How Old is the Shroud of Turin? 2

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- Mass Spectrometry

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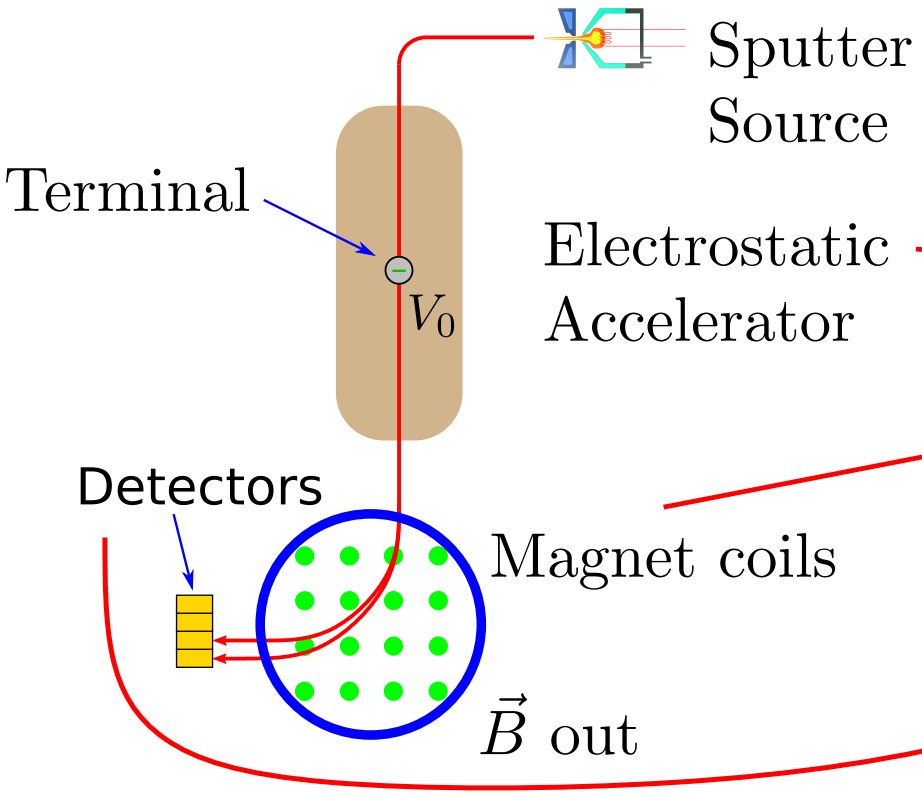
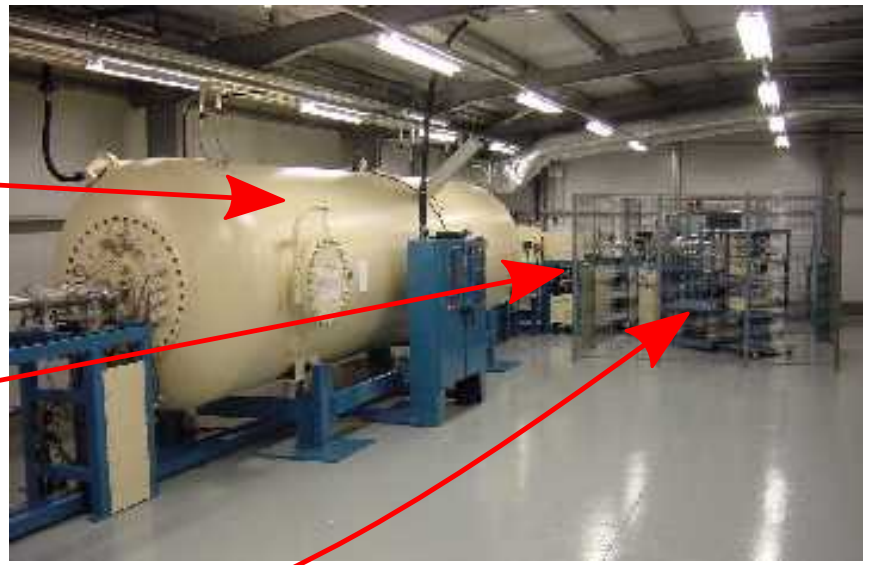
- Radiocarbon Dating.

The Shroud of Turin 5

- Supposed burial garment of Christ.
- Linen cloth $\approx 14' \times 14'$ with two faint images of the front and back of a $5'7''$ man bearing markings corresponding to thorn marks, lacerations (from flogging), bruises, and blood stains.
- First emerged in 1354 carried by Sir Geoffroi de Charny seigneur de Lirey, a knight.
- Public exhibitions started in 1389 (and charged an entrance fee).
- Moved to the royal chapel of the Cathedral of San Giovanni Battista in Turin, Sicily in 1578.
- Original exhibitions were sanctioned by the pope as a 'representation' of the true Shroud.
- Since then no pope has challenged its authenticity.
- Dating the Shroud
    - Images look like photographic negatives.
    - Tests begun in the early 1970's were inconclusive.
    - The church only permitted small amounts of the Shroud to be dated.
    - In 1989 the Shroud was dated using radiocarbon methods.

