LIVE $^{129}I-^{129}Xe$ DATING. Kurt Marti, Chem. Dept. B-017, Univ. of California, San Diego, La Jolla, California 92093.

Introduction: We discuss a new technique of cosmic ray exposure age dating using cosmic ray produced ^{129}I and ^{129}Xe components. We will use the term "live ^{129}I" to set apart from the well established "extinct ^{129}I" used for early solar system chronology, as introduced by Reynolds (1960) and successfully applied to meteorites and other planetary objects. The chronometer pair in both cases is the radioisotope ^{129}I ($T_{1/2} = 1.57 \times 10^7$y) and radiogenic $^{129}Xe_r$ as the stable daughter. Obviously the most useful information can be expected from materials which did not contain extinct ^{129}I, but which contain target elements for cosmic ray reactions producing ^{129}I. Before we consider the reactions of interest, it is useful to discuss the need for a new method.

Galactic Cosmic Ray Flux: Nishiizumi et al. (1980) carried out a systematic study of cosmic ray exposure ages of chondrites as a test for possible variation of the cosmic ray flux during the past few million years. Four calibrations were carried out using radioisotopes of varying half-lives: ^{22}Na(2.6y), ^{81}Kr(2.1×10^5y), ^{26}Al(7.2×10^5y) and ^{53}Mn(3.7×10^6y). Three of these calibrations were in very good agreement, indicating constancy of the galactic cosmic ray intensity. Calibrations based on ^{26}Al disagreed in a systematic way. Moniot et al. (1983) used the nuclide ^{10}Be(1.6×10^6y) in an additional calibration, and the result was in excellent agreement with those of Nishiizumi et al. Chondritic meteorites cannot be used to study flux variations on 10^8y to 10^9y time scales, but many iron meteorites are well suited for this purpose. There exists an excellent K isotopic data base, due to the work of Voshage and co-workers (e.g. Voshage, 1962), who pointed out a discrepancy between production rates based on ^{40}K(1.28×10^9y) and those of the much shorter isotopes ^{39}Ar(269y), ^{36}Cl(3.0×10^5y), ^{26}Al and others discussed above. Space erosion was considered as a possible cause, but a "recent" increase of the galactic cosmic ray intensity was the preferred explanation. A different method for calculating ages of iron meteorites was recently developed by Marti et al. (1984), which uses shielding corrected ^{38}Ar production rates and eliminates meteorite samples with multistage irradiations. The results first confirm the suggestions of a "recent" increase of the cosmic ray flux and constrain the timing of the flux change to $\leq 2 \times 10^8$y. Furthermore, unexplained differences appear if exposure ages less than 200My are compared to those based on the $^{40}K-^{41}K$ method. Monitors for the 10^7-10^8y interval are required to further constrain the past cosmic ray flux. The ^{129}I half-life is quite appropriate and makes this nuclide very attractive, since appropriate shielding corrections can be obtained as shown below.

Reactions on Te: Te is an ideal target element for reactions yielding ^{129}I, and it will be especially suitable if low-energy secondary particles are predominant. The reactions $^{128}Te(n,\gamma)\ ^{129}Te \xrightarrow{\beta^-} {}^{129}I$ and $^{130}Te(n,2n)\ ^{129}Te \xrightarrow{\beta^-} {}^{129}I$ are both important. Browne and Berman (1973) estimate the resonance integral

$$R = \int_{E_1}^{E_2} \frac{\sigma_\gamma(E)}{E}\, dE \approx 1.098\text{b}$$

(E_1 = 0.5eV; E_2 = 7KeV) and the thermal cross-section is σ_γ = 0.215b. The (n,2n) cross-sections are estimated to be ~ 1.5b for E_n ~15MeV, as observed for similar targets (e.g. Leich et al., 1984, this volume). Kohman (1967) estimated the ^{129}I production rate by (n,2n) reactions on ^{130}Te to be about 0.4 atoms/min^{-1} g^{-1}(Te), using the analogous reaction $^{56}Fe(n,2n)\ ^{55}Fe$ and measured ^{55}Fe activity in iron meteorites. Nishiizumi et al. (1983) measured ^{129}I contents in 3 meteorites which are in reasonable agreement with this

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estimate, but they also notice that (n,γ) reactions are substantial for shielded sample locations. Proton reactions on ^{130}Te via the reaction channels $(p,2n)$, (p,pn); and (p,γ) on ^{128}Te all make additional, but small, contribution to ^{129}I. In all these reactions, ^{129}Xe is produced via its precursor ^{129}I, and this presents an ideal parent-daughter relationship. Cosmic ray reactions on Te provide a dating system which is independent of (self-correcting for) shielding, as long as the exposure geometry remains constant, because the fractional isobaric production ratio $P(^{129}I)/P_{129} \simeq 1$. For the case of a complex exposure history, these assumptions obviously are not valid and, for this reason, this method may also prove useful in identifying complex exposure histories.

