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HALF LIFE OF ^{26}Al

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ABSTRACT

The half-life of ^{26}Al has been redetermined because of suggestions of an error in the accepted value based on its use in calculating ^{21}Ne production rates from cosmic rays in meteorites. Two solutions of ^{26}Al were analyzed for the specific radioactivity and mass spectrometric determination of the ^{26}Al concentration. The half-life obtained for ^{26}Al was 7.05×10^5 years $\pm$ 3.7% at the two sigma level. This is identical to the accepted value of 7.16×10^5 years and indicates that problems with the ^{21}Ne production rate is not due to an erroneous half-life.

INTRODUCTION

The half-life of ^{26}Al is being redetermined because of some inconsistent results obtained when using the reported half-life for calculating cosmic-ray exposure ages of meteorites. The cosmic-ray exposure age is conveniently calculated from the ^{21}Ne content and production rate, which is normally assumed to be consistent.

Production rates of ^{21}Ne are deduced from a variety of other cosmic-ray produced radionuclides. The production rates, in units of 10^{-8} ccSTP $^{21}\text{Ne}/\text{g}$ Myr, are (1) 0.46 based on ^{26}Al ($t_{1/2} = 7.2 \times 10^5$ yr), (2) 0.30 based on ^{53}Mn ($t_{1/2} = 3.8 \times 10^6$ yr), and (3) 0.3 based on ^{10}Be ($t_{1/2} = 1.6 \times 10^6$ yr) [Herzog and Anders, 1971; Miller et al., 1981; Moniot et al., 1982, and Englert and Herr, 1978]. The two lower values for production rates are consistent with tritium/ ^3He and $^{39}\text{Ar}/^{38}\text{Ar}$ ages [Fisher, 1972] and ^{81}Kr derived ages [Finkel et al., 1978].

The production rate based on ^{26}Al is about 50% higher than that based on other radionuclides and could be explained if the reported half-life is 30 to 40% low [Muller et al., 1981 and Moniot et al., 1982] or if the cosmic ray flux varies over time [Moniot et al., 1982 and Muller et al., 1981].

It is, therefore, appropriate to redetermine the half-life of ^{26}Al . The best previous ^{26}Al half-life was measured by Rightmire, Kohman, and Hintenberger [1958]. Their value was later adjusted based on a more accurate branching ratio between positron emission and electron capture. Samworthy, Warburton, and Engelbertink, 1972]. The half-life in current use is $7.16 \pm 0.32) \times 10^5$ years.

EXPERIMENTAL PROCEDURE

The method used to measure the half-life consists of a mass spectrometric isotope dilution determination of the ^{26}Al concentration in a solution coupled with a measurement of the specific radioactivity of the same solution. The ^{26}Al was made previously by irradiating high pure silicon with protons at Los Alamos Meson Physics Facility (LAMPF) for a period of 3 years. The total fluence on the target was approximately 10^{23} protons. The aluminum was separated and purified with an HDEHP extraction and an oxalic acid anion exchange column [Thomas et al., 1983].

The ^{26}Al was further purified for mass spectrometric analysis. Two different procedures were used, resulting in two source solutions of ^{26}Al for mass spectrometry and measurement of the specific radioactivity. The final chemical procedures were performed in clean room facilities, using N.B.S. purified reagents.

The first clean-up procedure used an HF anion exchange procedure to remove Mg and Na from the aluminum. Approximately 2 micrograms of ^{26}Al in a 2 M HCl solution was evaporated to dryness. Twice the aluminum was dissolved in 0.5 ml concentrated HF and evaporated to dryness. The anion exchange resin (DOWEX AG-1-X8, 100-200 mesh) was loaded into a 2 mm I.D. Teflon column to give a column length of 2 cm. The column was prepared by washing it with 10 column volumes (c.v.) of 4 M HF and 10 c.v. of 0.5 M HF.

The ^{26}Al was dissolved in 0.250 ml of 0.5 M HF and loaded onto the column. The column was washed with 15 c.v. of 0.2 M HF to remove Na and Mg. The ^{26}Al was eluted with 15 c.v. 4M HF and evaporated to dryness. Source solution A was prepared by dissolving the ^{26}Al in 20 ml of 2 M HNO_3 .

An equal amount of ^{26}Al was purified to provide a second source solution B. The procedure used the oxalic acid anion exchange column described in Thomas et al. [1983]. It was modified for the small ^{26}Al sample by utilizing a smaller column (2 cm x 2 mm) and by use of N.B.S. reagents.

The specific radioactivity of the source solutions was obtained from three gravimetric aliquots from each of the two source solutions. Approximately 1 ml of the source solution was diluted with 4 ml 2 M HNO_3 and loaded into a scintillation vial. The activity of the ^{26}Al was determined by measuring the 1.808 MeV gamma ray on a Ge(Li) gamma-ray detector by the Nuclear Chemistry Group at Los Alamos. The procedure for obtaining the specific activity calculated by the facilities at Los Alamos, is described in Balagna [1980]. The specific radioactivity is corrected for the 99.764% branching ratio of the 1.808 MeV gamma ray decay.

The ^{26}Al concentration was determined mass spectrometrically from traced and untraced gravimetric aliquots of the two source solutions. The tracer for solution A was prepared from pure Johnson Mathe aluminum rod dissolved in 2 M HNO_3 . The tracer for solution B was prepared from pure aluminum foil obtained from Alpha Chemicals. The mass spectrometer source was a triple filament design with approximately one nanogram of aluminum evaporated onto each of the side filaments. The ion beam current was approximately 10^{-11} amps.

