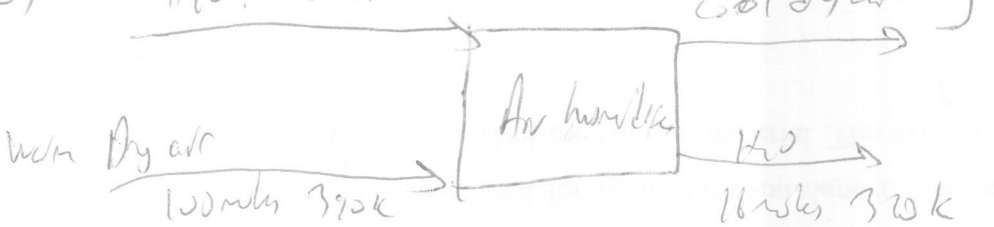
1) Suyla 452



Calculate Heat loss

H_2O 20moles 320 k → H_2O 16moles 320K

4moles $H_2O(l)$ → 4moles $H_2O(g)$ $\Delta H_w = ?$

Air 100moles 390K → Air 100moles 320K

390K → 320K $\Delta H_{air} = ?$

} difference is loss

We need: C_p values of O_2 and N_2 between 320-390K

and ΔH_{latent} of H_2O at 320K

Use HSC

			A	B	C	D	
79 mole	N_2 =>	320-350K	29.278	-1.567	-0.257	3.619	J/mol K
		350-390K	27.753	0.605	0.728	4.960	
21 mole	O_2 =>	320-390K	22.060	20.887	1.624	-8.207	

$$C_p = A + B\times10^{-3}T + \frac{C\,10^5}{T^2} + D\cdot10^{-6}T^2$$

$$\Delta H = H_{320} - H_{390} = \int_{390}^{320} C_p\,dT$$

$$H_{320} - H_{390} = A\cdot T\Big|_{350}^{320} + \frac{B\times10^{-3}}{2}T^2\Big|_{390}^{320} = \frac{C\times10^5}{T}\Big|_{390}^{320} + \frac{D\cdot10^{-6}}{3}T^3\Big|_{320}$$

for N_2

$$H_{320} - H_{390} = 79\left[\begin{array}{l} 27.753\times(350-390) + \left(\frac{0.605\times10^{-3}}{2}\right)\times(350^2-390^2) - (0.728\times10^5)\cdot\left(\frac{1}{350}-\frac{1}{390}\right) \\ 29.298\times(320-350) + \left(\frac{-1.567\times10^{-3}}{2}\right)\times(320^2-350^2) - (-0.007\times10^5)\cdot\left(\frac{1}{320}-\frac{1}{350}\right) \\ + \frac{\left(\frac{4.960\times10^{-6}}{3}\right)(350^3-390^3)}{\left(\frac{3.419\cdot10^{-6}}{3}\right)(320^3-350^3)} \end{array}\right]$$

$$= 79\left[\begin{array}{llll} -1110.12 & -8.954 & 21.333 & -27.187 \\ -878.94 & + 15.748 & - -0.1875 & + -11.518 \end{array}\right]$$

$$-2042.116 = -161327.204\ \text{J} = -161.327\ \text{kJ}$$

for O_2

$$H_{320} - H_{390} = 21\left[22.060(320-390) + \left(\frac{20.887\times10^{-3}}{2}\right)\times(320^2-390^2) - (1.621\times10^5)\left(\frac{1}{320}-\frac{1}{390}\right) + \left(\frac{-8.207\times10^{-6}}{3}\right)\cdot(320^3-390^3)\right]$$

