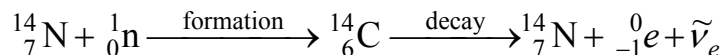


Caffeine Problems for Week 9:

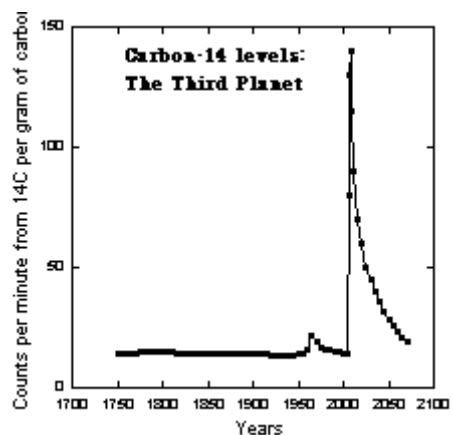
Chem 1C (Kahn)

Background: Carbon-14 radioisotope forms in the atmosphere when high-energy neutrons collide with the nitrogen-14 nuclei. The atmospheric carbon-14 is rapidly converted into $^{14}\text{CO}_2$, which is assimilated by plants. The carbon-14 decays slowly (half-life 5730 ± 40 years) into nitrogen-14 by emitting an electron and antineutrino.



Under the normal conditions the rate of the formation and decay of carbon-14 are in balance such that the level of $^{14}\text{CO}_2$ in the atmosphere is constant. Because living plants assimilate some of this $^{14}\text{CO}_2$, the level of carbon-14 in living organisms is also constant and corresponds to about 15 disintegrations per gram of carbon. When the photosynthesis stops, the assimilation of $^{14}\text{CO}_2$ stops but its disintegration will not stop and the level of carbon 14 will drop. This allows dating of the organic material because the level of carbon-14 in biologically generated organic material is related to the length of time between now and the time the material stopped assimilating $^{14}\text{CO}_2$. Carbon-14 dating is widely used to determine the age of artifacts, such as the famous [Ötzi Iceman](#), which was dated to 3370 to 3100 BC. The importance of this method was recognized by awarding its developer, Dr. Willard Libby the 1960 Nobel Prize in Chemistry.

Problem: In year 2070, a deep space mission from a planet orbiting star *70 Virginis* has finally landed on Earth with hopes of finding the source of unusual radio emissions. Their space mission was inspired by the observation of strong emission of nonrandom radiowaves from the Earth that they first observed in 1897. However, during their journey, the radio signals dropped significantly on 06/06/2006 and disappeared shortly thereafter. After orbiting the Earth without finding any radio sources, the spacecraft landed in White Mountains in California next to the 4800-years old Brislecone pine. Trying to understand what happened on the Earth, the scientists took samples from the tree rings and analyzed the carbon-14 content. From this information they were able to reconstruct a data on the levels of carbon-14 in the tree material for the past 320 years (graph above):



Which explanation for the lack of radio waves is most consistent with the carbon-14 data?

- 1) The sudden loss of ozone layer occurred on 06/06/2006 allowing radio waves to escape to the outer space
- 2) The nuclear reactions on the Sun had suddenly stopped for a period of several years on 06/06/2006
- 3) All the fossil fuels on Earth spontaneously ignited on 06/06/2006 due to a release of a catalyst when the volcano we call Yellowstone erupted
- 4) A massive release of harmful chemicals shut down photosynthesis on Earth for several years on 06/06/2006
- 5) A large number of nuclear and thermonuclear explosions occurred on Earth on 06/06/2006.

