Experiment no. X (for B.Sc. V sem students)

Aim: *To determine the composition of a given binary mixture (ethanol-water) from the study of the viscosity-composition curve at lab. temperature.*

Requirements: Ostwald viscometer, relative density bottle, pure ethanol, distilled water.

Theory: The force of friction which one part of the liquid offers to another part of the liquid is called viscosity. For measuring the viscosity coefficient, Ostwald viscometer method is used which is based on Poiseuille's law. According to this law, the rate of flow of liquid through a capillary tube having viscosity coefficient, η, can be expressed as

$$\eta = \frac{\pi \cdot r^4 tP}{8\mathrm{vl}}$$

where, v= vol. of liquid (in ml)
t= flow time (in sec.) through capillary
r= radius of the capillary (in cm)
l= length of the capillary (in cm)
P= hydrostatic pressure (in dyne/sq.cm)
η= viscosity coefficient (in poise).

Since, the hydrostatic pressure (the driving force) of the liquid is given by $P = \rho g h$ (where h is the height of the column and ρ is the density of the liquid);

$$\eta \propto P\,t \;;\; \text{Or,} \quad \eta \propto \rho\, g\, h\, t$$

If, η_1 and η_2 are the viscosity coefficients of the liquids under study, ρ_1, ρ_2 , are their densities and t_1 and t_2 are their times of flow of equal volume of liquids through the same capillary respectively, then

$$\eta_1 \propto \rho_1\, g\, h\, t_1 \text{ and } \eta_2 \propto \rho_2\, g\, h\, t_2$$

Hence,
$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2}$$

The SI physical unit of viscosity is the pascal-second (**Pa·s**), (i.e., $kg \cdot m^{-1} \cdot s^{-1}$). If a fluid with a viscosity of one **Pa·s** is placed between two plates, and one plate is pushed sideways with a shear stress of one pascal, it moves a distance equal to the thickness of the layer between the plates in one second. The cgs unit for the same is the **poise** (P), (named after J. L. Marie Poiseuille). It is more commonly expressed, as **centipoise** (**cP**). [1 cP = 0.001 Pa·s]. Water at 20 °C has a viscosity of 1.0020 cP.

Procedure:

1) Different compositions of water-ethanol mixtures were prepared (with respect to ethanol).
2) Viscometer was rinsed and filled with specific amount (say 20ml) of mixture.
3) Time of flows were recorded for each solution as well as for the given unknown composition mixture.
4) Specific amount of different composition mixtures were weighted for relative density measurements.

5) $\frac{\eta_1}{\eta_2}$ (on left Y axis) and ρ_l (on right Y axis) vs composition were plotted on the same graph.

Observation and calculation:

a) Relative density measurements:

Wt. of the empty R.D. bottle = X.XXXXg

Wt. of the empty R.D. bottle + pure water = X.XXXX g

Wt. of the empty R.D. bottle + pure ethanol = X.XXXX g

Wt. of the empty R.D. bottle + 20% ethanol (v/v in water): X.XXXX g

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Wt. of the empty R.D. bottle + 80% ethanol (v/v in water): X.XXXX g

$$\text{Relative density} = \left(\frac{\text{Mass}}{\text{Vol}}\right)_{liq} \Big/ \left(\frac{\text{Mass}}{\text{Vol}}\right)_{water} = \frac{(\text{Mass})_{liq}}{(\text{Mass})_{water}}$$ (since, volume is same for all)

b)Combined table for the measurement of flow times and relative densities:

Composition (V% of ethanol in water)	Flow times (sec)				$\frac{\eta_1}{\eta_2}$	ρ_l
	t_1	t_2	t_3	mean		
0						
20						
30						
40						
60						
80						
100						
Unknown						

Composition of binary mixture = (x1+x2)/2 % ethanol in water.

Result:

Composition of the given binary mixture of the ethanol-water was found to be X% (v/v) ethanol in water.

Prepared by Dr. S. Saha, BHU.

Experiment No.: **Date:**

Aim: *To determine the composition of a given binary mixture (ethanol-water) from the study of the surface tension - composition curve at lab. temperature.*

Requirements: Stalagmometer (Traube's), rubber tube with screw pinch cock, relative density (R.D.) bottle, stand, balance, weighing box, beaker, unknown liquid, distilled water.

Theory: The measurement of surface tension by stalagmometer is based on the fact that drop of a liquid (at end of the stalagmometer /capillary tube) falls when weight of the drop just equal to the surface tension of the liquid.

Thus, the weight of the drop (due to force of the gravity) which pulls the drop downward is equal to **vdg**, where, **g** is the gravitational force, **v** is volume of the drop and **d** is the density of the liquid (i.e., **mg** = **vdg**).

