1ª PROVA DE TERMODINÂMICA I (Prof. Frederico W. Tavares)

1) **(40Ptos)** Num refrigerador por compressão de vapor operando em estado estacionário com vazão de 20 kg/min de HFC-134a, o evaporador fornece vapor saturado a –50 °C, o compressor tem eficiência de 75% e o condensador fornece um fluido a 1.0 MPa e 20 °C. No diagrama PH do HFC-134a, identifique o ponto correspondente a cada corrente do refrigerador. Calcule as potencias térmica e elétrica e o coeficiente de desempenho do refrigerador.

2) **(40Ptos)** Uma corrente de 3 kmol/min de metanol a 1 atm e 100 °C é alimentada num trocador de calor, cuja fração de vapor (em base molar) é de 70%. Calcule a taxa de troca de calor, considerando que o processo opera em estado estacionário e o metanol, em fase gasosa, é descrito pela equação de estado do virial truncada:

$Z = 1 + \frac{BP}{RT}$	
$H^R = BP\text{-}PT\frac{dB}{dT}$	$S^R = \text{-}P\frac{dB}{dT}$

$B = 4{,}4.10^{-4}\text{-}\frac{0{,}34}{T}$ $\left(B \; em \; \frac{m^3}{mol}, T \; em \; K\right)$	
$\frac{C_p^{gi}}{R} = 2{,}2 + 1{,}2.10^{-2}\,T$ $(T \; em \; K)$	$ln(P^{sat}) = 17 - \frac{3600}{T-33}$ $(P^{sat} \; em \; kPa, T \; em \; K)$

3) **(20Ptos)** Mostre que $H = H(T,S)$ é dado por: $dH = C_P V\left(\frac{\partial T}{\partial V}\right)_P d\ln T + \left[T - V\left(\frac{\partial T}{\partial V}\right)_P\right]dS$ e escreva as derivadas usando a equação do virial, $\frac{PV}{RT} = 1 + \frac{B}{V} + \frac{C}{V^2}$

