Surface Tension as a Function of Temperature and Concentration of Liquids.

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Abstract

The solution of detergent, sugar and fresh milk of different concentrations were prepared by adding water into them. The surface tension of such solutions was calculated by using capillary rise method. The temperature dependent study was made for water, the increased temperature of water decreases surface tension. Similarly the increased % of sugar and detergent in the water lowers the surface tension of solution. While for a milk, the additive water in milk shows increase of surface tension.

Keywords: capillary tube, detergent, sugar, milk, temperature, surface tension.

Introduction

Liquids possess some properties like density, viscosity, surface tension etc. Out of these properties, surface tension is the only property of liquid because of which the solids having greater density than that of liquid can float on to the surface of liquid. Also the shapes of drop are governed by the property of surface tension. The purity of certain liquids decides the value of surface tension. Surface tension of different liquids according to various parameters like temperature, concentration was studied.

Liquids are distinguished from gases, they exhibit a free surface. The free surface of liquid possesses certain mechanical properties; these mechanical properties are due to cohesion between molecules, which is molecular attraction. The free surface of liquid i.e. surface of a separation between liquid and liquid or gas acts like a stretched (elastic) thin membrane, this membrane is under tension and tries to contract. The property of free liquid surface showing contracting tendency is called surface tension.

$T = F/L$, N/m or dynes/cm

The surface tensions of different materials like Mercury at $0^{O}C$ = 0.44 N/m, for Water at 0 ^{O}C = 0.076 N/m and 100 ^{O}C = 0.059 N/m and for soap solution at 20 ^{O}C = 0.025 N/m reported by [1]. Surface tension plays in interesting phenomenon capillarity. It is common observation that water in glass container rises up slightly, where it touches the glass. The water is said to "wet" the glass. For water at room temperature the value of surface tension T= 0.073 N/m, adding soap reduces the surface tension to 0.025 N/m. Organic liquids and aqueous solutions typically have surface tension in this range. The surface tension of liquid metals is typically an order of magnitude larger than that of water. Liquid

mercury at room temperature has a surface tension of 0.487 N/m [2]. The increased temperature decreases the surface tension was reported by [3]. The cohesive properties of liquids can be changed by the addition of small amount of other substances e.g. molecules in oils are hydrophilic and oils will not dissolve in pure water. Molecules of soaps and detergents have both hydrophobic and hydrophilic portions. The hydrophilic part attaches itself to the water surface, and the hydrophobic portion surrounds oil or grease [4].

Surface tension, also often known as interfacial tension is an important property of a liquid. In simple terms, it is the force acting on the surface of a liquid, tending to minimize the surface area it affects physical properties such as wet ability of a liquid. Often surface tension is observed as the formation of a meniscus in containers or as the formation of droplets or bubbles on a surface. In the dairy industry, surface tension of milk is an important property as it has an impact on the formation of emulsions [5]. Surface tension of milk is approximately seventy percent of surface tension of water. It affects creaming, fat globule membrane function, and foaming processes carried out in the dairy industry. [6, 7].

The surface tension values from the two sources are slightly different. This may be due to variations in the milk quality from two different regions. The cow breed, age, lactation period, stages of milking, different quarters of udder, weather, temperature etc. are some of the factors that would affect the physical properties of milk [7]. Surface tension of different homogenized milk and cream, available in New Zealand, has been measured using the 'Capillary Rise' method as well as the automated Wilhelmy Plate method. Increasing the fat content is found to have an inverse effect on the surface tension. This effect diminishes progressively for fat concentrations beyond 30% [8]. The phenomenon of denser objects floating on a liquid surface is a simple yet fascinating occurrence in nature. We observe this from the common day experience of small floating drawing clips to insects walking on water [9].

There are many observations illustrating this peculiar behavior of free surface of liquid. viz., water slowly leaking from a tap does not merge continuously but in a succession of drops, liquids like water, alcohol tend to rise in capillary tube above free surface, a sewing needle floats on the surface of water when placed carefully and produces small depression in the surface.

