DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-20-071

SECTION A. Project Title: Novel Methods to Produce an Ar-37 Standard

SECTION B. Project Description and Purpose:

This ECP covers the Laboratory Directed Research and Development (LDRD) project which started in FY-18 and will continue into FY-21. The development of an innovative method to produce argon 37 (Ar-37) is needed to aid in nuclear non-proliferation efforts among international communities, including the United States. Argon-37 has been specifically identified as a critical indicator of an underground nuclear detonation, however, there is no commercial supply currently available. Three promising photonuclear pathways will be explored in this research, all utilizing bremsstrahlung photons to stimulate target nuclei. In one pathway, bremsstrahlung photons collide with stable argon. Following photon absorption, an excited argon-38 (Ar-38) nucleus releases a neutron, resulting in Ar-37. In a second pathway, stable potassium 39 (K-39) is irradiated and releases two neutrons, generating potassium 37 (K 37) which then decays to Ar-37. In the third pathway, photon bombardment on calcium-40 (Ca-40) produces Ar-37 either by the emission of two protons and a neutron [Ca-40(γ, 2pn)Ar-37] or by two neutrons and a proton [Ca-40(γ, 2np)K 37]. Generating a measurable quantity of Ar-37 by any or all of these pathways would provide proof of principle leading to opportunities for large scale sample production by the scientific community. A consistent supply of Ar-37 would be useful for nuclear forensics training, testing innovative detectors, detector calibration exercises, and field tests conducted by safeguards inspectors monitoring non-proliferation treaties such as the Comprehensive Nuclear-Test-Ban Treaty (CTBT). While Ar-37 was recently produced by researchers who activated Ca-40 with reactor neutrons, an alternative supply is necessary as reactor availability is unpredictable and costly. In addition, the yet-unexplored photonuclear approach utilizes electron linear accelerators (LINAC) that have a wide range of power output, allowing for optimization of Ar-37 generation. This effort would not only provide an important alternate method, but would enhance Idaho National Laboratory's (INL) upward trajectory to becoming a world leader in radioactive isotope production.

Detection of a nuclear detonation through radionuclide identification is a verification method valuable to the United States Departments of Energy (DOE), Homeland Security, and the International Atomic Energy Agency. An Ar-37 standard is valuable to these agencies as a verification method and to many national laboratories who require samples for field testing and detector studies. Currently, the CTBTO's International Monitoring System (IMS) monitors for radio-xenon and radio-argon isotopes to verify clandestine nuclear explosions detonated underground. Radioactive, gaseous Ar-37 is produced when energy released from an explosion is absorbed by calcium residing in the soil and rocks surrounding the area, seeping out slowly after the explosion has occurred. 1-3 The half-life of Ar-37 (35 days) is nearly three times longer than the longest half-life of the radio-xenon isotopes monitored which allows for collection long after the detonation, making its identification valuable during on-site inspections. 4 Samples of Ar-37 allow safeguards inspectors to perform critical training scenarios, enhancing their skills in nuclear forensics and detector operation techniques prior to de facto inspections. Samples of Ar-37 are also useful as detector calibration sources that enable quantitative measurements on-site. Furthermore, Ar-37 standards are valuable to national laboratories conducting detector operation studies and field tests. The current method of production is via nuclear reactors through the Ca-40(n,α)Ar-37 reaction, however, alternative methods of production would allow for an increased supply, currently desirable by the CTBTO. In addition, the availability of nuclear reactors is unpredictable, requiring long lead times and considerable planning. This work proposes the investigation of several new experimental routes to produce Ar-37 via the utilization of electron LINAC-generated bremsstrahlung photons.

Research Plan:

Specific Aim 1: Determine expected activities and initial accelerator parameters.

