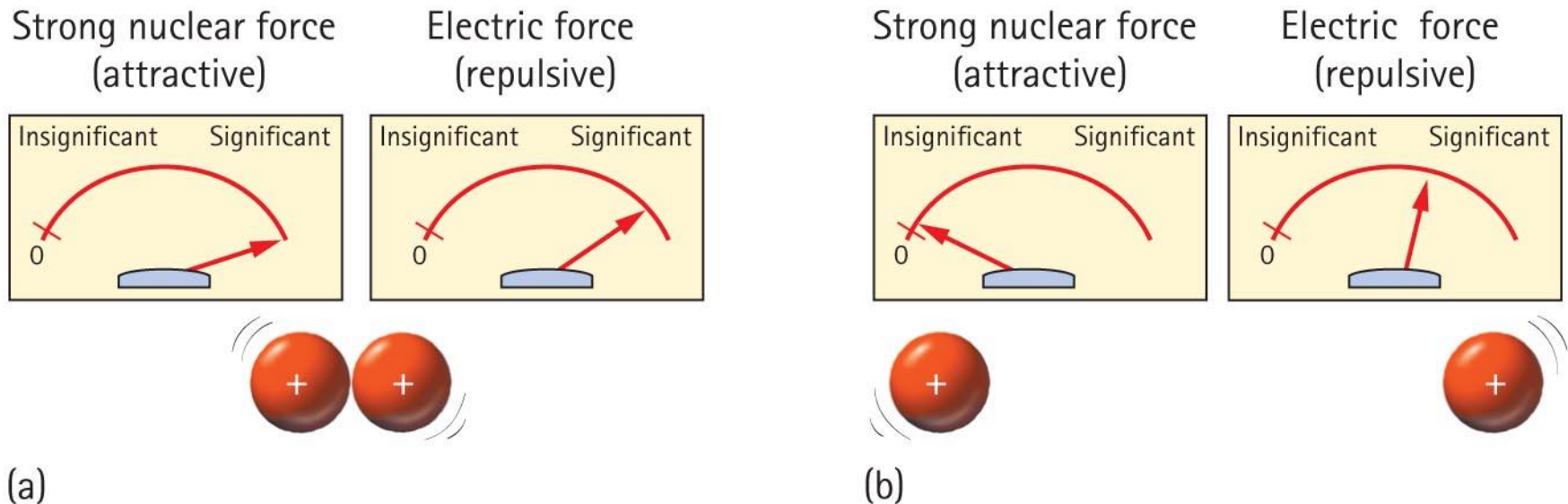# RADIOACTIVITY & HALF-LIFE

Part 2

Radioactivity

Radioactivity:

- Results from radioactive decay, which is the process whereby unstable atomic nuclei transform and emit radiation.

- Has existed longer than the human race.

- Most elements are not radioactive (99.9%)

- Elements greater than 82 may be radioactive

The Atomic Nucleus and the Strong Nuclear Force

The strong nuclear force (SNF) : a very distance sensitive attraction between nucleons.

Strong nuclear force | Electric force | Strong nuclear force | Electric force
(attractive) | (repulsive) | (attractive) | (repulsive)

(a) (b)

- Strong nuclear force
  - Binds protons and neutrons
  - Very short ranged, less than 10^{-15} m
  - Overcomes proton-proton Coulomb repulsion

Repulsion is large...

$$F_{Coulomb} = \frac{kq_1q_2}{r^2}$$

...when distance is small

Half-Life

Half-life:

- is the *rate of decay* for a *radioactive isotope*.
- is the time required for *half of an original quantity* of an element to decay.
- is *constant* and independent of any physical or chemical change the atom may undergo.
- *can be calculated* at any given moment by measuring the rate of decay of a known quantity using a radiation detector.

Half-Life

Radioactive isotopes decay at a rate characteristic of each isotope. Rates are described by half-life.

