





- Mass Spectrometry

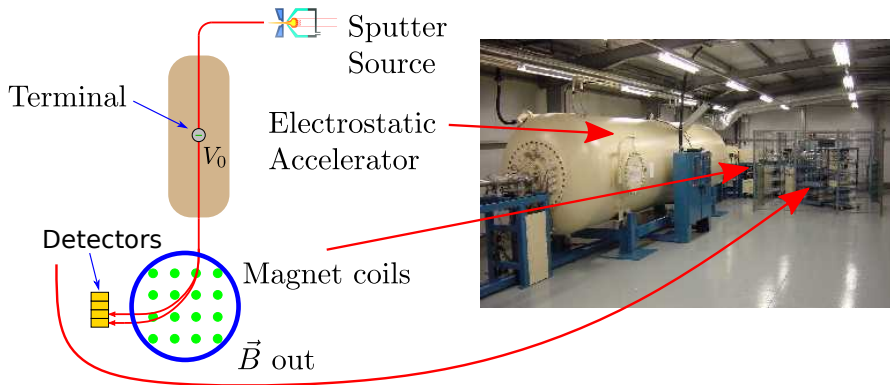


- Mass Spectrometry
- Radiocarbon Dating.



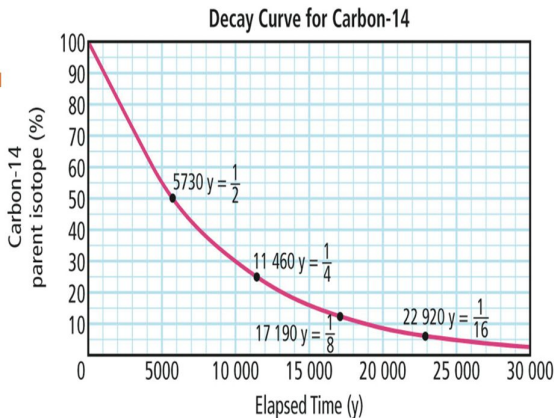
- Supposed burial garment of Christ.
- Linen cloth $\approx 14' \times 14'$ with two faint images of the front and back of a 5'7" man bearing markings corresponding to thorn marks, lacerations (from flogging), bruises, and blood stains.
- First emerged in 1354 carried by Sir Geoffroi de Charny seigneur 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

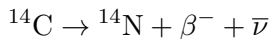


Carbon Ratios

$^{12}_6\text{C}$	$^{13}_6\text{C}$	$^{14}_6\text{C}$
98.89%	1.11%	10^{-9}

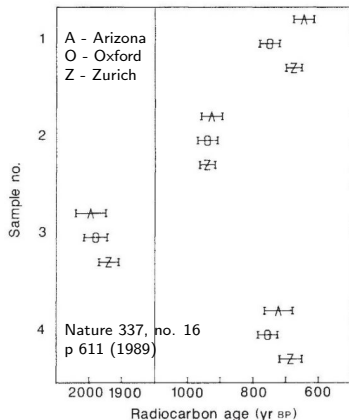


The radioactive isotope ^{14}C decays via



where β^- is an electron and $\bar{\nu}$ is a particle called the neutrino. The ratio $R = ^{14}\text{C}/^{12}\text{C}$ 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.

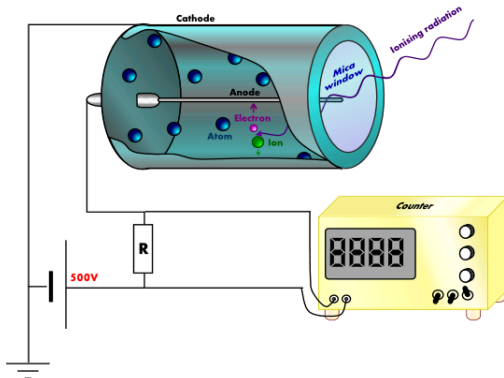
How old is the shroud? The typical uncertainty in these measurements is about 40 years. Are the results of the three labs consistent?



