화공 열역학 과제1

#05

2019101074 안용성

2019101074 안동우

49. (a) $\frac{PV}{RT} = 1 + \frac{B}{V} + \frac{C}{V^2}$

$$\frac{12\,bar \times V}{83.145\,bar\cdot cm^3/mol\cdot K \times 298K} = 1 + \frac{-145\,cm^3/mol}{V} + \frac{7200\,cm^6/mol^2}{V^2}$$

$$V = 2064.8\,cm^3/mol \left(1 - \frac{145\,cm^3/mol}{V} + \frac{7200\,cm^6/mol^2}{V^2}\right)$$

i) $V = \frac{P}{RT} = \frac{12\,bar}{83.145\,bar\cdot m^3/mol\cdot K \times 298K} = 2065\,cm^3/mol$

interpolation 내삽법 $\Rightarrow V = 1918\,cm^3/mol$

(b) $T_c = 282.34$, $P_c = 50.45\,bar$, $\omega = 0.087$

$T_r = \frac{298}{282.3} = 1.056$, $P_r = 0.2361$

$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}} = -0.364$

$B^1 = 0.139 - \frac{0.172}{T_r^{4.2}} = 0.0021\,8$

$\frac{BP_c}{RT_c} = B^0 + \omega B^1 = -0.364 + 0.087 \times 0.0021\,8 = -0.303\,8$

$Z = 1 + \left(\frac{BP_c}{RT_c}\right)\frac{P_r}{T_r} = 1 - 0.3038 \times \frac{0.2361}{1.056} = 0.9315$

$V = \frac{ZP}{RT} = 0.9317 \times 2064.8 = 1923.86\,cm^3/mol$

c) $P = \frac{RT}{V-b} - \frac{a(T)}{V(V+b)}$ ← $a(T) = 0.42748\frac{T_r^{-0.5}R^2T_c^2}{P_c} = 454810\,bar\cdot cm^6/mol^2$

← $b = 40.35\,cm^3/mol$

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

$V = \left(2064.8 + 40.35 - \frac{454810(V-40.35)}{12V(V+40.35)}\right) cm^3/mol$

$= \left(2105.2 - \frac{37900.8(V-40.35)}{V(V+40.35)}\right) cm^3/mol$

$V = 1915\,cm^3/mol$

(d) $a(T) = 0.42748\frac{(1+(0.480+1.574\omega-0.176\omega^2)(1-T_r^{0.5}))^2R^2T_c^2}{P_c} = 454750\,\frac{bar\,cm^3}{mol^2}$

