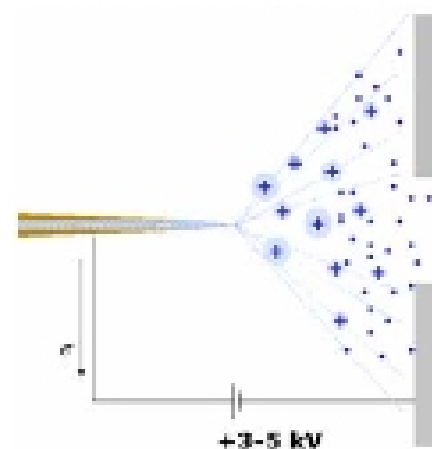


Lecture 3: Ionization Techniques – Part II

CU- Boulder
CHEM 5181
Mass Spectrometry & Chromatography
Taught by S. Kato / Slides from J. Kimmel
Fall 2009

Electrospray Ionization

- Atmospheric pressure ionization
- Enables MS detection of **large, non-volatile molecules** (e.g., proteins) with **no fragmentation** (→Nobel Prize 2002)
 - Search "ESI-MS" = 13,000 articles
 - Fenn's 1985 A Chem paper cited 845 times
- Liquid elutes through a high voltage tip
- Coulombic explosions yield a continuous mist of bare, gas-phase ions (positive or negative)
- Conveniently coupled to liquid separations
- Characterized by multiply charged ions



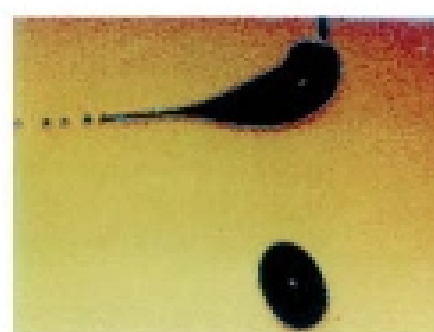
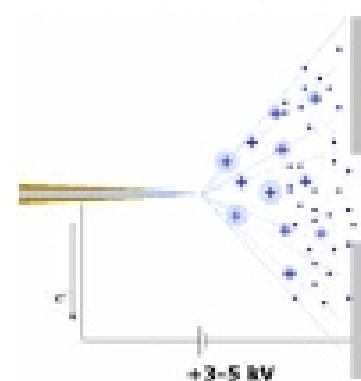
Electrospray Mechanism

-An electrolytic analyte solution is pushed through the conductive end of capillary (id 10-100 μm) at very low flow rate (0.1-10 $\mu\text{L}/\text{min}$) held a few mm from the entrance of the MS

-High potential (2-4 kV) induces a strong electric field ($10^6 - 10^7 \text{ Vm}^{-1}$)

-For positive field, cations will move towards the liquid surface and anions will move towards the conductive tip.

-Repulsions between adjacent cations combined with the pull of the cations towards the grounded MS inlet cause the surface to expand into a so-called 'Taylor cone.'



Gomez & Tang, Phys Fluids, 1986, 6:606-614

ESI Mech (con't)

Balance induced E field and surface tension of liquid

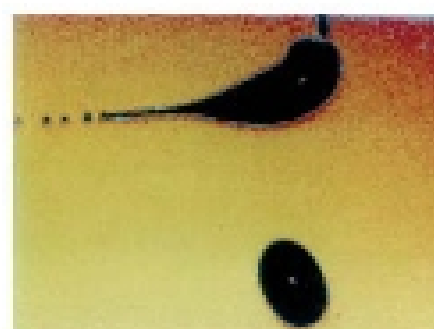
Tip of the cone elongates into a filament, which breaks up and emits a stream of charged droplets towards the inlet of the mass spectrometer.

Evaporation of solvent from the droplets increases the charge density.

At the 'Rayleigh limit,' repulsion between cations equal surface tension, causing 'Coulombic explosions' that produce even finer droplets.

This process of evaporation and explosion repeats until fully desolvated ions are released.

The release of ions occurs either by repeated fission events until total evaporation of the solvent (*Charge Residue Model*) or by direct ion emission from a charged droplet (*Ion Evaporation Model*).

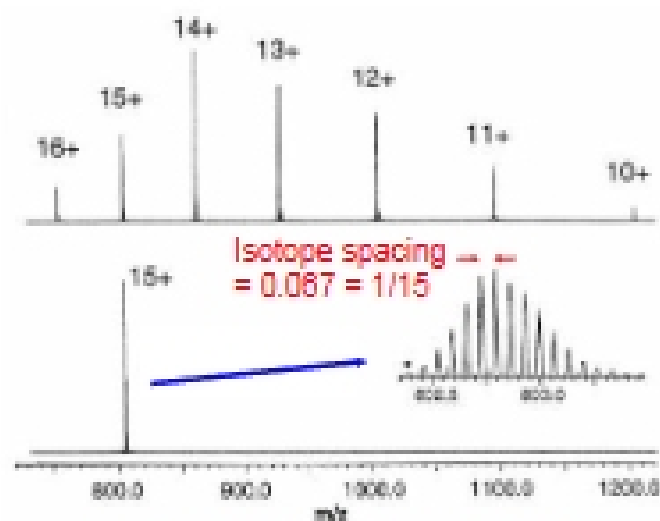


Gomez & Tang, Phys Fluids, 1986, 6:606-614

ESI Mass Spectrum

High charge states make m/z practice for most mass analyzer types.

z can be determined by isotope distribution or sequence of peaks (see section 1.8.1 of De Hoffmann and HW #2)



ESI-MS of Cytochrome C, ~12,380 Da

From Fig 12-16 Lamber

ESI Source Design

ESI source must:

1. Move ions from solution to the gas phase
2. Transfer the gas-phase ions from atmospheric pressure to vacuum
3. Yield ion beam with maximum current and minimum kinetic energy distribution

On 1.

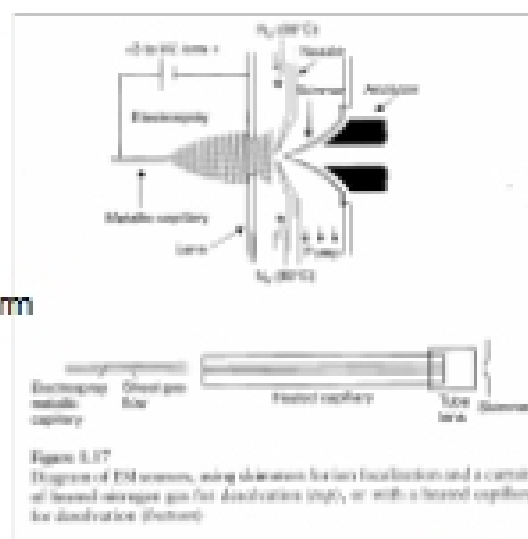
- Stable spray requires user optimization
- High flow rates may require nebulizing gas to form droplets

On 2.

- Heated drying gas + capillary encourage desolvation, and limits solvent analyte-adduct formation during expansion
- Pumping speed places practical limit on size of entrance aperture
- Transfer of ions between stages of decreasing pressure can result in a total ion loss on the order of four to five orders of magnitude

On 3.

- Harnessing expansion
- Constant Velocity = high E distribution



From de Hoffmann

For discussion, see: "ESI Source Design and Dynamic Range Considerations," A. P. Bruins, in "Electrospray Ionization Mass Spectrometry," R. G. Cole, 1997.