Radiation Physics and Chemistry 245 (2026) 113843

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

"KATIL" dissolution station for medical radiometals production using solid targets

Ruben Dallakyan [a], Andranik Manukyan [a,*], Armine Grigoryan [a], Davit Arshakyan [a], Kim Hovhannisyan [a], Nikolay Dobrovolski [a], Francisco Alves [b]

[a] AANL - A. Alikhanyan National Science Laboratory, Alikhanyan Brothers Street, 2, 0036, Yerevan, Armenia
[b] ICNAS - Institute for Nuclear Science Applied to Health, Azinhaga de Santa Comba, 3000-548, University of Coimbra, Coimbra, Portugal

ARTICLE INFO

Keywords:
Cyclotron
Solid target
Isotope production
Dissolution
Production automation

ABSTRACT

A standalone dissolution system for coin-type solid targets, named KATIL, was evaluated. 290 mg natural zinc target for $^{68}Zn(p,n)^{68}Ga$ production was used for the test. The target was irradiated for 1 min at 1.1 μA intensity, and 12.3 MeV (after the degrader) energy of the proton beam from an IBA C18 cyclotron, and complete dissolution was achieved within a maximum of 10 min using 6 - 10 M HCl. The calculated activity, based on gamma spectroscopy, was 30 MBq of ^{68}Ga.

KATIL is designed to operate with existing solid target modules, such as NIRTA Compact or a similar design module, enabling automated post-irradiation dissolution directly in the irradiation vault and eliminating the need for manual transport of a shielded container with irradiated targets. The system consists of a lead-shielded control unit and an apparatus unit equipped with pneumatic valves, a 3-way solenoid valve, a peristaltic pump, and a Teflon dissolution chamber.

This system enables the advantages of solid targets to be fully utilized while significantly simplifying the transfer of irradiated material to the hot cell. The KATIL allows dissolution of a range of solid targets, such as Zn, Mo, Y, and Ni for medical radiometals production.

1. Introduction

Medical isotopes have been produced for decades using three main types of target materials: liquid, gas, and solid. Compared to solid targets, the production processes involving liquid and gas targets are generally simpler. In these cases, the operator primarily initiates and controls the transfer of the target material before and after irradiation through automated lines connected to the target station, typically via a computer interface. Meanwhile, solid targets lead to higher production activities of the final radioisotope, reducing the amount of expensive enriched material used for target preparation.

In contrast, the use of solid targets presents additional challenges. For example, in the case of NIRTA-type modules (Nirta Solid Compact Model TS06) offered by IBA, the operator must manually load the target before the irradiation. After bombardment, the irradiated target is automatically unloaded into a shielded container within the cyclotron bunker. However, the container remains inside the bunker until the radiation dose rate decreases to safe levels, often requiring a considerable waiting period. This delay makes the approach impractical for the routine production of short-lived radionuclides.

Some manufacturers have proposed capsule-based transfer systems for solid targets (ALCEO Solid Target Processing System; Pneumatic Target Transfer System Model). These systems rely on vacuum transfer lines installed within dedicated trenches or conduits to prevent capsule obstruction during transportation. More recently, other companies have introduced integrated target systems that combine the solid target module with an in situ dissolution unit (Gelbart and Johnson, 2019; D.O. T.S. target). Such designs enable the operator to dissolve the irradiated target material directly within the module and transfer the resulting solution to the hot cell, eliminating the need for manual handling and reducing radiation exposure.

However, these integrated systems require purchasing entirely new equipment, which may not be feasible for facilities already equipped with solid target modules.

This article is part of a special issue entitled: ASRP 2025 published in Radiation Physics and Chemistry.

* Corresponding author.
E-mail address: a.manukyan@aanl.am (A. Manukyan).

https://doi.org/10.1016/j.radphyschem.2026.113843
Received 11 December 2025; Received in revised form 20 February 2026; Accepted 22 March 2026
Available online 23 March 2026
0969-806X/

To address this challenge, a standalone dissolution station, named KATIL, for coin-type solid targets, was developed. This system can be installed directly beneath existing target modules, such as the NIRTA or similar designs (Fig. 1). The KATIL unit connects to the hot cell through capillary PTFE tubing, allowing safe and efficient transfer of the dissolved target solution. The system is nearly maintenance-free, utilizes readily available and inexpensive components, and can be easily integrated into existing infrastructure without significant modifications.

