CM3215

Fundamentals of Chemical Engineering Laboratory

Viscosity Measurement

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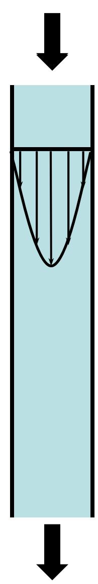

We can use flow through a tube to measure viscosity:

Hagen-Poiseuille Equation:

without gravity

$$Q = \frac{\pi\left(p_0 - p_L\right)R^4}{8\mu L}$$

with gravity

$$Q = \frac{\pi\left(p_0 - p_L + \rho g L \cos\beta\right)R^4}{8\mu L}$$

(when the capillary is tilted, is always constant)

Assumptions:

- Steady state
- Incompressible
- Newtonian
- No end effects

Reference: Morrison, An Introduction to Fluid Mechanics, Cambridge, 2013.

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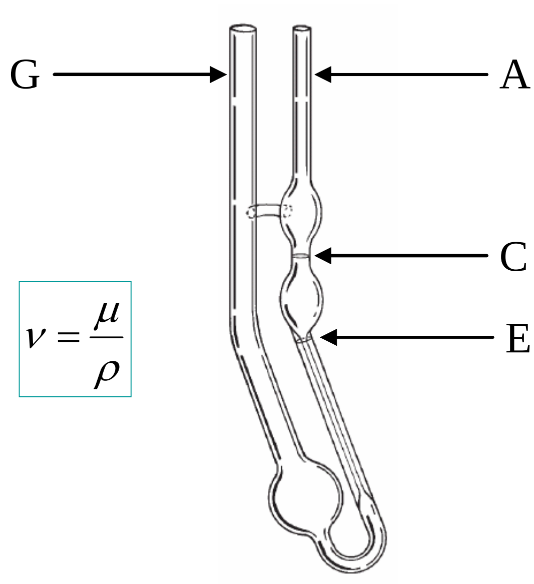
Cannon-Fenske Viscometer

- Gravity driven
- Results in *kinematic viscosity*
- Requires loading a fixed volume that is specific to the supplied calibrations

$$\nu = \frac{\mu}{\rho}$$



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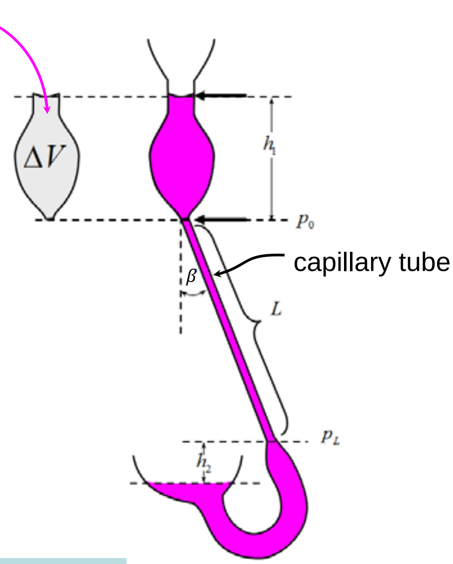
$$Q = \frac{\Delta V}{\Delta t}$$ (volume)

$$Q = \frac{\pi\left(p_0 - p_L + \rho g L \cos\beta\right)R^4}{8\mu L}$$ Hagen-Poiseuille

Neglect Δp, solve for ν:

$$\nu = \frac{\mu}{\rho} = \left(\begin{matrix}correction\\ factor\end{matrix}\right)\left(\frac{\pi R^4 g\cos\beta}{8\Delta V}\right)\Delta t$$ (volume)

Kinematic Viscosity, ν $\nu = \alpha\Delta t$



(For complete analysis, see Morrison, *An Introduction to Fluid Mechanics*, Example 7.4, p508)

$$\mu = \rho\alpha\Delta t$$

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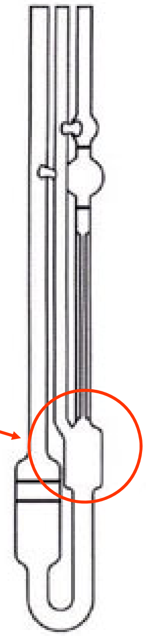
Ubbelohde Viscometer

