# Assignment 12

1. Show that for a Van-der-Waals gas, $p_c = \frac{a}{27b^2}$, $v_c = 3b$, $T_c = \frac{8a}{27Rb}$, where c denotes critical conditions.
2. Now show that the reduced equation of state for the Van-der-Waals gas gas is,

$$\left(p_r + \frac{3}{{v_r}^2}\right)(3v_r - 1) = 8T_r$$

where, the reduced pressure, specific volume and temperature are $p_r = p/p_c$, $v_r = v/v_c$, $T_r = T/T_c$,

3. Prove that $\left.\frac{\partial u}{\partial p}\right|_T = -T\left.\frac{\partial v}{\partial T}\right|_p - p\left.\frac{\partial v}{\partial p}\right|_T$

4. Show that $\left.\frac{\partial p}{\partial T}\right|_s = \frac{c_p}{Tv\beta}$
5. Show that $c_p - c_v = T\left.\frac{\partial v}{\partial T}\right|_p \left.\frac{\partial p}{\partial T}\right|_v$
6. Show that for a Van-der-Waals gas, $c_v$ is a function of T only
7. Determine $c_p - c_v$ for Van-der-Waals gas. State whether $c_p$ is a function of T only?
8. Show that Joule-Thompson's coefficient, $\mu = \left.\frac{\partial T}{\partial p}\right|_h = \frac{1}{c_p}\left(T\left.\frac{\partial v}{\partial T}\right|_p - v\right)$ and is zero for ideal gas.
9. With reference to the figure, determine the enthalpies at the points 1*, 2* and 3* which lie on the isobar P=0.1 MPa, using the property relations used. The temperatures at points 1, and 3* are $50^oC$ and $150^oC$ respectively. Relevant property fits at constant pressure are given below. Compare the values of enthalpy obtained with steam table values.

Property fits along the isobar (p=0.1 MPa)

$C_{pf} = 8.41056x10^{-06}T^2 - 5.81708\ x10^{-04}T + 4.18952$ (kJ/kgK)

$C_{pg} = -1.61558x10^{-07}T^3 + 8.85428x10^{-05}T^2 - 1.62498x10^{-02}T + 2.97423$ (kJ/kgK)

Saturation poperties

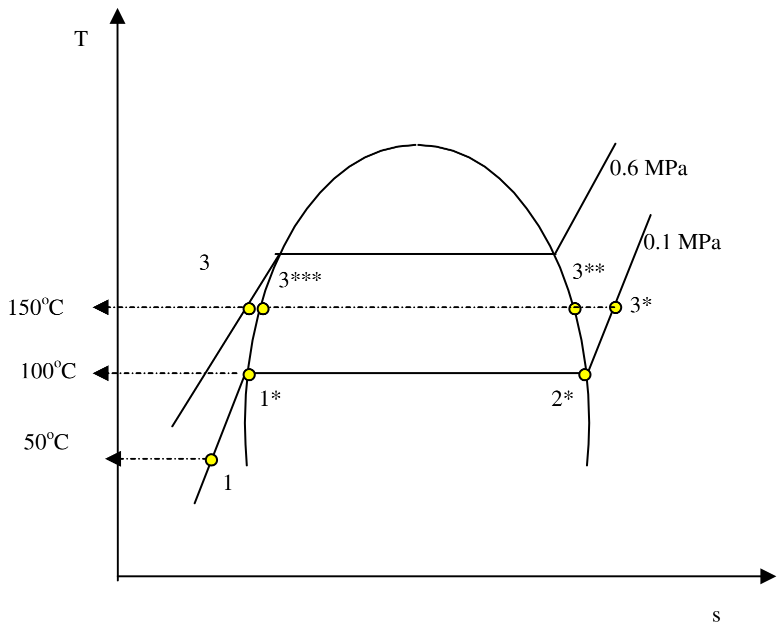
$P_{sat} = 8.56688x10^{-07}T^3 - 2.53198x10^{-04}T^2 + 3.09515x10^{-02}T - 1.36108$
(for $T=150^oC$)

$v_{fg} = -1.72712x10^{-05}T^3 + 6.35816x10^{-03}T^2 - 0.809280T + 36.2854$ ($m^3$/kg)
($80<T<=120^oC$)

$v_{fg} = -1.88453x10^{-06}T^3 + 1.01210x10^{-03}T^2 - 0.186313T + 11.9252$ ($m^3$/kg)
($120<T<=180^oC$)

(all T are in degree celcius)

(Ans: $h_{1*}$=419.168 kJ/kg, $h_{2*}$=2654.067 kJ/kg, $h_{3*}$= 2754.906 kJ/kg )




10. With value of $h_{3*}$ obtained in the previous problem, determine, the enthalpy at P=0.6 MPa and 150°C. This may be obtained by moving along the isotherm 3*-3**-3*** and 3. To calculate the enthalpy change along the isotherm T=150°C (in gaseous region), PVT relation is required. *Redlich Kwong* equation $P = \frac{RT}{(v-b)} - \frac{a/T^{0.5}}{v(v+b)}$ is to be used, where $a = 0.4275\frac{R^2T_c^{2.5}}{P_c}$ and $b = 0.08664\frac{RT_c}{P_c}$ where $P_c$, $T_c$ are the critical pressure and critical temperature (22.064 MPa and 373.946°C). (Trapezoidal integration may be used to evaluate the integral). For the path 3***-3, the specific volume can be assumed to be a function of T only and is independent of P.

$$v_f = 3.42455\text{x}10^{-09}T^2 + 9.67286\text{x}10^{-08}T + 9.99233\text{x}10^{-04}$$

(Ans: $h_{3**}$ = 2748.677 kJ/kg, $h_{3***}$=632.857 kJ/kg, $h_3$=632.237 kJ/kg)