More Calculations, Radioactive Decay and Half-life

Unit Learning Goal

Throughout this unit we will be focusing on achieving the following goal with respect to our overall goal of **understanding concepts.**

We are learning to describe the periodic trends in the periodic table, and how elements combine to form chemical bonds.

To support this goal today's goals are…

- We learning about the relationship between isotopic abundance of an element's isotopes and the relative atomic mass of the element.
- We are learning to solve problems using this relationship.

LAST CLASS…

Problem 1 finding atomic mass

An element consist of two isotopes.

Isotope A - abundance of 75.00 %, and mass is 14.000 amu.

Isotope B - abundance of 25.00 %, and mass is 15.000 amu.

What is the atomic mass of the element?

Atomic mass = (14.00u x 0.7500) + (15.000 u x 0.2500)

= 14.25

Other types of calculations

2. Finding the mass of one of the isotopes given atomic mass and abundance.

3. Finding abundance given atomic mass and mass of each

NOTE – if atomic mass is not given use the mass in the periodic table.

Problem 2: finding mass of one isotope

- Bromine has two naturally occurring isotopes. Bromine-79 has a mass of 78.918amu and is 50.69% abundant.
  - relative abundance – Ra

- Using the atomic mass reported in the periodic table, determine the mass of bromine-81, the other isotope of bromine.

$$\text{Atomic mass} = (m_{Br79} \times Ra) + (m_{Br81} \times Ra)$$

* Ra for Br81 = 100 – 50.69 = 49.31

Problem 2: finding mass of one isotope

Atomic mass = (mBr79 x Ra) + (mBr81x Ra)

$$79.90\text{(mass from periodic table)} = (78.917 \times 0.5069) + (m_{Br81} \times 0.4931)$$

$$79.90 = 40.003 + 0.4931\, m_{Br81}$$

$$79.90 - 40.003 = 0.4931\, m_{Br81}$$

$$39.897 = 0.4931\, m_{Br81}$$

$$80.91\text{ amu} = m_{Br81}$$

the mass of bromine-81 is 80.91 amu

Problem 3: finding relative abundance

- Gallium consists of two naturally occuring isotopes with masses of 68.926 and 70.925 amu.
- The average atomic mass of Ga is 69.72 amu.
- Calculate the abundance of each isotope.

- Note – if atomic mass is not given use the mass in the periodic table.

Average atomic mass = (mass ^{69}Ga)(X) + (mass ^{71}Ga)(y)

Where x and y are the relative abundances of ^{69}Ga and ^{71}Ga respectively. So, 69.72 = 68.926(X) + 70.925(**y**)

Can't have 2 unknowns?????

Let the abundance of 1 isotope = x, then the abundance of the other will be 1- X . In this way the problem will have 1 unknown.

(Substitute 1 - X for y)

So $\quad 69.72 = (68.926)(X) + (70.925)(\mathbf{1 - X})$

$69.72 = 68.926\,X + 70.925 - 70.925\,X$

$-1.2 \quad = -1.999\,X$

$X = 0.60280$

$0.603 \times 100 = 60.3\%$

I am NOT teaching the math...

