GEOCHEMISTRY

“Radiogenic Isotope Dating System”

“K-Ar Scheme”

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INTRODUCTION

- Each age-dating scheme involves precise measurement of the concentration of an isotope.
- The decay scheme thus selected to obtain the ages which is less than a few half-lives of the radioactive decay.
- If the radioactive decay has advanced too far, the resolution of the method deteriorates.
- *Radioactive decay is a statistical process*. *(*For further detail refer to the radioactivity lecture.)*

RADIOGENIC ISOTOPES IN GEOCHEMISTRY

Geochronology

Used to determine the ages of the rock & minerals

Petrogenesis

Used to determine the geological processes

Decay constants and half-lives of some naturally occurring, radioactive isotopes commonly used in geochronology

Parent Isotope	Daughter Isotope	Decay Constant (10^{-10} yr^{-1})	Half-life (*Ga*)
^{40}K	^{40}Ar	5.543	1.28
^{87}Rb	^{87}Sr	0.1420	48.8
^{138}La	^{138}Ce	0.0267	259
^{147}Sm	^{143}Nd	0.0654	106
^{176}Lu	^{176}Hf	0.194	36
^{187}Re	^{187}Os	0.164	42.3
^{232}Th	^{208}Pb	0.4948	14.01
^{235}U	^{207}Pb	9.8485	0.704
^{238}U	^{206}Pb	1.5513	4.468

K-Ar system

- The parent isotope, potassium, is common in rocks and minerals, while the daughter isotope, argon, is an inert gas that does not combine with other elements.
- K–Ar method used for dating lavas as young as a few million years to the older one.
- It decays in two different ways:

$$^{40}K_{19} \longrightarrow {}^{40}Ca_{20} + \beta^{-}$$

$$^{40}K_{19} + e \longrightarrow {}^{40}Ar_{18}$$

* *Decay constant:* $\lambda = \lambda_{Ar} + \lambda_{Ca}$

* *β- particle decay is more common than electron capture.*

**K-Ar decay scheme is used for age calculation instead of K-Ca decay scheme*

The age of the rock is obtained from the equation:

$$\left({}^{40}Ar\right)_P = \left(\frac{\lambda_{Ar}}{\lambda_{Ar} + \lambda_{Ca}}\right)_I + \left({}^{40}K\right)_p \left(e^{\lambda t} - 1\right)$$

where,

$\left({}^{40}Ar\right)_P$ -- accumulated amount of the daughter product

$\left({}^{40}K\right)_p$ -- residual amount of the parent product

$\left(\frac{\lambda_{Ar}}{\lambda_{Ar} + \lambda_{Ca}}\right)_I$ -- fraction of initial Potassium to Argon.

λ – decay constant

t – age of the rock

K-Ar system

- The method works well on *young igneous rocks* that have not been heated since they formed.
- It cannot be used in *sedimentary rocks consisting of the detritus of older rocks.*
- Also, unsuccessful in *metamorphic rocks with complicated thermal histories.*
- Since potassium is usually added by alteration, the daughter-parent ratio and the age might be too low.
- Some uncertainties related to post-formational heating of a rock are overcome in a *modification of the* ***K–Ar*** *method that uses the* ^{40}**Ar/**^{39}**Ar** *isotopic ratio.*

K-Ar METHOD

- A potassium-bearing sample is split into two fractions:

  - one is analysed for its potassium content,

  - other is fused in a vacuum to release the argon gas.

- The ^{40}***Ar*** is determined by mixing with a known amount of another isotope ^{38}***Ar.***

- The amount of the ^{36}***Ar*** present is then determined relative to ^{38}***Ar*** to provide an estimate of the background atmospheric correction.

