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Contents

Surface Tension of Liquids (Water, Chloroform and Acetone) by Capillary Rise Method

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Abstract

Surface tension is a crucial property of liquids that depends on the liquid's composition. This study aims to compare the surface tension of water, chloroform, and acetone using the capillary rise method. It involves using a capillary tube with a known radius, dipping it vertically into a liquid, and measuring the height to which the liquid rises in the tube. The surface tension of the liquid can then be measured experimentally. This relates to height of the liquid in the tube, the radius of the tube, and the surface tension of the liquid. The height of the liquid in the tube is dependent on the radius of the tube, with a smaller radius resulting in a greater height. The surface tension of the liquid is inversely related to the radius of the capillary tube.

Keywords: *capillary tube, surface tension; liquid (Water, Chloroform, Acetone)*

1. Introduction

Surface tension is a fundamental property of liquids that arises from the cohesive forces between the molecules at the liquid's surface. This property is a crucial for various natural phenomena and industrial applications. In this study, the surface tension of three different liquids, namely water, chloroform, and acetone, is investigated.

Surface energy (Vikash, 2021) can be observed in the way that the surface of a liquid tends to minimize its own area, forming into a smooth, round shape when possible. The energy required to increase the surface area of a liquid by a unit of area is known as surface tension. Surface tension of given liquid is a function of temperature (Yaws, 2014). The surface tension of chloroform was found to be higher than that of water, while the surface tension of acetone was lower than that of water (Hall & Pugsley, 2020). Understanding and controlling surface tension can be crucial in a wide range of applications (Gheribi & Chartrand, 2019; Ghoufi et al., 2016; Bing et al., 2017; Khan et al., 2020 & Monko et al., 2017). Water is a common liquid with unique surface tension properties. It is known for its relatively high surface tension. This means that water

molecules at the surface tend to stick together strongly, resulting in a "skin-like" effect on the water's surface. This property allows small objects like insects to seemingly defy gravity and "walk" on the surface of water. It also causes water drops to form nearly spherical shapes due to the minimization of surface area.

Chloroform is a volatile organic compound that has a higher surface tension than water. This means that the cohesive forces between chloroform molecules at its surface are stronger than those in water. As a result, chloroform tends to form an even more rounded and elevated meniscus when placed in a capillary tube compared to water. Understanding the surface tension of chloroform is important in various chemical and biological applications.

Acetone is another organic solvent with different surface tension characteristics. In contrast to water, acetone has a lower surface tension. This means that the surface molecules of acetone do not hold together as strongly as those in water. Consequently, acetone tends to spread out more on surfaces and forms flatter menisci in capillary tubes. This property of acetone can be advantageous in certain industrial and laboratory processes.

2. Materials & experiments

In this study, a tipped pointer traveling microscope, three types of liquids (Water, Chloroform, and Acetone), two capillary tubes of different radii and a needle were used to measure the surface tension of given liquids. The capillary tubes were made of borosilicate glass and had inner radii of 0.046 cm and 0.053 cm respectively. The experimental setup consisted of three sub-systems: a PC/monitoring system, a capillary rising system, and a high-speed imaging system. To measure the surface tension, we used the capillary tube method, in which the height of rise (h) of the liquid in each capillary tube was measured and used to calculate the surface tension (T_l) of the liquids is given by

$$T_l = \frac{rh\rho g}{2cos\theta} \qquad \qquad …(1)$$

Where, r is the radius of the capillary tube, ρ is the density of the liquid, g is the acceleration due to gravity and θ is the contact angle between the liquid and the capillary tube.

The capillary rise method, a single capillary tube was used and the height of rise (h) and height of the liquid were measured as in Fig1 . The densities of the liquids (Water, Chloroform, and Acetone) were given.

The surface tension (T_l) of polar liquid depends on temperature and critical temperature [9]. The relation between them is given by

$$T_l = A \, (t_c - t)^{\frac{3}{2}} \qquad \qquad …(2)$$

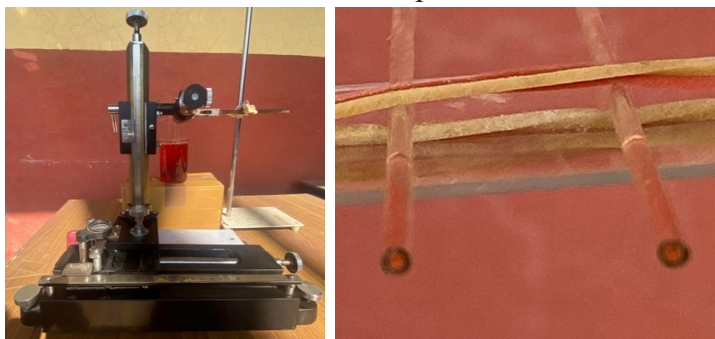Where, A proportional constant t_c Critical temperature and t variation temperature.

