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An Experimental Apparatus For Effusive-Flow Characterization of Arbitrary Geometry Target/Vapor Transport Systems For Radioactive Ion Beam Applications

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Outline Of Presentation

- **Theory of the effusive-flow process**
- **Experimental apparatus**
- **Experimental results with conventional and high-conductance target/vapor transport systems**
- **Conclusions**

Theoretical Description of the Effusive-Flow Process

- Following diffusion-release, radioactive species randomly move through the voids within the target matrix and along a vapor-transport system to an ion source where a fraction of the species are ionized and accelerated.

Vapor transport takes place in the Knudsen flow regime. The number of particles left in a vapor-transport system under evacuation after a time *t* is given by:

$$N = N_0 . e^{-\lambda t} \, e^{-\frac{t}{\tau_c}}$$

where τ_c is the characteristic time for a particle to go through the system given by

$$\tau_c = N_b \, \tau_{ad} + \frac{\overline{L}}{\upsilon}$$

with

$$\tau_{ad} = \tau_0 . e^{-\frac{H_{ad}}{k_B T}}$$

and H_{ad} is the enthalpy of adsorption; N_b is the average number of bounces;and *L* the average distance traveled per particle in the system.

In order to delineate the *diffusion* and *effusive-flow* processes

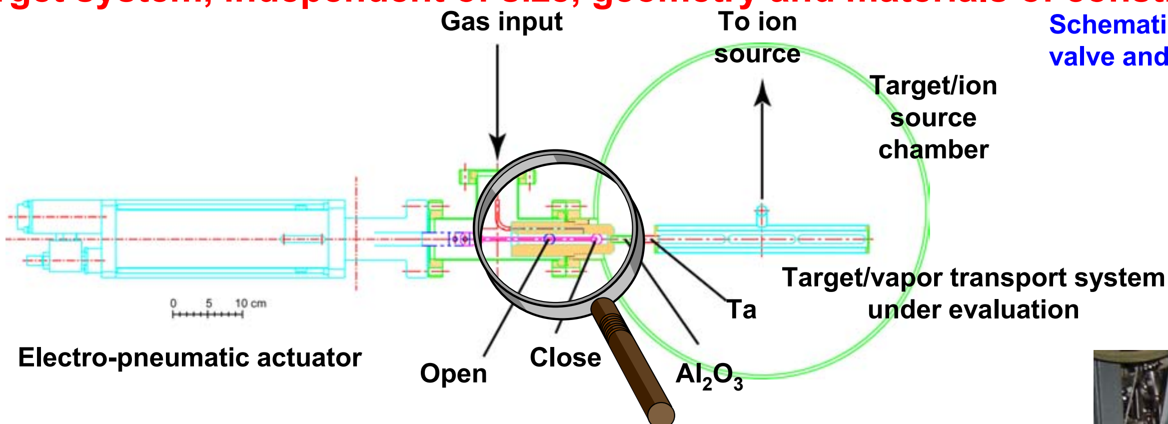
- **A method must be affected for independently measuring one or the other**

In order to minimize *effusive-flow* times through target/vapor transport systems, the system must be

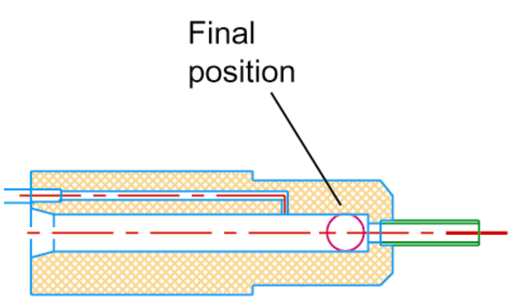
- **Made of low enthalpy of adsorption materials and be optimally coupled to the ion source in terms of size and geometry.**

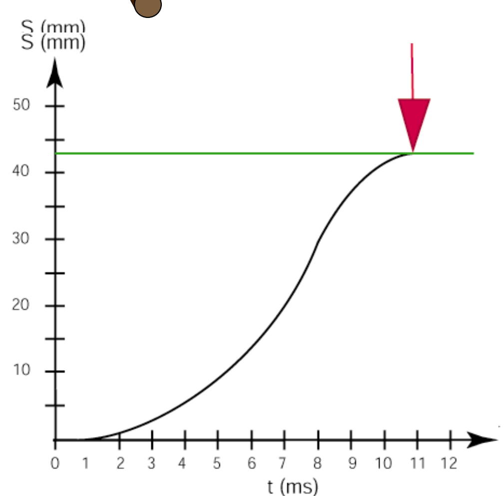
A Fast-Valve Experimental Apparatus for Measuring Effusive-flow Times Through Arbitrary Geometry and Size Vapor Transport Systems

- We have developed an experimental method that can be used to determine effusive-flow times of arbitrary geometry target/vapor transport systems. The technique utilizes a fast valve to measure effusive-flow times as short as 0.1 ms for any chemically active or inactive species through any target system, independent of size, geometry and materials of construction.