The shorter the half-life of a substance $\Rightarrow$ the faster it disintegrates and the more active the substance.
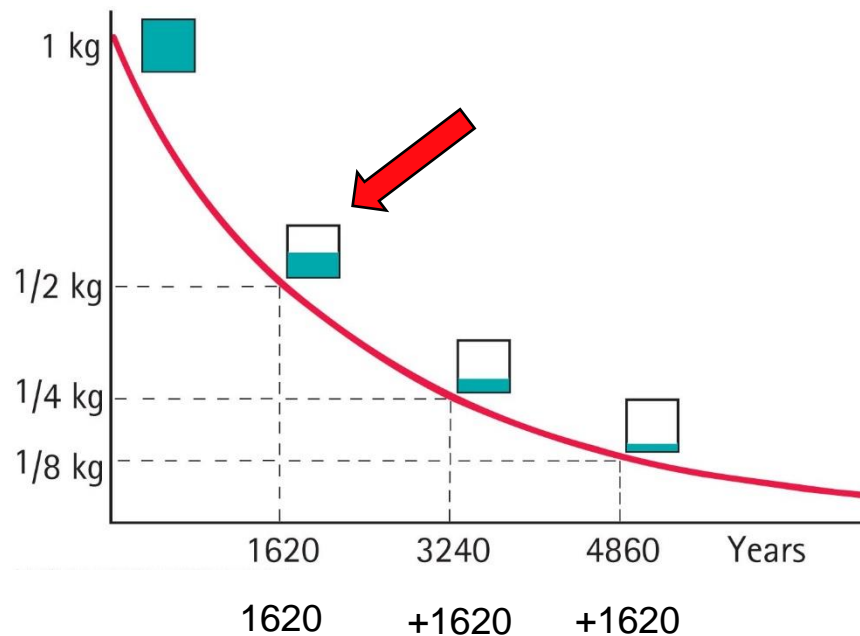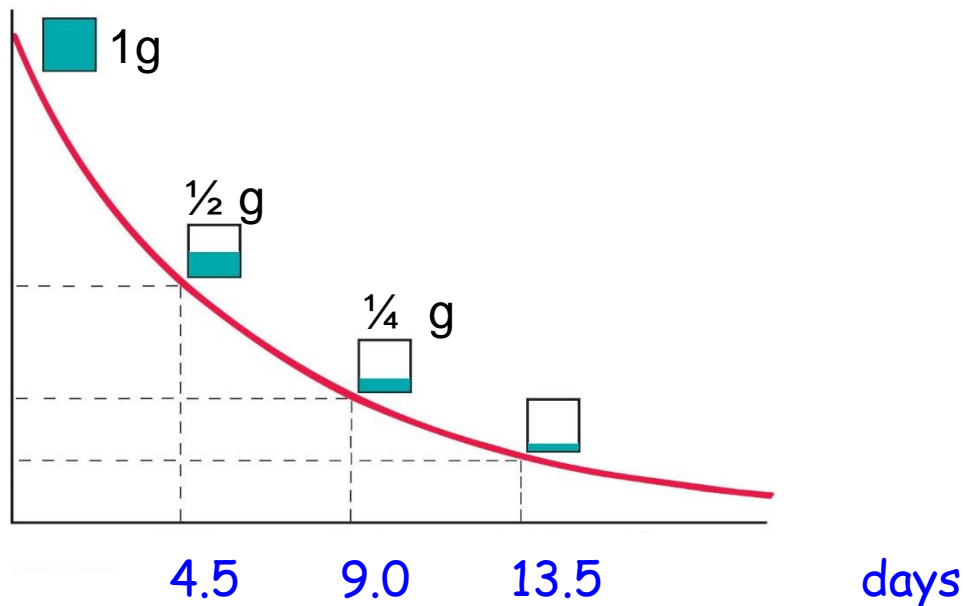
A certain isotope has a *half-life* decay shown on the graph below.
—What is the half life of this isotope?
—The amount of that isotope remaining at the end of 9 days will be? 18 days?

Radioisotope Half-lives
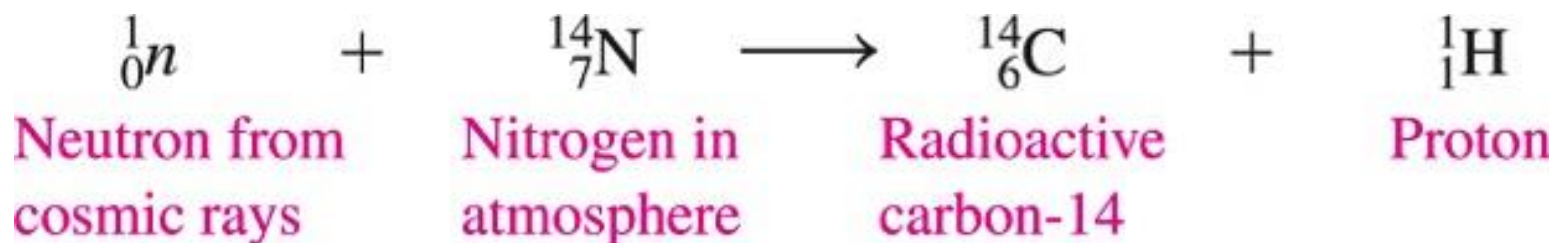
Half-Lives of Some Radioisotopes

Element	Radioisotope	Half-Life	Type of Radiation
Naturally Occurring Radioisotopes			
Carbon-14	$^{14}_{6}C$	5730 yr	Beta
Potassium-40	$^{40}_{19}K$	1.3×10^{9} yr	Beta, gamma
Radium-226	$^{226}_{88}Ra$	1600 yr	Alpha
Strontium-90	$^{90}_{38}Sr$	38.1 yr	Alpha
Uranium-238	$^{238}_{92}U$	4.5×10^{9} yr	Alpha
Some Medical Radioisotopes			
Carbon-11	$^{11}_{6}C$	20 min	Positron
Chromium-51	$^{51}_{24}Cr$	28 days	Gamma
Iodine-131	$^{131}_{53}I$	8.0 days	Gamma
Oxygen-15	$^{15}_{8}O$	2.0 min	Positron
Iron-59	$^{59}_{26}Fe$	44 days	Beta, gamma
Radon-222	$^{222}_{86}Rn$	3.8 days	Alpha
Technetium-99m	$^{99m}_{43}Tc$	6.0 h	Beta, gamma

Chemistry Link to the Environment: Dating Objects

Radiological dating is a technique used by geologists, archaeologists, and historians to determine the age of ancient objects.

