SAND2014-20051PE

Used Fuel Disposition Campaign

Potential for Gas Separation by Thermal Diffusion in the High-Burnup Demonstration Cask

Charles Bryan
Sandia National Laboratories

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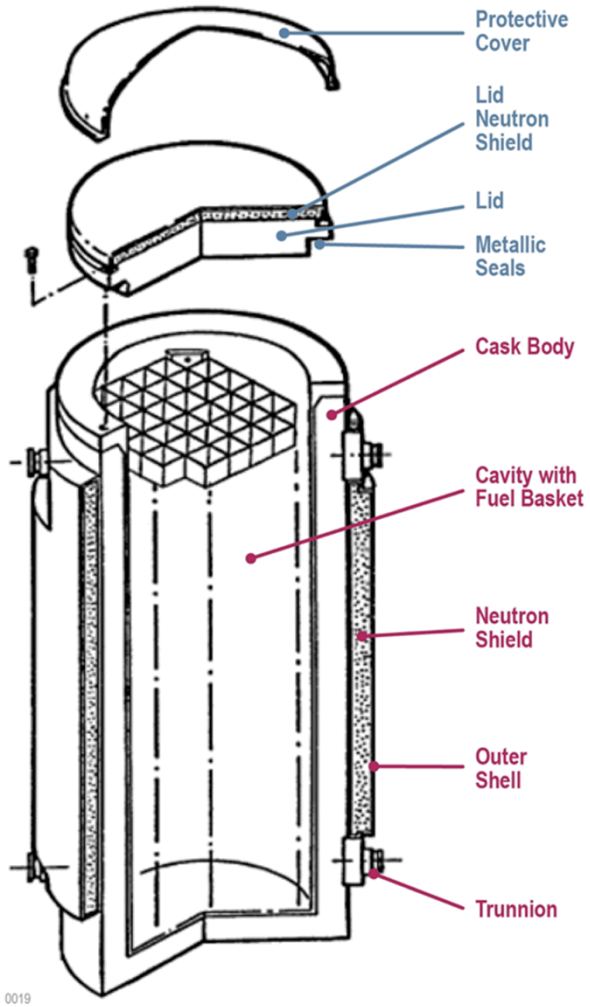
High Burn-Up Demonstration Project:
Gas Separation via Thermal Diffusion?

- Demo cask (TN-32) filled with helium
- Periodic gas sampling for Krypton as an indicator for cladding failure
- Gas samples will taken from top of the canister.
- Can thermal diffusion result in vertical compositional gradients within the canister?
- Can He and Kr be sufficiently separated by this process (He at the top) to inhibit detection of Kr?

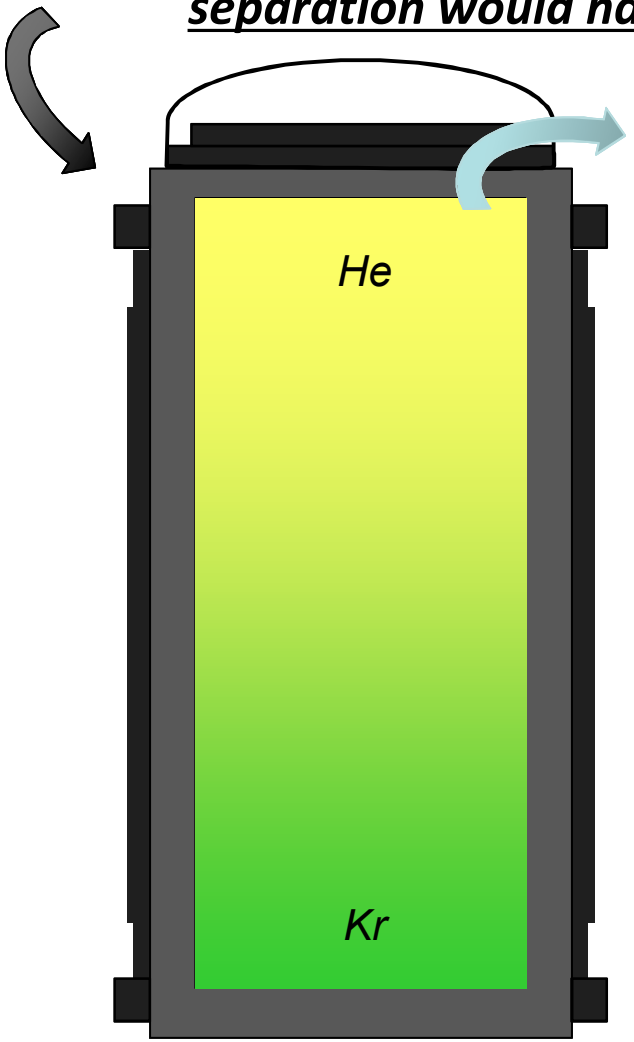
It is not necessary to quantify the amount of Kr present; it is only necessary to detect it. How much separation would be required to limit detection? What is the gas volume sampled, and what are detection limits? What are expected amounts of Kr present? *Assume a large degree of separation is necessary to affect detection.*

Relevance to the High-Burnup Demo Cask?