$b = 0.08664\frac{RT_c}{P_c} = 40.35\,cm^3/mol$

$V = \left(2105.2 - \frac{37879(V-40.35)}{V(V+40.35)}\right) cm^3/mol$

$V = \frac{P}{RT} = 2065\,cm^3/mol \Rightarrow V = 1916\,cm^3/mol$

(e) $P=\frac{RT}{V-b}-\frac{a(T)}{(V+2.41426)(V-0.41426b)}$

$a(T)=48601.71\ bar\ cm^6/mol^2$

$b=0.0777\frac{RT_c}{P_c}=36.23\ cm^3/mol$

$V=\frac{RT}{P}+b-\frac{a(T)}{P}\frac{V-b}{(V-0.41426)(V+2.41426)}$

$V=\left(2101.0-\frac{40524(V-36.23)}{(V-15.005)(V+87.40)}\right)cm^3/mol$

i) $V=\frac{P}{RT}=2065\ cm^3/mol$

$V=1899\ cm^3/mol$

50. $\frac{PV}{RT}=1+\frac{B}{V}+\frac{C}{V^2}$

a) $\frac{18bar\times V}{83.145\times523}=1+\frac{-152.5}{V}+\frac{-5800}{V^2}$

$V=2415.8\ cm^3/mol\times\left(1-\frac{152.5}{V}-\frac{5800}{V^2}\right)$

$V=\frac{RT}{P}=2416 cm^3/mol$

$V=2249 cm^3/mol$

(b) $T_c=641.1K$ $P_c=220.55bar$ $\omega=0.345$

$T_r=0.8082$ $P_r=0.08161$

$B^0=0.083-\frac{0.422}{T_r^{1.6}}=-0.5103$

$B^1=0.139-\frac{0.172}{T_r^{4.2}}=-0.2816$

$\frac{BP_c}{RT_c}=B^0+\omega B^1=-0.6075$

$Z=1-0.6075\frac{0.08161}{0.8082}=0.9387$

$V=\frac{ZRT}{V}=2248 cm^3/mol$

(c) 1800kPa, 250°C일때 $V=124.9 cm^3/g$

$MW=18.016 \Rightarrow V=124.9\times18.016=2252 cm^3/mol$

63 (d) $T_c = 369.8\,K$ $P_c = 42.48\,bar$

$T_r = \frac{343}{369.8} = 0.9275$ $P_r = \frac{25.94}{42.48} = 0.6106$

$a(T) = 0.42748 \times \frac{0.9275^{-0.5} \times 83.14^2 \times 369.8^2}{42.48}$

$= 98770.71\ bar\ cm^6/mol^2$

$b = 0.08664 \times \frac{RT_c}{P_c} = 64.15\ cm^3/mol$

i) Vapor $\Rightarrow V = \frac{RT}{P} + 64.15 - \frac{98770.71}{P} \times \frac{(V-64.15)}{V(V+64.15)}$

for Ref

$V = 7722.5\ cm^3/mol$

ii) Liquid : $b \approx V^L$ $V_0 = 64.15\ cm^3/mol$

$V = 64.15 + V(V+64.15)\frac{RT + 64.15P - VP}{98770.71}$

$\Rightarrow$ Iteration

$V = 142.9\ cm^3/mol$

- $Z = 1 + B^0\frac{P_r}{T_r} + \omega B'\frac{P_r}{T_r}$ (gas)

$B^0 = -0.3427$

$B' = -0.09652$ → $V = \frac{ZRT}{P} = 805\ m^3/mol$

$Z = 0.7319$ RK식과 비교 : RK보다 12% 작음

- $V^{sat} = V_c Z_c^{(1-T_r)^{0.2857}}$

$V_c = 200\ cm^3/mol$ $Z_c = 0.216$

$V^{sat} = 200 \times 0.216^{(1-0.9275)^{0.2857}} = 109.0\ cm^3/mol$

RK식보다 비교 : RK식으로 구한 것이 31% 크다.

(h) $T_c = 425.1K$ $P_c = 37.96 bar$ $\omega = 0.2$

$T_r = 0.948$ $P_r = 0.0005$

$a(T) = 0.42748 \times \frac{T_r^{-0.5} R^2 T_c^2}{P_c} = 14447332 \, bar \cdot cm^6/mol^2$

$b = 80.69 \, bar \, cm^3/mol^2$

i) Vapor : $V^v = \frac{RT}{P} + 80.69 - \frac{14447332}{P} \times \frac{V - 80.69}{V(V+80.69)}$

V Newton $V_0 = 1260 cm^3/mol$

↳ $V^v = 1768.1 cm^3/mol$

ii) Liquid

$V = 80.69 + V(V+80.8)\left(\frac{RT + 80.69P - VP}{14447332}\right)$

↳ Newton $\begin{cases} V_0 = b = 80.69 \\ V_1 = 110.85 \end{cases}$

⋮

↳ $V = 166.4 cm^3/mol$

- Vapor

$T_r = 0.95$ $P_r = 0.8$ $Z^0 = 0.1410$ $Z^1 = -0.054$

$T_r = 0.95$ $P_r = 0.6$ $Z^0 = 0.6981$ $Z^1 = -0.1110$

$T_r = 0.93$ $P_r = 0.6$ $Z^0 = 0.1369$ $Z^1 = -0.0514$

$Z^2 = 0.41695$

~~$T_r = 0.95$~~

$Z_1 = -0.0195$

$Z = Z^0 + \omega Z^1 = 0.41695 + 0.2 \times (-0.0195) = 0.40105$

$V = \frac{ZRT}{P} = 505.35 cm^3/mol$

⇒ RK의 03 근삿값의 5%오차

- Liquid

$V^{sat} = V_c Z_c^{(1+T_r)^{0.2857}}$ → $V_c = 255$ $Z_c = 0.274$ $V^{sat} = 146.4 cm^3/mol$ ☆

RK가 25% 오차

3.56 (a) $T_c = 282.3k$

$P_c = 50.40bar$ $T_r = 1.162$

$w = 0.087$ $P_r = 0.6944$

[Lk]