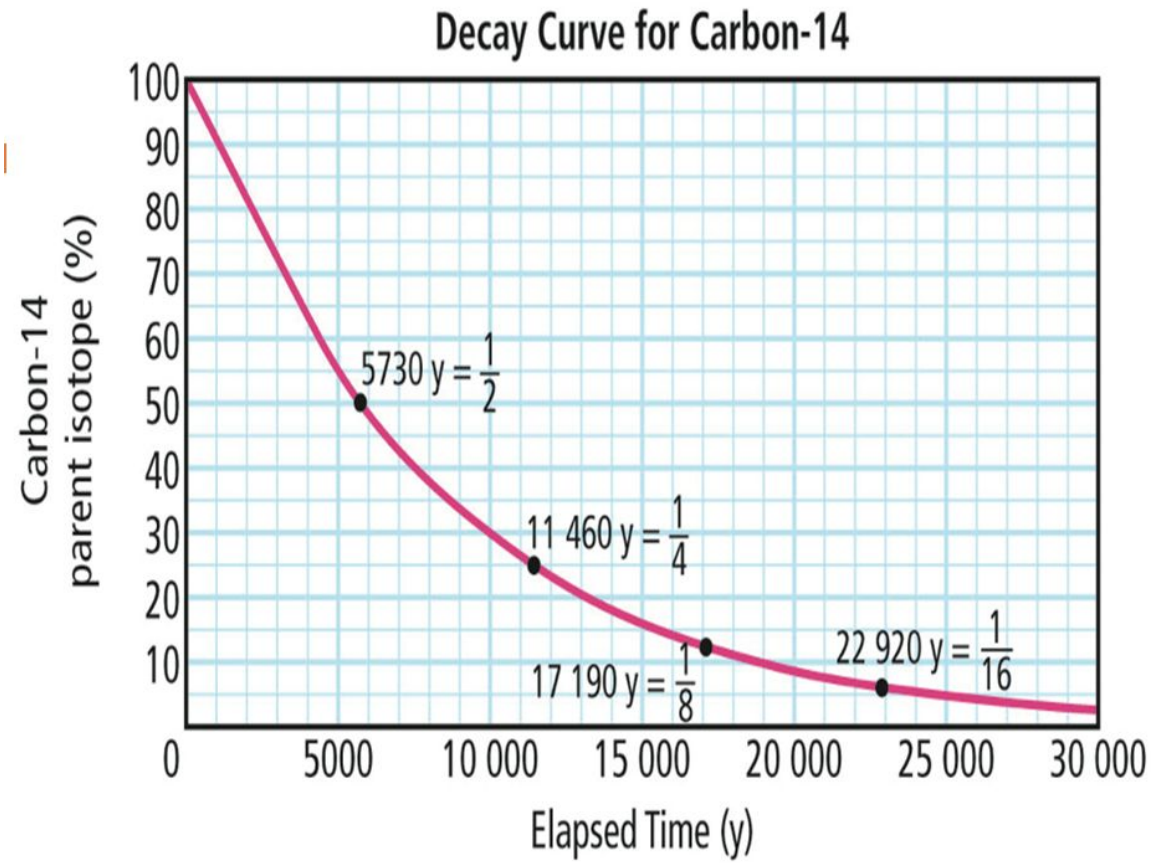
A Mass Spectrometer





Carbon Ratios

$^{12}_{6}\mathrm{C}$	$^{13}_{6}\mathrm{C}$	$^{14}_{6}\mathrm{C}$
98.89%	1.11%	10^{-9}

