

## 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](http://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.

Prepare a safety section in your laboratory notebook detailing all safety issues associated with this laboratory.

#### **Introduction**

Viscosity is one of the primary fluid properties that is used in the design and analysis of chemical-processing equipment. Viscosity is dependent on fluid composition and temperature, and both variables must be taken into account when performing design calculations. Each group will examine the viscosity of sugar solutions at three temperatures.

We measure viscosity with Cannon-Fenske viscometers (Morrison, 2013), and our measurements are in terms of kinematic viscosity  $\nu$ , 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  $\mu$ .

**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.
2. Measure the densities of the sucrose solutions (see Procedure A in the appendix).
3. Receive the appropriate Cannon-Fenske viscometers from the TA and inspect the glassware for cleanliness and dryness. Clean if necessary. There are several different sizes of viscometers available in the lab: 350, 300, and 200 for viscous fluids, 75, 100 for fluids of intermediate viscosity, and 50 for less viscous fluids including water. The correct viscometer to use for each concentration and temperature is indicated in the accompanying table. Each viscometer has its own birth

certificate with a unique viscometer constant, which is its calibration constant. Note that the calibration constant is a function of temperature. Identify your viscometer with a serial number, which is imprinted on the glassware and its certificate (posted on the web and also in a binder in the lab).

wt% sucrose	20°C	40°C	60°C
0	<-----50----->		
10	<-----50----->		
20	75	<-----50----->	
30	100	<-----75----->	
40	<-----100----->		75
45	<-----100----->		
50	<-----200----->		100
60	300	200 or 300	200 or 100
65	350	300	200

- Using the water baths in the laboratory, measure the viscosity of your solutions at the three assigned temperatures: room temperature, 40°C, and 60°C (see Procedure B in the appendix).
- Shut down the station (see Shut Down procedure in the appendix).

### Data Analysis

- Determine the room-temperature densities of your two sugar solutions from your measurements; share with classmates. Report the average densities (all concentrations) based on all class replicates. Determine also the 95% CI based on the combination of replicate, reading, and calibration error.
- Determine viscosities (in *cp*) for your two solutions from average efflux times using the calibration constants for your viscometers at the appropriate temperatures. Be sure to

interpolate the viscometer calibration constants to get the calibration value for the temperatures you need. Fill out the Google form promptly to share data with classmates.

- Using all the class data, report the viscosity as a function of concentration and temperature along with its 95% CI.
- Compare your values of density and viscosity with values from the literature (consider uncertainty).
- At each measurement temperature, plot viscosity versus solution concentration using data from all laboratory groups. Choose your scale (linear, log, linear-log) based on how the data behave. Put all three temperature plots on the same, single graph. Note: put all class data, not averages here.
- For each of the three temperatures, find a best-fit line to the class' data of viscosity versus concentration. Do not pre-average viscosities—let the least-squares algorithm do the accommodation among the data points. You should get a fit good enough to use to interpolate between data points (NOTE: an exponential is not an acceptable function to fit to the data of viscosity versus concentration – the fit is too rough; look for a better way. Note also that a linear fit on a plot of  $\ln \mu$  versus concentration is the same as an exponential fit). Report the equations of the lines that fit the data.
- Determine the concentration of the *mystery* samples based on their viscosity and density results. Justify the accuracy of the answer you report.
- As always, attach raw data tables to your report as an appendix (do not

include raw data tables in the report). Error bars are the usual way to express uncertainty on graphs; you are responsible for making your graphs readable and understandable.

**References:**

Morrison, Faith, *An Introduction to Fluid Mechanics*, Cambridge University Press, New York, 2013.  
Perry and Green, *Perry's Handbook of Chemical Engineering* (multiple editions possible).  
Lide, *CRC Handbook of Chemistry and Physics* (multiple editions possible).

## Appendix: Procedures and Assigned Operating Conditions

### Assigned Concentrations

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

### Shut Down Procedure

1. Dispose of your sugar solution in the sink. Use a pipette bulb to expel the solution from the viscometer.
2. Clean the viscometers and pycnometer (see Procedure C in the appendix)
3. You must return the clean, dry glassware to the TA for inspection.
4. Dry off any wet table-tops with paper towels.
5. Turn off all the electronic devices and properly store them.

40

### Procedure A: Measure the density of the sucrose solutions

1. Inspect the pycnometer and ensure that it is clean and dry. If not clean, clean it with water; give it a final rinse with acetone and dry it with dry air (see shut-down procedure for more details on cleaning methods).
2. Weigh the clean, dry pycnometer with its matching top.
3. Fill the pycnometer with solution and fit the matching top into the

bottom. Fluid will squirt out of the capillary in the top so that a precise volume is retained in the vessel.

4. Wipe the pycnometer clean and weigh the filled pycnometer.
5. Calculate density as weight of fluid divided by the volume of the pycnometer.
6. Dispose of the sucrose solution by pouring it down the drain.
7. Clean all empty glassware with water, especially be sure to rinse the inside of the top (or it will clog with dried sugar). Use a pipette bulb or ear syringe to force clean, distilled water through the capillary several times to ensure that no sugar remains. Store with a small piece of Kimwipe to separate the pycnometer from its associated cap.

### Procedure B: Measure viscosity

1. Load solution in viscometer (see Cannon-Fenske instructions on web).
2. Put the viscometer in a bath and clamp it securely so that the tube is vertical.
3. You must allow the viscometer to come to thermal equilibrium (about 5 minutes in our case since time is limited) in the bath at the measurement temperature. It is advisable to do the runs that have the shortest expected efflux times first.
4. Draw fluid up into the upper reservoir and measure efflux time, the time of passage of the meniscus from one timing mark to another; (see Cannon-Fenske instructions on web).
5. Do a minimum of three replicates of efflux time for each viscosity/temperature combination. There is a listing on the web of approximate efflux times to help you plan your experiments.

***Procedure C: Glassware cleaning***

***It is essential to remove all sugar from pycnometers and viscometers since sugar crystals can form and plug small passageways.***

1. Clean the viscometers and pycnometer thoroughly using water; use a pipette bulb or ear syringe to force clean, distilled water through the capillary several times to ensure that no sugar remains. Discard the water.
2. Add approximately 10-15ml of acetone to the viscometer and again use the pipette bulb to force the acetone through the capillary. Be sure to expose every internal surface of the viscometer with acetone; this will make it possible to dry the viscometer (the acetone scavenges the water).
3. Dry the viscometer with the high-pressure dry air provided (should take less than a minute if all water has been scavenged by the acetone).