Figures of Merit for the
Aerodyne Aerosol Mass Spectrometer

Jose-Luis Jimenez
Aerodyne Research
Billerica, MA

Figures of Merit for the AMS

• Particle transmission efficiency
  – 100% relative to CPC at 350 nm

• Sensitivity
  – Detection limit = 3 * $\sigma$ of 1-min. data when there is a filter on the inlet
    • Depends on the $m/z$, through signal and background
    • Benchmark for NO$_3$: ~5 ng m$^{-3}$
    • Same as "signal-to-noise" ratio

• Signal intensity
  – “Ions-per-Particle”: sum of ions for $m/z$ 30 + $m/z$ 46 when sampling 350 nm (mobility diameter) pure dry NH$_4$NO$_3$ particles
    • Watch out for DMA problems, calibrate size with PSLs
    • NIST PSL size standards (Duke PSLs can 4.5% off => 15% by mass)
More measures of Signal Intensity

• Ionization Efficiency: ions detected per molecule evaporated
  – Same as IPP, more meaningful units
  – This is a parameter of the program, most fundamental
  – This is what you determine when you do the mass calibration
  – Oldest ~ 2 x 10^{-7} ions/molecule; Newest ~ 8 x 10^{-6}
  – Directly related to Amps-per-Torr or Amps-per-mb
    • This is what MS manufacturers specify
    • Not used any longer because it is not fully determined in our system
      (depends on assumed ionization volume & molecular speed)

• Air Beam Signal
  – Depends on your instrument configuration
  – Newest: ~ 1.4 x 10^7 Hz for m/z 28 (N_2^+)
  – Oldest: ~ 1.0 x 10^6 Hz for m/z 28 (N_2^+)

Even More measures of Signal Intensity

• Ionization Efficiency to Air Beam Ratio
  – Should be approximately constant
  – Could change if you tune the ionizer
  – Newest AMS: ~ 8.0 x 10^{-6} / 1.4 x 10^7 = 0.57 x 10^{-12}
    = 0.57 pAB (“pico-Air-Beams”)  
  – Oldest AMS: ~ 2.0 x 10^{-7} / 1.0 x 10^6 = 0.20 x 10^{-12}
    = 0.20 pAB (“pico-Air-Beams”)
The Worsnop-Jayne’s Law

AMS Sensitivity vs. time

Worsnop-Jayne's Law
~ x 5 sensitivity every year

\[ y = 4 \times 10^6 e^{-0.0044x} \]

\[ R^2 = 0.9918 \]

AMS Detection Limit for NO3 (ug m\(^{-3}\))

Jan-99 Jul-99 Jan-00 Jul-00 Jan-01 Jul-01 Jan-02 Jul-02 Jan-03

Houston
New York
G-1
Now

The Worsnop-Jayne’s Law, Part II

First Component of Worsnop-Jayne’s Law
~ x 3 signal every year

AMS Signal vs. time

Second Component of Worsnop-Jayne’s Law
~ 70% lower noise every year

AMS Noise vs. time

Don’t have good data for this one.
(We paid more attention to the signal Intensity since it is the larger effect).
Estimated by ratioing other 2.
AMS Single Particle Detection

Increasing Particle Time-of-Flight / Aerod. Diameter

Single Particle Threshold

Single Particle NOT Counted (for Number Dist.) but Averaged in (for Mass Dist.)

Single Particles of Increasing Size; Counted and Averaged in

Large Single Particle with Smaller Fraction of Chemical Component

For Each Mass/Charge Ratio of the Quadrupole

Electronic Noise

• Electronic noise
  – Normally only dominant for high masses
  – Can go up and affect your sensitivity, but hard to see
  – Also determines how well you can do the multiplier calibration, and what multiplier setting you run
  – Check: switch off filament, look at “relative” RMS noise in TOF & MS labels (“Rel”)
    • Relative to Caltech AMS during CRYSTAL-FACE, July 2002
    • Normally between 0.5 and 2
Background (Ion) Noise

- Ionic noise
  - Dominant for usual masses: 30, 44, 46, 48
  - This is the reason why the detection limit depends on the ion peak
    - As well as on the fragment fraction for the species
    - That’s the main reason why we have higher detection limits for organics
  - Check in the summary window
    - Relative to Caltech AMS during CRYSTAL-FACE, July 2002
    - Normally between 0.1 & 10
    - Good to monitor baking, changes after loosing vacuum, etc.
    - Near future: also relative to your own initial background (menu parameters)