K/Ar DATING

PYHSICAL TECHNIQUES OF DATING

- RADIOMETRIC DATING
- C-14
- K/Ar
- DATING WITH COSMOGENIC RADIONUCLIDES
- URANIUM SERIES…
- RUBIDIUM STRONTIUM…
- TRAPPED CHARGED DATING(AGE DETERMINATION USING RADIATION DAMAGE)
- TL/OSL
- ESR
- FISSION TRACK METHOD…

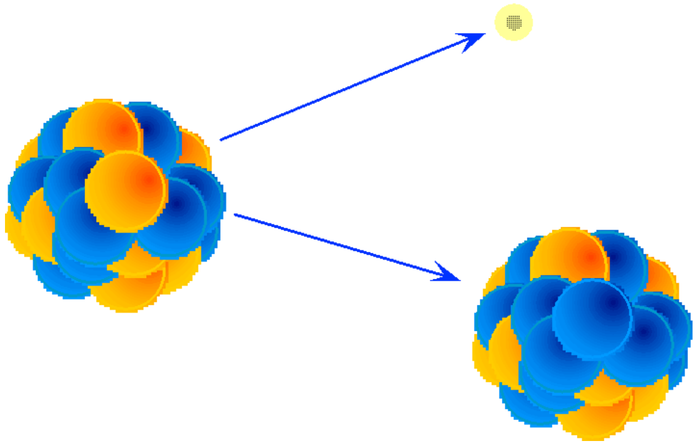
Radiometric Dating

uses continuous decay to measure time since rock formed

only possible since late 1890's -- radioactivity discovered in 1896

as minerals crystallize in magma;
They trap atoms of radioactive isotopes in their crystal structures

radioactive isotopes will decay immediately and continuously



as time passes, rock contains less parent and more daughter

most common radiometric dating systems

- uranium-thorium-lead dating

U-238, U-235, Th-232

each of these decays through a series of steps to Pb

U-238 to Pb-206 half-life = 4.5 by
U-235 to Pb-207 half-life = 713 my
Th-232 to Pb-208 half-life = 14.1 my

- potassium-argon dating

…argon is a gas--may escape

(ages too young--daughter missing)

K-40 to Ar-40 half-life = 1.3 by

- rubidium-strontium dating

Rb-87 to Sr-87 half-life = 47 by

- radiocarbon dating

$$^{14}N_7 + {}^{1}n_0 \rightarrow {}^{14}C_6 + {}^{1}H_1$$

$$^{14}C_6 \rightarrow {}^{14}N_7 + \beta^-$$


0
100
10,000
1,000,000
100,000,000
Years ago
10
1000
100,000
10,000,000
1,000,000,000
Isotope Techniques
Uranium to Lead (minerals)
1 million to 4.5 billion years
Rubidium to strontium (minerals)
60 million to 4.5 billion years
Potassium to argon (minerals)
10,000 to 3 billion years
Uranium series disequilibrium (minerals, shell, bone, teeth, coral)
0 to 400,000 years
Carbon 14 (minerals, shell, wood, bone, teeth, water)
0 to 40,000 years
Radiation Exposure Techniques
Fission track (minerals, natural glass)
500,000 to 1 billion years
Thermoluminescence (minerals, natural glass) and optically stimulated luminescence (minerals)
0 to 500,000 years
Electron spin resonance (minerals, tooth enamel, shell, coral)
1,000 to 1 million years
Other Techniques
Geomagnetic polarity timescale (minerals)
780,000 to 200 million years
Amino acid racemization (shells, other biocarbonates)
500 to 300,000 years
Obsidian hydration (natural glass)
500 to 200,000 years
Dendrochronology (tree rings)
0 to 12,000 years
Lichenometry (lichens)
100 to 9,000 years

K/Ar Dating method

The potassium-argon (K-Ar) isotopic dating method is especially useful for determining the age of lavas. Developed in the 1950s, it was important in developing plate tectonics and in calibrating the geologic time scale. **Potassium-argon dating,** method of determining the time of origin of rocks by measuring the ratio of radioactive argon to radioactive potassium in the rock. This dating method is based upon the decay of radioactive potassium-40 to radioactive argon-40 in minerals and rocks

Potassium is the eighth most abundant element in earth's crust and forms numerous minerals. It has three natural isotopes.

