Summary for Tutorial 5

QL
(Dated: November 18, 2008)

Keep in mind: You still need to read the lecture notes. My summary can't have everything in it. If there's an error, please email me.

I. RADIOCARBON DATING_ACTIVITY MEASUREMENT

How many decays we have per unit time?

$$A(t) = |\frac{dN(t)}{dt}| = Counts/unit\ time \quad (1)$$

$$A(t) = \lambda \times N(t) \quad (2)$$

$$N(t) = N_0 \times e^{-\lambda t} \quad (3)$$

For ^{14}C: half life $T_{1/2} = 5730y$, decay constant $\lambda = \frac{ln2}{T_{1/2}} = 1.21 \times 10^{-4}/y$.

$Statistical\ uncertainty = \sqrt{Counts}$

II. RADIOCARBON DATING_AMS

How many ^{14}C are there in the sample?

A. Tandem accelerator

Energy of the particle after pass through the accelerator:

$$E = (1 + q) \cdot V \quad (4)$$

with q the charge of the particle, V the terminal potential of the accelerator.

The radius of the trajectory is given by:

$$r = \frac{\sqrt{2mE}}{qB} \quad (5)$$

with m the mass of the particle, B the magnet field.

Example:

Given $V = 2MV$, $q = 3^+$, $B = 0.1T$, what's the radius of ^{12}C?

$V = 2MV = 2 \times 10^6 V$; $q = |q| \times 1.6 \times 10^{-19} C$; $m = A \times 1.67 \times 10^{-27} kg$

$$E = (1 + 3) \times 1.6 \times 10^{-19} C \times 2 \times 10^6 V = 1.28 \times 10^{-12} J \quad (6)$$

$$r = \frac{\sqrt{2 \times 12 \times 1.67 \times 10^{-27} kg \times 1.28 \times 10^{-12} J}}{3 \times 1.6 \times 10^{-19} C \times 0.1T} = 4.72m \quad (7)$$

Thus the radius of ^{12}C in the magnetic field is 4.72m.

B. Efficiency of AMS

Example

If the measured counts for ^{14}C is $N_{net} = 100 \pm 10$, and the efficiency is $\epsilon_c = 1\%$, what is the size of the sample?

Number of ^{14}C in the sample is:

$$N(^{14}C) = 100/1\% = 10^4 \quad (8)$$

Number of ^{12}C in the sample is:

$$N(^{12}C) = 10^4/(1.3 \times 10^{-12}) = 7.69 \times 10^{15} \quad (9)$$

Mass of the sample:

$$m = \frac{7.69 \times 10^{15}}{6.022 \times 10^{23}} \times 12g = 1.5 \times 10^{-7} g \quad (10)$$

III. POTASSIUM ARGON DATING

^{40}K can decay to two different nuclei. 11% ^{40}K decays to ^{40}Ar.

$$N(^{40}K) = N_0 e^{-\lambda t} \quad (11)$$

$$N(^{40}Ar) = N_0(1 - e^{-\lambda t}) \times 0.11 \quad (12)$$

Thus the ration is given by:

$$\frac{N(^{40}Ar)}{N(^{40}K)} = 0.11 \times (e^{\lambda t} - 1) \approx 5.82 \times 10^{-11} t \quad (13)$$

Thus we can infer the age of the sample by measuring the ratio.