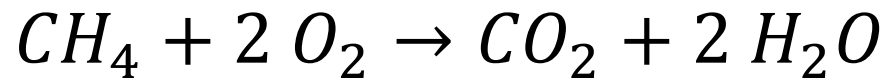


Enthalpy of Reaction

How many liters of methane must be burned to produce 1 kg of cement (CaO)? The cement reaction is:



The combustion of methane is:



The thermodynamic data are:

$$\Delta_f H^\circ(CO_2) = -393.5 \text{ kJ/mol}$$

$$\Delta_f H^\circ(H_2O) = -286 \text{ kJ/mol}$$

$$\Delta_f H^\circ(CH_4) = -74.9 \text{ kJ/mol}$$

$$\Delta_f H^\circ(CaO) = -634.9 \text{ kJ/mol}$$

$$\Delta_f H^\circ(CaCO_3) = -1207.9 \text{ kJ/mol}$$



Enthalpy of Reaction

Step 1: Calculate the enthalpies of reaction for each process.

$$\Delta_{rxn}H^{\circ} = \Delta_fH^{\circ}(CaO) + \Delta_fH^{\circ}(CO_2) - \Delta_fH^{\circ}(CaCO_3)$$

$$\begin{aligned}\Delta_{rxn}H^{\circ} &= (-634.9) + (-393.5) - (-1207.9) \\ &= +179.5 \text{ kJ/mol}\end{aligned}$$

$$\Delta_{rxn}H^{\circ} = 2\Delta_fH^{\circ}(H_2O) + \Delta_fH^{\circ}(CO_2) - \Delta_fH^{\circ}(CH_4)$$

$$\begin{aligned}\Delta_{rxn}H^{\circ} &= 2(-286) + (-393) - (-74.9) \\ &= -890.1 \text{ kJ/mol}\end{aligned}$$

Step 2: Calculate the number of moles of CaO in 1 kg.

$$n_{CaO} = \frac{m_{CaO}}{M_{m,CaO}} = \frac{1000 \text{ gm}}{56 \frac{\text{gm}}{\text{mol}}} = 17.85 \text{ moles}$$

Enthalpy of Reaction

Step 3: Calculate total heat required to produce 1 kg of CaO.

$$q_{CaO} = n_{CaO} \Delta_{rxn} H^{\circ} = (17.85 \text{ moles}) \left(179.5 \frac{\text{kJ}}{\text{mol}} \right)$$

$$q_{CaO} = 3204 \text{ kJ}$$

Use this value to calculate the number of moles of CH₄ needed and finally the volume of V_f

$$n_{CH_4} = \frac{-q_{CH_4}}{\Delta_{rxn} H^{\circ}} = \frac{-3204 \text{ kJ}}{-890.1 \text{ kJ/mol}} = 3.6 \text{ moles}$$

$$V_{CH_4} = \frac{n_{CH_4} RT}{P} = \frac{(3.6)(0.08206)(298)}{1} = 88.0 \text{ L}$$