Fig. 1. Measurement of height and radii of capillary tube using travelling microscope.

The chloroform is an organic solvent having density 1.4832 g/cm³ at 20 °C. The density of Acetone is 0.7857 g/cm³.

3.   Calculations and analysis

Observation:

Least count of main scale (L.C) = 0.05 cm

Least count of vernier scale (V.C) = 0.001cm

In this experiment, we can be measured the surface tension by the help of given value of h and r for two capillary tubes separately. Now the value of h and r can be obtained with the help of table 1 and 2 respectively.

Table 1: Height of liquid (h)

Liquid	Tubes	Height of liquid (cm)				Rises height of liquid (h) (cm)
		Total Reading	Total Reading	h_1	h_2	$h = h_1 {-} h_2$
Water	1	7.075	3.955	4.46	1.602	2.862
	2	6.559				
Chloroform	1	6.323	6.256	1.36	0.68	0.68
	2	6.282				
Acetone	1	6.217	6.274	2.05	1.025	1.025
	2	6.289				

Table 2: Radii of capillary tubes (r)

S.N	Microscope reading for position of inner right wall of the tubes		
	Total reading	Total reading	Radius of the capillary tube (r)
1	16.607	16.614	0.046
2	2.855	2.908	0.053

Table 3: Surface tension of the liquid (T_l)

S.N.	Liquid	Height of the liquid, h(cm)	Radius of the capillary tube, r (cm)	Surface tension of the liquid (dyne/cm)
1	Water	2.862	0.046	69.42
			0.053	
2	Chloroform	0.68	0.046	24.575
			0.053	
3	Acetone	1.025	0.046	19.505
			0.053	

Table 4: Comparing standard and experimental value of surface tension of different liquids

S.N.	Liquids	Experimental Values (dyne/cm)	$\bar{x} \pm S.E$	Standard values (dyne/cm)	Temperature (ºC)
1	Water	69.42	6.817 ± 0.364867	72	23
2	Chloroform	24.575	6.3025 ± 0.028991	27.16	23
3	Acetone	19.505	6.253 ± 0.050912	23.32	23

Calculation of the surface tension of the different liquid (Water, Chloroform, and Acetone) by using the above equation (1).

Radius of capillary tube 1 (r_1) = 0.046 cm

Radius of capillary tube 2 (r_2) = 0.053 cm

For Water, the density of water (ρ) = 1 g/cm^3

The measured and standard value of surface tension of the liquids (Water, Chloroform, and Acetone) are predicted in table 3 and 4 respectively and those values are close agreement with the standard results.

4. Results and disscussion

The results of the study showed that the surface tension of water and organic liquids like Chloroform and Acetone can be measured using the capillary rise method. The values of surface tension obtained were all positive, indicating that the surface tension acts in an upward direction. The surface tension of chloroform was found to be higher than that of water, while the surface tension of acetone was lower than that of water. These results suggest that the surface tension of a liquid is influenced by its molecular structure and intermolecular forces. Water, being a polar molecule, has a higher surface tension than non-polar molecules like chloroform and acetone. Additionally, the fact that the surface tension of acetone is lower than that of water could be due to the presence of a carbonyl group in its molecular structure, which can disrupt the intermolecular forces between acetone molecules.
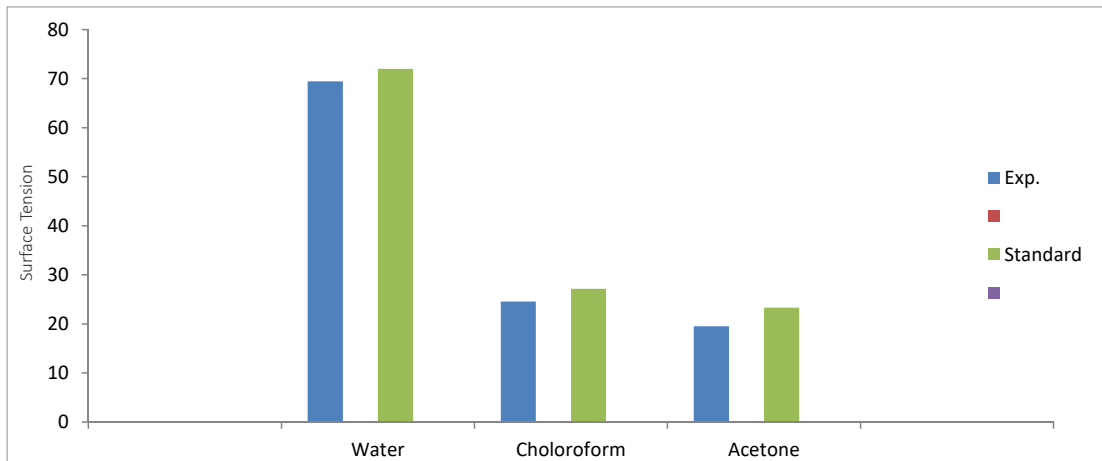
Fig. 2. Bar diagram of different liquids (Water, Chloroform and Acetone)

