Short Lived (extinct) Radionuclides SLR

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(Dated: June 9, 2019)

Short Lived Radionuclides (SLR) are those isotopes with half-lives ($t_{1/2}$) $<10^8$ years. Here we explore the use of the conventional isochron diagram to establish the initial ratio of an extinct SLR relative to a stable isotope of the same element. This *initial ratio* of a SLR provides a clue to the nature of the pre-solar system environment prior to the initiation of collapse of a fragment of an ISM molecular cloud that ultimately evolves into our Solar System. The *initial ratio* of a SLR may also be used to identify the triggering event that lead to the formation of our solar system.

I. DETERMINING THE INITIAL ABUNDANCE OF A SLR ISOTOPE

Using the Rb-Sr isotope system, the convention isochron is established by plotting a graph with data from minerals in equilibrium in a rock at the time of crystallization [note that these minerals are no longer in isotopic equilibrium, given each mineral now has its distinctive isotopic composition due to decay products being frozen in (i.e., minerals are no longer in diffusive equilibrium)]:

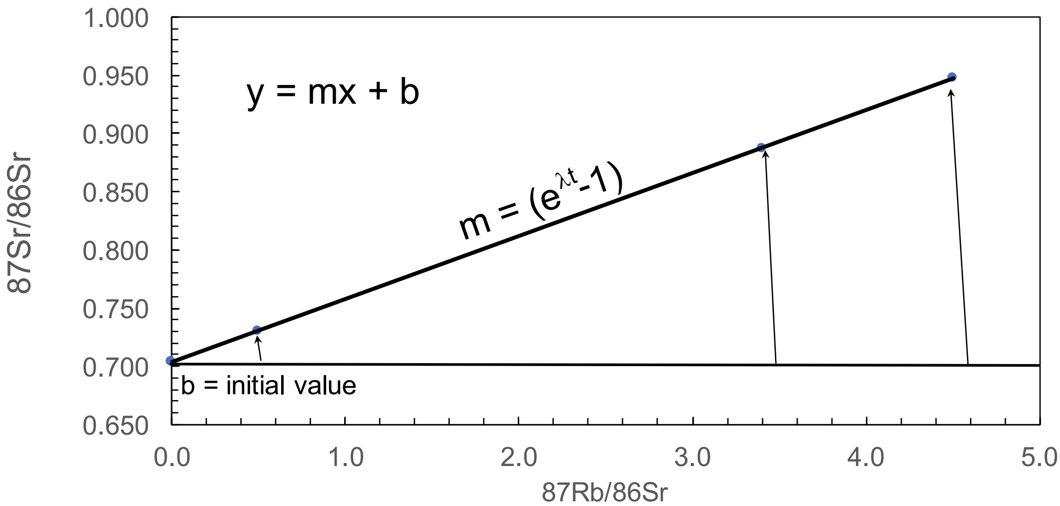

Figure 1: Rb-Sr isochron based on the measured ^{87}Rb/^{86}Sr and ^{87}Sr/^{86}Sr of minerals in a rock, where the slope (m) is equal to the crystallization age (m = (e$^{\lambda t}$ - 1)) and the intercept (b) is the initial (^{87}Sr/^{86}Sr)$_0$ of the rock.

$$\left(\frac{^{87}Sr}{^{86}Sr}\right) = \left(\frac{^{87}Sr}{^{86}Sr}\right)_0 + \left(\frac{^{87}Rb}{^{86}Sr}\right)(e^{\lambda t} - 1) \tag{1}$$

where λ is the decay constant (λ = ln(2)/$t_{(1/2)}$), t is age (years), and ( )$_0$ represents the initial ratio.

For a SLR, that is an extinct isotope system (e.g., ^{26}Al $\rightarrow ^{26}$Mg), we need to treat the decay system differently, because we no longer have any more of the parent isotope atoms to count, and consequently we cannot plot the usual values on the x-axis (abscissa). Also, the slope function (m) is now configured for decay of a short-lived system (i.e., where $\lambda \ll$ t).

$$\left(\frac{^{26}Mg}{^{24}Mg}\right) = \left(\frac{^{26}Mg}{^{24}Mg}\right)_0 + \left(\frac{^{26}Al}{^{24}Mg}\right)_0 (1 - e^{-\lambda t}) \tag{2}$$

Note for present day conditions when $t_{(1/2)} < 10^8$ years, $e^{-\lambda t}$ goes to 0 and thus, (1-$e^{-\lambda t}$) goes to 1 and the term can be dropped from equation (2).

We can overcome the problem of no more of the parent isotope atoms to count by introducing a stable isotope of the parent element and write an equivalence for the x-axis component.

$$\left(\frac{^{26}Al}{^{24}Mg}\right)_0 = \left(\frac{^{27}Al}{^{24}Mg}\right)_0 \left(\frac{^{26}Al}{^{27}Al}\right)_0 \tag{3}$$

Given both ^{27}Al and ^{24}Mg are stable isotopes, this ratio never changes through time and reflects the relative partitioning of these elements into the mineral during crystallization. Substituting this term into the radioactive decay equations then allows us to plot measured values on the x-axis and the slope (m) of the line (y = mx +b) becomes the initial ratios of the SLR to a stable isotope of the same element:

$$\left(\frac{^{26}Mg}{^{24}Mg}\right) = \left(\frac{^{26}Mg}{^{24}Mg}\right)_0 + \left(\frac{^{27}Al}{^{24}Mg}\right)_0 \left(\frac{^{26}Al}{^{27}Al}\right)_0 \tag{4}$$