TN-32 cask:



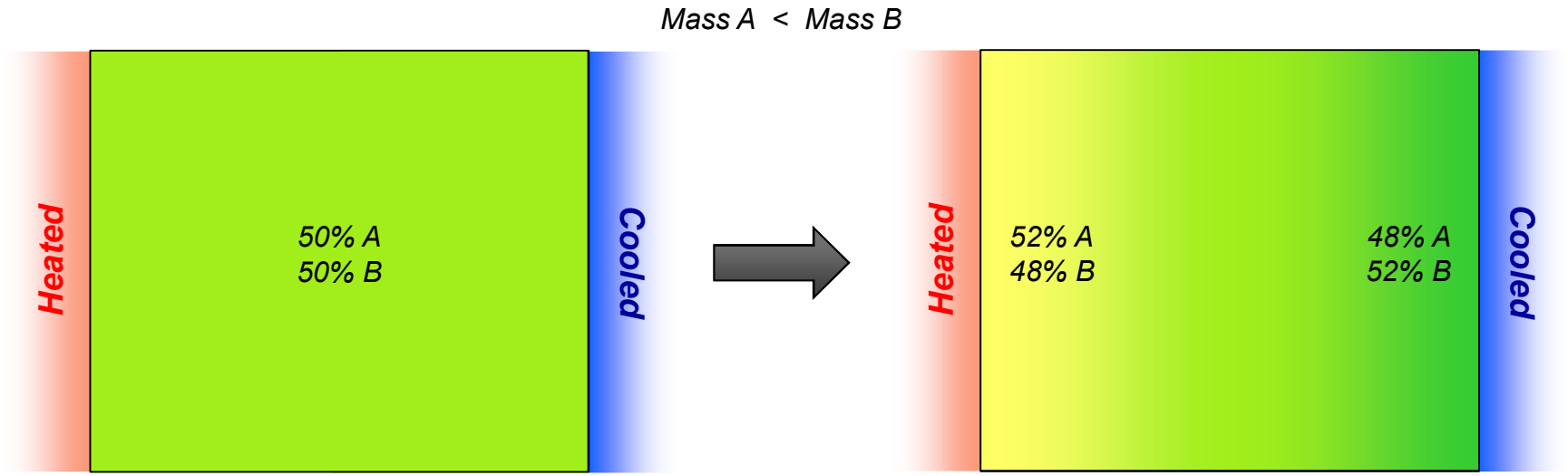
To inhibit detection of Kr, high degrees of vertical separation would have to occur



Samples will be taken from top of the canister. Can sufficient gas separation occur to inhibit Kr detection?

Thermal Diffusion:
Static System

In a 2-component static gas system with a temperature gradient, thermal (Soret) diffusion will result in a small amount of separation between the two gases. The lighter component will be slightly concentrated towards the hotter end, while the heavier component will slightly concentrated towards the cooler end. The degree of separation is a function of the masses and the temperature gradient:
He (4 AMU) and Kr (84 AMU) might be expected to separate measurably.