The system was developed for ^{68}Ga isotope production using zinc pressed-powder solid targets, but it can also be applied to the targets for many other isotopes. ^{68}Ga has a short half-life of 68 min, which makes rapid organization of the production process even more critical. With a dissolution system of this type for solid targets, the overall workflow is accelerated by 0.5–1 h compared with the previous method, which required manually removing the shielded container from the vault. This improvement helps to avoid significant decay losses of the ^{68}Ga.

2. Materials and methods

The KATIL system consists of two main components: the control unit (Green, lower part) and the apparatus unit (upper white part), separated by an aluminum plate (Fig. 2). Potential neutron-induced damage to the system was considered; however, due to the high energies of neutrons generated in the target and surrounding materials, effective neutron shielding would require excessive thickness. Therefore, the shielding design provides protection at least against gamma radiation, and the control unit is shielded with a 5 mm lead layer for control electronics protection.

The apparatus unit houses the pneumatic control system, including electromagnetic valves for the pneumatic lines, a three-way valve, and a peristaltic pump. The system is installed directly under the NIRTA solid target module. After irradiation, the NIRTA module releases the target, which drops into a 3D-printed guiding mechanism. This guider positions the target precisely in front of the dissolution chamber, where a pneumatic "finger" secures it in place.

Once the target reaches its designated position, pneumatic cylinders close the dissolution chamber tightly, forming a hermetically sealed compartment where the target itself serves as one of the chamber walls. The chamber is fabricated from Teflon (PTFE), chosen for its excellent chemical resistance and sealing properties, making it an ideal material for handling corrosive acids during dissolution.

Following chamber closure, the peristaltic pump initiates circulation of a preloaded acid solution from a sealed vial through the dissolution chamber and back into the same vial. The process continues until the target material is completely dissolved. A disk-type metal–ceramic heater is located behind the target position, allowing controlled heating of the acid when necessary to accelerate dissolution.

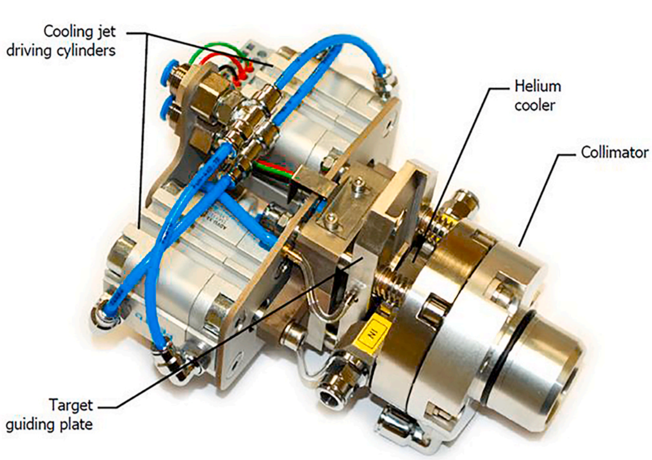

Fig. 1. Nirta compact solid target module, IBA, Belgium.

After complete dissolution, the resulting radioactive solution is automatically transferred via Teflon tubing to the hot cell for subsequent radiochemical processing.

As a test configuration, a target was prepared by pressing 290 mg of natural zinc powder (Goodfellow, 7.5 μm average particle size) onto a niobium target holder with a 30 kN force. The dimensions of the target are as follows: a 24 mm diameter, 2 mm thick target holder containing a central recess with a 12 mm diameter and 1 mm depth (Fig. 3). These parameters of the target holder were selected to meet the requirements of the NIRTA system. The mass of the pressed Zn is determined to degrade the proton beam energy from an incident 12.3 MeV to 4.5 MeV. Using a thicker Zn target material is not meaningful, as the ^{68}Zn(p, n)^{68}Ga reaction cross-section decreases. As a target holder material, Niobium was chosen because of its inertness to hydrochloric and nitric acids and, therefore, does not contaminate the final product.