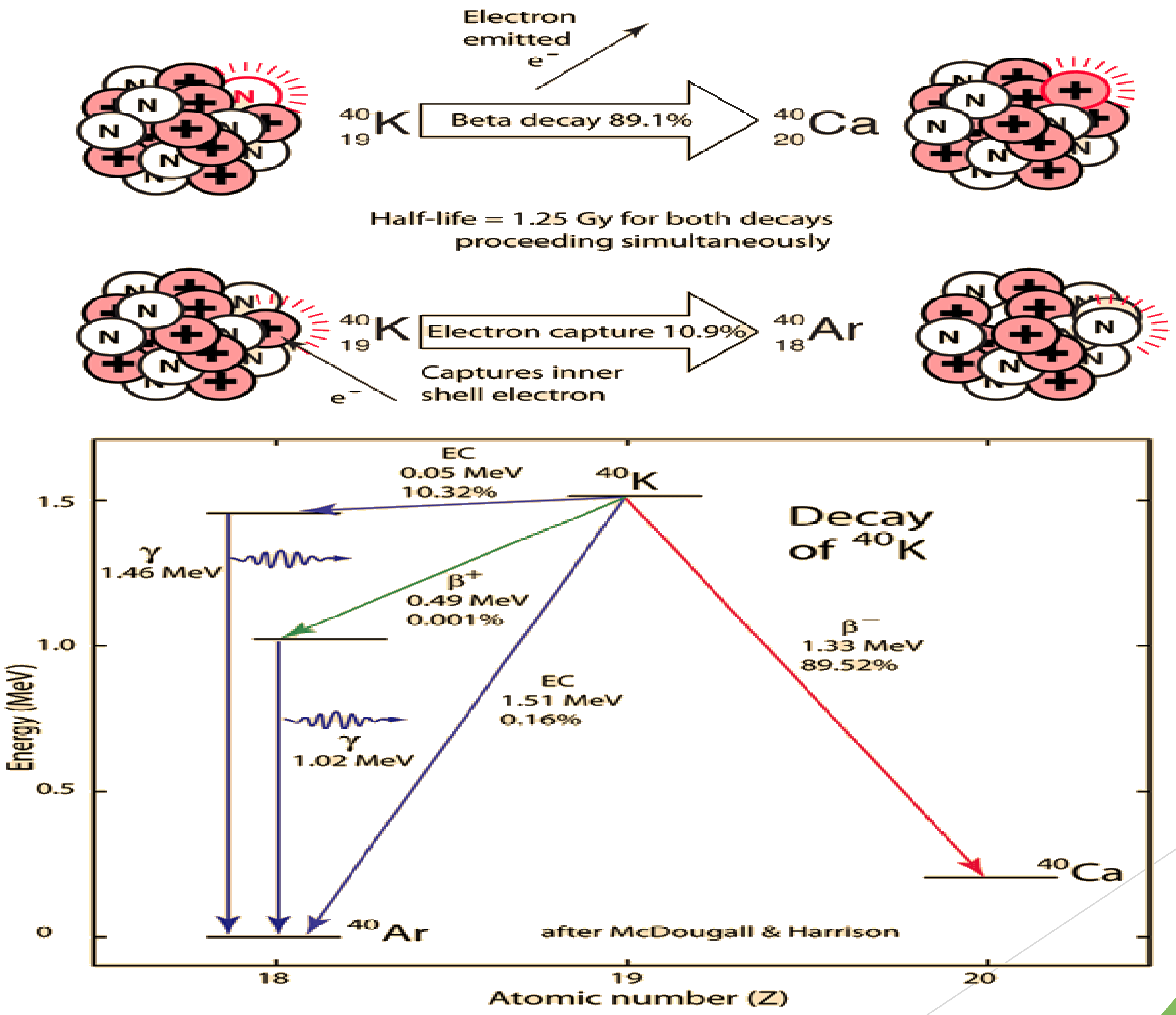
$^{39}_{19}K$ 93.2581%

$^{40}_{19}K$ 0.0117%

$^{41}_{19}K$ 6.7302%

K/Ar Dating method

The radioactive potassium-40 decays by two modes, by beta decay to ^{40}Ca and by electron capture to ^{40}Ar. There is also a tiny fraction of the decay to ^{40}Ar that occurs by positron emission. The calcium pathway is not often used for dating since there is such an abundance of calcium-40 in minerals and it is diffucult to determine the original values of calcium in the beginning, The calcium-potassium age method is seldom used, however, because of the great abundance of nonradiogenic calcium in minerals or rocks, which masks the presence of radiogenic calcium.
but there are some special cases where it is useful. The decay constant for the decay to ^{40}Ar is $5.81 \times 10^{-11} yr^{-1}$.



