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# Survismeter, 3-in-1 instrument for simultaneous measurements of Surface Tension, Inter Facial Tension (IFT) and Viscosity

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## Abstract

The article presents Inter Facial Tension (IFT) ($\gamma_{ift}$, N $m^{-1}$) of benzene-water; surface tensions ($\gamma$, N $m^{-1}$) and viscosities ($\eta$, N s $m^{-2}$) of ethanol, glycerol, ethyl acetate, n-hexane, diethyl ether, chloroform, benzene, carbon tetrachloride [$CCl_4$], formic acid, measured with Survismeter with ± $1.1\times10^{-5}$ N $m^{-1}$, ± $1.3\times10^{-5}$ N $m^{-1}$ and ± $1.1\times10^{-6}$ N s $m^{-2}$ accuracies respectively. Also the surface tension and viscosities of carboxymethylcellulose (CMC), dodecylbenzenesulfonicacid (DBSA) and tetramethylammoniumhydroxide (TMAH) in aqueous media have been measured with survismeter at 298.15 K. IFT of water and benzene interface *was* determined with survismeter. The survismeter saves resources, user's efforts and infrastructure more than 80 % as compared to usual methods and prevents 80% disposal of materials to environment. It very accurately measures surface tension and IFT of volatile and poisonous liquids at any desired temperatures as liquids are jacked *(jacketed)* in closed glass made bulbs.

***Keywords****: Survismeter, surface tension, viscosity, Inter Facial Tension*

## Introduction

There are numerous uses of viscosity, surface tension and interfacial tension in industrial cleaning, fabric cleaning, wettabilites, surface designing and drug designing etc. Several approaches are in practice for their measurement like viscometer, stalgmometer, contact angle and capillary rise methods etc. These are individual instruments with use of separate infrastructure, time, resources and laboratory occupation. Due to a crunch of resources and time the individual methods are not fitted in current trend of science and technology for last few decades because of emergence of green chemistry and nanotechnology. Also there has been much awareness for clean and green environment where discharge of volatile organic liquids suchas dioxane, benzene, and other industrial liquids which are carcinogeneous to environment is not safe. Hence there arose an urgent need to develop safe method to measure viscosity, surface tension and interfacial tension with use of minimum quantity of resources that will minimize discharge of effluents to environment after use. Currently surfactants are in focus for their wide uses in surface based technology and micro scale processes in physical and biological sciences. Hence wider studies on viscosities, surface tension and IFT are fundamental data for their influence on the surfaces and surface energetics to feed the surface based enzymatic reactions to mature them. The phenomenon like pesticides, spray ants, dry-cleaning, washing textile fabrics, drug disintegration, wet table packing materials and wrappers, cosmetics, surface coating doping, anti-aging creaminess etc., really require well defined role of the selective surfactants. Hence more and more studies on more and more surfactants are industrially useful. Therefore the carboxymethylcellulose, dodecylbenzenesulfonicacid and tetramethylammoniumhydroxide surfactants are highly useful in enormous ways so our studies are assumed to provide useful database to users.

We have developed and calibrated an alternative instrument survismeter for this purpose that permits measurement of viscosity, surface tension and interfacial tension simultaneously with single instrument. This minimize more than 80% resource and

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user's time as compared to separate instruments along with several plus points like poisonous and most volatile liquids or mixtures can be studied without their escape to environment. Hence survismeter is significant advancement over others [1-12] and is eco and environmental friendly. A sample is filled in its bulb No. 10 and after use the same is taken out via tube No. 11 whose inner diameter is 2 mm. The sample from bulb No. 10 is siphoned out using a manually operated suction pump number 14. So for changing the sample in bulb No. 10, the instrument remains fixed in the same position. So working of survismeter is very safe without any escape of solutions to environment or to user, every operation of it is in close manner.

**Operational handling:** Figure 1 presents its sketch, units 4-5-6-7-9-10, 2-7-8-9-10 and 15-16-18-19-B1-B2-1-10 measure viscosity, surface tension and IFT respectively. A 2/3 portion of bulb No. 10 is filled with wanted liquid via joint no.1 when unit 19-B1-B2 is not fitted in joint No.1. For viscosity joint No. 3 and 2 are stoppered and piston 14-17-18 is fitted with joint No. 4 to suck the liquid to bulb No. 5 from bulb no. 10 via bulbs 9 and 6. Stopper from joint No. 3 is withdrawn to evacuate liquid from bulb No. 9 to 10. The piston stopper No. 18 of unit 17-14 is withdrawn and viscous flow time (t, sec) for liquid within upper and lower marks of bulb No. 6 is noted down with $1x10^{-5}$ sec reproducibility. Similarly the liquid is sucked up to bulb No. 7 via bulb No. 9 and 8, the joint No. 4 and 3 are stoppered and stopper 18 with unit 17-14 is filled in joint no.2. The liquid from bulb No. 9 is evacuated like previous operation and piston stopper No. 18 is withdrawn and drop fall from capillary hanging in bulb No. 9 are counted for a liquid within upper and lower marks of bulb No. 8.