3. Results

The developed KATIL system demonstrated ease of operation. The main structural components are fabricated from aluminum and acrylic. At the same time, all tubing is made from PTFE or Viton, materials commonly used for seals and transfer lines in commercial liquid target systems.

The selected valve employs a quartz stator, providing an exceptionally low dead volume - on the order of a few μl, thereby minimizing material loss and contamination risk. Importantly, no seals are present in the path of the radioactive solution, effectively eliminating the possibility of leakage in the event of mechanical damage.

The system's performance was evaluated during ^{68}Zn(p,n)^{68}Ga production experiments. Dissolution was performed using 6 - 10 M HCl, due to the requirements of the Triskem ZR separation resin. The complete dissolution was achieved within a maximum of 10 min under the 20 °C ambient temperature. The following results for dissolution durations were achieved: 6 M HCl – 10.5 min, 8 M – 10 min, 10 M – 4 min. In all cases, the target material was 290 mg, and the HCl circulation flow rate was 0.8 ml/s. In case of routine production of ^{68}Ga, depending on the demand of patient's dose, the maximum mass of the Zn target is 100 mg. It means less time for dissolution.

During the cold (non-irradiated) tests, it was also noticed that metallic Zn foil with the same mass located in the same Niobium target holder dissolves faster than the pressed powder (6 M HCl – 3 min). We suppose the reason of powder's slower dissolution is probably the oxidation of the particles and the chemical reaction's products stucking between powder particles, slowing down the process.

Irradiation implemented under the following conditions: incident proton beam energy - 12.3 MeV after the degrader, irradiation duration - 1 min, beam Intensity - 1.1 μA.

At the Radioisotopes Production Center CSJC, where the cyclotron is installed, there are two vaults, one for the cyclotron and routine production, and the second one for the beam transport line, where our experiments were conducted. The KATIL system was installed under the solid target module only during the test production. After the irradiation, the dissolved target of 10 ml was transferred to the hot-cell via 0.8 mm inner diameter 30 m PTFE tube. After the transfer, the volume was 9.3 ml, which means that the loss is 7 % for the total procedure. The calculated activity of ^{68}Ga at EOB was 30MBq taking into account the 7 % of loss. The measurement was conducted with an ORTEC HPGe gamma spectrometer, using the 1077 keV gamma line of ^{68}Ga.

The system has been under continuous testing for approximately one year, mainly using non-irradiated natural zinc targets, but also during some test irradiations as described above. The conducted hot tests were with low produced activity, not for patient use. Throughout this period, only minor upgrades were implemented, and no maintenance was required.

The system was also tested with various target holder designs,

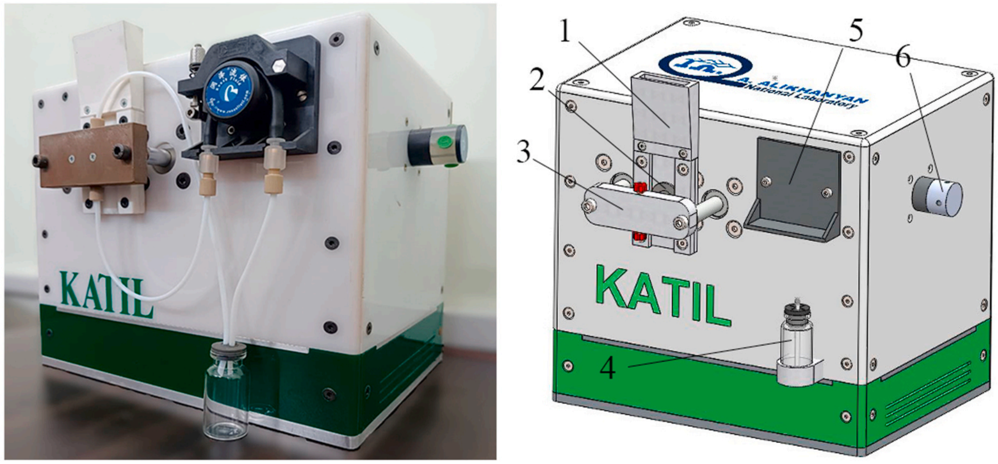

Fig. 2. KATIL Dissolution Station and. 1 – target guider, 2 – target's final position, 3 – dissolution chamber, 4 – Preloaded acid solution/dissolved target material vial, 5 – peristaltic pump. 6 – three-way valve.