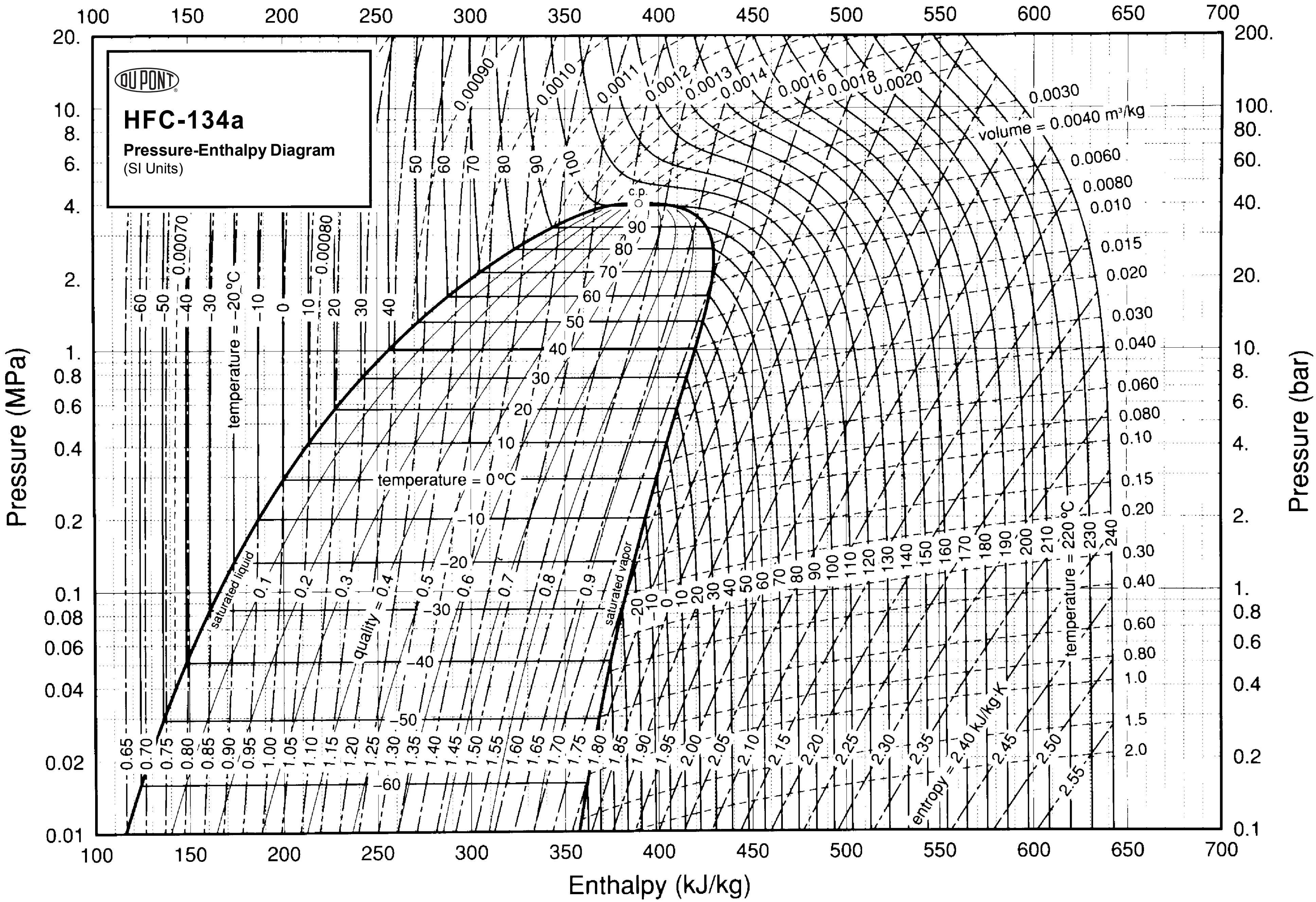
OBS: nas equações anteriores, todas as propriedades termodinâmicas são molares.

$$dU = TdS - PdV + \sum_i \mu_i dN_i \qquad dH = TdS + VdP + \sum_i \mu_i dN_i \qquad y_i P = x_i \gamma_i P_i^{SAT}$$

$$dA = -SdT - PdV + \sum_i \mu_i dN_i \qquad dG = -SdT + VdP + \sum_i \mu_i dN_i \qquad \Delta S_n^{VAP} = 8{,}0 + 1{,}987\ln(T_n)$$

$$dH = C_P dT + \left[V - T\left(\frac{\partial V}{\partial T}\right)_P\right]dP \qquad dS = \left(\frac{C_P}{T}\right)dT - \left(\frac{\partial V}{\partial T}\right)_P dP \qquad \frac{\Delta H_2^{VAP}}{\Delta H_1^{VAP}} = \left(\frac{T_2 - T_C}{T_1 - T_C}\right)^{0{,}38}$$

$$\left(\frac{\partial y}{\partial x}\right)_z \left(\frac{\partial x}{\partial z}\right)_y \left(\frac{\partial z}{\partial y}\right)_x = -1$$



DUPONT
HFC-134a
Pressure-Enthalpy Diagram
(SI Units)
Pressure (MPa)
Pressure (bar)
Enthalpy (kJ/kg)
volume = 0.0040 m³/kg
temperature = 220 °C
temperature = 0 °C
temperature = −20 °C
entropy = 2.40 kJ/kg·K
quality = 0.4
saturated liquid
saturated vapor
c.p.

