Experiment

Determination of the percentage (%) composition by viscosity method

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Date: …………………… **Room Temperature: 27 ºC**

Objective

To determine the percentage (%) composition of the given mixture consisting of two liquids *A* and *B* (non-interacting system) by viscosity method.

Requirements

(a) **Apparatus and Glassware:** Ostwald viscometer, Stopwatch, Clamp stand, Pipette.

(b) **Chemicals:**

- Cleaning mixture (Chromic acid solution)
- Liquid ***A*** (Distilled water)
- Liquid ***B*** (40 % (v/v) glycerol solution in water)

1. Principle

The resistance to flow exhibited by a liquid or the property by virtue of which a liquid oppose relative motion between its different layers is called internal friction or viscosity. The force of resistance, *F*, is given by the following equation:

$$F = \eta A \frac{du}{dx}$$

$$\therefore \quad \eta = \frac{F}{A} \times \frac{dx}{du}$$

where η (eta) is the **coefficient of viscosity** or simply viscosity constant, *A* is the area, *du* is the velocity difference and *dx* is the distance between two adjacent layers. Coefficient of viscosity may be defined as the tangential force per unit area required to maintain a unit velocity of displacement of two parallel layer of the liquid at unit distance apart, the space between the planes being filled with the viscous fluid.

The flow of homogeneous liquid through a capillary tube is given by Poisseuille's equation for determining coefficient of liquids as well as gases:

$$\eta = \frac{\pi \rho\, r^4 t}{8 l V}$$

where, ρ = the driving force in dynes cm^{-2}, *r* = radius of capillary in cm, *t* = the time (in second) required for the volume *V* of a liquid to flow through the tube of a length *l* (in cm).

Therefore, in CGS system the unit of η is expressed as g cm^{-1} sec^{-1}. It is called poise. In practice smaller unit centipoises (10^{-2} poise) and millipoise (10^{-3} poise) are also used. The SI unit is kg m^{-1} sec^{-1} therefore; one poise is equal to one tenth of SI unit (g cm^{-1} sec^{-1} = 0.1 kg m^{-1} sec^{-1}).

Ostwald's Viscometer

The conventional Ostwald viscometer consists of two limbs. The left hand limb contains a fine capillary tube (about 10 cm in length and 0.4 mm in diameter) and a small bulb ***M*** with two marks ***P*** and ***Q*** at the upper part of limb; through which a definite volume of liquid that is contained between the marks is allowed to flow under the force of its own weight. The right hand limb consists of a large glass bulb ***N*** at the lower end (**Fig. 1**).

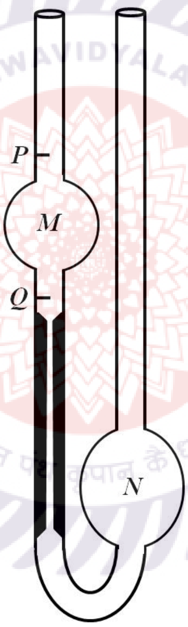

Fig. 1. Ostwald viscometer.

2. Solution Preparation

2.1. Cleaning mixture (chromic acid solution)

Mix solid $K_2Cr_2O_7$ with 7-8 times its weight of concentrated H_2SO_4.

2.2. Liquid *B* (40 % (v/v) Glycerol solution in water)

Dissolve 40 mL of pure glycerol in 100 mL volumetric flask and make upto the mark with distilled water.

2.3. Mixing the two liquids *A* and *B* in different proportions

By taking 40 % glycerol solution as liquid ***B***, mixture solution of 80, 60, 40, and 20 % of liquid ***B*** in the liquid ***A*** (distilled water) can be prepared as follows:

Preparation of 80 % mixture solution of liquid ***B*** in liquid ***A*** in the total volume of 20 mL

$$N_1V_1 \text{ (liquid } \boldsymbol{B}) = N_2V_2 \text{ (80 \% liquid } \boldsymbol{B})$$

$$100 \times V_1 = 80 \times 20$$

$$V_1 = 16 \text{ mL}$$

Take 16 mL of liquid ***B*** in a beaker and add 4 mL of liquid ***A*** (distilled water). Similarly, prepare 60, 40, 20, and 0 % liquid ***B*** solutions by dilution with liquid ***A*** of corresponding higher % of liquid ***B*** solution.

3. Procedure

Prepare a number of solutions by mixing the two liquids ***A*** and ***B*** in different proportions. For example, prepare the solutions of 20, 40, 60, 80, and 100 % of the liquid ***A*** by volume. Determine the time of flow for each mixture solution by viscometer as following.