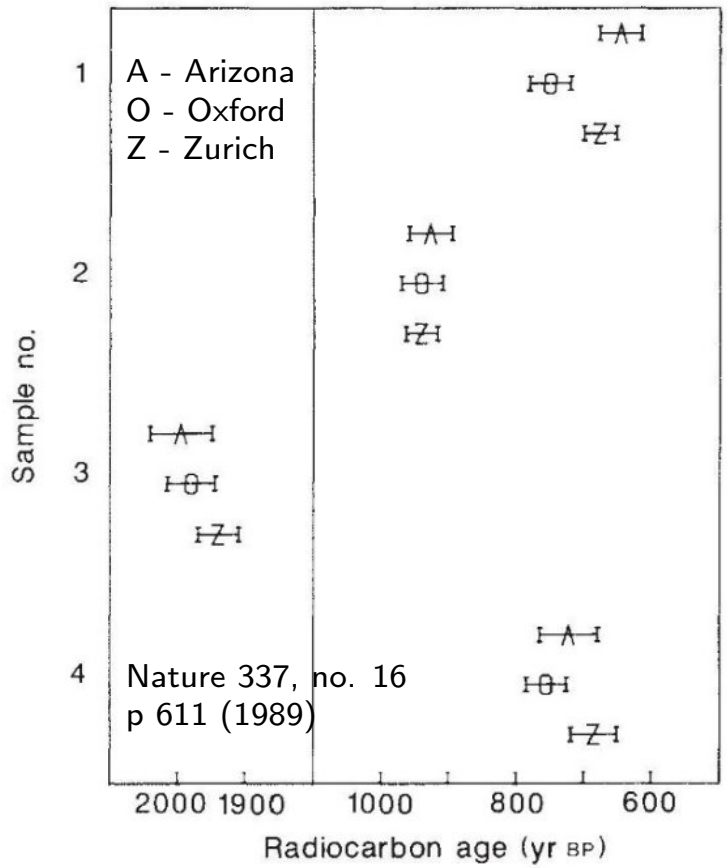


The radioactive isotope $^{14}\mathrm{C}$ decays via

$$^{14}\mathrm{C} \rightarrow {}^{14}\mathrm{N} + \beta^- + \overline{\nu}$$

where β^- is an electron and $\overline{\nu}$ is a particle called the neutrino. The ratio $R = {}^{14}\mathrm{C}/{}^{12}\mathrm{C}$ was measured in 1989 to determine the age of the shroud. The results are shown here. The shroud is sample 1. The other samples are controls. Ages are in years BP (before 1950). Note the break in the age scale.

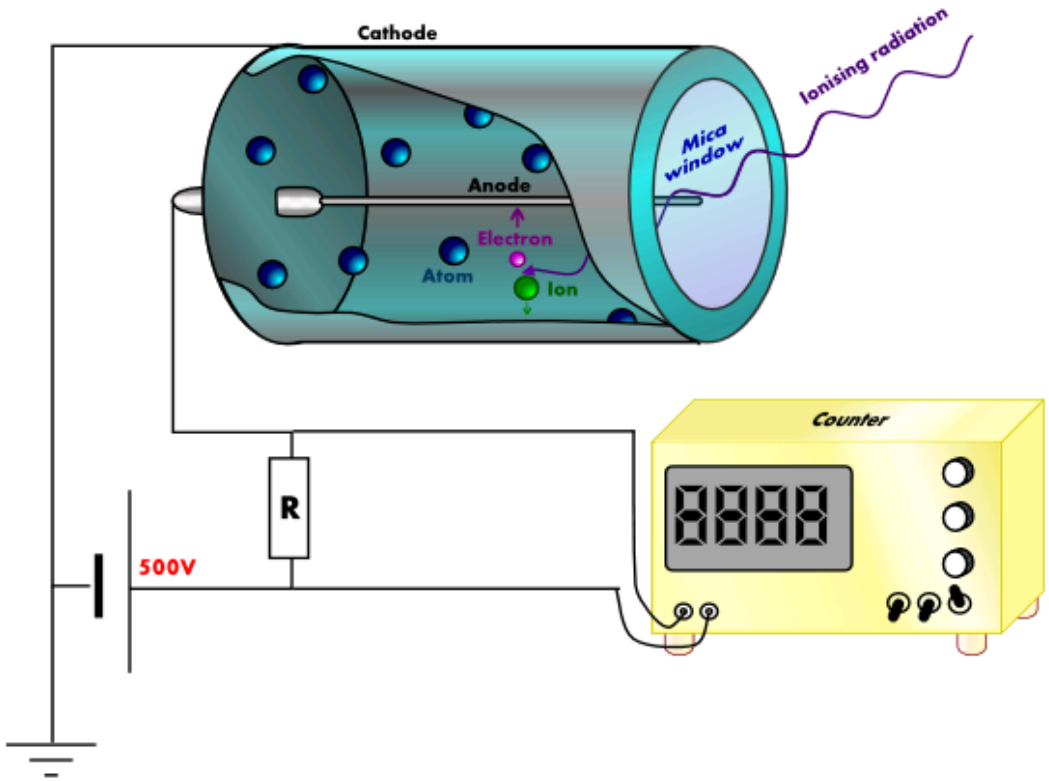
How old is the shroud? The typical uncertainty in these measurements is about 40 years. Are the results of the three labs consistent?



