EXPERIMENT 7

STUDY OF VARIATION OF SURFACE TENSION WITH THE CONCENTRATION OF A DETERGENT

Structure

7.1 INTRODUCTION

In Experiment 6, you determined the surface tension of a liquid or a dilute solution given to you. In this experiment, you will be determining the surface tension of detergent solutions of different concentrations and study the change in surface tension with the change in concentration of the detergent.

Expected Learning Outcomes

After performing this experiment, you will able to:

- ❖ determine the surface tension of different detergent solutions having different concentrations.

7.2 PRINCIPLE

The basic principle of this experiment is similar to that of experiment 6.

Here, we will be determining the surface tension of detergent solutions having different concentrations and study the effect of change in concentration on the surface tension.

From equation 6.8, you know that,

$$\frac{\gamma_1}{\gamma_2} = \frac{(V/n_1) \times d_1 \times g}{(V/n_2) \times d_2 \times g} = \frac{d_1/n_1}{d_2/n_2} = \frac{n_2 d_1}{n_1/n_2}$$

where, γ_1 and γ_2 are the surface tensions of two individual liquids, and d_1 and d_2 are their densities, respectively.

Thus, for the determination of surface tension of any liquid, the number of drops produced from equal volume of two liquids and their densities must be known, in addition to the surface tension of the reference liquid (e.g. water).

7.3 REQUIREMENTS

Traube's Stalagmometer	1
Weighing bottle/Specific gravity bottle	1
Rubber stopper	1
Rubber tube (small piece)	1
Pinch cock	1
Clamp stand	1
Thermometer $(110^{\circ}) - \frac{1}{10}$ degree	1
Large beaker or glass trough	1

In addition, you will be using with detergent solutions of different concentrations and a bottle of distilled water.

7.4 PROCEDURE

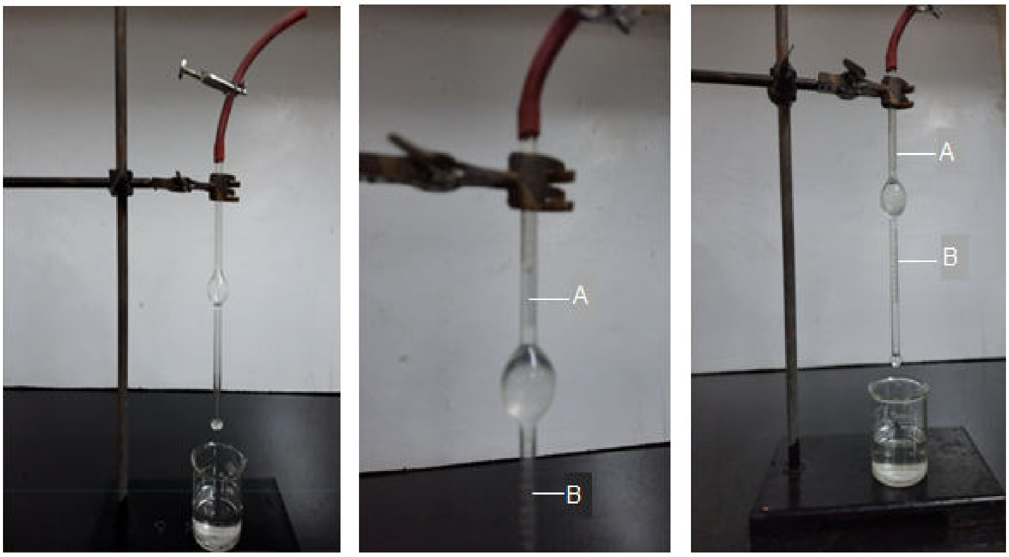
> Chromic acid is prepared by dissolving potassium dichromate ($K_2Cr_2O_7$) in conc. H_2SO_4.

Before starting the experiment, the stalagmometer should be cleaned by chromic acid solution to remove oil, grease etc. sticking on the inner capillary surface and then washed with distilled water and finally with acetone or alcohol, and dried by passing air.

1. Attach a small rubber tubing with a screw pinch cock to the upper end of the stalagmometer.

2. Fix the stalagmometer on a stand with the help of a clamp. Place a beaker containing water below the stalagmometer as shown in Fig. 7.1 a).

3. Fill it with distilled water by sucking it little above the mark A. Close the pinch cock and insert the stalagmometer into the beaker, see Fig. 7.1 b).



a) b) c)

Fig. 7.1: Apparatus for the determination of surface tension.

4. Then, open the pinch cock gently such that the detergent solution flows out slowly.

5. Adjust the air inflow so that the number of drops formed should not exceed 15 drops per minute, see Fig. 7.1 c).

6. Count the number of drops obtained when a fixed volume of water flows between the marks A and B, i.e., count the number of drops when the water level reaches from A to B.

7. Refill the stalagmometer and repeat the counting of drops thrice, and record it in the observation Table 7.2.

8. Now remove the stalagmometer from the beaker, wash it thoroughly and dry it.

9. Fill it with given detergent solution (e.g. S_1) and reset the stalagmometer in the weighing bottle. Count the number of drops fallen for the same volume of the liquid/ given dilute solution between the marks A and B.

