Surface Tension Measurement and Adsorption Isotherm Determination Using the Drop Weight Method

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Surface and Colloid Science

Surface tension calculation from the drop weight method

- Tate (1864)

$$W = 2\pi r\sigma$$

- Harkins and Brown (1919)

$$W = 2\pi r\sigma f = \frac{r\sigma}{F}$$

$$F \equiv \tfrac{1}{2}\pi f$$

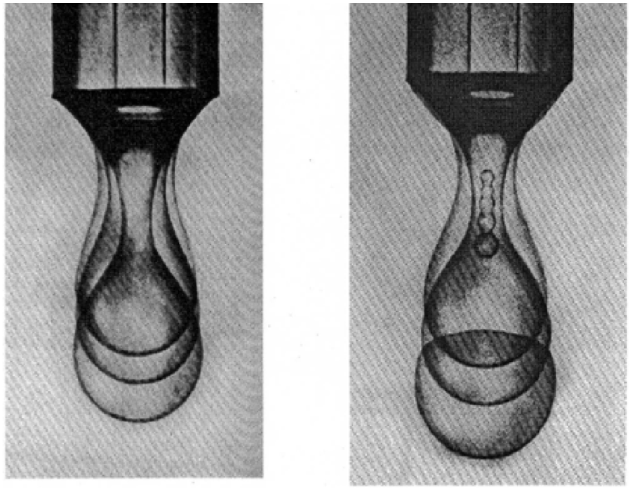
- Heertjes et al. (1971)

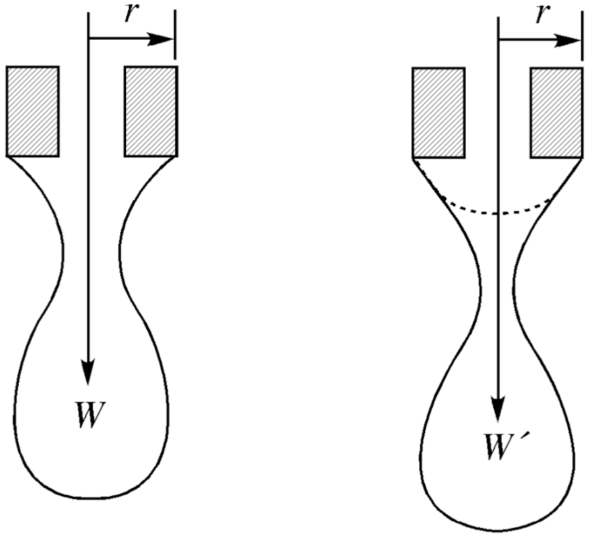
$$F = 0.14782 + 0.27896\left(\frac{r}{V^{1/3}}\right) - 0.1662\left(\frac{r}{V^{1/3}}\right)^2$$

