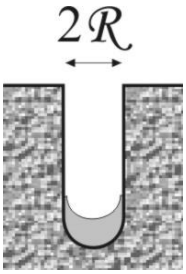
Problem 14-12 Kelvin equation – concave surface

Equilibrium vapour pressure of a liquid at the temperature of 40 °C is 4.2 kPa. Three moles of this liquid occupy at 40 °C the volume of 540 cm^3 and its surface tension is 48 mN m^{-1}. Calculate the pressure at which will condense the vapour of the studied substance on a porous solid with cylindrical pores (see attached picture) of diameter $6 \cdot 10^{-8}$ m. Assume complete wetting.



[p_r = 3.366 kPa]

Solution:

T =313.15 K

p^s_∞ = 4.2 kPa

$\mathcal{D} = 6 \cdot 10^{-8}$ m , $\mathcal{R} = 3 \cdot 10^{-8}$ m

γ = 48 mN m^{-1} = 0.048 N m^{-1}

n= 3 , V = 540 cm^3 $\Rightarrow$ $V_m^{(\ell)} = \frac{540}{3}$ cm^3 mol^{-1} = $1.8 \cdot 10^{-4}$ m^3 mol^{-1}

Vapour pressure above the concave meniscus is lower than the saturated vapour pressure above the planar surface:

$$\ln \frac{p^s_r}{p^s_\infty} = -\frac{2\gamma V_m^{(\ell)}}{\boldsymbol{R}T \cdot \mathcal{R}} = -\frac{2 \cdot 0.048 \cdot 1.8 \cdot 10^{-4}}{8.314 \cdot 313.15 \cdot 3 \cdot 10^{-8}} = -0.221238$$

$$\frac{p^s_r}{p^s_\infty} = 0.801526$$

p^s_r = 0.801526 · p^s_∞ = 0.801526 · 4.2 = 3.366 kPa