ISOTOPE PRODUCTION IN METEORITES AND COSMIC RAY VARIATION

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ABSTRACT

The depth profiles of cosmic ray tracks and radio-isotopes such as ^{53}Mn, ^{26}Al, ^{60}Co etc measured in some chondrites indicate that the isotope production rates are a sensitive function of the size of the meteoroid and depth within it. Based on these data the source functions of several stable and radioactive isotopes in meteoroids having radii in the range of about 6 to 100 cm are computed. The production rates of ^{21}Ne and ^{22}Ne enable us to calculate the exposure ages correctly and identify meteorites with complex exposure history.

The radionuclide data in meteorites are examined in view of these production estimates. Except for the solar cycle modulation in galactic cosmic ray fluxes which is probably different in different regions of the heliosphere, there are no definite indications of any significant long term time variations in GCR fluxes.

1. Introduction

The concentration of stable and radioactive nuclides produced in cosmic ray interactions in meteoroids depends on the cosmic ray flux along the orbit of the meteoroid. The stable nuclides, such as isotopes of neon, have been used to determine the exposure ages of meteoroids whereas the radioactive isotopes, most of which attain secular equilibrium, are used to estimate the fluxes over time periods of the order of mean life of the radioisotope. In this way using meteoroids as monitors of cosmic ray intensity, several suggestions such as those by Forman and Schaeffer (1979) and Nishiizumi et al (1980) have been put forth implying variations of cosmic ray intensity over various periods of time in the past.

The basic assumption involved in these suggestions is that the production rates of various nuclides from the contemporary fluxes are known so that any departures from such values can be ascertained and attributed to different fluxes of cosmic rays. Recent studies by Bhattacharya et al (1980) & Potdar (1981), indicate that (1) there is significant depth variation in the isotope production rates within a meteoroid (2) the production rates depend on the size of the meteoroid and (3) there are several cases of meteorites with multiple exposure history either on the parent body or in the interplanetary space (Bhandari and Potdar 1982). In view of these possibilities, it is difficult to attribute any differences in isotope concentrations observed in meteorites uniquely to cosmic ray flux variations. Some of the possible cases are re-examined in this analysis.

2. Experimental Approach

We have followed three approaches to estimate contemporary production rates and to identify meteorites with anomalous concentration of isotopes. Firstly we have measured the depth profiles of some of the nuclides such as ^{10}Be, ^{22}Na, ^{26}Al, ^{53}Mn, ^{54}Mn and ^{60}Co in selected chondrites whose preatmospheric size could be determined from cosmic ray track density (Bhattacharya et al 1979, Potdar 1981). These meteorites i.e. Madhipura (L), Udaipur (H), Bansur (L), St. Severin (LL), Dhajala (H) and Kirin (H) are found to have preatmospheric radius of about 6, 9, 15, 20, 50 and 100 cm respectively. Based on the profiles of ^{53}Mn and ^{26}Al a model has been developed to estimate production rates of several nuclides, produced in low energy interactions, as a function of depth. Secondly the production rates of neon isotopes was estimated from such a model (Bhandari and Potdar 1982) which enabled us to determine the meteoroid exposure ages, and to identify chondrites with multiple exposure history. Thirdly aliquots from about a dozen chondrites have been studied simultaneously for tracks, rare gases and some radionuclides. These measurements confirm that, with a few exceptions, the calculated production rates agree with the observed values.

3. Discussion and Conclusions

In this way a basic framework of isotope production profiles has been developed. Within this framework we consider the data in various chondrites from which cases of multiple exposure have been excluded. The analysis leads to the conclusions that

(1) The effect of solar cycle modulation is very clearly demonstrated by meteorites when size and depth dependence is taken into account.

(2) Some cases of anomalous activity of short lived isotopes with half life upto a few years probably relate to different GCR fluxes at high heliolatitudes in the interplanetary space as can be inferred from orbital characteristics of such meteorites.

(3) Only a few cases of chondrites with anomalous activity, not fully explained by (1) and (2) are found but there is no definite evidence of long term variation of cosmic ray fluxes within the Solar system over the past few million years.

References

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