** It may be assumed that all of the radiogenic ^{40}**Ar** now present in a rock has formed and accumulated since the solidification of the rock.*

Ar-Ar METHOD

- Introduced by two Geochronologist *C. M. Merrihue and G. Turner.*
- Better known as ^{38}***Ar/*** ^{39}***Ar*** method.
- This method overcomes the *post formational heating alteration* and also the argon complexity by *conversion of the* ^{39}***K*** *in the rock to* ^{39}***Ar****.*
- The sample is heated progressively to drive out argon at successively higher temperatures.
- The ^{40}***Ar/*** ^{39}***Ar*** isotopic ratio of the argon released at each temperature is determined in a mass spectrometer.
- The age computed for each increment is plotted against the percentage of ***Ar*** released. This yields an ***age spectrum*****.**

Hypothetical age spectrum and $^{40}Ar/^{39}Ar$ isochron for a sample that has experienced no secondary heating (after Dalrymple, 1991).

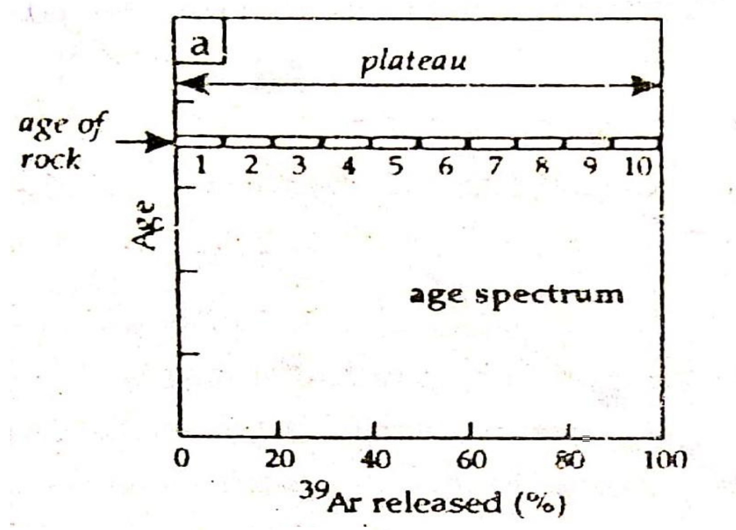

Fig a –

If the rock has not been heated since it was formed, the argon increments given out at each heating stage will yield the same age.

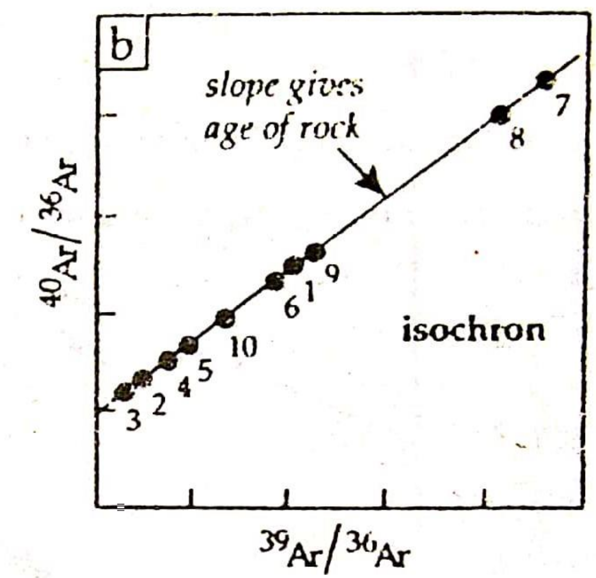

Fig b –

measuring the abundance of a non-radiogenic ^{36}Ar fraction and comparing the isotopic ratios $^{40}Ar/^{36}Ar$ and $^{39}Ar/^{36}Ar$.

In an unheated sample all points fall on the same straight line.

REFERENCES & FOR FURTHER STUDIES

- *Lowrie, W., (2007): Fundamentals of Geophysics, Cambridge University Press*
- *Mason, B. and Moore, C.B., (1991): Introduction to Geochemistry, Wiley Eastern.*
- *White, W. M., (2015): Geochemistry, John Wiley & Sons, Ltd.*