ABUNDANCE OF COSMIC-RAY ELEMENTS FROM SULFUR TO NICKEL AS A FUNCTION OF ATMOSPHERIC DEPTH

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(Received 7 September, 1982; in revised form 28 February, 1983)

Abstract. The measured elemental composition of cosmic rays with charge 16 \( \leq Z \leq 28 \) as a function of atmospheric depth was compared with a propagation calculation including energy loss. The resulting composition at the top of the atmosphere has better precision than previously possible on balloon borne experiments, and agrees well with the only satellite data available in this charge range. The extrapolation method also provides checks on assumed cross-sections for interactions of cosmic rays in air.

1. Introduction

The measured elemental composition of the cosmic radiation at Earth is the basis for estimates of the cosmic-ray source composition. In addition, the near-Earth measurement of abundances of elements rare at the source can be used to constrain models of the cosmic-ray confinement in the Galaxy.

We present here new measurements of the relative abundance of elements in the charge (\(Z\)) interval 16 \( \leq Z \leq 28 \) and the energy interval 330 to 1200 MeV amu\(^{-1}\), measured with single element charge resolution on a high-altitude balloon using the Washington University detector system described in Paper I (Crane et al., 1983). Because of an unusual flight altitude profile we have data of high statistical accuracy over a wide range of atmospheric depths (4 to 30 g cm\(^{-2}\)).

We have compared the observed depth dependence of the relative abundances with the depth dependence calculated with a computer code developed at Goddard Space Flight Center. The comparison permits extrapolation of relative abundances to the top of the atmosphere (TOA) with greater precision and a better estimate of the resulting uncertainty than was possible for any previous balloon-borne observation. This comparison between observed and calculated depth dependences of abundances also permits estimates of the accuracy of semi-empirical partial cross-sections (Silberberg and Tsao, 1973a, b, 1977a, b, c; Tsao and Silberberg, 1975, 1979) for nuclear interaction of heavy cosmic rays with the atmosphere.

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The only published measurement of cosmic-ray composition over a similar charge and energy interval which did not require an extrapolation to the top of the atmosphere was from the satellite HEAO-3 (Engelmann et al., 1981). While those results are free of any atmospheric extrapolation, significant corrections are required in their analysis because of nuclear interactions in the large amount of material in their detector.

In Section 2 we describe the experiment, including the charge, energy, and atmo-

Fig. 1. Density cross-plot of the square root of ionization ($\sqrt{T}$) vs the Cherenkov signal divided by ionization ($C/I$). An increasing number of events is represented by a progression of darker characters.