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Monika Thakur
Department of Chemistry,
A.S. College, Khanna,
Ludhiana, Punjab, India

Hina Wadhwa
Science Mistress, GMS Kotla
Ajner, Mumbai, India

Correspondence
Monika Thakur
Department of Chemistry,
A.S. College, Khanna,
Ludhiana, Punjab, India

Experimenting with stalagmometer and viscometer on day to day drinking liquids

Monika Thakur and Hina Wadhwa

Abstract
The Surface Tension and Viscosity measurements were conducted for day to day drinking liquids. A total of eight samples including milk, juice and soft drinks which are commonly available in the market were taken for the study. The main aim of the study was to evaluate the surface tension and viscosity of these liquids with reference to fresh water. The work revealed that the full fat milk has highest viscosity (1.24centipoise) and least surface tension (60.87 dynes/cm) as compared to fresh water sample which has viscosity (0.85centipoise) and surface tension (71.84 dynes/cm) at 27.1 ºC.

Keywords: Ostwald’s Viscometer, Traube’s Stalagmometer, Canned juice, Fresh juice, Soft drinks, Milk

1. Introduction
In our day to day life, we often come across the numerous consequences of surface tension and viscosity. For example, it is surface tension that enables an ant to walk at the surface of water, gives dew drops the spherical shape, which does not allow water and oil to mix together, etc. Similarly, we come across many examples of viscosity in our daily lives such as texture of paints and oils, choice of lubricants for machines, content of fat in milk, etc. This paper gives us an idea of simple instruments used for determining surface tension and viscosity of liquids. In the present study Ostwald’s viscometer and stalagmometer have been used to determine the viscosity and surface tension, respectively, of some daily use liquids.

2. Ostwald’s Viscometer
The most commonly used viscometers are the gravity type viscometers, in which simplest and most common design is the Ostwald’s viscometer, named after Wihelm Ostwald. This viscometer (Fig.1.) is made of glass and is U-shaped, having two bulb reservoirs (marked A and B) and a capillary tube. There are two marks (C&D) etched above and below bulb A.

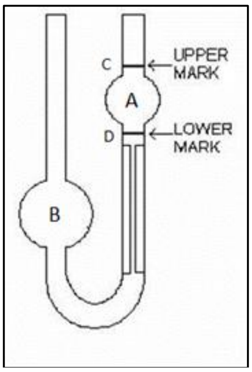

Fig 1

Liquid is added in the lower reservoir B and pulled up by suction into the upper reservoir a upto mark C. It is then allowed to drain by gravity back into reservoir B. The time taken by the liquid to drain from point C to D is noted and coefficient of viscosity (η) is calculated using the formula

$$\frac{\eta}{\eta 0} = \frac{dt}{d0t0}$$

Where, η is the viscosity of liquid under study, η_0 is viscosity of reference liquid (generally water), d is the density of liquid under study, d0 is density of reference liquid, t is time of flow of liquid, t0 is time of flow of reference liquid.

2.1 Principle

Ostwald's viscometer method is based on Poiseuille's law, according to which the rate of flow of liquid through a capillary tube having coefficient of viscosity η, can be expressed as

$$\eta = \frac{\pi p r^4 t}{8Vl}$$

Where V is volume of liquid flowing through capillary of length 'l' with radius 'r' for time 't', generating a hydrostatic pressure 'p'.

If same volume of liquid is used every time for measurement then,

η = kpt

Where k is a constant and is equal to,

$$\frac{\pi r^4}{8Vl}$$

Therefore, $\eta \propto$ pt

It is the hydrostatic pressure which acts as the driving force for the flow of liquid and is given as
p = hdg

The coefficient of viscosity, η, of the liquid under study can be written as,

$\eta \propto$ hdgt

Correspondingly, the coefficient of viscosity, $\eta 0$, of reference liquid can be written as,

$\eta 0 \propto$ hd0gt0

Using these expressions we have,

$$\frac{\eta}{\eta_0} = \frac{dt}{d_0 t_0}$$

3. Traube's Stalagmometer

Traube's Stalagmometer (Fig.2) is a classical instrument for carrying out surface tension measurements of the liquids. It is a glass tube widened in the middle similar to a pipette. The lower end has a fine capillary inside it and the upper end has a wide tube with rubber tubing at the top of it. There is a bulb in the central part with marks A and B etched above and below it.

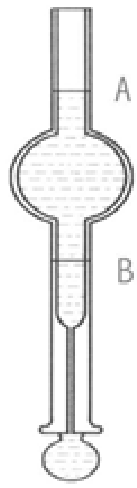

Fig 2

The test liquid is filled from the upper end and is allowed to fall freely under the force of gravity forming drop, and then, by counting the number of drops or the mass of drops, surface tension of the liquid under study can be calculated.

3.1 Principal

Traube's Stalagmometer works on the principle of Tate's Law. As the size of the falling drop at the tip of the tube grows, its weight goes on increasing. It remains attached to the tip of the tube due to an upward force, which is due to intermolecular attractions in the liquid and is imbalanced at the surface resulting in surface tension, acting around the circumference of the tube. When the downward force due to gravity becomes slightly greater than the upward acting force, the drop detaches from the tip of the tube.

The upward force can be given as,

$$F=2\pi r\gamma \qquad (1)$$

Where**,** $\gamma$is the surface tension, 'r' is the radius of the tube tip (outer radius of the tube is taken if the liquid wets the tube completely, and inner radius of the tube is taken if the liquid does not wet it at all.)