On the other hand, the force tending to uphold the drop = $\mathbf{2\pi r\gamma}$**;** where $\mathbf{2\pi r}$ is the circumference of a circular surface, γ is the surface tension of the liquid. Unit of surface tension are dyne/cm (CGS system) and Newton/meter (SI system) where, *1dyne/cm = 1mN/m*

At equilibrium, (i.e. when two forces are balanced): $2\pi r\gamma = vdg$ (i)

If **n** is the number of drops in volume **V** of the liquid, the volume of each drop will be $v = \frac{V}{n}$

Then, from equation (i) we have, $2\pi r\gamma = \frac{Vdg}{n}$ (ii)

If $\mathbf{n_1}$ and $\mathbf{n_2}$ are the number of drops counted for the same volume of two liquids (**1** & **2**) of densities $\mathbf{d_1}$ and $\mathbf{d_2}$, using the same stalagmometer, then

$$2\pi r\gamma_1 = \frac{Vd_1 g}{n_1} \quad \text{(iii)}$$

$$2\pi r\gamma_2 = \frac{Vd_2 g}{n_2} \quad \text{(iv)}$$

Dividing equation (iii) by (iv); $\frac{\gamma_1}{\gamma_2} = \frac{n_2 d_1}{n_1 d_2}$

Therefore, surface tension of the liquid (**1**) $\boldsymbol{\gamma_1}$, with respect to liquid (**2**) $\boldsymbol{\gamma_2}$ can be expressed as: $\gamma_1 = \frac{n_2 d_1}{n_1 d_2}\gamma_2$

In case, the second liquid is the pure water (w), then surface tension of liquid (l) with respect to water can be expressed by: $\gamma_l / \gamma_w = \frac{n_w\, d_l}{n_l\, d_w}$.

Procedure:

1. Note the laboratory temperature.
2. Prepare the various composition of ethanol and water in form of 0%, 20%, 40%, 60%, 80%, 100% ethanol by volume.
3. Take the weight of the empty & filled (with distilled) R.D. bottle (with stopper). Then, weigh the R.D. bottle filled with prepared solution and unknown given liquid.
4. Clean the stalagmometer properly with distilled water. Now fix the stalagmometer on the stand & adjust the number of falling drops in between 15-20 per minute by the help of the screw pinch cock (this adjustment is essential otherwise proper drop will not form).
5. Immerse the lower end of stalagmometer in a beaker containing distilled water, in order to suck water till the upper mark of the stalagmometer.
6. Start counting the number of drops when the water level just reaches the upper mark & stop when the level just passes the lower mark. Take 2 readings for each solution.
7. Repeat the same procedure for the prepared solution as well as for the given unknown composition water-ethanol solution.

Observations:

1. Laboratory temperature: x $^{\circ}$C

2. Density measurement:

Weight of empty R.D.bottle (w_1) =…g.

Weight of R.D.bottle with water (w_2) =…g.

Weight of R.D. bottle with 0% mixture (w_3) =…g. (similarly weigh for 10, 20, 40, 60, 100% and unknown composition ethanol in water mixture).

$$\text{Relative density} = \frac{\text{wt. of liquid}}{\text{Wt. of water}}$$

3. **Table**: Counting the no of drops:

Composition (% of ethanol in water)	No. of drops			Rel. surface tension	ρ
	n1	n2	Mean	γ_l/γ_w	(rel. density)
0 10 20 40 60 100					

Calculations:

1. Determination of the density of the liquid (d_l):

$$\frac{\text{Density of liquid } (d_l)}{\text{Density of water } (d_w)} = \frac{\text{Weight of liquid } (w_l)}{\text{Weight of water } (w_w)}$$

Density of liquid $(d_l) = \frac{w_l}{w_w} d_w$ (Take density of water =1.0g/ml at 25 °C)

2. Determination of the relative surface tension of different composition solution using the relation $\gamma_l/\gamma_w = \frac{n_w\, d_l}{n_l\, d_w}$ (Surface tension of water (γ_w) =71.97dyne/cm at 25°C)

Precautions:

1. Drops should be properly formed.
2. The stalagmometer should be kept in vertical position while measuring.
3. Same stalagmometer should be used for water and liquid.
4. Observe carefully when the water and liquid are just passing the upper and lower marks of the stalagmometer.

Result: The composition of the given binary mixture was found to be ……….% ethanol in water.

Prepared by Dr. S. Saha, BHU.

Comments/ extra information on viscosity experiment:

Strain is the geometrical measure of deformation representing the relative displacement between particles in the material body, i.e. a measure of how much a given displacement differs locally from a rigid-body displacement.

Stress is a measure of the average amount of force exerted per unit area. It is a measure of the intensity of the total internal forces acting within a body across imaginary internal surfaces, as a reaction to external applied forces and body forces.

A **Newtonian fluid** (named for Isaac Newton) is a fluid whose stress versus rate of strain curve is linear and passes through the origin. The constant of proportionality is known as the viscosity.

For example, water is Newtonian, because it continues to exemplify fluid properties no matter how fast it is stirred or mixed. Contrast this with a non-Newtonian fluid, in which stirring can leave a "hole" behind (that gradually fills up over time - this behaviour is seen in materials such as pudding, starch in water or cause the fluid to become thinner, the drop in viscosity causing it to flow more (this is seen in non-drip paints, which brush on easily but become more viscous when on walls).

