Galactic Cosmic Ray Isotopic Composition from the ACE Cosmic Ray Isotope Spectrometer (CRIS)

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Data from the CRIS instrument have been used to derive the isotopic composition of all elements from Li ($Z = 3$) through Zn ($Z = 30$) during a solar minimum period extending from December 1997 through September 1999. Results are available in the following forms:

- the file "isotope_table.pdf" is a one-page formatted listing of the isotopic abundances, as percentages of the element,
- the file "isotope_table.txt" contains the same data as computer-readable ascii text.

In addition, the file "mass_histograms.pdf" contains a collection of plots showing the mass histograms used for deriving the isotopic composition.

The CRIS instrument, which consists of a scintillating optical fiber trajectory (SOFT) hodoscope for measuring particle trajectories followed by stacks of silicon solid state detectors for measuring particle energy losses, identifies particle charge and mass using the dE/dx versus total energy technique. It has been described in detail by Stone et al. (1998).

The present analysis employed only particles stopping in ranges 3 through 8 of the instrument. In these ranges two or more measurements of particle charge and mass are available and were required to be consistent. In addition, for most nuclides the data set was restricted to particles having angles of incidence within $< 25°$ of the normal to the surface of the silicon detectors since the best mass resolution is obtained for small incidence angles. However, in a few cases where very rare isotopes are separated from adjacent isotopes by two mass units so that the best mass resolution is not required, particles with incidence angles $< 65°$ (nearly the full angular acceptance of the instrument) were included to improve statistical accuracy. These wide-angle data were used only for deriving the abundances of ^{46}Ca, ^{48}Ca, ^{64}Ni, and the isotopes of Cu and Zn. The mass histograms (mass_histograms.pdf) combine data from the ranges 3 through 8 using the narrow-angle data set for Li through Ni and the wide-angle data set for Cu and Zn.

In order to obtain the tabulated isotopic composition, data from each range were analyzed separately. Corrections to the isotope fractions derived from the mass histograms were made to account for: 1) the overlap between adjacent isotope peaks, 2) energy differences between different isotopes of an element having the same range, 3) differences in probabilities for nuclear interaction losses in the instrument, and 4) different detection efficiencies in the SOFT hodoscope (significant only for elements with $Z \leq 6$). All of these corrections are relatively small and in no case are the combined corrections greater than 15% when comparing abundances of isotopes of a single element. For isotopes analyzed using the narrow-angle data set, the tabulated values were obtained by taking weighted averages of the 6 values corresponding to ranges 3 through 8. Conservative uncertainties were obtained from the rms deviation of the 6 values from that mean and are thus larger than the statistical errors associated with the number of events in the combined data set.

In the case of the isotope ^{59}Ni, for which no peak is detected above the spill-over from the adjacent isotopes, only an upper limit has been quoted. For the statistics-limited isotope ratios obtained from the wide-angle data set, the tabulated values were derived using data summed over ranges 3 through 8. Statistical uncertainties, which should dominate for these nuclides, are reported.

Isotopic compositions have been reported for a number of elements in publications from the ACE/CRIS team. Publications containing the most-current results for various elements are listed in Table 1, below. Values in the isotopic composition table agree within the quoted uncertainties with those values. However the agreement is not exact because of a variety of factors including differences in the time intervals and data selection criteria used. The published values should be regarded as the more-definitive results.

In addition to comparing with previously-published abundance determinations from ACE/CRIS, we have compared the values from the tables with published measurements from instruments on a variety of spacecraft including Ulysses, CRRES, ISEE-3, Voyager, and IMP-7&8. In most cases the results were consistent to within measurement uncertainties. The data were obtained at a variety of different energies (all within the range 30 to 500 MeV/nuc, however) and solar modulation levels. However in most cases these differences are not expected to have a major influence on isotopic composition. One exception is the case of heavy, electron-capture nuclides (Niebur et al. 2003) where electron attachment and decay introduces an energy dependence which is further modified by solar modulation. The values tabulated for these nuclides are averages over the CRIS energy interval (as for other nuclides) and real energy variations over this interval are reflected in the quoted uncertainties.

Absolute intensities of the various isotopes of elements from B through Ni can be obtained by combining the isotope fractions in the table with elemental fluxes available as level 2 data from the ACE Science Center web site (http://www.srl.caltech.edu/ACE/ASC/level2/index.html). Those data are reported for 7 energy intervals corresponding to CRIS ranges 2 through 8. The latter 6 of these 7 correspond to the ranges used to derived the isotope fractions. To obtain element intensities from the same time period as used for the isotope analysis, data from Bartels rotations 2244 through 2268 should be averaged.

Table 1.

Published ACE/CRIS Isotopic Composition Measurements

Element(s)	Reference(s)
Li, Be, B	de Nolfo et al. 2001, 2003
Be, Al, Cl, Mn	Yanasak et al. 2001
O, Ne	Binns et al. 2005
Mg, Al, Si	Wiedenbeck et al. 2003
Ca	Wiedenbeck et al. 2001b
V, Ti, Cr	Niebur et al. 2003
Fe, Co, Ni	Wiedenbeck et al. 2001a
Co, Ni	Wiedenbeck et al. 1999

References

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de Nolfo, G.A. et al. 2003, "New Measurements of the Li, Be, and B Isotopes as a Test of Cosmic Ray Transport Models", 4, 1777.

Niebur, S.M. et al. 2003, "Cosmic Ray Energy Loss in the Heliosphere: Direct Evidence from Electron-Capture-Secondary Isotopes", JGR 108(A10), 8033, doi:10.1029/2003JA009876.

Stone, E.C. et al. 1998, "The Cosmic-Ray Isotope Spectrometer for the Advanced Composition Explorer", Space Sci. Rev. 86, 285.

Wiedenbeck, M.E. et al. 1999, "Constraints on the Time Delay Between Nucleosynthesis and Cosmic-Ray Acceleration from Observations of ^{59}Ni and ^{59}Co", ApJL 523, L61.

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