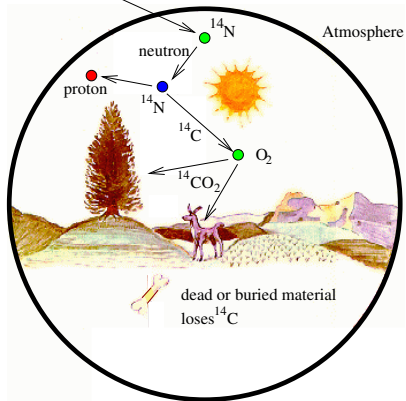
Laboratory	R
Arizona	1.20×10^{-12}
Oxford	1.18×10^{-12}
Zurich	1.19×10^{-12}

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.



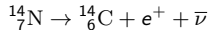
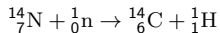
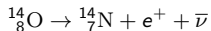
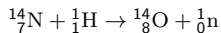
Cosmic ray proton



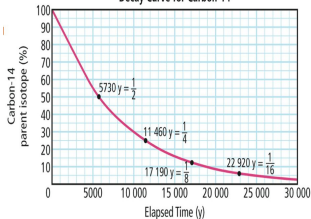
Carbon Ratios

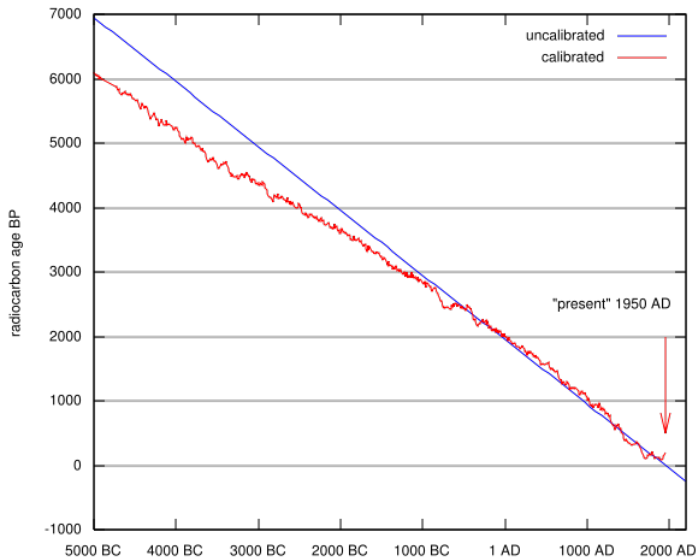
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Reaction Chain

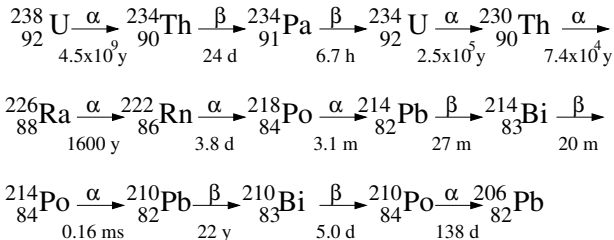


Decay Curve for Carbon-14

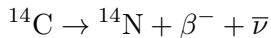




The figure below shows the decay scheme for ^{238}U which can be approximated as $^{238}\text{U} \rightarrow ^{206}\text{Pb} + \text{other decay products}$ where the half-life is determined by that first step. Why? A rock is found containing $m_U = 0.0042 \text{ kg}$ of ^{238}U and $m_{\text{Pb}} = 0.0024 \text{ kg}$ of ^{206}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?

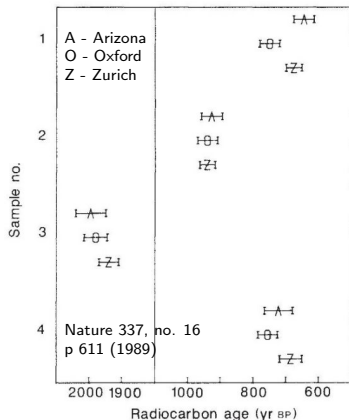


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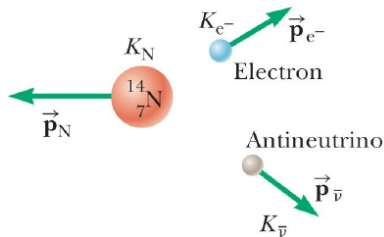