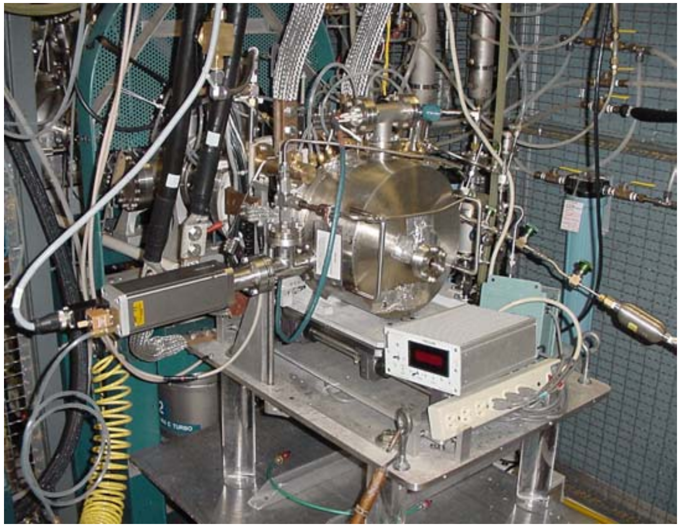


Schematic drawing of the fast valve and gas input system.

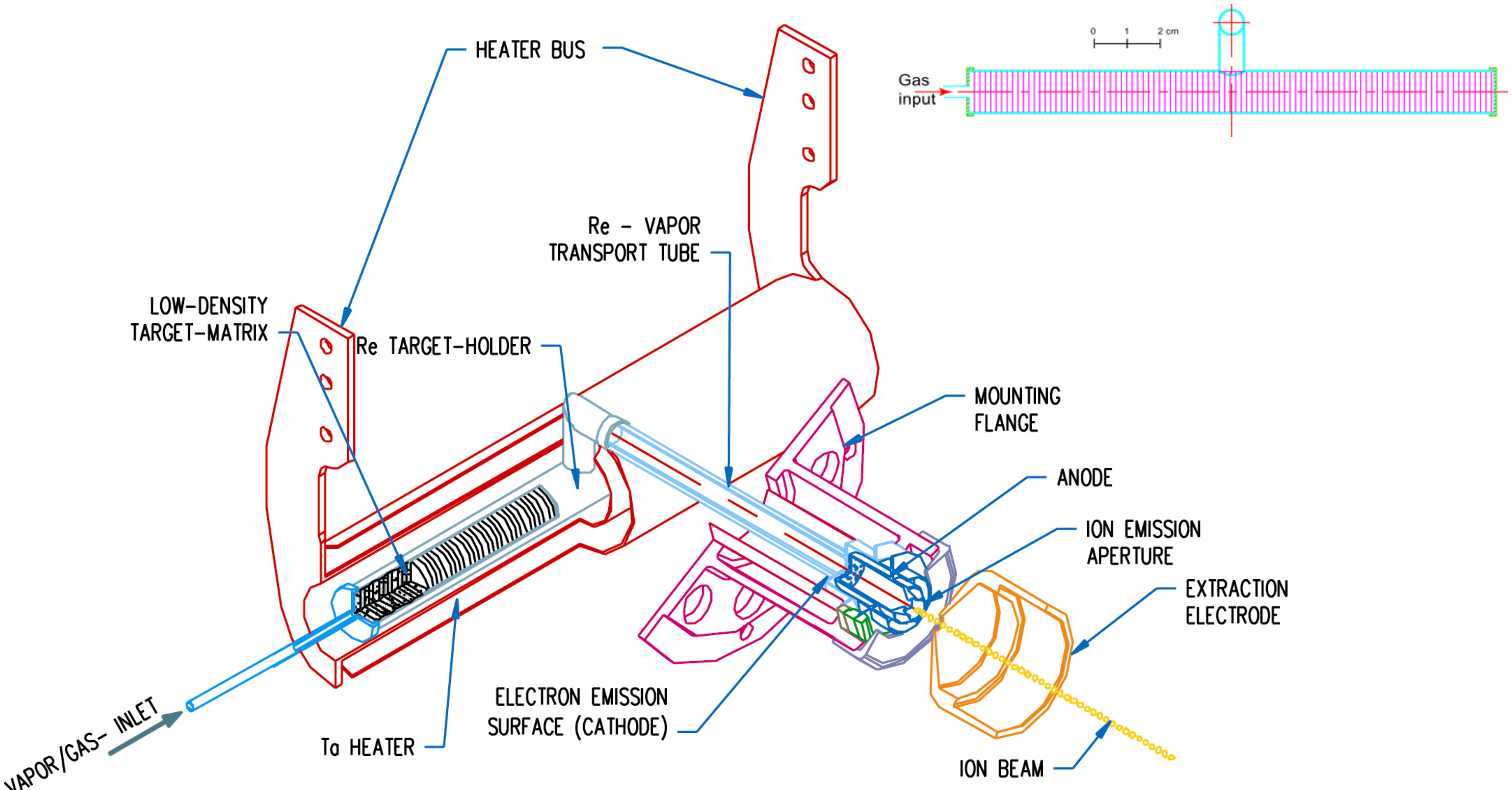




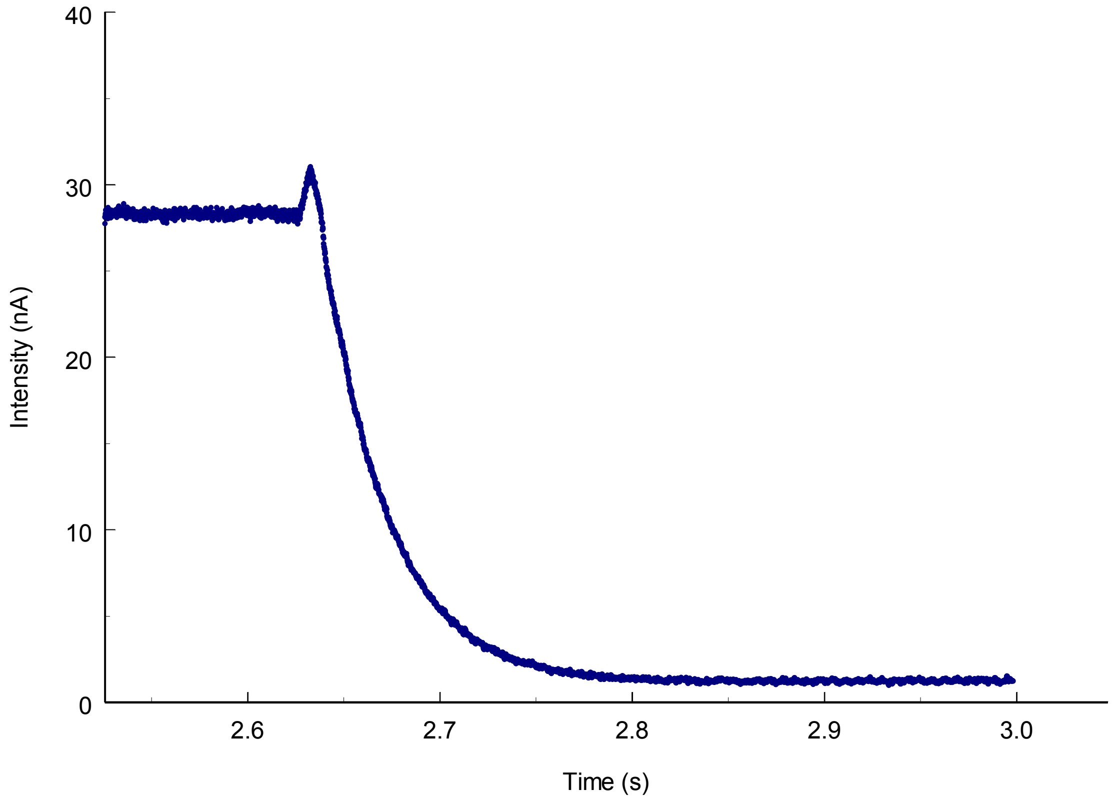
Picture of the experimental apparatus



