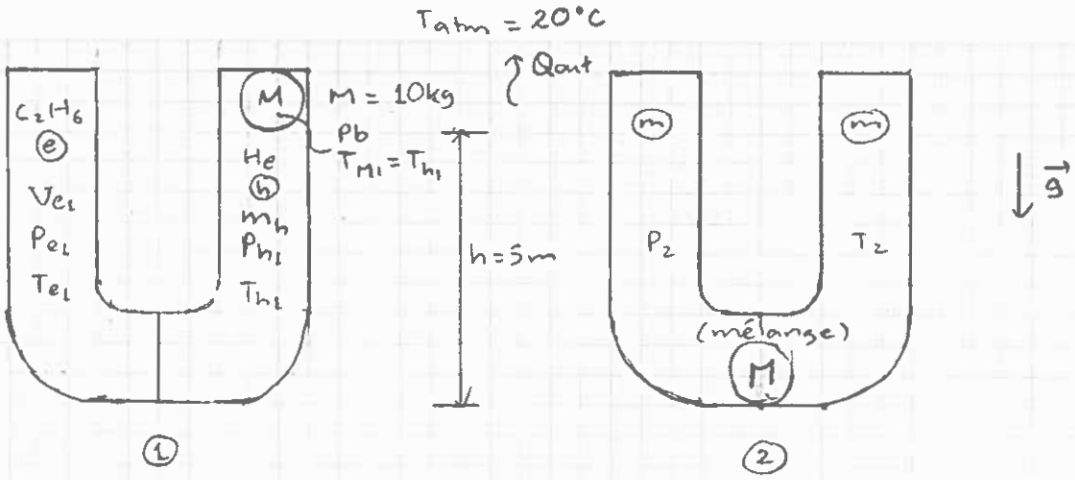
Réponses

# MEC1210 Automne 2024, TD6: Problème à faire en classe (solutionnaire)




$V_{e1} = 1.3014\ m^3$ $\quad m_h = 0.4017\ kg$

$P_{e1} = 150\ kPa$ $\quad P_{h1} = 200\ kPa$

$T_{e1} = 80°C$ $\quad T_{h1} = 60°C$

$T_{M2} = T_2$

équilibre thermique avec atmosphère ($T_2 = T_{atm}$)

a) $m_e = ?$

b) $Y_e, Y_h = ?$

c) $P_2 = ?$

d) $Q_{out} = ?$

e) $\dot{S}_{gen\ tot} = ?$

Suppositions additionnelles

Aucune

- Enceinte étanche
- $C_2H_6$, He et leur mélange → gaz parfaits à $C_p, C_v$ constantes
- M er. plomb (Pb) → substance incomp. avec $C_v$ constante
- $\Delta U$ & $\Delta S$ de partition/parois/air extadj $\simeq 0$
- $C_2H_6$ : $M_e = 30.07 \frac{kg}{kmol}$ ; $R_e = 0.2765 \frac{kJ}{kg \cdot k}$, $C_{pe} = 1.7662 \frac{kJ}{kg \cdot k}$
- He : $M_h = 4.003 \frac{kg}{kmol}$ ; $R_h = 2.0769 \frac{kJ}{kg \cdot k}$, $C_{ph} = 5.1926 \frac{kJ}{kg \cdot k}$
- Plomb : $C_{Pb} = 0.128\ kJ/kg \cdot k$

a) $m_e = ?$ : $P_{e1} V_{e1} = m_e R_e T_{e1}$

$$m_e = \frac{P_{e1} V_{e1}}{R_e T_{e1}} = \frac{(150\ kPa)(1.3014\ m^3)}{\left(0.2765 \frac{kPa \cdot m^3}{kg \cdot K}\right)(80+273)K} = \boxed{2.00\ kg}$$

b) $Y_e, Y_h = ?$ : $Y_e = \frac{N_e}{N_m}$ $\quad \Rightarrow N_e = \frac{m_e}{M_e} = \frac{2.00\ kg}{30.07 \frac{kg}{kmol}} = 0.06651\ kmol$

$Y_h = \frac{N_h}{N_m}$ $\quad N_h = \frac{m_h}{M_h} = \frac{0.4017\ kg}{4.003 \frac{kg}{kmol}} = 0.10035\ kmol$

