Problem 15-03 Spreading of a liquid on solid surface

A small amount of liquid was placed on a plane surface of a solid, the surface energy of which was 48.5 mJ m^{-2}. How will it behave? Will it spread? The interfacial tension liquid-solid surface has the value of 18.3 mN m^{-1}. The surface tension of the liquid has been determined by the capillary rise method: in the vertical capillary of inner diameter 0.16 mm the elevation of the liquid of 5.7 cm was measured. The liquid density is 0.912 g cm^{-3} and the studied liquid completely wets the walls of the capillary.

[$\gamma_{sg} > \gamma_{s\ell} + \gamma_{\ell g}$; $S_{\ell/s} = 9.8 > 0$, $\cos\theta > 1$ – liquid spreads ($\gamma_{\ell g} = 20.4$ mN m^{-1})]

Solution:

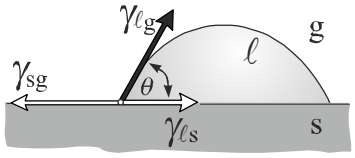
$\gamma_{sg} = 48.5$ mJ m^{-2}
$\gamma_{s\ell} = 18.3$ mN m^{-1}

$\gamma_{\ell g}$ –by capillary method: $\mathcal{D} = 0.16$ mm $= 1.6\cdot10^{-4}$ m
$\mathcal{R} = 8\cdot10^{-5}$ m
$h = 5.7$ cm $= 0.057$ m
$\rho = 0.912$ g $cm^{-3} = 912$ kg m^{-3}

$$\pi \mathcal{R}^2 \cdot h \cdot \rho \cdot g = 2\pi \mathcal{R} \cdot \gamma_{\ell g}$$

$$\gamma_{\ell g} = \frac{\mathcal{R} \cdot h \cdot \rho \cdot g}{2} = \frac{8\cdot10^{-5} \cdot 0.057 \cdot 912 \cdot 9.81}{2} = 0.0204 \text{ N m}^{-1} = 20.4 \text{ mN m}^{-1}$$

Spreading condition:



- Harkins spreading coefficient

$S_{\ell/s} = \gamma_{sg} - \gamma_{s\ell} - \gamma_{\ell g} =$
$= 48.5 - 18.3 - 20.4 = +9.8 > 0$ – liquid spreads

or

- Young equation:

$$\cos\theta = \frac{\gamma_{sg} - \gamma_{s\ell}}{\gamma_{\ell g}} = \frac{48,5 - 18,3}{20,4} = 1.48 > 1$$

- $\cos\theta > 1$ is impossible, the drop cannot take an equilibrium shape and the liquid spreads