EXPERIMENT II

SURFACE TENSION OF SOLUTIONS
            (S&G 5th ed. Expt. 26, 7th and 8th eds. Expt 25, plus tensiometer manual)

1.   Purpose

The surface tension of a series of aqueous solutions of two uncharged species, *n*-butanol (1-butanol) and of *tert*-butanol (2-methyl-2-propanol), is to be measured to obtain an estimate of the effective cross section area of these molecules in an aqueous environment.

2.   Pre-Lab Preparation

The experiment is carried out as in S&G but, rather than the capillary rise method, a Kibron AquaPi™ tensiometer will be used (Fig. 1). Be sure to read the instruction manual for this instrument before starting the experiment (photocopy available in the lab and from the course web site).
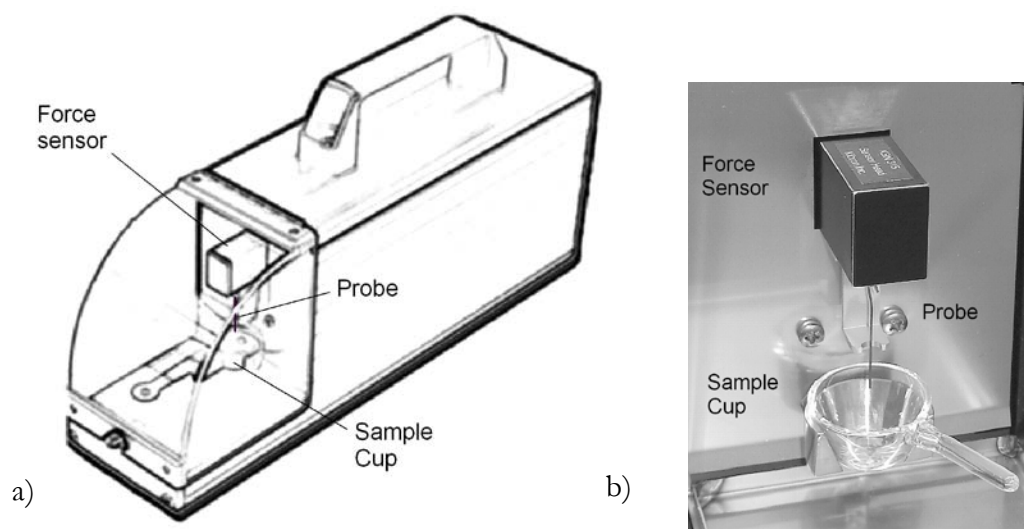

Fig. 1. Kibron AquaPi portable tensiometer; a) general view and b) close-up view of the force sensor, probe and sample cup.

   Work out in advance how to prepare (and how much*) two series of five solutions of the alcohols to be studied in the concentration range $\approx$ 0.1 to 0.7 M.

3.   Safety

Small quantities of concentrated sulphuric acid are used to clean some of the glassware. Handle this acid with care, ie, wear eye protection and disposable gloves (a lab coat is

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* $\approx$ 3 - 5 ml of solution are needed for a measurement.

highly recommended; a drop of sulphuric acid on your clothes will result later in an unsightly hole in the material). If some acid droplet lands on your skin, immediately rinse abundantly with water. A small butane torch is to be used; careful with the open flame.

4. Sample Preparation

It is necessary to be paranoid about organic contamination in this experiment. In particular, at the beginning clean the measuring glass cups with a few drops of concentrated sulphuric acid and rinse abundantly with distilled water. Prepare all the solutions with distilled water. Trace of grease from fingers may affect the results. Wear non-latex powder free disposable gloves throughout the experiment.

For each alcohol a stock solution of accurately known concentration has to be prepared (use a weighing bottle to weigh the required amount on the analytical balance); the maximum concentration of the alcohol should ≈ 0.7 M (do not try to prepare much higher concentrations as the solution may be saturated). Note also that the melting point of *tert*-butanol is 25.5 C, which means that depending on the room temperature of the day, one may find the compound frozen in the storage bottle; in this case, just run some warm water over the bottle to melt enough compound to prepare the solution.

Prepare the highest alcohol concentration in a 25 mL volumetric flask. Then prepare the four other solutions also in 25 ml volumetric flasks by 15/25 serial dilution, i.e., by pipetting 15 mL of the previous solution into a 25 mL volumetric flasks which is filled to the mark with distilled water; this will leave at least ≈10mL in the flasks, enough for the measurement. Depending on the number of 25 mL flasks available, the experiment is performed with this first set, then the same flasks may have to be used for the second alcohol.

5. Instrument preparation

Important note.

Be extra cautious with this instrument, in particular with the probe, the force sensor and the glass cup; these items are fragile and expensive to replace. Notify the instructor of any mishap.

5.1 Cleaning the measuring cups

(This step must be done in the fume hood while wearing protective disposable gloves and safety glasses)

It is recommended to clean two glass cups; only one may be used, the other one is put aside as a backup.

With a Pasteur pipette, dispense gently enough concentrated sulphuric acid to wet the inside of the cup, swirl gently the acid around then rinse abundantly with tap water, then distilled water. When not in use keep these cups resting upside down on a piece of clean tissue paper.

