wrist watches were more dangerous.
They emit all the radiations.
The people who made the watches got tongue cancer.
They use to paint the radium with brushes that they leaked.

http://www.blackcatsystems.com/GM/experiments/ex7.html

Found in flea market.
Not to wear all the time.

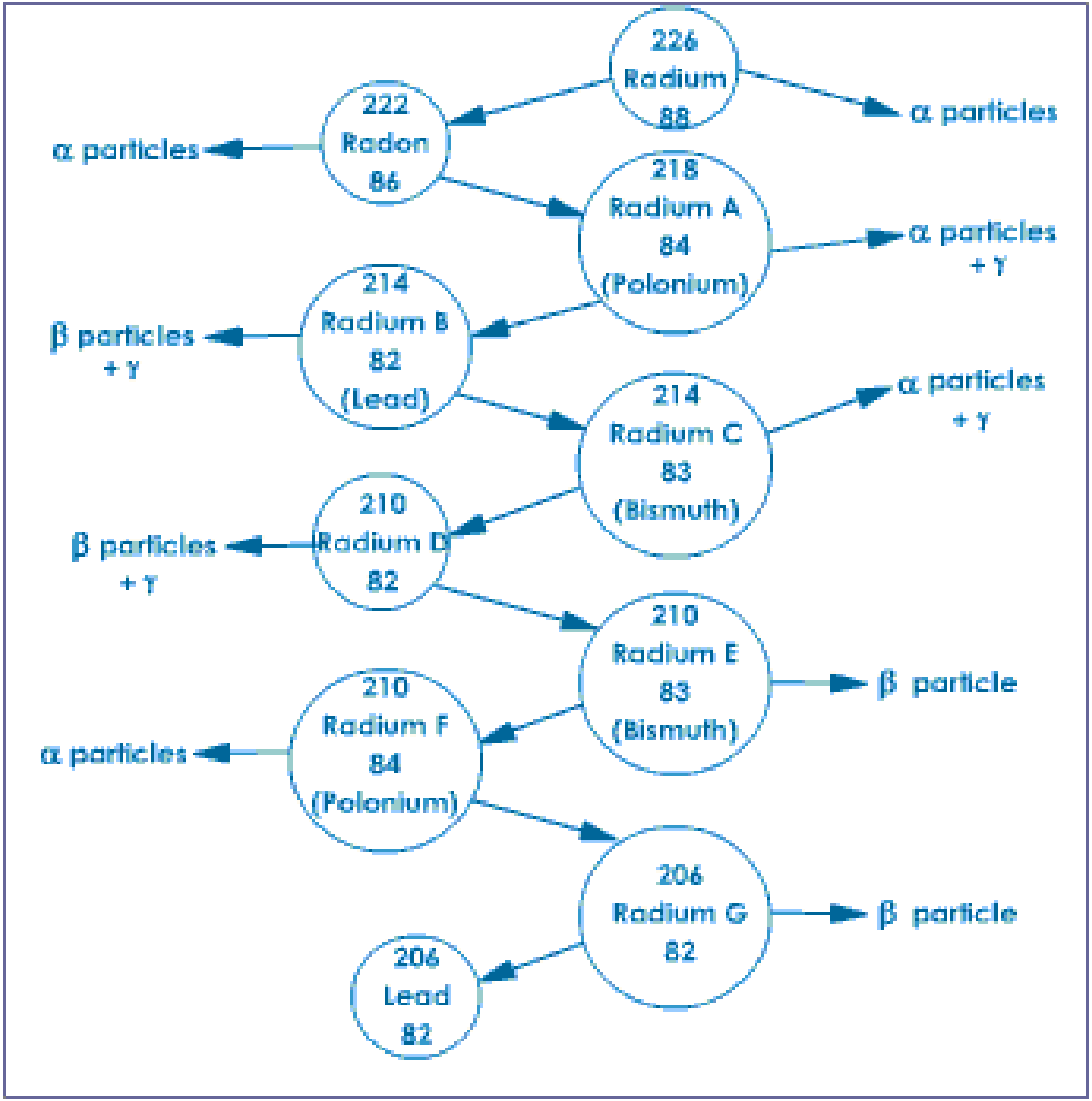
In the early days of the 20th century, the United States Radium Corporation had factories in New Jersey and Illinois, where they employed mostly women to paint watch and clock faces with their luminous radium paint. The paint got everywhere — hair, hands, clothes, and mouths.



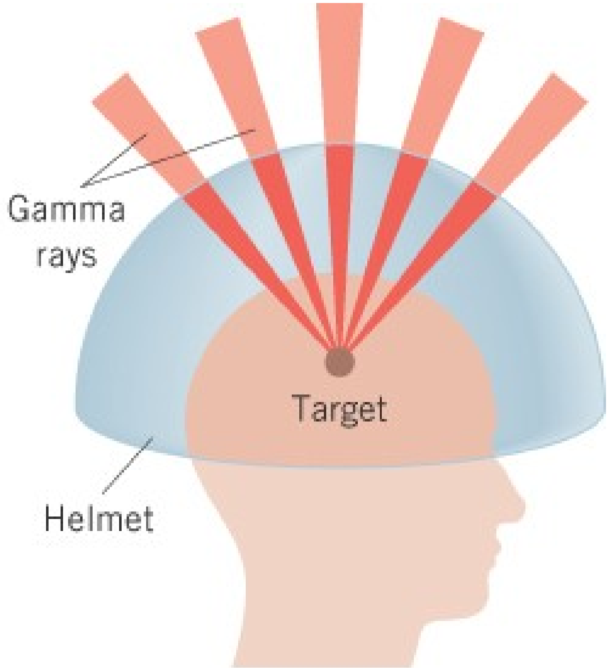
They were called the shining girls, because they quite literally glowed in the dark. And they were dying.

Kate Moore's new book *The Radium Girls* is about the young women who were poisoned by the radium paint — and the five who sued United States Radium in a case that led to labor safety standards and workers' rights advances.

Radioactivity wasn't well understood back then — in fact, radium was considered a wonder substance, and it turned up everywhere. "Radium truly was an international craze," Moore says. "It was in everything from cosmetics to food, and it very much had an allure to it."


226
Radium
88
α particles
222
Radon
86
α particles
218
Radium A
84
(Polonium)
α particles
+ γ
214
Radium B
82
(Lead)
β particles
+ γ
214
Radium C
83
(Bismuth)
α particles
+ γ
210
Radium D
82
β particles
+ γ
210
Radium E
83
(Bismuth)
β particle
210
Radium F
84
(Polonium)
α particles
206
Radium G
82
β particle
206
Lead
82

(*a*)

