Energy balance

The datum temperature for calculation is taken as 30 °C. (303K)

Energy balance around the Lime kiln

$$CaCO_3 \longrightarrow CaO + CO_2 \qquad \Delta H_{25} = 43.4 \text{ Kcal/mole}$$

$$C + O_2 \longrightarrow CO_2 \qquad \Delta H_{25} = -96.4 \text{ Kcal/mole}$$

Temperature of reaction is 1100^0 C

Inputs:

Temperature of input reactants = 30^0 C

Therefore heat of reactants =0

Heat of reaction at 1100^0C(ΔH_{1100}) = $-3.8*10^{09}$ calories

Outputs:

Out put temperature of products = T Kelvin

Heat output = $(mc_p\Delta t)_{Cao} + (mc_p\Delta t)_{Co2} + (mc_p\Delta t)_{C(unreated)} + (mc_p\Delta t)_{CaCO3(unreacted)} + (mc_p\Delta t)_{N2}$

$$= (4798.5T - 1.347*10^{11}/T^2 + 15.58*10^{06})(T-303)$$

From heat balance

$$3.8*10^{09} = (4798.5T - 1.347*10^{11}/T^2 + 15.58*10^{06})(T-303)$$

T= 520 K

Or T= 247^0 C

Energy balance around Slaker

$CaO + H_2O \longrightarrow Ca(OH)_2$ ΔH_{25}= -15.6 Kcal/mole

Reaction temperature = 100^0C

Inputs:

Temperature of input water stream = 30^0C

Temperature of input calcium oxide stream = 247^0C

Heat input by reactants = $0.775*10^{09}$ calories

Heat of reaction (ΔH_{100}) = $-4.824*10^{09}$ calories

Out puts:

Temperature of output stream = T Kelvin

Heat output = $(mc_p\Delta t)_{Ca(OH)2} + (mc_p\Delta t)_{H2O}$

$= (10.698*10^{06} + 3862.02T - 0.1054T^2)(T-303)$

From heat balance

$4.824*10^{06} = (10.698*10^{06} + 3862.02T - 0.1054T^2)(T-303)$

T= 720 K

Or T=447^0 C

Energy balance around ammonia absorption tower

Inputs:

Temperature of input brine = 30^0C

Temperature of input gases = 60^0C

Heat input = $(mc_p\Delta t)_{gases}$

= (1666.9*7440*30)

= $0.372*10^{09}$

outputs:

Temperature of output liquid stream = 40^0C

Temperature of output gas stream = 30^0C

heat output = $(mc_p\Delta t)_{NaCl}+(mc_p\Delta t)_{NH3}+(mc_p\Delta t)_{H2O}$

= (786.16*12200+1070.18*8671.9+6523.87*18026)(40-30)

= $1.363*10^{09}$ calories

From heat balance

$0.372*10^{09} = 1.363*10^{09}$ + heat removed

Heat removed = $0.99*10^{09}$ calories

Water required for cooling the tower = $0.99*10^{09}/(1000*(45-30))$

= 66000 kg/hr

Energy balance around carbonating tower

NaCl + NH4OH +CO2 ⟶ NH4Cl + NaHCO3

Reaction temperature = 60^0C
Temperature of reactants = 30^0C
Heat input =0
Heat of reaction (ΔH_{60}) = $-5.8229*10^9$ calorie

Heat output = $25.29*10^6$

From heat balance

$5.8229*10^9 =- 25.29*10^6$ + heat removed

Heat removed = $5.848*10^9$

Cooling water required = $5.848*10^9/(1000*(45-25))$

= 292400 kg/hr

Heat balance around ammonia distiller

$2NH4Cl + Ca(OH)_2 \longrightarrow 2NH3 + CaCl2 + 2H2O$

$NH4OH \longrightarrow NH3 + H_2O$

Reaction temperature = 75^0C

Inputs:

Heat input $=(mc_p\Delta t)_{Ca(OH)2} + (mc_p\Delta t)_{H2O} + (mc_p\Delta t)_{NH4Cl} + (mc_p\Delta t)_{Nacl(unreacted)} + (mc_p\Delta t)_{NH4OH}$

=(294.8113*22489.6+122736.3866*4180+589.6226*22936+196.5408*12337.2+

480.56*11.560)(25)

= $0.5411*10^{09}$ calories

Heat of reaction $(\Delta H_{75})= 4.506*10^{09}$ calories

Outputs:

Temperature of output stream = 60^0C

Heat output $= (mc_p\Delta t)_{NH3} + (mc_p\Delta t)_{H2O} + (mc_p\Delta t)_{CaCl2} + (mc_p\Delta t)_{Nacl(unreacted)}$

$= 0.2824*10^{09}+1.78*10^{10}+0.1608*10^{09} +2.413*10^{06}$

$= 1.824*10^{10}$

From heat balance

$0.5411*10^{09}- 4.506*10^{09} + 2.25*10^{09} = 1.824*10^{10}$ + heat removed

Heat removed = $0.2951*10^{09}$ calories

Heat balance around calciner

2NaHCO3 ⟶ Na_2CO_3 + CO2 + H_2O

Reaction temperature =200^oC

Inputs:

Reactant temperature=30^0C

Heat input=0

Heat of reaction = 2.02*10^{10} calories

Outputs:

Output stream temperature= 180^0C

Heat output=$(mc_p\Delta t)_{Na2CO3}$ + $(mc_p\Delta t)_{H2O}$ +$(mc_p\Delta t)_{CO2}$

= 294.811*28900*150+294.812*8311.8*150+294.8113*10610.4*150

= 2.114*10^{09} calories

From heat balance

-2.02*10^{10} + heat supplied = 2.114*10^{09}

heat supplied = 2.23*10^{10} calories