High Burnup Demo Cask as a Static System

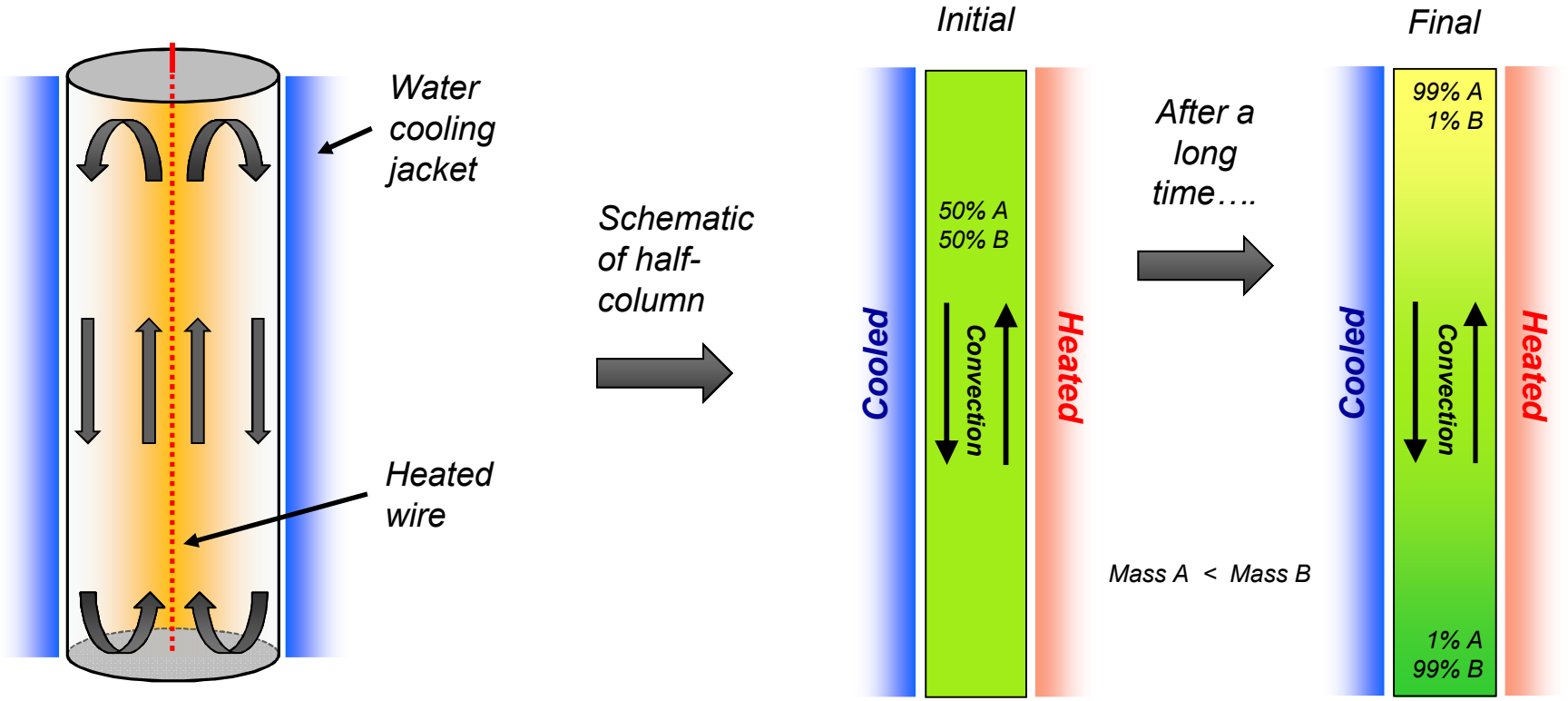
Static system?

- If the cask were a static system, significant separation of gas components could not occur. The temperature gradient is low, and is not vertical (the canister cools by heat loss from the sides), and would not yield a high degree of separation. Kr detection in a static system would not be impaired.

- **The cask is not likely to be a static system**, unless internal structures within the cask partition into into regions and inhibit convection. This does not appear to be the case. What is the effect of thermal diffusion in a convecting system?

Convecting System:
Example of a Clusius-Dickel column

Clusius-Dickel column. Gas-filled tube, with a heated wire in the center, and a water filled cooling jacket. Gas in the column convects, and the combination of convection and thermal diffusion results in development of a large vertical compositional gradient in the gas phase. *Convection does not mix the system, but rather promotes separation!*



