A MEASUREMENT OF THE COSMIC RAY ELEMENTS C TO Fe IN THE TWO ENERGY INTERVALS 0.5-2.0 GeV/n AND 20-60 GeV/n

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Introduction. The study of the cosmic ray abundances beyond 20 GeV/n provides additional information on the propagation and containment of the cosmic rays in the galaxy. Since the average amount of interstellar material traversed by cosmic rays decreases as its energy increases, the source composition undergoes less distortion in this higher energy region. However, data over a wide energy range is necessary to study propagation parameters. We present some measurements of some of the primary cosmic ray abundance ratios at both low (near 2 GeV/n) and high (above 20 GeV/n) energy and compare them to the predictions of the leaky box model. In particular, the integrated values (above 23.7 GeV/n) for the more abundant cosmic ray elements in the interval C through Fe and the differential flux for carbon, oxygen, and the Ne,Mg,Si group will be presented. Limited statistics have prevented the inclusion of the odd Z elements.

Instrument and the Exposure. The instrument has been previously described [1] and will be briefly reviewed here with the exposure parameters. The apparatus consists of a freon -12 gas Cerenkov detector (index of refraction = 1.001) for differential energy measurements between 20 and 60 GeV/n. Two banks of six 5-inch photomultiplier tubes viewed the freon gas which was contained in a thin fiberglass tank lined with millipore paper. The pulse height information from each set of tubes allowed correction for those cosmic ray events where a particle passage or delta rays obviously affected one bank of tubes. Two solid Cerenkov radiators (teflon and lucite) were included for charge identification. The teflon (effective index = 1.36) and pilot 425 (effective index = 1.52) radiators were placed in individual white boxes coated with $BaSO_4$ paint and each was observed by eight 5-inch photomultiplier tubes.

To further aid in event selection, two dual gap ion chambers filled with Xenon and a plastic scintillator (NE 102) were included. The scintillator was also housed in a light collecting box viewed by four tubes. An eight plane multi-wire hodoscope was used to determine the particle trajectory through the instrument. The track information was used in correcting the pulse height information for path length variations and for nonuniform response in the detectors, and it was an effective tool in removing background events such as showers, fragmentation events, and events outside the defined geometry of the experiment. For the detector arrangement, refer to Figure 2 in reference [1]. This instrument was flown from Pierre, South Dakota in September of 1978 at an average depth in the atmosphere of 3.6 g/cm^2. The collection factor for the flight was 2.8 M^2 ster.hrs.

Corrections to the Data. The track fitting routines screened the majority of atmospheric showers, some interacting events, and events that missed one or more of the detectors. The detector signals were corrected for the path length difference and the nonuniformity in detector response. Pulse height consistency criteria were then applied to eliminate remaining background events, mainly those interacting in the instrument. The energy calibration of the freon-12 Cerenkov counter was accomplished by isolating the elements and finding saturation values ($\beta = 1$). For oxygen, close to 150 photoelectrons were collected. Eight percent of this saturation signal was a scintillation component due to various effects including energetic delta rays. With this information, the energy measurement was unfolded following the method found in the appendix of reference [2]. The charge of the events above 20 GeV/n was determined by summing the saturated signals of the lucite and teflon Cerenkov detectors. The charge resolution (σ) obtained for events with kinetic energy >25 GeV/n was slightly better than 0.25. The separation into charge groups was done as suggested in both references [2] and [3]. The even integer charge is defined as $Z_{even} \pm 0.625$, and the odd integer charge is $Z_{odd} \pm 0.375$. The charge deconvolution or overlap corrections for C, N, and O are respectively 0.98, 1.09, 0.99 for energies greater than 25 GeV/n.

Finally nuclear fragmentation corrections for both the instrument and overlying atmosphere were performed according to the method outlined in reference [4] with the fragmentation cross-sections taken from reference [5]. The cross-sections were evaluated in the asymtotic region (E = 2 GeV/n) and applied to the 25 to 60 GeV/n energy interval with the assumption that the scaling correction is minor.

Results and Conclusions The results of the 1978 flight are listed in Tables I and II. The errors quoted are based on counting statistics only.

Table I

($E_K > 23.7$ GeV Per nucleon)

	Integrated Flux in particles/(M^2·Ster·Secs)	Ratios*
C	$(5.2 \pm 0.3) \times 10^{-2}$	0.98 ± 0.08
N	$(1.2 \pm 0.1) \times 10^{-2}$	0.23 ± 0.02
O	$(5.3 \pm 0.3) \times 10^{-2}$	1.00 ± 0.08
Ne	$(1.1 \pm 0.1) \times 10^{-2}$	0.21 ± 0.02
Mg	$(1.2 \pm 0.1) \times 10^{-2}$	0.23 ± 0.02
Si	$(8.8 \pm 1.3) \times 10^{-3}$	0.17 ± 0.03
MnFeCo	$(5.9 \pm 1.1) \times 10^{-3}$	0.11 ± 0.02

* Normalized to Oxygen

Table II

Differential Flux

in particles/(M^2·Ster·Secs·GeV per nucleon)

$(N \pm \Delta N)^{-m} \equiv (N \pm \Delta N) \times 10^{-m}$

Kinetic Energy (GeV/n)	Carbon	Oxygen	NeMgSi
25.8	$(3.6 \pm 0.3)^{-3}$	$(3.6 \pm 0.4)^{-3}$	$(2.3 \pm 0.3)^{-3}$
30.0	$(2.7 \pm 0.3)^{-3}$	$(2.3 \pm 0.3)^{-3}$	$(1.4 \pm 0.2)^{-3}$
33.9	$(1.6 \pm 0.2)^{-3}$	$(1.7 \pm 0.3)^{-3}$	$(8.3 \pm 1.9)^{-4}$
39.8	$(7.2 \pm 1.1)^{-4}$	$(9.3 \pm 1.3)^{-4}$	$(4.4 \pm 1.0)^{-4}$
50.6	$(1.9 \pm 0.4)^{-4}$	$(2.3 \pm 0.5)^{-4}$	$(1.6 \pm 0.5)^{-4}$
61.8	$(4.6 \pm 0.8)^{-4}$	$(3.7 \pm 0.8)^{-4}$	$(2.5 \pm 0.7)^{-4}$

The data is in general agreement with previous balloon results. A comparison of the ratios in Table I with the French-Danish experiment on HEAO-3 [6] is within one to two sigma of their values at 25 GeV/n except for the ratio Ne/O.

In Table III, we have selected some key primary to primary cosmic-ray abundance ratios at two widely separated energies. The lower energy values were taken from a 1976 balloon flight experiment that is fully described in reference [7].

Table III

	'76' Experiment $E_k = 1.2$ GeV per nucleon	This Experiment $E_k > 23.7$ GeV per nucleon
O/C	0.91 ± 0.02*	1.02 ± 0.08
Fe/O	0.086 ± 0.006	0.111 ± 0.022
Si/Fe	2.08 ± 0.16	1.49 ± 0.35

* Statistical error only

These ratios seem consistent with the phenomenological leaky box model for cosmic-ray propagation described in reference [8]. Specifically we compared our O/C data to the theoretical prediction plotted on figure 15 of reference [8]. Taking note of the uncertainty in our data, we find good agreement with this propagation model that uses the source abundances of Shapiro, Silberberg, and Tsao [9].

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