BGTD – 3. Egykomponensű (tiszta) közegek állapotdiagramjai, állapotegyenletek

3.3.1. $d = 6[m]$ $\quad p = 200[kPa]$ $\quad T = 20[°C]$

$$V = \frac{4}{3} r^3 \pi = \frac{4}{3}\left(\frac{d}{2}\right)^3 \pi = \frac{d^3 \pi}{6} = 113,0973[m^{3}]$$

$$M_{He_2} = 4\left[\frac{kg}{kmol}\right] \qquad R_{He_2} = \frac{\mathcal{R}}{M_{He_2}} = 2078,6\left[\frac{J}{kg\,K}\right]$$

$$p V_{mol} = \mathcal{R} T$$

$$pV = mRT = n\mathcal{R}T \Rightarrow m = \frac{pV}{RT} = 37,14[kg]$$

$$n = \frac{pV}{\mathcal{R}T} = 9,2851[kmol]$$

$$m = nM = 37,14[kg]$$

3.3.2. $T_1 = 25[°C]$ $\quad p_+ = 210[kPa]$ $\quad V = 0,025[m^3]$

$R = 287\left[\frac{J}{kg\,K}\right]$ $\quad p_0 = 100[kPa]$ $\quad T_2 = 50[°C]$

autógumiban az abszolútnyomás 25°C-on:

$$p_1 = p_0 + p_+ = 310[kPa]$$

$V = konst$ (eltekintünk a gumi térfogatváltozásától)

$$pV = mRT \underset{m=konst,\,V=konst}{\Longrightarrow} \frac{p}{T} = konst \Rightarrow p_2 = p_1\frac{T_2}{T_1} = 336,0067[kPa]$$

$$\Delta p = p_2 - p_1 = 26[kPa]$$

$$m_1 = \frac{p_1 V}{R T_1} = 0{,}0906\,[kg]$$

$$m_2 = \frac{p_1 V}{R T_2} = 0{,}0836\,[kg]$$

$$\Delta m = m_1 - m_2 = 0{,}007\,[kg]$$

3.3.3. $V_1 = 1\,[m^3]$ $T_1 = 25\,[°C]$ $p_1 = 500\,[kPa]$

$m_2 = 5\,[kg]$ $T_2 = 35\,[°C]$ $p_2 = 200\,[kPa]$

$T_{eq} = 20\,[°C]$ $R = 287\left[\frac{J}{kg\,K}\right]$

$$m_1 = \frac{p_1 V_1}{R T_1} = 5{,}8462\,[kg] \qquad V_2 = \frac{m_2 R T_2}{p_2} = 2{,}2099\,[m^3]$$

$$p_{eq} = \frac{(m_1 + m_2) R T_{eq}}{V_1 + V_2} = 284{,}1421\,[kPa]$$

3.3.4. $p_1 = 100\,[bar]$ $T_1 = 30\,[°C]$

$p_2 = 70\,[bar]$ $T_2 = 1\,[°C]$

adiabatikus + reverzibilis expanzió = izentropikus

politropikus kitevő ekkor: $n = \kappa$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} \qquad /\ln(\,)$$

$$\ln\frac{T_2}{T_1} = \ln\left[\left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}}\right] = \frac{\kappa-1}{\kappa}\ln\frac{p_2}{p_1}$$

$$\kappa = \frac{1}{1 - \ln\frac{T_2}{T_1} / \ln\frac{p_2}{p_1}} = 1{,}3929\,[1]$$

3.3.5. $p_1 = 5\,[bar]$ $\qquad p_2 = 1\,[bar]$

$T_1 = 100\,[°C]$ $\qquad T_2 = 650\,[K]$

$$pv = \frac{p}{\rho} = RT \Rightarrow \rho = \frac{p}{RT} \Rightarrow \frac{\rho_2}{\rho_1} = \frac{p_2 T_1}{p_1 T_2} = 0{,}1148\,[1]$$

3.3.6. $V = \text{konst}$ (merev falú rendszer)

$H_2 = \frac{2}{3} H_1$ $\qquad dh = c_p\, dT \quad \overset{\int_1^2}{\underset{c_p = \text{konst}}{\rightsquigarrow}} \quad h_2 - h_1 = c_p (T_2 - T_1)$

$$\frac{H_2}{H_1} = \frac{m h_2}{m h_1} = \frac{m c_p T_2}{m c_p T_1} = \frac{T_2}{T_1} = \frac{2}{3}$$

$$pV = mRT \Rightarrow p = \underbrace{\frac{mR}{V}}_{=\text{konst}} T \qquad \frac{p_2}{p_1} = \frac{T_2}{T_1} = \frac{2}{3}$$