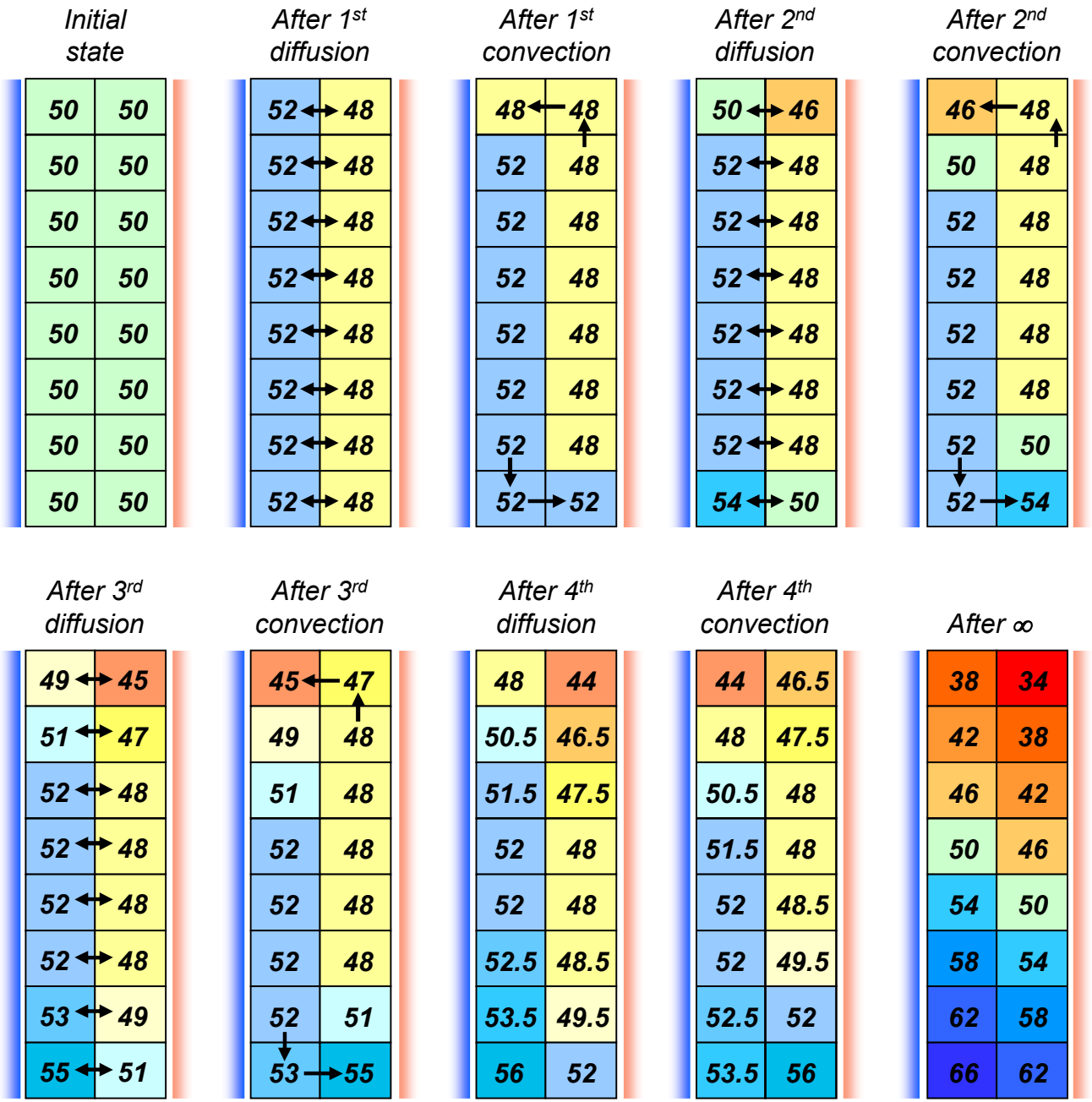
Used Fuel Disposition

Mechanism of separation:

Combined effects of diffusion and convection.

The numbers reflect the concentration of the lighter phase in the mixture.

In this example, the final enrichment is a function of the number of horizontal rows into which the column is discretized. In the real case, there is no discretization, and near-purity can be achieved at the ends of the column.



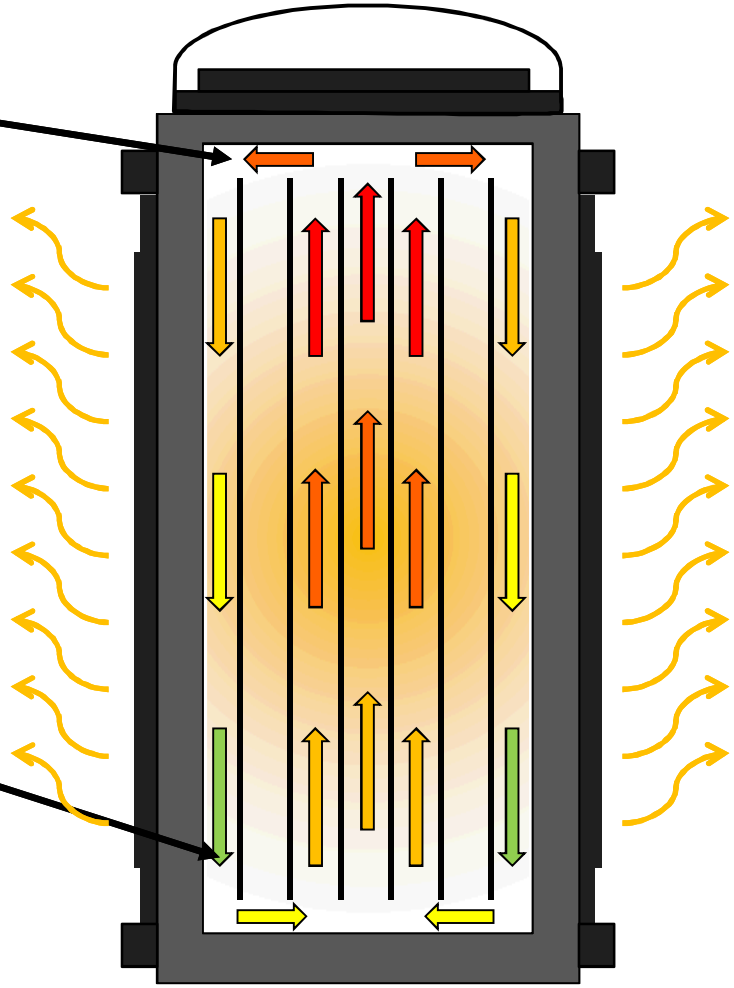
High-Burnup Demo Cask as a Convecting System

