Elemental fractionation in primitive solar nebula and early solar chronology

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Radioactive decay schemes of short-lived extinct nuclides such as 129I - 129Xe, 53Mn - 53Cr or 26Al - 26Mg systematics give unparalleled information on early solar system chronology. However, in order for these isotope systematics to give useful chronological information, a basic premise must in the first place be ascertained, that is, an assumption on a common primordial isotopic composition for radioactive parent nuclides must be ensured. Unfortunately, there is at present no definitive way to prove this very important assumption, and hence chronological information deduced from short-lived nuclides is apt to be equivocal. In this report, we propose a new approach based on a correlation diagram for initial isotopic ratios of parent and daughter elements (hereafter we call Swindle diagram), and we show that this approach is very useful in assessing this basic assumption. We applied this method to 129I - 129Xe and 53Mn - 53Cr systematics, that are at present only two cases for which we have analytical data to construct the Swindle diagram.

129I - 129Xe data on chondrules showed a fairly well defined negative correlation in a Swindle diagram (1). Therefore, Swindle et al. suggested that initial 129I/127I ratios in the samples had evolved in pre-meteoritic environment from a common primordial iodine with a same primordial 129I/129I ratio (R0), and that a chronological interpretation of 129I - 129Xe systematics may be justified. However, a closer examination of the characteristic correlation trend in a Swindle diagram suggests that I/Xe ratio in the pre-meteoritic reservoir had been subjected to a systematic fractionation, that is, I/Xe ratio had been increasing with time in a pre-meteoritic reservoir. We therefore argue that this characteristic elemental fractionation in I/Xe ratio resulted from the dissipation of the primitive solar nebula. Assuming that noble gas dissipation followed an exponential function of time, we infer that the time constant of the noble gas dissipation was about 25Ma. This time constant is within a generally assumed life span of the primitive solar nebula. On the basis of this dissipating nebula model, we show that I-Xe systematics can be reasonably used as an early solar system chronometer.

Although analytical data are still scanty and a final conclusion cannot be deduced from the available data alone, a Swindle diagram for a limited available data set for 53Mn - 53Cr shows a fairly systematic correlation. This suggests that meteorite samples inherited initial Mn isotopes which had evolved from a same primordial Mn in a pre-meteorite reservoir. Therefore, like I-Xe systematics, Mn-Cr systematics seems to reflect a chronological effect. The implication of this conclusion is that the origin of short-lived nuclide 53Mn in the meteorites is unlikely to be local and hence is not consistent with the X-wind origin.

On the basis of extinct nuclides as well as of long-lived nuclides, we briefly outline the chronology of early solar system.

Swindle et al. (1991) Geochim. Cosmochim. Acta, 55, 861-880.