Radiometric Dating of Rocks

The predictable rates at which radioisotopes decay provide a powerful way to determine the timescales over which geologic processes occur. By measuring amounts of certain isotopes in a rock, it's possible to calculate the amount of time since the rock solidified from cooling magma or from sedimentation.

The radioisotopes used in finding the ages of rock are ones with very long halflives. Rubidium 87 (symbol ^{87}Rb) has a halflife of 49 billion years, about 11 times the age of the Earth. It decays into Strontium 87 (symbol ^{87}Sr) when a neutron turns into a proton (beta decay).

Rubidium-Strontium Dating Method

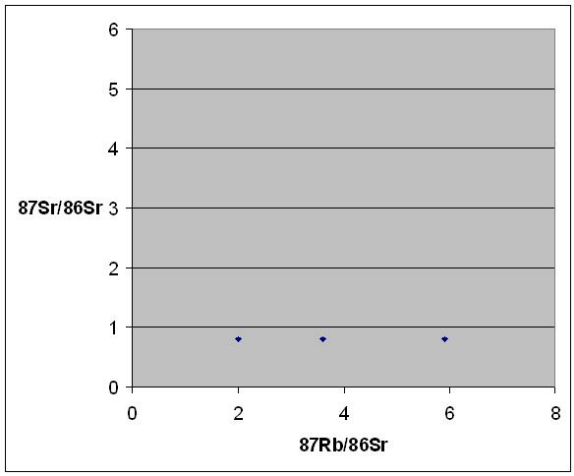
Most rocks, like the granite shown below, contain a variety of minerals. These different minerals have different chemical compositions. That is, different relative amounts of the various elements.

Two elements found in many rocks are Rubidium and Strontium (atomic numbers 37 & 38). Both have several abundant isotopes and the amounts of each isotope can be measured individually. The isotopes that are measured for this method are ^{87}Rb, ^{87}Sr, & ^{86}Sr. Samples are taken from perhaps 5 parts of the rocks, parts of differing mineral composition, and all three isotopes are measured for each one.

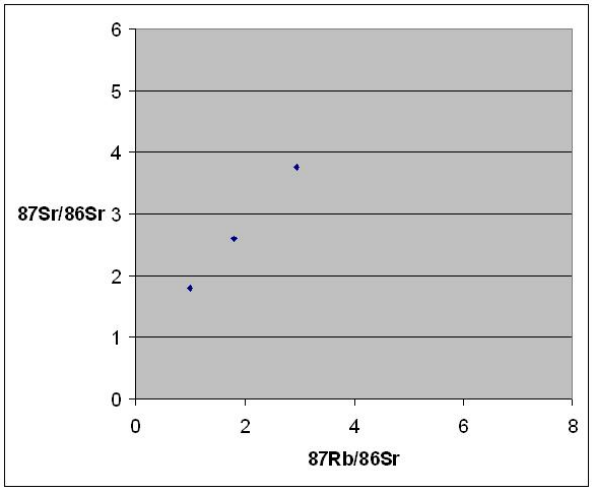
If this is done for a rock that is brand new, one that's just formed from cooling magma, it's found that the Strontium isotopes exist in the same proportions throughout the rock. That is, the ratio of ^{87}Sr to ^{86}Sr is the same in all parts. This is because they behave the same chemically even though they have different numbers of neutrons in their nuclei, and so they bond into minerals in the same way.

But over time, ^{87}Rb decays into ^{87}Sr and so the ratio $^{87}Sr/^{86}Sr$ increases, while the ratio $^{87}Rb/^{86}Sr$ decreases. These changing ratios are used to find the age of the rock.

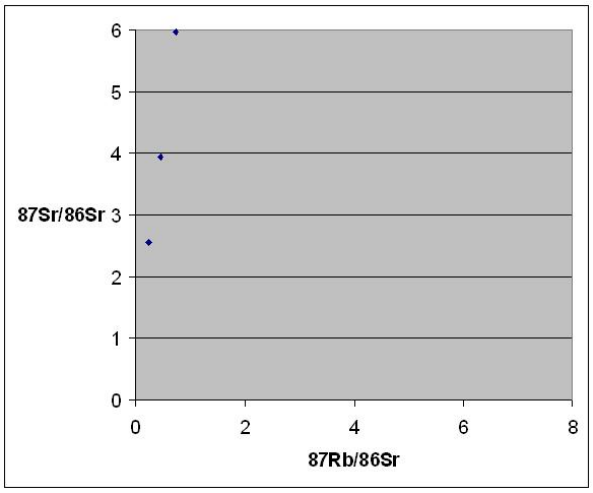
It works like this. Let's say you have a brand new rock. If you calculate the ratios $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ for each of 3 samples from inside the rock, all the $^{87}Sr/^{86}Sr$ should be the same, and all the $^{87}Rb/^{86}Sr$ should be different. So if you make a graph where each set of ratios is a point, it should look something like this.



Now let's say you reburied the rock and someone else dug it up 49 billion years from now (that's much longer than the present age of the Earth but I'm using this number for purposes of illustration). Since this is one halflife of ^{87}Rb, then half of the ^{87}Rb in each sample will have decayed. If this person plotted the same plot as you did, each of the points will have moved halfway to the vertical axis and the same distance up. The graph will look like this.



The slope of this line will be one. If this person then reburies the rock and a third person digs it up after an additional 49 billion years and performs the same task, his graph will look like this.



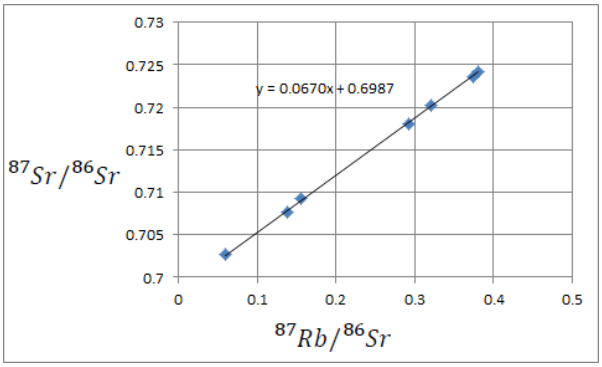
The slope will be three. It turns out that the slope of this line will be related to the number of halflives that have gone by, and the relationship has this form

$$m = 2^n - 1$$

Here m is the slope of the graph and n is the number of halflives.

That means that no matter how old is the rock, you can calculate the ratios for each sample, make the plot, find the slope of the plot, and determine the number of halflives that have passed from the above equation.

Here is a plot of data from a real rock.



The points have been fit to a straight line and the equation of the line is shown. The slope of the line is 0.0670, so from the equation above, the number of halflives that have passed since the rock formed is 0.0935. Since one halflife of ^{87}Rb is 49 billion years, this number of halflives is 4.58 billion years. This rock is actually a meteorite, which are older than Earth rocks, and this age reflects the age of the Solar System.

If a rock has not remained in pristine condition throughout its life, the method won't work. But in that case the points will not fall in a straight line. There is no plausible explanation for the linearity other than the validity of these age determinations.