TEQB – Teste 2022.2.1

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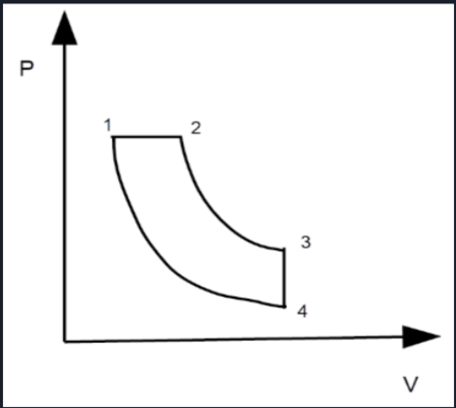
Conteúdo

Questão 1

Considere que tem 1 mol de um gás perfeito ($C_V = 5/2R$). Na figura estão representados estados deste gás (1, 2, 3 e 4) e transições reversíveis entre eles. $P_1 = 4.0\,\mathrm{bar}, T_1 = 293.15\,\mathrm{K}, T_4 = 197.27\,\mathrm{K}$, as transições $2 \rightarrow 3$ e $4 \rightarrow 1$ são adiabáticas, o calor envolvido na transição $1 \rightarrow 2$ é de 5466 J, e o calor envolvido na transição $3 \rightarrow 4$ é de -4100 J.

- $n = 1\,\mathrm{mol}$
- $C_V = 5/2R$
- $P_1 = 4.0\,\mathrm{bar}$
- $T_1 = 293.15\,\mathrm{K}$
- $T_4 = 197.27\,\mathrm{K}$
- $2 \rightarrow 3$: Adiabática
- $4 \rightarrow 1$: Adiabática
- $\Delta H_{1\rightarrow 2} = +5466\,\mathrm{J}$
- $\Delta H_{3\rightarrow 4} = -4100\,\mathrm{J}$



Q1 a)

Calcule T_2

$$\int_1^2 n\, C_P \; \mathrm{d}T = n\,(C_V + R)\;\Delta T = \Delta H_{1\to 2} = Q_{1\to 2} \implies$$

$$\implies T_2 = T_1 + \frac{Q_{1\to 2}}{n\,(C_V + R)} \cong 293.15 + \frac{5466}{1 * 3.5 * 8.31} \cong 480.98$$

Q1 b)

Calcule T_3 e V_3

(i) T_3

$$\int_{3\to 4} n\,C_V\,\mathrm{d}T = n\,(C_P + R)\,(T_4 - T_3) = Q_{3\to 4} \implies$$
$$\implies T_3 = T_4 - \frac{Q_{3\to 4}}{n\,(C_V)} \cong 197.27 - \frac{-4100}{1 * 2.5 * 8.31} \cong 394.52$$

(ii) V_3

$$P_3\,V_3^{\gamma} = \left(\frac{n\,R\,T_3}{V_3}\right) V_3^{C_P/C_V} = n\,R\,T_3\,V_3^{1.4-1} = n\,R\,T_3\,V_3^{0.4} \underset{\text{adiab. rev.}}{\overset{2\to 3}{=}}$$
$$= P_2\,V_2^{\gamma} = P_1\left(\frac{n\,R\,T_2}{P_2}\right)^{1.4} = \frac{n^{1.4}\,R^{1.4}\,T_2^{1.4}}{P_1^{1.4-1}} \implies$$
$$\implies V_3 = \left(\frac{n^{0.4}\,R^{0.4}\,T_2^{1.4}}{P_1^{0.4}\,T_3}\right)^{1/0.4} = \frac{n\,R\,T_2^{3.5}}{P_1\,T_3^{2.5}} \cong \frac{1 * 8.31 * (480.98)^{3.5}}{4.0 * 10^5 * (394.52)^{2.5}} \cong 16.41\,\mathrm{E}{-3}$$

Q1 c)

Calcule $W_{4\to1}$

$$W_{4\to1} + Q_{4\to1} = W_{4\to1} = \Delta U_{4\to1} = \int_4^1 n\,C_V\;\mathrm{d}T = n\,C_V\;\Delta T \cong$$

$$\cong 1 * 2.5 * 8.31(293.15 - 197.27) \cong 1.99\,\mathrm{E3}$$

Q1 d)

Calcule ΔS_{viz} no processo 1→4→3. (se não resolveu b, considere $T_3 = 400\,\mathrm{K}$)

$$\Delta S_{viz,1\to4\to3} = -\,\Delta S_{1\to3} = -\left(\int_1^3 n\,C_P\ \mathrm{d}T/T + n\,R\,\ln(P_1/P_3)\right) =$$

$$= -n\,3.5\,R\,\ln(T_3/T_1) - n\,R\,\ln\frac{P_1}{\left(\frac{n\,R\,T_3}{V_3}\right)} = -n\,R\left(3.5\,\ln(T_3/T_1) + \ln\frac{P_1}{\left(\frac{n\,R\,T_3}{V_3}\right)}\right) \cong$$

$$\cong 8.31\left(-3.5\,\ln\left(\frac{394.52}{283.15}\right) - \ln\frac{4.0 * 10^5}{\left(\frac{8.31*394.52}{16.41\,\mathrm{E}{-3}}\right)}\right) \cong -15.42$$

