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Atom trap trace analysis of Ca-41 samples at 1E-15 abundance level

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Calcium is an abundant element in the Earth's crust and minerals. It also exists extensively in organisms, especially in bones, teeth and shells. Research on the long-lived radioactive Ca-41 ($t_{1/2}$=9.94×10^5 yr, ^{41}Ca/Ca=2×10^{-15} ~ 3×10^{-14}) contributes to investgating kinetic processes in geoscience and biomedical science. Besides, G. M. Raisbeck and F. Yiou have proposed the possibility of using Ca-41 for radioactive dating in 1979 [1]. Ca-41 is a candidate for dating samples ranging from 5×10^4 to 1×10^6 years of age, expected to cover the gap between the dating ranges of C-14 and Cl-36.

Accelerator Mass Spectrometry (AMS) is the most common and sensitive method to analyze Ca-41 samples at present. A ^{41}Ca/Ca=(1.9±0.5) ×10^{-15} value has been measured by Wallner *et al* in 2004 [2]. For samples with Ca-41 abundance below 1×10^{-13}, the usage of CaH_2 (to generate molecule ion CaH_3^-) is necessary, which must be under careful treatment during production and storage, and the terminal voltage of Accelerator must be raised over 3MV, to eliminate the interference of K-41 – the isobar and decay product of Ca-41. Consequently, only several AMS systems can reach this sensitivity.

Atom trap trace analysis (ATTA) is an atomic optics technique for rare isotopes trace measurement [3]. It has been successfully applied on radioactive Kr-81, Kr-85 and Ar-39 dating. With our Ca-ATTA apparatus, it takes 10 hours to analyze a ^{41}Ca/Ca=1×10^{-15} sample with statistical uncertainty of 10%, consuming 160mg Ca. The metallic calcium samples are prepared by reducing CaO with aluminum from $CaCO_3$, produced from Ca^{2+} solutions through CaC_2O_4, with yield of 55%.

In an ATTA apparatus, atoms of interest can be selectively cooled and trap by laser resonant to their characteristic electron transitions in magnetic fields. This operation isolates all other elements or isotopes by laser frequency tuning. The atoms in the trap are detected by measuring fluorescence with sensitivity of single atom counting.

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[2]Wallner, A. , et al (2004). *Nuclear Inst & Methods in Physics Research B* 223, 759-764.

[3]Chen, Y. ,el al. *Science* 286(5442), 1139–1141.