3.3.7. $p_1 = 1{,}8\,[MPa]$ $\qquad T_1 = 450\,[°C]$ $\qquad T_2 = 1300\,[°C]$

$$pv = RT \Rightarrow \frac{p}{T} = \frac{R}{v} = \text{konst} \Rightarrow p_2 = p_1 \frac{T_2}{T_1} = 3{,}916\,[MPa]$$

3.3.8. $V = \text{konst}$ $\qquad p_1 = 300\,[kPa]$ $\qquad T_1 = 600\,[K]$ $\qquad m_2 = \frac{1}{2} m_1$

$p_2 = 100\,[kPa]$

- $pV = mRT \Rightarrow \frac{p}{mT} = \frac{R}{V} = \text{konst} \Rightarrow T_2 = T_1 \frac{p_2 m_1}{p_1 m_2} = T_1 \frac{p_2 m_1}{\frac{1}{2} m_1 p_1} =$

$$= 2 T_1 \frac{p_2}{p_1} = 400\,[K]$$

- $m = \text{konst}$ $\qquad \frac{p}{T} = \frac{mR}{V} = \text{konst} \Rightarrow p_2 = T_2 \frac{p_1}{T_1} = 200\,[kPa]$

3.3.9. $p = 3\,[MPa]$ $\qquad T_1 = 500\,[K]$ $\qquad \dot{n} = 0{,}4\left[\frac{kmol}{s}\right]$

$$p\dot{V} = \dot{n} \mathcal{R} T \Rightarrow \dot{V} = \frac{\dot{n} \mathcal{R} T_1}{p} = 0{,}5543\left[\frac{m^3}{s}\right]$$

$M_{CO_2} = 44\left[\frac{kg}{kmol}\right]$ $\qquad R_{CO_2} = \frac{\mathcal{R}}{M_{CO_2}} = 188{,}96\left[\frac{J}{kg\,K}\right]$ $\qquad \dot{m} = \dot{n} M = 17{,}6\left[\frac{kg}{s}\right]$

$$pv = \frac{p}{\rho_1} = RT_1 \Rightarrow \rho_1 = \frac{p}{RT_1} = 31,7528 \left[\frac{kg}{m^3}\right]$$

$$T_2 = 450\,[K]$$

$$\rho_2 = \frac{p}{RT_2} = 35,2808 \left[\frac{kg}{m^3}\right] \qquad \dot{V}_2 = \frac{\dot{m}}{\rho_2} = 0,4989 \left[\frac{m^3}{s}\right]$$

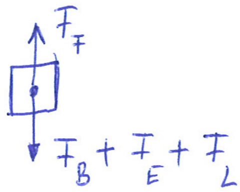
3.3.10. $d = 18\,[m]$ $\quad m_B = 120\,[kg]$ $\quad p_0 = 93\,[kPa]$ $\quad T_0 = 12\,[°C]$

$R = 287 \left[\frac{J}{kg\,K}\right]$ $\quad m_E = 70\,[kg]$ $\quad n = 2\,[1]$ $\quad g = 9,81 \left[\frac{m}{s^2}\right]$

$$V = \frac{d^3 \pi}{6} = 3053,6281\,[m^3]$$

$$\rho_0 = \frac{p_0}{RT_0} = 1,1370 \left[\frac{kg}{m^3}\right]$$

fellajtóerő: $F_F = \rho_0 g V = 34060,0762\,[N]$



$$F_F = F_B + F_E + F_L = g\,(m_B + n\,m_E + m_L) \Rightarrow$$

$$m_L = \frac{F_F}{g} - m_B - n\,m_E = 3211,9751\,[kg]$$

$$T_L = \frac{p_0 V}{R\,m_L} = 308,0669\,[K]$$

$$\hat{T}_0 = 25\,[°C] \Rightarrow \hat{\rho}_0 = 1,0874 \left[\frac{kg}{m^3}\right]$$