Q1 e)

Imagine uma transição isotérmica reversível (realizada a T_4) entre o estado 4 e um estado 5, com $W_{4\to5} = -3986\,\mathrm{J}$. Calcule V_5. (se não resolveu b, considere $T_3 = 400\,\mathrm{K}$ e $V_3 = 15.0\,\mathrm{dm}^3$)

$$-\,n\,R\,T_4\ln(V_5/V_4) = W_{4\to5} \implies V_5 = V_4\ \exp\left(-\frac{W_{4\to5}}{n\,R\,T_4}\right) \cong$$

$$\cong 16.41\,\mathrm{E}{-3} * \exp\left(-\frac{-3986}{1 * 8.31 * 197.27}\right) \cong 186.42\,\mathrm{E}{-3}$$

Q1 f)

(i)

Imagine uma forma de levar o gás de 1 a 3 de forma irreversível. Represente graficamente essa transição, bem como o trabalho associado.

(ii)

O coeficiente de Joule-Thomson do H_2 é negativo. Que consequências, em termos da 1 Lei da Termodinâmica, poderão existir no desenho de um motor de combustão, quando o H2 passa através da válvula de saída do depósito a 200K, num processo a entalpia constante?

Questão 2

- $C_{p,L} = 255.7\,\mathrm{J\,K^{-1}\,mol^{-1}}$
- $\alpha_{p,liq} \approx 1.4 * 10^{-3}\,\mathrm{K^{-1}}$
- $C_{p,G} = 239.0\,\mathrm{J\,K^{-1}\,mol^{-1}}$
- $\rho_{liq} = 0.703\,\mathrm{g\,cm^{-3}}$
- $\Delta H_{vap,(125.6\,^\circ\mathrm{C},1.01\,\mathrm{bar})} = 41.53\,\mathrm{kJ\,mol^{-1}}$
- $M_{(n-octano)} = 114.23\,\mathrm{g\,mol^{-1}}$

Q2 a)

Calcule ΔH e ΔG associados à passagem de $200\,\mathrm{g}$ de n-octano do estado ($125.6\,^\circ\mathrm{C}$, gás, $0.5\,\mathrm{bar}$) ao estado ($125.6\,^\circ\mathrm{C}$, líquido, $100\,\mathrm{bar}$)

(i)

$$
\begin{aligned}
&\Delta H = \\
&= \begin{pmatrix} \Delta H_{gas,(0.5\to 1.01)\,\mathrm{bar}} & + \\ +\Delta H_{(gas\to liq),1.01\,\mathrm{bar}} & + \\ +\Delta H_{liq,(1.01\to 100)\,\mathrm{bar}} & \end{pmatrix} = \\
&= \begin{pmatrix} 0 \quad \text{(gas perfeito)} & + \\ +n\ \Delta H_{vap} & + \\ +\displaystyle\int_{P_0}^{P_1} v\,(1-\alpha_p\,T)\ \mathrm{d}P & \end{pmatrix} = \\
&= \begin{pmatrix} (m/M)\ \Delta H_{vap} & + \\ +(m/\rho)\,(1-\alpha_p\,T)\,(P_1-P_0) & \end{pmatrix} = \\
&= \begin{pmatrix} (200/114.23) * 41.53 * 10^3 & + \\ +\dfrac{200 * 10^{-3}}{0.703 * 10^3} * (1-(1.4 * 10^{-3}) * (125.6+273.15)) * (100-1.01) * 10^5 & \end{pmatrix} \cong \\
&\cong 73.96\,\mathrm{E3}
\end{aligned}
$$