$$= 21\left[-1544.2 - 519.042 - 90.921 + 72.634\right]$$

$$= 21\left[-2081.529\right] = -43.712\ \text{kJ}$$

$$\Delta H_{298} = -205.039\ \text{kJ}$$

ΔH°_{rxn} of $H_2O_{(l)} \rightarrow H_2O_{(g)}$ 43.093 kJ/mol

$\Delta H_w = 4 \cdot 43.093 = 172.372$ kJ

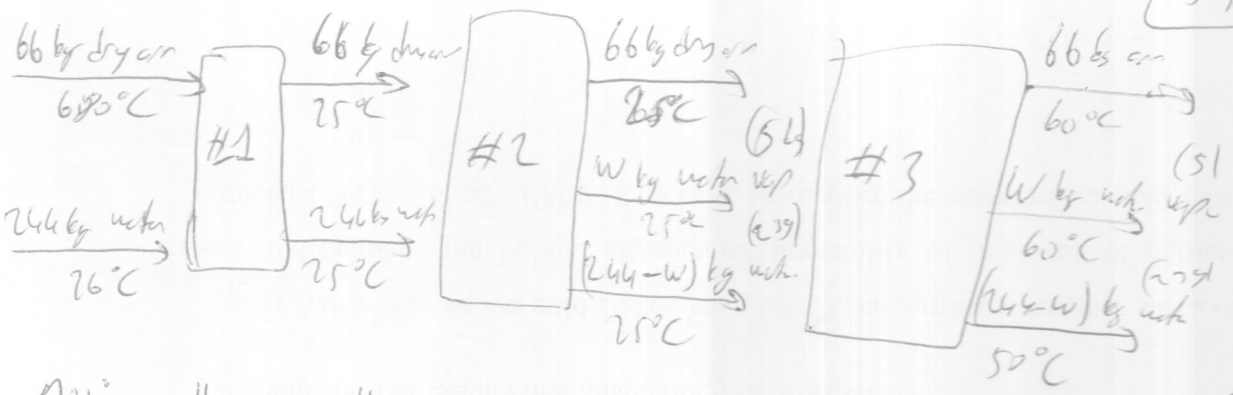
Total Heat $= Q_2 \Delta H_w + \Delta H_{cal} + \Delta H_{loss}$

$172.372 - 205.034 + \Delta H_{loss}$

$\Delta H_{loss} = 32.662$ kJ

Sayfa 453

2)



ΔH_{vap} $H_2O_{(l)} \rightarrow H_2O_{(g)}$ at 25°C 2440 kJ/kg

$H_{680} \rightarrow H_{25}$ 700 kJ/kg

$C_p\ H_2O_{(g)} = 1.869$ kJ/kg°C $\quad C_p\ H_2O_{(l)} = 4.184$ kJ/kg°C

$C_{p,\ dry\ air} = 1.009$ kJ/kg°C

#1) $\Delta H_{air} = H_{25} - H_{680} = 66\text{ kg}\,(-700\text{ kJ/kg}) = -46200$ kJ

$\Delta H_{water} = H_{25} - H_{26} =$ $\quad$ n. $C_p \Delta T = (244\text{ kg})(4.184\text{ kJ/kg°C})(-1\text{°C})$

$= -1020$ kJ

#2) $\Delta H^\circ_{vap} = W\,(2440\text{ kJ})$ $\quad$ 12200 kJ

#3) $\Delta H^\circ_{air} = H_{60} - H_{25} = (66\text{ kg})(1.009\text{ kJ/kg°C})(60-25\text{°C}) = 2330$ kJ

$\Delta H^\circ_{vap} = H_{60} - H_{25} = (W\text{ kg})(1.869\text{ kJ/kg°C})(60-25\text{°C}) = W\cdot(65.4)$ kJ

$\Delta H^\circ_{water} = H_{60} - H_{25} = (244-W)(4.184\text{ kJ/kg°C})(50-25\text{°C}) = 25520 - (104.6)W$

Heat loss $\Delta H_L = 7360$ kJ

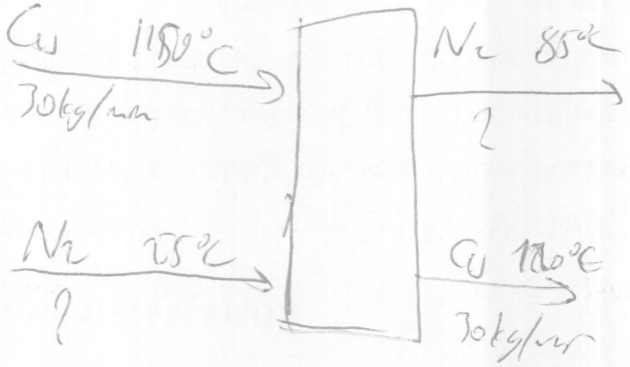
$\Delta H_{H_2O} = -46200 - 1020 + 2440W + 2330 + 65.4W + 25520 - 104.6W + 7360$

$= -12010 + 2400.8W \Rightarrow$ $\boxed{W = 5\text{ kg}}$

c) Heat balance for Adiabatic process

There is no heat loss in this process

Example



$H^\circ_{Cu,1150^\circ C} = 46.978\ kJ/mol$ $H^\circ_{N_2,25^\circ C} = 0\ kJ/mol$ $MW_{Cu} = 63.55$