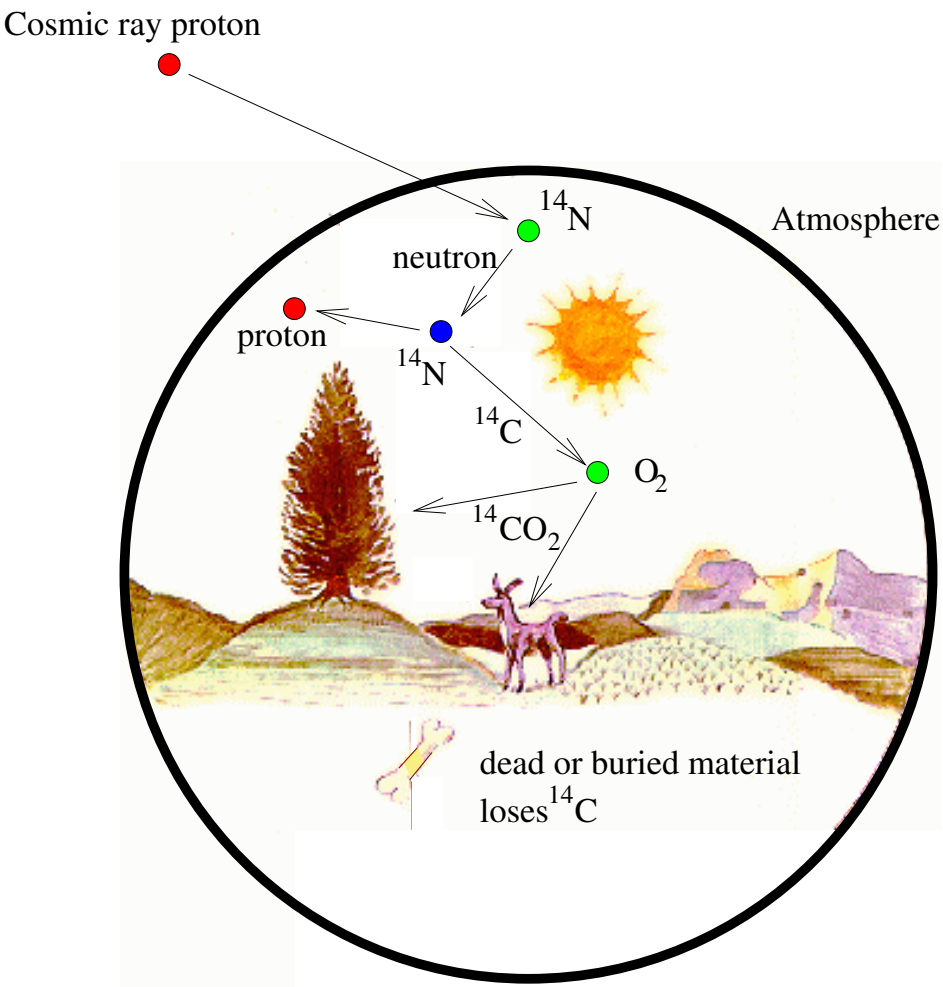
Laboratory	R
Arizona	1.20×10^{-12}
Oxford	1.18×10^{-12}
Zurich	1.19×10^{-12}

A freshly prepared sample of a radioactive isotope has an activity of $R_0 = 3.7 \times 10^8$ decays/s. After a time $\Delta t = 4$ *hr* the activity has dropped to $R_1 = 3.0 \times 10^8$ decays/s. What is the decay constant?

A Geiger-Muller tube (or GM tube) is the sensing element of a Geiger counter instrument that can detect a single particle of ionizing radiation. It is a type of gaseous ionization detector with an operating voltage in the Geiger plateau.



Radiocarbon Dating



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Reaction Chain

$$^{14}_{7}\mathrm{N} + ^{1}_{1}\mathrm{H} \rightarrow ^{14}_{8}\mathrm{O} + ^{1}_{0}\mathrm{n}$$