   Repeat the counting process thrice and record the observations in the observation table.

10. Now dilute the given detergent solution to different concentrations and repeat the above procedure for all diluted detergent solutions (S_1, S_3, S_4 etc.) and note your observations in the table.

While doing the experiment, the following precautions should be taken.

Specific gravity is a term sometimes used in place of density. Specific Gravity is the ratio of density of a substance to that of water. Since it is a ratio of two densities, it is expressed without units.

$$\text{Specific Gravity} = \frac{\text{density of solution (in kg dm}^{-3})}{\text{density of water (in kg dm}^{-3})}$$

The density of water is 1 kg dm^{-3}; therefore, specific gravity of a liquid or solution is its density expressed without units.

Precautions

- The stalagmometer should be cleaned and dried before use.
- While sucking the liquid into the stalagmometer, no air bubble should be formed.
- Stalagmometer should be held in a vertical position throughout the drop counting process.
- Drop formation should be adjusted at a slower rate and should not exceed fifteen drops per minute.

You can record your observations in the space given below.

7.5 OBSERVATIONS

Temperature, *t* = …………………… °C

Density of water at t^0C = d_w =………… kg dm^{-3}

Surface tension of water at t^0C = γ_w =………….. N m^{-1}

(use γ_w from Table 6.3 of previous experiment)

Table 6.2

Number of drops formed equal volume of detergent solutions (between marks A and B)					
		Detergent solutions			
Sr. no.	Water	S_1	S_2	S_3	S_4
i ii iii	….. ….. …..	….. ….. …..	….. ….. …..	….. ….. …..	….. ….. …..
Average	….. n_{w_1}	….. n_{S_1}	….. n_{S_2}	….. n_{S_3}	….. n_{S_4}

Mass of empty specific gravity bottle $= w_1 =$..............g

Mass of specific gravity bottle +detergent solution $= w_2 =$..............g

Mass of specific gravity bottle + Water $= w_3 =$..............g

The calculations to be done are also explained below:

7.6 CALCULATIONS

Density of the solution 1 =

$$d_{S_1} = \frac{\text{Mass of the detergent solution } S_1}{\text{Mass of water}} \times \text{density of water}$$

$$d_{S_1} = \frac{w_2 - w_1}{w_3 - w_1} \times d_w$$

Relative surface tension of the detergent solution (s_1) $= \frac{\gamma_{S_1}}{\gamma_w} = \frac{d_{S_1} \times n_w}{d_w \times n_{S_1}}$

Absolute surface tension of the detergent solution (s_1)

$$= \gamma_{S_1} = \gamma_w \times \frac{d_{s_1} \times n_w}{d_w \times n_{s_1}} = \text{........N m}^{-1}$$

Likewise repeat the determination of density and calculations of surface tension for detergent solutions and get $\gamma_{S_2}, \gamma_{S_3}$ ....etc.

The surface tension of water γ_w at different temperatures is given again in Table 7.2 for your reference.

Table 7.2: Surface Tension of water at different temperatures

Temperature/^{0}C	Surface Tension (10^3 γ / N m^{-1})
0	75.83
5	75.09
10	74.36
15	73.62
20	72.88
21	72.73
22	72.58
23	72.43
24	72.29
25	72.14
26	71.99
27	71.84
28	71.69
29	71.55
30	71.70

From the following steps, you can verify the relationship between the density of a liquid and density of water as given by specific gravity measurement.

Specific gravity of a detergent solution

$$= \frac{\text{Density of a detergent solution}}{\text{Density of water}}$$

$$= \frac{\text{Mass of detergent solution/Volume of detergent solution}}{\text{Mass of water/ (same) Volume of water}}$$

$$= \frac{\text{Mass of detergent solution}}{\text{Mass of water}}$$

Since we use same specific gravity bottle for measuring the masses of water and liquid, volume is same in both the cases.

Hence, Density of a detergent solution $= \frac{\text{Mass of detergent solution}}{\text{Mass of water}} \times \text{Density of water}$

This relationship holds only if masses of water and liquid are measured using same specific gravity bottle.

35	70.66
40	69.92
45	69.18
50	68.45
55	67.71
60	66.97
100	61.80

The result obtained can be reported as shown below:

7.7 RESULT

i) The absolute surface tension of the detergent solutions (S_1, S_2, S_3 S_4) at temperature …. ^{0}C are as follows:

γ_{s_1} = ……….. N m^{-1}

γ_{s_2} = ……….. N m^{-1}

γ_{s_3} = ……….. N m^{-1}

γ_{s_4} = ……….. N m^{-1}

ii) Plot a graph between surface tensions γ_{s_1}, γ_{s_2}, γ_{s_3}, γ_{s_4} and concentration values for different concentrations (c_1, c_2, c_3, c_4). Discuss this graph with you counsellor and find the possible reasons for the variation of surface tension with concentration of the detergent solution.