Fig. 3. Pressed natural zinc powder onto a niobium target holder.

including the locally inclined target (LIT) holder developed in our laboratory (Dallakyan et al., 2024, 2025; Avetisyan et al., 2024), and demonstrated full compatibility and stable operation in all configurations.

4. Discussion and summary

The KATIL system is a standalone dissolution system for coin-type solid targets. for medical radioisotopes routine production. The system successfully addresses one of the key challenges associated with solid target production method of medical radionuclides - by dissolving of the solid target at the target vault, and safe and fast transfer to the hot-cell. Its electronic control module is protected with a 5 mm lead shield. All tubes and valve's inner parts are from chemically inert materials, and have very low dead volume. KATIL was tested during the test production of the ^{68}Ga, using 290 mg of natural zinc pressed powder solid target. The dissolution process lasted a maximum of 10 min, which is important for the short-lived radionuclide production.

By combining the KATIL dissolution unit with the Locally Inclined Target (LIT) holder**,** the production workflow becomes significantly more efficient. The KATIL system minimizes radiation exposure to personnel, reduces downtime between irradiations, and enables faster chemical processing.

5. Limitations

The present work was performed under relatively short irradiation durations and low beam currents; therefore, additional studies under higher irradiation loads and routine production conditions are required to fully evaluate the scalability and long-term operational robustness of the system. Furthermore, although the control unit demonstrated adequate performance during the experiments, extended testing under higher radiation doses will be necessary to confirm the control unit's reliability for broader operational scenarios. It should be noted that the KATIL system is designed to operate within the beamline vault associated with solid target irradiation rather than in the main cyclotron vault used for F-18 production.

CRediT authorship contribution statement

Ruben Dallakyan: Writing – review & editing, Supervision, Funding acquisition. **Andranik Manukyan:** Writing – original draft, Resources, Methodology, Investigation, Conceptualization. **Armine Grigoryan:** Writing – review & editing. **Davit Arshakyan:** Investigation. **Kim Hovhannisyan:** Investigation. **Nikolay Dobrovolski:** Investigation, Formal analysis. **Francisco Alves:** Supervision.

Funds

The research was supported by the Higher Education and Science

Committee of MESCS RA (Research project No. 24LCG-2G028) and IAEA Coordinated Research Project F22073 "Production of cyclotron-based Gallium-68 radioisotope and related radiopharmaceuticals" - "Development of Gallium-68 Radioisotope at AANL (YerPhI) under C18 Proton Beam of Armenian Cyclotron".

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

References

ALCEO solid target processing system. Available online: https://www.comecer.com/alceo-solid-target-processing-system/#product_finder.
Avetisyan, A., Dallakyan, R., Dobrovolski, N., et al., 2024. Numerical modeling of cooling processes of a locally inclined target with a Nirta solid compact target module. J. Contemp. Phys. 59, 1–10.
Dallakyan, R., Dobrovolski, N., Grigoryan, A., et al., 2024. Influence of the target holder material on the cooling processes of locally inclined targets in the Nirta solid compact target module. J. Contemp. Phys. 59, 129–137.
Dallakyan, R., Dobrovolski, N., Grigoryan, A., et al., 2025. Analysis of thermal characteristics of locally inclined targets under irradiation by proton beams with a gaussian current distribution. J. Contemp. Phys. 60, 1–7.
D.O.T.S. target. Available online: https://dots-target.com/.
Gelbart, W.Z., Johnson, R.R., 2019. Solid target system with In-Situ target dissolution. Instruments 3, 14.
Nirta solid compact model TS06. Available online: https://elexcomm.com/product/539d84643beb6ec14b00000d.
Pneumatic target transfer system model PT02. Available online: https://elexcomm.com/product/5da052fad755896167f4536f.