

P. 8.1) CO₂ at 15MPa and 25°C is throttled to 0.1MPa. Determine the temperature and fraction vapor. (NOTE: there is a typo. Part (c) makes no sense at 1.5MPa.)

Solution: Ebal for a valve, $\Delta H = 0$

(a) assume ideal gas,

$$\Rightarrow \Delta H = 0 = C_p(\Delta T) \Rightarrow T_2 = 298K$$

(b) by PREOS.XLS with Ref=224.1K, 0.1MPa, "Liquid".

$$H_2 = H_1 = 9695 \text{ J/mol, then } "T_{2\text{sat}}" = 184.1K. q = (9695-0)/(17066-0) = 57\%$$

Note: This is just an estimate, because CO₂ is not really liquid at 0.1MPa

Note2: If you solved this using 1.5MPa, you get 281K.

(c) Note: for the problem statement at 1.5MPa, there is no difference from (b).

At 5.27bar, 216.6K, $H_{\text{solid}} = H_{\text{satVap}} - H_{\text{sub}}$,

$$H_{\text{sub}} = H_{\text{vap}} + H_{\text{fus}} = 17829 - 2420 + 43.2 * 44 * 4.184 = 23362 \Rightarrow H_{\text{solid}} = 17829 - 23362 = -5533.$$

$$C - C_{\text{eq}} \Rightarrow \ln(P_{\text{sat}}/P_{\text{ref}}) = -(H_{\text{sub}}/R) * (1/T - 1/T_{\text{ref}})$$

$$\Rightarrow 1/T = 1/216.6 - \ln(1/5.27)/(23362/8.314) = 0.005208 \Rightarrow T = 192$$

$$\text{At 1bar, } 192K = H_{\text{satVap}} = 17322 \Rightarrow H_{\text{solid}} = 17322 - 23362 = -6040$$

$$\Rightarrow q = (9695 + 6040)/(23362) = 67\%$$

FYI: This one way to make "dry ice." You throttle/spray it into "bag" and compress it into a block. See also CO₂ chart in Perry's Handbook, Chapter 3.

P8.2) CO is liquefied from 300bar, 150K to 1bar. Compute q and S_{gen}.

Soln: Ref=82.0K, 0.1MPa, liq. $H(150,30) = 4139$. Ebal: $\Delta H = 0$; $q = (4139-0)/(6048-0) = 68\%$

$$S_f = 0.68 * 73.83 + 0 = 50.2; S(150,30) = 27.365 \Rightarrow S_{\text{gen}} = 50.2 - 27.4 = 22.8 \text{ J/mol-K.}$$

P8.3) Same CO using 90% efficient turbine.

$$\Delta S_{\text{rev}} = 0 \Rightarrow q = 27.635/73.83 = 0.374; W_{\text{rev}} = 0.374 * 6048 - 4139 = -1877 \text{ J/mol} \Rightarrow W_{\text{act}} = -1689$$

$$H_{\text{out}} = 4139 - 1689 = 2450 \Rightarrow q = 2450/6048 = 40.5\% \Rightarrow 1 - q = 59.5\%$$

P8.4) Methane at 300K, 250bar is liquefied (~Linde style) with outlet pressure = 30bar. Compute fraction liquefied.

Soln: Ref=111.8K, 1bar; $qH_8 + (1-q)H_6 = H_3 = 10654$; $T_{\text{sat}}(30\text{bar}) = 176.7K$

$H_{\text{satVap}} = 8289$; $H_{\text{satLiq}} = 4104$; $H_8 = H(300,3\text{MPa}) = 13455$;

$$q = (10654 - 4104)/(13455 - 4104) = 70\% \Rightarrow 1 - q = 30\%$$