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Improving ion mobility spectrometer sensitivity through an optimized sample gas flow

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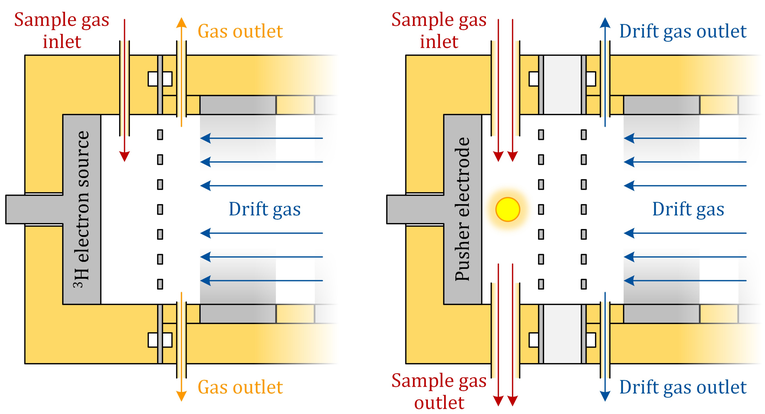
Abstract

The gas flow transporting the sample molecules into and through the reaction region of an ion mobility spectrometer (IMS) has a profound influence on its response, determining both sensitivity and response time. In the past, several key improvements relating to the sample gas flow have been reported, for example the use of a drift gas counter-flow by Baim et al. [1], on-axis sample introduction by St. Louis et al. [2] or side-flow sample introduction by Lee et al. [3].

Here, we aim to optimize the sample gas flow inside an IMS equipped with an extended field switching shutter [4]. By introducing a laminar flow curtain orthogonal to the drift direction through the small field-free reaction region, a significant increase in sensitivity and decrease in response time could be achieved for this already extremely sensitive IMS, pushing limits of detection into the sub-ppt$_v$-range [5].

Original vs. improved ion source design

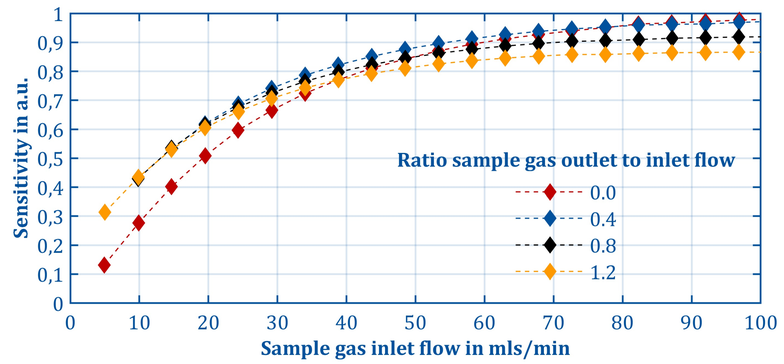


» Radioactive tritium source replaced by orthogonally mounted, non-radioactive X-Ray and UV (not visible in picture) ionization sources

» Extended field switching shutter with a second grid, improving shielding of the reaction region and thus sensitivity [4]

» Dedicated sample gas inlet and outlet creating a laminar gas flow through the reaction region, improving sensitivity and speed [5]

Continuous sample introduction sensitivity

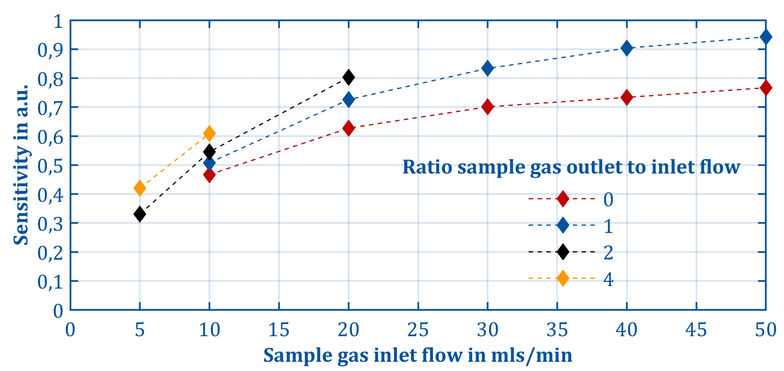


» Monomer plus two times dimer for 1 ppb$_v$ acetone in purified air

» As shown in [5], 10% of sample molecules are ionized and injected per second, requiring high sample gas inlet flows to replenish them

» Laminar flow design only helps for low sample gas inlet flows, at high inlet flows the whole reaction region is swept for any flow ratio

Pulsed sample introduction sensitivity



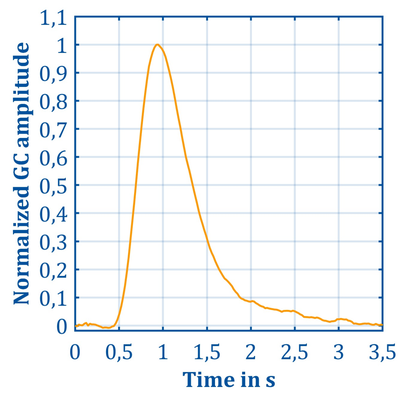
» 1 ppb$_v$ acetone injected from a six-port valve with 200 µl loop

» Again, higher sample gas inlet flows increase sensitivity

» However, guiding the sample gas flow is highly important now

» Even at a ratio of four, thus theoretically diluting the sample by a factor of four, sensitivity still improves due to sharper GC peaks

Peak from pulsed sample introduction



» 1 ppb$_v$ acetone injected from a six-port valve with 200 µl loop

» Sample inlet flow: 50 mls/min

» Sample outlet flow: 50 mls/min (Limited by flow controller)

» Measured FWHM: **630 ms**

» Higher sample gas outlet flow would reduce this further

» Remaining tailing likely due to lack of inactivated surfaces and operation at 45°C

Limits of detection

Substance	X-Ray APCI Monomer	X-Ray APCI Dimer	UV APPI Monomer
2-Butanone	360 ppq$_v$	40 ppt$_v$	280 ppt$_v$
2-Pentanone	310 ppq$_v$	35 ppt$_v$	110 ppt$_v$
2-Hexanone	320 ppq$_v$	30 ppt$_v$	140 ppt$_v$
1-Octanol	390 ppq$_v$	35 ppt$_v$	-
Benzene	-	-	60 ppt$_v$

» Calculated from calibration curves and 3σ noise for 1s averaging

» Lowest actually measured concentration is 50 ppt$_v$

Acknowledgements & References

[1] M.A. Baim, H.H. Hill: Anal. Chem. 1982, 54, 1, 38-43
[2] R.H. St. Louis, W.H. Siems, H.H. Hill: J. Chrom. A, 1989, 479, 221-231
[3] G. Lee, T. Willy, U. Chiluwal, H. Shokri, G.A. Eiceman: „New Ion Mobility Spectrometer Sideflow Design for Decreased Memory Effects in IMS", ISIMS Conference 2017, Warsaw
[4] A.T. Kirk, M.J. Küddelsmann, A. Bohnhorst, M. Lippmann, S. Zimmermann: Anal. Chem., 2020, 92, 7, 4838-4847
[5] A.T. Kirk: „Driftzeit-Ionenmobilitätsspektrometer mit hoher analytischer Leistungsfähigkeit – Modellierung, Entwurf und Umsetzung", ISBN 978-3844074420