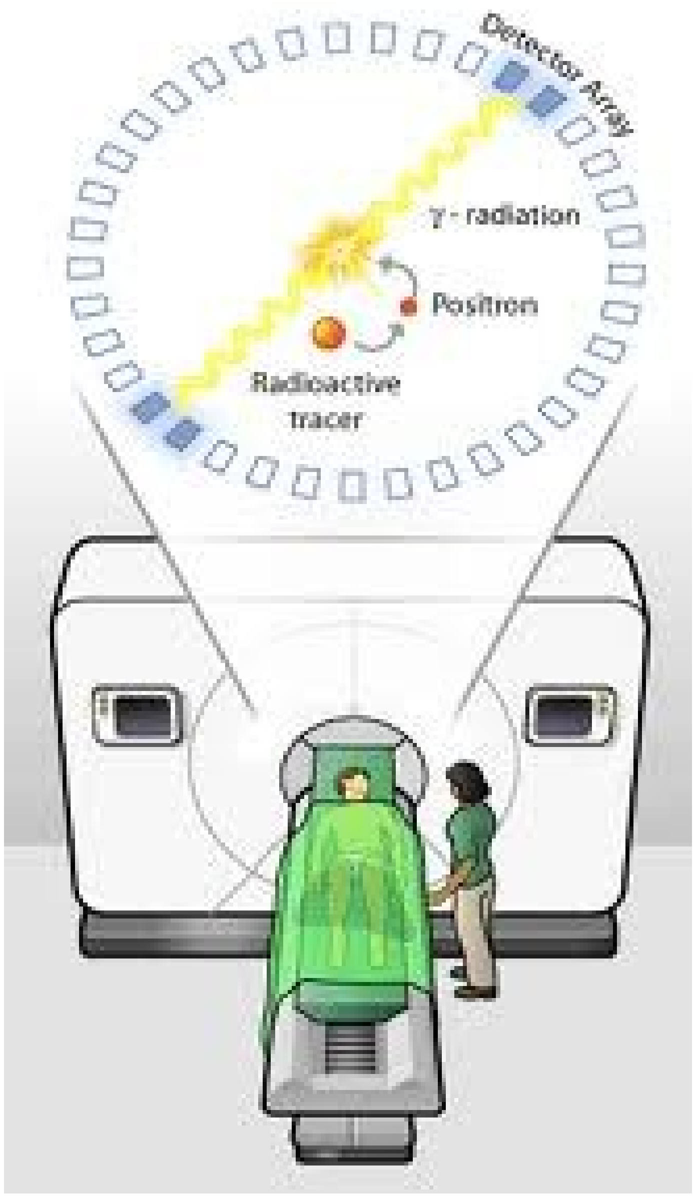


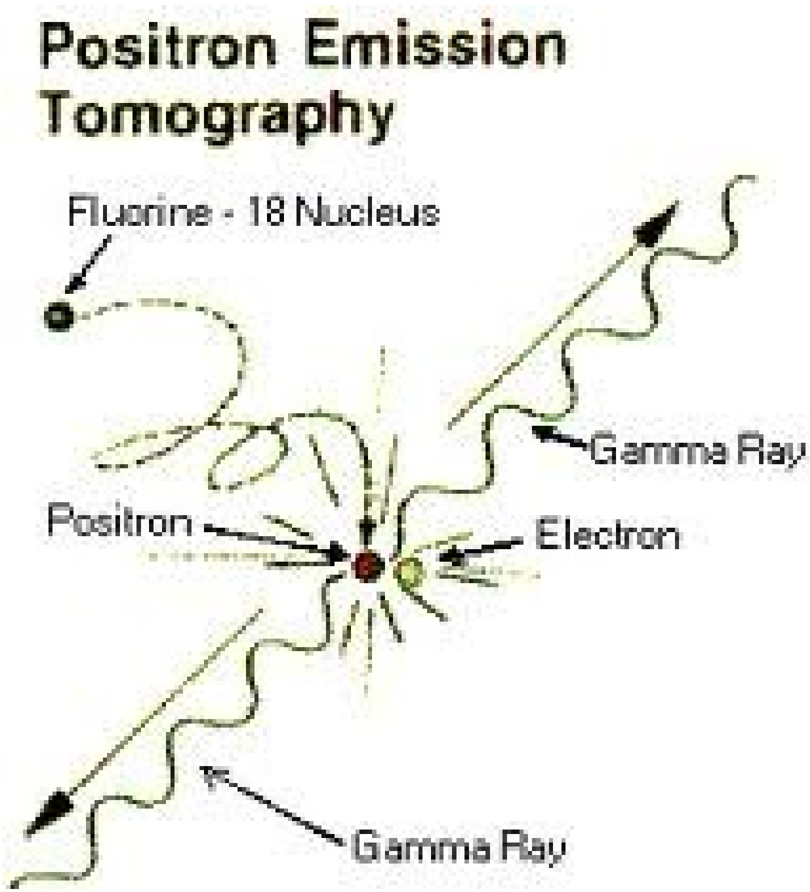
(*b*)

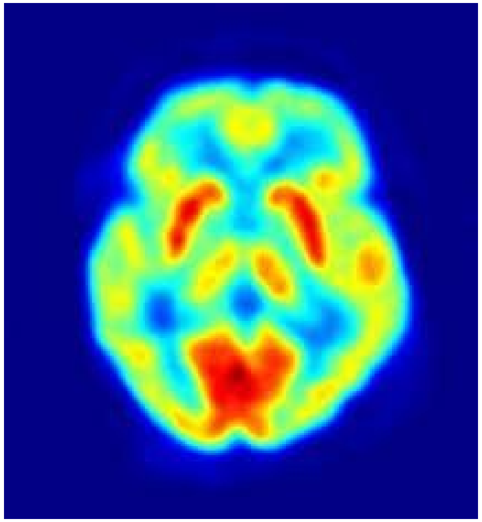
Gamma knife

http://www.gammaknife.org/

PET SCAN

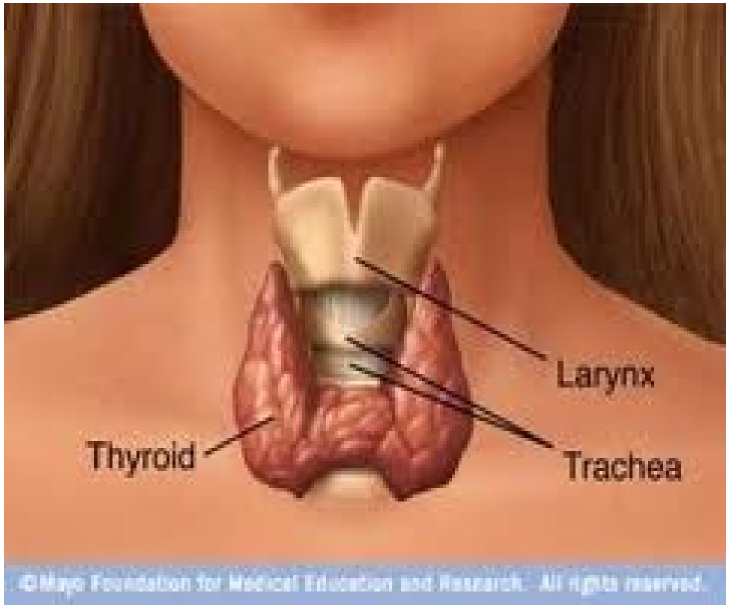

Detector Array
γ - radiation
Positron
Radioactive tracer


Positron Emission Tomography
Fluorine - 18 Nucleus
Gamma Ray
Positron
Electron
Gamma Ray



Here is a list of some positron emitters :

Carbon-11 (20 min)
Nitrogen -13 (9 min)
Oxygen-15 (2min)
Fluorine-18 (110 min)
Iodine-124 (4.2 days)

