Ratio of neutron capture cross sections for ^{186}Os and ^{187}Os at 25-keV neutron energy*

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The ratio of the neutron capture cross sections for ^{186}Os and ^{187}Os was measured at the 25-keV iron-filtered neutron beam facility of a 10-MW reactor. A value of 0.41 ± 0.04 was obtained. Using this ratio, the age of the universe was determined via the Re-Os β-decay clock to be approximately 19×10^9 years.

[NUCLEAR REACTIONS ^{186,187}Os(n,γ), $E_n = 25$ keV, measured cross-section ratio.]

The ratio of the neutron capture cross sections for ^{186}Os and ^{187}Os in the neutron energy region near 25 keV (corresponding to a stellar temperature of 3×10^8 K) is required to calibrate the Re→Os β-decay clock[1] which can be used to determine the age of the universe. This dating technique is discussed in detail elsewhere.[1,2] The cross sections for the above nuclei have been measured[2] recently at the Livermore 100-MeV electron linac in the neutron energy range from 2 eV to 150 keV. Due to the astrophysical importance of the cross-section ratio near 25 keV, an additional measurement at the 25-keV iron-filtered neutron beam facility[3] at the National Bureau of Standards (NBS) 10-MW reactor seemed appropriate.

The NBS 25-keV filtered beam facility provides a very pure (99.4%) and intense (5×10^5 neutrons/cm^2 sec) source of 25-keV neutrons with an energy spread of 15% (full width at half maximum). The energy distribution is shown in Fig. 1. The samples were placed in the beam at a distance of 1 cm from a C_6D_6 liquid scintillator[4] and contained within a 29.3-cm (diam)×62-cm (length) ^{6}Li cylinder. This whole assembly was entombed in a 30-cm thick lead and borated polyethylene vault to minimize room background (Fig. 2). The beam flux was monitored with a ^{235}U ionization chamber and was constant to 1%. The γ-ray spectra from the scintillator were collected in groups of 256 channels and dumped on paper tape for later analysis. The pulse-height data were weighted with the response function of the detector to yield a result

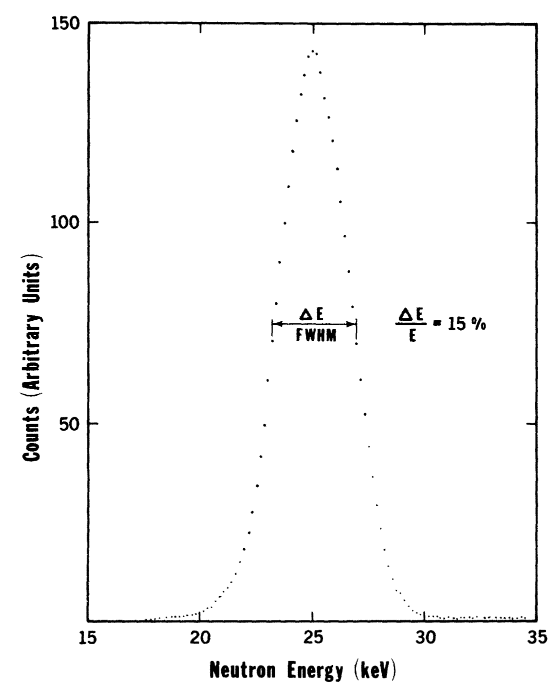

FIG. 1. Energy distribution of the 25-keV neutron filtered beam at the NBS 10-MW reactor.

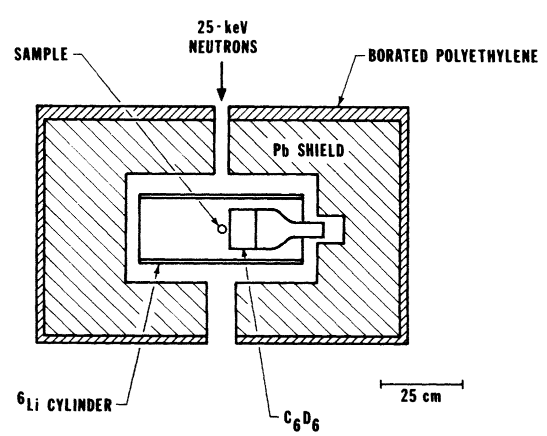

FIG. 2. Schematic diagram of the experimental setup.

TABLE I. Cross-section ratio obtained from the present experiment.

Run	$\sigma_{186}/\sigma_{187}$
1	0.35 ± 0.08
2	0.42 ± 0.10
3	0.46 ± 0.10
4	0.49 ± 0.11
5	0.38 ± 0.09
6	0.42 ± 0.10

proportional to the total energy of the capture event.[4] The samples were powdered metallic osmium enclosed in a Be can and consisted of 3.278 g of Os (enriched to 78% in ^{186}Os) and 2.959 g of Os (enriched to 71% in ^{187}Os). The background was determined by including in the measurement an empty sample can and a can filled with carbon to simulate the Os neutron scattering cross section at 25 keV. Since the ^{186}Os and ^{187}Os samples were not isotopically pure, it was necessary to account for the impurities which consisted of the other stable Os isotopes. This was done using previously measured cross sections[2] for these isotopes.

To insure a consistent set of data, several experimental runs were made. The statistical uncertainty in the experimental data (with background subtracted) was less than 1% for any given run. However, there was a systematic uncertainty in the determination of the background; this was due to a low signal to background ratio ($\frac{1}{3}$) which was sensitive to conditions in other nearby experiments. Although measures were taken to reduce the effects of the reactor environment to a minimum, it caused each run to have approximately a ± 20% uncertainty in the ratio. The six cross-section ratios ($\sigma_{186}/\sigma_{187}$) (25 keV) obtained in this experiment along with their uncertainties are listed in Table I. The average of these six ratios is $\langle\bar{\sigma}_{186}/\bar{\sigma}_{187}\rangle = 0.41 \pm 0.04$.

The quantity of direct astrophysical interest is the cross-section ratio Maxwellian averaged for a temperature $kT \cong 25$ keV. However, for these nuclei the level density (ρ) at this energy is high ($\bar{D} = 1/\rho = 30$ eV for ^{186}Os; $\bar{D} = 4.5$ eV for ^{187}Os), so that the cross-section ratio will not be very sensitive to the temperature in this region. Therefore, the above value of 0.41 should be indicative of the Maxwellian-averaged ratio for $kT \cong 25$ keV. A Maxwellian-averaged ratio of $\bar{\sigma}_{186}/\bar{\sigma}_{187} = 0.39 \pm 0.03$ was obtained for $kT = 30$ keV in the previous measurement at the Livermore linac[2] so that the present result is in good agreement with that result.

With these results the Re→Os dating technique yields an age of the universe equal to approximately $19 \pm 4 \times 10^9$ yr as discussed elsewhere.[2] This is somewhat larger than the ages determined from the red-shift[2] (17×10^9 yr) and from the U-Th dating technique[1,2] (14×10^9 yr) but not outside the range of uncertainties in these numbers.

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