UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

College of Science Outreach

The Age of the Earth

Watch the clip from Chapter 5, "The Age of the Earth" from Part 2 of the DVD "The Life and Work of Ernest Rutherford", (time codes 24:09 - 28:33 min)

Until the nineteenth century it was thought that the Earth was only a few thousand years old. Archbishop Usher in the seventeenth century had worked out the number of generations in the Bible before Christ's birth, starting with Adam and Eve, and he calculated that the Earth was created in 4004BC.

1. Using this theory, how old would the Earth have been in 1904?

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Unfortunately, this did not tie in at all with what geologists were thinking. They had deduced that some rocks were made of layers of sedimentation which had been laid down and compressed, requiring much longer periods of time to produce the effect.

In 1862 Lord Kelvin calculated that if the Earth had started as a white-hot ball of molten material and then cooled down, it must be a few tens of millions of years old.

2. What had Lord Kelvin been unable to take into account in his calculations? (Hint: Ernest Rutherford, in his Royal Society lecture, had turned it around so that Kelvin wouldn't be offended)

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Rutherford realised that minerals containing uranium also contained helium as a result of the uranium decaying by alpha particle emission. Since the decay rate of uranium was known by that time, the amount of helium in the rock gave an indication of how long the uranium had been decaying, giving Rutherford his first approximation of the age of the Earth, (several hundreds of millions of years.)

3. Where did the helium in the rock come from?

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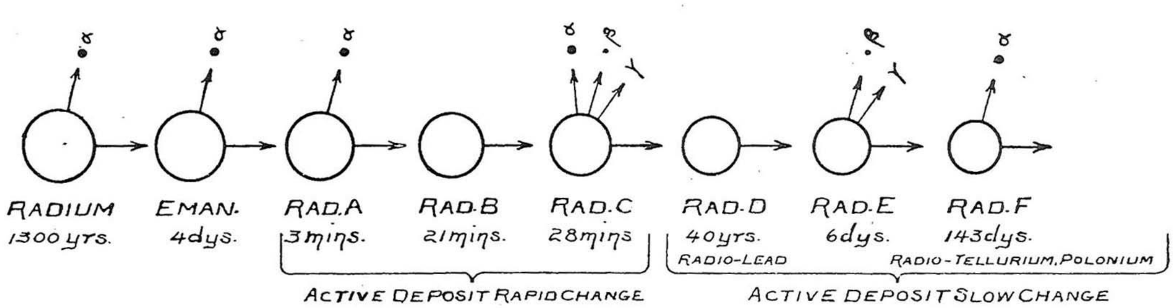
4. How old did the rocks seem to be?

5. What flaw was there in this simple method?

Rutherford and Bertram Boltwood later worked on measuring the rate of decay of other materials, including radium. It was known by then that one element giving off radiation became a different element, and then another and so on, giving a "radioactive series". The elements produced were still being analysed to discover what they were - meanwhile they were given names like "Radium A", "Radium B", as in the series below:



[From "Radioactivity", p450, E Rutherford, Cambridge University Press, 1905]

6. Use a periodic table to establish the names of the elements labelled "EMAN", "RAD.A", and "RAD.B" in the diagram. (Radium has a mass number of 226)

7. The first daughter product from radium in the diagram is labelled “EMAN” for “emanation”. Why was it given this name?

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Rutherford measured the decay rates very precisely, and also established an important relationship:

the rate of decay of an element is related to its half-life.

(The half-life is the time it takes for half the atoms of an element to decay, and the faster the rate of decay the shorter the half-life). Using this method Rutherford deduced that the half-life of radium is 1600 years. He and Boltwood also established that in a rock containing uranium, there was always a constant ratio for

$$\frac{\text{concentration of uranium}}{\text{concentration of radium}}$$

8. Explain why this ratio remains constant even though the uranium and radium are constantly decaying.

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The decay series above continues after radium-F and eventually produces a stable product, lead. Using the same reasoning as for the ratio of uranium to radium, Boltwood used the ratio of uranium to lead to show that a sample of rock was 2.2 billion years old, a factor of 10 larger than Rutherford’s earlier estimate, and just about half the value currently thought to be the age of the Earth. Nowadays, for higher accuracy, two isotopes of uranium are used simultaneously for dating rocks: uranium-235 with a half-life of 700 million years and uranium-238 with a half-life of 4.5 billion years.

9. Roughly what fraction of the original uranium-238 will remain in such a rock today?

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