Conventional Target/Vapor-Transport System

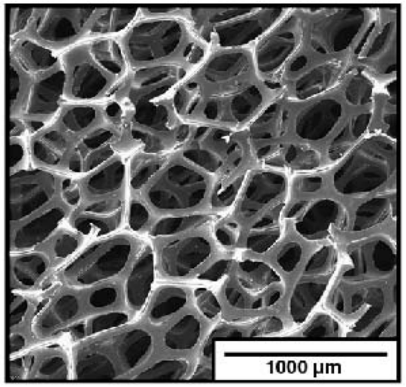


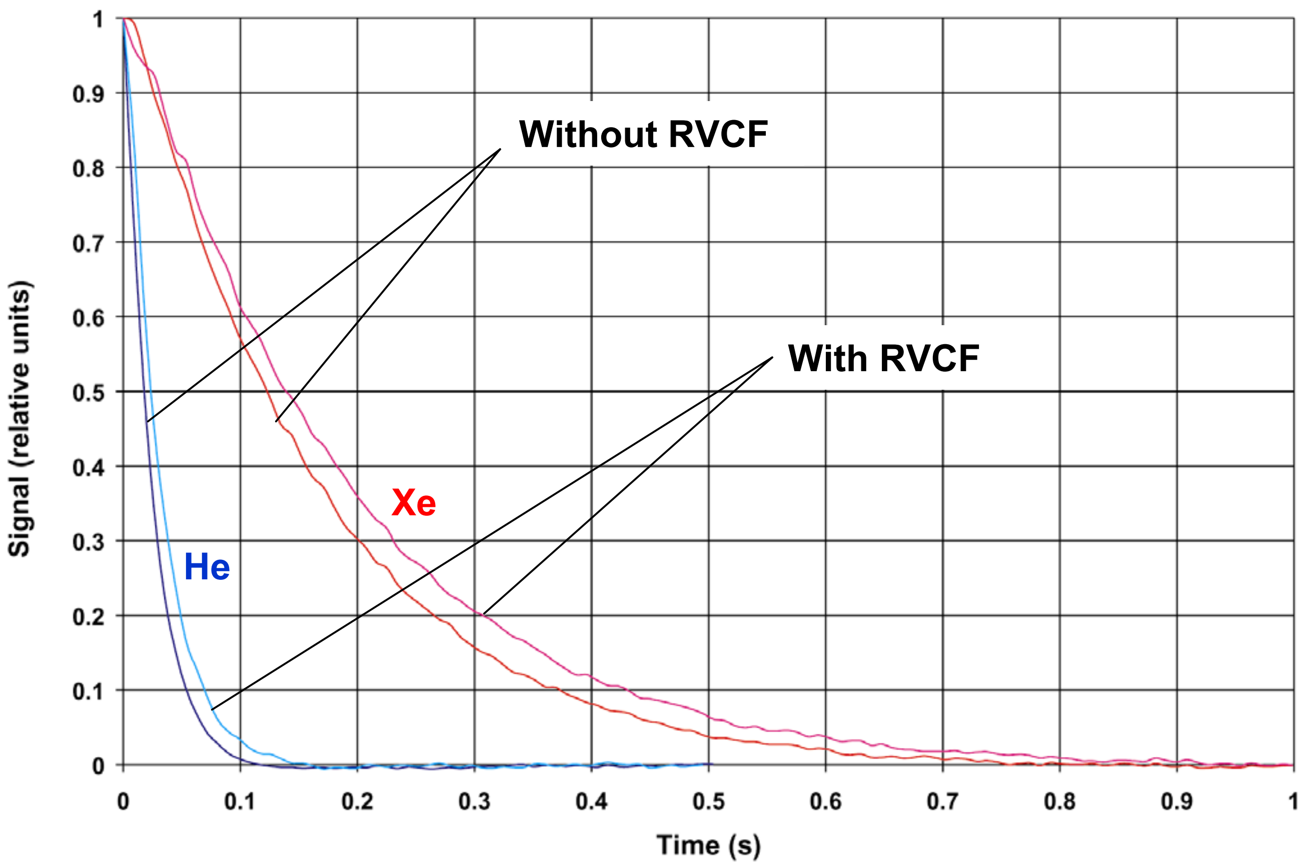
Mass Analyzed *He*$^+$ Signal Following Closure Of The Fast Valve



