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Phys. Rev. C **85**, 028801 — Published 3 February 2012

DOI: 10.1103/PhysRevC.85.028801

Measurement of ^{120}Te(α,n) cross sections relevant to the astrophysical p-process

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The statistical Hauser-Feshbach (HF) model performs poorly in calculating the (γ,α) rates that are critical to the p-process. Experimental work on elastic scattering of the tellurium isotopic chain [1] provided a new parametrization of the α-optical potential and consequently new HF calculations of the (α,x) cross sections on $^{120-130}$Te. However, reliable experimental cross sections of these isotopes have not been measured at energies relevant to the p-process. To test the reliability of the HF calculations, we measured the (α,n) cross sections on ^{120}Te, one of the p-nuclei, using the activation technique. The results are compared with the HF model calculations.

Photodisintegration reaction rates for the p-process in stars [2], in particular the (γ,α) rates, are critical for the production of heavy p-nuclei and the branchings of the p-process path [3]. These rates are typically calculated with the statistical Hauser Feshbach (HF) model [4] in a reaction network involving thousands of nuclei. However, the HF model predictions are in disagreement with measured (α,γ) cross sections at low energies [5, 6]. To improve the reliability of the HF reaction rates, experimental verifications and constraints are needed.

In recent years, a number of α-beam activation measurements have been conducted for targets relevant to p-process [5–13]. Cross sections of the corresponding (α,x) reactions were measured at, or close to, the astrophysically relevant energy.

However, low energy experimental data of α-induced reaction cross sections for tellurium isotopes are very scarce. One early attempt to measure the ^{130}Te(α,n) cross sections [14] claimed to have measurement down to about 6 MeV; but no error bars were reported. These claimed cross sections are several orders of magnitude higher than a typical HF calculation. The discrepancy is likely due to a lack of understanding of the background. Another measurement of the same reaction, presented one relevant data point at 10 MeV [15], but the associated uncertainty was nearly as large as the measured data point. To the authors' knowledge, no α-induced reaction cross sections have been measured for ^{120}Te, one of the so-called p-nuclei.

Recent high-precision measurements on α-elastic scattering cross sections on the tellurium isotopic chain have been conducted at Notre Dame [1]. A new parametrization of the α-optical potential was proposed and applied for calculating the corresponding (α,x) reaction cross sections on tellurium isotopes. Reliable experimental data of the cross sections are needed for further comparisons.

To compensate for the lack of data, we measured the cross sections of ^{120}Te(α,n) reaction using the activation technique in order to compare with the new calculations. The ^{120}Te oxide targets were activated using an α-beam of 10.4-11 MeV provided by the FN tandem accelerator at Notre Dame. The enrichment of the targets was 99.4%. A Silicon detector was positioned at 135° in the target chamber to monitor the stability of the beam and target. It was also used in the RBS measurement. The beam current was measured with a Faraday cup mounted at the end of the chamber and integrated in time intervals of one second. The details of the activation setup can be seen in a similar proton-beam activation measurement on ^{120}Te [16].

$E_{c.m.}$ [MeV]	Cross section [μb]	S-factor [10^{24} MeV b]
9.99	10.9±1.0	0.73±0.07
10.14	29.1±3.0	1.22±0.13
10.63	143±13	1.45±0.13

TABLE I: Measured cross sections and S-factors for the ^{120}Te(α,n) reaction.

After each irradiation, the target was removed from the activation chamber and then transported to an off-line γ-ray counting station. The γ-activity of the isotope ^{123}Xe, produced from the ^{120}Te(α,n) reaction, was measured. The counting system consisted of two HPGe clovers placed face-to-face in close geometry with a gap of 4.9 mm. A 0.59 mm thick Cu plate was placed in front of each clover to reduce the count rate from X-rays. The detector setup was shielded inside a Pb castle with 10 cm thick walls and a 3 mm Cu inner lining. The details of the setup and calibration for the counting system can be found in previous activation measurements [6, 16].

The isotope ^{123}Xe, produced from the ^{120}Te(α,n) activation, has a half-life of 2.08 hours [17]. The two characteristic γ-lines are at 148.9 keV and 178.1 keV with intensities of 48.9% and 14.9%, respectively [17]. The ^{120}Te(α,n) cross sections were obtained from the counting of these γ-decays. The details on the efficiency calibration and analysis procedure have been discussed in Refs. [6, 16].

The measured cross sections and S-factors of the

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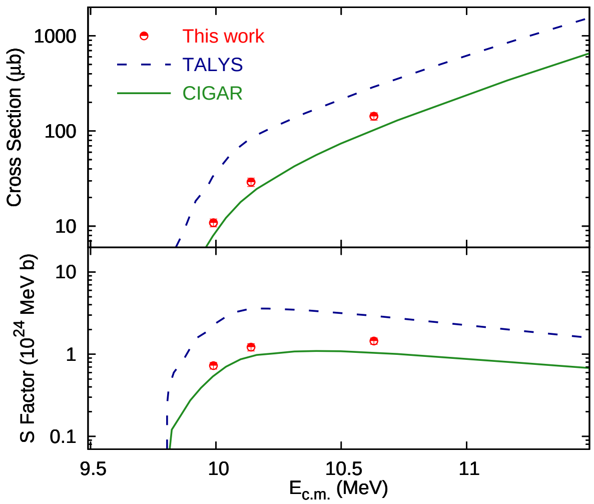

FIG. 1: (Color online) Cross sections and S factors of ^{120}Te(α,n). Experimental data points are from this work. The solid line was calculated using the HF computer code CIGAR [18]. The dashed line was calculated using the code TALYS [21].

^{120}Te(α,n) reaction are listed in Table I and depicted in Fig. 1. The calculations (solid line) using the HF computer code CIGAR [18] are also shown. The code was adapted to accommodate various forms of the optical potential, in particular, for the new parametrization based on the experimental work of α-elastic scattering on tellurium isotopes [1]. The widely used α-optical potential model of McFadden and Satchler [19] was used for the calculations and the nucleon (n or p) potential was taken from the global parametrization in Ref. [20]. The CIGAR calculations agree with the data to within 40%. The systematic deviations are probably due to the uncertainty of the global potential models used. For comparison, calculations from another statistical code, TALYS [21], using the default parameters (dashed line) are also shown in Fig. 1.

This experiment has been conducted in order to support the systematic study of the α-optical potential along the tellurium isotopic chain [1]. We measured near-threshold cross sections of the ^{120}Te(α,n) reaction using the activation technique, providing the first reliable α-induced reaction cross section data at low energies on tellurium isotopes. The ^{120}Te(α,n) data and previous measurements on nearby Cd and Sn isotopes were compared to the predictions from the new parametrization of the α-optical potential derived from high-precision α-elastic scattering cross section data [1]. The reader is referred to Ref. [1] for further discussion and conclusions.

This work has been supported by the National Science Foundation under grant No. PHY0758100 and the Joint Institute for Nuclear Astrophysics, NSF-PFC under grants No. PHY0822648 and PHY0216783. N. Ö., R.T. G., and C. Y. have also been supported by TUBİTAK (grants No. 104T2467 and 108T508).

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