22nd IGORR

Activation Test of High-Density MoO_3 Pellets for Production of ^{99}Mo Using Multipurpose Research Reactor (RSG-GAS)

June2025

Koichi Mimura, CTC

Badan Riset dan Inovasi Nasional（BRIN）
and Chiyoda Technol Co. (CTC)

BRIN

Herlan Setiawan[1], Rohadi Awaludin[1], Tita Puspitasari[1], Marlina[1], Indra Saptiama[1], Miftakul Munir[1], Moch Subechi[1], Chaidir Pratama[1], Ahid Nurmanjaya[1], Arni Aries[1], Anis Rohanda[1]

1: Research Center for Radioisotope, Radiopharmaceuticals and Biodosimetry Technology, National Research and Innovation Agency, BRIN, Indonesia.

Endang Sarmini[2], Daya Agung Sarwono[2]

2: Directorate for Nuclear Infrastructure Management, National Research and Innovation Agency, BRIN, Indonesia.

CTC

○Koichi Mimura, Akio Ohta, Takashi Saito, Takashi Ishii, Kazutaka Tottori, Hiroshi Kawamura, Ataru Inoue, Toshikazu Hosoda

Significance and Purpose of Joint Irradiation Tests

Currently, 100% of the radioisotope ^{99}Mo (^{99m}Tc), which is used by about 1 million people annually as a radioisotope for cancer diagnosis in Japan, is the most widely distributed radioisotope in Japan. In addition, since about 1 million cancer patients occur annually in Japan, this radioactive isotope is positioned as an essential drug from the perspective of security to protect the safety and security of the people of Japan. For this reason, it has become indispensable to be able to stably import 99Mo in an emergency (stabilization by diversifying import destinations) and to partially localize the product.

From this point of view, we attempted to verify the technical feasibility of importing 99Mo using a research reactor (RSG-GAS reactor) owned by Indonesia with Indonesia, which has established a friendly cooperative relationship so far, while conducting irradiation tests. The results are reported jointly by BRIN and CTC.

Position between Indonesia and Japan

There are several direct flights a day.

Soekarno-Hatta International Airport (Jakarta) is about 40 km far from the institute.

As a member of the Global South, it is a very important country.

Flow of irradiation test

CTC (Japan)

MoO$_3$ Pellet Production

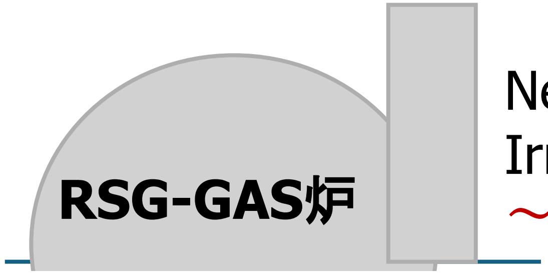
↓

Inner Capsule Fabrication

Thermal Calculation

Export →

BRIN (Indnesia)



Neutrogen Irradiation
～100 h at 5MW

Nuclear Calculation

↓

Irradiated Capsule removal and dismantling

↓

Irradiated MoO$_3$ pellet dissolution

After removing the ampoule containing irradiated MoO$_3$ pellets from the reactor,A minimum of 3 days is required according to the procedures set by the country.

Therefore, it is 4 days later at the earliest to arrive at the hot facility in JRIA.

Since the end of irradiation (EOI) is on Friday, then capsule removal and dismantling can be done on Monday. While if the EOI ends on Monday/Tuesday, the process of can be done one day after.

