# Thermo 1

# Recitation #11

(05/02/23)

→ using the excel tool for PR EoS and solving problems on Peng-Robinson eq.

# directions for using the PREOS excel sheet

1. **Props sheet** → input the gas name and experimental properties in cells A4 to H4. Properties can be taken from sheets 'crit. props' and 'IG Cps'

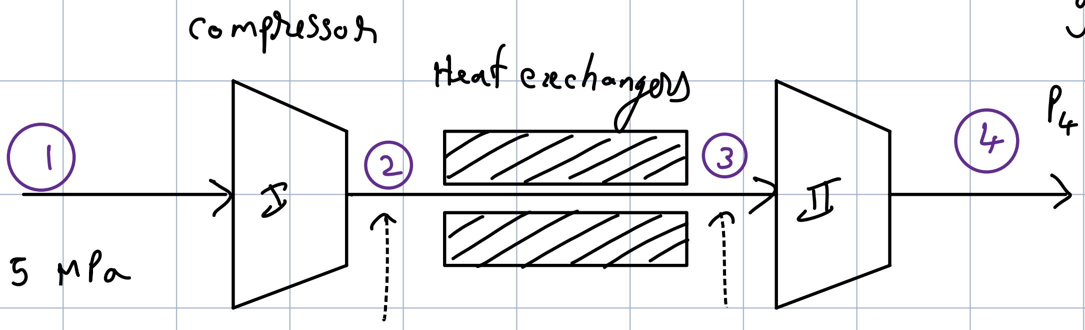
2. **Ref. Sheet** : choose the correct index no. in cell A15, If you see values in the row indexed 1 or 2 choose the index which has lower fugacity value.

3. **Back to props sheet** : input values for current state to get desired thermodynamic parameter.

☆ **Note** : Cells with blue font are supposed to be user input. So only change those values.

$MW = 16.04$ $g\ mol^{-1}$

## Q1



$P_4 = 5$ MPa

$P_1 = 0.05$ MPa

$T_1 = -120$ °F

$= 188.706$ K

$P_2 = 1.5$ MPa

$T_3 = -120$ °F

$= 188.706$ K

(a) $W_{S_{1\to2}} = W_{S_{12}} = \Delta H_{12} = H_2 - H_1$

$S_1 = S_2 = -8.990127$ J/mol K.

