Theory behind Radiocarbon Dating

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What is radiocarbon dating?

Radiocarbon dating is a method of finding the age of a fossile (a dead plant or an animal) or an ancient artifact containing carbon. This dating method is based on the amount of radioactive ^{14}C isotope remaining in the sample.

From where does ^{14}C come to our environment?

The origin of ^{14}C is due to a reaction of ^{14}N with cosmic rays in the upper atmosphere. One of the particles in cosmic rays is neutrons. ^{14}N undergoes neutron capture reaction with neutrons to produce ^{14}C as shown in the following reaction.

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C \qquad \text{Reaction (1)}$$

Subsequently ^{14}C get oxidized to produce $^{14}CO_2$ in the atmosphere.

How does ^{14}C come to a fossile?

Not only ^{14}C, all the other carbon isotopes are also available in fossils. Carbon has several isotopes. The most abundant isotopes are ^{12}C (98.9%) , ^{13}C (1.1%) and ^{14}C (1 part per trillion). ^{14}C is radioactive while most other carbon isotopes are stable. Both plants and animals tissues consist of different carbon sources such as carbohydrates, amino acids, fatty acids and so on. Plants obtain their carbon sources mainly through photosynthesis in which they absorb carbon as carbon dioxide from atmosphere. Through food chains, carbon stored in plants including radioactive ^{14}C transfers from plants to animals. Since ^{14}C has a half life of 5730 years, which means it takes 5730 years to become disintegrate half of the ^{14}C number of atoms from its original count, ^{14}C still remains in the fossils we find.

How does the ^{14}C in fossils allow predicting its age?

The ratio of ^{12}C to ^{14}C in the atmosphere is more or less constant and therefore all the living beings that constantly gain carbon sources have approximately same ratio of ^{14}C:^{12}C during their life time. The moment after the death, plants or animals tissues stop getting their carbon supply. At this point, ^{12}C content in the dead tissue will remain constant, while 14C atoms start reducing since they radioactively decay. In other words, ^{14}C:^{12}C ratio in a dead tissue reduces continuously. If the present ^{14}C:^{12}C ratio of the dead tissue you found can be determined, you can calculate the time elapsed after death of the tissue.

How to measure and calculate the time elapsed of a dead tissue?

^{14}C undergoes the following decay reaction emitting beta particles:

$$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}\beta \qquad \text{Reaction (2)}$$

If the amount of beta particles can be measured using an appropriate beta detection instrument the present 14C count can be obtained. According to the radioactive decay law, the number of radioactive atoms decreases exponentially with time. We can use the general radioactive decay equation for this calculation which is

$$N_t = N_0 e^{(-\lambda t)} \qquad \text{Equation (1)}$$

where N_t and N_0 are the final and initial number radioactive atoms available in the sample respectively, λ is the decay constant which equals to ln 2/ half-life, and t is the elapsed time. In radiocarbon dating, number of atoms would be the ratio of ^{14}C/ total stable C isotopes in which total stable carbon count isotope roughly equals to ^{12}C count.

Eg. If the $^{14}C/^{12}C$ ratio of a fossil is 35% compared to a living sample what is the age of the fossil?
Re-arranging Equation (1) we can obtain

$$t = \left[\frac{ln\left(\frac{N}{N_0}\right)}{-\ln 2} \right] t_{1/2} \qquad \text{Equation (2)}$$

where t1/2 = 5730 years and N/N_0 = 0.35 t = 8680 years

The ratio of $^{14}C/^{12}C$ available in the atmosphere found to be different to different geological time periods. In order to correct this error people have found the

^{14}C ratio during different geological time and made a calibration curve which useful to estimate the calendar age of a given sample.

With the advancement of mass spectrometry, the amount of ^{14}C was directly measured using accelerated mass spectrometry (AMS) instead of measuring the number of beta particles emitted. The advantages of this method are required sample size is smaller and quicker analysis.

Who invented the of theory radiocarbon dating?

Willard Libby is the founder of radiocarbon dating. He won the Noble Prize in Chemistry for this invention in 1960.

What are the applications and findings obtained using this theory?

There are many forensic and archeological applications of radiocarbon dating while some of the results revealed many facts in history. One famous incident was the radiocarbon dating measurement taken to examine the authenticity of Shroud of Turin, a linen cloth associated with burial of Jesus where the results showed it was a much later product than the time of Jesus.

Is the radiocarbon dating applicable for any aged fossils like dinosaurs?

Remember that the half life of ^{14}C is 5730 years. As a rule of thumb, radioactivity cannot be measured after 10 half lives have elapsed, because at that time the number of radioactive atoms will be too low. Therefore, radiocarbon dating is applicable only the age of the sample is less than 60 000 years old.

How reliable is the radiocarbon dating in age determination?

One needs to keep in mind that the radiocarbon tells you the time elapsed from death to present. It will not provide any information of the life time of the organism. Therefore, estimation of an age of a tree with several hundred years old can give erroneous results.

In addition there are many other facts that contribute to error in radiocarbon measurements due to change in $^{14}C/^{12}C$ ratio. Some of the reasons are as follows.

- Natural disasters such as volcano eruptions, and other major natural disasters.
- Human activities such as coal and oil burning, nuclear testing and weakening of ozone due to green house effects may decrease 14C/12C ratio.
- Contamination of carbon from a different geological age to the given sample can give erroneous results in radiocarbon dating.

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IUPAC Nomenclature of Coordination Compounds

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Systematic naming of chemical compounds is of utmost importance due to the fact that nonsystematic trivial names, common names, industrial trade names, and other names create chaos within the scientific community. A broadly accepted system of naming chemical compounds must resolve any ambiguities which might arise and should clarify any confusion over the way in which nomenclature should be used. Furthermore, the naming system must provide a comprehensive set of guidelines to name all known and any new compounds and it should be as simple as possible in order to assist all levels of scientists.

Chapter IR-9 of the 2005 revised Red Book; "Nomenclature of Inorganic Chemistry, IUPAC Recommendations 2005," published for the International Union of Pure and Applied Chemistry (IUPAC) by The Royal Society of Chemistry provides a complete set of guidelines for the naming of coordination compounds. The scope of this article is only to provide an introductory set of instructions sufficient within the undergraduate context of coordination chemistry. Furthermore, it is important to note that the IUPAC recommendations provided for coordination compounds overlap to a great extent with systematic naming of both inorganic and organic compounds.

Werner-type coordination compounds, where the coordination entity comprised of a central metal atom (or atoms) surrounded by ligands are named using additive nomenclature. The name identifies the central metal atom, its oxidation state, the ligands that are attached
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