MoO_3 Pellet Production

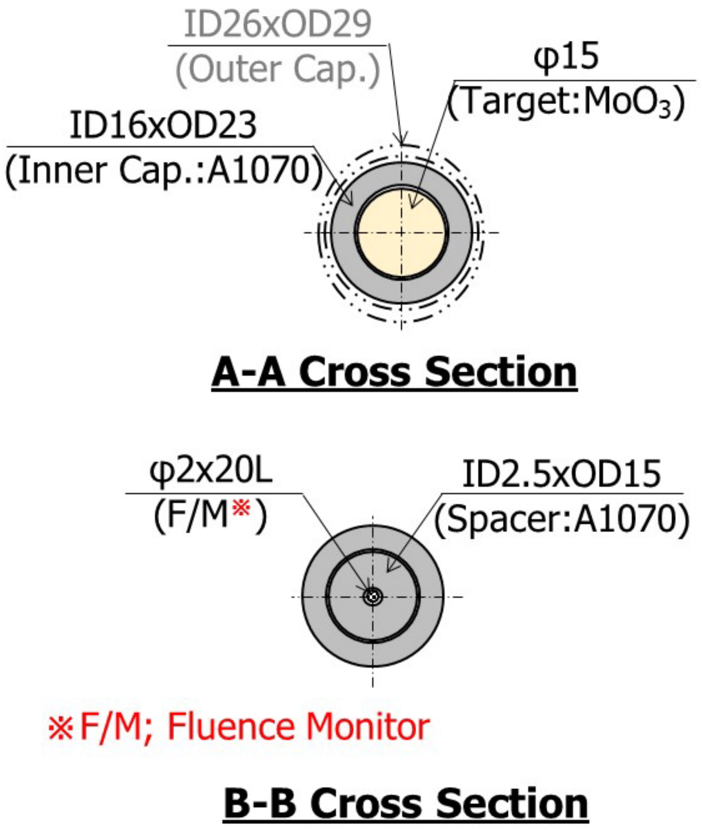
	Natural Pellet		Enriched Pellet	
Name	N1	N2	E1	E2
^{98}Mo Enrichment (%)	25		50	
Quantity (piece)	2		2	
Sintering Density (T.D.)	94.1	94.0	93.7	93.8
Diameter (mm)	14.995	15.003	15.011	15.008
Height (mm)	9.949	10.144	10.328	9.976

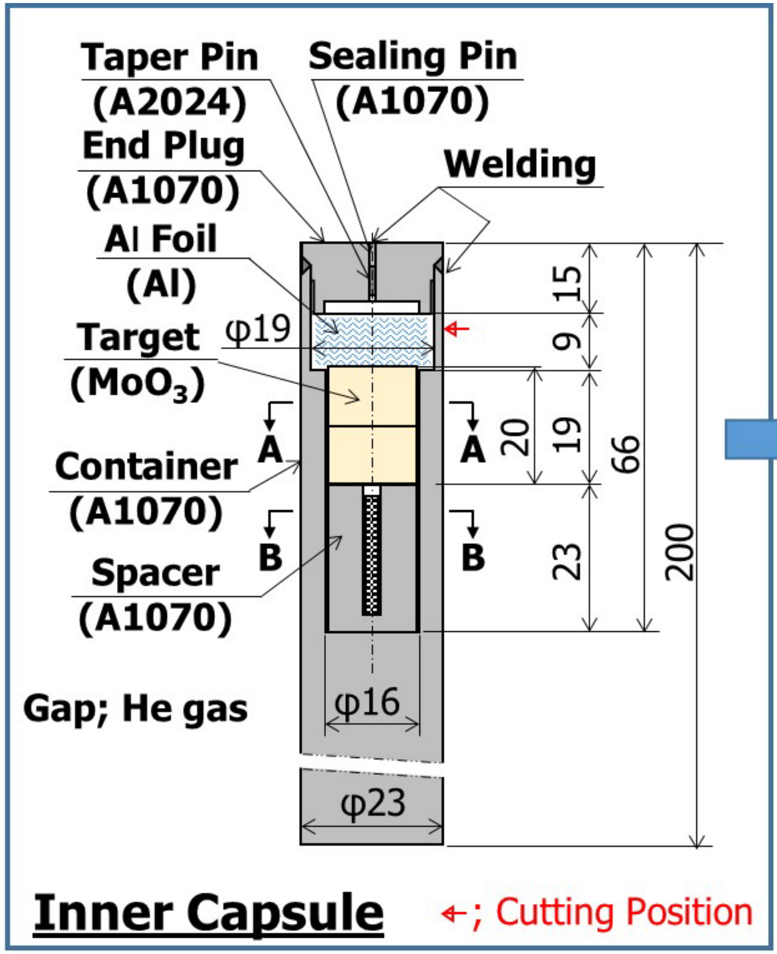
○Two pellets were each loaded into one inner capsule.