### *IFT*

Denser liquid is taken in bulb No. B1 and B2 of unit 13 fitting hollow stopper No. 18 and using piston. When B2 is filled, the piston stopper No. 18 is withdrawn and airtight stopper is fitted in joint No. 19 and unit 13 is fitted in joint 1. The bulb 10 contains benzene (immiscible lighter liquid) and capillary of B1 remains dipped in it. The stopper is removed from joint 19 and pressure passage unit 15-16-18 is fitted in it. The passage unit No. 15 allows 4-7 drops $min^{-1}$ in benzene medium and drops for water within upper and lower marks of B1 are noted down. Similarly the drops are also counted in air in place of benzene.

## Results

The t (viscous flow time), n (drop numbers) and $n_{ift}$ (drop numbers for interfacial tension) data are fitted in usual equations [3] for $\eta$, $\gamma$ and $\gamma_{ift}$ values respectively with 95.5% confidence level. The data are in Tables 1 and 2.

***Table 1.*** **Surface tensions ($\gamma/10^{-3}$ N $m^{-1}$) and viscosities ($\eta\pm$ $4.4x10^{-5}$ N s $m^{-2}$) with literature, $\Delta$ = exp.-lit. The exp and lit are for experimental and literature, respectively.**

**Measurements with survismeter**

| | | ***Surface tension*** | | ***Exp.-lit*** | ***Viscosity*** | | ***Exp.-lit*** |
|---|---|---|---|---|---|---|---|
| Systems | T. K | Lit. | Exp. | $\Delta$ | Lit. | Exp. | $\Delta$ |
| Ethanol | 293.15 | 22.40 | 22.46 | 0.06 | 1.060 | 1.061 | 0.001 |
| Glycerol | 298.15 | 64.00 | 64.03 | 0.03 | 1.490 | 1.489 | -0.001 |
| glycerol | 293.15 | 63.40 | | | 1.490 | | |
| Ethyl acetate | 298.15 | 23.15 | 23.17 | 0.02 | 0.441 | 0.443 | 0.002 |
| n-hexane | 298.15 | 17.90 | 17.86 | -0.04 | 1.790 | 1.794 | 0.004 |
| Diethyl ether | 293.15 | 72.8 | 72.768 | -0.032 | 0.233 | 0.2332 | 0.002 |
| Chloroform | 293.15 | 27.1 | 27.101 | 0.001 | 0.58 | 0.5810 | 0.001 |
| Benzene | 293.15 | 28.9 | 28.889 | -0.011 | 0.652 | 0.6518 | -.0002 |
| $CCl_4$ | 293.15 | 27.0 | 27.002 | 0.002 | 0.969 | 0.9691 | 0.0001 |
| Formic acid | 293.15 | 31.40 | 31.44 | 0.040 | 1.465 | 1.4649 | -0.0001 |
| DMF | 293.15 | 39.0673 | 39.0653 | 0.020 | 1.5656 | 1.5651 | 0.0005 |
| Acetonitril | 293.15 | 29.8579 | 29.8590 | 0.011 | 0.4379 | 0.4378 | 0.0001 |

*References 2, 4, 5 and 6 for Literature data.*

***Table 2.*** **Number of drop of water in air ($n_a$) and benzene ($n_b$) at 305.65 K for interfacial surface tension (IFT) between water and benzene. 0.8725 and 0.99455x10$^3$ kg m$^{-3}$ densities of benzene and water respectively were used, 71.10x10$^{-3}$ N m$^{-1}$surface tension of water at 31.5$^0$C.**

| $n_a$, of water in air | $n_b$, of water in benzene | IFT, 1x10$^{-3}$Nm$^{-1}$ |
|---|---|---|
| 46 | 13 | 30.81 |
| 46 | 13 | 30.81 |
| 46 | 13 | 30.81 |
| 46 | 13 | 30.81 |
| 46 | 13 | 30.81 |