5.2 Installing the "DyneProbe".

The probe (called "DyneProbe" by Kibron), is a calibrated wire dangling from a force sensor (see Fig. 1). During measurement, the mechanism of the instrument first lifts the

cup to immerse the probe into the liquid to be tested, then lowers the cup to have the probe pulled out of the liquid; the surface tension is obtained by measuring the force required to detach the probe from the liquid surface.

Check visually that the probe is installed. Notify the instructor if it is not in place or if the probe falls off; *do not try to hook it back on the loop yourself.*

5.3 Calibration.

Check with the instructor whether the Kibron tensiometer has been already calibrated for the day. If not, fill a clean cup with high purity water (obtained from the "Millipore" apparatus) and place it on the cuvette holder underneath the probe. Start the calibration by pressing Cal and MSR/ON buttons at the same time on the control box. In this calibration mode, the instrument cycles through several sets of measurements while displaying various intermediate results. The process may take over ten minutes. The display will indicate when the calibration is completed.

6. Data collection

Measuring procedures

- Before testing each new solution clean the end of the probe by heating it to a red glow using the butane mini-torch available in the lab (the instructor will demonstrate the technique)

- Fill the glass cup with the sample to be tested using a clean Pasteur pipette (if there is enough sample, it is advisable to use a few drops to "rinse" the cup with each new sample).

- Gently place the cup on the cuvette holder underneath the probe (*try to avoid knocking off the probe*) and close the plastic cover.

- Press the "MSR/ON" button to initialize the measurement. The measurement is completed when the enunciator "PKHOLD" appears on the screen.

- If more readings of the same sample are desired, just press the "MSR/ON" button again.

- Before testing a new solution, rinse the cuvette with distilled water and clean the probe as described above.

With the instrument properly calibrated, measure the surface tension of distilled water. A value smaller than 72 mN m^{-1} indicates that something is not clean enough (either the water, the sample cup or the measuring probe are contaminated).

Measure in turn the surface tension of each of the alcohol solutions; take at least three readings for each. Record the ambient temperature for possible correction of the recorded readings.

7. Calculations and interpretation

As indicated in the tensiometer instruction manual, if the calibration was performed at a temperature different from 20 C, the readings may have to be multiplied by the factor $F = (ST_t/ST_{20})_{water}$ to obtain the "true" surface tension corrected for 20 C; for this

purpose, the values of the surface tension of water (ST_i) at different temperatures are listed on the control box.

Follow the text book description to process your corrected data: For the solutions, a plot of the surface tension γ versus $\ln c$, the logarithm of the bulk concentration should be a straight line with slope $-RT\Gamma$, where R is the gas constant, T the temperature in Kelvin and Γ is the "surface concentration", from which the effective cross sectional area of the two alcohol molecules studied may be derived.

For a more complete theoretical treatment than the one presented in S&G, see also Refs. 1-3.

Discuss how your final results relate to the effective size of the alcohol molecules studied: absolute sizes, and size relative to each other. In this context, rationalize your results using a simple ball and stick models and accepted values for bond length and Van der Waals radius; when doing this, one must realize that one is trying to estimate an effective size of the molecule, *i.e.*, the molecule is not immobile and therefore occupies an average region of space which may be different in size from the dimension of the fixed model molecule[†]. With these models, estimate the effective average cross section area of the two alcohol molecules positioned in different orientations with respect to the solution surface. Comparing with your experimental results, decide which orientation may be the most appropriate. How do the predictions agree with the experimental results and to what extent do you expect an agreement?

More generally, can you think of practical applications for which it is important to know the value of the surface tension? Are there other ways to obtain this parameter?

8.   References

W.J. Moore, *Physical Chemistry*, 4th Ed., Prentice–Hall, New Jersey (1972).

A.W. Adamson, *Physical Chemistry of Surfaces*, 2nd Ed., Interscience Publishers, N.Y. (1967).

N.K. Adam, *The Physics and Chemistry of Surfaces*, 3rd Ed, University Press, Oxford (1941).

Kibron AquaPi, A Portable Microtensiometer User's Guide. Rev. E, May 2009.

[†] Simple computer molecular modeling can be used to obtain some of the size parameters relevant to this discussion; one of the free software available on the web (ACD Chemsketch) for this purpose has been loaded on one of the Pchem lab computer

Chem 366W report check list Date submitted: _____

A report will not be accepted without all the items of this list checked. If a checked item is found missing in the report, the report will be automatically down-graded.

Student Name:_____

Report: Surface Tension Aqueous Solutions

Title page.

Correct title of the experiment ....☐

Student Name & student ID ....☐

Partner name (*if applicable*) _____

Date of performance of experiment...☐

Abstract...☐

Introduction and theory ....☐

Experimental

Changes from text description mentioned (*if applicable*)...................................☐

Sample ID, ser no, stock solution …etc recorded (*if applicable*) ....☐

Results

Results as Tables ....☐

Graphs

 Size, at least ½ page ....☐

 Axis labelled ....☐

 Axis labels have units..☐

 Axis scales are sensible ....☐

Only significant figures ....☐

Uncertainties quoted...☐

Raw data provided (*electronic form, if applicable*) ....☐

Calculations

Sample calculation provided..☐

Error analysis ....☐

Sample error calculation provided ....☐

Discussion

Comments on results..☐

Questions in text book and in manual answered ....☐

Comparison with literature value(s) ....☐

Conclusion..☐

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