MCG2531 - THERMO 2

CHAP. 11.1 — SOLUTIONS AUX PROB. SUGGÉRÉS

11.1

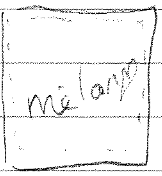
a) Mélange de gaz parfaits $y_i = \forall_i / \forall$

	$\forall_i/\forall$	y_i	M_i	$y_i M_i$	fm_i
H_2	0,35	0,35	2	0,7	3,28 %
CO	0,5	0,5	28	14	65,73 %
CO_2	0,15	0,15	44	6.6	30,99 %

$$M_{mél} = \sum y_i M_i = 21,3 \text{ kg/kmol}$$

$$fm_i = \frac{m_i}{m_{TOT}} = \frac{y_i M_i}{M_{mél}}$$

b)



$\forall = 1L = 0,001 m^3$ Hyp: Gaz parfait

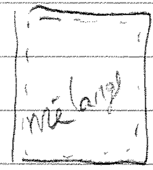
$P = 100$ kPa

$T = 20°C$ $P\forall = mRT \Rightarrow m = \frac{P\forall}{RT}$

$$R = \frac{\bar{R}}{M} = \frac{8,31451}{21,3} = 0,39035 \text{ kJ/kgK}$$

$$\boxed{m = 8,7 \times 10^{-4} \text{ k}}$$

c)



①

$\forall_1 = 0,001 m^3$

$P_1 = 100$ kPa

$T_1 = 20°C$

②

$\forall_2 = \forall_1$

$T_2 = 100°C$

Trouver ${}_1Q_2$

Hypothèses: Ⓐ Syst. fermé $\rightarrow (m = \text{const})$ Ⓑ ${}_1W_2 = 0$

Ⓒ $\Delta E_p = \Delta E_c = 0$ Ⓓ Gaz parfait

Cons. Masse: $\frac{dm_{vc}}{dt} = \overset{A}{\cancel{\sum \dot m_e}} - \overset{A}{\cancel{\sum \dot m_s}}$ $m = \text{const}$

$m_{H_2} = fm_{H_2} \cdot m = 0,0000287$ kg

$m_{CO} = fm_{CO} \cdot m = 0,0005744$ kg

$m_{CO_2} = fm_{CO_2} \cdot m = 0,0002709$ kg

1^er Principe: $$\,_1Q_2 = \overset{Ⓑ}{\cancel{\,_1W_2}} + m_2(u_2 + \overbrace{\cancel{\frac{V_2^2}{2}} + \cancel{gz_2}) - m_1(u_1 + \cancel{\frac{V_1^2}{2}} + \cancel{gz_1}}^{Ⓒ})$$

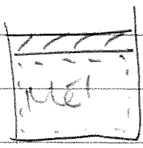
$$\,_1Q_2 = m(u_2 - u_1) = \left[m_{H_2}u_{2H_2} + m_{CO}u_{2CO} + m_{CO_2}u_{2CO_2}\right] - \left[m_{H_2}u_{1H_2} + m_{CO}u_{1CO} + m_{CO_2}u\right.$$

$$= m_{H_2}(u_2 - u_1)_{H_2} + m_{CO}(u_2 - u_1)_{CO} + m_{CO_2}(u_2 - u_1)_{CO_2}$$

$$= \underbrace{m_{H_2}c_{v_{H_2}}}_{\hookrightarrow 10.0849}(T_2 - T_1) + \underbrace{m_{CO}c_{v_{CO}}}_{\hookrightarrow 0,7445}(T_2 - T_1) + \underbrace{m_{CO_2}c_{v_{CO_2}}}_{\hookrightarrow 0.6529}(T_2 - T)$$

$$\boxed{\,_1Q_2 = 71,6\ J}$$

11,2



①
$\forall_1 = 1L = 0,001m^3$
$P_1 = 100\ kPa$
$T_1 = 20°C$

②
$\forall_2 = 0.2L$

Hypothèses: Ⓐ Syst. fermé (m = const) Ⓑ $\,_1Q_2 = 0$ Ⓒ Réversible
Ⓓ Gaz Parfait Ⓔ $\Delta E_p = \Delta E_c = 0$