$$\hat{F}_F = 32574,2541\,[N]$$

$$\hat{m}_L = 3060,5152\,[kg]$$

$$\hat{T}_L = 323,3126\,[K]$$

3.3.11. $V_1 = 0,5\,[m^3]$ $T_1 = 20\,[°C]$ $p_1 = 600\,[kPa]$

$V_2 = 0,5\,[m^3]$ $T_2 = 30\,[°C]$ $p_2 = 150\,[kPa]$

$T_{eq} = 15\,[°C]$

$$m_1 = \frac{p_1 V_1}{R T_1} \qquad m_2 = \frac{p_2 V_2}{R T_2}$$

$$p_{eq} = \frac{(m_1 + m_2) R\, T_{eq}}{V_1 + V_2} = \frac{\left(\frac{p_1 V_1}{\cancel{R} T_1} + \frac{p_2 V_2}{\cancel{R} T_2}\right)\cancel{R}\, T_{eq}}{V_1 + V_2} =$$

$$= \frac{\left(\frac{p_1 V_1}{T_1} + \frac{p_2 V_2}{T_2}\right) T_{eq}}{V_1 + V_2} = 366,1677\,[kPa]$$

3.3.12. $m = 5\,[kg]$ $p_1 = 200\,[kPa]$ $T_1 = 500\,[K]$

$R = 286\left[\frac{J}{kg\,K}\right]$ $\quad p \sim \frac{d^2 \pi}{4} \sim d^2 \sim r^2$

$V_2 = 2V_1$

$$V_1 = \frac{m R T_1}{p_1} = 3,575\,[m^3] \Rightarrow V_2 = 2V_1 = 7,15\,[m^3]$$

$$\frac{p}{r^2} = konst \Rightarrow \frac{p}{r^2} = \frac{p_1}{r_1^2} \Rightarrow p(r) = \frac{p_1}{r_1^2} r^2$$

$$V(r) = \frac{4}{3} r^3 \pi \Rightarrow p(V) = \frac{p_1}{\left(\frac{3V_1}{4\pi}\right)^{\frac{2}{3}}} \left(\frac{3V}{4\pi}\right)^{\frac{2}{3}} = \frac{p_1}{V_1^{\frac{2}{3}}} V^{\frac{2}{3}}$$

$$W_t = -\int_{V_1}^{V_2} p(V)\,dV = -\frac{p_1}{V_1^{2/3}} \int_{V_1}^{V_2} V^{\frac{2}{3}}\,dV = -\frac{p_1}{V_1^{2/3}}\left[V_2^{\frac{5}{3}} - V_1^{\frac{5}{3}}\right] \cdot \frac{3}{5} =$$

$$= -932,99\ kJ$$

3.3.13.

	1	2	3	4
p [bar]	1	8	9,6	9,6
$v\left[\frac{m^3}{kg}\right]$	0,567	0,07875	0,07875	0,1035
T [K]	300	300	360	525,8268

$R = 189\left[\frac{J}{kgK}\right]$ $\quad \varkappa = 1,33\ [1]$

$$v_1 = \frac{RT_1}{p_1} = 0,567\left[\frac{m^3}{kg}\right] \qquad v_2 = \frac{v_1}{8} = 0,07875\left[\frac{m^3}{kg}\right]$$

$1 \to 2$: izoterm : $n = 1$

$$pv^1 = konst \Rightarrow p_2 = p_1\frac{v_1}{v_2} = 8p_1 = 8\ [bar]$$

$2 \to 3$: izochor : $n \to \infty$ $\quad \left(w_f = -\int_{v_2}^{v_3} p(v)\,dv = 0\right)$

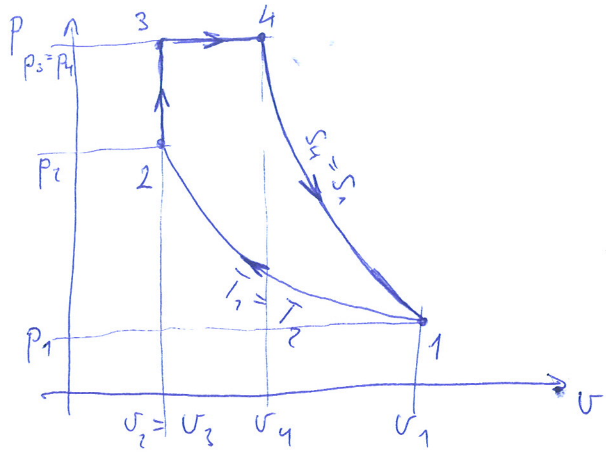
$$\frac{T}{p^{\frac{n-1}{n}}} = konst \quad , \quad p_3 = 1,2\,p_1 = 9,6\ [bar]$$

