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Novel Photonuclear Methods to Produce an Argon-37 Standard

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Changing the World's Energy Future

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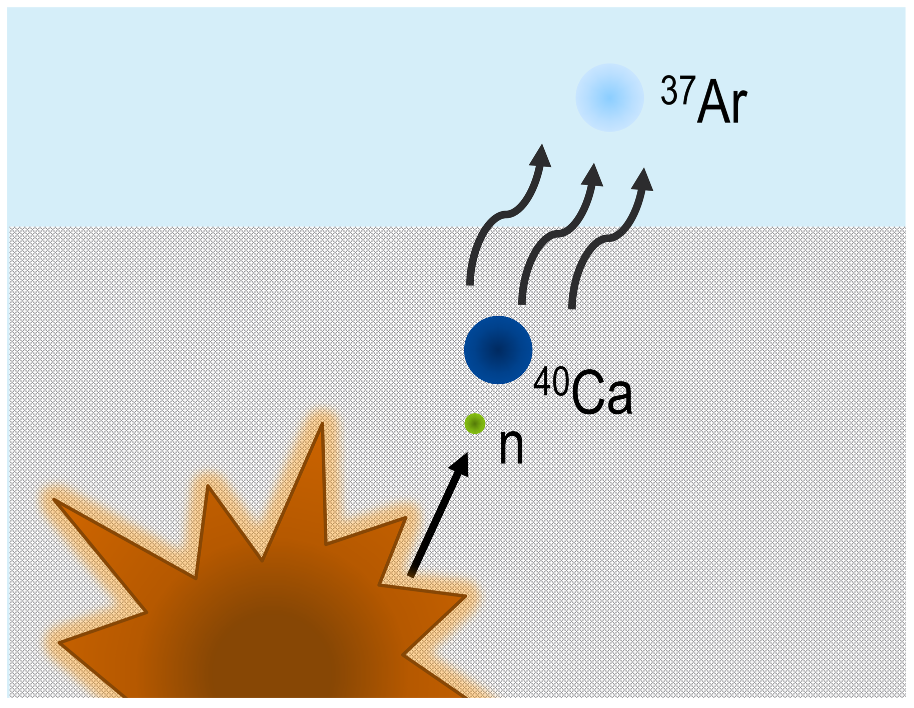
Motivation and Significance

The mission of this research is to explore novel photonuclear-based pathways into the production of ^{37}Ar. Argon-37 is generated as fission neutrons interact with ^{40}Ca in the explosion-environment, therefore, it uniquely indicates the occurrence of an underground nuclear explosion. Due to a 35-day half-life, longer than other gas radioisotopes that are currently monitored for under the Comprehensive Nuclear-Test-Ban Treaty, ^{37}Ar research continues to be developed into its detection for non-proliferation efforts. The longer half-life allows for a longer time period from the time of the explosion for field inspections. Production of ^{37}Ar, through this novel approach, could lead to the development of a standard that would allow for more accurate detector calibration and efficiency measurements leading to more reliable quantification. Standards would also be useful to test novel detectors and to improve models predicting diffusion pathways through the underground environment.

^{40}Ca(n,α)^{37}Ar



Technical Approach: Photonuclear Production

Three photonuclear production pathways using argon, potassium, and calcium targets are being explored:

- Photonuclear production of ^{37}Ar, using linear accelerators, has been successfully performed using cost-effective targets.
- Gas extraction methods are being developed to isolate argon from the target material.
- Detection of ^{37}Ar with Amptek X-123SDD x-ray detector with 0.5 mil Be window have been performed over multiple ^{37}Ar half-lives.