Convecting System?

~1”-2” gap between the top of the basket and the lid

Pathways exist at the top and bottom of the basket for large-scale convection of gases within the cask.

~1”x1” slots for water drainage in cell dividers at the basket bottom and (?) in the extruded Al support rails; larger slots at four locations for basket lifting device

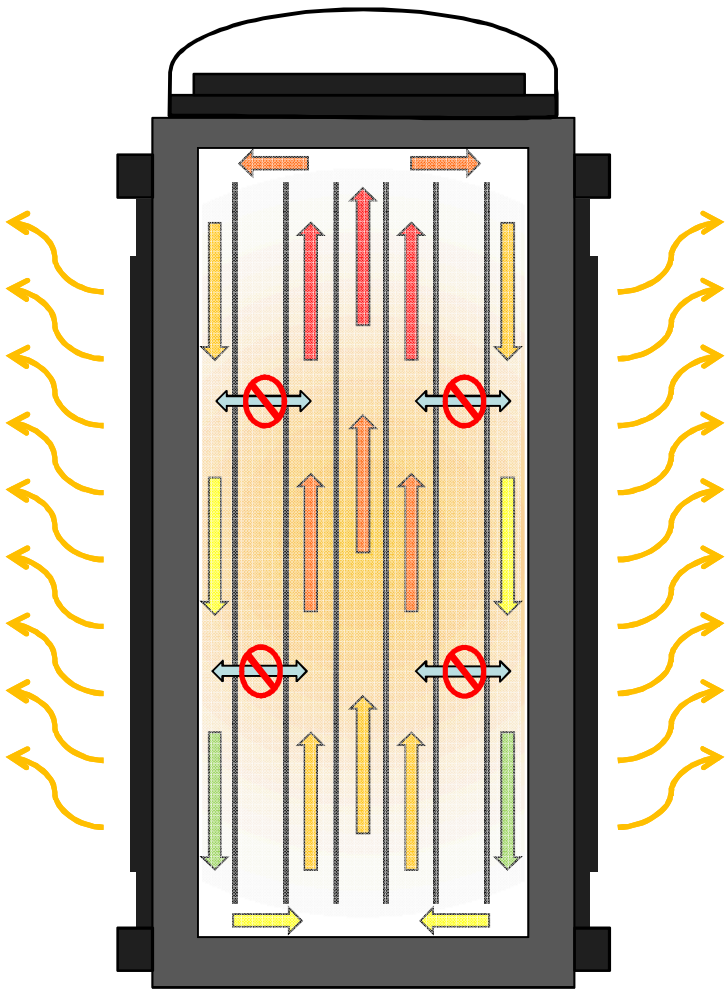


Looks a little like a Clusius-Dickel column!

Will vertical separation of He and Kr occur?

High-Burnup Demo Cask as a Convecting System

Convecting System?



Will vertical separation of He and Kr occur?

Unlikely.

High degrees of separation require the combined effects of:

- convection
- thermal diffusion

Diffusive exchange between the rising and falling limbs of the convection cell **cannot occur**—there are no perforations in the basket partitions. Convection alone will only mix the system.

Conclusions

Factors favoring gas separation by thermal diffusion:

- Large mass difference between He and Kr
- Convecting system, stable for a very, very long time

Factors limiting separation by thermal diffusion:

- Relatively small temperature gradients
- Basket partitions do not allow diffusion between rising and falling limbs of the convecting system.
- Complex internal structure may promote turbulence and mixing

Gas separation, if it occurs, will be small—the gas sampling location should not affect ability to detect Kr (assuming that Kr is present in amounts significantly above the detection limit).