Safe Operating Procedure

(Revised 06/29/2021)

SAFETY PROTOCOL: KrSTC / PNNL KRYPTON SOURCE

Part A: Source Description

The source in use at CENPA consists of an airtight ampule filled with zeolite beads impregnated with ^{83}Rb, encased in a lead shielding brick. The source outlet is a VCR-type flange enabling the daughter isotope, ^{83m}Kr, to be connected to a gas system. In NPL 108, this is connected to a germanium cryostat where the krypton is cryopumped onto the detector to study surface events.

The ^{83}Rb decays by electron capture with a half-life of 86 days, preferentially populating a short-lived excited state of krypton, ^{83m}Kr. The ^{83}Rb decay has a total energy of 919 keV and produces gammas and conversion electrons up to 800 keV, with the typical gamma energy 520-550 keV. The source is created by adsorbing a $RbCl_2$ solution onto the zeolite beads so the rubidium decays in place. The lead shielding is designed to attenuate the gammas to a safe level, and a bend in the gas line blocks all direct shine paths to the ampule.

The ^{83m}Kr decays by internal transition with a half-life of 1.8 hours, populating the stable ground state, ^{83}Kr. The ^{83m}Kr decay has a total energy of 42 keV, producing gammas or conversion electrons up to 32 keV. The krypton atoms in the gas phase diffuse out of the zeolite beads and fill the gas volume.

The source is manufactured at PNNL and the assembly has been designed for typical source activities of ~5 mCi. While there is no general limit to the activity of such a source, those in use on KrSTC are generally weaker than others at CENPA and typically start with ≲2 mCi of activity. ^{83m}Kr sources stronger than 10 mCi are NOT within the scope of this SOP.

Fig. 1: photo of a krypton metastable source (right) prepared for use at CENPA, with valve stem and VCR fittings visible. The lead shielding brick is covered in plastic tape to prevent unnecessary lead exposure.

Part B: General Regulatory Requirements

The following safety and security protocols must be implemented when working with krypton metastable sources:

1. All radiation workers must be at least 18 years of age and have completed required radiation safety training. **Never handle radioactive material prior to the completion of radiation safety training.** See: https://www.ehs.washington.edu/training/radiation-safety-training-%E2%80%93-online

2. All radiation workers manipulating this source must receive orientation specific to this source.

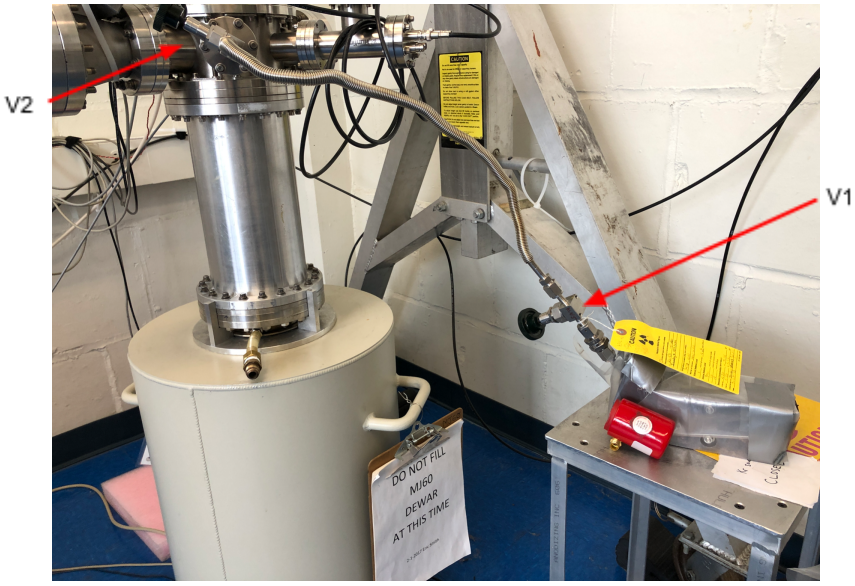
3. All research protocols involving radioactive material must be approved by CENPA.

4. Implement good ALARA practices (time, distance and shielding) to minimize exposure when using radioactive sources.

5. If required by the Radiation Safety Office, dosimeters must be worn when using or moving radioactive sources.

6. Contact Jason Detwiler (jasondet@uw.edu) and Gary Holman (holman@uw.edu) immediately if you:
    a. Find that a source has gone missing.
    b. Suspect that you have received a significant exposure to radiation.
    c. Think that any radioactive source is leaking or damaged.

Part C: LEGEND / KrSTC Source Connection and Operation Procedures



Installing/replacing the Kr source on the vacuum system:

Before installation, there may be substantial pressure built up inside the Kr source; these steps are intended to pump out any residual gases without damage to the source or the turbopump:

1. The source ships with the Kr source output valve (V1) attached, as in the photo on pg. 1. This valve should be closed initially. The knob on the valve is typically removed for shipment after closing the valve.
2. Ensure the Pfeiffer turbopump is OFF and the KrSTC vessel is not under vacuum.
3. Connect the source to the KrSTC cryostat using the VCR flexible hose, adapter and the 2 ¾" CF adapter containing the second valve (V2).
4. Turn on the Pfeiffer pump.
5. With the pump running, open the Kr source output valve V1.
6. Once the source has been pumped out, the Kr valve V1 can be opened/closed without causing significant damage to the turbopump.

Introducing Kr to the cryostat:

Once the Kr source is installed and any residual gases have been pumped away, follow the steps below to input Kr gas into the KrSTC:

1. The turbopump should be ON
2. Open the valve on the VCR hose near the cryostat (V2). Watch for vacuum spikes and close the valve if the vacuum value does not settle.
3. Open the Kr source valve near the source (V1). Watch for vacuum spikes and close the valve if the vacuum value does not settle.

Other considerations:

- Always close the source valves (V1 always, V2 as a precaution) when the source is not in use
- If the source is exposed to air, the zeolite will become contaminated and require baking. Baking the source is not covered in this SOP.
- If the source has been closed for a long time, expect significant buildup of krypton and other gases. Pump out the source with a warm cryostat to prevent excessive cryopumping to detector surfaces.

Hazards

- Radioactive hazard : This is an unsealed source, the ^{83m}Kr is in the gas phase and can be released.
    - If the source is opened to air, the zeolite will act as a getter and absorb air, blocking the channels for the Kr to escape rending the source sealed. Minimal hazard, but requires baking the source to reopen.
    - If the source is connected to a vacuum system and evacuated with a turbo and/or backing pump, this will release the source gas to the room air. Because of the short half-life and low decay energy, there is no health risk to this procedure. But this should not be the standard configuration.
- Lead hazard : The source ampule is encased in a lead shielding brick. Care should be taken in handling.
    - The lead is wrapped in thick plastic to prevent contact. Inspect the plastic when moving the source to ensure complete containment.
    - If you observe that the plastic wrap has been damaged and lead exposure possible, stop work and appropriately re-contain the lead block.