$MW_{N_2} = 28.014$

$H^\circ_{Cu,120^\circ C} = 2.367\ kJ/mol$ $H^\circ_{N_2,85^\circ C} = 1.749\ kJ/mol$

$n_{Cu} = 472.07\ mol$ $\Delta H_t = 0$ $Q = 0$

$$\Delta H_{Cu} + \Delta H_{N_2} = 0$$

$$n_{Cu}(H_{120} - H_{1150}) + n_{N_2}(H_{85} - H_{25}) = 0$$

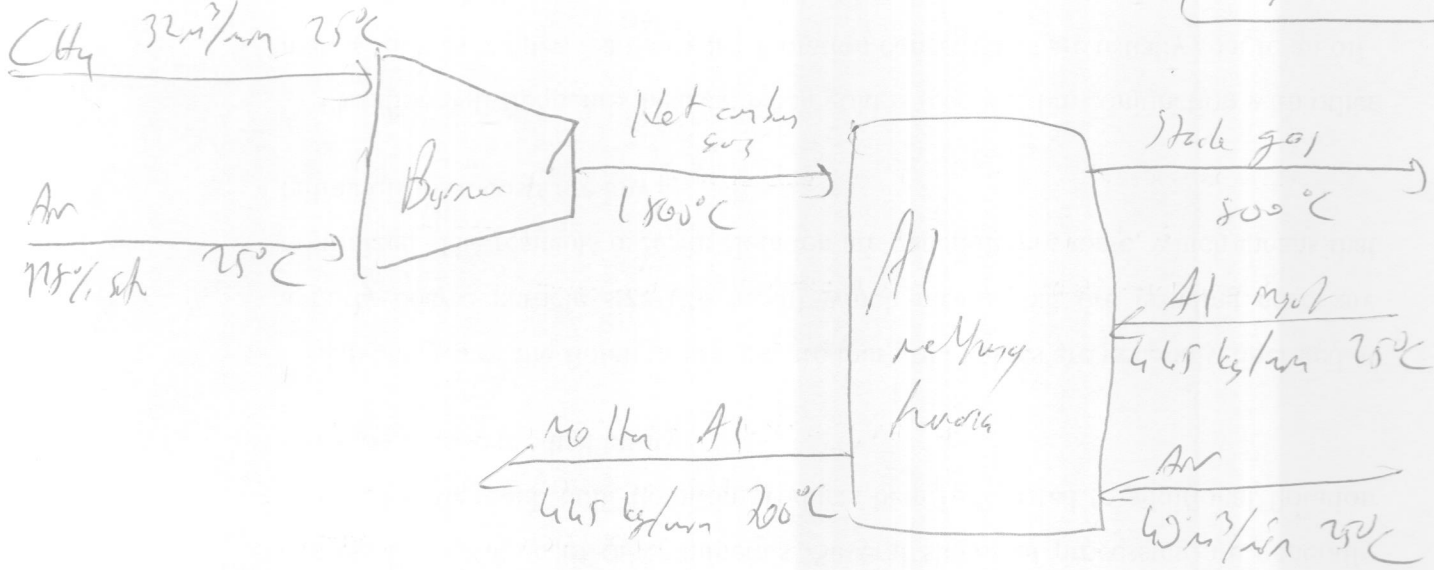
$$472.07\,(2.367 - 46.978) + n_{N_2}(1.749 - 0) = 0$$

$$-20115.37 + n_{N_2}(1.749) = 0 \Rightarrow n_{N_2} = 11501.07\ mol$$

$1\ mol \quad 0.0274\ m^3$

$= 257.62\ m^3/min$ N_2

3)



- 1) Burner

$$CH_4 + 2O_2 \xrightarrow{25^\circ C} CO_2 + 2H_2O \quad \text{at STP}$$

32 m³/min 64 m³/min 32 m³/min 64 m³/min

1 mol gas 22.4 L

0.0224 m³

1428.57 mol 2857.14 1428.57 2857.14 m³/min

+ 110% theor 75.52 m³/min O_2 (3371.48 mol) 284.10 m³/min N_2 (12682.99 mol)

$$\Delta H_{rxn} = n_{CO_2} \cdot H^\circ_{f,CO_2} + n_{H_2O} \cdot H^\circ_{f,H_2O} - n_{CH_4} \cdot H^\circ_{f,CH_4} - n_{O_2} \cdot H^\circ_{f,O_2}$$

1428.57 x 1.(−393.505) + 2.(−241.826) − 1.(−74600) − 2.0

kJ/mol (−74600)