The age of ancient objects is determined by measuring the amount of carbon-14 present.

Chemistry Link to the Environment: Dating Objects

$$\_0^1n \; + \; \_7^{14}N \; \longrightarrow \; \_6^{14}C \; + \; \_1^1H$$

Neutron from cosmic rays   Nitrogen in atmosphere   Radioactive carbon-14   Proton

Carbon-14 is produced in the upper atmosphere by the bombardment of nitrogen-14 by high-energy neutrons from cosmic rays.

Carbon-14 reacts with oxygen to form radioactive carbon dioxide which is absorbed by plants.

Chemistry Link to the Environment: Dating Objects

$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$$
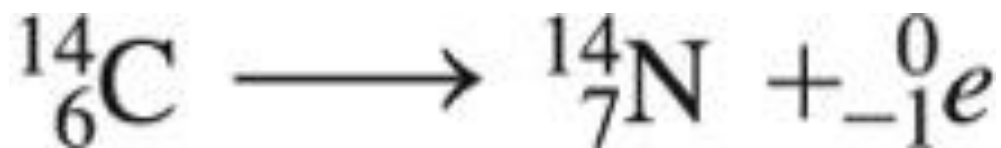
The uptake of carbon-14 in the CO_2 stops when the plant dies.

As the carbon-14 decays, the amount of radioactive carbon decreases.

In a process called carbon dating, scientists use the half-life of carbon-14 (5730 yr) to calculate the length of time since the plant died.

Dating Using Half-Lives

The age of a bone sample from a skeleton can be determined by carbon dating.

- The bones assimilate carbon until death.
- The number of half-lives of carbon-14 from a bone sample determines the age of the bone.
- The half-life of carbon-14 is 5730 yr.
- A bone sample has 25% of the activity of C-14 found in a living animal.
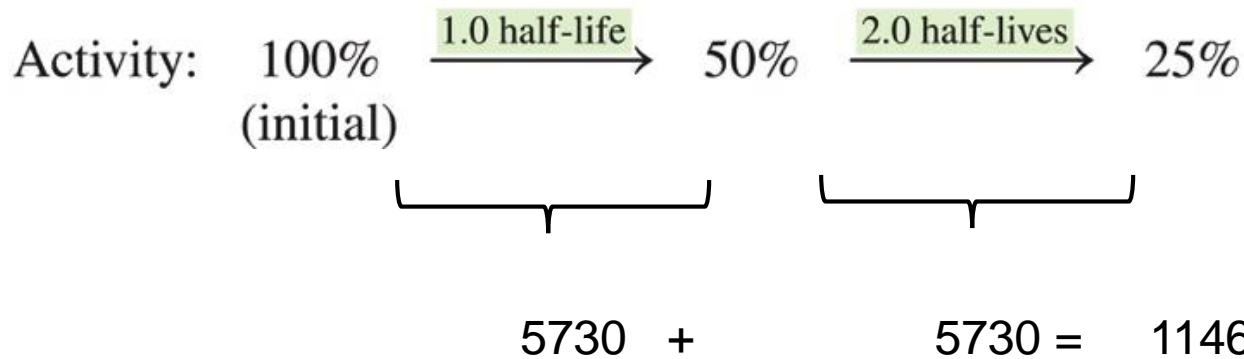- How many years ago did the prehistoric animal die?

Dating Using Half-Lives

A bone sample has 25% of the activity of C-14 found in a living animal. The half-life of carbon-14 is 5730 yr. How old is this sample?

State the given and needed quantities.

ANALYZE THE PROBLEM	Given	Need	Connect
	1 half-life of C-14 = 5730 yr, 25% of initial C-14 activity	years elapsed	number of half-lives

Write a plan to calculate the unknown quantity.

Activity: 100% (initial) $\xrightarrow{\text{1.0 half-life}}$ 50% $\xrightarrow{\text{2.0 half-lives}}$ 25%

5730   +   5730 =   11460 years

Radioactive Waste

- A sample of plutonium-239 waste from a nuclear reactor has an activity of 20,000 counts/m. How many years will it take for the activity to decrease to 625 counts/m?

- The half-live for Pu-239 is 24,000 years.

Half-Life Calculation

- Iodine-131 is used to measure the activity of the thyroid gland. If 88 mg of I-131 are ingested, how much remains after 24 days ($t_{\frac{1}{2}}$ = 8 days)?

- First, find out how many half-lives have passed.

Phosphorus-32, a radioisotope used in the treatment of leukemia, has a half-life of 14.3 days. If a sample contains 8.0 mg of phosphorus-32, how many milligrams of phosphorus-32 remain after 42.9 days?