Problem 14-08 Kelvin equation – vapour pressure above a drop

Saturated vapour pressure above a liquid (M = 183 g mol^{-1}) at the temperature of 33°C is 5.2 kPa. Its surface tension is 68 mN m^{-1} and density 0.88 g cm^{-3}. What is the vapour pressure above a drop with diameter of 0.3 μm?

[p_r^s = 5.6 kPa]

Solution:

p_∞^s = 5.2 kPa

d = 0.3 μm = 3·10^{-7} m, r = 1.5·10^{-7} m,

T = 33 + 273.15 = 306.15 K

ρ = 0.88 g cm^{-3} = 880 kg m^{-3}

M = 183 g mol^{-1} = 0.183 kg mol^{-1}

γ = 68 mN/m = 0.068 N/m

Kelvin equation: $$\boldsymbol{R}T \cdot \ln \frac{p_r^s}{p_\infty^s} = \frac{2\,\gamma\, V_m^{(\ell)}}{r} \quad , \quad V_m^{(\ell)} = \frac{M}{\rho}$$

$$\ln \frac{p_r^s}{p_\infty^s} = \frac{2\,\gamma\, M}{\boldsymbol{R}Tr\,\rho} = \frac{2 \cdot 0.068 \cdot 0.183}{8.314 \cdot 306.15 \cdot 1.5 \cdot 10^{-7} \cdot 880} = 0.074075$$

$$p_r^s = 1.07689 \cdot p_\infty^s = 1.07689 \cdot 5.2 = 5.6 \text{ kPa}$$