Enthalpy of Reaction

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

$$CaCO_3 \rightarrow CaO + CO_2$$

The combustion of methane is:

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

The thermodynamic data are:

$$\Delta_f H^o(CO_2) = -393.5\ kJ/mol$$

$$\Delta_f H^o(H_2O) = -286\ kJ/mol$$

$$\Delta_f H^o(CH_4) = -74.9\ kJ/mol$$

$$\Delta_f H^o(CaO) = -634.9\ kJ/mol$$

$$\Delta_f H^o(CaCO_3) = -1207.9\ kJ/mol$$

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

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

$$\Delta_{rxn}H^o = (-634.9) + (-393.5) - (-1207.9)$$

$$= +179.5\ kJ/mol$$

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

$$\Delta_{rxn}H^o = 2(-286) + (-393) - (-74.9)$$

$$= -890.1\ kJ/mol$$

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

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

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

$$q_{CaO} = n_{CaO}\Delta_{rxn}H^{o} = (17.85\,moles)(179.5\,\frac{kJ}{mol})$$

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

Use this value to calculate the number of moles of CH_4 needed and finally the volume of Vf

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

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