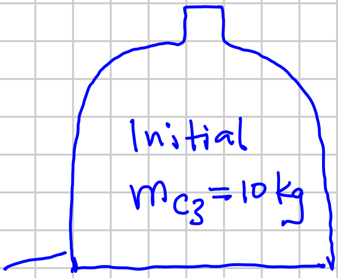
Qs related to 1-component p-T, p-V diagrams

2-component — " —

@ End of each Usage



Volume Tank = 25 L

Known:

(a) $T_{outside} \sim T_{tank\ inside}$

(b) m_{C_3} (cumulative) used up

$m_{C_3} = 10$ kg

$V_{C_3} = 25 \text{ L} \cdot \underbrace{\frac{m^3}{1000 \text{ L}}}_{\times 1} = 0.025 \text{ m}^3$

Initially (no usage)

(a) p Use ideal gas eq. - need T ?

(c) V_g / V_t

Hints: Conserve!
Assume | Ask

$\boxed{T = 0\,°C}$

- Either: Gas + Liquid $\underline{p} = p_v(T)$, Use Table
Gas-Like Assume $pV \cong nRT$
Liquid-Like

$T = 0°C \quad p_v = 4.769$ bara

$m = 10 \text{ kg} = m_g + m_L$

$V \overset{\sim}{=} 0.025 m^3 = V_g + V_L$

$$(T, p_v) \; @ \; \begin{cases} \rho_L = \dfrac{m_L}{V_L} = 527.22 \ kg/m^3 \\ \rho_g = \dfrac{m_g}{V_g} = 10.325 \ kg/m^3 \end{cases}$$

Assume all $(1-\epsilon_g)$ is Liquid $\Rightarrow V_L^* = 0.018 \, m^3$

Assume all $(1-\epsilon_L)$ is Gas $\Rightarrow V_g^* = 0.97 \ m^3$

$$\boxed{V_L^* < V_{tank} < V_g^*} \text{ - Check}$$

$\Rightarrow$ 2-phases

$$0.025 m^3 = V_{tank} = V_L + V_g$$

$$m_L / \rho_L + m_g / \rho_g$$

Amran

$$\frac{m_L}{\rho_L} + \frac{(m - m_L)}{\rho_g} = 0.025$$

$$\Rightarrow m_L \Rightarrow m_g$$

$$\Downarrow \qquad \Downarrow$$

$$V_L \qquad V_g$$

$$V_g^* < V_{tank} \Rightarrow p < p_v(T)$$

Problem 1 – **Gas Grill Propane Tank Depletion**

Consider a domestic outdoor grilling propane (C_3) tank with 10 kg of propane filling a 25 L (liter) container.

Determine the following quantities at the end of each usage of the grill, where the cumulative amount removed is given as a percentage of the initial propane mass in the tank – e.g. 2%, ... 28%, ... 92%, for an arbitrary number of usages until the tank "runs empty".

Known after each usage:

(a) Outdoor (tank) temperature (^{o}C); could vary after each usage (ranging from -20^{o}C to +60^{o}C).
(b) Cumulative propane used (% of mass initially in tank).

To be calculated after each usage:

(a) Pressure in the tank.
(b) Mass propane remaining in the tank (kg).
(c) Gas volume as a % of tank volume.
(d) Whether the tank has two phases or one phase (1 or 2); if 1, which phase (gas or liquid).

Plot tank pressure (left y-axis) and liquid vol-% (right y-axis) in tank versus cumulative propane mass consumed.

The properties of propane are estimated by the Soave-Redlich-Kwong (SRK) equation of state model as given in Table 1. Using the three hints below, find simple equations that give the vapor pressure and phase densities as a function of temperature or vapor pressure.

Hint 1. Fit *all* of the vapor pressure "data" in Table 1 to the Antoine equation given by $p_v(T)=A-B/(C+T)$, where you minimize the sum of squares of $\Delta p_v=(p_v^{Antoine}-p_v^{Table})$ by changing A, B, and C. Use this (your) custom best-fit Antoine equation to solve the problem above.

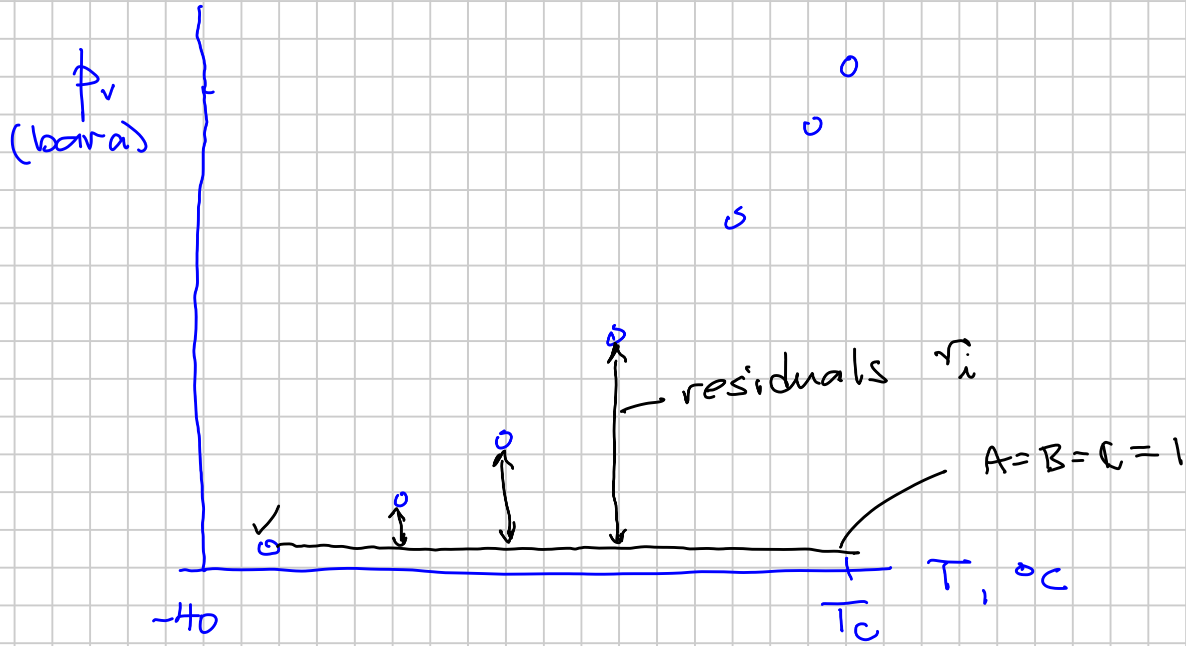
Hint 2. Use Excel Trend Line to fit the gas density "data" (only up to 60^{o}C) in Table 1 as a linear function of pressure and zero intercept. What do we call this best-fit equation?