Time Spectra for *He* and *Xe* Through the Conventional Target/Vapor Transport System

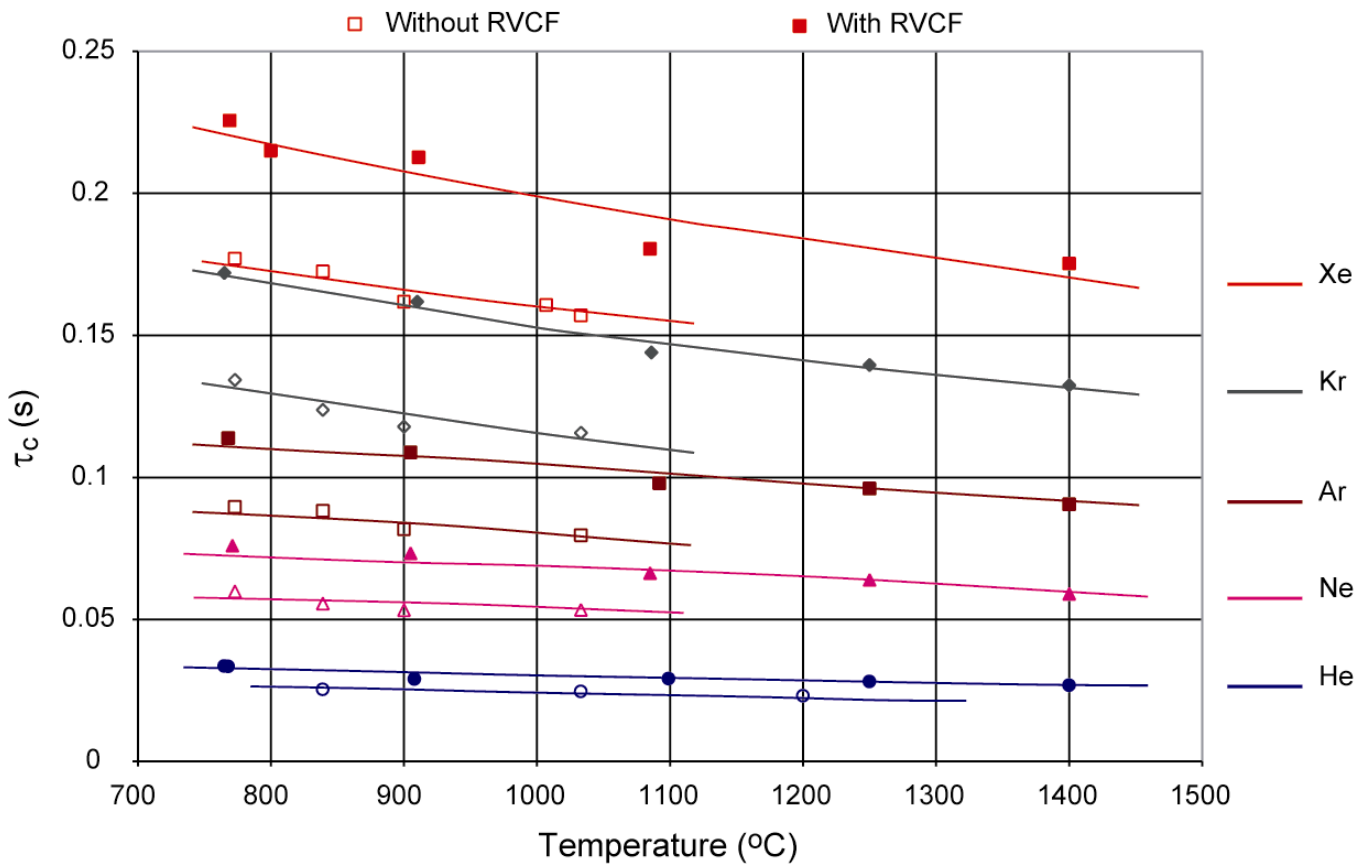
A SEM of an uncoated Reticulated Vitreous Carbon Fiber (RVCF)





