Lab#7

Determination of Interfacial Tensions

Learning Objectives:

- Construct and interpret a graph showing the interfacial tension versus temperature for the system air-water
- Determine the interfacial tension for the system air-oil.
- Determine the interfacial tension of water-oil using: kerosene as the hydrocarbon fluid.
- Determine the effects of adding a surfactant in the interfacial tension of water-oil systems.
- Discuss the accuracy of the interfacial tensions obtained by comparing them with published values.

Materials and Equipment

- Distilled water
- Kerosene.
- House dish detergent (surfactant)
- Capillary tubes
- Thermometer
- Hotplate with stirrer
- Electronic balance (with 1 mg precision)
- Pendant Ring Fisher tensiometer, Sigma 703 tensiometer.
- Pipettes, beakers.
- Pycnometer.

General Skills and Background from Class

- Interfacial tension material from McCain text book (pages 333-338)
- Brochure IFT-instructions available in acrobat form provided here
- Use Excel spread sheets and graphs
- Fit trend lines
- Work with different units and to convert one set to another
Experimental Procedure

A. The Capillary Rise Method: Equipment used in the determination of surface or interfacial tension by the capillary rise method is shown in Figure 1. For determination of interfacial tension, the vapor is replaced with a liquid. In this experiment we will use similar equipment. See instructions and animation in the following web site: http://web.umr.edu/~gbert/SurfaceTension/cap.html

![Figure 1. Sketch of Equipment to Determine Surface Tension](image)

At equilibrium, the height of the liquid in the capillary is related to the surface tension by

\[2\pi r A_\tau = \pi r^2 h (\rho_l - \rho_v) g\]

where \(A_\tau = \sigma \cos \theta\)

\[2\pi r = \text{length on which the surface tension acts}\]
\[ \pi r^2 h = \text{volume of liquid above the beaker surface.} \]

The angle \( \theta \) that the liquid surface makes with the solid surface is called the contact angle. Since we do not have values for this we will assume that this angle is 0 – that is our substances will be wetting.

**Procedure:**

1) Clean and dry the capillary tubes and the beaker.
2) Fill beaker half-full of liquid.
3) Immerse the capillary tubes.
4) Let the liquid reach above the point on the capillary where the reading will be taken.
5) Raise the capillary slightly, let the surface stabilize, and measure the height of liquid above the free surface level in the beaker.

**B. The Ring Method:**

The equipment used in the determination of interfacial tension with the ring method is shown in figure 2. The method measures the force required to pull a ring out of a liquid. This force must be equal to the surface tension of the liquid times the total length that its surface contacts the ring.

![Figure 2. Interfacial Tensiometer](image)

**Operation:**

In making a determination of surface tension, careful preparation of the sample and the
surface tensiometer must precede the actual operation of the instrument.

The platinum-iridium ring should be cleaned by first dipping it in petroleum naptha (to remove hydrocarbons) then squirting it with acetone (to remove the benzene) and allowing the acetone to evaporate. Following this, flash the ring in a bunsen burner flame to remove the residual hydrocarbons. The glass container for the sample also must be carefully cleaned to avoid contamination of the sample.

The preceding instructions are particularly applicable when preparing for oil sample determinations. A comparable degree of cleanliness, however, should be sought for other determinations as well. Since surface tension is dependent upon temperature, consideration must be given to this factor. For theoretical work, temperatures must be specified; however, 25°C is the temperature most commonly used.

• Measuring Surface Tension:

The cleaned platinum-iridium ring should first be attached to the hook at the end of the lever arm. The arrest mechanism should be holding the arm at this time.

The liquid to be measured is transferred to the clean glass vessel and placed on the sample table. The sample table is moved around until it is directly beneath the platinum-iridium ring. Raise the sample table until the ring is immersed in the test liquid. The ring should be in the liquid, beneath the surface so that the entire ring will be wetted. About 1/8 inch immersion is considered sufficient.

The torsion arm is now released and the instrument adjusted to a zero reading. Adjust the knob on the right side of the case until the index and its image are exactly in line with the reference mark on the mirror. Be careful to keep the ring in the liquid during this manipulation, raising or lowering the sample table (if necessary) by means of the knob adjustment underneath the table. Now turn the knob beneath the main dial on the front of the case until the vernier reads zero on the outer scale of the dial.