^{38}Ar(γ,n)^{37}Ar

^{39}K(γ,np)^{37}Ar

^{39}K(γ,2n)^{37}K⟶^{37}Ar

^{40}Ca(γ,n2p)^{37}Ar

^{40}Ca(γ,^{3}He)^{37}Ar

Results

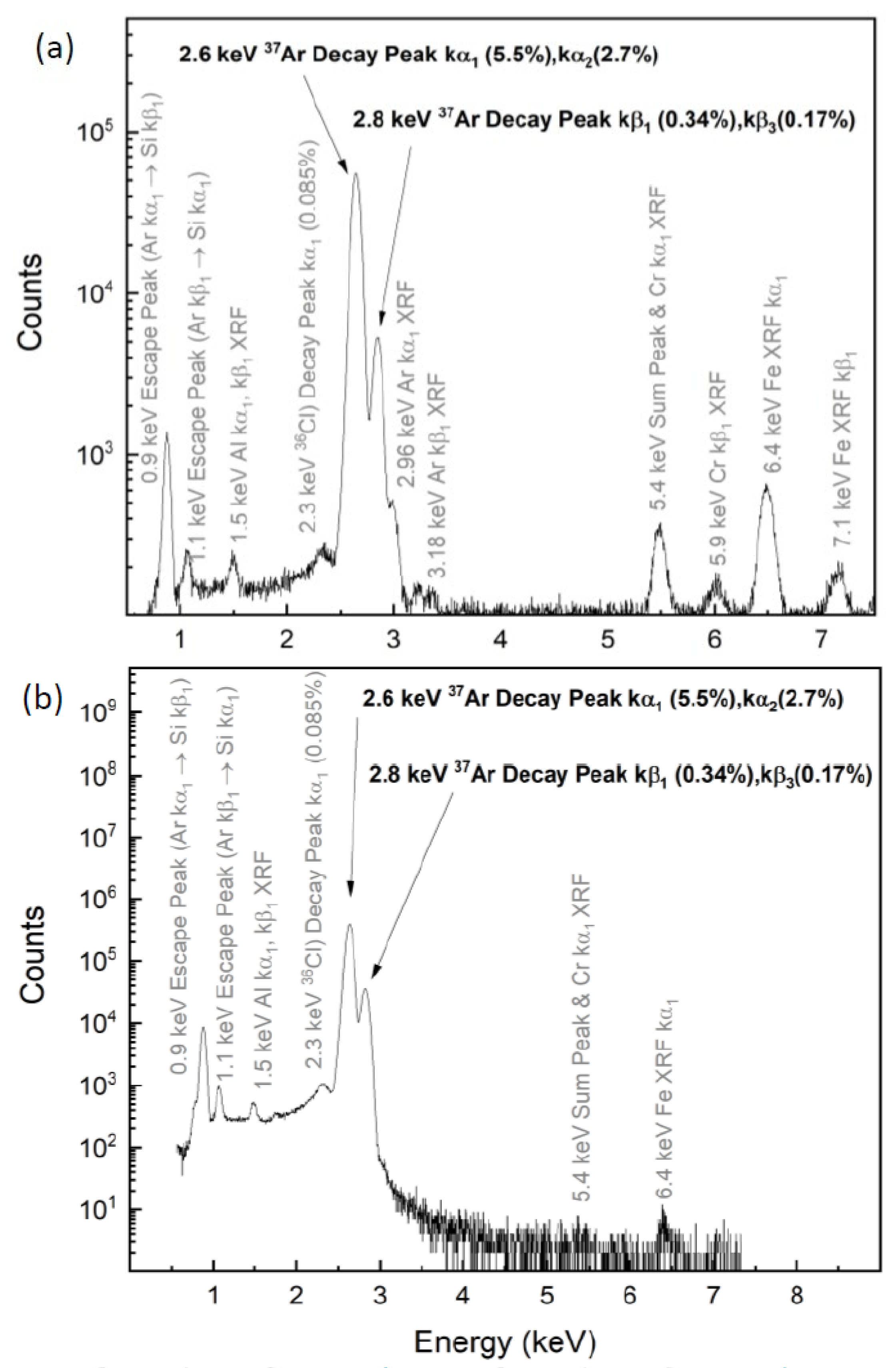


Figure 1: Energy spectra for (a) ultra-pure argon irradiated for 9 hours with a 9.2 kW electron beam and (b) potassium chloride irradiated for 7.7 hours with a 1 kW electron beam.

Argon-37 produced via the ^{38}Ar(γ,n) method can be distributed directly without the need for chemical separations but does not produce carrier-free ^{37}Ar. The ^{39}K(γ,np)/^{39}K(γ,2n)^{37}K ⟶ ^{37}Ar and ^{40}Ca(γ,n2p)/^{40}Ca(γ,^{3}He) pathways have shown the potential to produce ^{37}Ar that is not diluted by stable argon. The impurity ^{36}Cl was detected in the UPA irradiated target. Production of ^{36}Cl can be eliminated by irradiating below the reaction ^{39}Ar(γ,np)^{36}Cl threshold energy of 21 MeV. Production of ^{37}Ar can then be boosted by irradiating an enriched ^{38}Ar sample. Tritium is also produced but will likely be able to be extracted chemically.

The production of ^{36}Cl is generated from the chlorine in the stable sample and through the ^{39}K(γ,^{3}He)^{36}Cl reaction. The gas separation method will need to be adjusted to remove chlorine from the sample. The measured ^{37}Ar production rate resulted in 838 ± 132 μCi or 27 ± 4 μCi · g^{-1} of initial KCl mass.

This project has demonstrated multiple efficient pathways for the novel photonuclear production of the radioisotope ^{37}Ar. A continuation of this work will be performed to optimize the chemical separation and the production routes presented.

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