CARBON DATING

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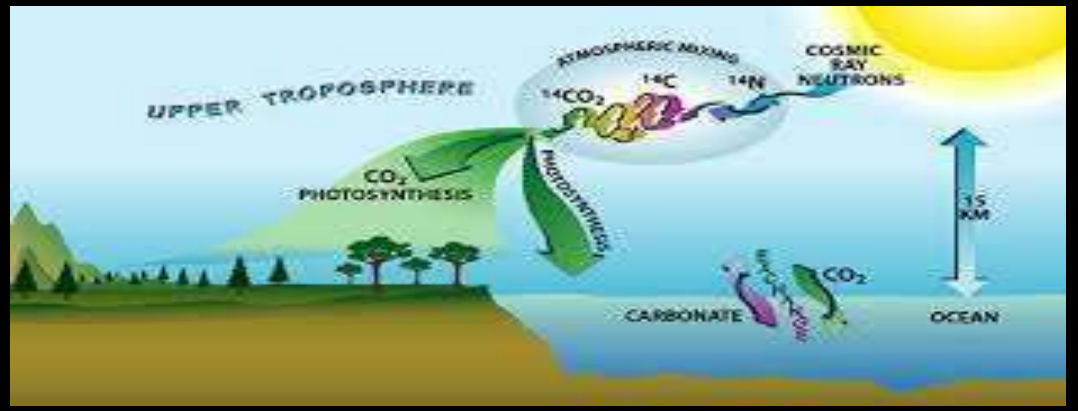
WHAT IS CARBON DATING

- As soon as a living organism dies, it stops taking in new carbon.
- The ratio of carbon-12 to carbon-14 at the moment of death is the same as every other living thing, but the carbon-14 decays and is not replaced.
- The carbon-14 decays with its half-life of 5,730 years, while the amount of carbon-12 remains constant in the sample.
- By looking at the ratio of carbon-12 to carbon-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 fairly precisely.

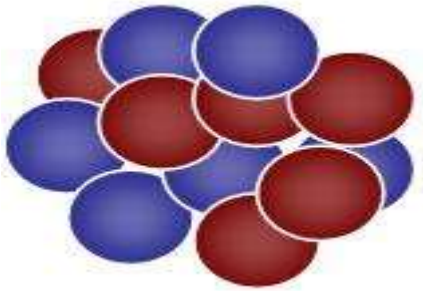


All carbon atoms have 6 proton in its nucleus
but the nucleus may also contain 6, 7, or 8 neutrons.

Protons
Neutrons

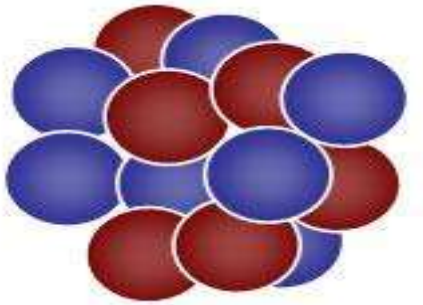
carbon-12

Carbon with 6 protons and 6 neutrons is called carbon-12 (^{12}C).
This is a stable nucleus. 99% of all natural carbon is ^{12}C.



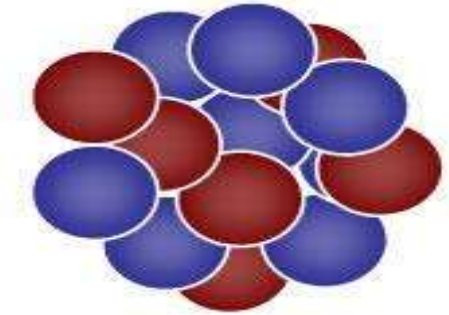
carbon-13

Carbon with 6 protons and 7 neutrons is called carbon-13 (^{13}C).
This is also a stable nucleus. 1% of all natural carbon is ^{13}C.



