dis/min per μg of Pu^{239}, and the half-life of Pu^{239} is 24 400 years. The estimated probable error for the half-life of Pu^{239} is 2 percent, the uncertainty coming mainly from the uncertainty in the geometry.

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Evidence for Si^{32}, a Long-Lived Beta Emitter[*,†]

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Neutron-irradiated quartz has been found to contain 14.3-day P^{32} more than two years after the end of irradiation. This is evidence for a long-lived Si^{32} formed from stable Si^{30} by the capture of two neutrons. The ratio of half-life of Si^{32}, in years, to neutron capture cross section of Si^{31}, in barns is 600.

PREVIOUS work[1,2] has indicated that the unknown nuclide Si^{32} might be a long-lived beta emitter. This communication reports direct evidence (via isolation of its P^{32} daughter) for such a long lived Si^{32}.

Quartz, that had been intensively irradiated with thermal neutrons at the Hanford pile and allowed to cool for more than two years,[3] has been found to contain small amounts of 14.3-day P^{32}. The radiophosphorous was separated from approximately 100-gram samples of the quartz by volatilization of the silicon as SiF$_4$ from sulfuric and hydrofluoric acids in the presence of phosphate carrier. It was then purified by ammonium phosphomolybdate and magnesium ammonium phosphate precipitations. Included also were CuS scavengings and decontamination from vanadium by reduction of added V^{5+} carrier prior to some of the phosphate precipitations. The identification of the separated radioactivity as P^{32} was made from the decay and absorption characteristics of the radiations.

Table I lists the results on the phosphorous activity isolated from three samples of the quartz. The SiF$_4$ evaporation took up to two weeks. The carrier was added in several portions during the evaporation. Column three of the table lists the midpoint of this evaporation period. Column four gives the observed initial counting rate of the purified phosphorous. The chemistry extended over a period of 10 to 26 days and the chemical yields were between 15 and 50 percent. Finally, the last column lists the P^{32} activity of the original quartz calculated from the observed activity, the chemical yields, and the decay periods. As an additional check on radiochemical purity, the decay of the phosphorous sample IV was followed for 10 days and then subjected to an additional cycle of radiochemical purification. The result was no change (less than 5 percent) in specific activity and in the absorption characteristics.

TABLE I. P^{32} content of old neutron-irradiated quartz.

Sample	Wt of quartz used (g)	Date of SiF$_4$ evaporation	P^{32} activity observed (counts/min)	Specific activity of the quartz (counts/min g)
II	110	2/6/53	6.4	0.5
III	120	3/2/53	6.9	0.5
IV	120	5/6/53	31.0	0.8
			Weighted average	0.66

Several samples of unirradiated quartz, treated chemically in an identical manner, showed no P^{32} activity. Our limit of detection was about one-fiftieth of that observed in the most active sample isolated from the irradiated quartz.

Table I shows that there is P^{32} activity associated with neutron-irradiated quartz long after that formed directly by pile radiations has died away. In addition this activity is essentially constant over a period of about three months. A reasonable interpretation is that a long-lived parent, Si^{32}, has been formed from stable Si^{30} by the capture of two neutrons. From the weighted average of the specific activities indicated in Table I (0.66), the detection efficiency of our end-window proportional counters for P^{32} radiations (~45 percent), the irradiation conditions (flux and time), the thermal neutron capture cross section of Si^{30} (0.2 barn) and the half-life of Si^{31} (156 min), we calculate the ratio of half-life of Si^{32}, in years, to neutron capture cross section of Si^{31}, in barns, to be 600. The thermal neutron absorption cross section of Si^{31} is not known. For a cross section of 0.1 barn, the half-life of Si^{32} is calculated to be 60 years.

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[*] Since preparation of this manuscript, evidence for the production of Si^{32} in the 340-Mev proton spallation of chlorine, has been presented by M. Lindner, Phys. **91**, 642 (1953).

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[1] M. Lindner, Phys. Rev. **89**, 1150 (1953).

[2] A. Turkevich and Althea Tompkins, Phys. Rev. **90**, 247 (1953).

[3] We thank Dr. F. T. Hagemann of the Argonne National Laboratory for making this quartz available to us.