

Analytica/China

"Ion sources - from EI and CI to API. What is principally changing - and why?"

A Tutorial on Ionization Sources

The ever increasing performance of mass spectrometric systems is often gauged in terms of mass resolution, mass accuracy, and sensitivity. These figures of merit are usually associated with the "analyzer". Driving these figures of merit to hitherto unheard levels, novel developments include the Orbitrap analyzer commercially introduced in 2005 and still evolving, ion funnels and ion transfer stages in various novel powerful designs, differential mobility devices such as FAIMs, to name a few. Along this line, more than 50 new acronyms for novel ion sources operating at atmospheric/ambient pressure have been coined in the past two decades suggesting a parallel development with regard to modern ion sources, including DART, DESI, and many, many more. Nevertheless, ions generally formed in the various API sources are mostly protonated molecules $[M+H]^+$, sometimes adducts $[M+X]^+$, and, to a far lesser extent, radical cations M^{*+} . This suggests that at least comparable ionization mechanisms are generally operative in API despite the numerous methods developed so far.

The question arises, why is that?

In order to unravel the various deeply folded processes operative in API sources, we will first have a look at the classical methods i) electron ionization (EI), and ii) chemical ionization (CI), where the latter is driven by EI of reagent gases, generating the CI reagent ions, which in turn ionize the analyte(s) present. The typically collision free environment in EI leads to very well documented and compiled ion populations comprised of molecular radical and fragment ions, respectively. Even theories such as Quasi Equilibrium Theory (QET) for the molecular description and calculation of ionic fragmentation pathways were successfully developed and the predictions are quite reasonable. A similar picture can be drawn for classical CI, i.e. operation at source pressures around 1 mbar with the source matrix gas comprised essentially of the reagent gas: The generated excess reagent ion population usually drives all chemical equilibria involving analyte ionization steps to completion. In other words: Thermodynamical properties such as gas phase acidities and basicities can be taken with some confidence to predict the generated analyte ion population.

This picture largely changes in API. Here, phenomena as for example i) "ion suppression", ii) efficient formation of protonated molecules – despite the usage of dry nitrogen as discharge gas, iii) shifts towards higher analyte charge states upon "super charging agents" to the gas matrix in nano-electrospray, and iv) the frequent failure when using thermodynamical properties such as gas phase acidities/basicities for the prediction of AP ionization mechanisms, are repeatedly observed.

Again, the question arises, why is that?

These issues and phenomena will be highlighted in some depth in the second part of the tutorial. Ion cluster chemistry will play a pivotal role. It will be illustrated how cluster ion chemistry potentially drives ionization pathways into unexpected directions – along with a discussion on the frequent absence of cluster ions in the recorded API mass spectra.