Constraint: $\left(\frac{r}{V^{1/3}}\right) \in (0.3, 1.2)$

- Surface tension

$$\sigma = \frac{V|\rho_2 - \rho_1|gF}{r}$$





Szyszkowski equation describes surface tension of binary aqueous solutions

- Szyszkowski equation

$$\sigma = \sigma_0 - RTB \ln \left(1 + \frac{m_2}{a}\right)$$

Adsorption isotherm is modeled by Gibbs adsorption equation

- Gibbs adsorption equation: ideal solution

$$\Gamma_{2,1} = -\frac{x_2}{RT}\frac{d\sigma}{dx_2}$$

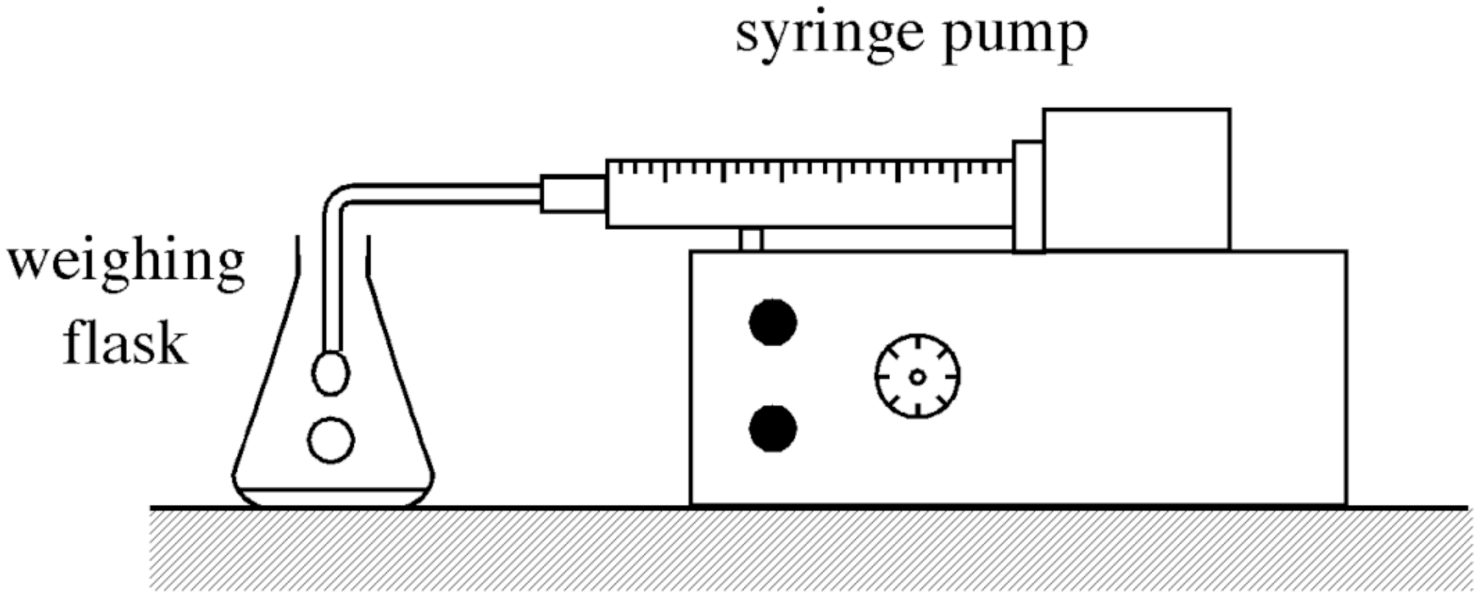
- Gibbs adsorption equation: ideal dilute solution

$$\Gamma_{2,1} = -\frac{m_2}{RT}\frac{d\sigma}{dm_2}$$

- General Gibbs adsorption equation

$$\Gamma_{2,1} = -\frac{m_2}{RT\left[1 + \frac{d\ln\gamma_2^H}{d\ln m_2}\right]}\frac{d\sigma}{dm_2}$$

Objective: Determining concentration dependence of surface tension



- Surface tension of water and aqueous solutions
  - $\sigma = \frac{mg}{r} F(r, V)$
  - $F = 0.14782 + 0.27896 \left(\frac{r}{V^{1/3}} \right) - 0.1662 \left(\frac{r}{V^{1/3}} \right)^2$
- Surface tension of aqueous n-butanol solution vs. concentration
  - Determine Szyszkowski parameters a and B
  - $\sigma = \sigma_0 - RTB \ln \left(1 + \frac{m_2}{a} \right)$

Objective: Constructing adsorption isotherms

- Relative adsorption of n-butanol at air-water interface vs. concentration (adsorption isotherm)
- Ideal dilute Gibbs adsorption equation

$$\Gamma_{2,1} = -\frac{m_2}{RT}\frac{d\sigma}{dm_2}$$

- General Gibbs adsorption equation

$$\Gamma_{2,1} = -\frac{m_2}{RT\left[1 + \frac{d\ln\gamma_2^H}{d\ln m_2}\right]}\frac{d\sigma}{dm_2}$$

Molality m_2	Activity Coefficient γ_2^{H}
0.003	0.9971
0.006	0.9942
0.010	0.9906
0.020	0.9823
0.030	0.9753
0.040	0.9691
0.050	0.9638
0.070	0.9546
0.100	0.9433
0.150	0.9276
0.200	0.9161
0.250	0.9058

Objective: Determining factors affecting surface tension

- Surface tension of water vs. nozzle size
- Surface tension of water vs. drop formation time
- Surface tension of 0.01 mM Triton X-100 surfactant solution vs. drop formation time
- Compare surface tension measured by various techniques
  - Drop weight, du Noüy ring, Wilhelmy slide, sessile/pendant drop