Quiz 10
Chemical Engineering Thermodynamics
March 23, 2017

Determine the fugacity (MPa) for ethane at (a) 7°C (280°K) and 1 MPa and (b) 7°C (280°K) and 4.0 MPa using the virial equation and the shortcut vapor pressure.

T_c = 305.3 °K, P_c = 4.9 MPa , V_c = 147 cm^3/mole, ω = 0.099, R = 8.314 J/(mole °K) = 8.314 cm^3MPa/(mole°K)

Determine if the short cut method is appropriate.
Calculate the vapor pressure and determine the state for each condition.
Determine if the virial equation is appropriate. (***Accept if you are within 10% of the criterion***)
Calculate the fugacity (using different methods for the different states).

$$\log_{10} P_r^{sat} = \frac{7}{3}(1+\omega)\left(1-\frac{1}{T_r}\right) \qquad 9.11$$

Shortcut vapor pressure equation. Use care with the shortcut equation below T_r = 0.5.

$$\ln \varphi = \frac{BP}{RT} \qquad 9.31$$

$$Z = 1 + (B^0 + \omega B^1)P_r/T_r \quad \text{or} \quad Z = 1 + BP/RT \qquad 7.6$$

$$\text{where } B(T) = (B^0 + \omega B^1)RT_c/P_c \qquad 7.7$$

$$B^0 = 0.083 - 0.422/T_r^{1.6} \qquad 7.8$$

$$B^1 = 0.139 - 0.172/T_r^{4.2} \qquad 7.9$$

$$\text{Subject to } T_r > 0.686 + 0.439P_r \text{ or } V_r > 2.0 \qquad 7.10$$

Poynting correction.

The fugacity is then calculated by

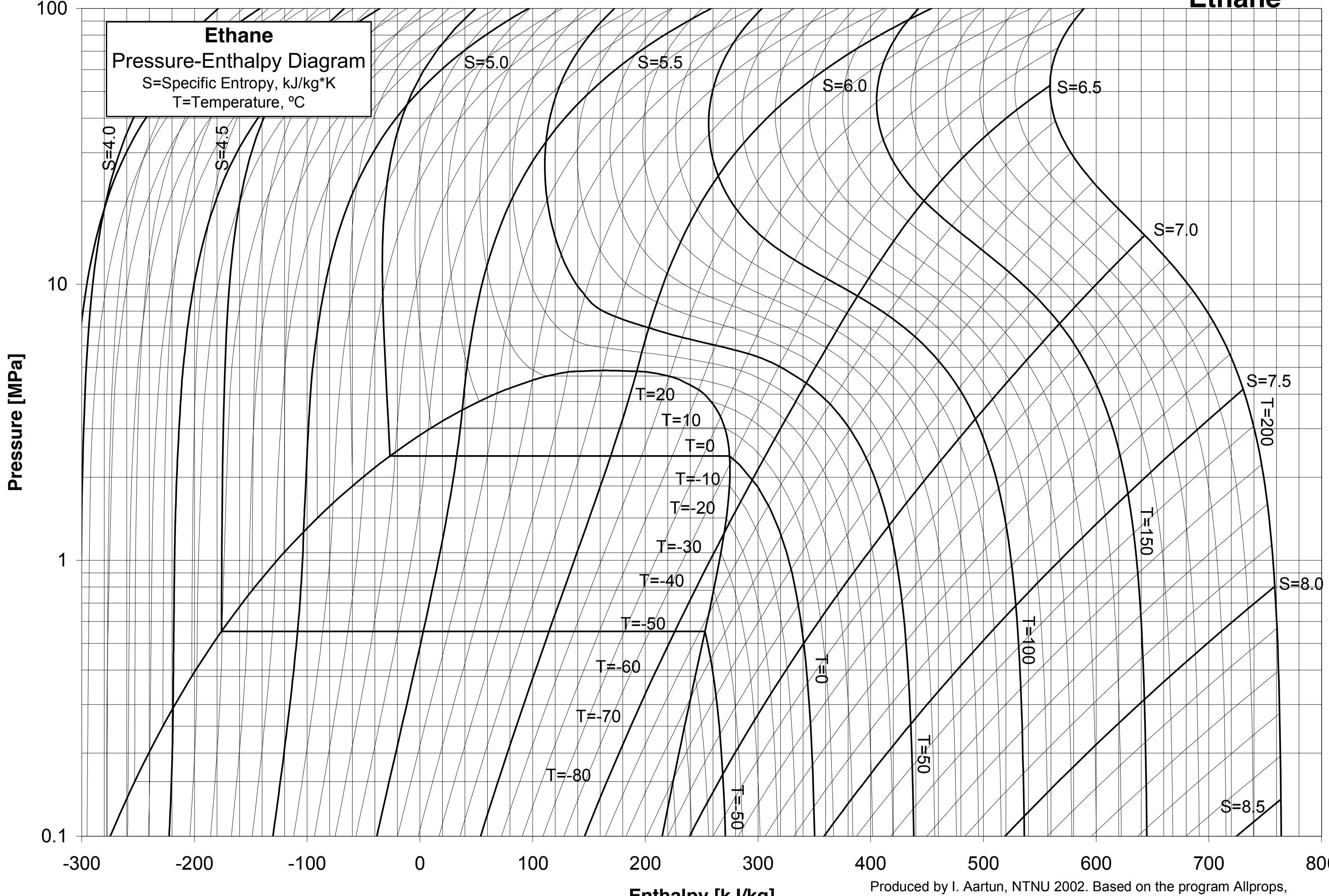
$$f = \varphi^{sat} P^{sat} \exp\left(\frac{V^L(P - P^{sat})}{RT}\right) \qquad 9.39$$