$\cdot\ H_1 = -3550.082$ J/mol

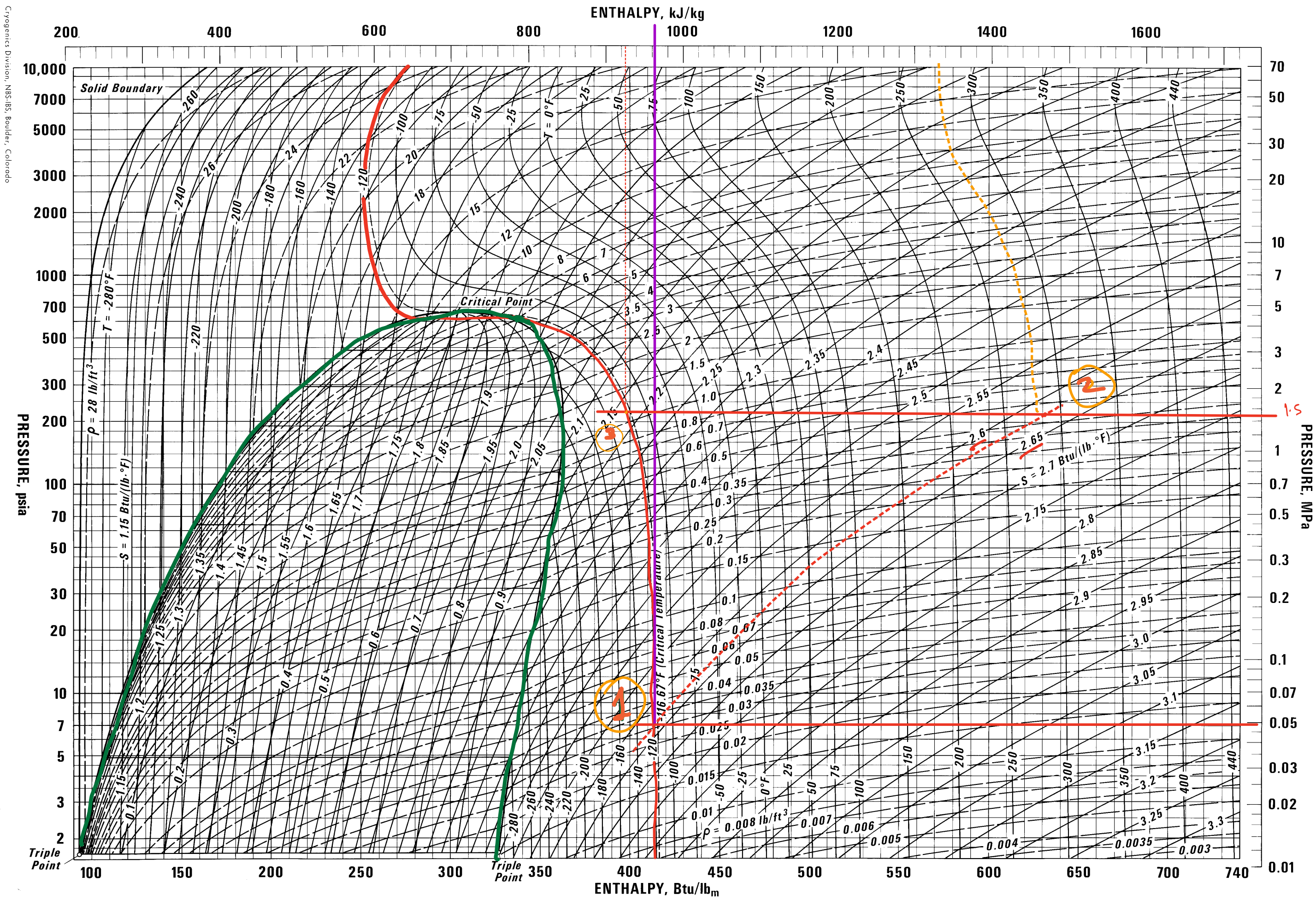
Action on excel sheet ⇒ Now input $P_2$ and apply 'goal seek' to achieve value of $S_1$ by changing T to get the value of $T_2$

$T_2 = 424.47188$ K —(b)

PH diagram for Methane (only for comparison. we do not use values from this chart)

## E.10 PRESSURE-ENTHALPY DIAGRAM FOR METHANE

(Source: NIST, Thermophysics Division, Boulder, CO, USA, used with permission.)



$H_2 = 4818.6121 \text{ J/mol}$

$W_{S_I} = H_2 - H_1 = 4818.6121 - (-3550.082)$

$= 8368.6941 \text{ J/mol}$

$= 521.739 \text{ J/g}$

$W_{S_I} = 521.739 \text{ kJ/kg}$ — (a)