Hint 3. Use Excel Trend Line to fit the liquid density "data" (only up to 60^{o}C) in Table 1 to a 2nd-degree polynomial in temperature.

Least Squares Non-Linear Regression

"Best Fit" an equation to "data"

$p_v = A - B/(T+C)$ Table 1 - cols. 1 & 2

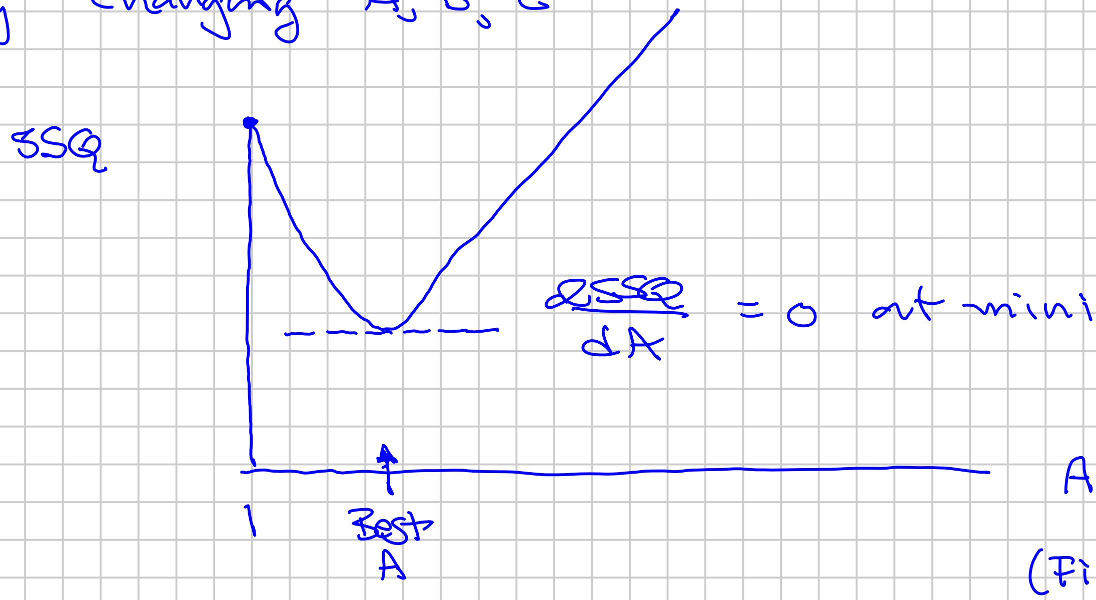


$$\underset{min}{SSQ} = \sum r_i^2 = \sum \left[\frac{\overbrace{(p_v^A}^{\text{Model}} - \overbrace{p_v^{Table})}^{\text{Data}}}{p_{v,ref}} \right]^2$$

Reference Value e.g. $= p_v^{Table}$

$r_i = \underline{\underline{\Delta_i}}$

by changing A, B, C



$\frac{\partial SSQ}{dA} = 0$ at minimum

(Fix B & C)

$$\log_{10} p_v [mmHg] = [A' - B'/(C' + T_c)]$$

$$\log_{10} \left(p_v [bar] \cdot \underbrace{\frac{mm\,Hg}{0.00133\,bar}} \right) = A' - B'/(C' + T_c)$$

$$\log_{10} p_v [bar] - \log_{10}(0.001333) = A' - B'/(C' + T_c)$$

$$\log_{10} p_v [bar] = \underbrace{[A' + \log(0.00133)]}_{A} - B'/(C' + T_c)$$

Gas Density Model :

$$p V_g \simeq n_g R T \qquad m_g = n_g \cdot M_g$$

$$\rho_g = \frac{m_g}{V_g}$$

$$p V_g = \left(\frac{m_g}{M_g}\right) R T \Rightarrow \frac{m_g}{V_g} = \frac{p M_g}{RT}$$

$$\rho_g \simeq \left(\frac{M_g}{RT}\right) \cdot p$$

$$\rho_g \simeq a \cdot p \quad ?$$

$$p \Leftarrow \begin{cases} T \\ m_g \\ V_g = V_{tank} \\ \rho_g = \dfrac{m_g}{V_{tank}} \end{cases}$$

if : 1(G)

$$\boxed{\rho_g \simeq \frac{M_g}{RT} p}$$

$$\boxed{p} = \left(\frac{m_g}{V_{tank}}\right) \cdot \frac{RT}{M_g}$$

R, T, M_g

$R = 0.08314$ bar, K, m^3, kg-mole
(kmol)