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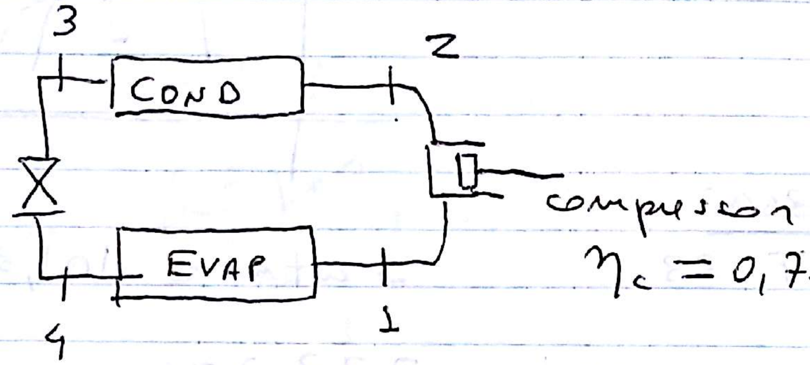
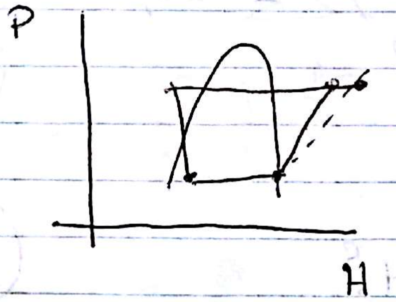
1)



$\eta_c = 0{,}75$

Correntes	1	2'	2	3	4
T(°C)	-50	63	87	20	-50
P (MPa)	0,03	1	1	1	0,03
$\bar{H}$ (KJ/kg)	370	445	470	230	230



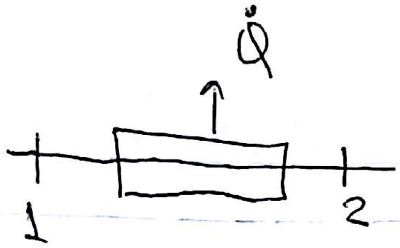
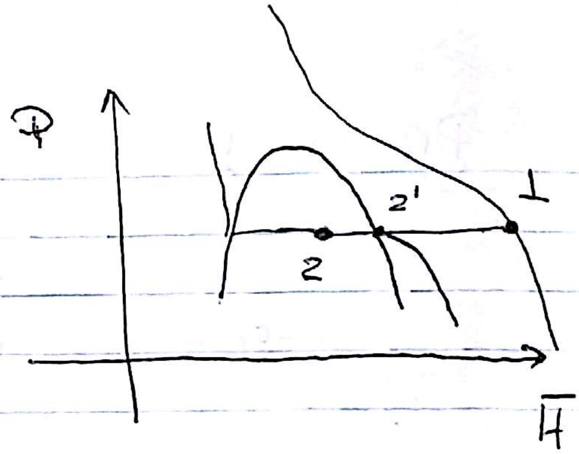
30

$\dot{Q}_2$ = Pot. Térmica $= 20 \frac{kg}{min} (\bar{H}_1 - \bar{H}_4) = 2.800$ KJ/min

$\dot{W}_c$ = Pot. Elétrica $= 20$ kg/min $(\bar{H}_2 - \bar{H}_1) = 2000$ KJ/min

$$CE = \frac{\dot{Q}_2}{\dot{W}_c} = 1{,}4$$

10,0

2)  

$$\ln P^s = 17 - \frac{3600}{T-33}$$

1 atm = 101,3 KPa

$$T_n = \frac{3600}{17 - \ln P_n^s} + 33 = 323,75\,K = 50,6\,°C$$

$T_1 = 100\,°C = 373,15\,K$
$T_2 = 50\,°C = 323,75\,K$

$\Delta S_n^v = 8 + 1,987 \ln(323,75) = 19,5$
$\Delta H_n^v = 6308,2$ cal/gmol

10,0

$Q = \Delta \bar{H}_{12'} - 0,3\,\Delta H_n^v$

10,0

$$\Delta \bar{H}_{12'} = -H_1^R + \int_{T_1}^{T_{2'}} C_p' \, dT + H_2^R$$

$$H^R = P\left[B - T\frac{dB}{dT}\right] \qquad \frac{dB}{dT} = \frac{0,34}{T^2}$$