If you add water to ethanol for instance, you get a different volume than that expected simply by the addition of volumes. You may, for instance, add 5mL of water to 50mL of ethanol and expect 55mL of solution, but volume is actually smaller. Why is that? If water and ethanol did not interact, if it the solution were ideal, you would expect no changes in expected volume.

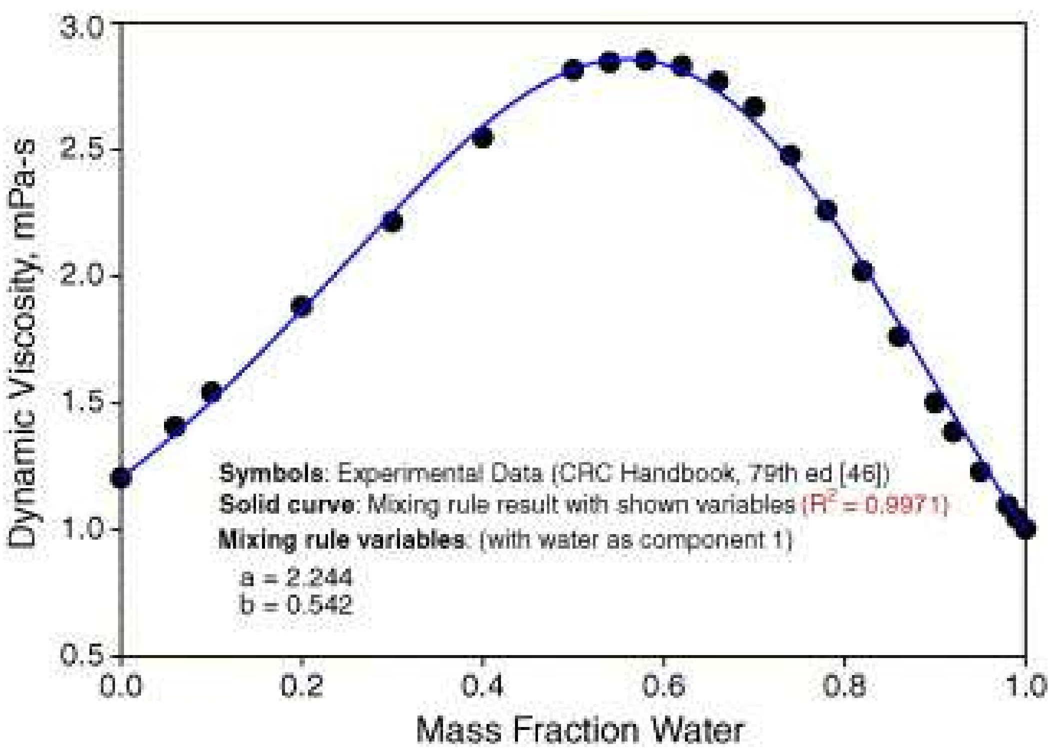

Figure 1. Change of Viscosity for different composition of water in ethanol. (web resource)

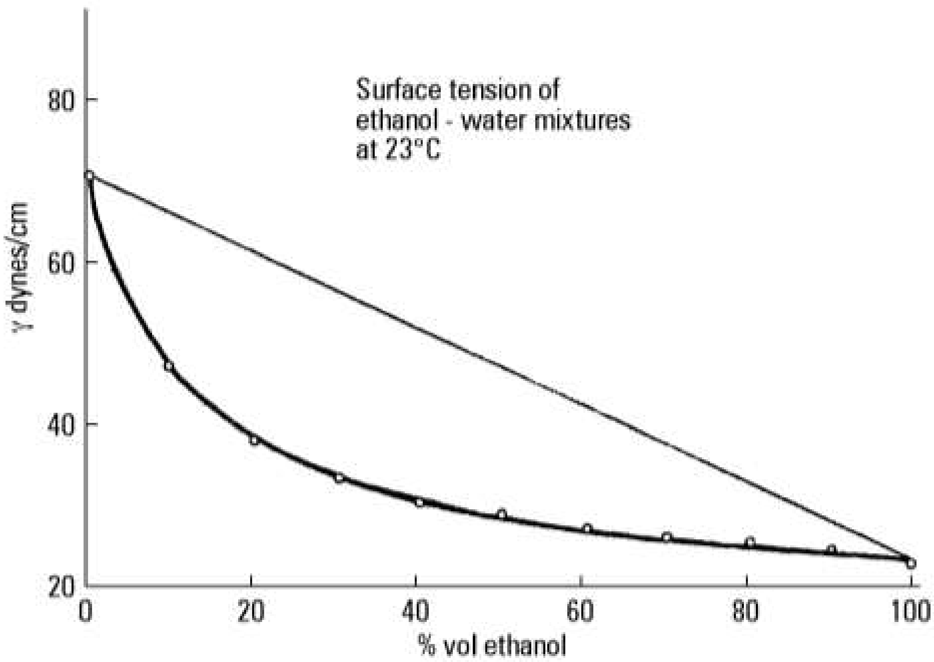

Figure 2. Change of surface tension for different composition of water in ethanol.
(web resource)