The surface tensions of the different liquids (Water, Chloroform and Acetone) are compared by Fig. 2 column picture. In this diagram, the surface tension of water is greater than chloroform and acetone because the effect of temperature on the surface tension i.e. the decrease in surface tension with increase of temperature and inter-molecular force of attraction also decreases.
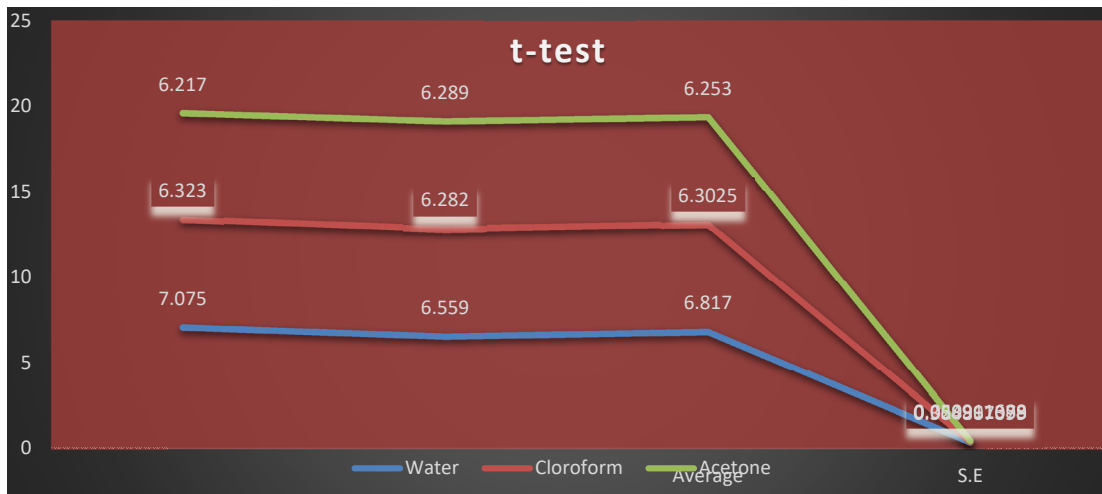

Fig. 3. The graph by the t-test (S.E. =0.600927)

Fig.3. shows that the liquids are slowly increasing and then going on a straight line. This is plotted by the statistical data of different liquids (Water, Chloroform and Acetone). We have calculated the average value and standard deviation of different liquids using by the given statistical data, The standard errors of the surface tension (mean ± standard error) of the different liquids were calculated by using the T-test.

5. Conclusion

In conclusion, the capillary rise method was found to be an effective method for determining the surface tension of the different liquids, including water, chloroform, and acetone. The

experimental values of surface tension were compared with standard literature values. The experimental values were found to be reasonably close to the literature values for all three liquids: water, chloroform, and acetone. Water, being a polar molecule, had a higher surface tension than non-polar molecules like chloroform and acetone. The surface tension of acetone was found to be lower than that of water, possibly due to the presence of a carbonyl group in its molecular structure, which can disrupt the intermolecular forces between acetone molecules. The standard error of the surface tension measurements was found to be 0.600927. These findings provide a better understanding of the factors that influence surface tension and may be useful in a range of applications where surface tension plays a role, including in the design of microfluidic devices, the development of new surfactants, and the optimization of industrial processes. It's important to note that the capillary rise method assumes ideal conditions, and real-world factors such as impurities in the liquids or imperfections in the glass capillary tubes may introduce errors.

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