On absolute dating with ^{14}C and ^{41}Ca

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^{14}C

It is well-known that ^{14}C ($t_{1/2}$ = 5,700 yr) requires a calibration curve to determine an absolute age from the measurement of the ^{14}C content in a material to be dated. Global calibration curves have been established for the entire ^{14}C dating range of about 50,000 years from the measurement of ^{14}C in absolutely dated archives [1-3]. However, sometimes 'plateaus' in the calibration curve hamper considerably the determination of a precise ^{14}C date, such as for the famous Minoan eruption of the Greek Island of Santorini some 3500 years ago [4].

Direct absolute ^{14}C dating would require the measurement of both ^{14}C and its stable beta-decay product $^{14}N^*$. The age of an object can thus be determined from a measured abundance ratio of $^{14}N^*/^{14}C$ and the known half-life. Although this is considered to be impossible because the feeble radiogenic $^{14}N^*$ signals are always overwhelmed by the omnipresence of nitrogen on Earth, an attempt at absolute ^{14}C dating has been discussed before [5].

^{41}Ca

Another radioisotope of considerable interest for archaeological dating is ^{41}Ca ($t_{1/2}$ = 100,000 yr). Bones contain a considerable amount of Ca, and the longer half-life would be ideal for dating the remains of hominides back to about 1 million years. This would make radiocalcium dating a particularly interesting tool [6]. Since a global calibration curve cannot be established for ^{41}Ca (it doesn't form a globally distributed gas like $^{14}CO_2$ from cosmogenic ^{14}C in the atmosphere), absolute dating through measurement of $^{41}Ca/^{41}K^*$ ratios would be required. Again, there is the problem of the omnipresence of potassium on Earth.

In this presentation we will discuss the possibility for absolute dating of ^{14}C and ^{41}Ca by utilizing the kinematics of the beta decays leading to recoil energies of $^{14}N^*$ and $^{41}Ca^*$ of only $\leq$6.9 and $\leq$2.2 eV, respectively. A major question in the decay process is the probability of retention of the radiogenic isotopes within the original molecule, e.g. benzene ($^{12}C_5\mathbf{^{14}C}$) changing to $^{12}C_5\mathbf{^{14}N^*}$ or bone hydroxyapatite ($^{40}Ca_4\mathbf{^{41}Ca}(PO_4)_3OH$) changing to $^{40}Ca_4\mathbf{^{41}K^*}(PO_4)_3OH$.

^{14}C and ^{41}Ca can both be measured by accelerator mass spectrometry (AMS). But assuming that a retention of the decay products is likely, a sensitive method of detecting the minute amounts of stable radiogenic isotopes has to be found. We hope for stimulating discussions on these questions at the Symposium.

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[2] A. G. Hogg et al., "SHCal20 southerm hemisphere calibration, 0 – 55,000 years cal BP," Radiocarbon **62/4** (759-778.

[3] T. J. Heaton et al., "Marine20 – the marine radiocarbon age calibration curve (0 – 55,000 cal BP)," Radiocarbon **62/4** (2020) 779-820.

[4] W. Kutschera, "On the enigma of dating the Minoan eruption of Santorini," Proc. Nat. Acad. Sci. USA **117** (2020) 8677-8679.

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[6] Kutschera et al., "Studies towards a method for radiocalcium dating of bones," Radiocarbon **31/3** (1989) 311-323.