Solution for Problem 4.32

10.213

Calculate the volume occupied by 50 kg of propane at 35 bar and 50 ℃, using the following:

(a) The ideal gas model

$$PV = NRT = \frac{M}{MW}RT$$ *(1 point for correct equation)*

$$V = \frac{MRT}{P(MW)}$$

$$V = \frac{(50 \quad 10^3 g)(0.08314\frac{Lbar}{molK})(323K)}{(35bar)(44.10\frac{g}{mol})}$$

$$\boxed{V = 869.9L}$$ *(1 point)*

(b) The Redlich-Kwong equation of state

$$P=\frac{RT}{v-b}-\frac{a}{T^{1/2}v(v+b)}$$

Where $a=\frac{0.42748R^2T_c^{2.5}}{P_c}$ and $b=\frac{0.08664RT_c}{P_c}$

From Appendix A,

P_c = 42.44 bar, T_c = 370.0K

Calculating

$$a=\frac{0.42748(0.08314\frac{L^2bar}{molK})^2(370.0K)^{2.5}}{42.44bar}=183.34\frac{L^2barK^{1/2}}{mol^2}$$

$$b=\frac{0.08664(0.08314\frac{Lbar}{molK})(370.0K)}{42.44bar}=0.0628\frac{L}{mol}$$

Substitute values into RK EOS,

$$P=\frac{RT}{v-b}-\frac{a}{T^{1/2}v(v+b)}$$

$$35bar=\frac{(0.08314bar)(323K)}{v-0.0628\frac{L}{mol}}-\frac{183}{(323K)^{1/2}v(v+0.0628\frac{L}{mol})}$$

Solving for v numerically,

$$v=0.1093\frac{L}{mol}$$

$$V=\frac{M}{MW}v$$

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$$V = \frac{50000\,g}{44.10\,\frac{g}{mol}}\,0.1093\,\frac{L}{mol}$$

$$\boxed{V = 123.9\,L}$$

(2 points)

The Peng-Robinson equation of state

$$P = \frac{RT}{v-b} - \frac{a\alpha(T)}{v(v+b)+b(v-b)}$$

Where $a = 0.45724\frac{R^2T_c^2}{P_c}$, $b = 0.07780\frac{RT_c}{P_c}$

$\alpha(T) = [1+\kappa(1-\sqrt{T_r})]^2$, $\kappa = 0.37464 + 1.54226\omega - 0.26992\omega^2$

From Appendix A,

P_c = 42.44 bar, T_c = 370.0K, ω=0.152

Calculating

$$a = 0.45724\frac{(0.08314\frac{Lbar}{molK})^2(370.0K)^2}{42.44bar} = 10.195$$

$$b = 0.07780\frac{(0.08314\frac{Lbar}{molK})(370.0K)}{42.44bar} = 0.0564$$

$$\kappa = 0.37464 + 1.54226(0.152) - 0.26992(0.152)^2 = 0.603$$

$$\alpha(T) = [1+(0.603)(1-\sqrt{\frac{323K}{370K}})]^2 = 1.081$$

Substitute values into PR EOS,

$$P = \frac{RT}{v-b} - \frac{a\alpha(T)}{v(v+b)+b(v-b)}$$

$$35bar = \frac{(0.08314\frac{Lbar}{molK})(323K)}{v - 0.0564\frac{L}{mol}} - \frac{(10.195)(1.081)}{v(v+0.0564\frac{L}{mol}) + 0.0564\frac{L}{mol}(v-0.0564\frac{L}{mol})}$$

Solving for v numerically,

$$v = 0.0942 \frac{L}{mol}$$

$$V = \frac{M}{MW} v$$

$$V = \frac{50000 g}{44.10 \frac{g}{mol}} 0.0942 \frac{L}{mol}$$

$$\boxed{V = 106.8 L}$$

(2 points)

(c) The compressibility charts

$$P_r = \frac{P}{P_c} = \frac{35bar}{42.44bar} = 0.825$$

$$T_r = \frac{T}{T_c} = \frac{323K}{370.0K} = 0.873$$

Using Tables C.1 and C.2 (by interpolation)

$z^{(0)} = 0.1349$

$z^{(1)} = -0.0520$

$$z = z^{(0)} + \omega z^{(1)}$$

z = 0.1349 + 0.152(-0.0520)

z = 0.127 *(1 point)*

$$V = nv = \left(\frac{M}{MW}\right)\left(\frac{zRT}{P}\right)$$

$$V = \left(\frac{50000g}{44.10\frac{g}{mol}}\right)\left(\frac{0.127(0.08314\frac{Lbar}{molK})(323K)}{35bar}\right)$$

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$\boxed{V = 110.5L}$ *(1 point)*

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The textbook software, ThermoSolver: www.wiley.com/college/koretsky

Using Peng-Robinson Equation of State,

$$v = 0.0942 \frac{L}{mol}$$

$$V = \frac{50000\,g}{44.10\,\frac{g}{mol}} 0.0942 \frac{L}{mol}$$

$\boxed{V = 106.8L}$ *(1 point)*

Using Compressibility Chart,

$$v = 0.0971 \frac{L}{mol}$$

$$V = \frac{50000\,g}{44.10\,\frac{g}{mol}} 0.0971 \frac{L}{mol}$$

$\boxed{V = 110.1L}$ *(1 point)*