Zachary Ahmad
PSE 380
Due 2/24/21

2.69) Is it reasonable to assume that at the given states, the substance behaves as an ideal gas?

a) Oxygen at 30°C, 3 MPa
b) Methane at 30°C, 3 MPa
c) Water at 30°C, 3 MPa
d) R-134a at 30°C, 3 MPa
e) R-134a at 30°C, 100 kPa

a) Given $T = 30°C + 273 = 303\ K$, $P = 3\ MPa$

From table A.2. → $T_c = 154.6\ K$, $P_c = 5.04\ MPa$
$T > T_c$, $P < P_c$
so, yes oxygen behaves as an ideal gas.

b) $303K = T$, $P = 3\ MPa$
From table A.2. → $T_c = 190\ K$, $P_c = 4.60\ MPa$
so, yes methane behaves as an ideal gas. ($T > T_c$, $P < P_c$)

c) $T = 303\ K$, $P = 3\ MPa$
From table A.2. → $T_c = 647.3\ K$, $P_c = 22.12\ MPa$
since ($T < T_c$, $P < P_c$) water does not act as ideal gas.
from B.1.1. → $P_{sat} = 4.246\ kPa \approx 0.004246\ MPa$
$P > P_{sat}$ so water is in compressed liquid state.

d) $T = 303\ K$, $P = 3\ MPa$, from A.2. → $T_c = 374.2\ K$, $P = 4.06\ MPa$
since ($T < T_c$, $P < P_c$) R-134a does not act as an ideal gas.
from B.1.1. $P_{sat} = 0.771\ MPa$. $P > P_{sat}$ so R134a is a compressed liquid.

e) $T = 303\ K$, $P = 100\ kPa$, from A.2. $T_c = 374.2\ K$, $P = 4.06\ MPa$
($T < T_c$, $P < P_c$) but referring to B.5.1., we see
$P_{sat} = 771\ kPa$ $P < P_{sat}$ so
yes, R-134a acts as an ideal gas.

- I understand how to solve this problem.

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2.87) Find the compressability for carbon dioxide at 60°C and 10 MPa using Fig D.1.

From table A.2., for CO_2, $T_c = 304.1$ K, $P_c = 7.38$ MPa, $R = 0.1889$ kJ/kg K

equation (2.13) p.60 → $T_r = \frac{T}{T_c}$

(60+273)

→ $\frac{333}{304.1} = 1.095$

(P.60)

$P_r = \frac{P}{P_c} = \frac{10}{7.38} = 1.355$

from the generalized compressability chart (D.1.)

at $T_r = 1.095$, $P_r = 1.355$

compressability (z) = <u>0.45</u>

- I understand how to solve this problem

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2.89) A cylinder fitted with a frictionless piston contains butane at 25°C, 500 kPa. Can the butane reasonably be assumed to behave as an ideal gas at this state?

Given: $T = 25°C = 298\,k$, $P = 500\,kPa$

From Table A.2., we see that $T_c = 425.2\,k$ and $P_c = 3.8\,MPa$

Referring to formulas from last question...

$$T_r = \frac{T}{T_c} = \frac{289}{425.2} = 0.6797$$

$$P_r = \frac{P}{P_c} = \frac{0.5}{3.8} = 0.13158$$

Figure D.1. at reduced temp, $T_r = 0.679 \approx 0.7$

$P_{r,sat} = 0.1$ (reduced pressure of saturated liquid)

Since $P_r > P_{r,sat}$, butane is in liquid state.

<u>No</u>, it is not behaving as an ideal gas; it would need to have pressure < 380 kPa.

- I understand how to solve this problem.

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2.98) Determine the pressure of nitrogen at 160 K, $v = 0.00291\ m^3/kg$ using ideal gas, the van der Waals EOS, and the nitrogen table.

From table A.5., R for nitrogen is 0.297 kJ/kg K so, we use

$$PV = mRT, \quad P = \frac{RT}{v}$$

$$P = \frac{0.297 \times 160}{0.00291} = 16329.9 \approx \underline{16.329\ MPa}$$

Using van der Waals: $P = \frac{RT}{v-b} - \frac{a}{v^2 + cbv + db^2}$

and $c, d = 0$ and equation becomes:

$$P = \frac{RT}{v-b} - \frac{a}{v^2}$$

and from Table D.1. we know that $b_0 = \frac{1}{8}$, $a_0 = \frac{27}{64}$

From A.2., $P_c = 3.39\ MPa$, $T_c = 126.2\ K$, and from A.5., $R = 0.297\ kJ/kg\ K$

$$a = \frac{\frac{27}{64} \cdot (0.297)^2 \cdot (126.2)^2}{3.39 \times 10^6} = 1.748 \times 10^{-1}\ kPa(m^3/kg)^2$$

$$b = \frac{\frac{1}{8} \cdot (0.297) \cdot (126.2)}{3.39 \times 10^6} = 1.382 \times 10^{-3}\ m^3/kg$$

$$P = \frac{0.297 \cdot 160}{0.00291 - 1.382 \times 10^{-3}} - \frac{1.748 \times 10^{-1}}{(0.00291)^2} = \underline{10.457\ MPa}$$

From table B.6.2., $P = \underline{10\ MPa}$

- I understand how to solve this problem.