SelexION device: the solution to selectivity challenges in quantitative analysis

Differential mobility separations enhanced with chemical modifiers: a higher dimension in selectivity

High selectivity is a key component of successful quantitative analysis. The ever-increasing sensitivity and throughput requirements of MS analytical assays often pose method development challenges. One of the most common issues encountered is the presence of a matrix interference which must be eliminated by adjusting HPLC conditions, or by modifying sample preparation.

Interferences can be present as an un-resolved chromatographic peak, or as a high baseline. In some cases, separation of isomers is required. If a high baseline problem cannot be solved, LOQ's and dynamic range are adversely impacted. Resolving a difficult chromatographic interference can require slower chromatography or more complicated and labor-intensive sample clean-up. It also slows down data review if peak integration must be manually adjusted on a sample by sample basis.

Significant advances have been made in increasing MS/MS selectivity beyond the gold standard MRM. For example, MRM^3 on the QTRAP systems[1] adds additional selectivity by increasing the number of fragmentation steps. Ion mobility presents another attractive option by introducing additional selectivity during sample introduction, following atmospheric pressure ionization. Although ion mobility techniques have been used extensively for qualitative applications, they have traditionally lacked the required ruggedness and speed required for quantitative analysis.

The SelexION device with the QTRAP or TripleTOF systems brings the power of differential ion mobility separation to quantitative analysis in complex matrices, enabled by multiple innovations in ion mobility.[2]

Figure 1. SelexION device. The DMS interface is directly coupled to the orifice plate. A modified curtain plate accommodates the DMS cell which can be easily installed and removed without the use of any tools and without venting the system. The source extension ring enables use of the standard SCIEX sources.

Key SelexION device innovations

- Planar geometry results in high speed and minimal diffusion losses for maximum sensitivity and UHPLC compatibility.[3]
- Planar geometry also allows the use of chemical modifiers, to add a higher dimension to selectivity and dramatically increases separation capacity.[2,4,5]
- Highly robust, reproducible, and stable for use in regulated analysis.
- Easy to maintain, and installable in minutes with no need to break vacuum or use any tools.

Innovative planar design

The SelexION device brings differential mobility separation (DMS) in a compact, easy to use device. It is integrated in the ion source region directly in front of the orifice and behind the curtain plate (Figure 1). The DMS cell consists of two parallel flat plates (10 x 30 mm, 1 mm gap) with an RF voltage (the Separation Voltage, SV) applied across the plates. Unlike traditional ion mobility, ions are not separated in time as they traverse the cell. They are separated in trajectory based on difference in their mobility between the high field and low field portions of the applied RF (Figure 2). As the ions migrate towards the walls of the DMS cell at different rates, they will be separated. By applying a second voltage offset (the Compensation Voltage, CoV) the trajectory of the desired ions can be corrected along the axis of the cell and towards the orifice. Other species will migrate away from the straight line due to the difference in mobility compared to the analyte of interest.

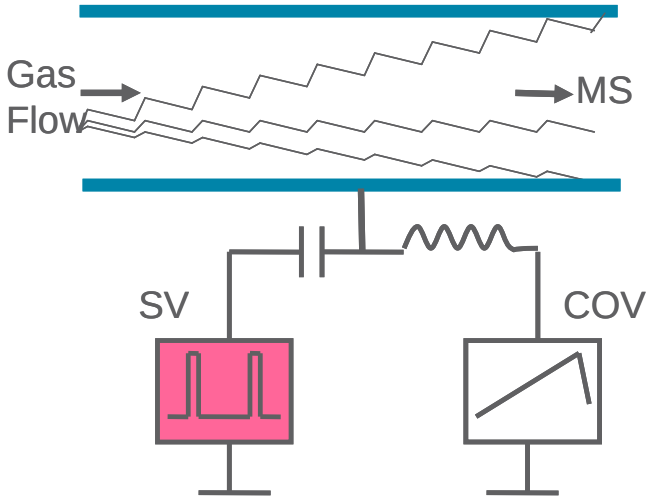

Figure 2. Differential mobility separation process. Innovative planar design of the DMS cell uses an asymmetric RF waveform (SV) to separate ions based on differential mobility between the high and low fields. The compensation voltage (CoV) is used to correct the trajectory of the ion of interest which traverses the cell and into the orifice while interferences are deflected into the cell walls.