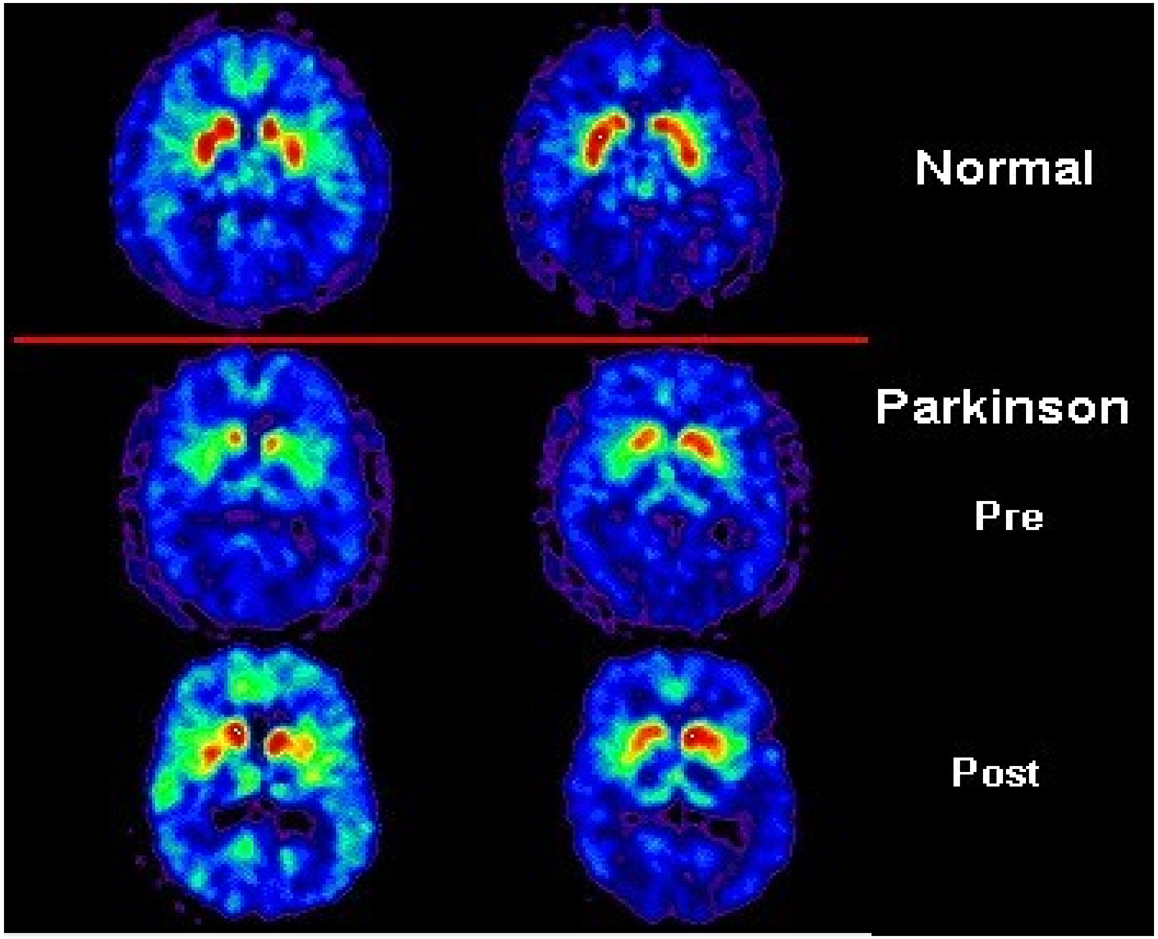


$$^{11}\mathrm{C} \rightarrow {}^{11}\mathrm{B} + \beta^{+} + \nu_e.$$

In beta plus decay, a proton is converted, via the weak force, to a neutron, a positron (also known as the "beta plus particle", the antimatter counterpart of an electron), and a neutrino.

http://www.isotopeworld.com/filestore/EIR_Medical%20Isotopes%20in%20the%2021st%20Century.pdf

http://videos.howstuffworks.com/multi-media-productions/1185-pet-scan-imaging-advances-video.htm



http://health.learninginfo.org/pet-scan.htm

Watch movie Marie Curie

RADIOACTIVE SUBSTANCES are used every day:

Gamma rays are used to kill bacteria in food. The food does not become Radioactive as the gamma rays go through and don't leave anything Behind. It might alter the taste !!! or induce other chemical reactions.

Food Irradiation http://en.wikipedia.org/wiki/Food_preservation

RADIOISOTOPES are used as tracers:

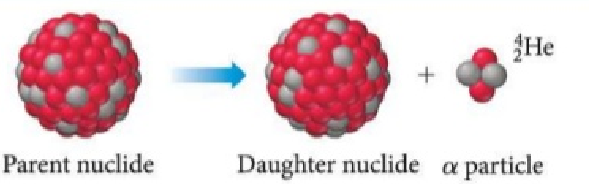
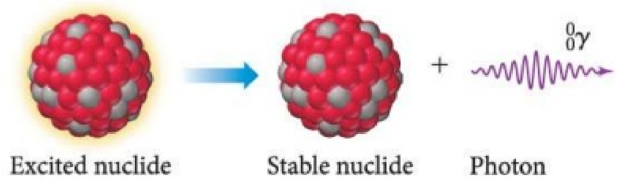
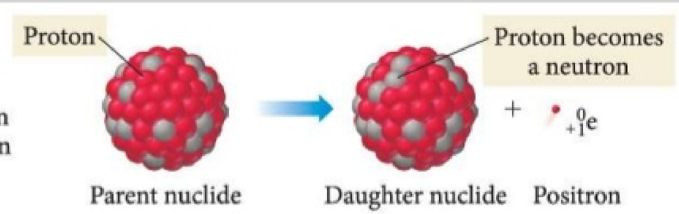
To detect leak in pipes underground

To detect tumors or bone fractures. The tracers go with the Blood stream to the hotspot.

To test how an automobile engine wear away....

Table 17.1 Selected Types of Radioactive Decay

TABLE 17.1 Selected Types of Radioactive Decay

Decay Mode	Process	Ionizing Power	Penetrating Power	Example
α		High	Low	$^{238}_{92}U \longrightarrow ^{234}_{90}Th + ^{4}_{2}He$
β		Moderate	Moderate	$^{228}_{88}Ra \longrightarrow ^{228}_{89}Ac + ^{0}_{-1}e$
γ		Low	High	$^{234}_{90}Th \longrightarrow ^{234}_{90}Th + ^{0}_{0}\gamma$
Positron emission		Moderate	Moderate	$^{30}_{15}P \longrightarrow ^{30}_{14}Si + ^{0}_{+1}e$

Note:

Alpha particles have low penetrating power but high ionizing power.
Beta particle have a lower ionizing power because it has less mass but more penetrating power.
Gamma rays have the lowest ionizing power and the largest penetrating power.

Ionizing particles include:

Charged particles (alpha, beta, protons, electrons and other charged particles)
Photons (x-ray, gamma rays) with energy larger than 10KeV
Neutrons

1)Charged particles use the coulomb's law to ionize.
2)Photons use: A)the photoelectric effect for low energy photons (the photon transfer the energy to The electron and disappear). B)The Compton effect for intermediate energy. (photons and electron Collide. The electrons gains energy). C) Pair production for energy larger than 1.02Mev. The Photon disappear and the pair positron and electron is produced. The positron combine with Electrons to produce gamma rays.
3) neutrons A) In neutron capture, an affected nucleus may absorb the neutron and eject energy as gamma or x rays or beta particles, or both. The secondary particles then cause ionization as discussed above. B)In fission, a heavy nucleus absorbs the neutron and splits into two lighter nuclei that are almost always radioactive.

For the following exercises the first number (after the element symbol) is the mass number and the second is the atomic atomic number To simplify the notation. So I will write Al(27,13) instead of $^{27}_{13}Al$

1) Which nuclear equation represents beta decay ?

A) Al (27,13) + He(4,2) = P (30,15) + n (1,0)

B) U(238,92) = Th (234,90) + He (4,2)

C) C(14,6) = N(14,7) + e (0,-1)

D) Ar(37,18) + e(0,-1) + Cl(37,17)

2) Which of the following nuclear reactions is classified as alpha decay ?

A) C(14,6) = N(14,7) + e(0,+1)

B) K(42,19) = C(42,20) + e (0,-1)

C) Ra (226,88) = Rn(222,86) + He (4,2)

D) H(3,1) = e(0,-1) + He (4,2)

3) /which equation represents nuclear disintegration resulting in release of a beta particle ?

A) Fr(220,87) + He (4,2) = Ac (224, 89)

B) Pu(239, 94) = U(235,92) + He(4,2)

C) P(32,15) + e(0,-1) = Si(32,14)

D) Au(198,79) = Hg(198,80) + e (0,-1)

4) In the nuclear equation Th(232,90) = Ra(228,88) + X , the letter X represents:

A) an alpha particle (B) a beta particle C) a gamma ray D) a neutron

5) In the following equation, which particle is represented by the letter X?

C(14,6) = N(14,7) + X

16)Which radiation has no electric charge associated with it? A) alpha rays B) beta rays
C) gamma rays D) all of these E) none of these.

17) When a nucleus emits a beta particle, its atomic number
A) remains constant, but its mass number changes
B) remains constant, and so does its mass number
C) changes, but its mass number remains constant
D) changes, and so does its mass number

18)When an alpha particle is ejected from a nucleus, the nucleus then has less:
A) mass B) charge C) both of these D) none of these

19) When a beta particle is ejected from a nucleus, the nucleus then has a greater:
A) mass B) charge C) both of these D) none of these

20) When a gamma ray is emitted by a nucleus, the nucleus then has appreciably less:
A) mass B) charge C) both of these D) none of these

21) the helium is a child balloon is composed of A) alpha particle remnants of radioactive processes
B) former beta particles (electrons) B) both of these

22) When radium (A=88) emits an alpha particle, the resulting nucleus has atomic number
A) 86 B) 88 C) 90 D) 92

23) When thorium (A=90) emits a beta particle, the resulting nucleus has atomic number
A) 88 B) 89 C) 90 D) 92 E) none of these

24) When a nucleus emits a positron, its atomic number
A) increases by 1 B) decreases by 1)

25) When a nucleus emits a beta particle, its atomic number
A) increases by 1 B) decreases by 1 C) increases by 2 D) decreases by 2

26) An element will DECAY TO AN ELEMENT WITH HIGHER ATOMIC NUMBER IN THE Periodic table if it emits: A) a beta particle B) a gamma ray C) an alpha particle

27) When the hydrogen isotope tritium-3 emits a beta particle, it becomes an isotope of
A) hydrogen B) helium C) lithium D) carbon

