THE CHARGE AND ISOTOPIC COMPOSITION OF $Z \geq 10$ NUCLEI IN THE COSMIC RAY SOURCE

W. R. Webber
Space Science Center
University of New Hampshire
Durham, N. H. 03824

Interstellar fragmentation provides the greatest contribution to the abundance of cosmic ray nuclei with $Z = 17\text{-}25$ observed at earth. The usual procedure to estimate the source abundance of these nuclei is to correct for this interstellar fragmentation using a propagation model and a set of fragmentation parameters for Fe nuclei and its products. Only a fraction of these fragmentation parameters have actually been measured and the accuracy of these as well as the semi empirical parameters used for the unmeasured cross sections is no better than $\pm$ 10-15%. As a result the actual source abundances of these nuclei can only be deduced to an accuracy of $\pm$ 2-3% of the Fe abundance.

Recently during a calibration run of our cosmic ray isotope telescope at the BEVALAC in which a $9.3\,g/cm^2$ CH_2 target was used to fragment $\sim$ 1 GeV/nuc Fe nuclei, both the isotopic and charge composition of the fragments were measured. It was noticed that the charge composition of the fragments was similar to that observed for cosmic rays at earth-not unexpected since the thickness of the target was equivalent to a slab length $\sim 2.5\,g/cm^2$ of H. In effect the target provided us with an intergrated measurement of the effects of interstellar propagation. Several relatively small and well known corrections can be made to this data to compare it directly with the observed cosmic ray composition. This comparison is shown in Table I. It is found that only 3 charges, S, A and Ca have finite source abundances and the source abundance accuracy is $\sim \pm$ 0.5% of Fe for charges with $Z = 17\text{-}25$.

TABLE I

Comparison of Fe fragmentation at the BEVALAC with Cosmic Rays in Interstellar Space

	BEVALAC - 9.3 g/cm^2 of CH_2, $\bar{E}$ = 850 MeV/nuc			Cosmic Rays Balloon 600 - 1000 MeV/nuc⁺		Source % of Fe
Charge	Measured*	Corrected for Rad Decay⁰	Normalized & Adjusted^{X}			
25	14.1	11.6	13.4 $\pm$ 0.6		13.1$\pm$0.4	-0.3$\pm$0.7
24	12.4	15.3	17.6 $\pm$ 0.7		17.7$\pm$0.5	+0.1$\pm$0.8
23	9.9	9.8	11.3 $\pm$ 0.5		10.4$\pm$0.4	-0.8$\pm$0.6
22	11.1	13.7	16.3 $\pm$ 0.7		17.2$\pm$0.5	+0.8$\pm$0.8
21	10.5	5.5	6.8 $\pm$ 0.4		7.5$\pm$0.3	+0.6$\pm$0.3
20	10.3	13.0	15.9 $\pm$ 0.7	Ca + Ar	25.6$\pm$0.6	+8.3$\pm$0.8
19	6.6	6.7	8.9 $\pm$ 0.5	+1.8	11.3$\pm$0.4	+0.5$\pm$0.6
18	6.0	6.7	9.0 $\pm$ 0.5	+1.0	16.6$\pm$0.6	+4.6$\pm$0.6
17	4.9	3.1	4.8 $\pm$ 0.4	+3.2	9.0$\pm$0.4	+0.8$\pm$0.5
16	5.1	7.0	10.2 $\pm$ 0.7	+3.5	33.0$\pm$1.5	+15.1$\pm$0.8
15	3.6	2.1	3.0 $\pm$ 0.3		7.5$\pm$1.5	

*Total Fe nuclei = 100. Data is extrapolated to the top of the telescope.
⁰Using measured individual isotopic cross sections.
ˣThe BEVALAC secondary production in 9.3 g/cm^2 of CH_2 is normalized to the cosmic ray production in interstellar matter. Normalization factor = 1.166. An adjustment is also made to convert the slab length production at the BEVALAC to the equivalent exponential path length distribution in interstellar space. This factor ranges from 0.99 for Mn to 1.24 for S.
⁺These values represent an average of values from Israel et al (1979), Young (1979) and Lezniak and Webber (1978) in the energy range 600-1000 MeV/nuc.