$\Delta \bar{H}_{12'} = -42,8$ atm L/gmol $= -1036,9$ cal/gmol

$Q = -1036,9 - 0,3 * 6308,2 = -2929,3$ cal/gmol

$\boxed{\dot{Q} = \dot{m}\, Q = -8788 \text{ Kcal/min} = -36771 \text{ KJ/min}}$

20,0

(3) $$d\bar{H} = \left(\frac{\partial \bar{H}}{\partial T}\right)_{\bar{S}} dT + \left(\frac{\partial \bar{H}}{\partial \bar{S}}\right)_T d\bar{S}$$

Como $d\bar{H} = T\,dS + \bar{V}\,dP$

$$\left(\frac{\partial \bar{H}}{\partial T}\right)_{\bar{S}} = T\cancel{\left(\frac{\partial \bar{S}}{\partial T}\right)_{\bar{S}}}^{\,0} + \bar{V}\left(\frac{\partial P}{\partial T}\right)_{\bar{S}} = \bar{V}\,\frac{C_P}{T}\left(\frac{\partial T}{\partial \bar{V}}\right)_P$$

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

Relação de Maxwell $d\bar{G} = -\bar{S}\,dT + \bar{V}\,dP$

$$\left(\frac{\partial \bar{S}}{\partial P}\right)_T = -\left(\frac{\partial \bar{V}}{\partial T}\right)_P$$

$$\boxed{d\bar{H} = \frac{\bar{V}\,C_P}{T}\left(\frac{\partial T}{\partial \bar{V}}\right) dT + \left[T - \bar{V}\left(\frac{\partial T}{\partial \bar{V}}\right)_P\right] d\bar{S}}$$

10,0

$$\frac{P\bar{V}}{RT} = 1 + \frac{B}{\bar{V}} + \frac{C}{\bar{V}^2}$$ Eq. Virial

$$\frac{P}{RT} = \frac{1}{\bar{V}} + \frac{B}{\bar{V}^2} + \frac{C}{\bar{V}^3} \quad \left[\frac{\partial (P/RT)}{\partial V}\right]_P = -\frac{P}{RT^2}\left(\frac{\partial T}{\partial \bar{V}}\right)_P$$

Assim: $$\bar{V}\left(\frac{\partial T}{\partial \bar{V}}\right)_P = -\frac{RT^2}{P}\bar{V}\left[-\frac{1}{\bar{V}^2} - \frac{2B}{\bar{V}^3} - \frac{3C}{\bar{V}^4}\right]$$

$$\bar{V}\left(\frac{\partial T}{\partial \bar{V}}\right)_P = \frac{RT^2}{P}\left[\frac{1}{\bar{V}} + \frac{2B}{\bar{V}^2} + \frac{3C}{\bar{V}^3}\right]$$

10,0

$$\left(\frac{\partial T}{\partial \bar{v}}\right)_P \left(\frac{\partial \bar{v}}{\partial P}\right)_T \left(\frac{\partial P}{\partial T}\right)_v = -1$$

$$\left(\frac{\partial T}{\partial \bar{v}}\right)_P = -\frac{\left(\partial P/\partial \bar{v}\right)_T}{\left(\partial P/\partial T\right)_{\bar{v}}}$$

$$\left(\frac{\partial P}{\partial \bar{v}}\right)_T = RT\left[-\frac{1}{\bar{v}^2} - \frac{2B}{\bar{v}^3} - \frac{3C}{\bar{v}^4}\right] = -\frac{RT}{\bar{v}}\left(1 + \frac{2B}{\bar{v}^2} + \frac{3C}{\bar{v}^3}\right)$$

$$\left(\frac{\partial P}{\partial T}\right)_{\bar{v}} = \left(\frac{1}{\bar{v}} + \frac{B}{\bar{v}^2} + \frac{C}{\bar{v}^3}\right)R + RT\left(\frac{dB/dT}{\bar{v}^2} + \frac{dC/dT}{\bar{v}^3}\right)$$