28) Which experiences the least electrical force in an electric field ? A) alpha particle
B) beta particle C) electron D) gamma ray

29 *) an element emits 1 alpha particle, 1 positron and 3 beta particles. Its atomic number:
A) decreases by 2 B) decreases by 1 C) stays the same D) increases by 1 E) increases by 2

30) In order for an atom to decay to an element which is one greater in atomic number, it can emit:
A) one alpha particle and 3 beta particles
B) one positron and 2 beta particles
C) one beta particle all of these

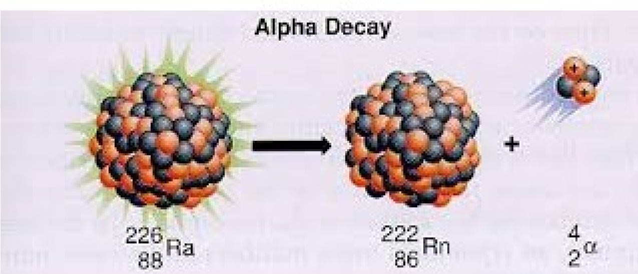
Einstein : mass is a form of energy. $E=m \times (c)^2$ or $E=m \times (300,000,000)^2$

A mass can turn into energy (during nuclear decay or nuclear reactions)

And energy can turn into mass (example: In a accelerator particles are accelerated, collide and their kinetic energy turns into new stuff.)

IN ANY RADIOACTIVE DECAY PROCESS, the mass deficit must increase. The total mass of the product must be Less than the mass of the reactant.

ENERGY released by reaction = mass deficit x $(300,000,000)^2$



Ra226 → Rn222 + He + energy

mass deficit x $(300,000)^2$

mass(Ra226)- mass(Rn222) – mass (helium) = Energy released

Energy is mostly in the kinetic energy of helium

The mass of a nucleon (proton or neutron) is called the atomic mass or 1 u. 1 u = 1.66 10^{-27}kg . So the parent is carbon-14 the mass is 14 u

For nuclear reactions:

The unit of energy is eV (electron-volt) - 1 eV is 1.60 10^{-19} joules

1 MeV is 1 million eV = 1000,000 eV

E=m x $(c)^2$ means that the energy in one proton or neutron or 1 u is:

1 u (atomic mass) = 931 MeV (eV or electron volt is a unit of energy)

We can show that : if mass = 1.66 10^{-27}kg then energy = 1.66 10^{-27} x $(299\ 792\ 458)^2$ = 1.49 10^{-10} joules
(note the speed of light is about 300,000,000 but more precisely 299 792 458)
Is 1 eV is 1.60 10^{-19} joules then 1.49 10^{-10} joules is about 931,000,000 eV or 931 MeV
(divide 1.49 10^{-10} joules by 1.60 10^{-19} joules)

Consider for example the alpha decay of the most stable isotope of radium226, which has a half time of 1,600 years:
A) write the alpha decay
B) Find the mass deficit of the reaction
(mass of product – mass of reactants),
Mass of Ra-226 = 226.0254 u
Mass of Rn – 222=222.0175 u
Mass of helium , well check the periodic table.
C) Find the mass deficit in eV. 931 Mev = 1u
This is the energy produced by the reaction.

This energy goes to the kinetic energy of helium (less inertia) and to The gamma photon that is given off.

1) (A) Write the equation for the beta decay of lead 210 and (B) calculate the combined energy of the electron and the neutrino
Produced. Find the deficit in mass.
Mass lead 210 = 209.9848
NEGLECT THE MASS OF THE ELECTRON
To find the mass of the isotope of bismuth go here : http://www.periodictable.com
Click on bismuth then on technical data then find the right isotope.

2) Write the alpha decay of polonium 218 and B) calculate the combined energy of the alpha particle and the gamma photon released. Use http://www.periodictable.com

3) When the plutonium bomb was tested in New Mexico in 1945, approximately 1 gram of matter was converted into energy.
How many joules of energy were released in the explosion?
Hint: convert g to km. Use $E = mc^2$ to convert to joules then convert to eV.
$E = m\,(300{,}000{,}000)^2$ and 1 eV is $1.6\ 10^{-19}$ J

4) Determine the energy released when alpha converts Uranium238 into thorium 234

5) Find the energy released when beta minus decay changes thorium234 (90) into a daughter
To be determine ?
6) In a decay a gamma ray is produced and has an energy of 0.0496MeV
What is the wavelength of the gamma ray ? (E photon = 4.14 10 -15 x frequency unit is eV)

Induced Nuclear Reactions = transmutations = transforming the nucleus = bombard the nucleus with neutrons or alpha particles. This is how radio pharmaceuticals are made in hospitals.

A ***nuclear reaction*** is said to occur whenever the incident nucleus, particle, or photon causes a change to occur in the target nucleus.

https://en.wikipedia.org/wiki/Neutron_capture_therapy_of_cancer

Nuclear Reaction	Notation
${}^{1}_{0}n + {}^{10}_{5}B \rightarrow {}^{7}_{3}Li + {}^{4}_{2}He$	${}^{10}_{5}B\ (n, \alpha)\ {}^{7}_{3}Li$
$\gamma + {}^{25}_{12}Mg \rightarrow {}^{24}_{11}Na + {}^{1}_{1}H$	${}^{25}_{12}Mg\ (\gamma, p)\ {}^{24}_{11}Na$
${}^{1}_{1}H + {}^{13}_{6}C \rightarrow {}^{14}_{7}N + \gamma$	${}^{13}_{6}C\ (p, \gamma)\ {}^{14}_{7}N$

https://www.reference.com/science/use-isotope-sodium-24-9c75c5fe66f8bd81

http://astronomy.swin.edu.au/cosmos/C/CNO+cycle

Alpha particle as a bullet

You can fire energetic bullets into nuclei to transform one element into another.
You can use an alpha particle as the bullet. (positive). **The alpha particle is Absorbed by the nucleus which form a new and highly unstable nucleus.**

This immediately breaks down with emission of a proton or a neutron.

Example 1 :experiment done by Irene Curie and her husband → artificial radioactivity

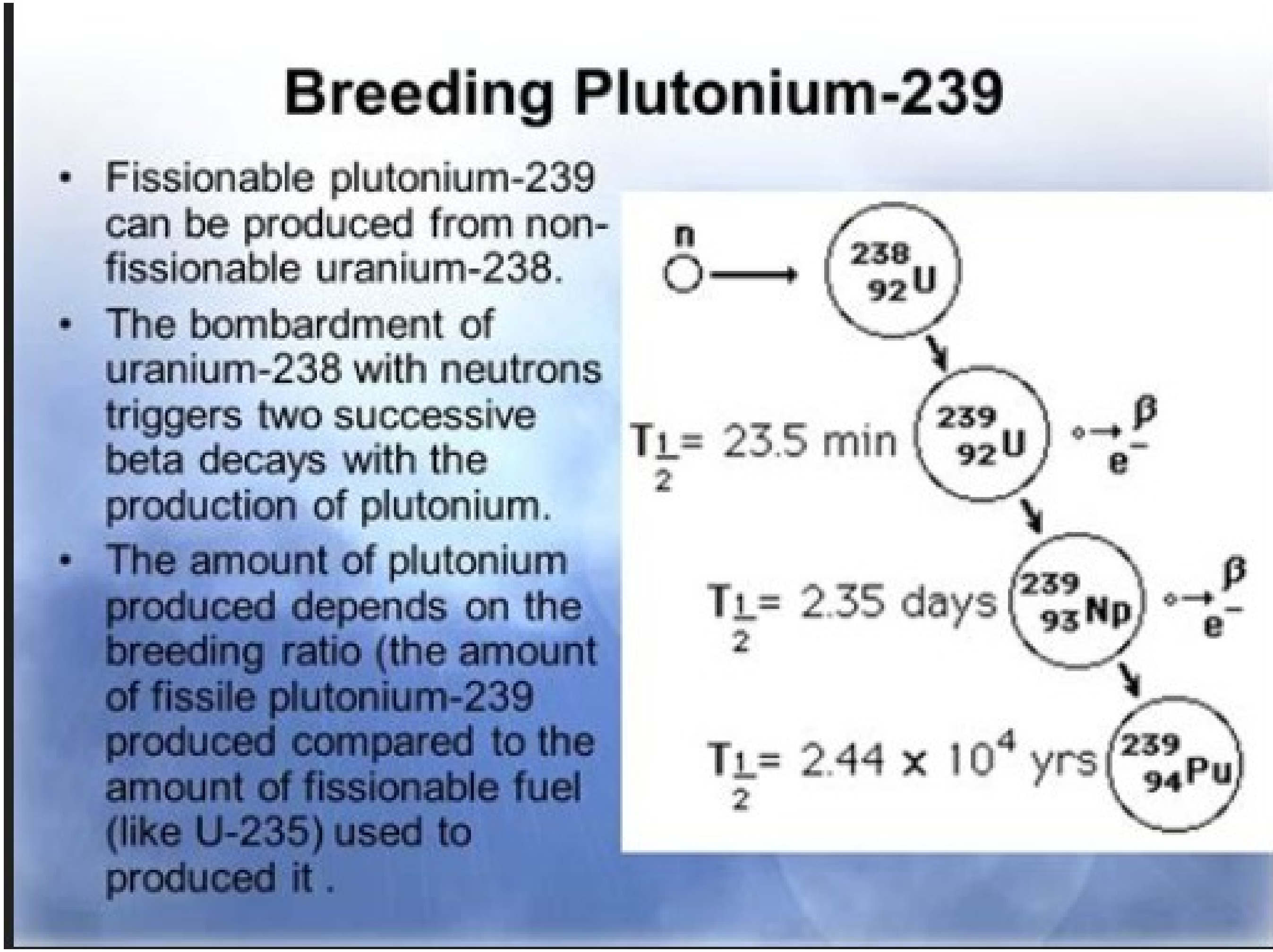
He-4 + Al-27 → (P-31) → ? + H http://www.3rd1000.com/history/nuclear2.htm