	(g)	(g)	$\Delta H^\circ_{f,298}$ (−393.505)	(−241.826)	(g)	(g)
	CH_4	+ O_2	+ N_2	→ CO_2	+ H_2O	+ O_2 + N_2
mol/min	1428.57	3371.43	12682.99	1428.57	2857.14	514.29 12682.99

$$\Delta H_{rxn} = -1146508.85 \text{ kJ/min}$$

	CH_4	CO_2	H_2O	O_2	N_2
H°_{298} kJ/mol	-74.600	-393.505	-241.826	0	0
H°_{800} kJ/mol	-30.372	-356.087	-212.724	25.270	23.869
H_{1800} kJ/mol	61.314	-297.623	-164.904	61.973	58.772
$H_{1800} - H_{298}$	135.914	95.882	76.922	61.973	58.772
$H_{800} - H_{1800}$	-91.686	-58.664	-47.820	-36.703	-34.903
$H_{800} - H_{298}$	44.228	37.418	29.102	25.270	23.869

	H°_{298}	$H^\circ_{660.3,s}$ (melting)	$\Delta H_{melting}$	$H^\circ_{660.3,l}$ (liquid)	$H^\circ_{660.3}$ (g)
Al	0	18.144	10.711	30.116	28.855

$$\sum H^{\circ}_{1800^{\circ}C,\,gas} = n_{CO_2} \cdot H^{\circ}_{CO_2,1800} + n_{H_2O} \cdot H^{\circ}_{H_2O,1800} + n_{O_2} \cdot H^{\circ}_{O_2,1800} + n_{N_2} \cdot H^{\circ}_{N_2,1800^{\circ}C}$$

$$= 1428.57 \cdot (95.882) + 2857.14 (76.922) + 514.29 (61.973) + 12682.99 (58.777)$$

$$= 1134027.85$$

In Burner process 124899 kJ/mn Heat lost

2) Melting

H_{a1} 1134027.85 kJ/mn

In = 1800°C Hot combustion gas: 1428.57 mol CO_2, 514.29 mol O_2, 2857.14 mol H_2O, 12682.99 mol N_2

25°C 445 kg/mn Al: 16493.70 mol Al — ΔH_{298}

25°C 40 m³/mn Air: 1785.71 mol/mn Air: 375 mol O_2, 1410.71 mol N_2 — ΔH_{298}

Out = 800°C Stack gas: 1428.57 mol CO_2, 889.29 mol O_2, 2857.14 mol H_2O, 14093.70 mol N_2

700°C Al: 16493.70 mol Al

$$\Delta H^\circ_{\text{reaction}} = \left[H^\circ_{800} - H^\circ_{1800}\right]_{\text{combustion gas}} + \left[H^\circ_{800} - H^\circ_{298}\right]_{air}$$

$$= 1428.57(-58464) + 2852.14(-47.820) + 514.29(-36.703) + 12682.99(-34.903) + 375(25.720) + 1410.71(73.869)$$

$$= -681698.7\ \text{kJ/mol}$$

$$\approx -638550.25\ \text{kJ/mol}$$

$$\Delta H^\circ_{R1} = \left[H^\circ_{660.3}(\text{solid}) - H^\circ_{298}\right] + \left[\Delta H_{\text{melting}}(\text{solid} \to \text{liquid})\right] + \left[H^\circ_{1900} - H^\circ_{660.3}(\text{liquid})\right]$$

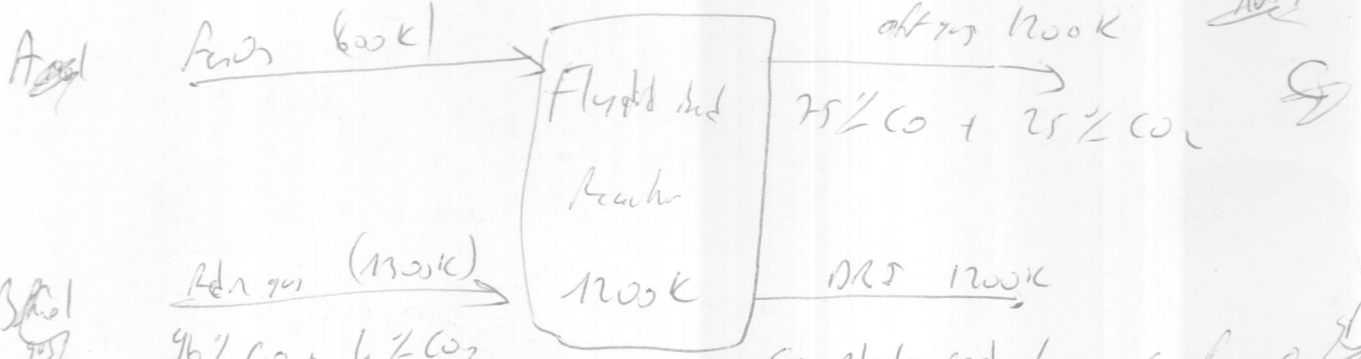
$$16493.70\ \text{mol} \times \left[18.144 + 10.711 + 1.261\right]$$