Answer: ^{69}Ga: 60.3%, ^{71}Ga: 39.7%

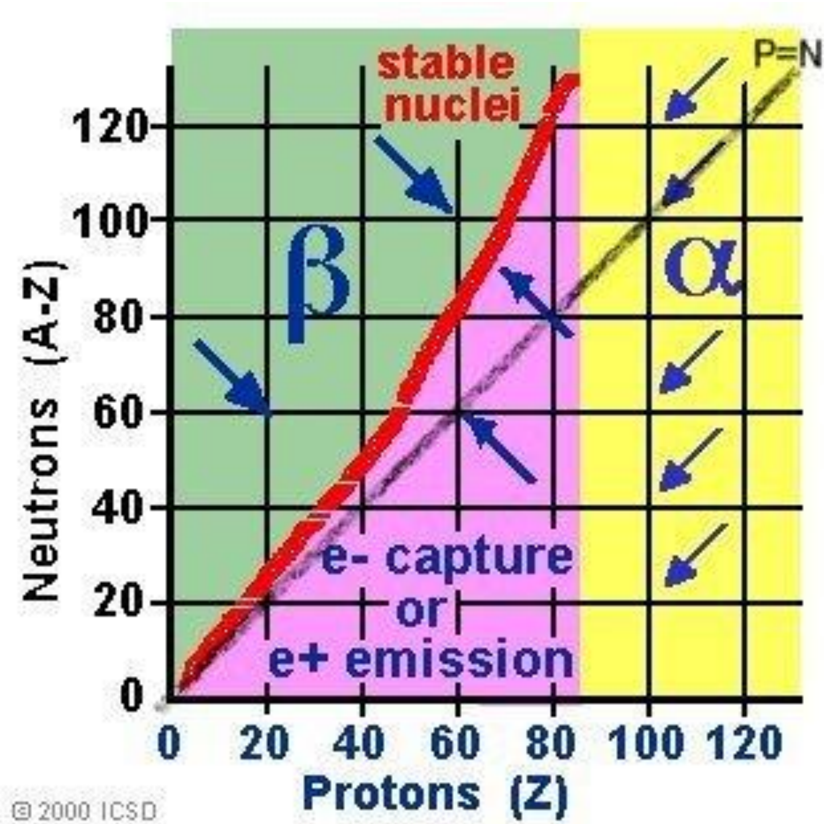
Radioactive Decay & Half-Life

Crash Course: Nuclear Chemistry

Nuclear Decay – Background

- Most of the isotopes which occur naturally are stable.
- A few naturally occurring isotopes and all of the man-made isotopes are unstable.
- Unstable isotopes can become stable by releasing different types of particles.
- This process is called **radioactive decay** and the elements which undergo this process are called **radioisotopes**
- These reactions are called NUCLEAR REACTIONS
  - Work towards making a stable nucleus

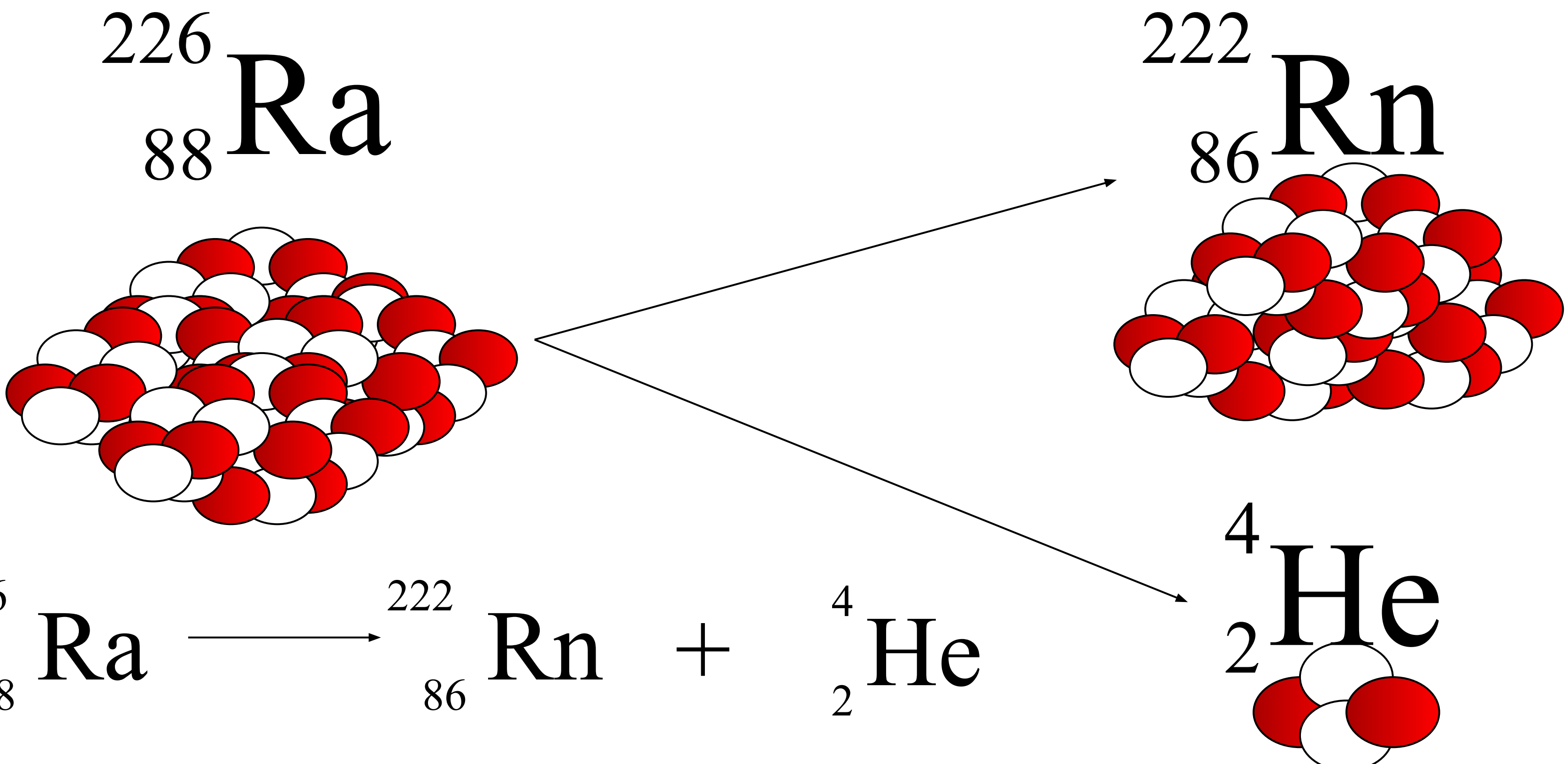
What Makes an Atom Unstable?