(H is just a proton). Find the missing element.

Example2:

Fluorine-19 emits a neutron when bombarded by an alpha particle.
The final product is sodium22 and neutron.
Write the Equation. Don't forget the step between the reactants and products.

Example3 : you can produce a radioactive element with a long half life like carbon14.
It's an artificially produced radioactive substance.
Boron 11 + helium = carbon14 + ?
Write the equation and include the step between.



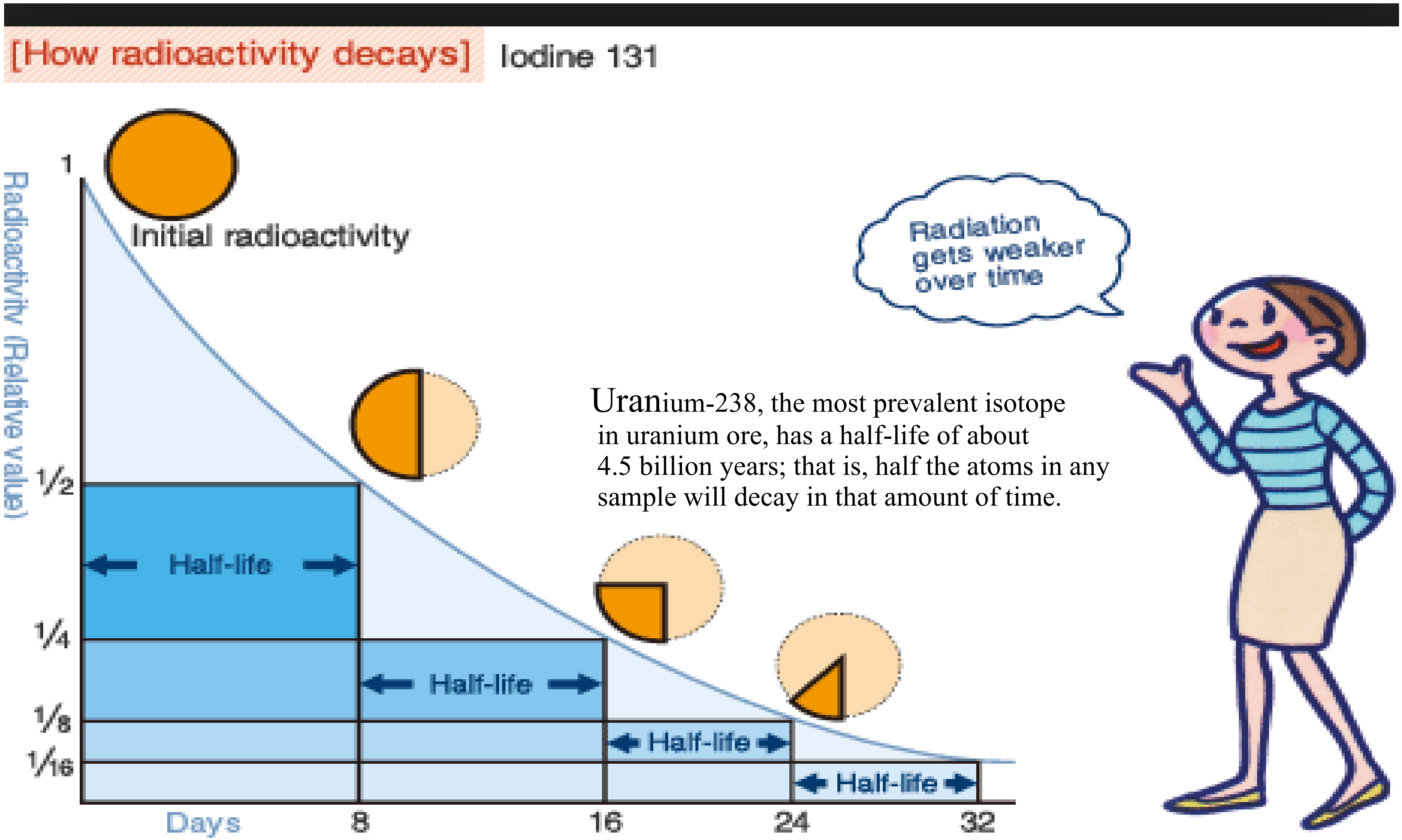
borg)

Uranium bomb was called …

Plutonium bomb was called: Fat man

Half-life

- Radioactive decay is a random process.
  - An unstable isotope will decay, but the exact amount of time until it decays is unknown.
- To overcome this, we talk about how much of a radioactive sample decays in a certain amount of time.
- **Half-life** is the time it takes for half the nuclei in a sample of a radioisotope to decay.
  - **The time interval during which each nucleus has a 50% probability of decaying.**



Uranium-238, the most prevalent isotope in uranium ore, has a half-life of about 4.5 billion years; that is, half the atoms in any sample will decay in that amount of time.

uranium 235 has a half-life of 'only' 700 million years.
Though both isotopes were at the time of Earth formation equally abundant,
natural uranium today consists today of 99.3% uranium 238 and only 0.70% uranium 235.

Some fission fragments
Are dangerous :

Strontium 90
Half life if 28.8 days
It's a bone seeker. Take the
Place of calcium. Produced
By bombs. Can enter the
Food chain. (grass/milk ..)

Iodine 131
8 days
From Fukushima for example.
Thyroid seeker.

Cesium 134 or 137
30 days or 70 days.
Bones or muscle seeker.
Take the place of potassium.
Enter the food chain.

Fission bomb = fall out
Fusion bomb = thermonuclear bomb = no fall out.
But fusion bomb can only be triggered by a fission bomb.