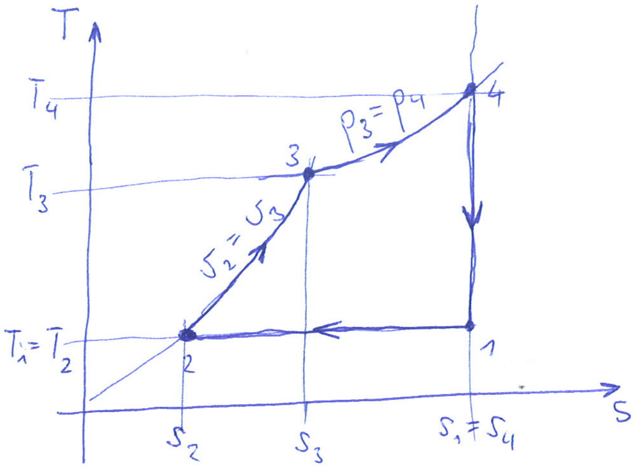
$$T_3 = \lim_{n\to\infty} T_2\left(\frac{p_3}{p_2}\right)^{\frac{n-1}{n}} = \lim_{n\to\infty} T_2\left(\frac{p_3}{p_2}\right)^{1-\frac{1}{n}} = T_2\frac{p_3}{p_2} = 1,2\,T_2 = 360\ [K]$$

$4 \to 1$: $q_{41} = 0$ és $s_4 - s_1 = 0 \Rightarrow$ izentropikus: $n = \varkappa$

$$T_4 = T_1\left(\frac{p_4}{p_1}\right)^{\frac{\varkappa-1}{\varkappa}} = 525,8268\ [K]$$

$$v_4 = \frac{RT_4}{p_4} = 0,1035\left[\frac{m^3}{kg}\right]$$



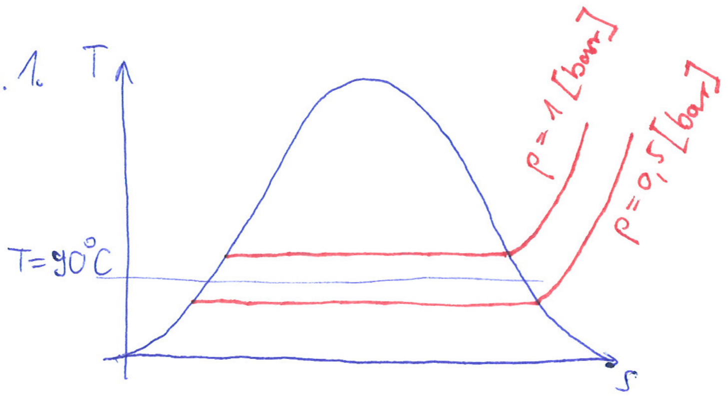


3.4. T-s / h-s / log p-h diagramm vagy:

https://web1.hszg.de/thermo_fpc/index.php (A)

https://webbook.nist.gov/chemistry (B)

3.4.1.



$m = 50\ [kg]$

$T = 90\ [°C]$ telített víz

$T = T_{sat} \Rightarrow p_{sat}(T_{sat})$

$p_{sat} \cong 0{,}75\ [bar]$ (diagramm)

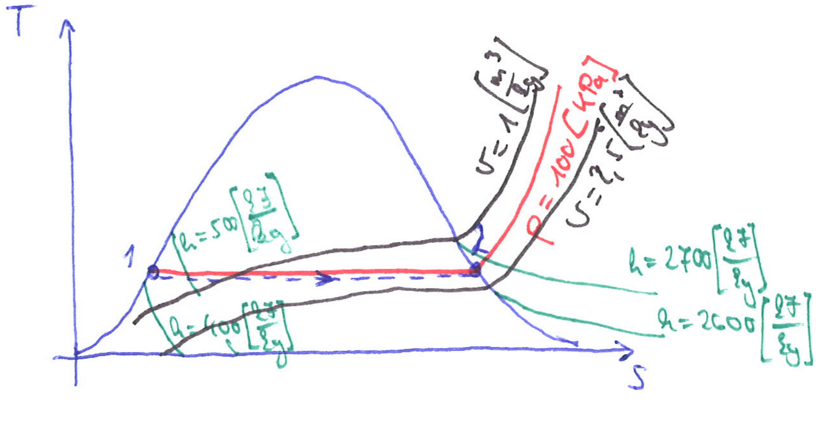
$p_{sat} = 0{,}701824\ [bar]$ (A)