(c) $T_3 = 188.706 \text{ K}$

$P_3 = 1.5 \text{ MPa}$

$H_3 = -4120.335 \text{ J/mol}$

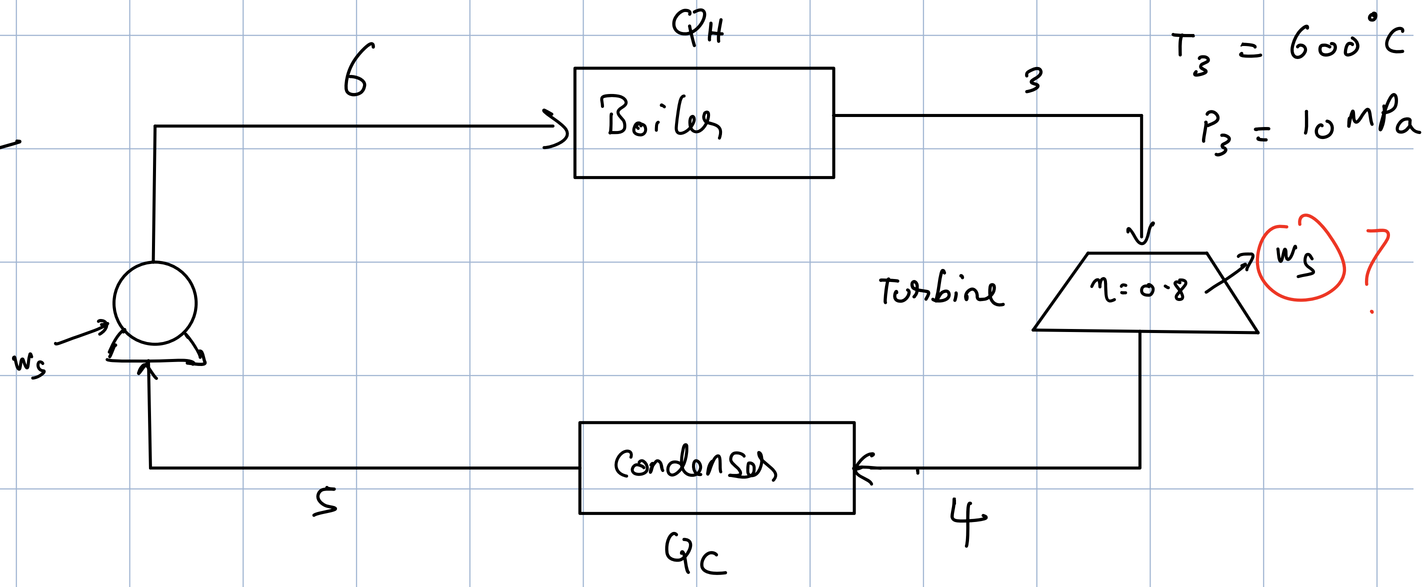
$W_S = \Delta H = H_3 - H_2 = -4120.335 - 4818.6129$

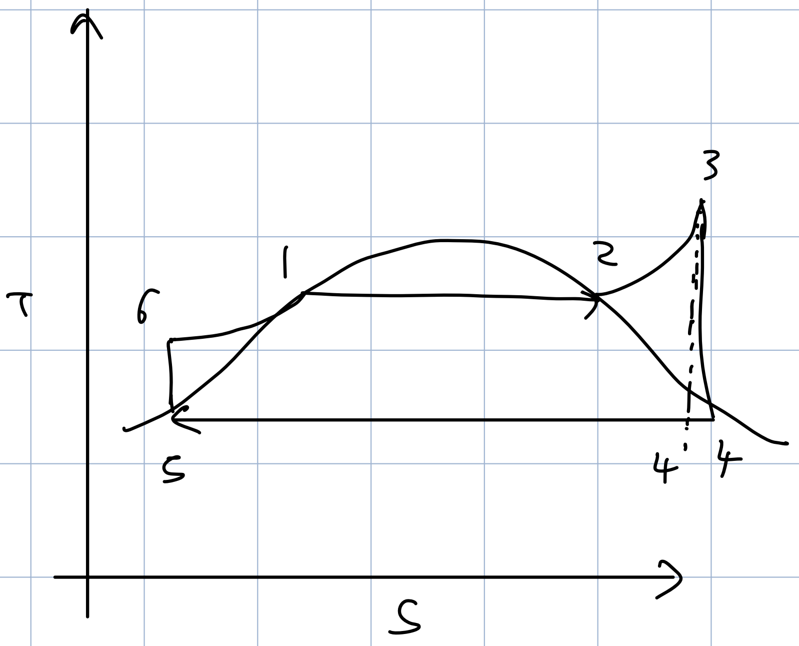
$= -8938.9471 \text{ J/mol}$

$\Delta H = -557.291 \text{ kJ/kg}$

Cooling requirement is 557.291 kJ/kg

## Q2





③ $T_3 = 873.15\,K$ $H_3 = 66902.759\ J/mol$

$P_3 = 10\ MPa$ $S_3 = 129.07059\ J/molK$

Now going from state ③ to ④ if we try to equate the entropy we don't get a solution. because entropy is in the three roof region.

So we equate the fegacity ratio to one by changing T (using goal seek) to get $T_4$.

⇐ Action on excel sheet.

