LOW-BACKGROUND RADIOCHEMISTRY TECHNIQUES FOR EXTREMELY RARE-EVENT PHYSICS SEARCH

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Motivation & Highlights

- *Radioanalytical chemistry methods and techniques have recently been widely involved in very low-level radioactivity measurements for physics experiments searching for extremely rare events such as double-beta decay, rare nuclear decays, and dark matter.*
- *All experiments searching for events with elusive rates are bound by the unavoidable* ***necessity to reduce to zero background levels and enlarge a target material*** *to identify feeble signals.*
- *For studying the 0νββ decay at* $\langle m_\nu \rangle$ *= 10–30 meV, a recent generation of experiments dealing with 100kg-scale detectors. To study the range of* $\langle m_\nu \rangle$ *< 10 meV, new, more sensitive experiments with* ***the mass of the investigated isotope ~ 1–10 tonnes (***$\langle m_\nu \rangle$ ***= 3–10 meV) are required****.*
- *New experiments with masses of the studied isotope of interest for one tonne or more will require a* ***background index of approximately*** $5 \cdot 10^{-6}$ ***ckky.***
- *Controlling and monitoring the required* ***radiopurity in the target material and its purification and recycling*** *requires the development and involvement of radiochemical methods of purification and separation.*
- *The construction of the detector itself, its peripheral sub-systems and shieldings needs* ***the development of special surface cleaning procedures and highly-sensitive radio-assay methods.***

Purification & Recycling of $^{100}MoO_3$ for AMoRE-II

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Batch #	Al [ppm]	K [ppm]	Fe [ppm]	Ni [ppm]	Cu [ppm]	Ti [ppm]	Cr [ppm]	Sr [ppb]	Ba [ppb]	Pb [ppb]	Th [ppt]	U [ppt]
Projected requirements												
	<1	<1	<1	<1	<1	<1	<1	<1	<3	<1	<10	<10
Purified powder (over 100 produced batches). ICP-MS @ CUP												
Range, min - max	< 0.1 - 0.6	< 0.2 - < 0.5	< 0.05	< 0.05	< 0.2	< 0.2	< 0.2	< 0.2	< 4	< 0.5	< 2.3	< 4

	^{228}Ac	^{228}Th	^{226}Ra	^{40}K
	HPGe array @ CUP [μBq/kg]			
Raw $^{100}MoO_3$	260 ± 50	210 ± 50	260 ± 50	8500 ± 1400
Purified $^{100}MoO_3$	< 27	< 16	110 ± 30	1700 ± 340

- Efficient purification method developed
- Clean chemical facilities and equipment designed and installed
- ~150 kg of $^{100}MoO_3$ powder was purified at CUP within the last 3 years
- ~99% production efficiency, 1% irrecoverable losses
- 50 kg per year is the current capacity
- Could be easily enlarged to over 100 kg per year

Th and U assay at sub-ppt level

Copper bulk samples	Th, ppt	U, ppt
NOSV 2014 (October, 2019 meas.)	4.3 ± 0.29	1.66 ± 0.04
NOSV 2014 (May, 2019 meas.)	5.13 ± 1.2	1.55 ± 0.7
NOSV 2016	**0.34 ± 0.12**	**0.29 ± 0.04**
NOSV 2021	**0.26 ± 0.01**	**0.29 ± 0.06**
OFE Mitsubishi	2.19 ± 0.21	1.28 ±0.19
OFE Aurubis 2018	0.98 ± 0.08	1.01 ± 0.05
OFE Aurubis 2021	0.98 ± 0.14	0.83 ± 0.11
OFE Wonil 2023 ROK	0.75 ± 0.15	0.43 ± 0.12

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- Selective to Th and U solid phase extraction method was developed using UTEVA Eichrom resin
- Methods were applied to copper and $^{100}MoO_3$ samples and measured with ICP-MS at CUP
- ~0.1 ppt detection limit for Th and U in copper
- ~1 ppt detection limit for Th and U in molybdenum samples

Surface purity control

	Th, ppt	U, ppt
Cu Sensor holders		
Raw material NOSV 2021	**0.26 ± 0.01**	**0.29 ± 0.06**
Machined after surface cleaning	**0.34 ± 0.09**	**0.41 ± 0.08**
Brass Screws, Sanco company, Korea		
No cleaning brass	**89.25 ± 0.39**	**20.75 ± 0.56**
Sonication with ethanol	**5.69 ± 0.14**	**1.39 ± 0.15**
HNO_3 etching	**1.43 ± 0.13**	**0.49 ± 0.12**

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