Because aluminum is mono-isotopic it was not possible to experimentally obtain the mass fractionation correction for the $^{26}\text{Al}/^{27}\text{Al}$ isotopic ratio. Therefore, the $^{26}\text{Al}/^{27}\text{Al}$ ratios have been arbitrarily adjusted by a factor of 0.9814 to account for mass fractionation in the mass spectrometer. This factor is equal to the square root of the mass ratio of $^{26}\text{Al}/^{27}\text{Al}$. In addition, we are unable to correct for the slowly varying mass fractionation during the measurement of each sample. The ratios reported are the weighted average of the ratios for each sample with an average internal precision of <0.05%. However, because we are unable to correct for fractionation during the analysis the accuracy of the ratios is less than the internal precision. We have arbitrarily assigned an error to each sample isotopic ratio equal to the observed shift in the ratio from the first ratio measurement to the final measurement. This error was generally in the range of about 0.5%. The masses of the two aluminum isotopes used in the calculations are ^{26}Al , 25.9869 amu, and ^{27}Al , 26.98153 amu.

RESULTS AND DISCUSSIONS

The specific radioactivities of the two source solutions are given in Table 1. The results are the weighted averages of a number of counts per each sample. (The weighting is based on the variance of each data set). The standard deviation is at the 1 sigma level and includes a 2.0% deviation for the absolute calibration of the Ge(Li) detectors. The precision of the measurements of the activity of the two source solutions is quite good at <3.0%.

The results from the isotope dilution analysis of the two source solutions is given in Table 2. The precision of the ^{26}Al concentrations is better than 1%. The accuracy could have been determined if it were possible to correct for the mass fractionation of the samples; rather than assuming the error.

Combining the mass spectrometric analysis with the measurements of the specific radioactivity gives the decay constant for ^{26}Al as shown in Table 3. The half life obtained from the averaged decay constants is 7.05×10^5 years $\pm 3.7\%$ at the two sigma level. This result agrees very well with the previous determination of 7.16×10^5 years and confirms the value for the half-life of ^{26}Al .

With this new determination of the ^{26}Al half-life value it seems clear that an erroneous half-life is not the source of the discrepancies in the observed ^{21}Ne production rates. It is unlikely that all the other half-lives are in error, thus our results suggest a further investigation of the consistency of the cosmic-ray flux over the past 2 to 3 million years or in other assumptions used in calculating the production rates.

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TABLE 1
SPECIFIC RADIOACTIVITY

<u>Sample</u>	<u>Activity (Gammag/min)</u>	<u>Specific Activity (Gammag/min g solution)</u>
20 [*]	4588 ($\pm$ 2.85%)	4259 ($\pm$ 2.85%)
21 [*]	4446 ($\pm$ 4.24%)	4160 ($\pm$ 4.24%)
22 [*]	4469 ($\pm$ 3.40%)	4172 ($\pm$ 3.40%)
Weighted Mean		4209 ($\pm$ 2.79%) [†]
31 ⁺	3001 ($\pm$ 3.18%)	4235 ($\pm$ 2.83%)
32 ⁺	4280 ($\pm$ 2.83%)	4209 ($\pm$ 3.50%)
33 ⁺	4135 ($\pm$ 1.53%)	3922 ($\pm$ 1.53%)
Weighted Mean		4011 ($\pm$ 2.36%) [†]

^{*}Source Solution A.

⁺Source solution B.

[†]Includes $\pm 2\%$ error estimates for detector calibration.

Errors are given at the 1 σ level

TABLE 2
MASS SPECTROMETRY ISOTOPE DILUTION RESULTS

<u>Sample</u>	<u>Al Tracer Added (g)</u>	<u>²⁶Al in Traced Sample (g)Δ</u>	<u>Source Solution Concentration (g ²⁶Al/g Solution)</u>
5*	4.2591 x 10 ⁻⁶ (± 0.098%)	5.137 x 10 ⁻⁸	9.686 x 10 ⁻⁸ (± 0.44%)
10*	8.5640 x 10 ⁻⁶ (± 0.093%)	5.722 x 10 ⁻⁸	9.719 x 10 ⁻⁸ (± 0.78%)
15*	1.3161 x 10 ⁻⁵ (± 0.091%)	5.079 x 10 ⁻⁸	9.613 x 10 ⁻⁸ (± 0.71%)
Weighted Mean			9.675 x 10 ⁻⁸ (± 0.34%)
41 ⁺	7.8217 x 10 ⁻⁶ (± 0.049%)	9.134 x 10 ⁻⁸	9.039 x 10 ⁻⁸ (± 1.53%)
42 ⁺	1.3404 x 10 ⁻⁵ (± 0.049%)	9.531 x 10 ⁻⁸	9.426 x 10 ⁻⁸ (± 1.33%)
44 ⁺	1.1167 x 10 ⁻⁵ (± 0.049%)	9.671 x 10 ⁻⁸	9.569 x 10 ⁻⁸ (± 1.58%)
Weighted Mean			9.338 x 10 ⁻⁸ (± 0.85%)

ΔErrors are the same as given in the concentration column.

†Corrected for ²⁶/27 mass fractionation, assigned error is estimate of accuracy. See text.

*Source solution A.

+Source solution B.

Errors are given at the 1 σ level.

TABLE 3
 ^{26}Al DECAY CONSTANT

<u>Sample</u>	<u>λ ($\pm 1\sigma$)</u>
Solution A	$1.882 \times 10^{-12} \text{ min}^{-1} (\pm 2.81\%)^+$
Solution B	$1.858 \times 10^{-12} \text{ min}^{-1} (\pm 2.51\%)$
Weighted Average	$1.868 \times 10^{-12} \text{ min}^{-1} (\pm 1.87\%)$
^{26}Al Half Life	$7.05 \times 10^5 \text{ years } (\pm 3.7\%)*$

⁺Standard deviation at 1 σ level.

*Standard deviation at 2 σ level.