* when the fugacity values for both vapor & liquid region is the same we get fegacity ratio as one, which implies that the compound is in phase equilibrium.

④

$T_4 = 321.355\ K$

$P_4 = 0.01\ MPa$

$H^V = 46511.26$ J/mol

$H^L = 1896.068$ J/mol

$S^V = 144.966$ J/molk

$S^L = 6.1318$ J/molk

$S_3 = S_4' = 129.07059$

$$q' = \frac{\overset{S_4}{129.07059} - \overset{S^L}{6.1318}}{\underset{S^V}{144.966} - \underset{S^L}{6.1318}} = 0.8855$$

$$H_4' = \overset{H_L}{1896.068} + \overset{q'}{0.8855}\left(\overbrace{46511.26 - 1896.068}^{H^V - H^L\ (\Delta H^{vap})}\right)$$

$= 41402.82$ J/mol

$$w_s' = \Delta H' = H_4' - H_3 = -25499.938 \ \mathrm{J/mol}$$

$$\eta_T \, w_s' = W_s = \Delta H = -21674.94 \ \mathrm{J/mol}$$

$$W_s = -21.674 \ \mathrm{kJ/mol}$$

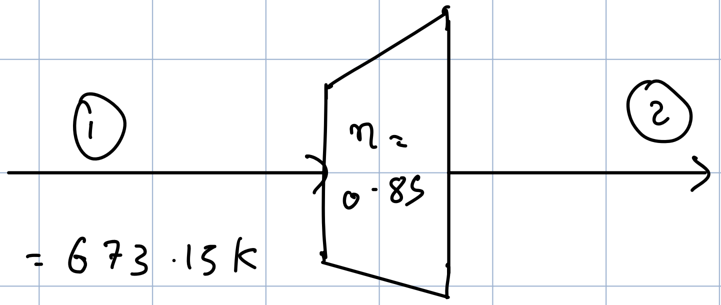
$$H_4 = \Delta H + H_3 = 45227.819 \ \mathrm{J/mol}$$

$$q = \frac{\overset{H4}{45227.819} - \overset{H^L}{1896.068}}{\underset{H^V}{46511.26} - \underset{H^L}{1896.068}} = 0.9712$$

$$S_4 = \overset{S^L}{6.1318} + \overset{q}{0.9712}\,(\overset{S^V}{144.966} - \overset{S^L}{6.1318})$$

$$S_4 = 140.97 \ \mathrm{J/molK}$$

## Q3



$T_2 = ?$

$P_2 = 0.275$ MPa

$T_1 = 400\,^\circ C = 673.15\,K$

$P_1 = 7$ MPa

① $T_1 = 673.15\,K$ $\qquad H_1 = 56849.075$ J/mol

$P_1 = 7$ MPa $\qquad S_1 = 114.2827$ J/molK

* Even here we set fugacity ratio to one to get $T_2$.

(2') $\underline{T_2 = 404.604\,K}$ $\qquad H^V = 49188.998$ J/mol

$P_2 = 0.275$ MPa $\qquad H^L = 8770.2457$ J/mol

$S_2' = S_1$ $\qquad S^V = 125.01908$ J/molK

$S^L = 25.1235$ J/molK

$$q' = \frac{\overset{S_2'}{114.2827} - \overset{S^L}{25.1235}}{\underset{S^V}{125.019} - \underset{S^L}{25.1235}} = 0.8925$$

$$H_2' = \underset{H_L}{8770.2457} + \underset{q'}{0.8925}(\underset{H^V}{49188.998}\ \ \underset{H^L}{8770.24}) = 51888.68 \text{ J/mol}$$

$$W_s' = H_2' - H_1 = -4960.395 \text{ J/mol}$$

$W_s = W_s' \eta = -4216.336 \quad J/mol$

$= -4216.336 \ \frac{J}{mol} \times \frac{10^3}{18} \times \frac{mol}{kg}$

(b) $W_s = -234.24 \quad kJ/kg$

$H_2 = W_s + H_1 = 52632.735 \quad J/mol$

$H_2 > H^V$

$\therefore$ outlet is still superheated.