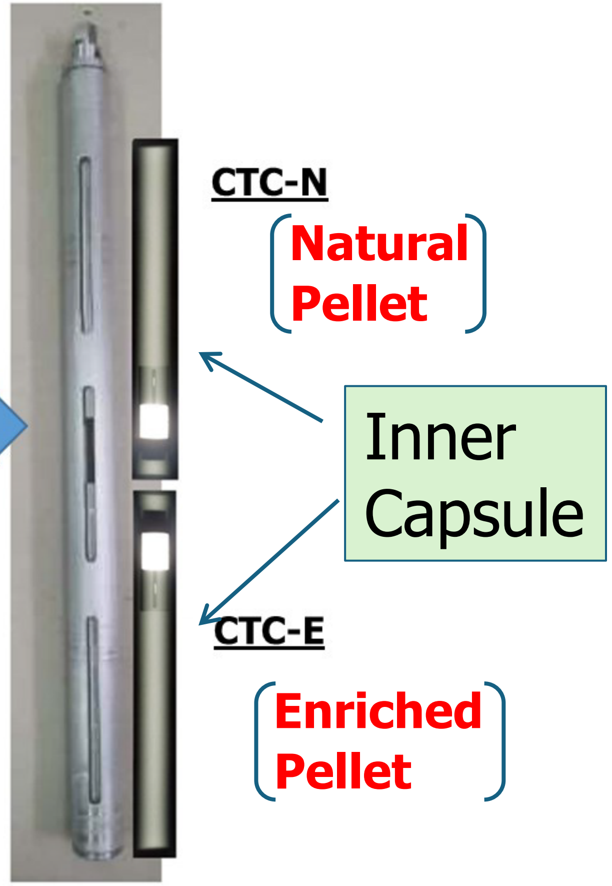
○As a manufacturing method, Spark Plasma Sintering Method was used.

○After sintering, in order to convert MoO_2 on the pellet surface to MoO_3, pre-calcination is performed, and after pre-calcination it is verified that MoO_2 is not present by X-ray diffraction.

Capsule Outline







The outer surface of inner capsule contact to the flowing water on the pool due to the ventilation hole on the design of outer capsule

Flow rate of primer cooling water : 3.150 m^3/h, Water temperature: 28.5 °C

Thermal neutron flux : 4.2 $x10^{13}$ $/cm^2s$

Thermal Calculation of Irradiation Capsule

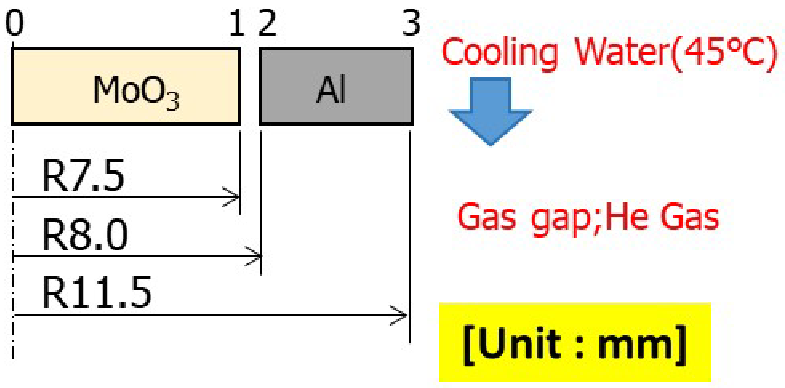
(1-D Calculation Code : GENGTC)

◆ Calculation Conditions

Item	Function	Data
Heating Conditions	γ Heating Rate (Reactor power:5MWt)	1.03【MoO_3】, 0.831【Al】 (W/g)
Cooling Conditions	Temp. of Cooling Water	45 (°C)
	Surface Heat Transfer Coefficient	0.0116 (W/mm^2/°C)
Specimen Properties (MoO_3;95%TD)	Density	4.5E-3 (g/mm^3)
	Thermal Conductivity	$3.74E\text{-}3 - 9.96E\text{-}6 \cdot T + 2.64E\text{-}8 \cdot T^2$ (W/mm/°C)
	Thermal Expansion	1.343×1.0E-6 (/°C)
Properties of Al and He gas		Data in GENGTC code