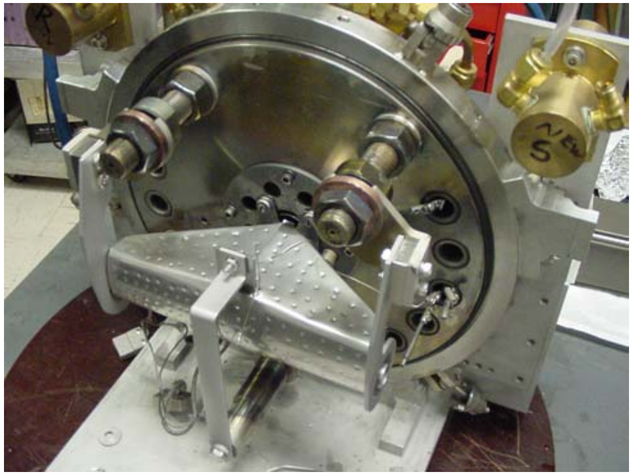
- **As noted the presence of RVCF has little effect on the effusive-flow times.**
- **The average distance traveled per particle is 114 m and 91 m with and without RVCF in the target reservoir.**

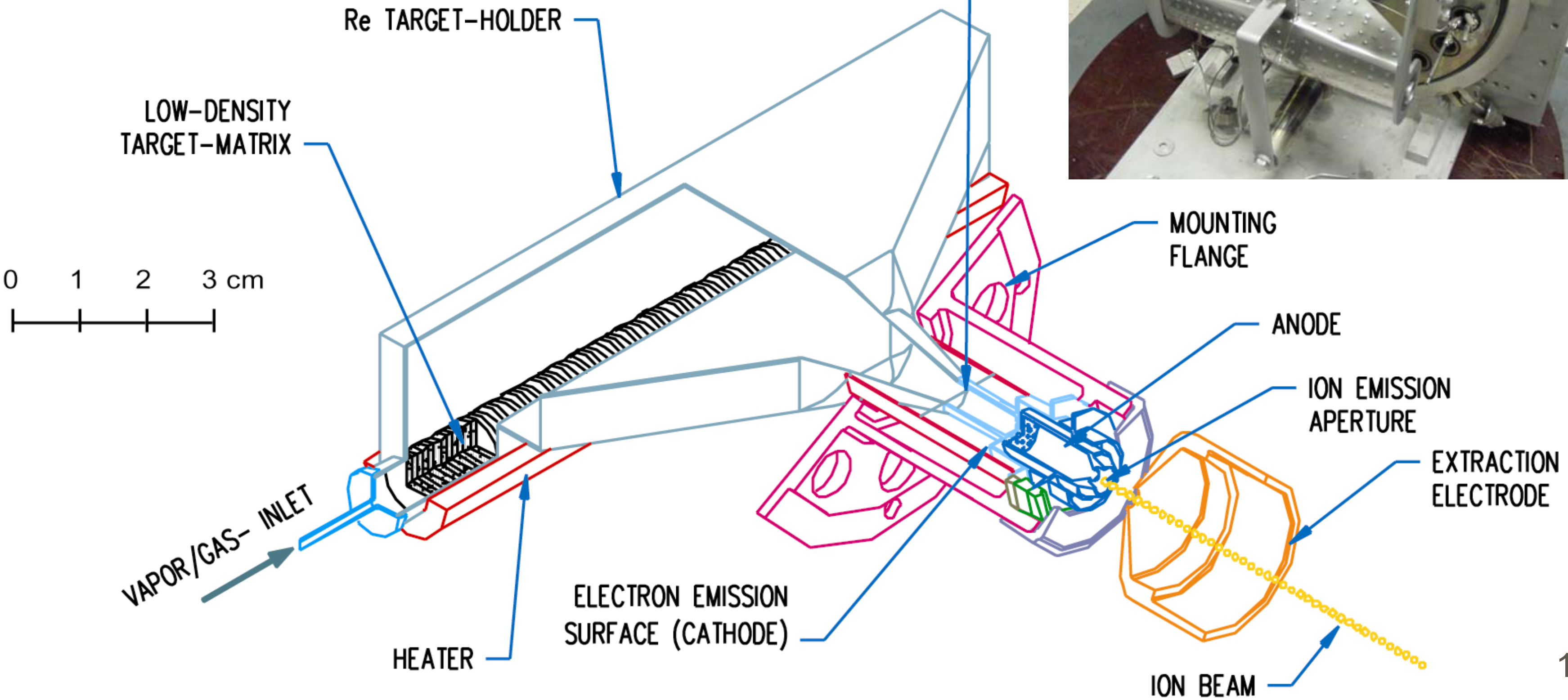
Time Spectra for Noble Gases Through the Conventional Target/Vapor-Transport System