These deductions regarding

G. Setti, G. Spada, and A. W. Wolfendale (eds.), Origin of Cosmic Rays, 31–32.

the source composition may be compared with the isotopic composition data for cosmic rays that we have measured on balloon flights with this same telescope. Earlier, preliminary isotope data from our 1977 balloon flight was presented (Webber, et.al., 1979 a,b). In this paper we present combined data from the 1976 and 1977 flights. BEVELAC calibration data on the mass distribution peak shapes is used in this latest analysis. The overall mass resolution σ for the balloon data is virtually identical to that obtained at the BEVALAC calibration and slowly increases from a $\sigma \sim 0.28$ AMU at C to ~ 0.38 AMU at Fe. Data on the isotopic composition of all nuclei with Z = 6-26 is available but we will examine only S,A, Ca and Fe here as well as Ne and Mg. The balloon data is shown in Table II. Comparison of these isotopic abundances with those predicted on the basis of conventional propagation models leads to the following source abundances; $^{32}S \simeq S = 13.7 \pm 2.0\%$; $^{36}A \simeq A = 3.2 \pm 1.0\%$; $^{40}Ca \simeq Ca = 8.5 \pm 1.6\%$ of Fe. For Fe we find $^{56}Fe = 91.7\%$; $^{54}Fe = 4.1 \pm 3.8\%$, and $^{58}Fe \lesssim 4.2\%$ of all Fe. The source abundances obtained in this manner are in good agreement with those obtained from the charge comparison. These source abundances are also consistent with average solar cosmic ray abundances (eg S = 16.8%, A = 3.2% and Ca = 8.4% of Fe according to Cook et.al., 1979).

TABLE II

ISOTOPIC ABUNDANCES (SELECTED ELEMENTS 1976 + 1977 DATA)

Isotope	Energy Interval (MeV/nuc)	Events	Events at Top of Atm	Events (MeV/nuc)	% of Element
^{20}Ne	436 - 589	358	1287	8.41	61.9
^{21}Ne		50 ± 15	169	1.19	8.7 ± 3.3
^{22}Ne	410 - 552	140	526	3.98	29.3 ± 2.7
^{24}Mg	484 - 664	564	1981	11.10	72.2
^{25}Mg		81 ± 20	278	1.85	12.0 ± 3.6
^{26}Mg	458 - 628	116	412	2.42	15.8 ± 1.6
^{36}A	536 - 730	26	87	0.45	45.9 ± 13.5
^{38}A	517 - 701	23	76	0.42	42.9 ± 13.3
^{40}A		5 ± 3	18	0.11	11.2 ± 7.5
^{40}Ca	568 - 788	46	162	0.73	45.3 ± 6.6
^{42}Ca	550 - 762	29	102	0.48	29.8 ± 5.9
43		≤ 8	≤ 25	≤ 0.12	≤ 7.5
^{44}Ca		15	53	0.28	17.1 ± 5.7
^{54}Fe	662 - 921	25 ± 12	95	0.37	6.5 ± 3.8
^{56}Fe	646 - 899	275	1281	5.06	89.2
^{58}Fe	630 - 876	≤ 12	≤ 59	≤ 0.24	≤ 4.2

Using these same procedures we find the source abundance of ^{22}Ne to be $22.2 \pm 2.7\%$ of all Ne, or 4 σ higher than the measured solar cosmic ray ^{22}Ne abundance of 11.6% (Mewaldt et.al., 1979). The ^{21}Ne abundance we measure is consistent with a complete fragmentation origin. For ^{25}Mg and ^{26}Mg the source abundances are determined to be $7.5 \pm 3.9\%$ and $14.6 \pm 1.9\%$ of all Mg, respectively. The solar values for these isotopes are 10.1% and 11.2% of all Mg. A possible enhancement of ^{26}Mg of 2σ relative to the solar value, and in conjunction with the ^{22}Ne enhancement is evident.

References

Cook, W.R., Stone, E.C. and Vogt, R.E., Ap. J. (in press).

Israel, M.H., Klarmann, J., Love, P.L., and Tueller, J., 1979, Proc. 16th Int. Cosmic Ray Conf., Kyoto, 1, 323.

Lezniak, J.A., and Webber, W.R., 1978, Ap. J., 223, 676.

Menwaldt, R.A., Stone, E.C., Vogt, R.E., 1979, Ap., J., 231, L97

Webber, W.R., Kish, J., and Simpson, G., 1979a, Proc. 16th Int. Cosmic Ray Conf., Kyoto, 1, 424.

Webber, W.R., Kish, J., and Simpson, G., 1979b, Proc. 16th Int. Cosmic Ray Conf., Kyoto, 1, 430.

Young, J.S., 1979, PhD Thesis, University of Minnesota.