

P1.1-2 (1-1 in text): Conductivity of a dilute gas

Section 1.1.2 provides an approximation for the thermal conductivity of a monatomic gas at ideal gas conditions. Test the validity of this approximation by comparing the conductivity estimated using Eq. (1-18) to the value of thermal conductivity for a monatomic ideal gas (e.g., low pressure argon) provided by the internal function in EES. Note that the molecular radius, σ , is provided in EES by the Lennard-Jones potential using the function `sigma_LJ`.

a.) What is the value and units of the proportionality constant required to make Eq. (1-18) an equality?

Equation (1-18) is repeated below:

$$k \propto \frac{c_v}{\sigma^2} \sqrt{\frac{T}{MW}} \quad (1)$$

Equation (1) is written as an equality by including a constant of proportionality (C_k):

$$k = C_k \frac{c_v}{\sigma^2} \sqrt{\frac{T}{MW}} \quad (2)$$

Solving for C_k leads to:

$$C_k = \frac{k \sigma^2}{c_v} \sqrt{\frac{MW}{T}} \quad (3)$$

which indicates that C_k has units $\text{m} \cdot \text{kg}^{1.5} / \text{s} \cdot \text{kgmol}^{0.5} \cdot \text{K}^{0.5}$.

The inputs are entered in EES for Argon at relatively low pressure (0.1 MPa) and 300 K.

"Problem 1.1-2"

\$UnitSystem SI MASS RAD PA K J

\$TABSTOPS 0.2 0.4 0.6 0.8 3.5 in

T=300 [K]

F\$='Argon'

P_MPa=0.1 [MPa]

P=P_MPa*convert(MPa, Pa)

"temperature"

"fluid"

"pressure, in MPa"

"pressure"

The conductivity, specific heat capacity, Lennard-Jones potential, and molecular weight of Argon (k , c_v , σ , and MW) are evaluated using EES' built-in functions. Equation (3) is used to evaluate the proportionality constant.

k=conductivity(F\$,T=T,P=P)

cv=cv(F\$,T=T,P=P)

MW=molarMass(F\$)

sigma=sigma_LJ(F\$)

C_k=k*sigma^2*sqrt(MW/T)/cv

"conductivity"

"specific heat capacity at constant volume"

"molecular weight"

"Lennard-Jones potential"

"constant of proportionality"

which leads to $C_k = 2.619 \times 10^{-24} \text{ m} \cdot \text{kg}^{1.5} / \text{s} \cdot \text{kgmol}^{0.5} \cdot \text{K}^{0.5}$.

- b.) Plot the value of the proportionality constant for 300 K argon at pressures between 0.01 and 100 MPa on a semi-log plot with pressure on the log scale. At what pressure does the approximation given in Eq. (1-18) begin to fail at 300 K for argon?

Figure 1 illustrates the constant of proportionality as a function of pressure for argon at 300 K. The approximation provided by Eq. (1-18) breaks down at approximately 1 MPa.

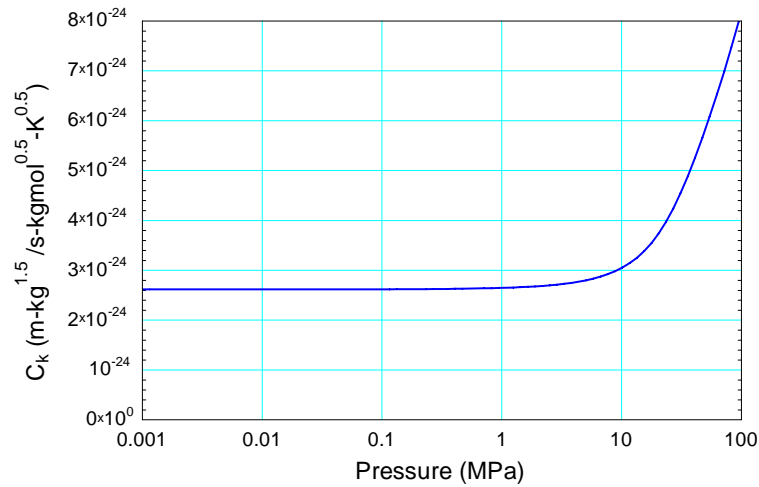


Figure 1: Constant of proportionality in Eq. (3) as a function of pressure for argon at 300 K.