$$^{14}_{8}\mathrm{O} \rightarrow ^{14}_{7}\mathrm{N} + e^{+} + \overline{\nu}$$

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

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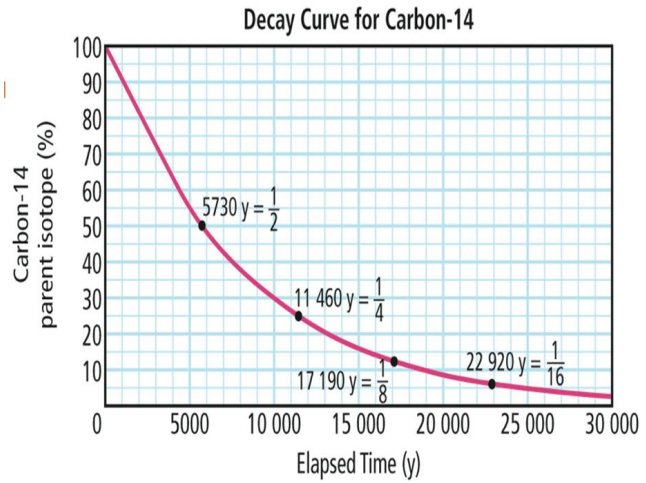
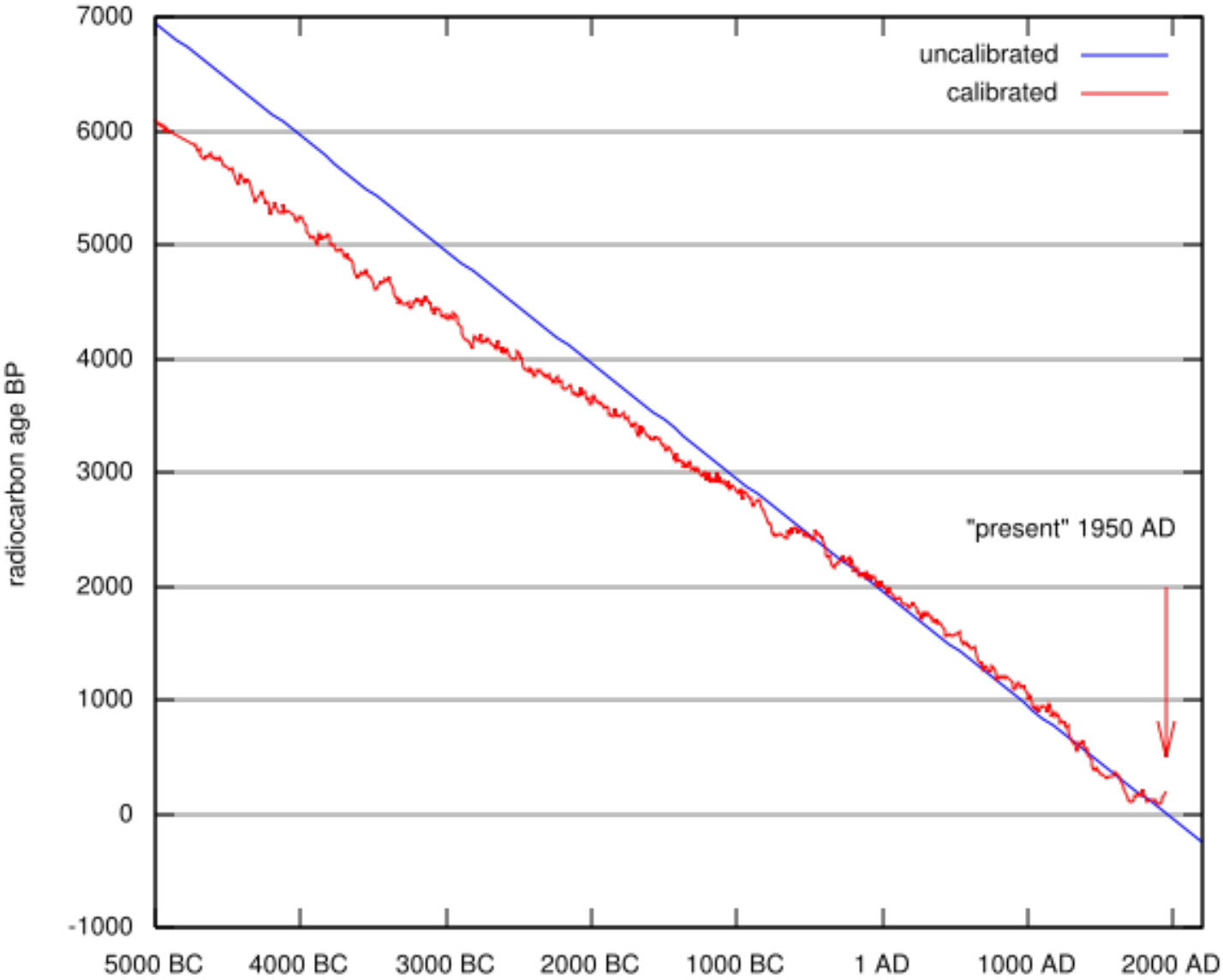


Radiocarbon Calibration Curve



The figure below shows the decay scheme for $^{238}\mathrm{U}$ which can be approximated as $^{238}\mathrm{U} \rightarrow {}^{206}\mathrm{Pb} +$ other decay products where the half-life is determined by that first step. Why? A rock is found containing $m_U = 0.0042\ kg$ of $^{238}\mathrm{U}$ and $m_{Pb} = 0.0024\ kg$ of $^{206}\mathrm{Pb}$. Assume the rock contained no lead at all when it was formed so all the lead present is from the decay of uranium. What is the age of the rock? What does this say about the age of the Earth?