Extensive modeling will be performed to estimate initial accelerator beam energies, irradiation times, and experiment geometries. The modeling will help determine if irradiations should be conducted at higher beam energies to include additional Ar-37 producing reactions or build production gradually at lower beam energies. Modeling will be performed to estimate expected activities using predicted material geometries, purities, chemical compositions, and irradiation parameters. Expected activities will be used to resolve shipping for radioactive packages returning to INL.

Specific Aim 2: Resolve x-ray detection procedures.

The vacuum sealed custom detection chamber will be designed and fabricated to include ports for gas input/output. Schematic representations will be drafted. Fabrication will be determined based on the optimal material chosen. Testing of the chamber will be conducted for verification of gas transfer and detection quality. There are no commercially available calibration sources with energies in the range of 2.8 keV, therefore project researchers will determine a method to calibrate and measure x-ray detector efficiency. If necessary, a program will be coded to read and parse files generated by the x-ray detector. Following irradiation, detection of argon samples will take place at a department laboratory at the INL Research Center (IRC).

Specific Aim 3: Optimize argon gas collection and transfer.

Creation of argon targets will be optimized based on irradiation pressure requirements to minimize residual argon loss. Custom irradiation ampules will also be designed and fabricated. Gas collection methods and custom flame seal of the ampules will occur at the IRC 611-104.

Specific Aim 4: Irradiate samples and perform post-irradiation analysis.

Sample holders will be designed and fabricated. Samples will be filled at INL's Materials and Fuels Complex and shipped to the Idaho Accelerator Center (IAC). Multiple sample irradiations will be performed at the IAC where optimal irradiation times and accelerator beam parameters will be determined. The automated system and HPGe detector will be provided by the IAC for K-37 detection. Post-irradiation analysis on K-37 decay will be conducted if applicable.

Specific Aim 5: Characterize Ar-37.

Data obtained through x-ray spectroscopy will be analyzed in real-time as well as following sample detection. Comparisons will be made with pre-irradiation modeling and calculations. If applicable, mass spectrometry will be utilized to further characterize Ar-37 production at INL's IRC.

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

Emissions of small amounts of radioactive gases will occur. These emissions are covered in the APAD for the IRC complex.

Discharging to Surface-, Storm-, or Ground Water

N/A

Disturbing Cultural or Biological Resources

N/A

Generating and Managing Waste

Some gaseous byproducts are contained in the argon sample. When the sample is no longer needed it will be allowed to decay and be vented out the exhaust system.

Releasing Contaminants

When chemicals are used during the project there is the potential for spills that could impact the environment (air, water, soil).

Using, Reusing, and Conserving Natural Resources

Project personnel will contact WGS to identify waste streams, handling, storage, and disposal requirements. All applicable waste will be diverted from disposal in the landfill when possible. Project personnel will use every opportunity to recycle, reuse, and recover materials and divert waste from the landfill when possible. All waste generated will be transferred to the WGS organization for appropriate disposition.

SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification:
Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not “connected” to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

References:
10 CFR 1021, Appendix B, B3.6, "Small-scale research and development, laboratory operations, and pilot projects" and B3.10 "Particle accelerators".

Justification:
The proposed R&D activities are consistent with CX B3.6 "Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); small-scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions, provided that construction or modification would be within or contiguous to a previously disturbed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment;" and

B3.10 "Siting, construction, modification, operation, and decommissioning of particle accelerators, including electron beam accelerators, with primary beam energy less than approximately 100 million electron volts (MeV) and average beam power less than approximately 250 kilowatts (kW), and associated beamlines, storage rings, colliders, and detectors, for research and medical purposes (such as proton therapy), and isotope production, within or contiguous to a previously disturbed or developed area (where active utilities and currently used roads are readily accessible), or internal modification of any accelerator facility regardless of energy, that does not increase primary beam energy or current. In cases where the beam energy exceeds 100 MeV, the average beam power must be less than 250 kW, so as not to exceed an average current of 2.5 milliamperes (mA).

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act) ☐ Yes ☒ No

Approved by Jason Sturm, DOE-ID NEPA Compliance Officer on: 9/10/2020