Cons. Masse: $m = const$ $m_{H_2} = 0,0000287\ kg$ $m_{CO_2} = 0,000\ 27$
$m_{CO} = 0,0005744\ kg$
(voir prob 11,1)

1^er Principe: $$\underset{Ⓑ}{\cancel{\,_1Q_2}} = \,_1W_2 + m_2(u_2 + \underbrace{\cancel{\frac{V_2^2}{2}} + \cancel{gz_2}) - m_1(u_1 + \cancel{\frac{V_1^2}{2}} + \cancel{gz_1}}_{Ⓔ})$$

$$\,_1W_2 = m(u_1 - u_2) = \left[m_{H_2}u_{2H_2} + m_{CO}u_{2CO} + m_{CO_2}u_{2CO_2}\right] - \left[m_{H_2}u_{1H_2} + m_{CO}u_{CO} + m\right.$$

$$= m_{H_2}c_{v_{H_2}}(T_1 - T_2) + m_{CO}c_{v_{CO}}(T_1 - T_2) + m_{CO_2}c_{v_{CO_2}}(T_1 - T_2)$$

2^e Principe: $$\frac{dS_{vc}}{dt} = \overset{Ⓐ}{\cancel{\sum \dot{m}_e s_e}} - \overset{Ⓐ}{\cancel{\sum \dot{m}_s s_s}} + \overset{Ⓑ}{\cancel{\sum \frac{\dot{Q}_{vc}}{T}}} + \overset{Ⓒ}{\cancel{\dot{S}_{gen}}}$$

$$S_2 - S_1 = 0$$

$$\therefore\ 0 = m_{H_2}(s_2 - s_1)_{H_2} + m_{CO}(s_2 - s_1)_{CO} + m_{CO_2}(s_2 - s_1)_{CO_2}$$

$$(s_2 - s_1)_{H_2} = c_{v_{H_2}} \ln\left(\frac{T_2}{T_1}\right) + R_{H_2} \ln\left(\frac{v_{2H_2}}{v_{1H_2}}\right)$$

$$\hookrightarrow = \frac{\forall_{2H_2}/\cancel{m_{H_2}}}{\forall_{1H_2}/\cancel{m_{H_2}}} = \frac{\forall_{2H_2}}{\forall_{1H_2}} = \frac{\cancel{y_{H_2}}\forall_2}{\cancel{y_{H_2}}\forall}$$

$$\therefore 0 = m_{H_2}\left[c_{v_{H_2}} \ln\left(\frac{T_2}{T_1}\right) + R_{H_2} \ln\left(\frac{\forall_2}{\forall_1}\right)\right] + m_{CO}\left[c_{v_{CO}} \ln\left(\frac{T_2}{T_1}\right) + R_{CO} \ln\left(\frac{\forall_2}{\forall_1}\right)\right]$$
$$+ m_{CO_2}\left[c_{v_{CO_2}} \ln\left(\frac{T_2}{T_1}\right) + R_{CO_2} \ln\left(\forall_2/\forall_1\right)\right]$$

$c_{v_{H_2}} = 10,0841$ $\quad R_{H_2} = 4,1573$ kJ/kg K $\quad \frac{\forall_2}{\forall_1} = \frac{0,2}{1} =$