carbon-14

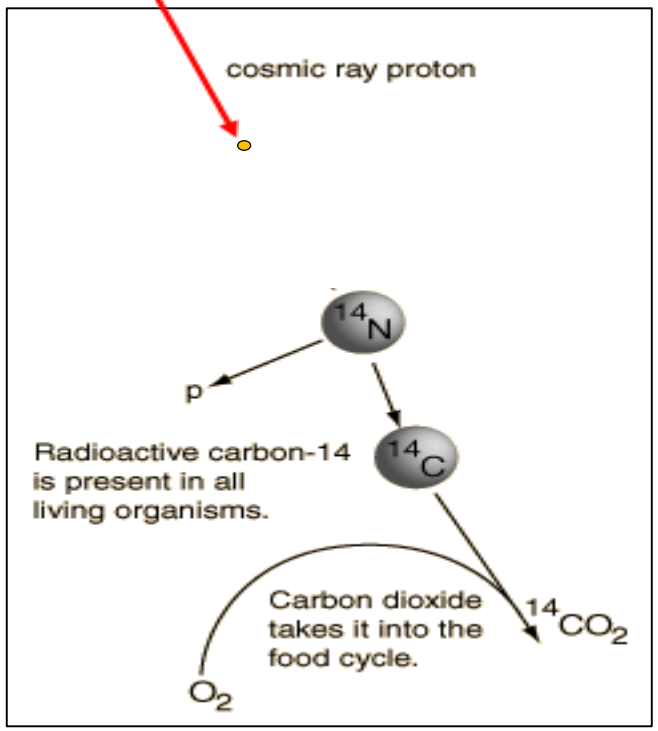
Carbon with 6 protons and 8 neutrons is called carbon-14 (^{14}C).
This is an unstable radioactive isotope. About 1 in 10^{12} carbon atoms in the atmosphere is ^{14}C.



Radioactive carbon (^{14}C) is generated in the upper troposphere when a cosmic ray (typically a proton) hits the nucleus of an atom and produces a neutron (among other things) that is then captured by a nitrogen atom (^{14}N)

$$^{14}_{7}\mathrm{N} + {}^{1}_{0}n \Longrightarrow {}^{14}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H}^{+}$$

In the process the ^{14}N becomes ^{14}C, and a H^{+} ion (a proton) is released.



Generation of radioactive ^{14}C occurs primarily in the upper troposphere, but C (mostly as CO_2) mixes thoroughly in the atmosphere, and is incorporated into living organisms.

The proportion of ^{14}C to ^{12}C in living tissue is comparable with the proportion in the atmosphere or to a water body for aquatic organisms.

Animals get their ^{14}C dose from the food that they consume.

When the organism (or a tissue) dies absorption of ^{14}C ceases, and the amount of ^{14}C gradually decays.

Radioactive carbon (^{14}C) decays back to nitrogen (^{14}N) emitting an electron ($\bar{e}$) and an antineutrino ($\bar{\nu}$) with no mass or charge.

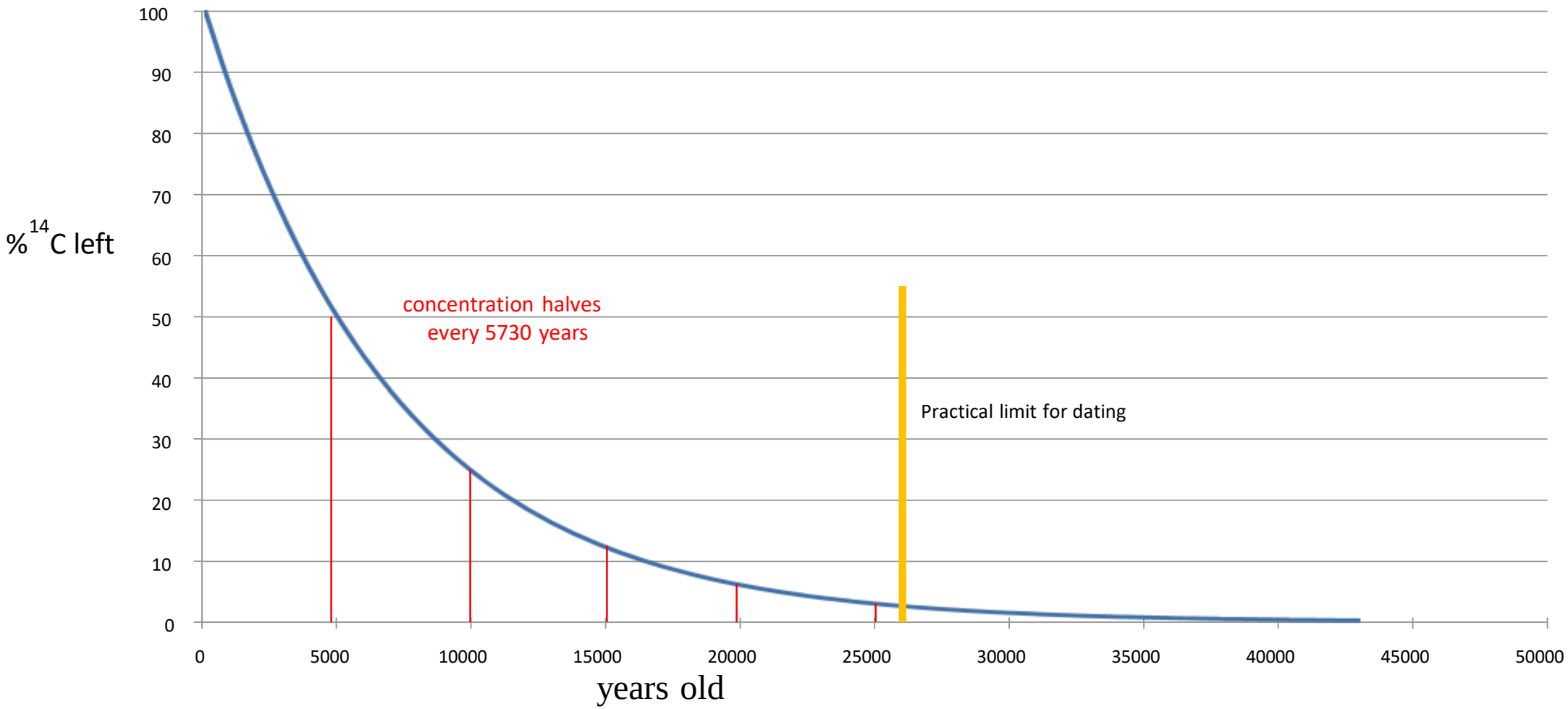
$$^{14}_{6}\mathrm{C} \Longrightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}e^{-} + {}^{0}_{0}\bar{\nu}$$