Lower the sample table until the ring is in the surface of the liquid, adjusting the knob on the right side of the case to keep the index lined up with the reference mark on the mirror. The surface of the liquid will become distended, but the index must be kept on the reference. Continue the two simultaneous adjustments until the distended film at the surface of the liquid breaks. The scale reading at the breaking point of the distended film is the apparent surface tension.

• Converting Scale Reading:

Readings of the surface tensiometer give apparent surface tension. In order to obtain the true surface tension the following relationship is used:

\[ \sigma = P \times F \]
where $\sigma$ is the true value, $P$ is the apparent value as indicated by the dial reading, and $F$ is a correction factor. The correction factor $F$ is dependent on the size of the ring and the size of the wire used in the ring, the apparent surface or interfacial tension, and the densities of the two phases. This relationship is:

$$F = 0.7250 + \frac{0.01452P}{C^2 (\rho_1 - \rho_2)} + 0.04534 - \frac{1.679}{R/r}$$

(9)

where,

$F =$ the correction factor

$R =$ the radius of the ring, cm

$r =$ the radius of the wire of the ring, cm

$P =$ the apparent value or dial reading, dyn/cm

$\rho_1 =$ the density of the lower phase, gm/cc

$\rho_2 =$ the density of the upper phase, gm/cc

$C =$ the circumference of the ring, cm

C. The Wilhemy Plate method:

In this method, a plate (Wilhemy plate) is lowered on the surface of the liquid, and the force applied over the wetted perimeter of the plate is measured. This method is based on the assumption that the contact angle between the liquid and the plate is zero. The Sigma 703 tensiometer, shown in figure 3 will be used for this procedure.
Operation

Before starting your measurements, you must clean the containers and the plate following similar procedures described previously for the ring method. Handle the Wilhelmy plate very carefully. Don’t bend it.

Turn the measurement mode knob to the “W” position. Turn the switch to “Normal” position. Hang the Wilhelmy plate on the hook. Place your sample vessel filled with liquid in the stage. Lift the stage by turning the knob until the Wilhelmy plate is fully submerged. Lower the stage until the Wilhelmy plate is completely above the surface of the liquid.

Turn the taring knob until the value on the display shows zero. Lift the stage slowly and stop as the Wilhelmy plate just touches the surface of the liquid. The surface tension of the liquid can now be seen on the display.

An alternative procedure is to lift the stage until the Wilhelmy plate is fully submerged, adjust the taring knob to zero and slowly lower the stage until the plate detaches itself from the liquid. The surface tension can be read on the display.

REQUIRED:

1) Using the three methods described above, determine the surface tension of

   • Water
   • Kerosene
   • Soapy solution (you will prepare this solution)

2) Determine the interfacial tension of water-kerosene using the ring method and the plate method.
3) Determine the surface tension of an air-water system versus temperature (from 20 to ~60 °C). Plot your results.

4) Discuss the effect of temperature upon surface tension.
5) Discuss the differences of surface tension between:
   - Oil and water
   - Oil and surfactant solution

6) Discuss the uncertainty in measuring IFT using the capillary rise method (procedure 1)
7) Discuss the associated errors in measuring the IFT using the ring method (procedure 2)
8) Discuss the associated errors in measuring the IFT using the plate method (procedure 3)
9) Compare the results obtained from all methods.

**Your report should contain the following elements**

A brief abstract telling problem, solution, value of this work, telling which tests you used and why you chose them. Include an evaluation of your success in applying the methods.

Conclusions
A brief introduction
Methods used, including selection of temperatures and rationale for this selection.

In developing your conclusions, Answer the following questions:

What can you say about each procedure? – Which one provides more reliable results and why?
Which one is easier to use?
How do your experimental results compare with those published for water?
What is the effect of decreasing the diameter of the capillary upon the capillary rise?

Headings for your report may follow this pattern (with some flexibility in discussion sections):
Abstract
1. Conclusions
2. Introductions
3. Temperature effect upon interfacial tensions.
4. Comparison of methods to determine IFT
5. Discussion of errors in measuring IFT.
6. Nomenclature
7. References
## Appendix 1

### Table 1. Surface Tension of Water in Contact with Air - SI units

<table>
<thead>
<tr>
<th>Temperature - $t$ ($^\circ$F)</th>
<th>Surface Tension in contact with air - $\sigma$ $10^{-3}$ (lb/ft)</th>
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<tbody>
<tr>
<td>32</td>
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<tr>
<td>40</td>
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Surface tension of kerosene at 25 °C = 25 dynes/cm