

Notes 15

I. Age equations

II. The isochron method (Rb-Sr dating as an example)

Isochron equation

P = number of parent atoms (^{87}Rb , ^{147}Sm , ^{238}U , or ^{235}U)

D = number of daughter atoms (^{87}Sr , ^{143}Nd , ^{206}Pb , or ^{207}Pb)

P_0 = initial value

D_X = index nuclide (^{86}Sr , ^{144}Nd , ^{204}Pb , or ^{204}Pb)

$$P = P_0 e^{-\lambda t} \quad (^{14}\text{C})$$

$$P_0 = P e^{\lambda t}$$

$$D = D_0 + (P_0 - P) \quad (1: \text{closed system assumption})$$

$$D = D_0 + (P e^{\lambda t} - P)$$

$$D = D_0 + (P(e^{\lambda t} - 1)) \quad (D_0 \text{ can equal zero for K-Ar})$$

$$D/D_X = D_0/D_X + ((P/D_X)(e^{\lambda t} - 1)) \quad \text{- isochron equation (Rb-Sr, Sm-Nd, or U-Pb)}$$

Have one equation, two unknowns: t and D_0/D_X . If we have two materials with identical t and D_0/D_X , but different D/D_X and P/D_X , we can solve uniquely for t and D_0/D_X . (see figure). In this case we have made a second assumption (2: that the two materials formed at the same time with identical daughter isotopic compositions). Note that the above equation is the equation of a line, $y=mx+b$, where $y = D/D_X$, $m = e^{\lambda t} - 1$, $x = P/D_X$, and $b = D_0/D_X$.

Rb and Sr are both large ion lithophiles (LIL's).

Sr^{+2} has an ionic radius of 1.3 Å

Rb^{+1} has an ionic radius of 1.7 Å

so both clearly qualify as "large".

Rb - alkali metal, Group IA, valence +1, substitutes in K-bearing (1.6 Å) minerals (micas, K-feldspar), typical concentrations of several to 100's of ppm (minor or trace element).

Sr-alkaline earth, Group IIA, valence +2, substitutes in Ca-bearing (1.2 Å) minerals (plagioclase, calcite, aragonite), typical concentrations of several to hundreds of ppm (minor or trace element).

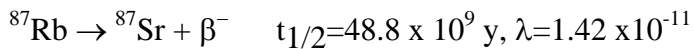
Rb (Z=37) isotopes

⁸⁵ Rb	72.17%	(stable and not radiogenic)
⁸⁷ Rb	27.83%	(radioactive)

Sr (Z=38) isotopes

⁸⁸ Sr	82.53%	(stable and not radiogenic)
⁸⁷ Sr	7.04%	(radiogenic)
⁸⁶ Sr	9.87%	(stable and not radiogenic)
⁸⁴ Sr	0.56%	(stable and not radiogenic)

$$^{87}\text{Sr}/^{86}\text{Sr} = 0.71025 \pm 0.000007 (2\sigma)$$



In the Rb-Sr system, $P=^{87}\text{Rb}$, $D=^{87}\text{Sr}$, and $D_x=^{86}\text{Sr}$, so that the isochron equation for Rb-Sr is:

$$^{87}\text{Sr}/^{86}\text{Sr} = ^{87}\text{Sr}_0/^{86}\text{Sr} + ((^{87}\text{Rb}/^{86}\text{Sr})(e^{\lambda t} - 1))$$

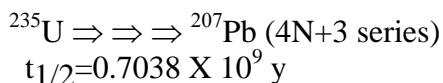
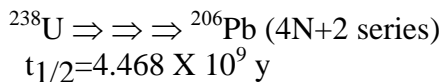
An evolution (or isochron) diagram illustrates the isochron equation graphically.

A linear array generated by minerals with different Rb/Sr ratios can be a “mineral isochron”; one generated by rocks with different Rb/Sr ratios can be a “whole rock isochron”.

There are two possible interpretations of linear arrays in evolution diagrams. They may be the result of mixing of two different components and have no time significance, or they may have time significance as outlined above.

U-Pb decay schemes

The isotopes in question are related by two different decay schemes.



These decay schemes have intermediate daughters whose half-lives are short compared to the half-life of the ultimate parent. All schemes involve a series α and β decays. As β decay does not change the mass number, the nuclides in a given decay series cannot differ in mass number by other than a multiple of 4 (from α decay). When one is considering timescales

that are long compared to the half-lives of the intermediate daughters the intermediate daughters can be ignored as the number of atoms of intermediate daughters at a given time is small.

A significant amount of energy is given off during the transformation from the ultimate parent to the ultimate daughter in each decay scheme. For example, in the transformation from U-238 to Pb-206, 8 α particles and 6 β particles are given off, yielding a total Q of 47.4 MeV. Thus, U is one of the three (Th and K being the others) greatest heat producing elements in the earth, despite its low concentrations.

Standard evolution (isochron) diagrams with the standard isochron equation can be used in both decay schemes.: $D = {}^{206}\text{Pb}$ or ${}^{207}\text{Pb}$, $D_x = {}^{204}\text{Pb}$ for both, $P = {}^{238}\text{U}$ or ${}^{235}\text{U}$.