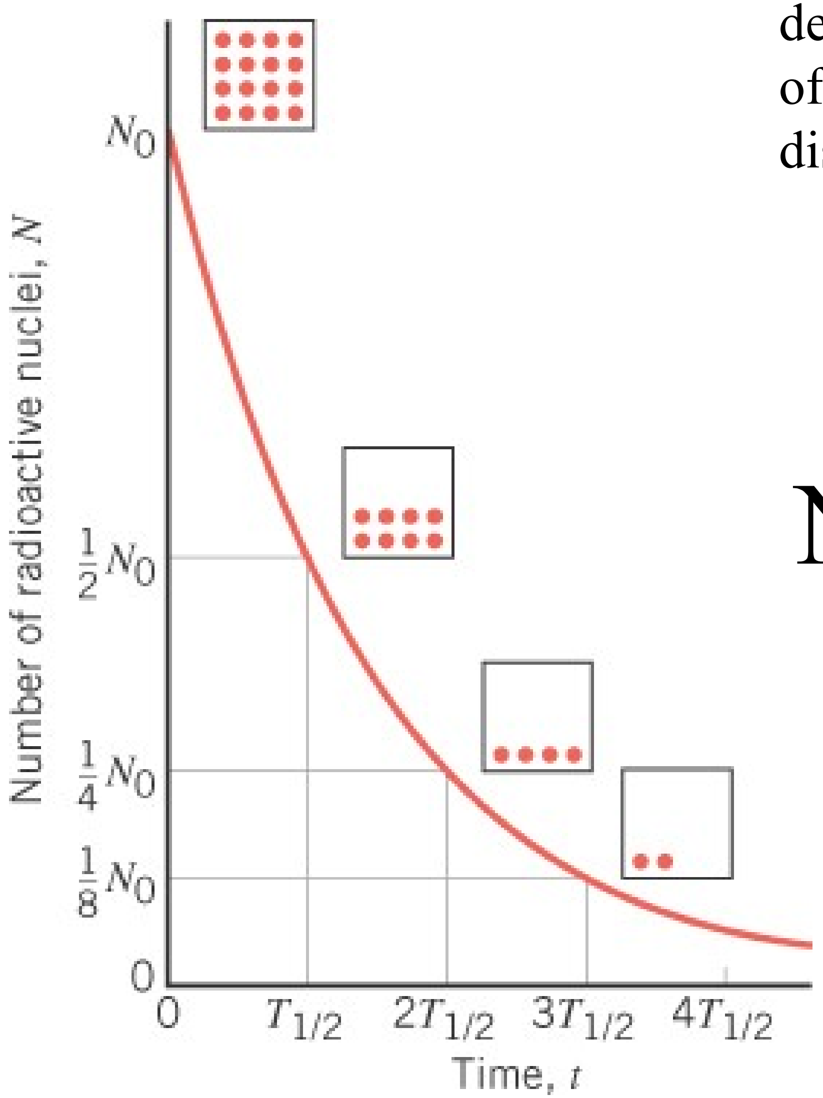
Long half life isotope like U238 is not that bad. The rate of decay is slow.
The short half life isotopes have a decay rate so large, they disappear quickly.

Half-life

- This table shows the half-life for several isotopes.
  - Notice that the half-lives range from extraordinarily short (2×10^{-21} s) to extremely long (4.5×10^{9} yr).

Table 31.2 **Some Half-Lives for Radioactive Decay**

Isotope		Half-Life
Polonium	$^{214}_{84}Po$	1.64×10^{-4} s
Krypton	$^{89}_{36}Kr$	3.16 min
Radon	$^{222}_{86}Rn$	3.83 d
Strontium	$^{90}_{38}Sr$	29.1 yr
Radium	$^{226}_{88}Ra$	1.6×10^{3} yr
Carbon	$^{14}_{6}C$	5.73×10^{3} yr
Uranium	$^{238}_{92}U$	4.47×10^{9} yr
Indium	$^{115}_{49}In$	4.41×10^{14} yr



The half-life of a radioactive decay is the time in which ½ of the radioactive nuclei disintegrate.

$$N = N_o\,(0.5)^{(t/T_{1/2})}$$

$$N = N_o\,e^{(-0.693t/T_{1/2})}$$

It doesn't work for objects more than 50,000 or 60,000 years old, but can give rough estimates of age within a 200-year range.

Half-life, cont'd

- Knowing the half-life is very useful.
  - Smoke detectors routinely use americium-241 since it has a half-life of 432 yrs.
    - Enough time to allow for proper operation for the device's lifetime
  - Nuclear medicine uses **technetium-99** since it emits gamma rays with a half-life of 6 hours.
    - More than enough time to track its passage through the body

Examples:

1) Thorium234 has a half-time of 24 days. If you have a 1kg block of thorium 234 , how much of it, is unchanged after 4 months (about 120 days)?

3) the half-life of iodine-131 (a beta - decay) is 8 days. If a sample of I-131 has a mass of 1gram, what will be the mass 40 days after ? (40 = 8x5)

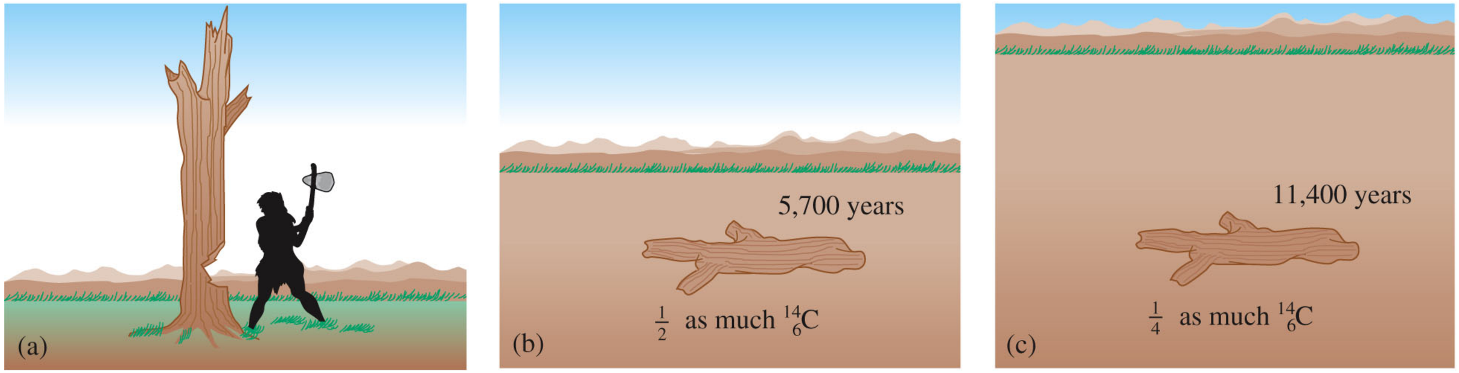
4) tungsten 176 has a half time of 2.5 hours. After how many hours will the disintegration rate of a tungsten176 sample drop to its 1/10 its initial value.
Hint: suppose initial mass is 100g so final mass is 10g
Try: trial and error then try to solve the log equation

Carbon dating, cont'd

- While a plant is alive, it absorbs carbon dioxide from the air.
  - CO_2 could be made from C-12, C-13 or C-14.
- Some animals eat the plant, while other animals eat the plant-eater.
- So, each organism is continuously replenishing the amount of C-14 in its body.
- Once the organism dies, no more C-14 is consumed so the level of C-14 begins to decrease.