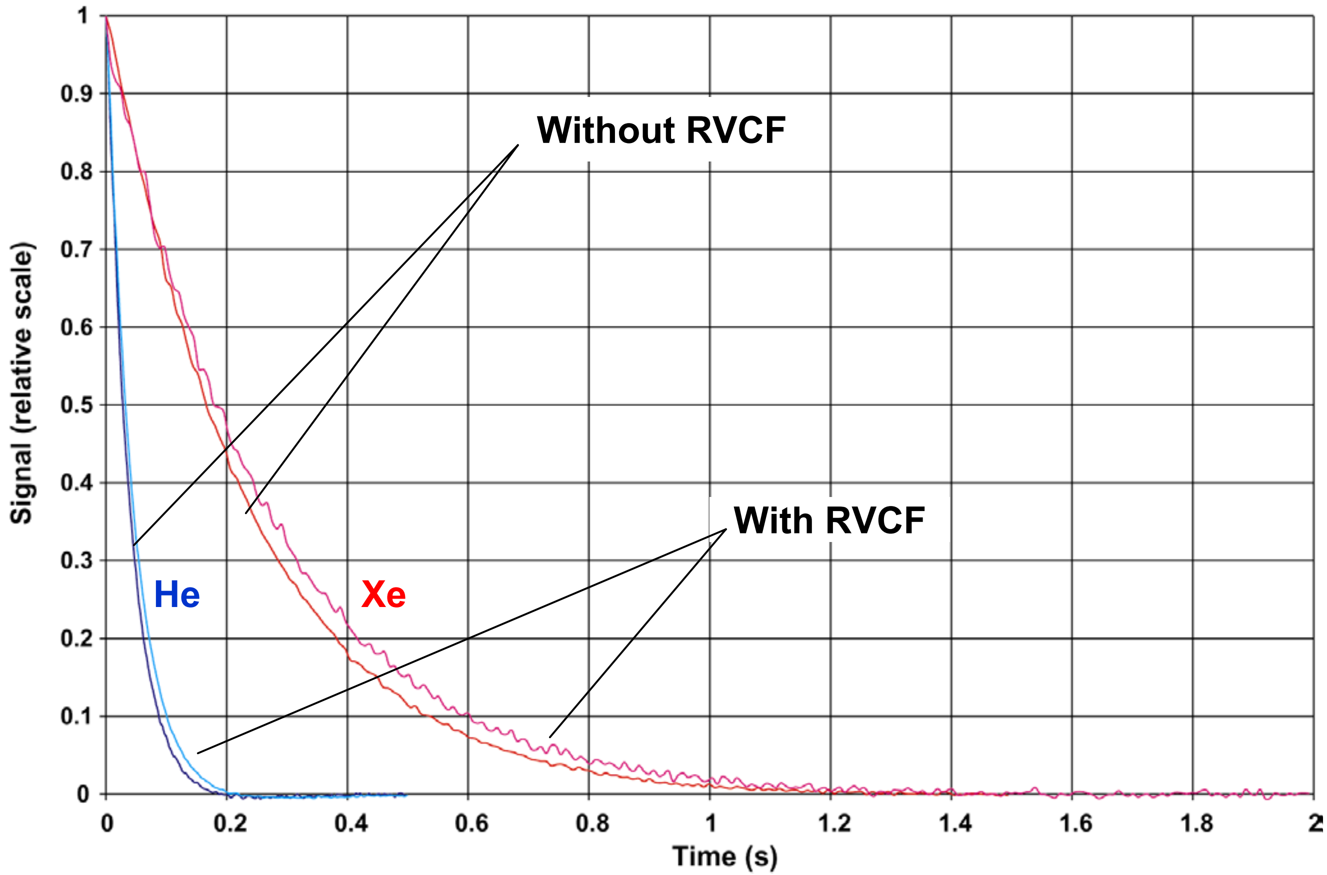
Species effuse faster when the target material reservoir is empty.

High Vacuum Conductance Target/Vapor-Transport System





Time spectra for *He* and *Xe* through the High Conductance Target/Vapor/Transport System

