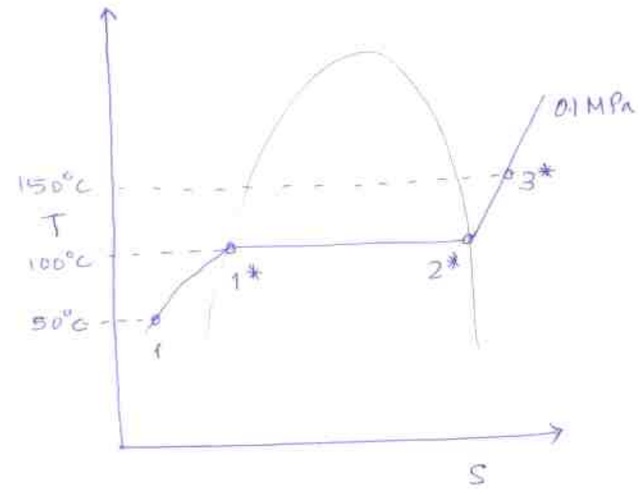
(9)

(8)



Given.

h at $T_{ref} = 50^\circ C$

$= 209.42\ kJ/kg$ (from tables)

Along the const pressure line 11^*

$$dh = C_p dT + \left(v - T\frac{\partial v}{\partial T}\Big|_p\right)\cancel{dp}^{\,0}$$

$$\Rightarrow \quad dh = C_p dT$$

Thus $$\int_{h_1}^{h_1^*} dh = \int_{T_1}^{T_1^*} C_{p_f} dT$$

$$h_1^* - h_1 = \int_{50}^{100} (8.41056\times10^{-6}T^2 - 5.81708\times10^{-4}T + 4.18952)$$

$$= \left[\frac{8.41056\times10^{-6}}{3}T^3 - \frac{5.81708\times10^{-4}}{2}T^2 + 4.18952T\right]_{50}^{100.}$$

$$= 209.75\ kJ/kg$$

$$\Rightarrow \quad h_1^* = 209.75 + 209.42$$

$$\boxed{h_1^* = 419.17\ kJ/kg}$$

Along the phase change 1^*2^*

Clasius Clapeyron Equation.

$$\frac{dp}{dT}\Big|_{T_{sat}} = \frac{h_{fg}}{T\,v_{fg}}$$

$$\Rightarrow \left.\frac{dp}{dT}\right|_{T_{sat}} \times T\, v_{fg} = h_{fg}$$

$$P = 4.99293\times10^{-7}\,T^3 - 9.69273\times10^{-5}\,T^2 + 7.99924\times10^{-3}\,T - 0.228425$$

for $(80 < T < 150^\circ C)$ (NOT GIVEN IN THE ASSGN)

$$\left.\frac{dp}{dT}\right|_{T_{sat}} = \left.(4.99293\times10^{-7}\times3)T^2 - (9.69273\times10^{-5}\times2)T + 7.99924\times10^{-3}\right|_{T=100^\circ C}$$

$$= 0.003593 \ \mathrm{MPa}/^\circ C$$

$$= 3.593 \ \mathrm{kPa}/^\circ C.$$

and $$\left.v_{fg}\right|_{T_{sat}} = \left.-1.72712\times10^{-5}\,T^3 + 6.35816\times10^{-3}\,T^2 - 0.809280\,T + 36.2854\right|_{T=100^\circ C}$$

$$= 1.6678 \ m^3/kg$$

thus. $$h_{fg} = 3.593\times1.6678\times373$$

$$\cancel{h_{fg} = 2235.17 \ kJ/kg}$$

$$h_{fg} = 2234.9 \ kJ/kg$$

$$h_2^* = h_1^* + h_{fg}$$

$$\boxed{h_2^* = 2654.07 \ kJ/kg}$$

Along the const pr. line $2^* 3^*$

$$dh = C_p dT$$

and
$$h_3^* = h_2^* + \int_{T_2^*}^{T_3^*} C_{pg}\, dT$$

$$= 2654.07 + \int_{100}^{150} (-1.61558\times10^{-7} T^3 + 8.85428\times10^{-5} T^2 - 1.62498\times10^{-2} T + 2.97423)\, dT$$

$$= 2654.07 + \left[\left(\frac{-1.61558\times10^{-7}}{4}\right) T^4 + \left(\frac{8.85428\times10^{-5}}{3}\right) T^3 - \frac{1.62498\times10^{-2}}{2} T^2 + 2.97423\, T \right]_{100}^{150}$$

$$= 2654.07 + 100.8384$$

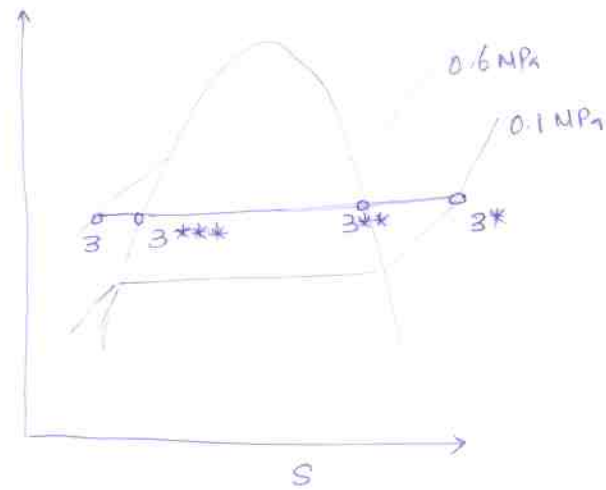
$$\boxed{h_3^* = 2754.91 \text{ kJ/kg}}$$