$N_m = N_e + N_h = 0.06651 + 0.10035$

$N_m = 0.16686\ kmol$

**Réponses**

$$y_e = \frac{0.06651}{0.16686} = \boxed{0.3986}$$

$$y_h = \frac{0.10035}{0.16686} = \boxed{0.6014} \qquad (= 1 - y_e)$$

c) $P_2 = ?$ : $P_2 = \dfrac{N_m R_u T_2}{V_m}$

$\Rightarrow T_2 = T_{atm} = 20°C = 293\,k$ (équilibre thermique)

$\Rightarrow V_m = V_{e_1} + V_{h_2}$

$\rightarrow V_{h_2} = \dfrac{m_h R_h T_{h_1}}{P_{h_1}} = \dfrac{(0.4017 kg)(2.0769 \frac{kPa\cdot m^3}{kg\cdot k})(333k)}{(200\,kPa)}$

$V_{h_2} = 1.3891\ m^3$

$V_m = 1.3014 + 1.3891 = 2.6905\ m^3$

$\Rightarrow N_m = 0.16686$ kmol (partie b)

$$P_2 = \frac{(0.16686\ kmol)(8.314 \frac{kPa\cdot m^3}{kmol\cdot k})(293k)}{(2.6905\ m^3)} = \boxed{151.0765\ kPa}$$

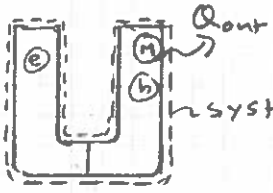
Solution alternative 1

$$P_2 = \frac{m_m R_m T_2}{V_m} = \frac{(m_e + m_h)\left(\frac{R_u}{y_e M_e + y_h M_h}\right) T_2}{V_m} = 151.0786\ kPa$$

Solution alternative 2

$$P_2 = P_{e_2} + P_{h_2} = \frac{m_e R_e T_2}{V_m} + \frac{m_h R_h T_2}{V_m} = 151.0783\ kPa$$

d) $Q_{out} = ?$ :




1ère loi :

$$\Delta E_{sys} = E_{in} - E_{out}$$

$$U_{m_2} - (U_{e_1} + U_{h_1}) + \Delta U_M + \cancel{\Delta U_{parois\ partition}}^{\simeq 0} + \cancel{\Delta E_{c_{sys}}}^{=0} + \Delta E_{p_M} = -Q_{out}$$

$$m_m\left(\frac{m_e}{m_m} u_{e_2} + \frac{m_h}{m_m} u_{h_2}\right) - (m_e u_{e_1} + m_h u_{h_1}) + M(u_{M_2} - u_{M_1}) - Mgh = -Q_{out}$$

**Réponses**

$$Q_{out} = m_e(u_{e1} - u_{e2}) + m_h(u_{h1} - u_{h2}) + M(u_{M1} - u_{M2}) + Mgh$$

$$Q_{out} = m_e C_{ve}(T_{e1} - T_2) + m_h C_{vh}(T_{h1} - T_2) + M C_{pb}(T_{h1} - T_2) + Mgh$$

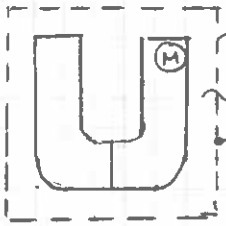
$$\Rightarrow C_{ve} = C_{pe} - R_e = 1.7662 - 0.2765 = 1.4897 \ \frac{kJ}{kg \cdot K}$$

$$\Rightarrow C_{vh} = C_{ph} - R_h = 5.1926 - 2.0769 = 3.1157 \ \frac{kJ}{kg \cdot K}$$

$$Q_{out} = (2.00\,kg)\left(1.4897 \frac{kJ}{kg \cdot K}\right)(80-20)°C \cdot \frac{K}{°C}$$
$$+ (0.4017\,kg)\left(3.1157 \frac{kJ}{kg \cdot K}\right)(60-20)°C \cdot \frac{K}{°C}$$
$$+ (10\,kg)\left(0.128 \frac{kJ}{kg \cdot K}\right)(60-20)°C \cdot \frac{K}{°C}$$
$$+ (10\,kg)\left(9.81 \frac{m}{s^2}\right)(5\,m) \times \frac{1\,kJ}{10^3\,kg \cdot \frac{m^2}{s^2}}$$

$$\boxed{Q_{out} = 280.518\ kJ}$$

e) $S_{gen\ tot} = ?$ :