The reactions $^{130}Te(n,\gamma)\ ^{131}Te \xrightarrow{\beta^-} {}^{131}I \xrightarrow{\beta^-} {}^{131}Xe$, and $^{130}Te(p,\gamma)\ {}^{131}I \xrightarrow{\beta^-} {}^{131}Xe$, produce ^{131}Xe which can serve as a convenient monitor for cosmic ray reactions on Te targets. In general, it may be necessary to correct for competing reactions which co-produce ^{129}Xe by different pathways such as extinct ^{129}I, discussed earlier, or spallation Xe from Ba or heavier elements. Such reactions may be monitored using other Xe isotopes, and corrections may be small in favorable cases such as in Te-enriched and Ba-depleted minerals (e.g. troilite) which did not incorporate extinct ^{129}I at the time of formation.

<u>Live ^{129}I - ^{129}Xe Ages</u>: The content of $^{129}Xe = {}^{129}Xe_T + {}^{129}Xe_R + {}^{129}Xe_S + {}^{129}Xe_{Te}$ can be corrected for trapped (T), radiogenic (R, from extinct ^{129}I) and spallation (S) components. The term of interest here ($^{129}Xe_{Te}$), produced from Te targets, can then be compared to the ^{129}I presently observed in the sample. The feasibility of ^{129}I measurements in meteorite samples by accelerator mass spectrometry has been demonstrated by Nishiizumi et al. (1983). The sensitivity of the technique can still be improved, and it may become possible to measure ^{129}I in sample sizes less than one gram. The ratio $^{129}Xe_{Te}/^{129}I)$ is related to the exposure age (T) by the relation:

$$F(T) \equiv \frac{\lambda_{129}T - 1 + e^{-\lambda_{129}T}}{1 - e^{-\lambda_{129}T}} = \left(\frac{^{129}Xe_{Te}}{^{129}I}\right)$$

It appears that exposure ages of about 10^7y to several 10^8y could be obtained, and that this range should overlap existing exposure age data at both ends. Murty and Marti (1984) recently tested the Xe systematics in the Cape York meteorite and observed a suitable mineral for I - Xe dating: Troilite which is free of silicate inclusions has Te concentrations of about 0.6 - 1.2ppm. They found that possible interferences from extinct ^{129}I may be monitored using ^{128}Xe from the $^{127}I(n,\gamma)$ reaction, and that the products ^{131}Xe from $Te(n,\gamma)$ and ^{83}Kr from $^{82}Se(n,\gamma)$ serve as monitors for the target elements and provide information regarding the neutron energy spectrum.

<u>Conclusion</u>: The live ^{129}I - ^{129}Xe method provides an ideal monitor for cosmic ray flux variations on the 10^7y - 10^8y time-scale. It is based on low-energy neutron reactions on Te, and these data, when coupled to those from other methods, may facilitate the detection of complex exposure histories.

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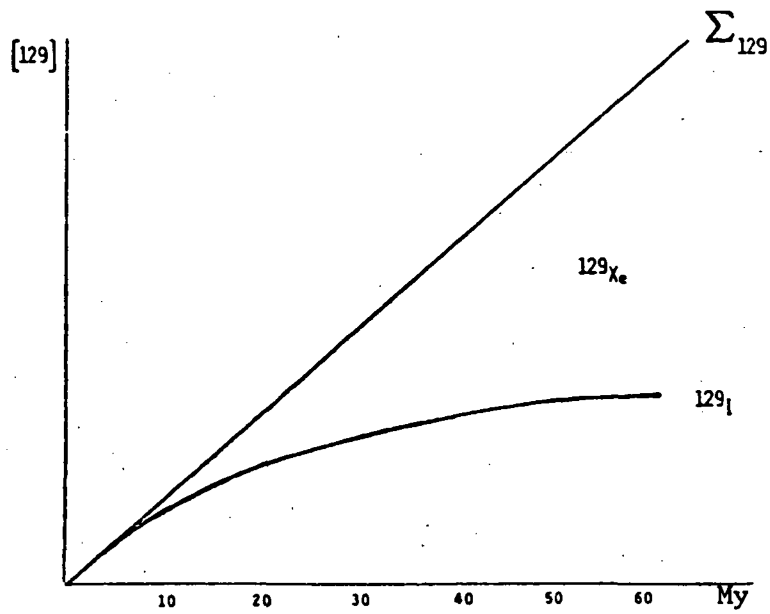

Figure 1: Relative abundances of ^{129}I and ^{129}Xe vs. time for a constant cosmic ray flux.