The downward force, due to gravity acting upon the liquid drop, can be given as,

$$W = mg \qquad (2)$$

Here, 'm' is the mass of the falling drop and 'g' is the acceleration due to gravity. Equating (1) and (2), we get,

$$2\pi r\gamma = mg$$

This expression is known as Tate's law.

In the above expression, to avoid the use of r (as it is difficult to find the radius of the tip) i.e. outer or inner radius of the tip of the tube, a relative approach is used by taking a reference liquid which may be ultrapure water or an ultrapure organic liquid as follows;

For liquid 1 (reference liquid) the above expression becomes,

$$2\pi r\gamma 1 = m1g \qquad (3)$$

For liquid 2 (unknown liquid, whose surface tension is to be calculated.)

$$2\pi r\gamma_2 = m_2 g \quad (4)$$

Dividing (3) and (4), we get

$$m_1\gamma_2 = m_2\gamma_1$$

$$\gamma_2 = \frac{m_2\gamma_1}{m_1} \quad (5)$$

From (5) the surface tension of an unknown liquid can be calculated.

Two approaches can be followed while using a Traube's stalagmometer in the laboratory.

- Drop number method
- Drop weight method

3.2 Drop number method

In this method, number of drops of test liquid falling between upper (A) and lower (B) marks of the stalagmometer is counted.

Consider the volume of the liquid contained between the upper and the lower marks of the stalagmometer is V, the mass of the liquid in this volume is M, and the density of this liquid is ρ, then

$$M = \rho V$$

The volume V corresponds to n drops of liquid from upper to lower mark,then the average mass m of one drop of liquid can be calculated as

$$m = \frac{M}{n} = \frac{\rho V}{n}$$

Substitute the value of m in (5)

$$m_1 = \frac{\rho_1 V}{n_1}$$

$$m_2 = \frac{\rho_2 V}{n_2}$$

We get,

$$\gamma_2 = \frac{\rho_2 n_1}{\rho_1 n_2}\gamma_1$$

Hence the surface tension of an unknown liquid can be calculated easily by knowing the no of drops n1 and n2 using stalagmometer, while the values of ρ1, and γ1 can be taken from the tables.

The value of ρ2 can be calculated by using specific gravity bottle.

3.3 Drop weight method

In this method, mass of known no of drops of both the liquids (reference liquid and unknown liquid), say 20 drops each, one by one, is measured by collecting the drops in an already measured specific gravity bottle. From this, the mass of one drop of each liquid can be found. Then using the expression,

$$\gamma_2 = \frac{m_2\gamma_1}{m_1}$$

The surface tension of unknown liquid is calculated.

Here m1 and m2 are the masses of one drop of reference liquid and unknown liquid respectively, and γ 1 and γ2 are the surface tensions of reference liquid and unknown liquid respectively.

4. Factors affecting viscosity and surface tension

Viscosity and Surface tension of a liquid is affected by a number of factors which should be considered while performing the experiment. These factors are enlisted below:

1. **Temperature:** Viscosity and Surface tension have an inverse relationship with temperature. Therefore temperature changes affect the viscosity and surface tension of a liquid.
2. **Pressure:** Compressing liquids at low or moderate pressure will have negligible effect on viscosity and surface tension, but a very high change in pressure can cause a change in these properties of a liquid.
3. **Composition:** Viscosity and surface tension of liquids also depends on the composition of the liquid. A pure liquid and a mixture of solution will have different viscosities and surface tension values.
4. **Inter molecular Forces:** Viscosity and surface tension have direct relationship with the intermolecular forces in the liquid.

5. Experimentation & Observation

Ostwald's Viscometer and Traube's stalagmometer have been used in present study to determine viscosity and surface tension of 8 samples. Density of liquids is determined using specific gravity bottle. Surface tension is calculated using the drop number method. Observations are made at temperature 27.1 °C. (Table 1.)

Table 1

	Sample	Desity (in g/ml)	Time of flow (in sec)	Viscosity (in centipoise)	No. of drops (n1)	Surface Tension (in dynes/cm)
1.	Skimmed milk	1.03	22.70	1.16	49	71.22
2.	Full fat milk	0.61	25.11	1.24	57	60.87
3.	Fresh pomegranate juice	1.05	20.75	1.08	39	91.66
4.	Canned pomegranate juice	1.06	21.40	1.12	37	96.98
5.	Pepsi	1.03	18.98	0.97	33	106.58
6.	Thums up	1.03	19.18	0.98	36	97.69
7.	Coke	1.03	19.66	1.00	37	94.87
8.	Diet coke	0.99	17.52	0.86	32	105.03
9.	Water	0.99	17.20	0.85	47	71.84

6. Conclusion
It can be concluded from the experimental values that Full Fat milk has highest viscosity (1.24centipoise) and lowest surface tension (60.87 dynes/cm) at given temperature. A comparison amongst values for soft drinks, revealed that Pepsi has highest surface tension
(106.58 dynes/cm) whereas Coke has lowest value (94.87dynes/cm). Coke was found to be most viscous (1.00cp) among cold drinks, while Diet coke showed least viscosity (0.86cp). Similarly, Canned Pomegranate juice was found to have higher viscosity (1.12cp) and surface tension (96.98 dynes/cm) than fresh pomegranate juice with values (1.08cp) and (91.66dynes/cm) respectively. Full fat milk was observed to be more viscous (1.24cp) than skimmed milk (1.16cp) and surface tension value calculated was higher for skimmed milk (71.22dynes/cm) than full fat milk (60.87dynes/cm). Further study can be performed to determine the effect of change in temp, pressure and composition on the surface tension and viscosity measurements of these samples.

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