$$= 496724.17\ \text{kJ/mol}$$

$$496724.17 - 638550.75 = \boxed{-141825.98\ \text{kJ/mol} \quad \text{Heat lost}}$$

5) System Balance on Reactive System

Steps 807



$$Fe_2O_3 + 3CO_{(g)} = 2Fe + 3CO_2$$

- Heat balance

I) Fe_2O_3 (600 K) → Fe_2O_3 (1200 K) $\quad \Delta H_I^\circ$

II) Rdn gas (1300 K) → Rdn gas (1200 K) $\quad \Delta H_{II}^\circ$

III) Rxn $Fe_2O_3 + 3CO_{(g)} \overset{1200K}{=} 2Fe + 3CO_2 \quad \Delta H_{III}^\circ$

IV) Heat loss is 11 kJ/mol Fe2O3 reduced

$$Fe_2O_3 + 3CO \rightleftharpoons 2Fe + 3CO_2$$

for 1 mol 3 mol CO consumed 2 mol Fe and 3 mol CO_2 produced

$$n_{CO}^{out} = n_{CO}^{in} - 3$$
$$n_{CO_2}^{out} = n_{CO_2}^{in} + 3$$

We have 1 mol Fe_2O_3

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2$$

1 mol 3 mol 2 mol 3 mol

We have X mol gas $\quad n_{CO}^{in} = 0.96X \quad n_{CO_2}^{in} = 0.04X$

3 M gas consumed 3 mol gases reduced total gas not change

$$n_{CO}^{out} = n_{CO}^{in} - 3 \qquad n_{CO}^{out} = 0.75X \quad n_{CO_2}^{out} = 0.25X$$

$$0.75X = 0.96X - 3 \Rightarrow 0.21X = 3 \quad X = 14.285 \text{ mol}$$

$n_{CO}^{in} = 13.714 \quad n_{CO_2}^{in} = 0.517 \quad n_{CO}^{out} = 10.714 \quad n_{CO_2}^{out} = 3.517$ mol

$n_{Fe_2O_3} = 1$ mol $\quad n_{Fe} = 2$ mol

We need

$H_{CO_2,1000K} = -349.006$ kJ/mol $\quad H_{Fe_2O_3,1000K} = -785.352$ kJ/mol

$H_{CO,1000K} = -343.328$ kJ/mol $\quad H_{Fe_2O_3,1000K} = -694.881$ kJ/mol

$H_{CO,1000K} = -82.108$ kJ/mol $\quad H_{Fe,1000K} = 35.119$ kJ/mol

$H_{C,1000K} = -78.672$ kJ/mol

I) $\Delta H_I^\circ = \left(H_{1100,Fe_2O_3} - H_{600,Fe_2O_3}\right) \cdot n_{Fe_2O_3} = (-694.881 + 785.357)\,kJ$

$\Delta H_I = 90.476\ kJ$

II) $\Delta H_{II} = n_{CO}^{in} \cdot \left(H_{1100,CO} - H_{1100,CO}\right) + nCO_2^{in}\left(H_{1100,CO_2} - H_{1100,CO_2}\right)$

$= 13.714\,(-82.108 + 78.672) + 0.517\,(-349.006 + 343.328)$

$= -50.057\ kJ$

III) $\Delta H_{III} = \Delta H_{rxn,1100\,k} = n_{Fe} \cdot H_{1100,Fe} + n_{Fe} \cdot H_{1100,CO_2} - n_{Fe_2O_3} \cdot H_{1100,Fe_2O_3} - n_{CO} \cdot H_{1100,CO}$

$= 2.(35.119) + 3.(-349.006) - 1.(-694.881) - 3.(-82.108)$

$= -35.575\ kJ$

IV) $\Delta H_L = 11\ kJ$

overall = Net effect = 15.844 kJ/mol (Fe_2O_3) required.