This planar design yields a stable, easy to tune system with high resolving power over a short distance. This enables high speeds and short residence times, resulting in minimal diffusion losses and enabling the use of short cycle times. By simply turning off the separation voltage, the cell becomes transparent with ions moving normally along the center line of the device. This means that it is possible to transmit ions through the mobility cell when not using the DMS mode. Signal loss does occur in transparent mode, so it is recommended that the cell is removed for maximum sensitivity in non-DMS mode.

Figure 3. Comparison of SelexION and SelexION+ device. The addition of the jet injector to the ion mobility cell improves ion transmission by 2 fold without loss in selectivity or resolution compared with the original SelexION device.

In a more recent improvement to the technology, a jet injector[6] has been developed that resides at the entrance to the DMS cell (Figure 3). This acts to reduce the ion residence time within fringing fields at the DMS inlet and provides a 2-fold increase in transmission over the standard SelexION device. This ion mobility cell configuration is called the SelexION+ device and is currently available only on the QTRAP 6500+ systems.

Chemical modifiers – the second dimension

Volatile reagents can be introduced into the gas flow which chemically modifies how the ions interact with the curtain gas during the DMS separation. Different species will have different affinities to form clusters with this chemical modifier. As the clustered ions move between the high field and low field portions of the applied RF, they will have different rates of clustering and de-clustering.

In the high field portion, ions will de-cluster due to the higher energy available. But in the low field, the clusters will form again. This interaction dramatically increases the separation capacity of the DMS cell, taking advantage of chemical properties such as proton affinity to add another dimension in the differential mobility effect.