$c_{v_{CO}} = 0,7445$ $\quad R_{CO} = 0,2969$

$c_{v_{CO_2}} = 0,6529$ $\quad R_{CO_2} = 0,1890$

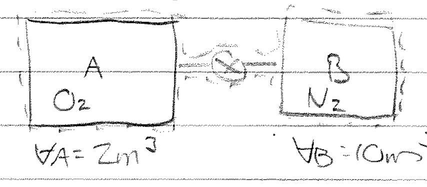
$$\Rightarrow 0 = 0,000895 \ln\left(\frac{T_2}{T_1}\right) - 0,00055$$

$$\Rightarrow \boxed{T_2 = 541,4\ K}$$

Du 1er principe: $\boxed{{}_1W_2 = -222\ J}$

11.3

isolés



①

$T_{A_1} = 10°C$

$P_{A_1} = 400 kPa$

$T_{B_1} = 50°C$

$P_{B_1} = 200 kPa$

②

état uniforme

$\forall_2 = \forall_A + \forall_B = 12 m^3$

a) Hyp: Ⓐ Syst fermé Ⓑ ${}_1Q_2 = 0$ Ⓒ ${}_1W_2 = 0$ Ⓓ $\Delta E_p = \Delta E_c = 0$
Ⓔ Gaz parfait

Cons. Masse: $\frac{dm_{vc}}{dt} = \cancel{\Sigma \dot{m}_e}^{Ⓐ} - \cancel{\Sigma \dot{m}_s}^{Ⓐ} \Rightarrow m = const$

$$m_{O_2} = \frac{P_{A_1}\forall_{A_1}}{R_{O_2} T_{A_1}} = \frac{400 \cdot 2}{0,25983 \cdot 283} = 10.880\ kg$$

$$m_{N_2} = \frac{P_{B_1}\forall_{B_1}}{R_{N_2} T_{B_1}} = \frac{200 \cdot 10}{0,2968 \cdot 323} = 20.862\ kg$$

1^er Principe: $\overset{\textcircled{B}}{\cancel{Q_2}} = \overset{\textcircled{C}}{\cancel{W_2}} + m_2\left(u_2 + \overset{\textcircled{D}}{\cancel{\frac{V_2^2}{2}} + \cancel{gz_2}}\right) - m_1\left(u_1 + \cancel{\frac{V_1^2}{2}} + \cancel{gz_1}\right)$

$m(u_2 - u_1) = 0 \Rightarrow m_{O_2}(u_2 - u_1)_{O_2} + m_{N_2}(u_2 - u_1)_{N_2} =$

$m_{O_2} c_{v_{O_2}}(T_2 - T_{A1}) + m_{N_2} c_{v_{N_2}}(T_2 - T_{B1}) = 0$

$c_{v_{O_2}} = 0{,}6618 \qquad c_{v_{N_2}} = 0{,}7448$

$10{,}88 \cdot 0{,}6618(T_2 - 283) + 20{,}862 \cdot 0{,}7448(T_2 - 323)$

$\Longrightarrow \boxed{T_2 = 310{,}3\ K}$

$P_2 = \dfrac{m_{TOT} R_{mél} T_2}{V_2}$ ✓ ✓ $\qquad m_{TOT} = m_{O_2} + m_{N_2} = 31{,}742\ kg$

$R_{mél} = \dfrac{\bar{R}}{M_{mél}} = fm_{O_2} R_{O_2} + fm_{N_2} R_{N_2} \Longrightarrow fm_{O_2} = \dfrac{m_{O_2}}{m_{TOT}} = 0{,}34$

$fm_{N_2} = 0{,}657$

$R_{mél} = 0{,}343 \cdot 0{,}25983 + 0{,}657 \cdot 0{,}2968$
$= 0{,}2841$

$\Longrightarrow \boxed{P_2 = 233{,}2\ kPa}$

b) 2^e Principe: $\dfrac{dS_{vc}}{dt} = \underset{\textcircled{A}}{\cancel{\sum \dot{m}_e s_e}} - \underset{\textcircled{A}}{\cancel{\sum \dot{m}_s s_s}} + \underset{\textcircled{B}}{\cancel{\sum \frac{\dot{Q}_{vc}}{T}}} + S_{gen}$