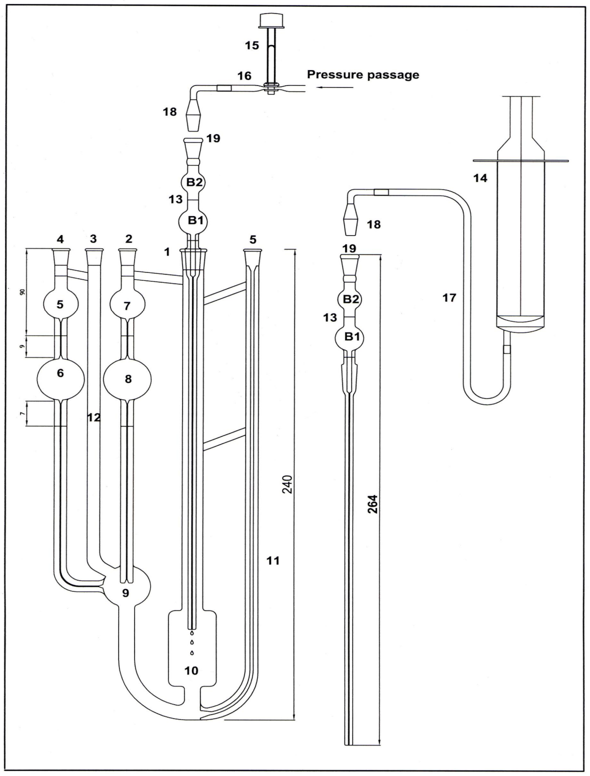

***Figure 1.*** **Survismeter IFT**

***Numbers 1, 2, 3, 4, 5 and 19 marked on upper ends of survismeter work as limbs, and the 5, 6, 7, 8, 9 and 10 marked in the bulbs, depict the operational bulbs. The numbers depicted along with the vertical lines illustrate the dimension of instrument and the darkened vertical tubes between the bulbs 6th and 9th and 8th and 9th, the capillaries to allow the viscous and drop wise flows respectively. Bulb number10 work as liquid reservoir, limb number 11 helps sucking out the liquid from bulb number 10, and number 12 controls pressure of bulb number 9***

## Discussion

Surface tensions and viscosities are close to the literature values. The surface tension are as diethylether >glycerol>formic acid>benzene> chloroform >$CCl_4$>ethyl ether>ethanol>n-hexane and viscosities as n-hexane>glycerol>formic acid>ethanol >$CCl_4$> benzene>chloroform> ethyl ether>diethyl ether.

The orders and the values infer a state of adhesive and frictional forces with stronger adhesive forces for diethyl ether and weaker forces for n-hexane. It infers stronger frictional forces with n-hexane but weaker forces with the diethyl ether and a reverse trend of adhesive and frictional forces are noted among the chosen solvents. The IFT data (Table 2) predict binding forces during drop formation applied on circumference on a lowermost tip of capillary, and on a liquid layer being formed during viscous flow.

Literature data [4-6] closely match our data of IFT. The 71.10x10$^{-3}$ N m$^{-1}$surface tension of water at 31.5$^0$C in air medium was reduced to 30.81x10$^{-3}$ N m$^{-1}$ when measured in benzene medium. Hence benzene applies buoyant force on drop wise flow. It is an asset for biofluids to prevent inters conversion, oxidation/reductions and evaporated.

The $\eta$ are for CMC > TMAH > DBSA where perhaps $\pi$-conjugation of benzene ring and –$SO_3^{-2}$ groups do develop stronger interaction in aqueous solution. Probably induction and streric effects might also be contributing to the additional development of forces (Figures 2 and 3). The CMC has 32 times higher $\eta$ values than those of both the TMAH and DBSA. However their $\gamma$ values are as TMAH > CMC > DBSA. Perhaps the 4 $CH_3$ groups expose $N^+$ and $OH^-$ groups develop slightly stronger surface forces than those of the CMC. The tetra methyl ring does develop hydrophobic interactions with weaker intermolecular forces. This trend of forces is followed by DBSA, the later contains dodecyl alkykl chains with stronger hydrophobic interactions than those of the CMC. But the $\eta$ with $\pi$-conjugation and –$SO_3^{-2}$ develop stronger hydrophilic interactions. Due to stronger hydrophobic interactions with bulk water and hydrophilic with broken water, a larger surface energy of solvent is utilized. Hence DBSA reduces the $\gamma$ of water by 27.305 dyne/cm. but TMAH with weaker hydrophobic interaction reduce the $\gamma$ of water by 35.967 dyne/cm. Similarly CMC due to stronger hydrophilic interactions in aqueous enhance the $\gamma$ by 29.262 dyne/cm. exceptionally higher $\eta$ of CMC are explained due to stronger friction forces between

CMC –water complexes.. The η vs c (Figure 3) shows a perfect linear relation which infer Newtonian behaviors of its aqueous solutions. However, TMAH behaves as non-Newtonian liquid after its 5.8 %, around this concentration zone a higher rate of increase in η is noted. There may be a possibility of maximum disruptions of water structure which lead to develop stronger interactions.

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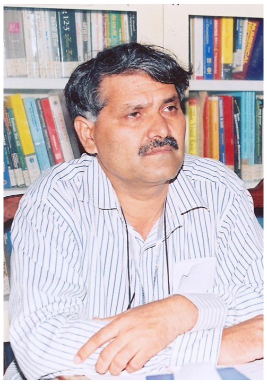

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