Non-equilibrium thermodynamics
Exercise 4
Transport of heat and mass

1

a) You have a system with 2 components dissolved in water and there is a temperature gradient and concentration gradients. Write the flux equations for the system.

b) You have a system where the only driving force is a gradient in chemical potential for one of the components. Show how Fick's law can be derived from non-equilibrium thermodynamics. What is the relation between l_{ii} and Fick's diffusion coefficient for the component in the specific mixture?

c) You have a system where the only driving force is a temperature difference. Show how Fourier's law can be derived from non-equilibrium thermodynamics. What is the relation between l_{qq} and the thermal conductivity of the material?

d) What is the Soret effect?

e) What is the definition of the thermal diffusion coefficient, D_T, the Soret coefficient, s_T, and the thermal diffusion factor, α_T?

f) What is the Dufour effect?

g) What is the definition of the heat of transfer, q^*?

2

A cylindrical container of length 5 mm is filled with an aquous solution of KCl, c_{KCl} = 0.01 kmol m^{-3}. The temperature on the left-hand side, l, is 20 °C, and on the right-hand side, r, 30 °C. In the stationary state a difference in concentration is established between the two sides, $c_{KCl,r}$ - $c_{KCl,l}$ = Δc_{KCl} = -1.25 · 10^{-4} kmol m^{-3}. The average Fick's diffusion coefficient for KCl in water is $D_{1,2}$ = 1.9 · 10^{-9} m^2s^{-1}.

a) Calculate the Soret coefficient, s_T, and the heat of transfer, q^* (use the mean temperature), for KCl in the solution.

b) Calculate the flux of KCl at the starting time, when $\Delta c_{KCl} = 0$.

3

A cylindrical container of length 1 dm is filled with propane with some dissolved methane at 346 K and 56 bar. At the left side the concentration of methane is $3.7 \cdot 10^{-4}$ mol/m^3 and at the right side the concentration is $4.0 \cdot 10^{-4}$ mol/m^3. Assume that the diffusion coefficient of methane in propane is $6.2 \cdot 10^{-9}$ m^2/s and that α_T is 8.9. Calculate the heat flux at these conditions.