T_r	P_r	Z^0	Z^1
1.15	0.6	0.8516	0.0237
1.15	0.8	0.8032	0.0396
1.2	0.6	0.8779	0.0326

$\rightarrow T_r = 1.162$ $P_r = 0.694$

$Z^0 = 0.8516 + \frac{0.0944}{0.2}(0.8032 - 0.8516) + \frac{0.012}{0.05}(0.8779 - 0.8516)$

$= 0.8368$

$Z^1 = 0.0333$

$\star Z = Z^0 + wZ^1 = 0.8397$

$V = \frac{ZRT}{P} = 0.8397 \times \frac{83.14 \times 326.15}{35} = 654 cm^3/mol$

해당하는 칸 642 보간법 $\therefore V = 642 \times 654 = 0.4198 m^3$

(b) $T_c = 282.3k$ $T_r = 1.145$

$P_c = 50.45bar$ $P_r = 2.281$

$w = 0.087$

T_r	P_r	Z^0	Z^1
1.15	2.0	0.476	0.1661
1.15	3	0.5042	0.0332
1.1	2	0.3953	0.0698

$\rightarrow Z^0 = 0.4760 + 0.281(0.5042 - 0.476) + \frac{1}{10}(0.3953 - 0.476)$

$= 0.4843$

$Z^1 = 0.1661 + 0.281(0.0332 - 0.1688) + \frac{1}{10}(0.0698 - 0.1661)$

$= 0.1174$

$\star Z = 0.4845$

$V = 0.4845 \times \frac{83.14 \times 323.15}{115} = 113.1 cm^3/mol$

$C = 0.2479 mol/cm^3$

$\therefore 0.2479 \times 0.25 \times 100^3 \times 10^{-3} = 62 kg$

3.59 $T_c = 369.8$ $P_c = 42.48$ bar $\omega = 0.152$

$T_r = 0.8653$

$P_r = 0.3766$

$V_c = 200 cm^3/mol$ $Z_c = 0.276$

i) Liquid :

$$V^{sat} = V_c \cdot Z^{(1+(1-T_r)^{\frac{2}{7}})} = 200 \times 0.276^{(1+0.8653)^{2/7}}$$

$$= 96.8 m^3/mol$$

$\Rightarrow$ 2892.7 mol

$\Rightarrow 2892.7 \times 44 \times \frac{1}{1000} = 127.1$ kg

ii) Vapor

T_r	P_r	Z^0	Z^1
0.85	0.4	0.0661	−0.0268
"	0.2	0.8881	−0.0715
0.9	0.4	0.178	−0.1118

$$\therefore Z^0 = 0.0661 + \frac{0.0234}{0.2}(0.8810 - 0.0661) + \frac{0.0453}{0.05}(0.178 - 0.0661)$$

$$= 0.3799$$

$$Z^1 = -0.0268 + \frac{0.0234}{0.2}(-0.0715 + 0.0268) + \frac{0.0453}{0.05}(-0.1118 + 0.0268)$$

$$= -0.0580$$

$Z = Z^0 + \omega Z^1 = 0.3711$

$V = \frac{ZRT}{P} = 617.07 cm^3/mol$

$\frac{0.35 \times 0.2}{617.07} \times 1000000 = 113.5$ mol

$\therefore \frac{113.5 \times 44}{1000} = 4.99$ kg

3.60 $T_r = \frac{T_1}{T_c} = 0.701$ $P_r = \frac{P_1}{P_c} = 0.069$

$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}} = -0.661$

$B' = 0.139 - \frac{0.172}{T_r^{9.2}} = -0.624$

$V = \frac{RT}{P}\left(1 + (B^0 + \omega B')\frac{P_c}{P_c}\right) = 9.4637 \times 10^3 \ cm^3/mol$

$\frac{16}{9.4637 \times 10^3} \times \frac{1000000 cm^3}{1m^3} = 1702.8 mol$

$\therefore 1702.8 \times 582 \times \frac{1}{1000} = 98.78 kg$

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62. (b) $T = 293$ $T_c = 260.9$ $P_c = 49.9$ $\omega = 0.434$

