Quiz 7
Chemical Engineering Thermodynamics
February 25, 2021

1) For a throttle valve, such as used in a refrigerator, $\Delta H = 0$. You might want to know analytic expressions in terms of $T, P, V, C_p, C_v, \alpha_p$, and κ_T for the change in **entropy and temperature** (μ_{JT}) across a throttle valve, $\left(\frac{\partial S}{\partial P}\right)_H, \left(\frac{\partial T}{\partial P}\right)_H$. Derive these analytic expressions.

2) Last week we calculated the COP for a **5-ton** cascade refrigerator for RNA/DNA using R134a and ethane.
Repeat that calculation of COP **using propane and ethane**. Determine the values **using PREOS.xls**. ***For the reference state use $H_R = 0$; $T = 298K$; $P = 0.1$ MPa; Real Fluid; and the lowest fugacity root with a solution.***

Stage 1 uses propane as a refrigerant and Stage 2 uses ethane. The condenser (8) is at 30°C, the inter-stage heat exchanger (6, 4) is at -30°C, and the evaporator (2) is at -86°C. The total cooling is **5 tons of refrigerant**. Assume that the heat exchanger has no thermal loss.
Use PREOS.xls to obtain all values.
The two compressors have an **efficiency of 0.85**.
1-ton refrigeration = 12,600 kJ/h

Fill the table values in the process stream table.

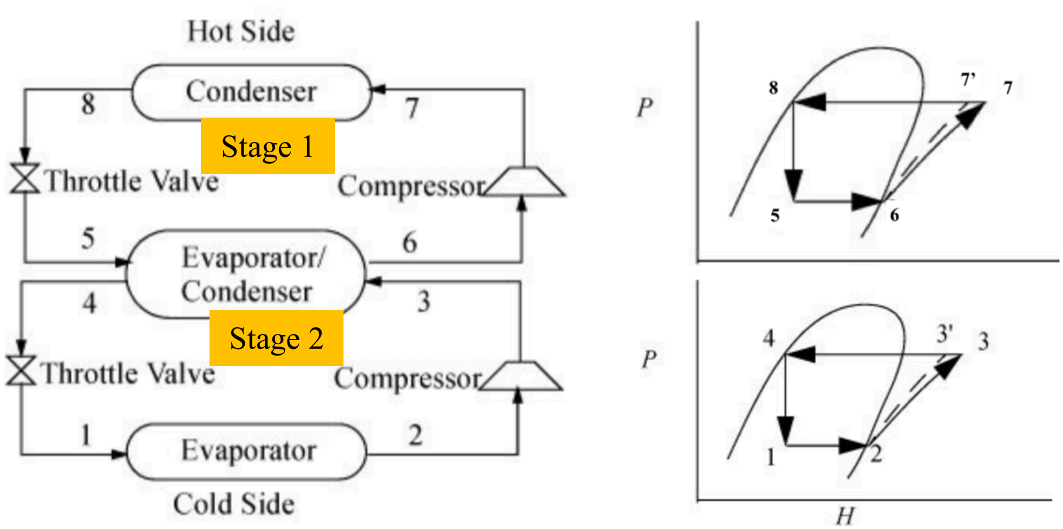

Figure 1. Cascade refrigeration cycle. The refrigerants do not mix in the evaporator/condenser. P-H diagrams for the upper and the lower cycles.

ANSWERS: Quiz 7
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$-S\ U\ V$
$H\ \ A$
$-P\ G\ F$

$$\left(\frac{\partial S}{\partial P}\right)_H$$

$$dH = V\,dP + T\,dS$$

$$\left(\frac{\partial H}{\partial P}\right)_H^{\,0} = V\left(\frac{\partial P}{\partial P}\right)_H^{\,1} + T\left(\frac{\partial S}{\partial P}\right)_H$$

$$\boxed{\left(\frac{\partial S}{\partial P}\right)_H = \frac{-V}{T}}$$

$$\left(\frac{\partial T}{\partial P}\right)_H$$

Triple Product Rule $\left(\frac{\partial H}{\partial T}\right)_P = C_P$

$$\boxed{\left(\frac{\partial T}{\partial P}\right)_H = \frac{-\left(\frac{\partial T}{\partial H}\right)_P}{\left(\frac{\partial P}{\partial H}\right)_T} = \frac{V(T\alpha_P - 1)}{C_P}}$$

$$\left(\frac{\partial H}{\partial P}\right)_T = V\left(\frac{\partial P}{\partial P}\right)_T^{\,1} + T\left(\frac{\partial S}{\partial P}\right)_T$$

Maxwell

$$= V - T\left(\frac{\partial V}{\partial T}\right)_P$$

$$= V - T V \alpha_P$$

Stream	P, Mpa	T, °C	η_e	State	H, J/mole	S, J/(mole K)	q	$\Delta Q/W_s$, J/mole	m', kg/h	ΔQ or W_s, kJ/h
ETHANE										
1	0.116	-86	-	L/V	-15,300	-77	0.295	0	183	0
2	0.116	-86	-	SV	-5,020	-22	1	10,300	183	62830
3'	1.06	19	1	SCV	-904	-22	1	4,120	183	25132
3	1.06	32	0.85	SCV	-178	-19.6	1	4850	183	29585
4	1.06	-30	-	SL	-15,300	-80.4	0	-15,100	183	-92110
Propane										
5	0.167	-30	-	L/V	-15,500	-66.3	0.36	0	349	0
6	0.167	-30	-	SV	-3,860	-18.4	1	11,600	349	92009
7'	1.08	40.6	1	V	9.32	-18.4	1	3,870	349	30696
7	1.08	48.6	0.85	V	692	-16.3	1	4552	349	36106
8	1.08	30	-	SL	-15,500	-69.2	0	-16,200	349	-128495
Net COP =	0.956452905	Carnot COP =	1.61							