Electron
emitted
e⁻
40 19 K
Beta decay 89.1%
40 20 Ca
Half-life = 1.25 Gy for both decays
proceeding simultaneously
40 19 K
Electron capture 10.9%
40 18 Ar
Captures inner
shell electron
e⁻
EC
0.05 MeV
10.32%
40K
Decay
of 40K
γ
1.46 MeV
β+
0.49 MeV
0.001%
β⁻
1.33 MeV
89.52%
EC
1.51 MeV
0.16%
γ
1.02 MeV
40Ca
40Ar
after McDougall & Harrison
Energy (MeV)
1.5
1.0
0.5
0
18
19
20
Atomic number (Z)

K/Ar Dating method

After helium, argon is the second most abundant noble gas in the rocks and the minerals of the earth.

Potassium is always tightly locked up in minerals whereas argon is not part of any minerals. Argon makes up 1 percent of the atmosphere. So assuming that no air gets into a mineral grain when it first forms, it has zero argon content. That is, a fresh mineral grain has its K-Ar "clock" set at zero.

Potassium-Argon dating has the advantage that the argon is an inert gas that does not react chemically and would not be expected to be included in the solidification of a rock, so any found inside a rock is very likely the result of radioactive decay of potassium. Since the argon will escape if the rock is melted, the dates obtained are to the last molten time for the rock. Since potassium is a constituent of many common minerals and occurs with a tiny fraction of radioactive potassium-40, it finds wide application in the dating of mineral deposits. The feldspars are the most abundant minerals on the Earth, and potassium is a constituent of orthoclase, one common form of feldspar.

K/Ar Dating method

For a radioactive decay which produces a single final product, the decay time can be calculated from the amounts of the parent and daughter product by

$$t = -\lambda \ln\left[\frac{N}{N_0}\right] = -\frac{\ln 2}{T}\ln\left[\frac{N}{N_0}\right]$$

where N_0 and N are the initial and final numbers of the parent isotope, λ is the decay constant and T is the half-life. But the decay of potassium-40 has multiple pathways, and detailed information about each of these pathways is necessary if potassiun-argon decay is to be used as a clock. This information is typically expressed in terms of the decay constants.

^{40}K Decay Constants

The measured amount of radiogenic $^{40}Ar^*$ in terms of the current measured amount of ^{40}K can be expressed as

Pathway	Decay constant ($10^{-10}yr^{-1}$)
λ_β , decay to ^{40}Ca	4.962
λ_{EC} , decay to ^{40}Ar	0.581
$\lambda_{total} = \lambda_\beta + \lambda_{EC}$	5.543

$$^{40}Ar^* = \frac{\lambda_{EC}}{\lambda_{total}}\, {}^{40}K(e^{\lambda_{total}t} - 1)$$

This can be solved for the time t

$$t = \frac{1}{\lambda_{total}} \ln\left[\frac{\lambda_{total}}{\lambda_{EC}} \frac{^{40}Ar^*}{^{40}K} + 1 \right]$$

When the values for the decay constants in the table above are used, the expression for the radiometric age becomes

$$t = 1.804x10^9 \ln\left[9.540 \frac{^{40}Ar^*}{^{40}K} + 1 \right]$$

Here, it is useful to make use of the series representation of ln(x+1), which may be approximated by x if x<< 1:

$$\ln(1+x) = x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \frac{1}{4}x^4 \ldots$$

Since the population of $^{40}Ar^*$ is usually quite small, the approximation of ln(x+1)≈x gives

$$t \approx 1.72x10^{10} \frac{^{40}Ar^*}{^{40}K}$$

1. When the radiometric clock was started, there was a negligible amount of ^{40}Ar in the sample.
2. The rock or mineral has been a closed system since the starting time.
3. The closure of the system was rapid compared to the age being determined.

*** ^{40}K is quantified with flame photometry or atomic absorption spectroscopy.**

*** ^{40}Ar is quantified with mass spectrometry.**

*** ^{40}Ar / ^{40}K ratio is shown the age.**

K/Ar Dating method

Advantages

-Accurate dating method
-Useful for dating very old materials. It can date up to a few billion years old

Disadvantages:

-Limited to dating volcanic rock (eg. The rock and not the artefact)
-Human interaction can interfere with dating
-Cannot date recent objects earlier than a 100000 years.
-Mainly based on assumptions
-Long process (1-2 weeks per sample)
-Costly (Few hundred dollars per sample)

References:

1.Absolute Age Determination / Mebus A.Geyh- Helmut Schleicher

2. http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/KAr.html

3. Radiometric Dating / Dr.Roger C. Wiens (2002)

4.Science Based Dating in Archeology / Martin Jim Aitken (1990)

THANKS