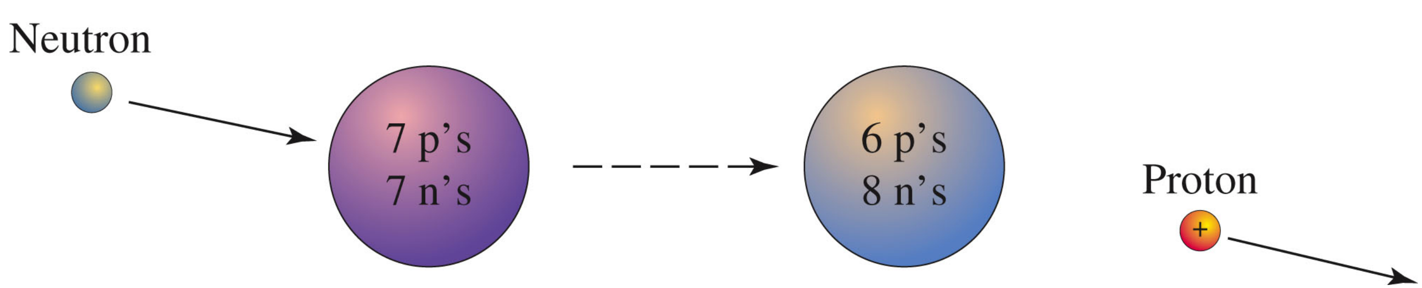
Carbon dating, cont'd

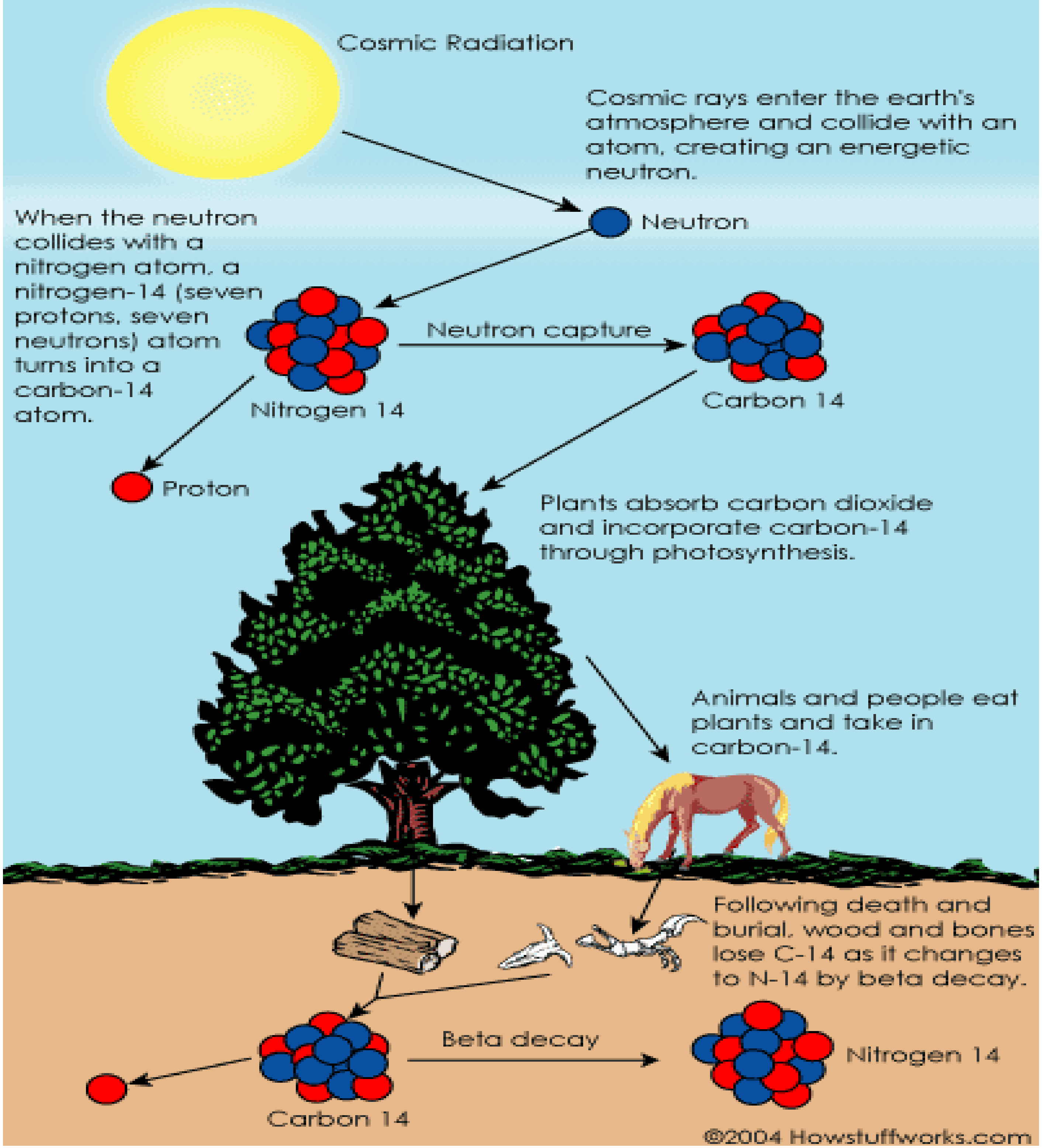
- This process can be used to determine how long ago an organism died.
  - We know the average amount of C-14 in a living organism.
  - We can measure the C-14 in a specimen.
  - Comparing the values and knowing the half-life, gives information on how long ago it died.



Carbon dating

- The regular rate of decay of a radioisotope can be used to measure time.
- **Carbon-14 dating** uses the decay-rate of carbon-14 to determine how long ago an organism died.
- Carbon-14 is naturally created from nitrogen in the upper atmosphere.




Cosmic Radiation
Cosmic rays enter the earth's atmosphere and collide with an atom, creating an energetic neutron.
Neutron
When the neutron collides with a nitrogen atom, a nitrogen-14 (seven protons, seven neutrons) atom turns into a carbon-14 atom.
Neutron capture
Nitrogen 14
Carbon 14
Proton
Plants absorb carbon dioxide and incorporate carbon-14 through photosynthesis.
Animals and people eat plants and take in carbon-14.
Following death and burial, wood and bones lose C-14 as it changes to N-14 by beta decay.
Beta decay
Carbon 14
Nitrogen 14
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a technique developed in 1949 that can estimate the age of carbon-containing objects to within about 200 years. Its pioneer, Willard Libby, won the 1960 Nobel Prize in Chemistry for developing the method that allows archaeologists to pin a rough date on biological artifacts.

It doesn't work for objects more than 50,000 or 60,000 years old, but can give rough estimates of age within a 200-year range.

We eat the plants and Become radioactive.

There are about 1000 radioactive Explosions every second.

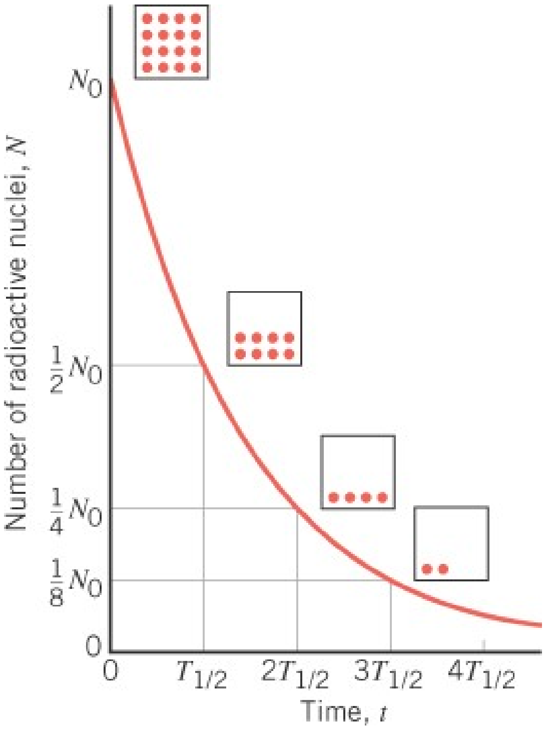
In addition we also contain Radioactive potassium called
Potassium 40 (potassium 39 is Stable). . About 3000 explosions Per second.

So altogether it's 4000 radioactive explosions per second
Or 4000 becquerels.

From potassium chance to get cancer In 50 years.:
2500 rem = 1 cancer
0.016rem = 6 millionth = 0.000006
6/1000,000 change to get cancer.
1800/300 million so 1800 die from
Self induced radioactivity.

(from Dr. Richard Muller, book *physics for future president*, Princeton press,)

31.7 Radioactive Dating



Conceptual Example 12 Dating a Bottle of Wine

A bottle of red wine is thought to have been sealed about 5 years ago. The wine contains a number of different atoms, including carbon, oxygen, and hydrogen. The radioactive isotope of carbon is the familiar C-14 with ½ life 5730 yr. The radioactive isotope of oxygen is O-15 with a ½ life of 122.2 s. The radioactive isotope of hydrogen is called tritium and has a ½ life of 12.33 yr. The activity of each of these isotopes is known at the time the bottle was sealed. However, only one of the isotopes is useful for determining the age of the wine. Which is it?

HALF-LIFE = time for half of the sample to decay so :

Final mass = original mass x $(½)^n$ n is the number of half life

Or **original mass = final mass x $(2)^n$**

$(1/2)^n$ is the remaining fraction

Number of half-life = time elapsed (t) / half-life (T)

TO ANSWER THESE QUESTIONS, USE THE REFERENCE TABLES (with half life)
Reference table go to slide 6: http://www.p12.nysed.gov/assessment/reftable/chemistry-rt/archive/chemref1-7.pdf

1) after 62 hours, 1g remains unchanged from a sample of ^{42}K. How much ^{42}K was in the original sample ?

2) if 80mg of a radioactive element decays to 10mg in 30 minutes, what is the element's half life ?

3) in 6.20 h, a 100g of Ag 112 decays to 25g. What is the half life of Ag112 ?