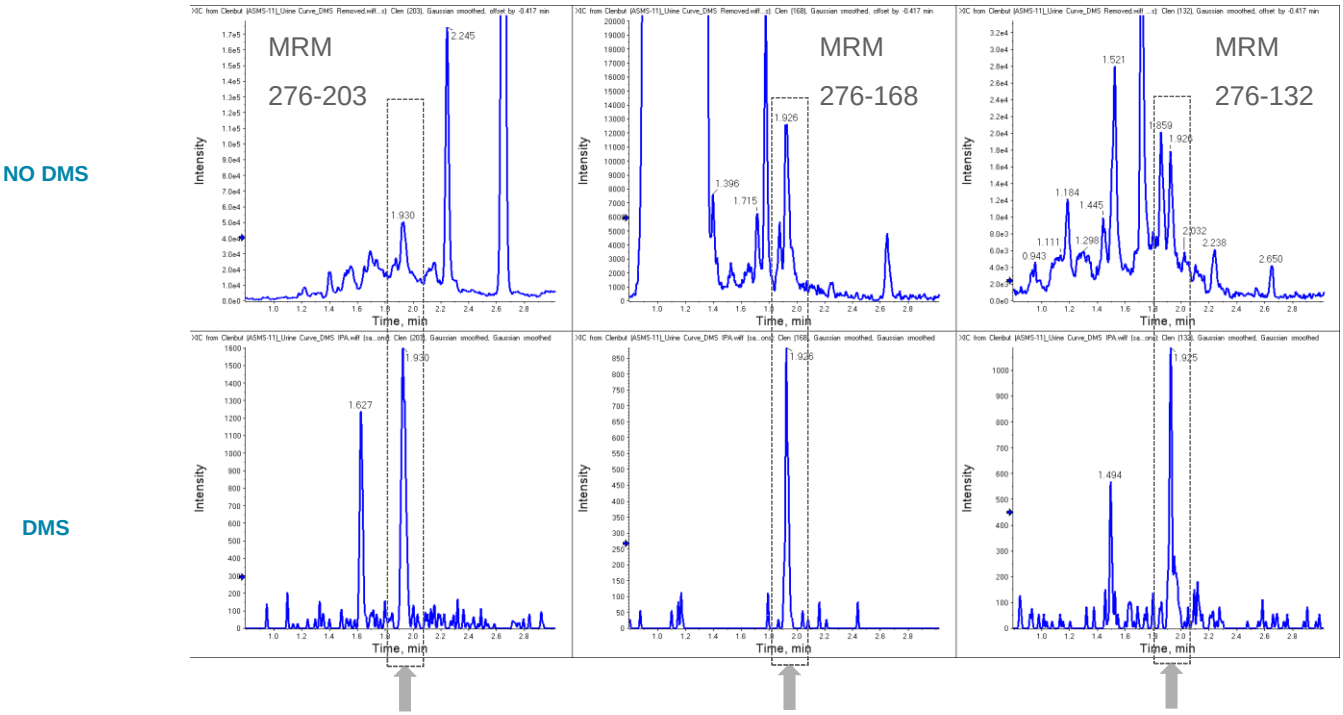

Figure 4. Analysis of clenbuterol in urine. This assay suffers from matrix interferences in all three MRM channels (top). Using the SelexION device with isopropanol as a chemical modifier resulted in the reduction or elimination of interferences in all three MRM channels (bottom).

Table 1. Clenbuterol QC results. Inter-day and intra-day precision and accuracy over four days for clenbuterol in urine. The SelexION device demonstrated excellent stability for satisfying bioanalytical acceptance criteria.

QC Level	Day	N	Mean	Std Dev	Percent CV	Accuracy
0.625 ng/mL	*1*	*5 of 5*	*0.588*	*0.070*	*12.0*	*93.3*
	2	*5 of 5*	*0.624*	*0.063*	*10.1*	*99.0*
	3	*5 of 5*	*0.632*	*0.062*	*9.8*	*101.1*
	4	*5 of 5*	*0.694*	*0.140*	*20.2*	*110.1*
	Average				***13.0***	***109.9***
6.25 ng/mL	*1*	*5 of 5*	*6.49*	*0.59*	*9.1*	*103.8*
	2	*5 of 5*	*6.27*	*0.49*	*7.8*	*100.3*
	3	*5 of 5*	*6.32*	*0.61*	*9.6*	*101.2*
	4	*5 of 5*	*6.3*	*0.67*	*10.6*	*100.9*
	Average				***9.3***	***101.5***
62.5 ng/mL	*1*	*5 of 5*	*56.2*	*5.5*	*9.8*	*90.0*
	2	*5 of 5*	*62.1*	*8.9*	*14.3*	*99.4*
	3	*5 of 5*	*55.1*	*3.4*	*6.2*	*88.2*
	4	*5 of 5*	*59.5*	*4.4*	*7.5*	*95.1*
	Average				***9.4***	***93.2***

Eliminating interferences and maintaining ruggedness

For quantitative analysis, maintaining signal across a large number of samples is critical. For highest detection sensitivity, the signal/noise of detected analytes is also a key factor to assay success.

LC-MS/MS analysis of clenbuterol in urine samples is known to exhibit a high degree of interferences in all major MRM transitions that can be monitored. These interferences also vary greatly in terms of complexity and intensity levels between different samples, posing a significant bioanalytical challenge.

Using DMS with isopropanol as a modifier, interferences are reduced or completely eliminated in all three MRM transitions in the urine matrix (Figure 4). Comparing urine from multiple different subjects, major interferences are present across different samples with significant variation in the profile. Using the selectivity of DMS, the chromatogram is dramatically cleaner, and the data is much easier to process.

High inter-day and intra-day reproducibility is critical for quantitative assays. The SelexION device demonstrates excellent stability and reproducibility. A batch consisting of a

standard curve in duplicate (concentration range: 63 pg/mL – 125 ng/mL

in urine) and three QC levels (n=5), was run four times on four consecutive days. Each batch contained a total of 60 samples. Inter-day and intra-day precision and accuracy were shown to be well within bioanalytical validation guidelines (Table 1).

A key component in the SelexION device is the excellent stability of compensation voltage over time (Figure 5). This is critical for quantitative precision and accuracy.

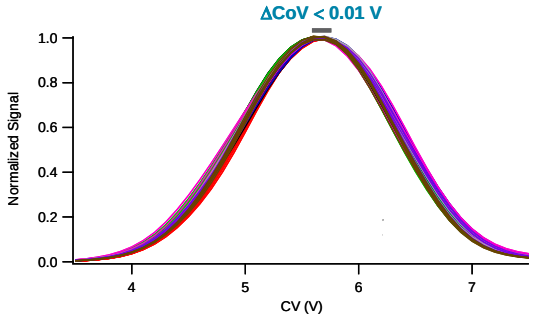

Figure 5. High Stability of Compensation Voltage. CoV stability is a key requirement for reproducible bioanalytical quantification with DMS. CoV remained within 0.01V when measured repeatedly over 24 hours demonstrating excellent stability.