$$^{238}_{92}\mathrm{U} \xrightarrow[4.5\text{x}10^{9}\,\mathrm{y}]{\alpha} {}^{234}_{90}\mathrm{Th} \xrightarrow[24\ \mathrm{d}]{\beta} {}^{234}_{91}\mathrm{Pa} \xrightarrow[6.7\ \mathrm{h}]{\beta} {}^{234}_{92}\mathrm{U} \xrightarrow[2.5\text{x}10^{5}\,\mathrm{y}]{\alpha} {}^{230}_{90}\mathrm{Th} \xrightarrow[7.4\text{x}10^{4}\,\mathrm{y}]{\alpha}$$

$$^{226}_{88}\mathrm{Ra} \xrightarrow[1600\ \mathrm{y}]{\alpha} {}^{222}_{86}\mathrm{Rn} \xrightarrow[3.8\ \mathrm{d}]{\alpha} {}^{218}_{84}\mathrm{Po} \xrightarrow[3.1\ \mathrm{m}]{\alpha} {}^{214}_{82}\mathrm{Pb} \xrightarrow[27\ \mathrm{m}]{\beta} {}^{214}_{83}\mathrm{Bi} \xrightarrow[20\ \mathrm{m}]{\beta}$$

$$^{214}_{84}\mathrm{Po} \xrightarrow[0.16\ \mathrm{ms}]{\alpha} {}^{210}_{82}\mathrm{Pb} \xrightarrow[22\ \mathrm{y}]{\beta} {}^{210}_{83}\mathrm{Bi} \xrightarrow[5.0\ \mathrm{d}]{\beta} {}^{210}_{84}\mathrm{Po} \xrightarrow[138\ \mathrm{d}]{\alpha} {}^{206}_{82}\mathrm{Pb}$$

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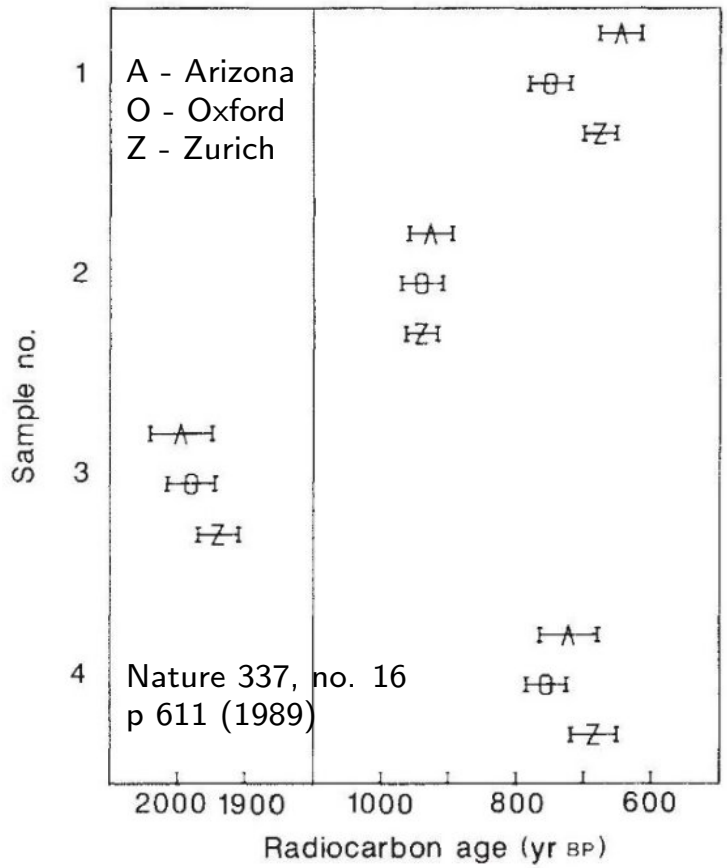