After about ten ^{14}C to ^{14}N half-lives (~57 ka) there is almost no more ^{14}C left in the tissue.

By measuring ^{14}C content, you can estimate how long ago the tissue died (providing that it isn't so old that the ^{14}C level is too low to measure accurately)

The half-life of the decay of ^{14}C to nitrogen is 5730 years so the concentration halves every 5730 years.

A practical limit for accurate dating is 26,000 years , but you can get less accurate dates up to 43,500 years and, some facilities provide rough dates to ~60,000 years.



Radiocarbon dating is an extremely useful technique for determining the ages of geological materials (that have some organic-derived carbon in them), and it is highly applicable to the study of Quaternary materials (that are younger than 50 ka).

But, interpretation of radiocarbon data can be quite complex, and several factors need to be taken into account to understand what the results actually mean.

LOGARITHMS

A formula to calculate how old a sample is by carbon-14 dating is:

- $t = [\ln (N_f/N_o) / (-0.693)] \times t_{1/2}$
- where ln is the natural logarithm,
- N_f/N_o is the percent of carbon-14 in the sample compared to the amount in living tissue
- $t_{1/2}$ is the half-life of carbon-14 (5,730 years).

EXAMPLE

If you had a fossil that had 10 percent carbon-14 compared to a living sample, then that fossil would be:

- t = [ln (0.10) / (-0.693)] x 5,730 years
- t = [(-2.303) / (-0.693)] x 5,730 years
- t = [3.323] x 5,730 years
- **t = 19040 years old**

LIMITATIONS

- The use of various radioisotopes allows the dating of biological and geological samples with a high degree of accuracy.
- However, radioisotope dating may not work so well in the future.
- Anything that dies after the 1940s, when Nuclear bombs, nuclear reactors and open-air nuclear tests started changing things, will be harder to date precisely.

OTHER ELEMENTS TO USE FOR CARBON DATING

- Radioactive dating elements include Uranium -235 (half-life = 704 million years)
- Uranium -238 (half-life = 4.5 billion years)
- Thorium-232 (half-life = 14 billion years)
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- Rubidium-87 (half-life = 49 billion years)

QUESTION 1

An old sample has 14% carbon-14 compared to a living sample, determine its age.

WORKED SOLUTION

- t = [ln (0.14) / (-0.693)] x 5,730 years
- t = [(-1.966) / (-0.693)] x 5,730 years
- t = [2.837] x 5,730 years
- **t = 16,256 years old**

QUESTION 2

The carbon-14 isotope has a 2:3 ratio to carbon-12 as compared to a living sample, determine its age.

WORKED SOLUTION

- t = [ln (0.40) / (-0.693)] x 5,730 years
- t = [(-0.916) / (-0.693)] x 5,730 years
- t = [1.322] x 5,730 years
- **t = 7575 years old**

THANK YOU