Experimental Work

Material and Methods

There are several general methods used for the determination of surface tension, some of them are as follows 1) Capillary rise method 2) Jaeger's method

3) Ferguson and Kennedy's method 4) Quincke's method etc.

From the above methods the capillary rise method is simple, easy and less expensive.

Procedure

CAPILLARY RISE METHOD

It is the simple laboratory method for the determination of surface tension of liquids which wets the walls of the tube, i.e. for which the angle of contact to be zero. A capillary tube is taken and the uniformity of its bore should be carefully tested. When a proper tube has been selected, it is thoroughly cleaned by rinsing it first with caustic soda, then with nitric acid and finally with distilled water. If the liquid whose surface tension is to be determined, for water the tube may be used straight way. For some other liquids than water, the tube must be properly dried by passing warm air through it, and then fixed vertically, alongside a plumb line, with its lowered end immersed in the experimental liquid contained in a thin glass beaker [4] When the capillary tube is dipped into a liquid like water shown in fig.1, which wets it and for which the angle of contact may be taken as zero. The liquid immediately rises up into it because of capillary action, if the tube be a fine one, the shape of the liquid meniscus is spherical and concave upward.

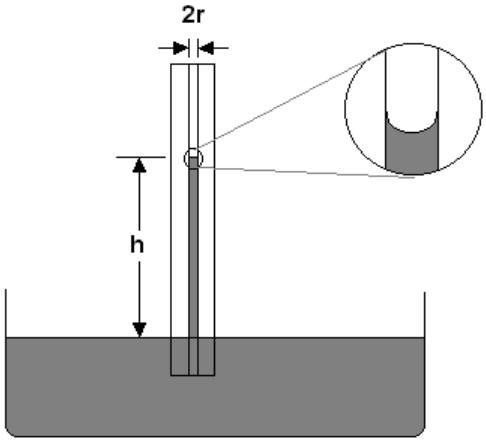

Fig.1 Capillary rise due to surface tension

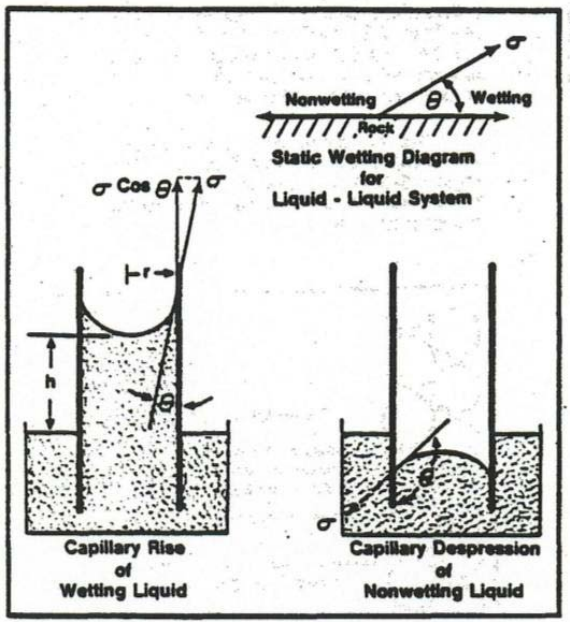

Fig.2 Shows angle of contact for wetting and non wetting liquids.

Let ‘r’ be the radius of the tube at the point up to which the liquid rises into it. then it will be practically the same as the radius if the concave meniscus, so that the excess pressure above the meniscus over that immediately below it is $2\sigma/r$ i.e. the pressure in the liquid, just below the meniscus is less than the atmospheric pressure, above it by $2\sigma/r$. Since the pressure on the liquid surface, outside the tube is atmospheric, the liquid will be forced up into the tube, until the hydrostatic pressure of the liquid column

in the tube equals the pressure 2σ/r. If the liquid rises to a height 'h' the hydrostatic pressure due the liquid column in the tube on the surface of liquid will clearly be 'hρg' [2, 4].

Where 'ρ' is the density of liquid.

