Theory

Surface tension is the apparent interfacial tensile stress (force per unit length of interface) that acts whenever a liquid has a density interface, such as when the liquid contacts a gas, vapor, second liquid, or solid. The liquid surface at an interface appears to act as a stretched elastic membrane.

A force balance on a segment of interface shows that there is a pressure jump across the imagined elastic membrane whenever the interface is curved. Surface tension also leads to the phenomena of capillary rise or depression. When the contact angle between the liquid and solid is less than 90 , the liquid tends to wet the solid surface and the tensile stress due to surface tension tends to pull the liquid free surface up near the solid, forming a curved meniscus. This capillary rise may be pronounced if the liquid is in a small diameter tube. The surface tension of the liquid can be calculated from the rise in the capillary tube by an appropriate equation (see Calculation section).

Apparatus

The surface tension analyzer consists of a 250mm long borosilicate glass capillary tube, of 0.5mm nominal ID, graduated from 0-10 cm in 0.1cm increments, a glass cylinder with tubulation, and a rubber stopper.

Measurement Procedure

1. Prepare the capillary as follows:
   a. Clean the capillary thoroughly with chromic acid.
   b. Rinse with distilled water
   c. Rinse with methanol
   d. Rinse with the sample to be analyzed
2. Place a quantity of sample in the cylinder
3. Place a small amount of petroleum jelly over the hole on the bottom side of the stopper. Hold the capillary tube straight up with the bottom resting on a bench top. Push down on the stopper, pushing the capillary tube through the stopper until approximately 1" of the tube is above the top of the stopper. **CAUTION:** Do not push the capillary tube into the stopper by pushing the tube with your hands as the tube may break, resulting in injury.
4. Place the stopper with capillary into the cylinder
5. Affix a rubber bulb (pipet filling bulb) to the cylinder tubulation and expel air through the tubulation until sample comes out of the top of the capillary
6. Repeat #5 and allow the meniscus inside the the capillary to come to equilibrium
7. Record the distance between the meniscus inside the capillary and the meniscus inside the cylinder
8. Repeat #5 - #7
9. Draw air out of the cylinder using the rubber bulb and allow the meniscus inside the capillary to come to equilibrium
10. Repeat #7
11. Repeat #9 & #10
12. Average the four readings

Calculation

Calculate the surface tension from the following equation:

$$y = (1/2)(h)(r)(d)(g)$$

where:
y = surface tension (dynes / cm)
h = distance between menisci (cm)
r = radius of capillary (cm) (see back of page)
d = density of sample (g/cc at measuring temperature)
g = acceleration due to gravity (cm/ sec / sec) (see back of page)

Capillary Radius

The capillary tube has a nominal ID of 0.5mm, with a tolerance of +/- 0.1mm. The uncertainty in the surface tension measurement is essentially the uncertainty in the bore dimension (+/- 20%). For very precise work, the radius of the capillary should be determined. This can be done by using pure benzene at known temperatures and with the use of the following table:

Temp., C	y	d
10.0	29.36	.8885
46.2	24.67	.8499
78.2	20.68	.8147

By comparing the measured surface tension of benzene at one of the temperatures given, to the theoretical, allows the actual radius of the capillary to be calculated:

r= (2)(y) / (h)(d)(g)

Acceleration Due to Gravity

The acceleration due to gravity is nominally 980.7 cm/sec/sec. The following tables provide values for g at various latitudes and altitudes.

Latitude	g, cm/s^2
0	978.039
5	978.078
10	978.195
15	978.384
20	978.641
25	978.960
30	979.329
35	979.737
40	980.171
45	980.621
50	981.071
55	981.507
60	981.918
65	982.288
70	982.608
75	982.868
80	983.059
85	983.178
90	983.217

Free Air Correction for Altitude

.0003066 cm / s^2 / m

Altitude, m	Correction, cm / s^2
200	.0613
300	.0920
400	.1226
500	.1533
600	.1840
700	.2146
800	.2453
900	.2759