Comparison

	Calculated (kJ/kg)	Steam tables (kJ/kg)	% deviation
h_1^*	419.17	417.5	0.4%
h_2^*	2654.07	2675.5	-0.8%
h_3^*	2754.91	2776.4	-0.77%

(10)

Along the isotherm $3^{*} - 3^{**}$



$$dh = c_p \cancel{dT}^{\,0} + \left(v - T \frac{\partial v}{\partial T}\bigg|_p \right) dp$$

and PVT relation specified is

Redlich kwong relation

$$P = \frac{RT}{(v-b)} - \frac{a/T^{0.5}}{v(v+b)}$$

diff. with respt. to to `T' at P = const

$$0 = R \left[\frac{(v-b) - T\left(\frac{\partial v}{\partial T}\right)}{(v-b)^2} \right] - a \left\{ \frac{-\left[T^{1/2}(2v+b)\frac{\partial v}{\partial T} + (v^2+bv)\frac{1}{2}T^{-1/2} \right]}{(v^2+bv)^2 T} \right\}$$

$\Rightarrow$

$$R\left[\frac{1}{(v-b)} - \frac{T(\partial v/\partial T)}{(v-b)^2} \right] = \frac{-a}{(v^2+bv)^2 T} \left\{ (2v+b)T^{1/2}\frac{\partial v}{\partial T} + (v^2+bv)\frac{1}{2}T^{-1/2} \right\}$$

$$\frac{R}{(v-b)} + \frac{a}{(v^2+bv)\,2\,T^{3/2}} = \frac{\partial v}{\partial T}\left[\frac{RT}{(v-b)^2} - \frac{a(2v+b)}{(v^2+bv)^2 T^{1/2}} \right]$$

$$\boxed{\frac{\partial v}{\partial T}\bigg|_p = \left[\frac{\frac{R}{(v-b)} + \frac{a}{2v(v+b)T^{3/2}}}{\frac{RT}{(v-b)^2} - \frac{a(2v+b)}{\cdots}} \right]}$$

$$v_g\Big|_{T=150^\circ C} = -876.92P^5 + 1468.4P^4 - 981.15P^3 + 333.07P^2 - 60.257P + 5.4654 \quad (m^3/kg) \text{ and P in MPa.}$$

(NOT GIVEN IN THE ASSGN)

As the expression is complex, it is integrated numerically using Trapezoidal integration. choosing $dP = 0.1$ MPa which yields.

$$\int_{h_{3^*}}^{h_{3^{**}}} dh = \int_{P_{3^*}}^{P_3^{**}} \left(v - T \frac{\partial v}{\partial T}\Big|_p \right) dp$$

$$= -6.229 \text{ kJ/kg}$$

Thus

$$h_{3^{**}} = 2754.91 - 6.229$$

$$\boxed{h_3^{**} = 2748.68 \text{ kJ/kg}}$$

Along the (isothermal) phase change line $3^{**}-3^{***}$

$$h_{fg} = \frac{\partial p}{\partial T}\Big|_{T_{sat}} \times T \times v_{fg}$$

$$P = 8.56688\times10^{-7}T^3 - 2.53198\times10^{-4}T^2 + 3.09515\times10^{-2}T - 1.36108$$

$$\frac{\partial P}{\partial T}\Big|_{T=150^\circ C} = (8.56688\times10^{-7}\times3\times T^2) - (2.53198\times10^{-4}\times 2T)$$

$= 0.01282 \text{ MPa/deg C.}$

$= 12.82 \text{ kPa}/°C$

$$v_{fg} = -1.88453\times10^{-6}T^3 + 1.01210\times10^{-3}T^2 - 0.186313\,T + 11.9252 \Big|_{T=150°C}$$

$= 0.3902 \ m^3/kg$

$h_{fg} = 12.82\times0.3902\times423$

$h_{fg} = 2115.82 \ kJ/kg$

$h_3^{***} = 2748.68 - 2115.82$

$$\boxed{h_3^{***} = 632.86 \ kJ/kg}$$

Along the isotherm $3^{***} - 3$

as v is just a function of T.

$$\int_{h_{3^{***}}}^{h_3} dh = \left(v - T\frac{\partial v}{\partial T}\Big|\right)\int_{P_{3^{***}}}^{P_3} dp.$$

$$\frac{\partial v}{\partial T}\Big|_{T=150°} = \left(3.42455\times10^{-9}\times2T\right) + \left(9.67286\times10^{-8}\right)\Big|_{T=150°C}$$

$$= 1.554\times10^{-05} \ \frac{m^3}{kg\,°C}$$

$$T\frac{\partial v}{\partial T}\bigg| = 0.00233 \ m^3/kg$$

$$v_f\Big|_{T=150^\circ C} = 0.00109 \ m^3/kg$$

$$h_3 = h_{3***} + (0.00109 - 0.00233)(0.5)\times 1000$$

$$= 632.86 - 0.619$$

$$\boxed{h_3 = 632.24 \ kJ/kg}$$

Comparison	Calculated (kJ/kg)	Steamtables (kJ/kg)	% dev.
3**	2748.68	2746.5	0.08 %
3***	632.86	632.2	0.1 %
3	632.24	632.3	− 0.01 %