$S_2 - S_1 = S_{gen}$

$\Delta S = m_{O_2}(s_2 - s_1)_{O_2} + m_{N_2}(s_2 - s_1)_{N_2} \longrightarrow = \left[c_{p_{N_2}} \ln\left(\frac{T_2}{T_{B1}}\right) - R_{N_2} \ln\left(\frac{P_{2N_2}}{P_{B1}}\right)\right] m$

$= \left[c_{p_{O_2}} \ln\left(\frac{T_2}{T_{A1}}\right) - R_{N_2} \ln\left(\frac{P_{2O_2}}{P_{B1}}\right)\right] m_{O_2}$

Besoin des pressions partielles P_{2O_2} et P_{2N_2}

$P_{2O_2} = y_{O_2} \cdot P_2$ et $P_{2N_2} = y_{N_2} P_2$

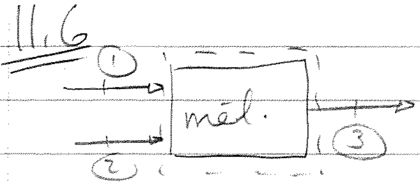
$n_{O_2} = \dfrac{m_{O_2}}{M_{O_2}} = 0{,}3400 \qquad n_{N_2} = \dfrac{m_{N_2}}{M_{N_2}} = 0{,}7451 \qquad n_{TOT} = n_{O_2} + n_{N}$
$= 1{,}0851\ km$

$y_{O2} = \frac{0,34}{1,0851} = 0,3133$ $\qquad$ $y_{N2} = \frac{0,7451}{1,0851} = 0,6867$

$\therefore P_{2_{O_2}} = 73,08 kPa$ $\qquad$ $P_{2_{N_2}} = 160,15 kPa$

$\therefore \boxed{\Delta S = 6.236 kJ/k}$

11,6



①	②	③
H_2	N_2	Mélange
$P_1 = 500kPa$	$P_2 = 500kPa$	$2H_2 : 1 N$
$T_1 = 20°C$	$T_2 = 200°C$	$P_3 = 490k$

a) Hypothèses: Ⓐ Syst. ouvert - ERP Ⓑ Adiabatique Ⓒ $\dot{W}_{vc} = ($
Ⓓ $\Delta E_p = \Delta E_c = 0$ Ⓔ Gaz parfait

Cons Masse: $\cancel{\frac{dm_{vc}}{dt}}^{Ⓐ} = \Sigma \dot{m}_e - \Sigma \dot{m}_s \Rightarrow \dot{m}_{H_2} + \dot{m}_{N_2} = \dot{m}_{mé}$

1er Principe:

$$\underset{Ⓑ}{\cancel{\dot{Q}_{vc}}} + \Sigma \dot{m}_e (h_e + \cancel{\frac{V_e^2}{2}} + \cancel{gz_e}) = \overset{Ⓒ}{\cancel{\dot{W}_{vc}}} + \Sigma \dot{m}_s (h_s + \cancel{\frac{V_s^2}{2}} + \cancel{gz_s}) + \overset{Ⓐ}{\cancel{\left[\frac{m_2 E_2 - m_1 E_1}{\Delta t}\right]}}$$

Ⓓ

$$\Sigma \dot{m}_e h_e = \dot{m}_s h_s$$

$$\dot{m}_{H_2} h_1 + \dot{m}_{N_2} h_2 = \dot{m}_{mél} h_3$$

$$\Rightarrow \div \dot{m}_{mél} \Rightarrow \frac{\dot{m}_{H_2}}{\dot{m}_{mél}} h_1 + \frac{\dot{m}_{N_2}}{\dot{m}_{mél}} h_2 = h_3 \Rightarrow fm_{H_2} h_1 + fm_{N_2} h_2$$

$$\Rightarrow fm_{H_2} (h_1 - h_3) = fm_{N_2} (h_3 - h_2)$$

$$fm_{H_2} Cp_{H_2} (T_1 - T_3) = fm_{N_2} Cp_{N_2} (T_3 - T_2)$$

$y_{H_2} = \frac{n_i}{n_{TOT}} = \frac{2}{2+1} = 0,6667$ $\qquad$ $y_{N_2} = 0,3333$