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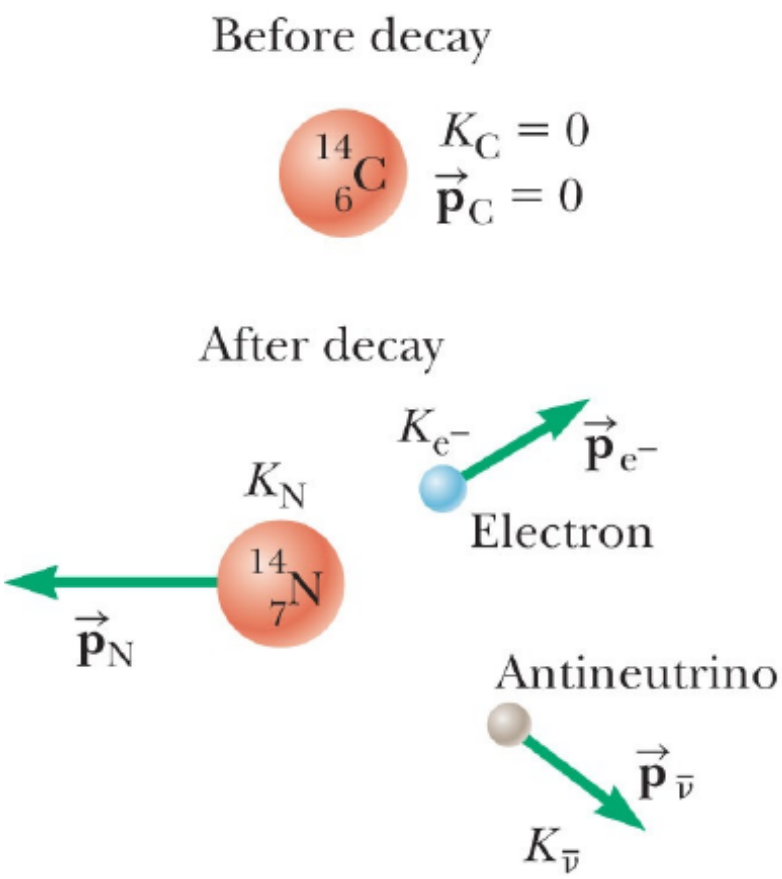
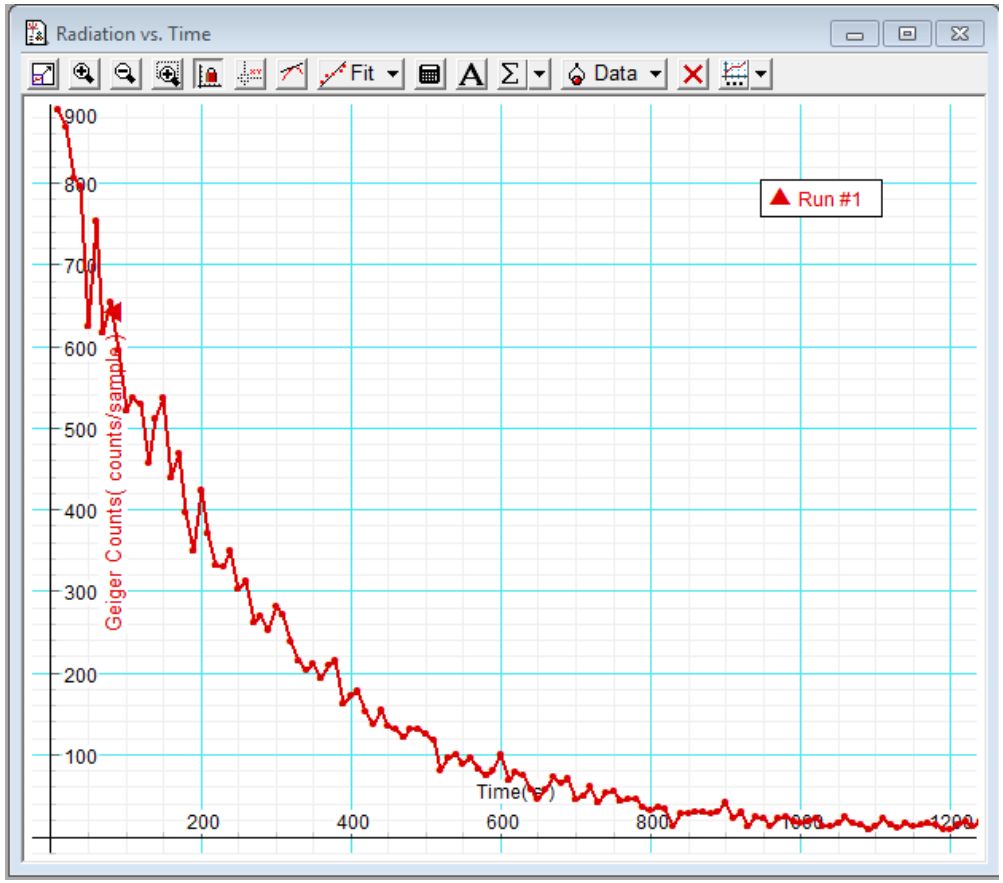
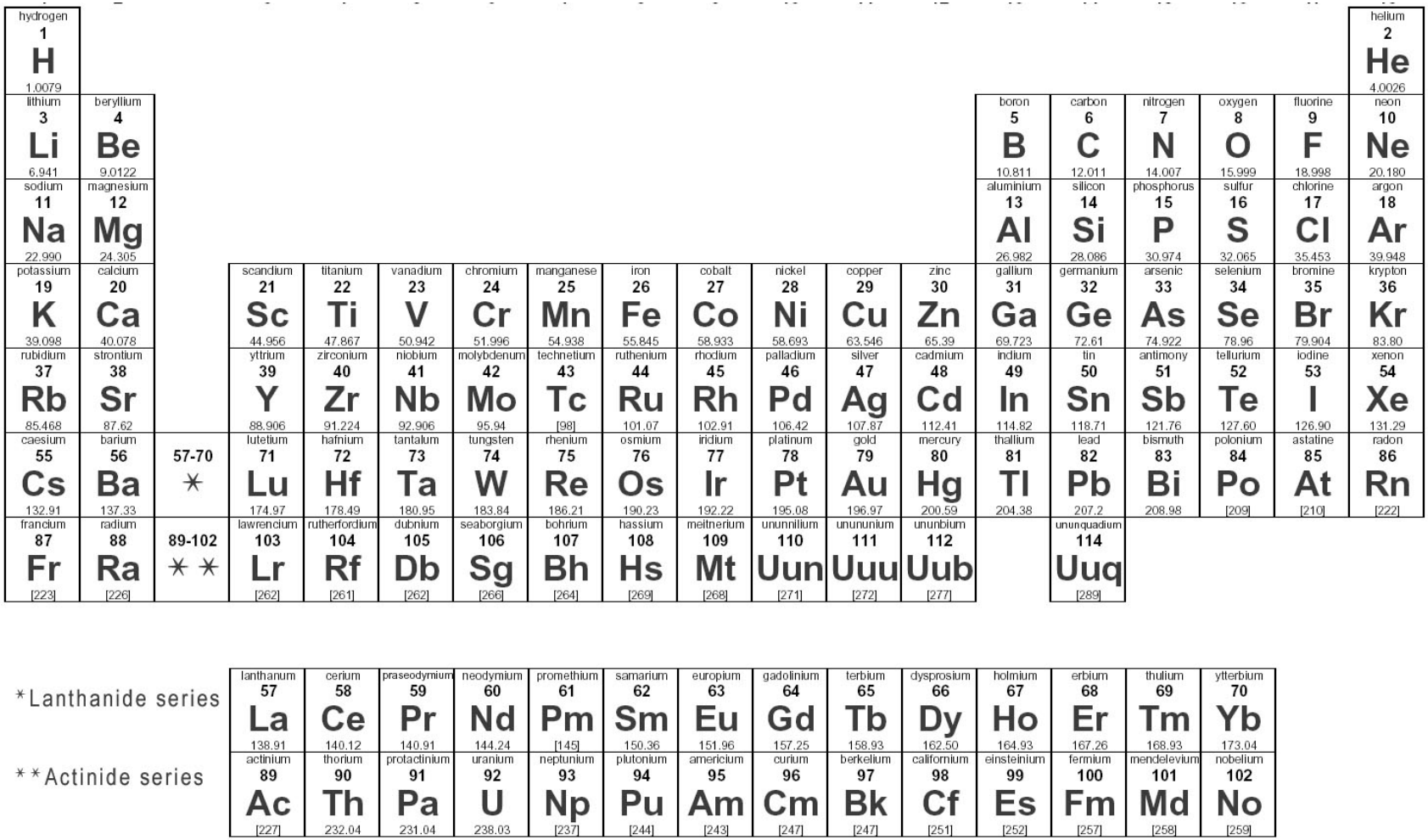