$v' = 0{,}001035 \left[\frac{m^3}{kg}\right]$ $\quad \rho' = 965{,}304 \left[\frac{kg}{m^3}\right] \Rightarrow \rho v \neq 1$

↓ 5÷8-ig tizedesjegyben való eltérés OK, de nem a 4-ben...

$V = mv' = \frac{m}{\rho'} = 0{,}05175\ [m^3]$

3.4.2. $m = 200\ [g]$ $\quad p = 100\ [kPa]$



diagrammról:

$h' \cong 420 \left[\frac{kJ}{kg}\right]$

$h'' \cong 2670 \left[\frac{kJ}{kg}\right]$

$v' \cong 0{,}001 \left[\frac{m^3}{kg}\right] = \frac{1}{\rho'}$

$v'' \cong 1{,}7 \left[\frac{m^3}{kg}\right]$

(A)-val: $p = 100\ [kPa] \longrightarrow T_{sat} = 99{,}6059\ [°C]$

ezeket használva:

$x = 0$: $v' = 0{,}00104315\ \left[\frac{m^3}{kg}\right]$

$h' = 417{,}436\ \left[\frac{kJ}{kg}\right]$

$x = 1$: $v'' = 1{,}69402\ \left[\frac{m^3}{kg}\right]$

$h'' = 2674{,}95\ \left[\frac{kJ}{kg}\right]$

$$\Delta V = V_2 - V_1 = m\left(v'' - v'\right) = 0{,}3386\ [m^3]$$

első főtétel: $H_2 - H_1 = Q + W_t$

$\hookrightarrow \int_{p_1}^{p_2} V(p)\,dp = 0$ /izobár/

$$Q = m\left(h'' - h'\right) = 451{,}5028\ [kJ]$$

3.4.3. $T_{sat} = 90\ [°C] \Longrightarrow p_{sat} = 0{,}701824\ [bar]$

$m = 10\ [kg]$ $m_V = 8\ [kg] = m'$, $m_G = 2\ [kg] = m''$

$v' = 0{,}00103594\ \left[\frac{m^3}{kg}\right]$ $v'' = 2{,}35915\ \left[\frac{m^3}{kg}\right]$

$$V = m_V v' + m_G v'' = \left(m_V v' + m_G v''\right)\frac{m_V + m_G}{m_V + m_G} =$$

$$= \left(\frac{m_V}{m_V + m_G} v' + \frac{m_G}{m_V + m_G} v''\right)\left(m_V + m_G\right) = \left((1 - x)v' + x v''\right)m =$$

$$x = \frac{m_G}{m_V + m_G} = \frac{m''}{m' + m''} = 0{,}2\ [1]$$

$$= 4{,}7266\ [m^3]$$

3.4.4. $V = 80\ [l]$ $m = 4\ [kg]$ R 134a

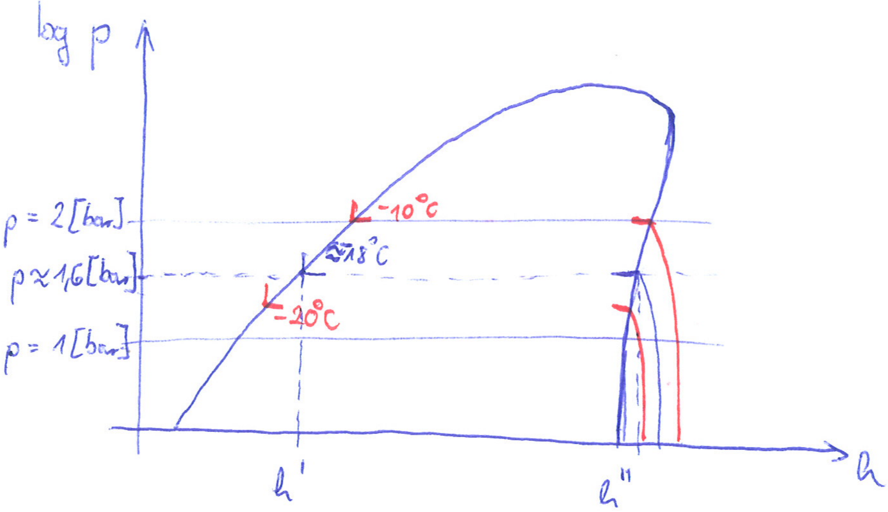
$p = 160\ [kPa] \Rightarrow T_{sat} \approx -18\ °C$

