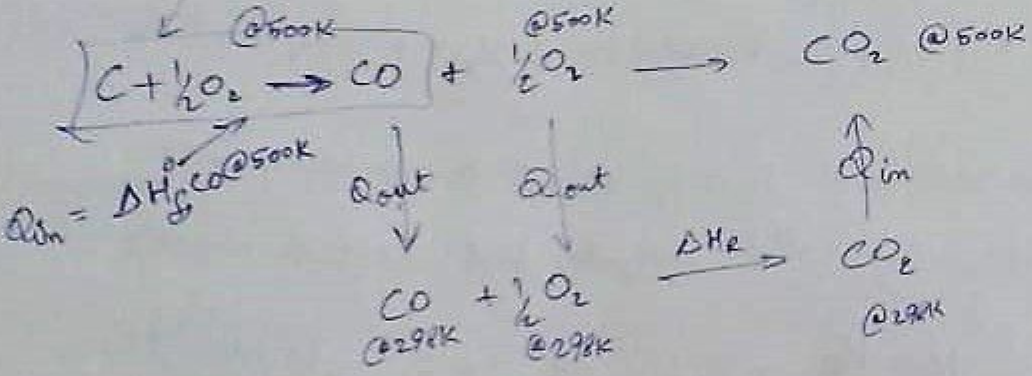
AS1200 - Tutorial 9, 23APR/2019

Solutions

1)

$$C + O_2 \longrightarrow CO_2 \quad 500K$$



$$\therefore \Delta H^o_{f,CO_2} @500K = \Delta H^o_{f,CO}(500K) - h_{sens_{CO}}(500K) - \frac{1}{2} h_{sens_{O_2}}(500K) + \Delta H_R + h_{sens_{CO_2}}(500K)$$

$$\Delta H_R = H_P - H_R = \Delta H^o_{f,CO_2}(298.15K) - \Delta H^o_{f,CO}(298.15K) - \frac{1}{2}\Delta H^o_{f,O_2}(298K)$$

$$= -393.522 \frac{kJ}{kmol} + 110.527 \frac{kJ}{kmol} - 0$$

$$= -282.995 \frac{kJ}{kmol}$$

$$\therefore \Delta H^o_{f,CO_2}(500K) = -110.003 \frac{kJ}{kmol} - 5.931 \frac{kJ}{kmol} - \frac{1}{2}(6.084)\frac{kJ}{kmol} - 282.995 \frac{kJ}{kmol} + 8.305 \frac{kJ}{kmol}$$

$$= -393.666 \frac{kJ}{kmol}$$

→ Same as in the table!

~~State~~ ~~Flame~~

$\phi = 1$: $H_2 + \frac{1}{2}(O_2 + 3.76N_2) \longrightarrow H_2O + 1.88N_2$

$\phi = 0.9$: $0.9H_2 + \frac{1}{2}(O_2 + 3.76N_2) \longrightarrow 0.9H_2O + 1.88N_2 + 0.05O_2$

$\phi = 1.5$: $1.5H_2 + \frac{1}{2}(O_2 + 3.76N_2) \longrightarrow 1\,H_2O + \frac{1}{2}H_2 + 1.88N_2$

If we derive in terms of ν_i' & ν_i'' it will be same expressions for all three cases, & it will be easy to just change the numbers.

Adiabatic $\Rightarrow$ $H_P = H_R = \left.\sum_i \nu_i' \left\{ \Delta H^\circ_{f,A_i} + h_{sens,A_i}(T) \right\}\right)_{\text{reactants}}$

$\longrightarrow \;= \left.\sum_i \nu_i'' \left\{ \Delta H^\circ_{f,A_i} + h_{sens,A_i}(T_f) \right\}\right)_{\text{products}}$

since $T_{react} = T_{ref}$, & species are all ref species, $H_R = 0$!

$\therefore$ we need to find conditions for $H_P = 0$, given ν_i'' s.

$$0 = H_P = \nu''_{H_2O}\left\{\Delta H^\circ_{f,H_2O} + h_{sens,H_2O}(T)\right\} + \nu''_{H_2}\left\{\cancel{\Delta H^\circ_{f,H_2}}^{\,0} + h_{sens,H_2}(T)\right\}$$
$$+ \nu''_{O_2}\left\{\cancel{\Delta H^\circ_{f,O_2}}^{\,0} + h_{sens,O_2}(T)\right\} + \nu''_{N_2}\left\{\cancel{\Delta H^\circ_{f,N_2}}^{\,0} + h_{sens,N_2}(T)\right\}$$

$\therefore$ we need to find T such that

$$\nu''_{H_2O} h_{s,H_2O}(T) + \nu''_{O_2} h_{sens,O_2}(T) + \nu''_{H_2} h_{s,H_2}(T) + \nu''_{N_2} h_{s,N_2}(T) = -\nu''_{H_2O}\Delta H^\circ_{f,H_2O}$$