Thus $2\sigma/r = h\rho g$ or $\sigma = rh\rho g/2$ --------- (1)

In case, however the angle of contact for the liquid be not zero shown in fig.2 and the tube not narrow, the surface tension 'σ' of the liquid acts inward along the tangent to the liquid meniscus at every point of its contact with the inner surface of the tube , making an angle 'θ' with the wall of the tube. If however , volume be not negligible, its valve may be determined by taking the meniscus to be hemispherical in shape of radius nearly equal to 'r' i.e. the same as that of tube at that place so that the volume of the liquid in the meniscus is equal to the difference between the volumes of the cylinder of radius 'r'.

$V = \pi r^2.r - (2/3)\ \pi r^3 = 1/3\ \pi r^3$ ------ (2)

In this case

$2\pi r\ \sigma \cos\theta = [\pi r^2 h + (1/3)\pi r^3]\ \rho.g$ ----- (3)

Where '$\pi r^2 h$' is the volume of the liquid column with height 'h' and

r – Capillary radius, σ – Liquid surface tension, ρ – Density of liquid,

θ – Wetting contact angle.

Therefore

$\sigma = \pi r^2 [h + (r/3)]\ \rho.g / 2\pi r \cos\theta$ ----- (4)

for $\theta = 0$, $\cos\theta = 1$ we have

$\sigma = r [h + (r/3)]\ \rho.g / 2$ dynes/cm ----- (5)

If 'θ' is greater than 90^0, cosθ is negative and the liquid column is depressed below, i.e. h is negative. Hence it is so difficult to introduce mercury for which ($\theta = 140^0$ nearly) into a fine capillary tube [3]

3. Results and Discussions

As mentioned before 'r' is the radius of the capillary tube and 'h' the height of the immersed liquid in the capillary measured by using travelling microscope we easily determine the surface tension of liquid. Due to increased temperature of water, impurities of any kind are evaporated and also the intermolecular forces are reduced thus by lowering the surface tension.

The sugar molecules are attracted more strongly by the liquid molecules. If this attraction exceeds that between the liquid molecules among themselves, it reduces the surface energy, resulting in a decrease in the surface tension of the solution.

Soaps and detergents have the effect of lowering the surface tension of water. This is desirable for washing and cleaning since the high surface tension of water prevents it from penetrating easily between

the fibers of material and into tiny crevices. Substances that reduce the surface tension of liquid are called surfactants.

Fig shows increase of surface tension with added percentage of water into the milk. Surface tension of pure milk is always lower than water. It affects creaming, fat globule membrane function. The surface tension values from different sources are also slightly different.

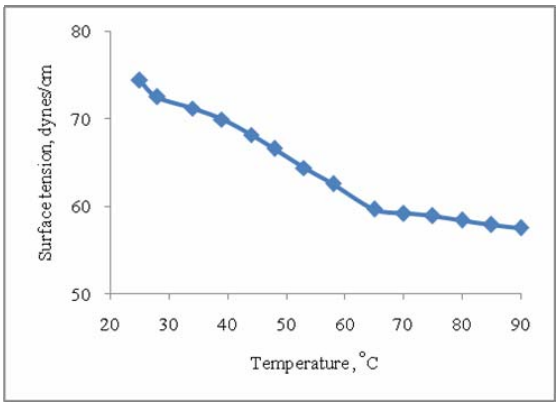

Fig. 3: Plot of temperature of water verses surface tension

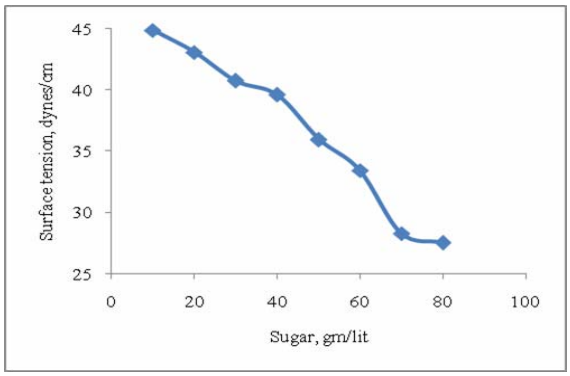

Fig. 4: Plot of sugar solution of different concentration verses surface tension**.**