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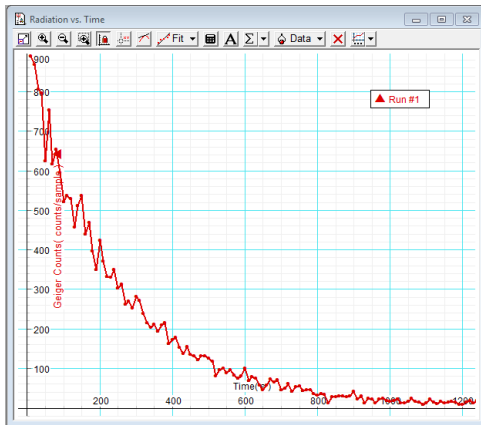
Before decay



After decay



${}^{14}\text{C}$ decay



${}^{137}\text{Ba}$ decay

The Periodic Chart

16

hydrogen 1 H 1.0079																		helium 2 He 4.0026																																													
lithium 3 Li 6.941		beryllium 4 Be 9.0122																																																													
sodium 11 Na 22.990		magnesium 12 Mg 24.305																																																													
potassium 19 K 39.098		calcium 20 Ca 40.078																																																													
rubidium 37 Rb 85.468		strontium 38 Sr 87.62																																																													
cesium 55 Cs 132.91		barium 56 Ba 137.33		57-70 * lanthanum 57 La 138.905		71 cerium 58 Ce 140.12		72 praseodymium 59 Pr 140.908		73 neodymium 60 Nd 144.24		74 promethium 61 Pm 144.913		75 samarium 62 Sm 150.36		76 europium 63 Eu 151.964		77 gadolinium 64 Gd 157.25		78 terbium 65 Tb 158.925		79 dysprosium 66 Dy 162.50		80 holmium 67 Ho 164.930		81 erbium 68 Er 167.259		82 thulium 69 Tm 168.930		83 ytterbium 70 Yb 173.054		84 lutetium 71 Lu 174.967		85 hafnium 72 Hf 178.49		86 tantalum 73 Ta 180.948		87 tungsten 74 W 183.84		88 rhenium 75 Re 186.21		89 osmium 76 Os 190.23		90 iridium 77 Ir 192.22		91 platinum 78 Pt 195.08		92 gold 79 Au 196.97		93 mercury 80 Hg 200.59		94 thallium 81 Tl 204.38		95 lead 82 Pb 207.2		96 bismuth 83 Bi 208.98		97 polonium 84 Po [209]		98 astatine 85 At [210]		99 radon 86 Rn [222]	
francium 87 Fr [223]		radium 88 Ra [226]		89-102 * * actinium 89 Ac [227]		103 lawrencium 103 Lr [262]		104 rutherfordium 104 Rf [261]		105 dubnium 105 Db [262]		106 seaborgium 106 Sg [264]		107 bohrium 107 Bh [264]		108 hassium 108 Hs [268]		109 meitnerium 109 Mt [268]		110 darmstadtium 110 Ds [271]		111 roentgenium 111 Rg [272]		112 copernicium 112 Cn [277]		113 nihonium 113 Nh [284]		114 flerkovium 114 Fl [289]		115 moscovium 115 Mc [288]		116 livermorium 116 Lv [293]		117 tennessine 117 Ts [294]		118 oganesson 118 Og [294]																											

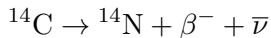
* Lanthanide series

** Actinide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

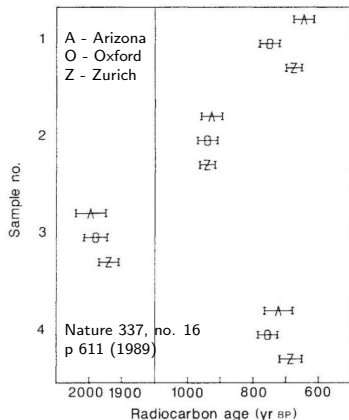
Video is [here](#).

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