- Look at Neutron/Proton Ratio
- Red Line = Stable
- Above the line = Beta-Decay
- Below the Line = Alpha-Decay

What is Alpha & Beta Decay?

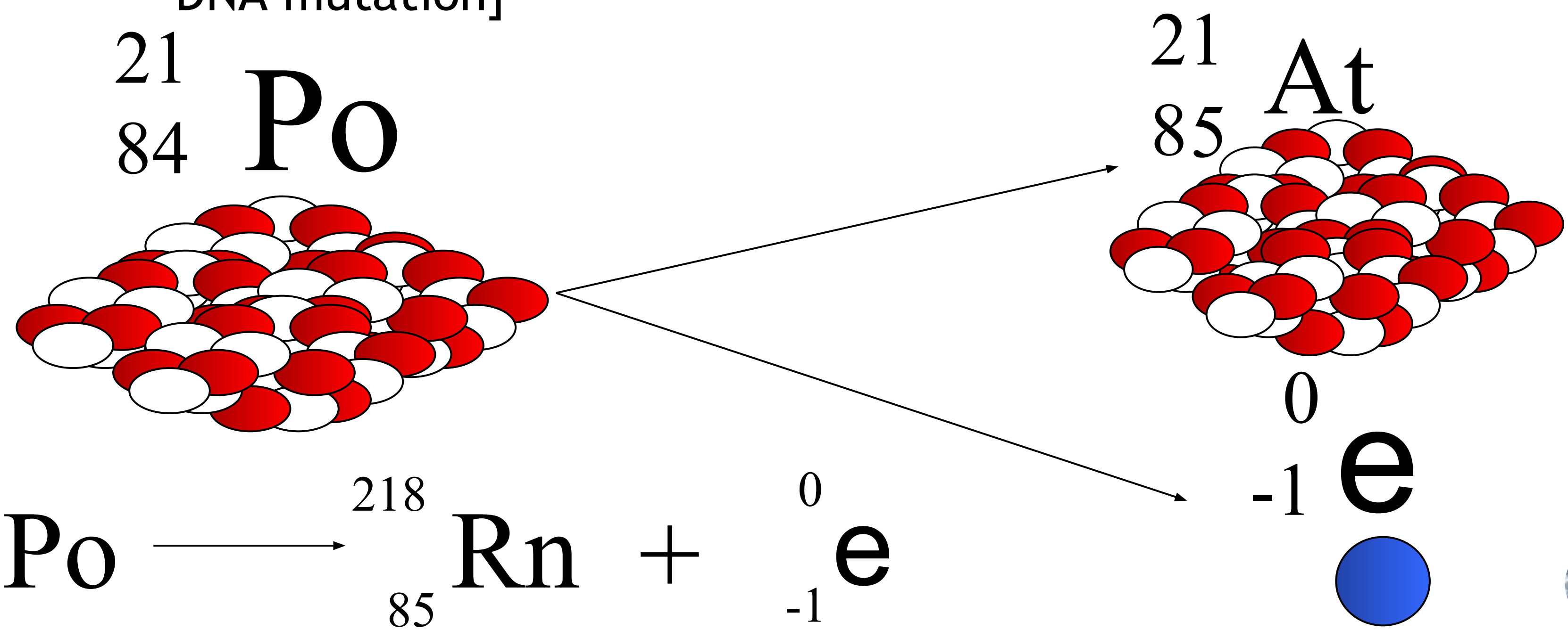
- Alpha Decay: an unstable isotope “ejects” an alpha particle from its nucleus.
  - An alpha particle is equivalent to a Helium atom; has low energy and can be stopped by paper or cloth



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

What is Alpha & Beta Decay?