Kinematic Viscosity, ν

$$\nu = \frac{\mu}{\rho}$$

- Gravity driven
- Results in kinematic viscosity
- ***Vented exit allows variable volumes to be charged***
- *Design eliminates* Δp



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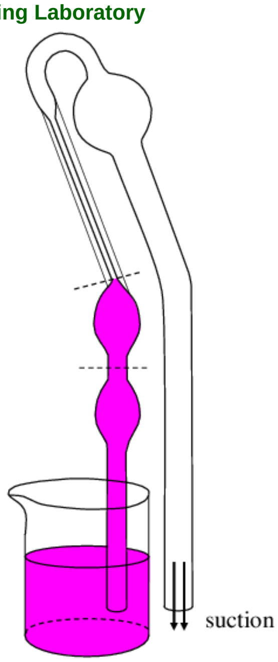
Loading a Cannon-Fenske Viscometer

- Accurate calibration requires using the calibrated volume
- Fill to top mark



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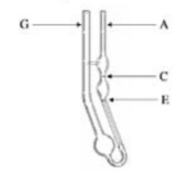
See class website for detailed instructions on operating the *Cannon-Fenske Routine Viscometers*

Instructions for the use of the Cannon-Fenske Routine Viscometer
Canon Instrument Company
Modified by F. A. Morrison 13 September 2007

1. Obtain a stop watch, a viscometer of appropriate size, and approximately 30 ml of sample to be measured.
2. Clean the viscometer using suitable solvents and by passing clean, dry, filtered air through the instrument to remove the final traces of solvents (clean, dry air is available at two locations on the east wall over the first-aid kit). Periodically, traces of organic deposits should be removed with chromic acid or non-chromium cleaning solution. Be careful when blowing air into the viscometer; do not drop.
3. If there is a possibility of lint, dust, or other solid material in the liquid sample, filter the sample through a sintered glass filter or fine mesh screen.
4. To charge the sample into the viscometer, invert the instrument and apply suction to tube G, immersing tube A in the liquid sample, and draw liquid to mark E (this can be accomplished by using the baby ear syringes provided; these seal well on the inside of tube G). Turn the instrument to its normal vertical position and wipe clean arm A. This procedure charges the viscometer with the correct amount of liquid for the calibration constant given.
5. Place the viscometer into the constant temperature bath using a ring stand and a clamp. Align the tops of the tubes of the viscometer vertically in the bath. Up to four viscometers may be present in the bath at one time.
6. Allow approximately 10 minutes for the sample to come to bath temperature at temperatures up to 40°C and 15 minutes for temperatures up to 100°C.
7. Leaving the viscometer in the bath, apply suction to tube A and draw the liquid slightly above mark C (this can best be accomplished using a pipet bulb on tube A).
8. To measure the efflux time, allow the liquid sample to flow freely down past park C, measuring the time for the meniscus to pass from mark C to mark E.
9. A check run may be made by repeating steps 7 and 8. Do a minimum of three measurements of efflux time.
10. Calculate the kinematic viscosity in mm^2/s (cSt) of the sample by multiplying the efflux time in seconds by the viscometer constant.



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- Each group takes the viscosity of two solutions at three temperatures.
- Data are shared with all lab classmates (Google Forms)
- See table for assignments (also given in the lab handout)

Spring 2016

station	solutions to measure (wt% sugar)	
2	10.0	30.0
4	30.0	50.0
6	mystery	10.0
7	mystery	50.0
8	mystery	30.0
9	50.0	mystery
10	10.0	50.0

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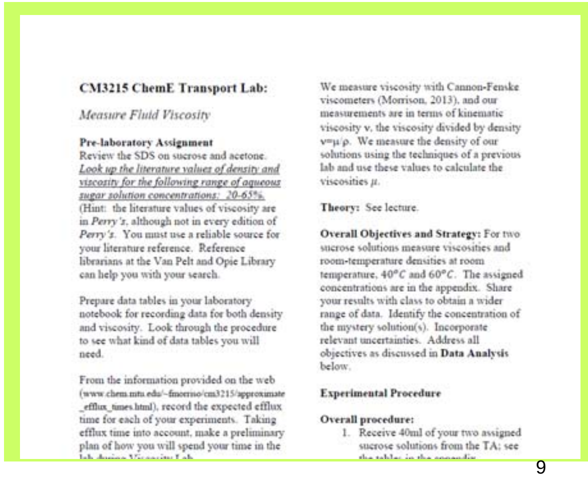
Lab: Measure Fluid Viscosity