$M_{mél} = \Sigma y_i M_i = 0,6667 \cdot 2 + 0,3333 \cdot 28 = 10,6667 kg$

$fm_{H_2} = \frac{y_{H_2} \cdot M_{H_2}}{M_{mél}} = 0,125$ $\qquad$ $fm_{N_2} = 0,875$

$\rightarrow Cp_{H_2} = 14,2091$ $\qquad$ $Cp_{N_2} = 1,0416$

$$\therefore\ fm_{H_2} C_{p_{H_2}} \cdot T_1 + fm_{N_2} C_{p_{N_2}} \cdot T_2 = \left(fm_{H_2} C_{p_{H_2}} + fm_{N_2} C_{p_{N_2}}\right) T_3$$

$$\boxed{T_3 = 354\,K = 81\,°C}$$

b) 2ᵉ Principe: $\underset{Ⓐ}{\cancel{\frac{dS_{vc}}{dt}}} = \sum \dot{m}_e s_e - \sum \dot{m}_s s_s + \overset{Ⓑ}{\cancel{\sum \frac{\dot{Q}_{vc}}{T}}} + \dot{S}_{gen}$

$$\Delta S = \dot{S}_{gen} = \dot{m}_s s_s - \sum \dot{m}_e s_e$$
$$= \dot{m}_{mél}\, s_3 - \dot{m}_{H_2} s_1 - \dot{m}_{N_2} s_2$$
$$= n_{tot}\, \bar{s}_3 - n_{H_2} \bar{s}_1 - n_{N_2} \bar{s}_2$$

$\div n_{TOT}$ $$\overline{\Delta s} = \bar{s}_3 - y_{H_2} \bar{s}_1 - y_{N_2} \bar{s}_2$$
$$= y_{H_2}(\bar{s}_3 - \bar{s}_1)_{H_2} + y_{N_2}(\bar{s}_3 - \bar{s}_2)_{N_2}$$

$$= y_{H_2}\left[\bar{C}_{p_{H_2}} \ln\left(\frac{T_3}{T_1}\right) - \bar{R} \ln\left(\frac{P_{3H_2}}{P_1}\right)\right] + y_{N_2}\left[\bar{C}_{p_{N_2}} \ln\left(\frac{T_3}{T_2}\right) - \bar{R} \ln\left(\frac{P_{3N_2}}{P_2}\right)\right]$$

$P_{3H_2} = y_{H_2} \cdot P_3 \longleftarrow$ pressions partielles $\longrightarrow P_{3N_2} = y_{N_2} \cdot P$

$$= 5{,}943 + 0{,}283 \quad \Rightarrow \quad \boxed{\overline{\Delta s} = 6{,}226\ kJ/kmol\,K}$$

S-11.1

mélange

$T = 25\,°C$
$P = 100\,kPa$

a)

	y_i	M_i	$y_i M_i$	fm_i
N_2	0,6	28	16,8	50,6 %
CO_2	0,3	44	13,2	39,8 %
O_2	0,1	32	3,2	9,6 %

$fm_i = \frac{y_i M_i}{M_{mél}}$

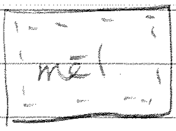
$$M_{mél} = \sum y_i M_i = 33{,}2\ kg/kmol$$

b) $P_i = P \cdot y_i$ $\quad \boxed{P_{N_2} = 60\,kPa \quad P_{CO_2} = 30\,kPa \quad P_{O_2} = 10\,k}$

c) $P\forall = \underset{50\,kg}{m} R_{mél} T$ $\quad R_{mél} = \frac{\bar{R}}{M_{mél}} = 0{,}25044$ $\quad \boxed{\forall = \frac{mR\overset{[K]}{T}}{P} = 37{,}3}$