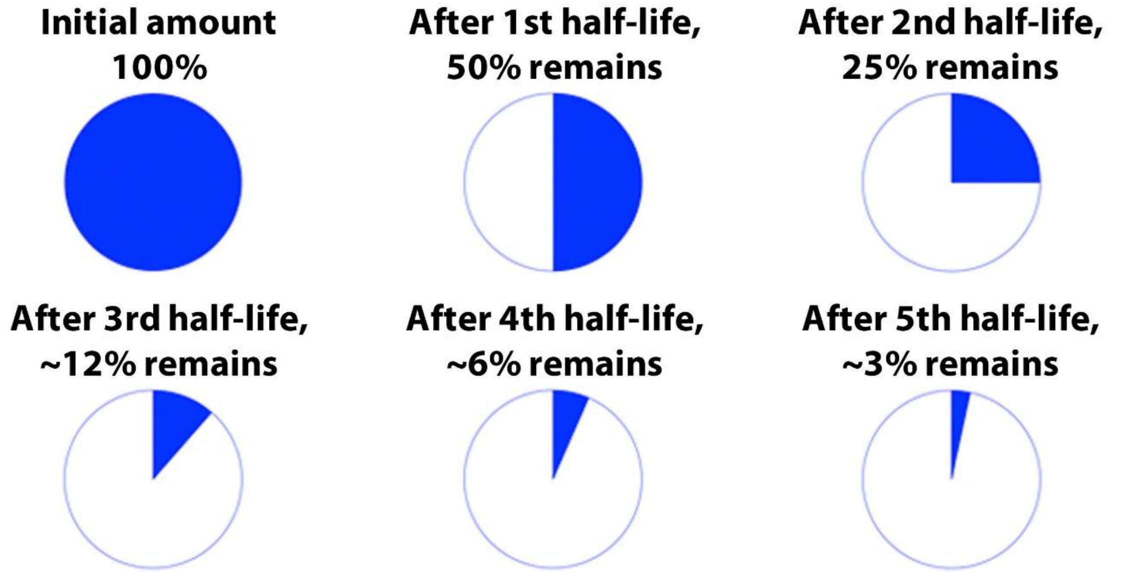
- Beta Decay: a neutron from the nucleus is converted to a proton and electron.
  - The electron is emitted in beta decay
  - The nucleus has one less neutron, but one extra proton.
  - Radiation can be stopped by aluminum foil or skin
  - [*gamma decay -radiation energy penetrates skin and cells – DNA mutation]



$$^{218}_{84}\mathrm{Po} \longrightarrow {}^{218}_{85}\mathrm{Rn} + {}^{0}_{-1}\mathrm{e}$$

Half-Life

- Radioactive elements decay over time.
- Radioactive elements have a **half-life**. Half-life occurs naturally in some of the radioactive elements while it could be artificially stimulated in some other elements
- **The half life of any given element is the time that is required for one half of the sample to decay.**



For example: If you have 10 grams of a radioactive element to start with…

after one half-life there will be 5 grams of the radioactive element left...

after another half-life, there will be 2.5 g of the original element left…

after another half-life, 1.25 g will be left.

Number of half-lives elapsed	Fraction remaining	Percentage remaining
0	$^1/_1$	100
1	$^1/_2$	50
2	$^1/_4$	25
3	$^1/_8$	12 .5
4	$^1/_{16}$	6 .25
5	$^1/_{32}$	3 .125
6	$^1/_{64}$	1 .563
7	$^1/_{128}$	0 .781
…	…	…
n	$1/(2^n)$	$100/(2^n)$

Example

A radioactive substance has a half-life of 20 minutes. If we begin with a 500 g sample, how much of the original sample remains after two hours?

Two hours is 120 minutes ➔ six half-lives.