(ii)

$$
\begin{aligned}
&\Delta G = \\
&= \begin{pmatrix} \Delta G_{gas,(0.5\to 1.01)\,\mathrm{bar}} & + \\ +\Delta G_{(gas\to liq),1.01\,\mathrm{bar}} & + \\ +\Delta G_{liq,(1.01\to 100)\,\mathrm{bar}} & \end{pmatrix} = \\
&= \begin{pmatrix} \displaystyle\int_{P_0}^{P_1} V\ \mathrm{d}P & + \\ +0 & + \\ +\displaystyle\int_{P_1}^{P_2} V\ \mathrm{d}P & \end{pmatrix} = \\
&= \begin{pmatrix} \displaystyle\int_{P_0}^{P_1} \frac{n\,R\,T}{P}\ \mathrm{d}P & + \\ +V\displaystyle\int_{P_1}^{P_2} \mathrm{d}p \quad \text{(vol liq constante em } \Delta P) & \end{pmatrix} = \\
&= \begin{pmatrix} (m/M)\,R\,T\,\ln(P_1/P_0) & + \\ +(m/\rho)\,(P_2-P_1) & \end{pmatrix} = \\
&= \begin{pmatrix} (200/114.23) * 8.31 * (125.6+273.15) * \ln(1.01/0.5) & + \\ +\dfrac{200 * 10^{-3}}{0.703 * 10^3} * (100-1.01) * 10^5 & \end{pmatrix} \cong \\
&\cong 6897.53
\end{aligned}
$$

Q2 b)

Calcule ΔS e ΔU associados à passagem de 200 g de n-octano do estado (50 °C, líquido, 1.01 bar) ao estado (200 °C, gás, 0.5 bar)

(i)

$$\begin{aligned}
&\Delta S = \\
&= \begin{pmatrix} \Delta S_{liq,1.01\mathrm{bar},(50\to125.6)°\mathrm{C}} & + \\ +\Delta S_{(liq\to gas),1.01\mathrm{bar},125.6°\mathrm{C}} & + \\ +\Delta S_{gas,1.01\mathrm{bar},(125.6\to200)°\mathrm{C}} & + \\ +\Delta S_{gas,(1.01\to0.5)\mathrm{bar},200°\mathrm{C}} & \end{pmatrix} = \\
&= \begin{pmatrix} \int_{T_0}^{T_1} n\,C_{p,liq}\,\mathrm{d}T/T + 0 & + \\ +n\,\Delta H_{vap}/T_1 & + \\ +\int_{T_1}^{T_2} n\,C_{p,gas}\,\mathrm{d}T/T + 0 & + \\ +0 + n\,R\int_{P_2}^{P_3}\mathrm{d}P/P & \end{pmatrix} = \\
&= \begin{pmatrix} n\,C_{p,liq}\ln(T_1/T_0) & + \\ +n\,\Delta H_{vap}/T_1 & + \\ +n\,C_{p,gas}\ln(T_2/T_1) & + \\ +n\,R\ln(P_3/P_2) & \end{pmatrix} = \\
&= \begin{pmatrix} 255.7 * \ln\left(\frac{125.6+273.15}{50+273.15}\right) & + \\ +41.53*10^3/(125.6+273.15) & + \\ +239.0*\ln\left(\frac{200+273.15}{125.6+273.15}\right) & + \\ +8.31*\ln(0.5/1.01) & \end{pmatrix} * (200/114.23) \cong \\
&\cong 337.82
\end{aligned}$$

(ii)

$$\begin{aligned}
&\Delta U = \Delta H - \Delta(PV) = \\
&= \begin{pmatrix} \Delta H_{liq,1.01\mathrm{bar},(50\to125.6)°\mathrm{C}} & + \\ +\Delta H_{(liq\to gas),1.01\mathrm{bar},125.6°\mathrm{C}} & + \\ +\Delta H_{gas,1.01\mathrm{bar},(125.6\to200)°\mathrm{C}} & + \\ +\Delta H_{gas,(1.01\to0.5)\mathrm{bar},200°\mathrm{C}} & \end{pmatrix} - \Delta(PV) = \\
&= \begin{pmatrix} \int_{T_0}^{T_1} n\,C_{P,l}\,\mathrm{d}T & + \\ +n\,\Delta H_{vap} & + \\ +\int_{T_1}^{T_2} n\,C_{P,g}\,\mathrm{d}T & + \\ +0 & \end{pmatrix} - (P_3V_3 - P_0V_0) = \\
&= \begin{pmatrix} n\,C_{P,l}(T_1-T_0) & + \\ +n\,\Delta H_{vap} & + \\ +n\,C_{P,g}(T_2-T_1) & \end{pmatrix} - P_3\left(\frac{n\,R\,T_3}{P_3}\right) + P_0\,(m/\rho_{liq}) = \\
&= \begin{pmatrix} C_{P,l}(T_1-T_0) & + \\ +\Delta H_{vap} & + \\ +C_{P,g}(T_2-T_1) & + \\ -R\,T_3 & + \\ +P_0\,M/\rho_{liq} & \end{pmatrix}(m/M) = \\
&= \begin{pmatrix} 255.7*(125.6-50) & + \\ +41.53*10^3 & + \\ +239.0*(200-125.6) & + \\ -8.31*(200+273.15) & + \\ +1.01*114.23/(0.703*10^6) & \end{pmatrix}(200/114.23) \cong \\
&\cong 130\,803.70
\end{aligned}$$