^{14}C decay

^{137}Ba decay

The Periodic Chart



Video is here.

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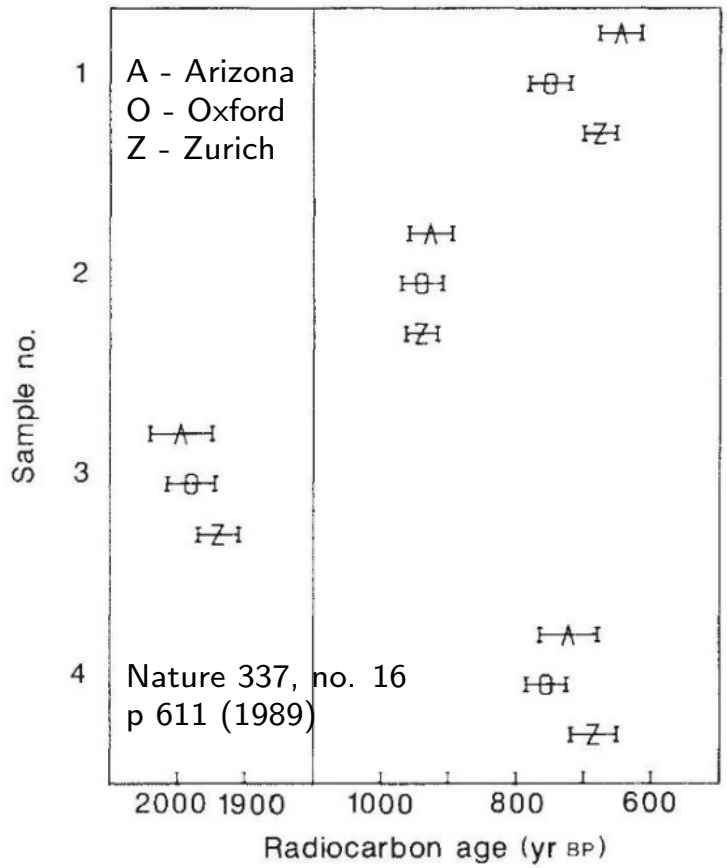

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