Calculating Avogadro’s Number

• The Theoretical Equation is:

\[ \langle X^2 + Y^2 \rangle = \left( \frac{nRT}{3\pi \eta a N_A} \right) t \]

• You need values of:
  – Number of degrees of freedom \( n \)
  – Temperature \( T \)
  – Viscosity “eta”
  – Radius \( a \)
  – Gas constant \( R \)
Movement of Spheres at 40X

\[ y = 1.94 \times 10^{-12}x \]

\[ y = 2.80 \times 10^{-12}x \]
Motion of Microspheres at 100X

$y = 6.18 \times 10^{-13} x$

$y = 1.17 \times 10^{-12} x$

Distance (m²)

Time (sec)
Error Analysis

• Use Best Slope (from automatic trend-line) to find your “best” $N_0$ (Avogadro’s Number)
  – Make sure you set Intercept =0 in the trend-line options
  – Make sure you formatted the “data label” on the trend-line equation to “scientific” and at least 2 digits (i.e. 3 significant digits)
Reminder: slope

\[ Slope = \frac{nRT}{3\pi \eta a N_A} \]
Statistical Error

• To find the “statistical” error, find a second slope that barely touches your data distribution (this measures the amount of “statistical” fluctuations inherent in your data:

• Use this alternate slope to calculate \( N_1 \), the 1\(^{st}\) alternate Avogadro’s number

• Statistical error = \( |N_1 - N_0| \)
Systematic Error

- To find the “systematic” error, assume the temperature is changed by 10K (to either 313K or 293K, you don’t need both)
- Use this alternate T AND the new value of viscosity (it changes a lot) to calculate $N_2$, the 2nd alternate Avogadro’s number
- Systematic error $= |N_2 - N_0|$
Adding errors

- Overall error = square root of (stat err ^2 + syst err ^2)

- At the end you should calculate how far your answer is from the nominal value of $N_{STD}=6.02E23$
  - $D=(N0-N_{STD})/(\text{Overall error})$
Hand in

• Each group should submit TWO spreadsheets, and one WORD (or equivalent) file by either by e-mail tofizprof@gmail.com, or by upload to the http://access2010.wikidot.com
  – (1) for 40X results
  – (2) for 100X results
  – (3) calculation of Avogadro’s Number along with estimation of statistical and systematic errors.

• SHOW all raw data and calculations
ERROR Analysis

• Statistical Error:
  • NA’ = \(\frac{(8.314)(294)}{3\pi(1.17\times10^{-12})(9.79\times10^{-4})(0.5\times10^{-6})} = 9.05E22\)
  • \(|9.05E22 - 1.72E24| = 1.62E24\)

• Systematic Error:
  • 3% of the radius of the microsphere: \(0.5\times10^{-6} \times 0.03 = 1.5E-8\)
  • \(0.5E-6 + 1.5E-8 = 5.15E-7\)
  • \(NA = (8.314)(294)/3\pi(6.18E-13)(9.79E-4)(5.15E-7) = 8.32E23\)
  • \(0.5E-6 - 1.5E-8 = 4.85E-7\)
  • \(NA = (8.314)(294)/3\pi(6.18E-13)(9.79E-4)(4.85E-7) = 8.84E23\)

• Temperature Difference of 10 K
  • \(294 - 10 = 284\) K
  • the viscosity for water at 284 K is \(1.27E-3\) kg/ms
  • \(NA = (8.314)(284)/3\pi(6.18E-13)(1.27E-3)(0.5E-6) = 6.38E23\)
  • \(294 + 10 = 304\) K
  • the viscosity for water at 284 K is \(7.81E-4\) kg/ms
  • \(NA = (8.314)(304)/3\pi(6.18E-13)(7.81E-4)(0.5E-6) = 1.11E24\)

\[\sum(\Delta NA) = [(8.32E232) + (8.84E232) + (6.38E232) + (1.11E242)]^{\frac{1}{2}} = 1.76E24\]