- Measure densities, efflux times of sugar solutions at various concentrations, temperatures
- Calculate viscosities; enter into Google Form
- Determine experimental uncertainty
- Determine best-fit line at three temperatures; plot on one graph; compare to literature
- Identify concentration of mystery solution (with uncertainty)



CM3215 ChemE Transport Lab:

Measure Fluid Viscosity

Pre-laboratory Assignment
Review the SDS on sucrose and acetone. *Look up the literature values of density and viscosity for the following range of aqueous sugar solution concentrations: 20-65%.* (Hint: the literature values of viscosity are in *Perry's*, although not in every edition of *Perry's*. You must use a reliable source for your literature reference. Reference librarians at the Van Pelt and Opie Library can help you with your search.

Prepare data tables in your laboratory notebook for recording data for both density and viscosity. Look through the procedure to see what kind of data tables you will need.

From the information provided on the web (www.chem.mtu.edu/~fmorriso/cm3215/approximate_efflux_times.html), record the expected efflux time for each of your experiments. Taking efflux time into account, make a preliminary plan of how you will spend your time in the lab during Viscosity Lab.

We measure viscosity with Cannon-Fenske viscometers (Morrison, 2013), and our measurements are in terms of kinematic viscosity ν, the viscosity divided by density $\nu=\mu/\rho$. We measure the density of our solutions using the techniques of a previous lab and use these values to calculate the viscosities μ.

Theory: See lecture.

Overall Objectives and Strategy: For two sucrose solutions measure viscosities and room-temperature densities at room temperature, $40°C$ and $60°C$. The assigned concentrations are in the appendix. Share your results with class to obtain a wider range of data. Identify the concentration of the mystery solution(s). Incorporate relevant uncertainties. Address all objectives as discussed in **Data Analysis** below.

Experimental Procedure

Overall procedure:
1. Receive 40ml of your two assigned sucrose solutions from the TA; see the tables in the appendix

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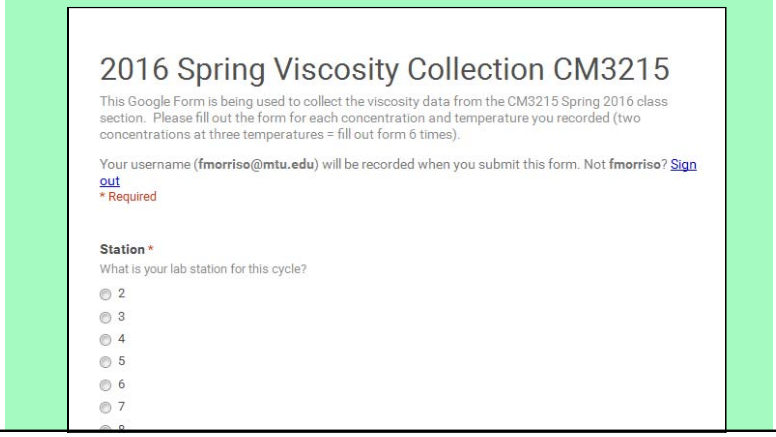
Class: In your submissions to the Google Form:

- Do not write 30%; just write 30
- Do do not write the units in your entries; it's going directly to Excel.
- If you want to use scientific notation, please write 3.14e3 for 3140 (do not write 3.14*10^3). It's going directly to Excel.



2016 Spring Viscosity Collection CM3215

This Google Form is being used to collect the viscosity data from the CM3215 Spring 2016 class section. Please fill out the form for each concentration and temperature you recorded (two concentrations at three temperatures = fill out form 6 times).

Your username (**fmorriso@mtu.edu**) will be recorded when you submit this form. Not **fmorriso**? Sign out

* Required

Station *
What is your lab station for this cycle?

- 2
- 3
- 4
- 5
- 6
- 7

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Prelab assignment (due Monday):

- Obtain the literature values of solution densities and viscosities before lab; this must be in your notebook for Monday’s prelab check.
- **Please do the pre-lab**—this is to enhance your laboratory experience
- Note the references where you found your values.
- See instructions for complete prelab assignment.