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Cross-Section Based Yield Comparison of ^{67}Cu Production from Enriched ^{68,70}Zinc Targets

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1. Introduction

Copper-67 (^{67}Cu) is a key theranostic radionuclide with applications in imaging and targeted radiotherapy [1]. Its production relies on proton-induced nuclear reactions, primarily using enriched zinc targets. The most studied reaction pathway is ^{68}Zn(p,2p)^{67}Cu [2, 3], which provides high yields at moderate proton energies. Alternatively, ^{70}Zn(p,x)^{67}Cu [4, 5] has been investigated as a secondary route, though its cross-section and efficiency remain less established.

Accurate cross-section measurements are essential for optimizing ^{67}Cu production, ensuring high yields while minimizing impurities. Previous studies have independently examined ^{68}Zn and ^{70}Zn targets [3, 5], but a direct comparison is necessary to assess their relative advantages. This study compiles experimental data from separate measurements of ^{67}Cu production via these two isotopes, providing a systematic analysis of their cross-section trends. The findings will aid in refining target selection and irradiation conditions, supporting the development of efficient ^{67}Cu production methods for medical applications.

2. Data Sources and Analysis Methods

This study is based on previously published cross-section measurements for the ^{68}Zn(p,2p)^{67}Cu and ^{70}Zn(p,x)^{67}Cu reactions. The cross-section data were obtained from two independent experimental studies, where enriched zinc targets were irradiated with proton beams and the resulting activation was analyzed via gamma-ray spectrometry.

To ensure consistency, all data were normalized and cross-compared over the full energy range up to 100 MeV. The measured excitation functions were analyzed to determine the optimal energy regions for ^{67}Cu production. Additionally, reaction yield calculations were performed based on the cross-section data and isotope decay parameters. The obtained production efficiencies were further evaluated in the context of enriched zinc target costs to assess the cost-effectiveness of each reaction route.

The details of the original experimental procedures, including target preparation, proton irradiation conditions, and gamma-ray spectrometry, can be found in the original publications [3, 5].

3. Cross-Section Data Comparison and Yield Estimation

The cross-section data for the ^{68}Zn(p,2p)^{67}Cu and ^{70}Zn(p,x)^{67}Cu reactions were obtained from previously published studies [3] [5]. Figure 1 shows the measured excitation functions for each reaction.

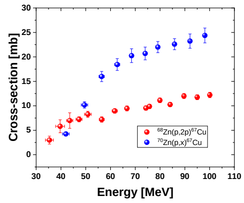

Figure 1. Measured excitation functions for ^{68}Zn(p,2p)^{67}Cu and ^{70}Zn(p,x)^{67}Cu reactions

The results indicate that the peak cross-section for ^{68}Zn(p,2p)^{67}Cu occurs at 100 MeV with a maximum value of 12.21 ± 0.55 mb, while ^{70}Zn(p,x)^{67}Cu reaches its highest value of 24.38 ± 1.52 mb at the same energy, nearly twice that of the ^{68}Zn reaction. These findings extend the available nuclear data beyond the previously reported 70 MeV limit, providing critical new insights into high-energy production pathways.

Based on these cross-section data, the estimated production yield for ^{67}Cu was calculated using the Radionuclide Yield Calculator (RYC) [6], a computational tool for predicting radionuclide production under specific irradiation conditions. Figure 2 presents the calculated yields of radionuclides using RYC.

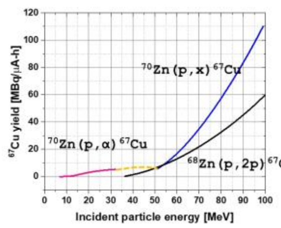

Figure 2. Calculated yields of ^{67}Cu were obtained using RYC

The analysis confirms that ^{70}Zn is the superior choice in the high-energy region (>60 MeV), while ^{68}Zn remains effective in the 40–60 MeV range.

4. Comparison and Discussio

The ^{68}Zn(p,2p)^{67}Cu reaction is a well-established and widely used production route for ^{67}Cu, particularly in the moderate proton energy range of 40–100 MeV. Below 30 MeV, the ^{70}Zn(p,α)^{67}Cu reaction has been employed (Kastleiner, 1999 #216), but its cross-section at higher energies remained largely unreported until recent studies. The work by G. Pupillo's group extended ^{70}Zn(p,x)^{67}Cu cross-section data up to 70 MeV (Pupillo, #196), while this study further expands it to 100 MeV (Jung, 2025 #289), revealing a significant advantage of the ^{70}Zn target in the high-energy region.

