



A Comparison of the 3 Main Forms of Ion Mobility Spectrometry

What is Ion Mobility Spectrometry?

When an ion moves through a gas under the influence of an electric field, the combination of acceleration due to the field and deceleration due to collisions with gas molecules leads to it very quickly acquiring a terminal velocity v , where

$$v=KE$$

E is the electric field strength and K is known as the ion's mobility.

The magnitude of v (and hence K) is related to the ion's collision cross-section; the larger the ion, the more likely it is to collide with gas molecules, so the lower its terminal velocity. Ion mobility in all its forms is based upon exploiting this fact; each of these forms is briefly outlined below.

1. Drift-Tube Ion Mobility Spectrometry (DT-IMS)

Drift tube IMS uses a long, gas-filled tube with a constant (and relatively low) electric field. Ions are injected at one end, and the time taken to travel the length of the tube is recorded. From this, the velocity of travel can be directly calculated, and if the field strength is known, the ions' mobilities can also be determined. If the travel time is to be known, ions must be injected into the system in short pulses, and then all the ions must be allowed to travel through to the detector before another pulse is injected.

2. Travelling-Wave Ion Mobility Spectrometry (TW-IMS)

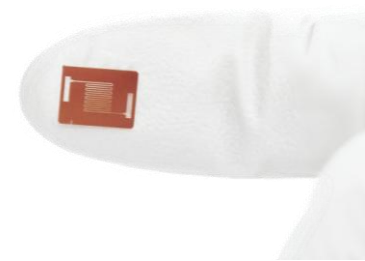
TW-IMS works along similar lines to DT-IMS. However, instead of having a constant electric field, TW-IMS uses alternating sections of positive and zero electric field, travelling parallel to the ions' direction of travel.

While in the positive section, ions move at $v=KE$, while in the zero-field section, they remain stationary. Travel time is still dependent on K , but now in two ways: firstly, the higher the mobility, the higher the velocity of travel while in the positive field; and secondly, the higher the velocity of travel, the longer the ions remain within the positive section of the wave. In the case where $v =$ velocity of wave travel, the ion is carried along at the front of the wave, effectively "surfing" it.

As it is still travel time through the system that is being measured, ions must still be fed into the system in short pulses.

3. Field Asymmetric Ion Mobility Spectrometry (FAIMS)/Differential Mobility Spectrometry (DMS)

Instead of applying a field parallel to the ions' travel, FAIMS uses an asymmetric alternating electric field, perpendicular to the direction of travel. This causes ions to drift towards one or the other electrode, depending on their values of K in high (K_h) and low (K_L) fields – only ions with a certain differential mobility ($K_h - K_L$) will pass through the system. By applying an additional DC compensation field, the value of this differential mobility can be changed, and by scanning through compensation field strengths, a spectrum of ions separated by their differential mobility can be obtained. For more details, see <http://www.owlstonenotech.com/ultrafaims/technology>.



At-A-Glance Comparison of IMS Techniques

Technology	Drift Tube IMS	Travelling Wave IMS	FAIMS/DMS
Collision cross-section (CCS) measurement	Direct (more accurate, based on low-field mobility)	Requires system calibration against known CCS	None
Can it be added to existing mass spectrometers?	Requires new mass spectrometer	Requires new mass spectrometer	Can retrofit with minor modifications to existing mass spectrometer ¹
Isomer separation and charge state separation	Possible	Possible	Possible
Orthogonality of separation	Poor – larger ions also have larger m/z	Poor – larger ions also have larger m/z	Highly orthogonal to MS
Linear dynamic range	Limit to size of ion packet in pulse which limits linear dynamic range (staggered pulsing can improve this)	Limit to size of pulse of ions which limits linear dynamic range (staggered pulsing can improve this)	Superior linear dynamic range (stream of ions instead of pulse, charge capacity constraint improved by multiple channels devices)
Duty cycle	Poor duty cycle (relative to other techniques, still 10s of ms timescale)	Better duty cycle than IMS because waves propel ions (1-10s of ms)	Ions analyzed as a continuous beam (fastest – μ s) but in scanning mode becomes slowest (s timescale) – hopping between different static settings can make it faster for target ions
Physical effects on ion structure	Ambient conditions for ions (aiding structural studies)	Field heating effects (potential for distortion or fragmentation of molecule structures)	Field heating effects (potential for distortion or fragmentation of molecule structures)
Resolving power	Highest resolving power	High resolving power (generally worse than DTIMS)	Less resolving power but 'high separation selectivity' i.e. experimental conditions can be changed to increase separation
Sensitivity	Lower sensitivity	Higher sensitivity	Highest sensitivity

¹True for Owlstone UltraFAIMS and Thermo FAIMS

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