- 500 g
- 250 g
- 125 g
- 62.5 g
- 31.25 g
- 15.625 g
- 7.8125 g

At the end of the stated time period, 7.8 g remains

or

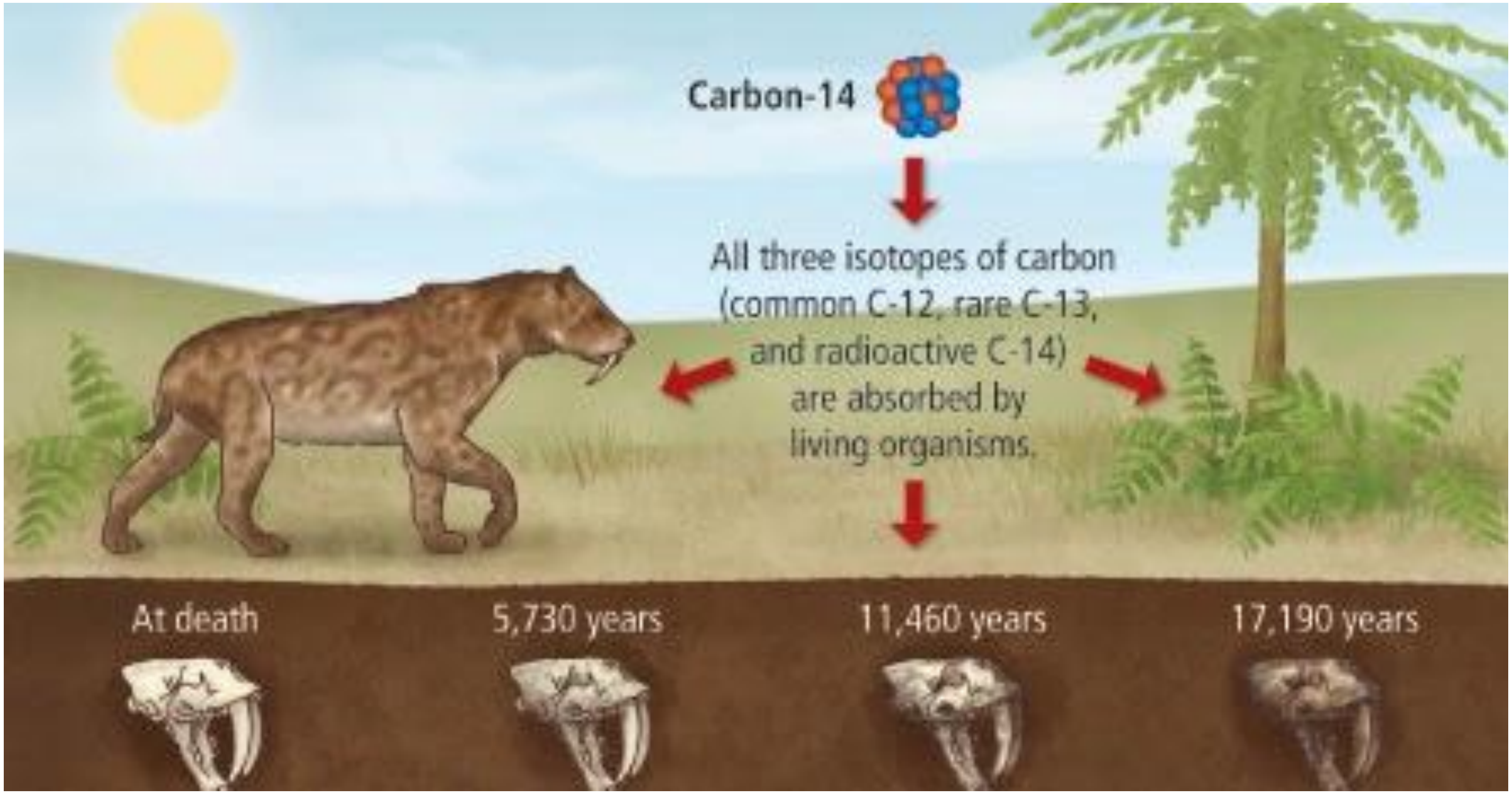
$(\frac{1}{2})^6 \times 500$ g

CARBON DATING

Another interesting fact:

- Half-life of ^{14}C is 5730 years
- This is very helpful in geological dating of any archaeological material.