$h' \approx 180 \left[\frac{kJ}{kg}\right]$

$h'' \approx 390 \left[\frac{kJ}{kg}\right]$

$v' \approx 0 \left[\frac{kJ}{kg}\right] \rightsquigarrow$ él. leolvashatatlan

$v'' \approx 0,12 \left[\frac{m^3}{kg}\right]$



(A)-val: $T_{sat} = -15,5878\ [°C]$

$v' = \frac{1}{\rho'} = 743,68241 \cdot 10^{-6} \left[\frac{m^3}{kg}\right]$ $h' = 179,37 \left[\frac{kJ}{kg}\right]$

$v'' = \frac{1}{\rho''} = 0,123489 \left[\frac{m^3}{kg}\right]$ $h'' = 389,269 \left[\frac{kJ}{kg}\right]$

(R134a-hoz csak a ρ érték állnak rendelkezésre (A)-ban)

$v = \frac{V}{m} = 0,02 \left[\frac{m^3}{kg}\right]$ $v = (1-x)v' + xv'' \Rightarrow$

$\Rightarrow x = \frac{v - v'}{v'' - v'} = 0,15688\ [1]$

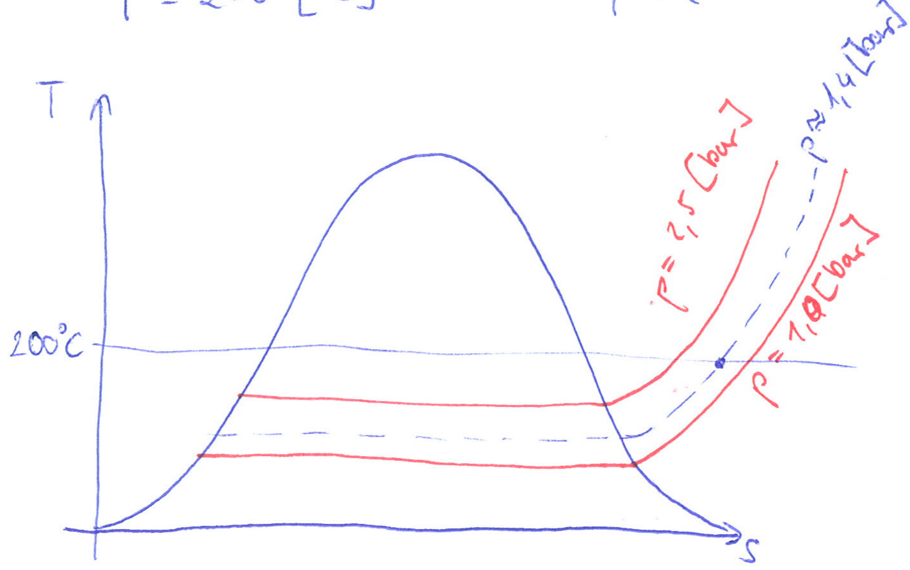
$h = (1-x)h' + xh'' = 212,2990 \left[\frac{kJ}{kg}\right]$

$H = m h = 849,196\ [kJ]$

$V_g = m_g v'' = x m v'' = 0,07749\ [m^3] \triangleq 77,49\ [l]$

3.4.5. $p = 1{,}4\ [bar] \Rightarrow T_{sat}(p = 1{,}4\ [bar]) = 109{,}292\ [°C]$

$T = 200\ [°C] \Rightarrow p_{sat}(T = 200\ [°C]) = 15{,}5467\ [bar]$



$p_{sat} > p \Rightarrow$ túlhevített gőz

leolvasni általában h-t tudunk:

$h = 2873{,}61 \left[\frac{kJ}{kg}\right]$ $\quad v = 1{,}54853 \left[\frac{m^3}{kg}\right]$