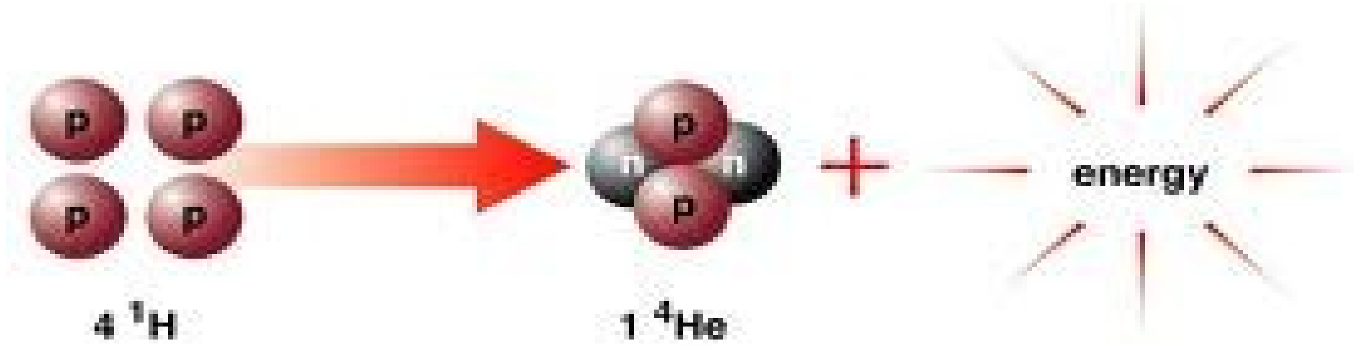
4)What is the mass of K-42 remaining in a 16 g sample of K-42 after 37.2 h ?

5) If 3g of Sr-90in a rock sample remained in 1999, approximately how many grams of Sr-90 were present in the original rock sample in 1943?

6) A sample of I-131 decays to 1g in 40 days. What was the mass of the original sample ?

7) A radioactive element has a half-life of 2 days. Which fraction represents the amount of an original sample
Of this element remaining after 6 days ?

FUSION

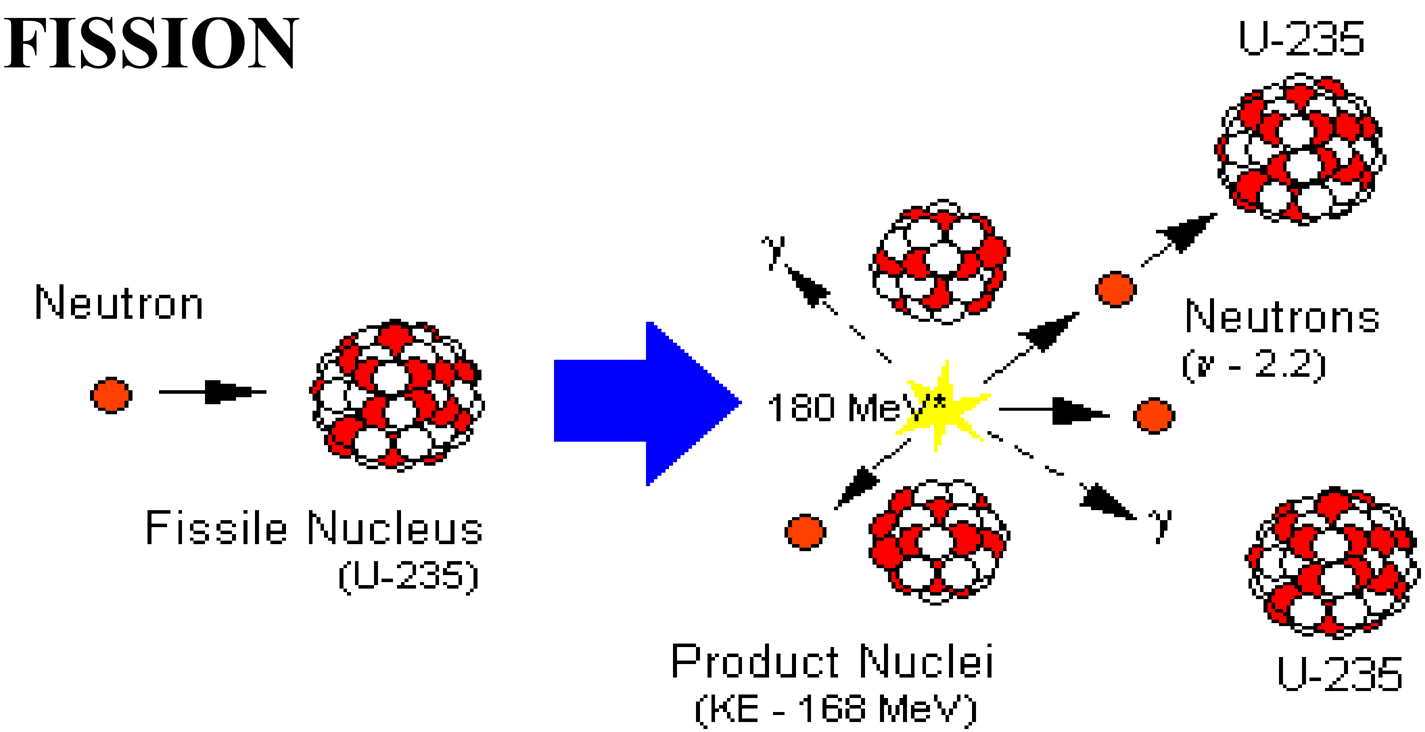


H-bomb
Thermonuclear bombs

In stars

Alternative energy?

FISSION



Atomic bombs

Nuclear power plant

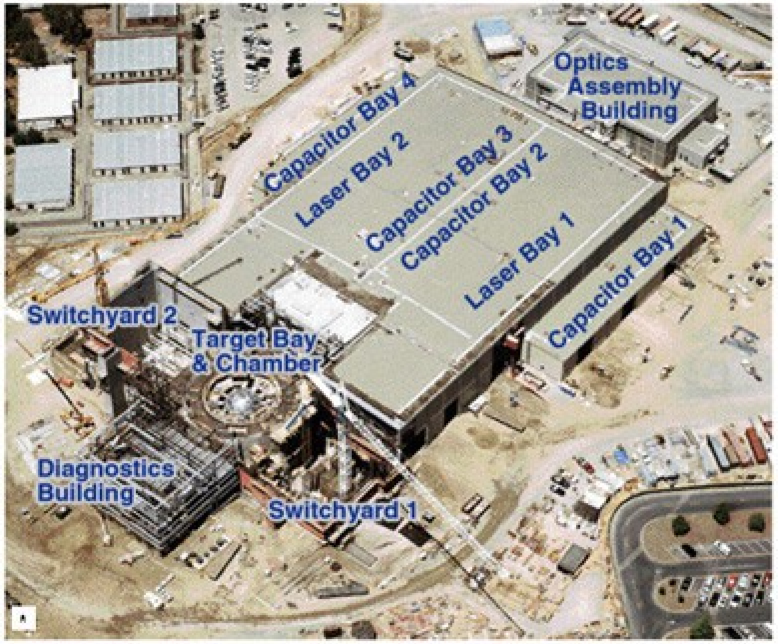
beryllium

http://www.bbc.co.uk/news/science-environment-24429621

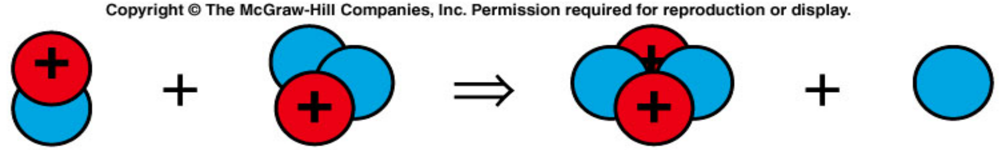
LASER FUSION

Done at Livermore at the National Ignition facility (NIF).
They need very powerful laser and a small and cold pellet of deuterium and tritium.
Use 192 lasers. Recently the energy produced matched the energy used.

http://www.dailymail.co.uk/sciencetech/article-1329611/2-2bn-superlab-scientists-creating-star-Earth.html



FUSION isotopes of
hydrogen to = helium



$$_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1$$

Masses

$_1H^2$	2.014 102 u		$_2He^4$	4.002 603 u
$_1H^3$	3.016 050 u		$_0n^1$	1.008 665 u
	5.030 152 u			5.011 268 u

Find the deficit in mass in u, convert to Mev
1 u = 931 million ev = 931 Mev (mass is energy, same thing)
1 million times the energy released in a chemical reaction !!

Source: physics of every day phenomena, McGraw-Hill 4e