- Cleaning the viscometer – The viscometer is cleaned with the chromic acid solution and then with distilled water. It is rinsed with alcohol and ether then dried.
- Clamp viscometer in a vertical position then attach rubber tube of the upper left arm of bulb ***M***. Now a sufficient volume of liquid (mixture solution) (~20 mL) is introduced by pipette inside the right limb (bulb ***N***) of the viscometer. Allow the liquid to remain for 15-20 minutes so as to attain the room temperature.
- Suck the liquid up into the left limb (bulb ***M***) of the viscometer above the mark ***P*** by mean of the rubber tubing attached to it. Then, allow the liquid to fall freely under the influence of gravity. Start a stop watch as soon as the descending liquid level crosses the upper mark ***P*** and stop it when the level reaches the lower mark ***Q***. Repeat above procedure three to four times to determine the mean time of flow (**to be sure that there are no serious deviation in any one of the reading from the average time**).
- Determine the time of flow by same procedure as mentioned above for all the mixture solutions prepared by mixing of the two liquids ***A*** and ***B*** and also given unknown mixed solution.

- Determine the composition of the given unknown mixture solution by comparison with values on a reference curve obtained from different known compositions of mixture solutions of the liquids ***A*** and ***B***.

4. Observation Table

Room Temperature: 27 °C

S. No.	**Percentage (%) of Compounds**		**Time of flow in minutes**
	A **(H_2O)**	***B*** **(Glycerol sol.)**	
1	0	100	5.06
2	20	80	3.60
3	40	60	2.65
4	60	40	2.10
5	80	20	1.71
6	100	0	1.47
7	**Unknown solution**		2.30

5. Calculation

Plot a graph by taking **the concentrations of one of the components say *B* along X-axis (abscissa) and corresponding time of flow in minutes along Y-axis (ordinate)**. Such a plot gives a straight line as shown in **Fig. 2.**

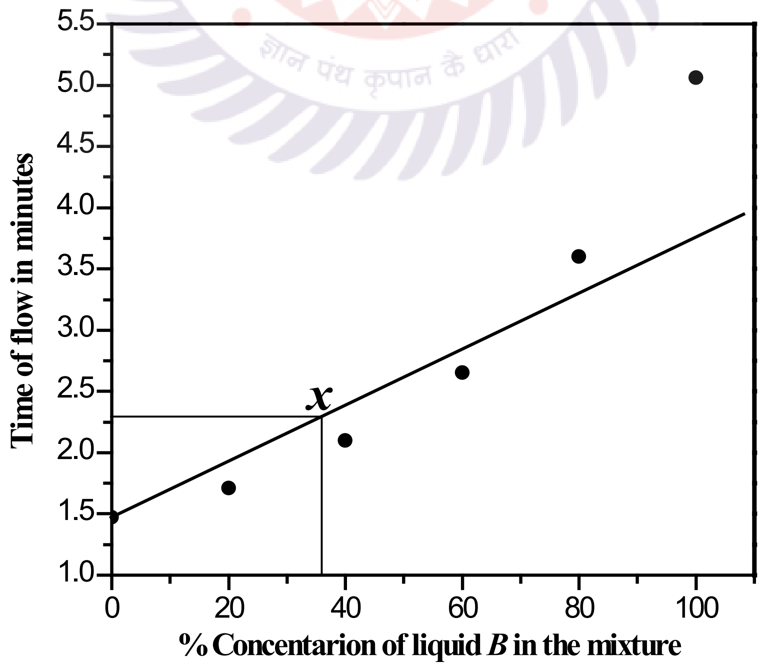

Fig. 2. Plot of percentage (%) of the component *B* versus time of flow.

The composition of the unknown solution can be calculated by marking the point on the straight line corresponding to its time of flow. The ***x*** mark represents the point corresponding to the unknown solution. A perpendicular drawn from this point on the concentration axis gives the percentage (%) of ***B*** in the unknown solution.

Hence, percentage (%) of ***A*** = 100 – Percentage (%) of ***B***

6. Results

The percentage (%) composition of the given unknown mixture is found to be 64 % of liquid ***A*** and 36 % of liquid ***B***.

7. Precautions

(i) The viscometer should be absolutely clean.

(ii) Same volume of mixture liquid (mixture or solution) should be introduced in to the viscometer each time.

(iii) Viscometer should always be held firmly in the vertical position in a suitable clamp during the course of experiment.

8. Further Reading

- Ebbing, D. D., *General Chemistry*. 10th ed.; Cengage Learning India Pvt. Ltd.: 2013.
- Elias, A. J., *A Collection of Interesting General Chemistry Experiments*. Revised ed.; University Press: 2007.
- Halern, A. M.; McBane, G. C., *Experimental Physical Chemistry: A Laboratory Textbook*. 3rd ed.; W. H. Freeman and Company: 2006.
- Kapoor, K. L., *A Textbook of Physical Chemistry: Experimental Aspects In Physical Chemistry (SI Units) Volume 7*. 1 ed.; McGraw Hill Education: 2019.
- Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*. 47th ed.; Vishal Publishing Co.: 2018.

APPENDIX

1. **Viscosity of water = 0.8007 centipoise at 30 ºC.**
2. **Viscosity of glycerol = 4.247 centipoise for 50 % by wt. aqueous solution at 30 ºC.**