Radiokrypton Dating Using Atom Trap Trace Analysis

Kirby Hermansen
Graduate Student

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Presentation Outline

- Overview of Radiometric Dating
- Choice of Krypton
- Atom Trap Trace Analysis (ATTA)
  - Advantages
  - Methodology
- Applications
Radiometric Dating

- Closed system (isotopic abundances unchanging)
- Known initial abundance ratios
- Determine final abundance ratios
- Calculate age via decay equations

\[ N = N_0 e^{-\lambda t} \]
Suitability of Krypton Isotopes

- $^{14}$C half life $\approx 6000$ yrs

- $^{81}$Kr
  - Half life $\approx 2.3e5$ yrs
  - Created similarly to $^{14}$C
  - Roughly constant over time
    - $^{81}$Kr/Kr $\approx 10^{-13}$

- $^{85}$Kr
  - Half life $\approx 11$ yrs
  - Created via reprocessing of nuclear fission fuels
  - Abundance has increased dramatically since $\approx 1950$
    - $^{85}$Kr/Kr $\approx 10^{-11}$

https://www.phy.anl.gov/mep/atta/research/atta.html
Methods for Radiometric Dating

- **Low-Level Counting (LLC)**
  - Count individual number of decays
    » Effective for short-lived $^{85}$Kr
    » Not for long-lived $^{81}$Kr

- **Accelerator Mass Spectrometry (AMS)**
  - Inject a sample into an accelerator
  - Select q/m and E for desired isotope
    » Good efficiency
    » Requires an accelerator, and a fairly large sample

- **Atom Trap Trace Analysis (ATTA)**
  - Trap and count individual atoms
    » Good efficiency
    » Tabletop apparatus
    » Needs a sample ~ 1/10 as large as AMS (50 μl Kr gas vs 500 μl)
    » Roughly 100 kg of water or 50 kg of ice is required
ATTA Apparatus

- Inject the Kr gas into the apparatus
- Slow the beam using Zeeman slower to < 10 m/s
  - Combination magnetic field and laser set at the resonance frequency
- Trap atoms in the magneto-optical trap (MOT)
- Individual atoms capture and emit photons at the resonance frequency

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Applications

$^{81}$Kr

- Climate analysis
  - Polar ice

- Aquifer studies
  - $^4$He degassing

- Geothermal activity
  - Yellowstone

$^{85}$Kr

- Dating young groundwater
- Tracer for ocean currents
Final Thoughts

- Radiometric dating is a really interesting field with many applications
- ATTA is an excellent machine for such work

- Thanks to Prof. Nazarewicz, and Tong Li
- Questions?
References

- http://www.phy.anl.gov/mep/atta/research/atta_applications.html
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- https://www.nature-com.proxy1.cl.msu.edu/articles/ngeo2302