S-11.2

① $\xrightarrow{+He \text{ à } 21°C}$ ②



$T_1 = 21\,°C$ $\qquad$ $T_2 = 21\,°C$

$P_1 = 100\,kPa$ $\qquad$ $P_2 = 136\,kPa$

$\forall = 0{,}028\,m^3$ $\quad y_{N_2} = 0{,}79$ $\quad y_{O_2} = 0{,}21$

Etat ①	y_i	M_i	y_iM_i	fm_i
N_2	0,79	28	22,12	0,767
O_2	0,21	32	6,72	0,233

$fm_i = \frac{y_iM_i}{M_{mél}}$

$M_{mél} = \sum y_iM_i = 28{,}84\,kg/kmol$ $\qquad$ $R_{mél} = \frac{\overline{R}}{M_{mél}} = 0{,}28$

$m_{mél} = \frac{P\forall}{R_{mél} \cdot T} = \frac{100 \cdot 0{,}028}{0{,}2883 \cdot 294} = 0{,}033\,kg$

$m_{N_2} = fm_{N_2} \cdot m_{mél} = 0{,}0253\,kg \longrightarrow n_{N_2} = m_{N_2}/M_{N_2} = 0{,}00090$

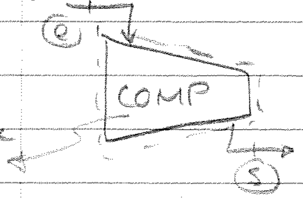
$m_{O_2} = fm_{O_2} \cdot m_{mél} = 0{,}0077\,kg$ $\qquad$ $n_{O_2} = 0{,}0002405\,kmol$

Etat ② $\quad P_2\forall_2 = n_2\overline{R}T_2$ $\qquad$ $n_2 = \frac{136 \cdot 0{,}028}{8{,}31451 \cdot 294} = 0{,}001558\,kmol$

$\therefore n_{He} = n_2 - n_{N_2} - n_{O_2} = 0{,}000412\,kmoles$

$m_{He} = n_{He} \cdot M_{He} = 0{,}000412 \cdot 4$ $\qquad$ $\boxed{m_{He} = 0{,}001649\,kg}$

S11.3



ⓔ

$T_e = 37\,°C$

$P_e = 100\,kPa$

$V_e = 50\,m/s$

ⓢ

$T_s = 237\,°C$

$V_s = 80\,m/s$

$q_{vc} = 3\,kJ/kg$

$\dot{Q}_{vc} = 15\,kW$

$\dot{m} = 5\,kg/s$

Hypothèses: Ⓐ Syst ouvert - ERP

Ⓑ $\Delta E_p = 0$

Ⓒ Gaz parfait.

Cons. Masse: $\overset{Ⓐ}{\cancel{\frac{dm_{vc}}{\Delta t}}} = \sum \dot{m}_e - \sum \dot{m}_s$ $\qquad$ $\dot{m} = const.$

1er Principe:

$$\dot Q_{vc} + \sum \dot m_e\Big(h_e + \frac{V_e^2}{2} + \overbrace{\cancel{gz_e}\Big) = \dot W_{vc} + \sum \dot m_s\Big(h_s + \frac{V_s^2}{2} + \cancel{gz_s}}^{\textcircled{B}}\Big) + \overset{\textcircled{A}}{\cancel{\left[\frac{m_2E_2 - m_1E_1}{\Delta t}\right]}}$$

$$\dot W_{vc} = \dot Q_{vc} + \dot m\left(h_e + \frac{V_e^2}{2} - h_s - \frac{V_s^2}{2}\right)$$

$$= \dot Q_{vc} + \dot m\left(\frac{V_e^2}{2} - \frac{V_s^2}{2}\right) + \dot m\left(h_e - h_s\right)$$

$$= -15 + 5\left(\frac{50^2}{2000} - \frac{80^2}{2000}\right) + \dot m_{CO_2} C_{p_{CO_2}}(T_e - T_s) + \dot m_{CO} C_{p_{CO}}(T_e - T_s) + \dot m_{O_2} C_{p_{O_2}}($$

$$= -24{,}75 + (T_e - T_s)\cdot\left(\dot m_{CO_2} C_{p_{CO_2}} + \dot m_{CO} C_{p_{CO}} + \dot m_{O_2} C_{p_{O_2}}\right)$$