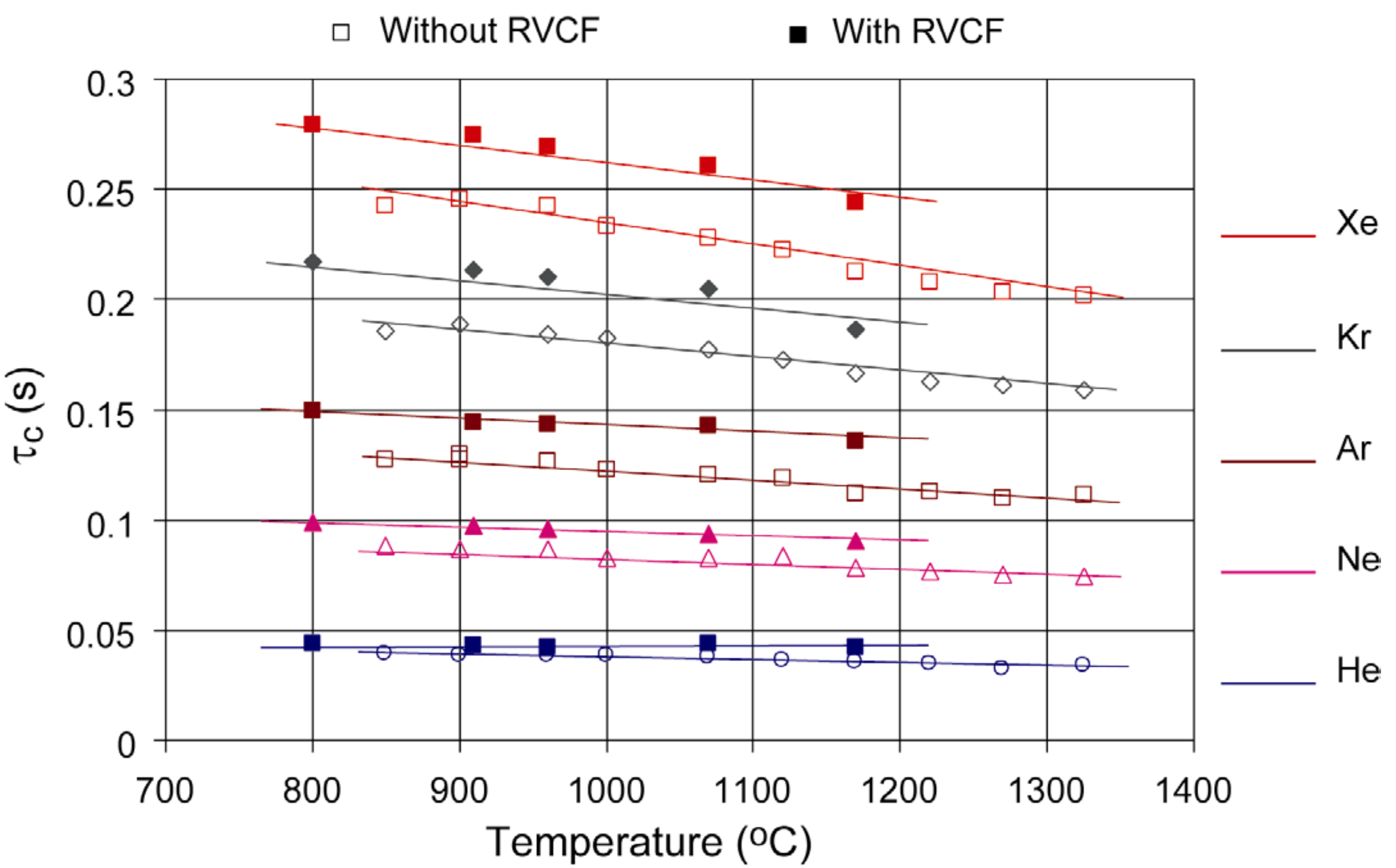


- Species effuse faster when the target material reservoir system is empty

- The average distance traveled per particle is 156 m and 114 m *with* and *without* RVCF in the target reservoir.

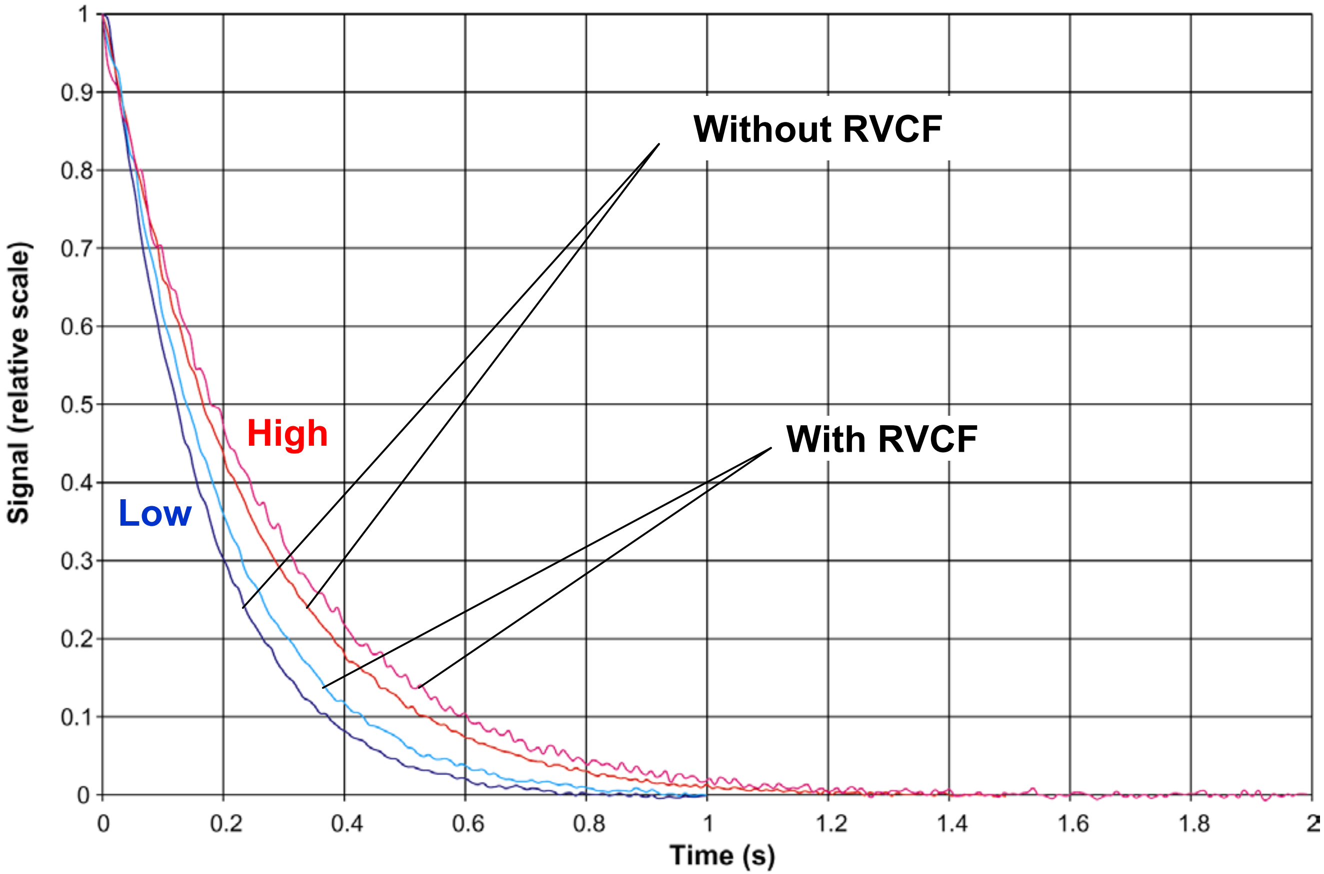
- RVCF does not significantly affect effusive-flow times.