$m = 454g$ $N = 6.6937 mol$

$V = \frac{2.4L}{6.6937 mol} \times \frac{1000 cm^3}{1L} = 358.5 \ cm^3/mol$

$T_r = 1.123$ $P = \frac{RT}{V-b} - \frac{a(T)}{V(V+b)}$

$a(T) = 3806436.2 bar \cdot cm^3/mol^2$

$b = 37.66 cm^3/mol$

$\therefore P = 49.128 bar$

(d) $T = 293K$ $T_c = 312.2K$ $P_c = 49.5 bar$ $\omega = 0.151$

$m = 454g$ $N = 5.925 mol$

$V = 405.06 cm^3/mol$ $T_r = 0.9385$

$a(T) = 6211105.3 bar \cdot cm^6/mol^2$

$b = 45.934 cm^3/mol$

$P = 34.1996 bar$

3.66 $V=\frac{0.4\,m^3}{15kg}\times\frac{10^6\,cm^3}{1m^3}\times\frac{1kg}{1000g}=26.7\,cm^3/g$

$V=27.056\,cm^3/g$ $P=9800kPa$

$V=26.408\,cm^3/g$ $P=10000kPa$

$P=9800+\frac{26.7-27.056}{26.408-27.056}\times 200=9910\,kPa$

3.70 $T_1=300k$ $P_1=4bar$ $T_2=415k$ $P_2=15bar$

$T_c=408.1k$ $P_c=36.48bar$ $\omega=0.181$

$T_{r_1}=0.7351$ $P_{r_1}=0.1096$

$T_{r_2}=1.017$ $P_{r_2}=2.056$

$M=58\,g/mol$ $V_1=105.742\,cm^3/mol$

$V_c=262.7\,cm^3/mol$

$\frac{V_c}{V_1}=\frac{262.7}{105.742}=2.483$

P_r	Z^0	Z^1
1.01	0.326	-0.0778
1.01	0.4533	-0.1052
1.02	0.3241	-0.0822

$Z^0=0.3359$

$Z^1=-0.0553$

$Z=Z^0+\omega Z^1=0.322$

$V_2=V_1\times\frac{I_{r_1}}{I_{r_2}}=105.742\times\frac{2.483}{1.754}=148.07\,cm^3/mol$

$\frac{P_2V_2}{ZRT_2}=1.754$

$V=148.07\,\frac{cm^3}{mol}\times\frac{58g/mol}{}=2.552\,cm^3/g$

morning gl

77. $T_c = \frac{47.6}{1+\frac{21.8}{2.016\times 23}} = 30.44\ K$

$P_c = 10.92\ bar$

$T_r = 0.294$

$\frac{\psi (T_r)^{-0.5}}{\Omega T_r} = \frac{\psi T_r^{-1.5}}{\Omega} = \frac{0.42748\times(0.821)^{-1.5}}{0.08664} = 6.6326$

$\beta = \Omega \frac{P_r}{T_r} = 0.08664 \times \frac{0.294}{0.821} = 0.03102$

$Z = 1 + \beta - q\times\beta\times\frac{Z-\beta}{Z(Z+\beta)}$

$= 1 + 0.03102 - 6.6326\times 0.03102 \times \frac{Z-0.03102}{Z(Z+0.03102)} = 0.11904$

$Z = 0.1151$ (2%)

81. Isochore $\left(\frac{dP}{dT}\right)_V$ = Constant

(a) $\frac{dV}{V} = \beta dT - K dP$

$\left(\frac{dP}{dT}\right)_V = \frac{\beta}{K}$ = Constant

(b) $PV = RT$

$\left(\frac{\partial P}{\partial T}\right)_V = \frac{R}{V}$ = Constant

(c) $P = \frac{-RT}{V-b} - \frac{a}{V^2}$

$\left(\frac{\partial P}{\partial T}\right)_V = \frac{R}{V-b}$ = Constant

3.95 $T_1 = 283k$ $P_1 = 6bar$

$T_2 = 313k$ $P_2 = ?$

$\frac{dV}{V} = \beta dT - K dP$

$\ln\left(\frac{V}{V_0}\right) = \beta\Delta T - K\Delta P \quad \leftarrow \frac{V}{V_0} = \frac{(1.0035)^2 P_0^2}{P_0^2} = 1.007$

$\ln(1.007) = 0.00699 = \beta\Delta T - K\Delta P$

$0.699 \times 10^{-2} = 250 \times 10^{-6}/k \times 30k - 45 \times 10^{-6}/bar \times P$

$\Delta P = 11.33\ bar$

$\therefore P_2 = 17.33 bar$