A critical factor in evaluating production efficiency is the generation of impurities, particularly ^{64}Cu. Although ^{64}Cu is a different isotope from ^{67}Cu, it exhibits identical chemical properties as copper, making chemical separation ineffective. This presents a challenge in obtaining high-purity ^{67}Cu for medical applications. Figure 3 illustrates the production yield of ^{64}Cu as a function of proton energy.

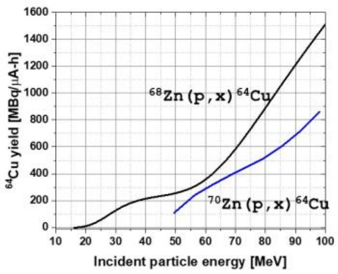

Figure 3. Calculated yields of ^{64}Cu were obtained using RYC

As shown in Figures 2 and 3, the ^{70}Zn(p,x)^{67}Cu reaction not only provides approximately twice the yield of ^{67}Cu compared to ^{68}Zn(p,2p)^{67}Cu but also produces significantly lower amounts of ^{64}Cu. This further enhances the practical advantage of using ^{70}Zn as a target material.

Since ^{64}Cu cannot be chemically separated from ^{67}Cu, an alternative purification strategy involves utilizing their different half-lives. ^{64}Cu has a half-life of 12.7 hours, whereas ^{67}Cu has a half-life of 2.6 days. By allowing sufficient decay time, ^{64}Cu will naturally reduce to negligible levels. However, extended decay periods also lead to the loss of ^{67}Cu activity, necessitating a balance between impurity reduction and overall yield preservation.

For an optimized approach, a cooling time of approximately two to three half-lives of ^{64}Cu (~24–36 hours) may be considered, reducing ^{64}Cu contamination while maintaining acceptable ^{67}Cu recovery. Future studies should explore the precise trade-off between decay time and final yield optimization.

Table 1 summarizes the production efficiency of ^{67}Cu relative to impurity ^{64}Cu, providing a comparative evaluation of the two production routes. These calculations were performed under the conditions of a 1 μA beam current and an irradiation time of 62 hours, which corresponds to the point at which the saturation factor of ^{67}Cu reaches 50 %.

Table 1. Comparison of ^{67}cu production efficiency relative to ^{64}Cu impurity for the two reaction routes

Target	Energy Range (MeV)	^{67}Cu @ EOB (MBq/μA)	^{64}Cu @ EOB (MBq/μA)	^{67}Cu/(^{64}Cu+^{67}Cu) @ EOB	^{67}Cu/(^{64}Cu+^{67}Cu) @ 24h post EOB
^{68}Zn	91-62	2,000	14,000	11.1 %	26.3 %
^{70}Zn	91-62	4,000	5,400	42.6 %	67.4 %

3. Conclusions

This study presents a comparative analysis of ^{67}Cu production via the ^{68}Zn(p,2p) and ^{70}Zn(p,x) reactions, incorporating newly extended cross-section data up to 100 MeV. The results confirm that ^{70}Zn exhibits significantly higher cross-sections in the high-energy region, yielding nearly twice as much ^{67}Cu as ^{68}Zn. Furthermore, the ^{70}Zn(p,x) pathway generates substantially lower amounts of ^{64}Cu, a chemically inseparable impurity, making it a more practical choice for high-purity ^{67}Cu production.

While the ^{70}Zn target offers superior production efficiency, economic factors remain a crucial consideration. Enriched ^{70}Zn is significantly more expensive than ^{68}Zn, necessitating a cost-benefit analysis when selecting target materials. Additionally, the presence of ^{64}Cu requires a careful balance between decay cooling and overall yield retention.

The findings of this study highlight the importance of optimizing both production efficiency and economic feasibility for large-scale ^{67}Cu supply. Future work should focus on refining tandem target configurations, optimizing irradiation conditions, and determining the optimal cooling duration to maximize ^{67}Cu purity while minimizing unnecessary loss.

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