

## EZ-Pi / Aqua-Pi: Accuracy and precision of the instrument for solvents with surface tensions in the range 20-80 mN/m.

Christoffer Johans and Pekka Suomalainen

June 24, 2003

### Overview

The purpose of this technical note is to study the accuracy and precision of the EZ-Pi / Aqua-Pi instruments by measuring a broad range of surface tensions. For this purpose the surface tensions of water, DMSO, DMF, acetone, methanol, and ethanol were measured, and the results were analyzed by common statistical means.

### Experimental

Surface tension measurements were carried out on a Aqua-Pi tensiometer (Kibron Inc, Helsinki). The measurement is based on a use of a novel microtensiometer and Du Nouy technique. The only difference between the Aqua-Pi and EZ-Pi instruments is that the AquaPi is also battery operated. The key component in the instruments is a microbalance adapted for measuring small forces. The resolution of the balance is 0.1 mN/m. While the surface tension measurement is based on the Du Nouy method, our approach utilizes small needles (probes) instead of a Du Nouy ring. The probes have a diameter of 0.5 mm and the measurement solutions are assumed to completely wet the surface of the probe. The maximum force exerted by the surface tension is recorded as the probes are withdrawn from the solution. One measurement, i.e. the recording of one surface tension value, takes approximately 25 s.

The instrument was calibrated by adjusting the measurement scale so that the surface tension of water (MQ, Millipore) corresponded to 72.8 mN/m

(standard calibration routine). All chemicals were of analytical grade (>99.5%). Dimethylsulfoxide (DMSO) and Methanol were obtained from Merck, Acetone was obtained from J.T.Baker, Ethanol from Primalco, and N,N-dimethylformamide (DMF) was purchased from Acros Organics.

3 ml of solvents was dispensed into the disposable plastic (PS) cuvettes and ten surface tension readings for each solvent were recorded. Due to the high rate of evaporation only 6 readings were obtained for acetone. In addition, 50 readings were recorded for water to assess the precision in longer experiments. The measurement probe was the same throughout the experiments, but was cleaned by flaming between different solvents.

### Results and discussion

The results of the statistical analysis and corresponding literature data [1, 2] are shown in Table 1 and the individual measurement values are collected in Table 2. The standard deviation (SD) varied in the range 0.05-0.07 mN/m and the coefficient of variation (CV%) in the range 0.07-0.31%. The CV% is defined as the ratio between the standard deviation and the mean value, and therefore increases with lower surface tension. The small standard deviation is a measure of the instruments precision. The 50 surface tension readings of water gave a mean surface tension of 72.9 mN/m and a SD of 0.06 mN/m (CV% 0.08). These results indicate the high precision of the instrument also during longer experiments.

Table 1: Mean value of surface tension, standard deviation, CV% and literature surface tension for water, DMSO, DMF, acetone, methanol, and ethanol.

Solvent	$\bar{\gamma}$ / mN/m	SD/ mN/m	CV%	$\gamma_{\text{Lit}}$ / mN/m
MQ-water (10)	72.8	0.05	0.07	72.8
MQ-water (50)	72.9	0.06	0.08	
DMSO	43.8	0.05	0.11	43.0
DMF	37.0	0.08	0.22	36.8
Acetone	23.8	0.08	0.34	23.3
Methanol	22.9	0.07	0.31	22.6
Ethanol	22.6	0.05	0.21	22.3

The accuracy of the instrument is of particular interest as the applied technique differs from that commonly used. Comparison of the mean surface tension values ( $\bar{\gamma}$ ) and the literature values show excellent agreement. These data are plotted in Figure 1. A line has been fitted to the data, giving a slope of 0.996, an offset of 0.52 mN/m and a coefficient of correlation of 0.9999. These values indicate that the accuracy is excellent throughout the studied surface tension range.

## Concluding remarks

This study shows that the Aqua-Pi / EZ-Pi instrument has excellent precision and accuracy in the sur-

face tension range 20-80 mN/m, and is thus suited for fast and easy measurement of a large variety of liquids.

## References

- [1] <http://www.bandj.com/BJSolvents/BJProperties.html>.
- [2] <https://www.e-organicchemicals.com/thio/dimethyl/>.

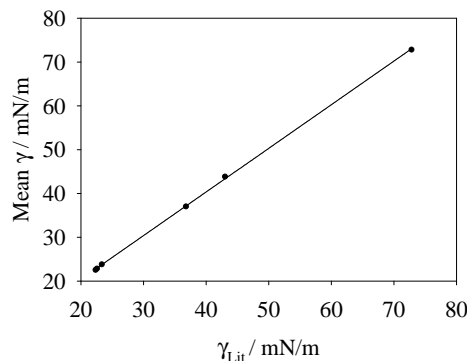


Figure 1: Mean measured surface tension values as a function of literature surface tension values of water, DMSO, DMF, acetone, methanol, and ethanol.

Table 2: Individual measured surface tension values for water, DMSO, DMF, acetone, methanol and ethanol.

Compound	Measurement#	$\gamma$ / mN/m
Water	1	72.8
	2	72.8
	3	72.8
	4	72.8
	5	72.8
	6	72.9
	7	72.9
	8	72.9
	9	72.8
	10	72.9
DMSO	1	43.9
	2	43.8
	3	43.9
	4	43.9
	5	43.8
	6	43.8
	7	43.8
	8	43.8
	9	43.8
	10	43.8
DMF	1	37.2
	2	37.1
	3	37.1
	4	37
	5	37
	6	37
	7	37
	8	36.9
	9	37
	10	37
Acetone	1	23.7
	2	23.8
	3	23.8
	4	23.9
	5	23.9
	6	23.9
Methanol	1	22.9
	2	22.7
	3	22.8
	4	22.9
	5	22.8
	6	22.8
	7	22.9
	8	22.9
	9	22.9
	10	22.9
Ethanol	1	22.5
	2	22.5
	3	22.6
	4	22.6
	5	22.5
	6	22.6
	7	22.6
	8	22.6
	9	22.6
	10	22.6