Saturated liquid volume can be estimated within a slight percent error using the **Rackett** equation

$$V^{satL} = V_c Z_c^{(1-T_r)^{0.2857}} \quad 9.40$$

$$Z_c = P_c V_c/(RT_c)$$

Ethane



Produced by I. Aartun, NTNU 2002. Based on the program Allprops,
Center for Applied Thermodynamic Studies, University of Idaho.

Answers Quiz 10
ChE Thermo
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(a) $T_r = \frac{280K}{305K} = 0.918$

$P_r = \frac{1.0MPa}{4.9MPa} = 0.204$

(-3) If calc. T_r but didn't state

(1) $T_r > 0.5$ so Shortcut Works

$P_{sat} = P_c \, 10^{7/3(1+\omega)(1-\frac{1}{T_r})}$

$= 4.9MPa \, 10^{7/3(1.099)(1-\frac{1}{0.918})}$

(2) $P_{sat} = 2.89MPa$

(3) @ 1MPa Vapor (-5) missing

$0.686 + 0.439(0.204) = 0.776 < 0.918$ (T_r)

(4) missing (-5) so Virial is appropriate

$B_0 = 0.083 - \frac{0.422}{T_r^{1.6}} = -0.407$

$B_1 = 0.139 - \frac{0.172}{T_r^{4.2}} = -0.107$

$B = (B_0 + \omega B_1) \frac{RT_c}{P_c} = -213 \frac{cm^3}{mole}$

②

$$\psi = \exp\left(\frac{-213 \frac{cm^3}{mole}\ 1MPa}{8.31 \frac{MPa\,cm^3}{mole\,K}\ 280}\right)$$

$= 0.913$

(5) $\boxed{f = 0.913\ MPa}$

(b) $P_{sat} = 2.89 MPa \quad P_r^{sat} = 0.590$

(1) $P = 4 MPa$ sc Liquid $P_r = \frac{4 MPa}{4.9 MPa} = 0.816$ (-5)

Test for virial Using P_{sat}

(2) $0.686 + 0.439(0.590) = 0.945 \sim T_r = 0.918$
within 10%

missing (-5)

(3) $\ln \phi^{sat} = \frac{BP^{sat}}{RT} = \frac{-213 \frac{cm^3}{mole} 2.89 MPa}{8.31 \frac{cm^3 MPa}{K\,mole} 280K} = -0.265$

P_{sat} (-5)

$\phi^{sat} = 0.767$

$f^{sat} = \phi^{sat} P^{sat} = (0.767) 2.89 MPa$

(-5) and Poynting than P_{sat}

$f^{sat} = 2.22 MPa$

(4) $V^{sat\,L} = 147 \frac{cm^3}{mole} \left(\frac{P_c V_c}{RT_c}\right)^{(1-T_r)^{0.2857}}$ 79.3 cm³/mol

math error (-1)

$= 147 \frac{cm^3}{mol} (0.284)^{0.489} = ~~120~~ \frac{cm^3}{mole}$

③

$$f = (0.767)(2.89\,MPa)\exp\left(\frac{79.3\,\frac{cm^3}{mol}(4\,MPa - 2.89\,MPa)}{8.31\,\frac{cm^3 MPa}{K\,mol}\,280\,K}\right)$$

⑤

$f = 2.35\ MPa$

2.30