Time Spectra for Noble Gases Through the High Conductance Target/Vapor-Transport System



Species effuse faster when the target material reservoir is empty.

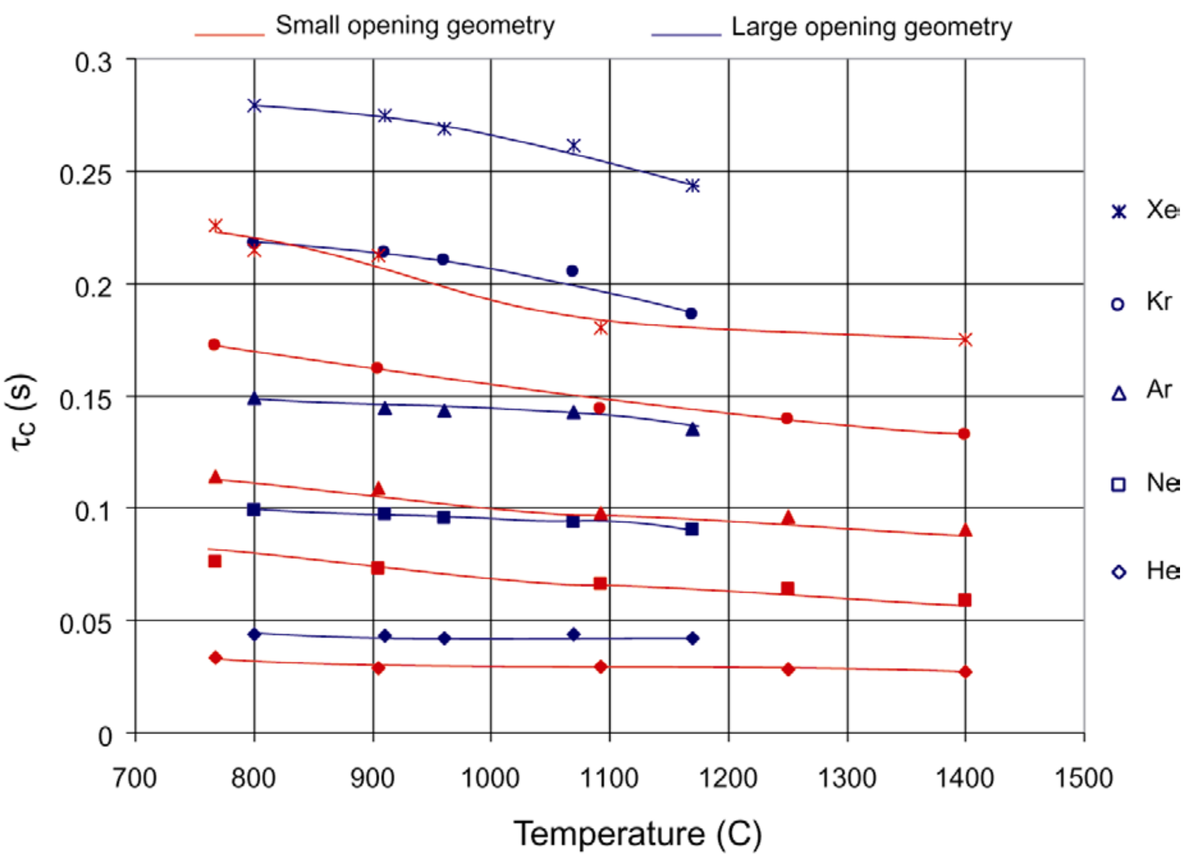
Comparisons of Time Spectra for *Xe* Through Conventional Serial Coupled and High Conductance Target/Vapor Transport System



- Species effuse more rapidly through the conventional serial coupled system than through the high conductivity geometry system with and without RVCF in the target material reservoir.

- RVCF does not significantly affect effusive-flow times.

Comparisons of Time Spectra for Noble gases Through Conventional Serial Coupled and High Vacuum Conductivity Geometry Systems



⇒ The conventional geometry with a small aperture is a better choice for transport of radioactive species for which sticking times are negligible.

⇒ Species travel longer distances in the high vacuum conductance system and so, take longer times to reach the ion source.

through the conventional geometry.

Conclusions

The Fast-Valve Experimental Apparatus Provides a Universal Means for:

- **Measuring effusive-flow times for chemically-active/-inactive species through arbitrary geometry and size vapor transport systems with flow-times as short as 100 μs;**
- **Optimizing coupling between target and ion source systems such that transport times are minimized;**
- **Delineation of the diffusion and effusive-flow processes.**