2) Contd — Tut 9, 23/Apr/2019

Case (i)

species	H_2O	H_2	O_2	N_2
ν_i''	1	0	0	1.88

$$RHS = -\nu''_{H_2O}\,\Delta H^{\circ}_{f,H_2O} = +1\times 241.826\ \text{kJ}$$ ← target value

Guessing T_{final}, (→ not needed)

T	h_{sens,H_2O} ($\nu''=1$)	h_{sens,O_2}	h_{sens,H_2}	h_{sens,N_2} ($\nu''=1.88$)	$\sum \nu_i'' h_{s,i}$
4000K	183.522	—	—	130.027	427.975 kJ
3000K	126.549	—	—	92.715	300.853 ..
2600K	104.520	—	—	77.963	251.090 ..
2500K	99.108	—	—	74.296	238.784 ..

$$T_f = \frac{241.826 - 238.784}{251.090 - 238.784}\times 100 + 2500 = \underline{2524.7\,K}$$

Case (ii) same RHS, but more species to share it! target $= +241.826 \times 0.9$ kJ $= 217.643$ kJ

T	h_{sens,H_2O} ($\nu_i''=0.9$)	h_{sens,O_2} ($\nu''=0.05$)	h_{sens,N_2} ($\nu''=1.88$)	$\sum \nu_i'' h_{s,i}$
2500K	99.108	78.328	74.296	232.790 kJ
2400K	93.741	74.453	70.640	220.893 ..
2300K	88.421	70.600	66.995	209.060 ..

→ extrapolation, = 2372.7K! → also ok!

$$\therefore T_f = \frac{217.643 - 209.06}{220.893 - 209.06}\times 100 + 2300 = \underline{2372.5\,K}$$

Case (iii) target $= 241.826$ kJ

T	h_{sens,H_2O} ($\nu_i''=1$)	h_{sens,H_2} ($\nu_i''=0.5$)	h_{sens,N_2} ($\nu_i''=1.88$)	$\sum \nu_i'' h_{s,i}$
2500K	99.108	70.498	74.296	274.033 kJ
2300K	88.421	63.387	66.995	246.065 ..

$$T_f = 2300 + \frac{241.826 - 246.065}{274.033 - 246.065}\times 100 = \underline{2284.8\,K}$$

Q3 Soln: AS1300 Tut 9, 23 APR 2017

$$Q_{in} + H_R = H_P$$

H_2 @ 400K, air @ 500K.

heat loss $= 100 \frac{kJ}{kg\ of\ H_2} = 200 \frac{kJ}{kmol\ of\ H_2}$

$\therefore Q_{in} = -200 \frac{kJ}{kmol\ of\ H_2}$

H_2 : air by wt $= \frac{1}{46}$

$H_2 + \frac{1}{2}(O_2 + 3.76N_2)$

$\frac{kg}{kmol} : \frac{4.76}{2} = 2.38 \times 28.8 \frac{kg}{kmol}$

$$\phi = \frac{(1/46)}{2/(2.38 \times 28.8)} = \underline{\underline{0.745}}$$

$0.745H_2 + \frac{1}{2}(O_2 + 3.76N_2)$

equivalent to

$$1H_2 + \frac{1}{2 \times 0.745}(O_2 + 3.76N_2) \longrightarrow H_2O + 0.17O_2 + 2.52N_2$$

($\frac{1}{2 \times 0.745} \to 0.67$)

$$H_R = 1\left\{\Delta H^{\circ}_{f,H_2}(T_{ref}) + h_{s,H_2}(400K)\right\} + 0.67\left\{0 + h_{s,O_2}(500K)\right\} + 2.52\left\{0 + h_{s,N_2}(500K)\right\}$$

($\Delta H^{\circ}_{f,H_2}(T_{ref}) = 0$)

$$= 1 \times 2.959 + 0.67 \times 6.084 + 2.52 \times 5.911 = \underline{21.931\ kJ}$$

for 1 kmol of H_2 in reactants

$$H_P = Q_{in} + H_R = -200 \frac{kJ}{kmol\ of\ H_2} + 21.931 \frac{kJ}{kmol\ of\ H_2}$$

$$= 1\left\{\Delta H^{\circ}_{f,H_2O}(T_{ref}) + h_{s,H_2O}(T_f)\right\} + 0.17\left\{0 + h_{s,O_2}(T_f)\right\} + 2.52\left\{0 + h_{s,N_2}\right.$$

$$= -241.826 + h_{s,H_2O} + 0.17\,h_{s,O_2} + 2.52\,h_{s,N_2} = -200 + 21.9$$

∴ We need to solve for

$$h_{0,H_2O}(T_f) + 0.17 h_{1,O_2}(T_f) + 2.52 h_{1,N_2}(T_f) = 63.757 \text{ kJ}$$

(target)

T_{guess}	h_{0,H_2O} (1)	h_{1,O_2} (0.17)	h_{1,N_2} (2.52)	$\Sigma \nu_i h_i$
1000K	26.000	22.703	21.463	83.946
800K	18.002	15.835	15.046	58.610

$$T_f = \frac{63.757 - 58.610}{83.946 - 58.610} \times 200 + 800 = 840.6 \text{ K}$$