GENGTC ; Generalized Gap Temperature Calculation

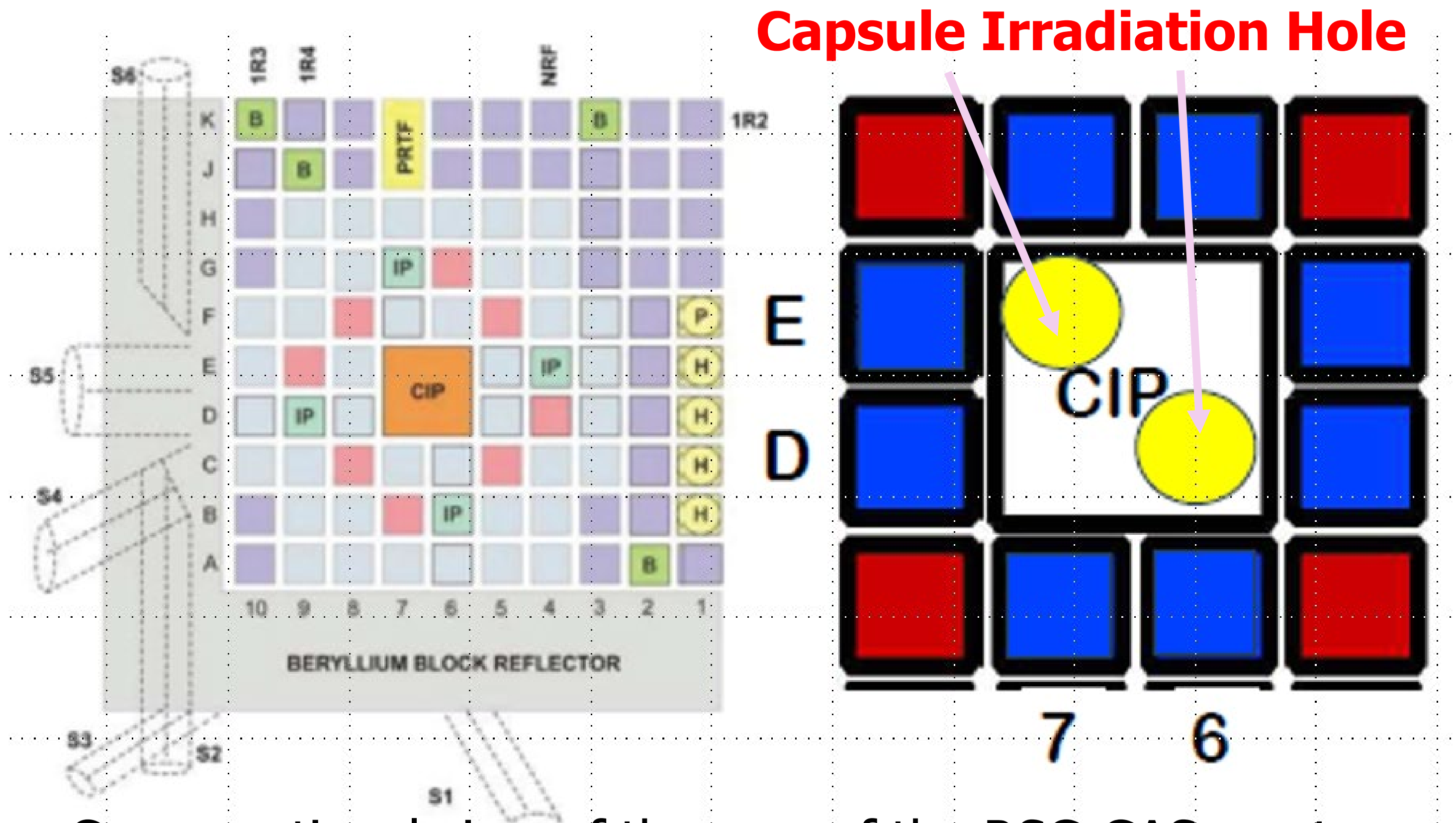
◆ Calculation Model for 1-D Thermal Calculation



Node No.	Part Name	Temperature(°C)
0	Center of Pellet	119.2
1	Surface of Pellet	97.5
2	Inner Surface of Container	46.8
3	Surface of Container	46.5

Neutron Irradiation Information

BRIN was established in 2021 by integrating the policy research departments of Indonesian government-affiliated research institutes and ministries and agencies, such as the former Indonesian Academy of Sciences and the former Indonesian Agency for Technology Evaluation and Application.