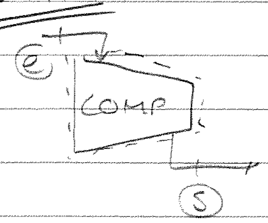
C_{pi}		y_i	M_i	y_iM_i	fm_i	$\dot m_i = fm_i \cdot \dot m$
0,8418	CO_2	0,5	44	22	0,6	3 kg/s
1,0413	CO	0,333	28	9,324	0,2543	1,271 kg/s
0,9216	O_2	0,167	32	5,344	0,1457	0,729 kg/s

$$fm_i = \frac{y_iM_i}{M_{mél}}$$

$$M_{mél} = \sum y_iM_i = 36{,}668 \text{ kg/kmol}$$

Du 1er principe: $\boxed{\dot W_{vc} = -928{,}9 \text{ KW}}$

S-11,4



Ⓔ	Ⓢ	y_i
$T_e = 67°C = 340K$	$T_s = T_e$	40% étha
$P_e = 6{,}8$ ATM	$P_s = 23{,}8$ ATM	60% méth

Trouver $\bar{q}_{vc}$ [kJ/kmol mél]

Hypothèses: Ⓐ Syst ouvert, ERP Ⓑ isotherme Ⓒ Réversible
Ⓓ Gaz parfait Ⓔ $\Delta E_p = \Delta E_c = 0$

Cons Masse $\overset{\textcircled{A}}{\cancel{\frac{dm_{vc}}{\Delta t}}} = \sum \dot m_e - \sum \dot m_s$ $\dot m = $ const.

1er Principe:

$$\dot Q_{vc} + \sum \dot m_e\Big(h_e + \underbrace{\cancel{\frac{V_e^2}{2}} + \cancel{gz_e}\Big) = \dot W_{vc} + \sum \dot m_s\Big(h_s + \cancel{\frac{V_s^2}{2}}}_{\textcircled{E}} + gz_s\Big) + \overset{\textcircled{A}}{\cancel{\left[\frac{m_2E_2 - m_1E_1}{\Delta t}\right]}}$$

$$\dot{W}_{vc} = \dot{Q}_{vc} + \dot{m}(h_e - h_s)$$
$$= \dot{Q}_{vc} + \dot{m}_{éth}(h_e - h_s)_{éth} + \dot{m}_{mét}(h_e - h_s)_{mét}$$
$$\downarrow \qquad\qquad\qquad \downarrow$$
$$c_{p_{éth}}\cancelto{0}{(T_e - T_s)} \qquad\qquad c_{p_{mét}}\cancelto{0}{(T_e - T_s)}$$

$$\underline{\underline{\dot{W}_{vc} = \dot{Q}_{vc}}}$$

2e Principe: $\overset{\text{Ⓐ}}{\cancelto{0}{\frac{dS_{vc}}{dt}}} = \sum \dot{m}_e s_e - \sum \dot{m}_s s_s + \sum \frac{\dot{Q}_{vc}}{T} + \overset{\text{ⓒ}}{\cancelto{0}{\dot{S}_{gen}}}$

$$\frac{\dot{Q}_{vc}}{T} = \dot{m}(s_s - s_e) \Rightarrow \dot{Q}_{vc} = T\left[\dot{m}_{éth}(s_s - s_e)_{éth} + \dot{m}_{mét}(s_s - s_e\right.$$
$$= T\left(\dot{n}_{éth}(\bar{s}_s - \bar{s}_e)_{éth} + \dot{n}_{mét}(\bar{s}_s - \bar{s}_e)\right.$$