$u = h - pv = 2656{,}8158 \left[\frac{kJ}{kg}\right]$

3.4.6. $p = 0{,}5\ [MPa] = 5\ [bar]$

$h = 2890 \left[\frac{kJ}{kg}\right]$

leolvasva: $T \approx 220\ [°C]$

(A)-val: $T = 216{,}023\ [°C]$

3.4.7. $T = 80\ [°C]$

$p = 5\ [MPa] = 50\ [bar]$

(A)-val: $h = 338{,}891 \left[\frac{kJ}{kg}\right]$

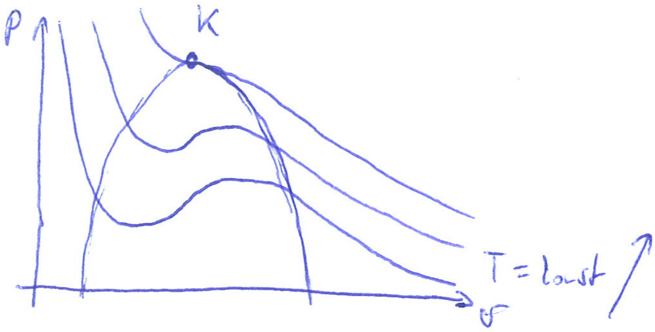
$v = 0{,}00102671 \left[\frac{m^3}{kg}\right]$

$u = h - pv = 333{,}7575 \left[\frac{kJ}{kg}\right]$

leolvasni log p-h -ról tudjuk kb. h-t, de v-t szinte lehetetlen

3.5. • ideális gáz: $pv = RT$

• Van der Waals anyag: $\left(p + \frac{a}{v^2}\right)(v-b) = RT$



Kritikus pont: izotermának első és második deriváltja is nulla → inflexiós pont

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

$$(1) \quad \left.\frac{\partial p}{\partial v}\right|_K = -\frac{RT_K}{(v_K-b)^2} + \frac{2a}{v_K^3} = 0$$

$$(2) \quad \left.\frac{\partial^2 p}{\partial v^2}\right|_K = \frac{2RT_K}{(v_K-b)^3} - \frac{6a}{v_K^4} = 0$$

$$(3) \quad p_K = \frac{RT_K}{v_K-b} - \frac{a}{v_K^2}$$

$\Rightarrow$ a, b, v_K kifejezhető

$$(1): \quad a = \frac{RT_K v_K^3}{2(v_K-b)^2}$$

$$(2): \quad \frac{2\cancel{RT_K}}{(v_K-b)^{\cancel{3}}} = \frac{6}{v_K^{\cancel{4}}} \cdot \frac{\cancel{RT_K}\cancel{v_K^3}}{2\cancel{(v_K-b)^2}} \Leftrightarrow 2v_K = 3v_K - 3b \Leftrightarrow v_K = 3b$$

$$\Leftrightarrow b = \frac{v_K}{3}$$

$$(1): \quad T_K = \frac{2a(v_K-b)^2}{Rv_K^3} = \frac{2a(3b-b)^2}{R(3b)^3} = \frac{8ab^2}{27Rb^3} = \frac{8a}{27Rb}$$

$$(3): \quad p_K = \frac{R\cdot\frac{8a}{27Rb}}{2b} - \frac{a}{9b^2} = \frac{4a}{27b^2} - \frac{3a}{27b^2} = \frac{a}{27b^2}$$

$$p_K = \frac{a}{27b^2} \Rightarrow a = 27b^2 p_K = 3 p_K v_K^2$$

$$T_K = \frac{8a}{27Rb} \Rightarrow b = \frac{8a}{27RT_K}$$

$$v_K = 3b \quad \cancel{\Rightarrow b = \frac{v_K}{3}}$$

$$v_K = 3b = 3\cdot\frac{8a}{27RT_K} = 3\cdot\frac{8\cdot 3p_K v_K^2}{27RT_K} = \frac{8}{3}\frac{p_K v_K^2}{RT_K} \Rightarrow$$

$$v_K = \frac{3}{8}\frac{RT_K}{p_K} \Rightarrow b = \frac{RT_K}{8p_K}$$

$$a = \frac{27R^2T_K^2}{64\,p_K}$$

- Beattie - Bridgeman:

$$p = \frac{\mathcal{R}T}{v_m^2}\left(1-\frac{c}{v_m T^3}\right)(v_m+B) - \frac{A}{v_m^2}$$

$$A = A_0\left(1-\frac{a}{v_m}\right) \Bigg| B = B_0\left(1-\frac{b}{v_m}\right)$$