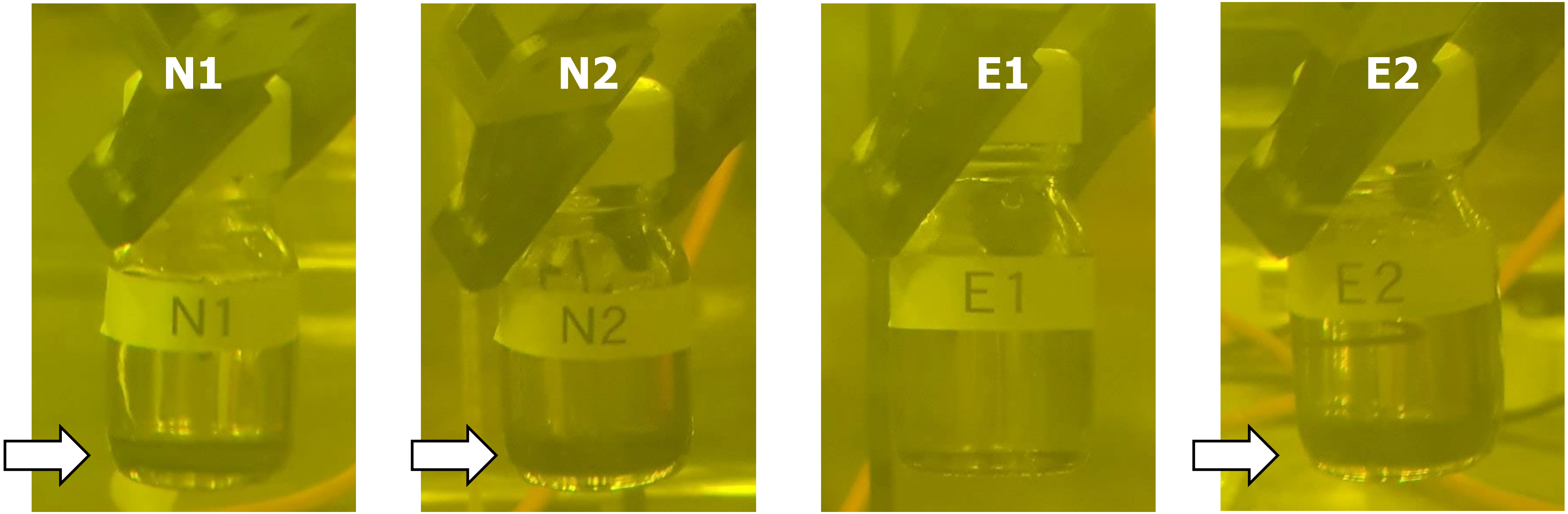
Cross-sectional view of the core of the RSG-GAS reactor

Our capsule was irradiated in position E7

Item	Contents
Rated power(MW)	30
Neutron flux ($n/cm^2/s$)	2×10^{14}
Coolant	Light water
Fuel elements	MTR
Fuel Material	U_3Si_2Al
Number of basic fuel elements	40
^{235}U enrichment rate (%)	19.75
^{235}U density (g/cm^3)	2.96
Reflective materials	Be

Observation of irradiated MoO3 pellet lysate

Dissolved liquid：30 mL 6M-NaOHaq



Only E1 was transparent, however the other solutions were black residue MoO_2 ? (⇨ part) was observed. The insoluble precipitate is thought to be the result of MoO_3 reduction. Some literature mentions the possibility of the formation of the transition compound Mo_4O_{11} before MoO_2. However, this is still not known for sure, further investigation is still needed.

Evaluation of the amount of ^{99}Mo produced in MoO_3 pellet solution

Pellet No.		N1	N2	E1	E2	E/N
^{98}Mo Enrhment (%)		25		50		(50/)
Weight [g]		7.72	7.87	7.75	7.97	—
^{99}Mo Activity Measurement	(mCi)	1640.2	1671.6	3064.0	3271.6	—
	M (mCi/g)	212	212	395	411	1.90 (403/212)

Currently, the calculated values are obtained by nuclear calculations using MCNP and ORIGEN.

Summary

○ Joint activities between BRIN and CTC will allow us to share each other's technologies and experience and build a strategic partnership. It was able to gain a foothold. In addition, we would like to promote the exchange of views toward the establishment of effective and efficient cooperative relationships.

○ Specifically, with regard to the production of ^{99}Mo solution, from the acceptance of irradiation capsule by BRIN to neutron irradiation, It was confirmed that each process such as capsule dismantling and MoO_3 pellet melting can be performed smoothly and accurately.