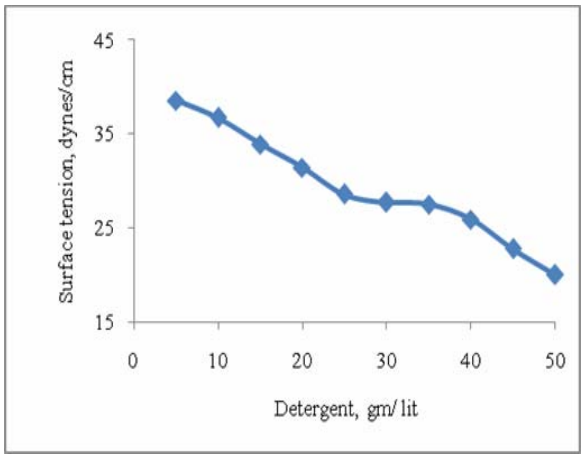

Fig. 5: Plot of detergent added in water verses surface tension**.**

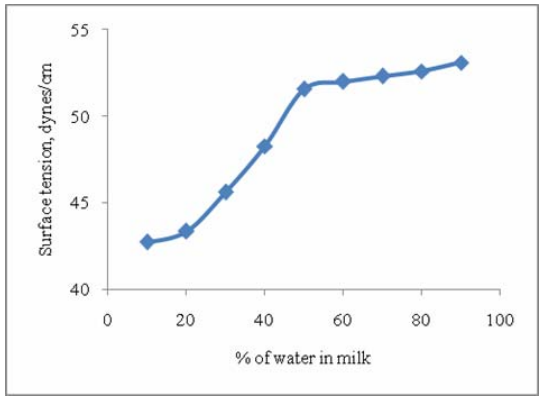

Fig. 6: Plot of % of water added in buffalo milk verses surface tension**.**

Factors Affecting Surface Tension

Various factors which affect the surface tension of a liquid are as follows.

Contamination of liquid surface

The surface tension of the liquid reacts immediately and more or less sharply to any contamination of the liquid surface. The presence of impurities of any kind of the surface may, bring about the marked change in the value of its surface tension , depending of course , on the degree of contamination.

Presence of dissolved substance in the liquid

Here two distinct cases arise, (a) when the substance is highly soluble in the liquid, and (b) when it is feebly soluble.

In case (a) obviously the solute molecules are attracted more strongly by the liquid molecules. If this attraction exceeds that between the liquid molecules among themselves, it follows that the presence of solute molecules in surface layer of the solution will result in a surface energy and in its surface tension.

In case (b) on the other hand, the molecules of the liquid itself moves into the interior of the liquid, their place in the outer layer being taken up by the solute molecules, resulting in a decrease in the surface tension of the solution, the concentration being higher in the outer layer than in the interior of the solution.

Applications

1) The larger is the value of surface tension, greater is the tendency to form drops i.e. the liquid cannot spread easily. Water is most often used for washing because water spreads easily. For this effect the surface tension of water must be reduced by adding detergent / soap into the water or by increasing temperature of water, both reduces the surface tension of water. The same is the reason why a photographer uses a wetting agent when developing a film.

2) When a ship at sea is caught in a storm, oil is poured on the surface of sea. The oil increases the surface tension of sea water and calms down the rough sea.

3) Blotting paper works on the capillary action.

Conclusions

Surface tension is one such property which gets affected by an amount of surface active reagents like detergent, sugar and milk added into the water. The increased % of detergent and sugar decreases the surface tension and the % of water in a milk increases the surface tension. The temperature dependent study was made for water, the increased temperature of water decreases surface tension.

Acknowledgement

The authors greatly thanks to the management authorities of M. G. Vidyamandir and the Principal, L.V .H. Arts, Science and Commerce College, Panchavati Nashik for giving valuable support to do this work.

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