$\Rightarrow$ 6 állandós állapotegyenlet: $\mathcal{R}, A_0, a, B_0, b, c$

$\langle\langle v_m \rangle\rangle = \frac{m^3}{kmol}$

hatékony: $0{,}8\,\rho_K > \rho \Leftrightarrow 1{,}25\,v_K < v$

3.5.1. $V = 3{,}27\ [m^3]$ $\quad M_{N_2} = 28\left[\frac{kg}{kmol}\right]$

$m = 100\ [kg]$ $\quad R_{N_2} = \frac{\mathcal{R}}{M} = 296{,}9429\left[\frac{J}{kgK}\right]$

$T = 175\ [K]$

$v = \frac{V}{m} = 0{,}0327\left[\frac{m^3}{kg}\right]$

- ideális gáztörvény: $p = \frac{RT}{v} = 1589{,}1440\ [kPa]$

• VdW: $p_K = 3\,390$ [kPa] (Wikipédiáról: Critical Point (thermodynamics))

$T_K = 126{,}2$ [K]

$$a = \frac{27R^2T_K^2}{64p_K} = 174{,}7627 \left[\frac{Pa\,m^6}{kg^2}\right]$$

$$b = \frac{RT_K}{8p_K} = 0{,}001382 \left[\frac{m^3}{kg}\right]$$

$$p = \frac{RT}{v-b} - \frac{a}{v^2} = 1495{,}8316 \text{ [kPa]}$$

• Beattie - Bridgeman:

$$\left.\begin{aligned} A_0 &= 136{,}2315 \left[\frac{kPa\,m^6}{kmol^2}\right] \\ a &= 0{,}02617 \left[\frac{m^3}{kmol}\right] \\ B_0 &= 0{,}05046 \left[\frac{m^3}{kmol}\right] \\ b &= -0{,}00691 \left[\frac{m^3}{kmol}\right] \\ c &= 4{,}20\cdot 10^4 \left[\frac{m^3K^3}{kmol}\right] \end{aligned}\right\}$$

Wikipédiáról
↳ figyeljünk az egységekre: ezek szerint részecskeszámmal és moláris fajtérfogattal számoljunk, az eredményt kPa-ban kapjuk

$$A = A_0\left(1-\frac{a}{v_m}\right) = 132{,}3377 \left[\frac{kPa\,m^6}{kmol^2}\right]$$

$$B = B_0\left(1-\frac{b}{v_m}\right) = 0{,}05084 \left[\frac{m^3}{kmol}\right]$$

$$n = \frac{m}{M} = 3{,}5714 \text{ [kmol]} \qquad v_m = \frac{V}{n} = 0{,}9156 \left[\frac{m^3}{kmol}\right]$$

$$p = \frac{RT}{v_m^2}\left(1-\frac{c}{v_mT^3}\right)(v_m+B) - \frac{A}{v_m^2} = 1505{,}0863 \text{ [kPa]}$$

$$R = 8{,}3144 \left[\frac{kPa\,m^3}{kmol\,K}\right]$$ – univerzális gázállandó

3.5.2. $V = 1\ [m^3]$

$m = 2{,}841\ [kg]$ $\Big\}$ $v = \frac{V}{m} = 0{,}351989 \left[\frac{m^3}{kg}\right]$

$p = 0{,}6\ [MPa]$

- ideális gázként: $T = \frac{pv}{R} = 457{,}2166\ [K]$

$M_{H_2O} = 18 \left[\frac{kg}{kmol}\right]$ $R = 461{,}9111 \left[\frac{J}{kg\,K}\right]$

- VdW: $p_K = 22{,}060\ [MPa]$ $\Big\}$ Wikipédiáról

$T_K = 647{,}096\ [K]$

$a = \frac{27 R^2 T_K^2}{64\, p_K} = 1708{,}568952 \left[\frac{Pa\, m^6}{kg^2}\right]$

$b = \frac{R T_K}{8\, p_K} = 0{,}00169368 \left[\frac{m^3}{kg}\right]$

$$p = \frac{RT}{v-b} - \frac{a}{v^2} \Rightarrow T = \frac{1}{R}\left(p + \frac{a}{v^2}\right)(v-b) = 465{,}4743\ [K]$$

- vízgőztáblázatból: $T = 200\ [^\circ C] = 473\ [K]$