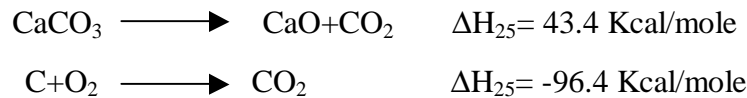


Energy balance

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

Energy balance around the Lime kiln



Temperature of reaction is 1100⁰ C

Inputs:

Temperature of input reactants = 30⁰ C

Therefore heat of reactants = 0

Heat of reaction at 1100⁰C (ΔH_{1100}) = -3.8×10^9 calories

Outputs:

Out put temperature of products = T Kelvin

Heat output = $(mc_p \Delta t)_{\text{CaO}} + (mc_p \Delta t)_{\text{CO}_2} + (mc_p \Delta t)_{\text{C(unreacted)}} + (mc_p \Delta t)_{\text{CaCO}_3(\text{unreacted})} + (mc_p \Delta t)_{\text{N}_2}$

$$= (4798.5T - 1.347 \times 10^{11}/T^2 + 15.58 \times 10^6)(T-303)$$

From heat balance

$$3.8 \times 10^9 = (4798.5T - 1.347 \times 10^{11}/T^2 + 15.58 \times 10^6)(T-303)$$

$$T = 520 \text{ K}$$

$$\text{Or } T = 247^0 \text{ C}$$

Energy balance around Slaker



Reaction temperature = 100°C

Inputs:

Temperature of input water stream = 30°C

Temperature of input calcium oxide stream = 247°C

Heat input by reactants = 0.775×10^9 calories

Heat of reaction (ΔH_{100}) = -4.824×10^9 calories

Out puts:

Temperature of output stream = T Kelvin

$$\begin{aligned} \text{Heat output} &= (mc_p \Delta t)_{\text{Ca(OH)}_2} + (mc_p \Delta t)_{\text{H}_2\text{O}} \\ &= (10.698 \times 10^6 + 3862.02T - 0.1054T^2)(T-303) \end{aligned}$$

From heat balance

$$4.824 \times 10^9 = (10.698 \times 10^6 + 3862.02T - 0.1054T^2)(T-303)$$

$$T = 720 \text{ K}$$

$$\text{Or } T = 447^\circ \text{C}$$

Energy balance around ammonia absorption tower

Inputs:

Temperature of input brine = 30°C

Temperature of input gases = 60°C

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

$$= (1666.9 \times 7440 \times 30)$$

$$= 0.372 \times 10^9$$

outputs:

Temperature of output liquid stream = 40°C

Temperature of output gas stream = 30°C

$$\begin{aligned} \text{heat output} &= (mc_p\Delta t)_{\text{NaCl}} + (mc_p\Delta t)_{\text{NH}_3} + (mc_p\Delta t)_{\text{H}_2\text{O}} \\ &= (786.16 \times 12200 + 1070.18 \times 8671.9 + 6523.87 \times 18026)(40-30) \\ &= 1.363 \times 10^9 \text{ calories} \end{aligned}$$

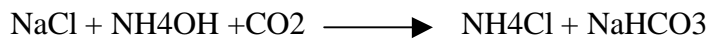
From heat balance

$$0.372 \times 10^9 = 1.363 \times 10^9 + \text{heat removed}$$

$$\text{Heat removed} = 0.99 \times 10^9 \text{ calories}$$

$$\begin{aligned} \text{Water required for cooling the tower} &= 0.99 \times 10^9 / (1000 \times (45-30)) \\ &= 66000 \text{ kg/hr} \end{aligned}$$

Energy balance around carbonating tower



$$\text{Reaction temperature} = 60^\circ\text{C}$$

$$\text{Temperature of reactants} = 30^\circ\text{C}$$

$$\text{Heat input} = 0$$

$$\text{Heat of reaction } (\Delta H_{60}) = -5.8229 \times 10^9 \text{ calorie}$$

$$\text{Heat output} = 25.29 \times 10^6$$

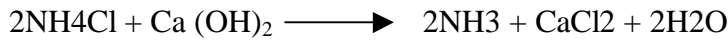
From heat balance

$$5.8229 \times 10^9 = -25.29 \times 10^6 + \text{heat removed}$$

$$\text{Heat removed} = 5.848 \times 10^9$$

$$\begin{aligned} \text{Cooling water required} &= 5.848 \times 10^9 / (1000 \times (45-25)) \\ &= 292400 \text{ kg/hr} \end{aligned}$$

Heat balance around ammonia distiller



Reaction temperature = 75°C

Inputs:

$$\text{Heat input} = (\text{mc}_p\Delta t)_{\text{Ca}(\text{OH})_2} + (\text{mc}_p\Delta t)_{\text{H}_2\text{O}} + (\text{mc}_p\Delta t)_{\text{NH}_4\text{Cl}} + (\text{mc}_p\Delta t)_{\text{NaCl}(\text{unreacted})} + (\text{mc}_p\Delta t)_{\text{NH}_4\text{OH}}$$

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

$$480.56 * 11.560) (25)$$

$$= 0.5411 * 10^{09} \text{ calories}$$

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

Outputs:

Temperature of output stream = 60°C

$$\text{Heat output} = (\text{mc}_p\Delta t)_{\text{NH}_3} + (\text{mc}_p\Delta t)_{\text{H}_2\text{O}} + (\text{mc}_p\Delta t)_{\text{CaCl}_2} + (\text{mc}_p\Delta t)_{\text{NaCl}(\text{unreacted})}$$

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

$$= 1.824 * 10^{10}$$

From heat balance

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

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

Heat balance around calciner



Reaction temperature = 200°C

Inputs:

Reactant temperature = 30°C

Heat input = 0

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

Outputs:

Output stream temperature = 180°C

$$\begin{aligned}\text{Heat output} &= (mc_p \Delta t)_{\text{Na}_2\text{CO}_3} + (mc_p \Delta t)_{\text{H}_2\text{O}} + (mc_p \Delta t)_{\text{CO}_2} \\ &= 294.811 \times 28900 \times 150 + 294.812 \times 8311.8 \times 150 + 294.8113 \times 10610.4 \times 150 \\ &= 2.114 \times 10^9 \text{ calories}\end{aligned}$$

From heat balance

$$-2.02 \times 10^{10} + \text{heat supplied} = 2.114 \times 10^9$$

$$\text{heat supplied} = 2.23 \times 10^{10} \text{ calories}$$