Overcoming high baseline

Quantification of Pentoxifylline in protein precipitated plasma is limited by a very high baseline in the MRM transition of m/z 279.2 → 99.2. Due to the relatively low masses used in this transition, chemical noise limits both the LOQ and assay linear range. By using DMS with methanol introduced as a modifier, the baseline is lowered dramatically (Figure 6). At 10 ng/mL in plasma, signal to noise was improved by a factor of 20 times on the QTRAP 5500 system compared to the same conditions without DMS.

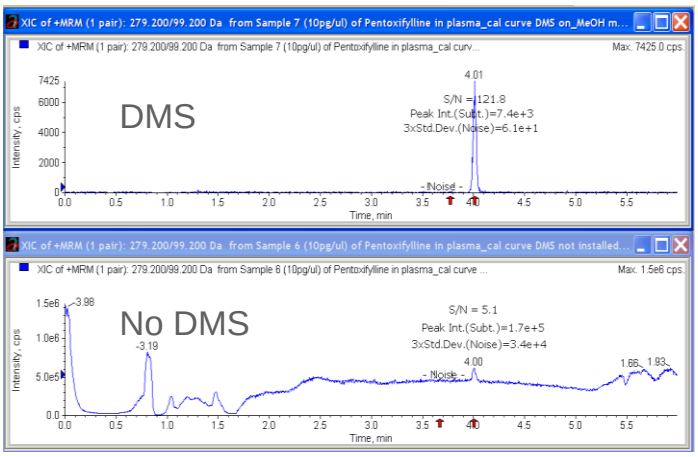

Figure 6. Pentoxifylline in protein precipitated plasma. Very high baseline is successfully removed with DMS, resulting in a 20-fold improvement in signal to noise at 10 ng/mL.

Separating isomers

The SelexION device enables separation of isobaric analytes. This can enable shorter run times if the analytes do not need to be resolved chromatographically. Ephedrine and pseudoephedrine are isobaric diastereomers. When using acetone as a chemical modifier in the DMS cell, the two analytes exhibit different mobility coefficients and are completely resolved by using different compensation voltages (CoV) as shown in Figure 7. Since the analytes are not resolved chromatographically in this case, and their MRM transitions are identical, their separation using DMS is essential to their quantitation. The optimum CoV values can be easily determined from the plot.

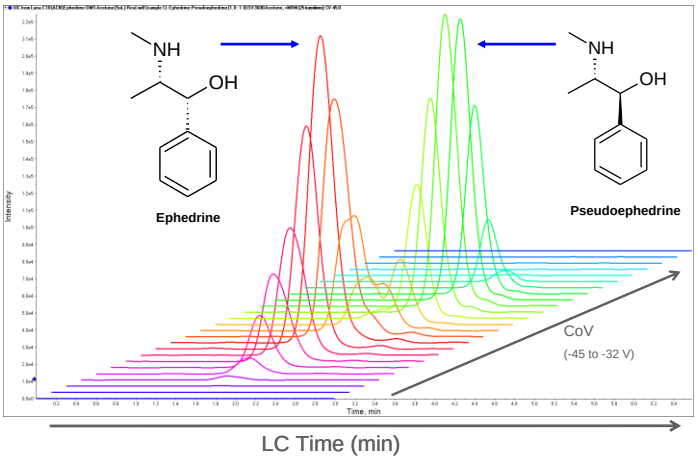

Figure 7. Separation of ephedrine and pseudoephedrine with the SelexION device. Analytes are completely resolved in CoV space even though they are not resolved in chromatographic space.

Conclusions

- SelexION device is a powerful tool enabling a higher dimension in selectivity while maintaining ruggedness.
- Using chemical modifiers in differential mobility separations dramatically increases resolving power.
- Innovative planar geometry of the SelexION device yields a compact and rugged device and allows the DMS cell to remain in place even when ion mobility is not in use.
- Excellent inter-day and intra-day precision and accuracy can be achieved with the SelexION device, to satisfy bioanalytical validation requirements.

Whether facing the challenge of resolving a chromatographic interference, eliminating a high baseline, or separating isomers, the SCIEX SelexION device with the QTRAP systems offers a powerful tool to help the bioanalytical scientist solve tough selectivity challenges.

References

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