$$\div \dot{N}_{TOT} \Longrightarrow \frac{\dot{Q}_{vc}}{\dot{N}_{TOT}} = \bar{q}_{vc} = T\left[y_{éth}(\bar{s}_s - \bar{s}_e)_{éth} + y_{mét}(\bar{s}_s - \bar{s}_e)_{mét}\right.$$

$$(\bar{s}_s - \bar{s}_e)_i = \bar{c}_p \ln\cancelto{0}{\left(\frac{T_s}{T_e}\right)} - \bar{R}\ln\left(\frac{P_{si}}{P_{ei}}\right)$$
$$\hookrightarrow = \frac{y_i P_s}{y_i P_e} = P_s/P_i = \frac{23.8}{6.8} = 3.$$

$$\therefore\ \bar{q}_{vc} = 340\left[0.4\left(-8.31451\ln(3.5)\right)_i + 0.6\left(-8.31451\ln(3.5)\right)\right]$$
$$\bar{q}_{vc} = -3541 \text{ kJ/kmol} \qquad \Longrightarrow \boxed{\bar{w}_{vc} = -3541. \text{ kJ/kmo}}$$

S-11,5

①

$T_{A_1} = 27\ °C$

$P_{A_1} = 200\ kPa$

$T_{B_1} = 152\ °C$

$P_{B_1} = 500\ kPa$

$n_{CO_2} = 1$ kmole

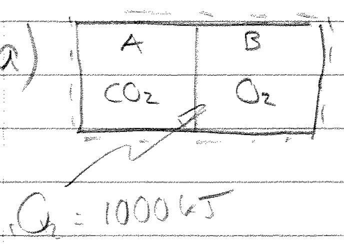
$n_{O_2} = 2$ kmoles

②

mélange uniforme

$V_2 = V_A + V_B$

a)



$Q_1 = 1000$ kJ

Hyp. Ⓐ Syst fermé (m = const) Ⓑ $W_{vc} = 0$ ⓒ $\Delta E_p = \Delta E_c = 0$
Ⓓ Gaz parfait

Cons. Masse : $m = \text{const.}$

Etat ① $\quad P_{A1} \forall_{A1} = n_{CO_2} \bar{R} T_{A1} \qquad \forall_{A1} = \dfrac{1 \cdot 8{,}31451 \cdot 300}{200} = 12.47$

$P_{B1} \forall_{B1} = n_{O_2} \bar{R} T_{B1} \qquad V_{B1} = \dfrac{2 \cdot 8{,}31451 \cdot 425}{500} = 14.135$

$\forall_2 = \forall_A + \forall_B = 26.606\,m^3$

1^er^ Principe : $\;{}_1Q_2 = \underset{B}{\cancel{{}_1W_2}} + m_2(u_2 + \overset{C}{\cancel{\tfrac{V_2^2}{2} + gz_2}}) - m_1(u_1 + \cancel{\tfrac{V_1^2}{2} + gz_1})$

$1000 = m(u_2 - u_1) = m_{CO_2}(u_2 - u_1)_{CO_2} + m_{O_2}(u_2 - u_1)_{O_2}$

$= m_{CO_2} C_{v_{CO_2}} (T_2 - T_{A1}) + m_{O_2} C_{v_{O_2}} (T_2 - T_{B1}$

$m_{CO_2} = n_{CO_2} \cdot M_{CO_2} = 1 \cdot 44 = 44\,kg \qquad C_{v_{CO_2}} = 0.6529$

$m_{O_2} = n_{O_2} \cdot M_{O_2} = 2 \cdot 32 = 64\,kg \qquad C_{v_{O_2}} = 0.6618$

$\therefore \boxed{T_2 = 388.6\,K}$

b) $P_2 \forall_2 = n \bar{R} T_2 \qquad P_2 = \dfrac{3 \cdot 8{,}31451 \cdot 388.6}{26.606} \Rightarrow \boxed{P_2 = 364.3}$