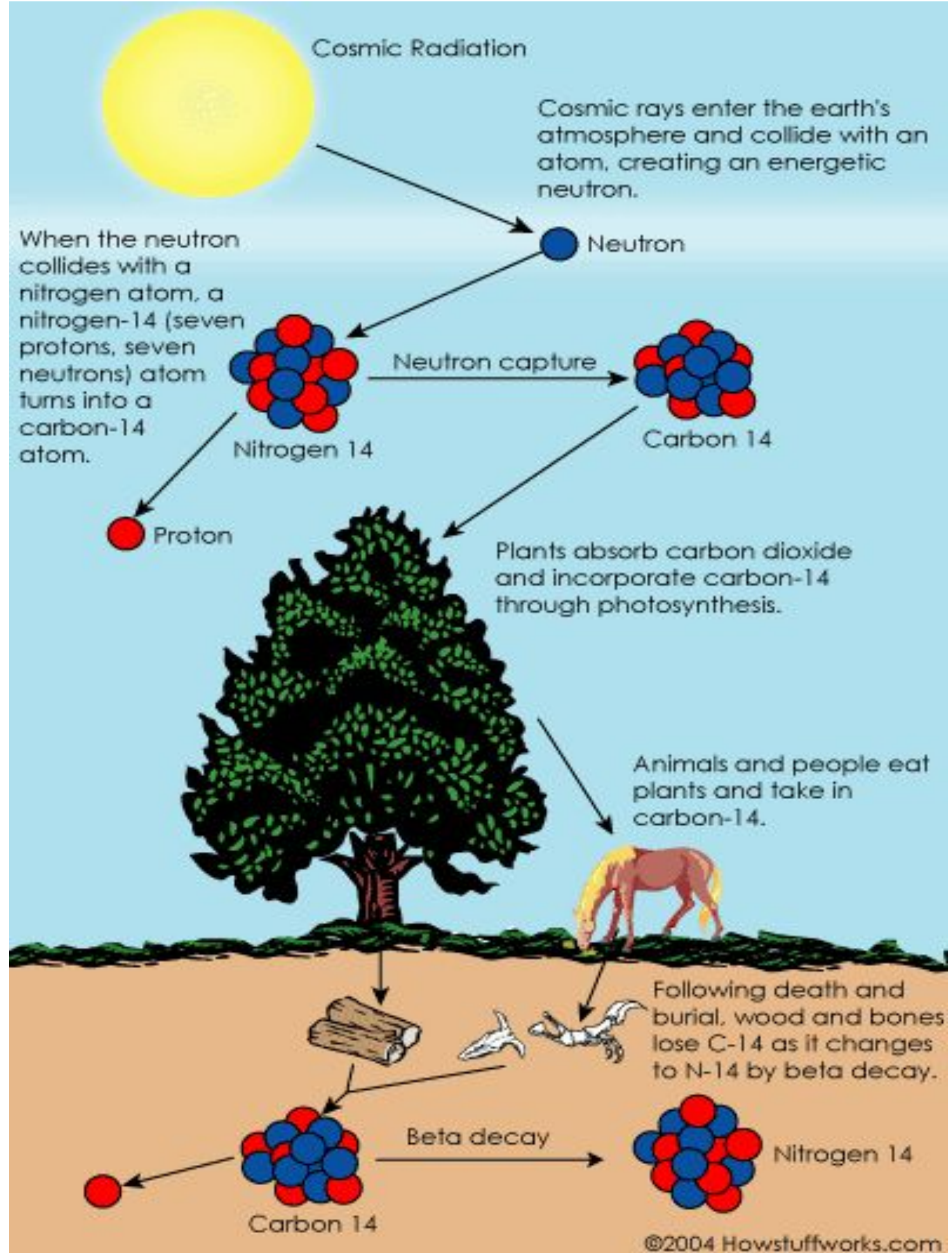
- The ratio of normal carbon (C-12) to C-14 in the air and in all living things at any given time is nearly constant.
- At this moment, your body has a certain percentage of C-14 atoms in it, and all living plants and animals have the same percentage.



- As soon as a living organism dies, it stops taking in new carbon.

- The carbon-14 decays with its half-life of 5,700 years, while the amount of carbon-12 remains constant in the sample.

- By looking at the **ratio of C-12 to C-14** in the sample and comparing it to the ratio in a living organism, it is possible to determine the age of a formerly living thing



Success Criteria

By the end of this lesson…

- I can solve problems using the relationship between isotopic abundance of an element's isotope and the relative atomic mass of the element.