Ultra-heavy elements in solar energetic particles above 10 MeV/nucleon

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Measurements below several MeV/nucleon show that abundances of elements heavier than Ni (Z=28) can be enhanced relative to oxygen by factors of $\sim$100 to 1000 (depending on species) in impulsive solar energetic particle (SEP) events. At higher energies, even large gradual events are often iron-rich and may contain admixtures of flare seed material. The Solar Isotope Spectrometer (SIS) on NASA's ACE spacecraft measures the composition of energetic nuclei for elements up to $\sim$Zr (Z=40) at energies from $\sim$10 to $>$100 MeV/nucleon, and has recorded $\sim$1000 nuclei heavier than Ni, including measurable quantities of Zn, Ge and Se (Z=30, 32, and 34). We present SIS observations of ultra-heavy SEPs that can be used to test models of acceleration and abundance enhancements in both gradual and impulsive events. We find that the long-term average composition for elements from Z=30 to 40 is similar to standard solar system values, but there is considerable event-to-event variability. For example, at energies $>$10 MeV/nucleon, the event of 23 July 2004 had a ($34<Z<40$)/O enhancement of $\sim$250-300 times the standard solar value.

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