Système inclut toutes les irréversibilités : $S_{gen\ sys} = S_{gen\ tot}$

Bilan d'entropie (2ème loi) : $\Delta S_{sys} = \int_1^2 \frac{\delta Q}{T_{front}} + S_{gen\ sys}$ ($A_{front}$)

$$S_{m2} - (S_{e1} + S_{h1}) + \Delta S_M + \Delta S^{\nearrow \simeq 0}_{\text{parois, partition, air ext adj}} = -\frac{Q_{out}'}{T_{atm}} + S_{gen\ tot}$$

$$m_m\left(\frac{m_e}{m_m} s_{e2} + \frac{m_h}{m_m} s_{h1}\right) - (m_e s_{e1} + m_h s_{h1}) + M(s_{M2} - s_{M1}) = -\frac{Q_{out}}{T_{atm}} + S_{gen\ tot}$$

$$S_{gen\ tot} = m_e(s_{e2} - s_{e1}) + m_h(s_{h2} - s_{h1}) + M(s_{M2} - s_{M1}) + \frac{Q_{out}'}{T_{atm}}$$

$\Rightarrow Q_{out}' = ?$ :


1ère loi sur sys. A

$$\Delta U^{\nearrow \simeq 0}_{\text{air ext adj}} = Q_{out} - Q_{out}'$$

$$Q_{out}' = Q_{out} = 280.518\ kJ$$

Réponses

$$\Rightarrow s_{e_2} - s_{e_1} = C_{pe} \ln \frac{T_2}{T_{e_1}} - R_e \ln \frac{P_{e_2}}{P_{e_1}} \qquad \rightarrow P_{e_2} = y_e P_2$$

$$= (1,7662) \ln\left(\frac{20+273}{80+273}\right) - (0.2765) \ln\left(\frac{0.3986 \times 151.0765}{150}\right)$$

$$= -0.076688 \text{ kJ/kg.k}$$

$$\Rightarrow s_{h_2} - s_{h_1} = C_{ph} \ln \frac{T_2}{T_{h_1}} - R_h \ln \frac{P_{h_2}}{P_{h_1}} \qquad \rightarrow P_{h_2} = y_h P_2$$

$$= (5.1926) \ln\left(\frac{20+273}{60+273}\right) - (2.0769) \ln\left(\frac{0.6014 \times 151.0765}{200}\right)$$

$$= 0.974232 \text{ kJ/kg.k}$$

$$\Rightarrow s_{M_2} - s_{M_1} = C_{pb} \ln \frac{T_{M_2}}{T_{M_1}} \qquad \text{(subs. incomp.)}$$

$$= C_{pb} \ln \frac{T_2}{T_{h_1}} = (0.128) \ln\left(\frac{20+273}{60+273}\right)$$

$$= -0.016380 \text{ kJ/kg.k}$$

$$S_{\substack{gen \\ tot}} = (2.00 \text{ kg})\left(-0.076688 \frac{\text{kJ}}{\text{kg.k}}\right) + (0,9017 \text{ kg})\left(0.974232 \frac{\text{kJ}}{\text{kg.k}}\right)$$

$$+ (10 \text{ kg})\left(-0.016380 \frac{\text{kJ}}{\text{kg.k}}\right) + \frac{(280.518 \text{ kJ})}{(20+273)\text{k}}$$

$$\boxed{S_{\substack{gen \\ tot}} = 1.0316 \frac{\text{kJ}}{\text{k}}}$$

Solution alternative pour $(s_{e_2} - s_{e_1})$ & $(s_{h_2} - s_{h_1})$

$$s_{e_2} - s_{e_1} = C_{ve} \ln \frac{T_2}{T_{e_1}} + R_e \ln \frac{V_m}{V_{e_1}} = 1,4857 \ln \frac{293}{353} + 0.2765 \ln \frac{2.6905}{1.3019}$$

$$= -0.076706 \text{ kJ/kg.k}$$

$$s_{h_2} - s_{h_1} = C_{vh} \ln \frac{T_2}{T_{h_1}} + R_h \ln \frac{V_m}{V_{h_1}} = 3.1157 \ln \frac{293}{333} + 2.0769 \ln \frac{2.6905}{1.3891}$$

$$= 0.974263 \text{ kJ/kg.k}$$

$$S_{\substack{gen \\ tot}} = 1.0315 \frac{\text{kJ}}{\text{k}}$$