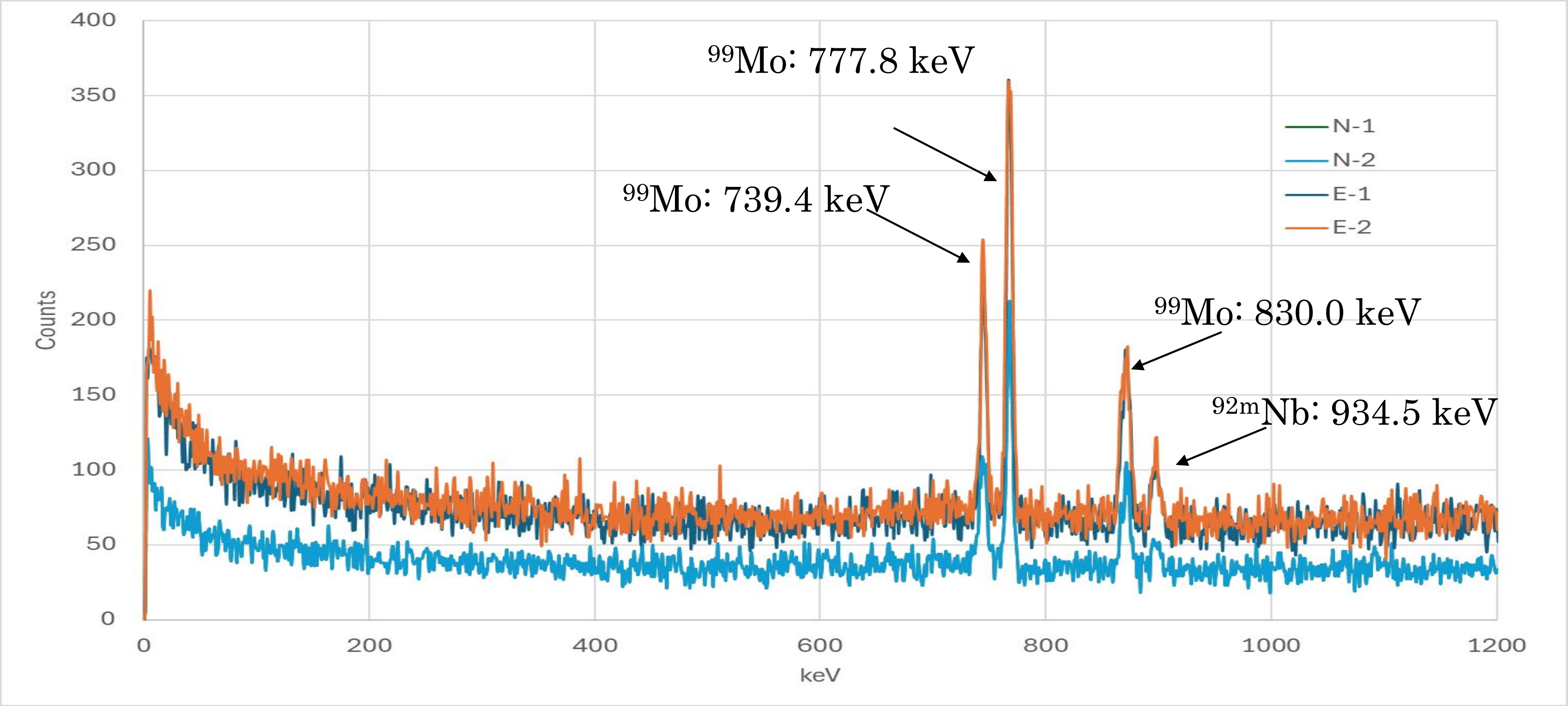
○ In order to actually start ^{99}Mo solution production, it is necessary to consider the following items.

◆Demonstration of irradiation capsule fabrication technology in Indonesia
◆Checking the accuracy of thermal calculations of irradiation capsule performed by BRIN
◆Raw material quality inspection of ^{99}Mo solution by a pharmaceutical company in Japan
◆Improvement of annual operating rate for stable supply (70~80% target)
◆Detailed confirmation of the evaluation accuracy of the amount of ^{99}Mo produced when irradiating the 98Mo concentrated material

付録

（2）BRIN -MoO3ペレット溶解試験-

・不純物測定（カウント数の高い低エネルギー側を鉛で遮蔽した場合）



Mo由来以外の放射性物質はできていない。^{92}Mo(n,p) ^{92m}Nb

（参考） BRIN -MoO_3ペレット溶解試験-

・不純物測定(低エネルギー側)