Thermodynamics of the Simplest Combustion Reaction (25°C)

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$

$$\Delta_r H^\circ = 2\Delta_f H^\circ(H_2O_{(g)}) - 2\Delta_f H^\circ(\underbrace{H_{2(g)}}_{0}) - \Delta_f H^\circ(\underbrace{O_{2(g)}}_{0})$$

$$= 2(-241.826 \text{ kJ mol}^{-1})$$

$$\boxed{\Delta_r H^\circ = -483.652 \text{ kJ mol}^{-1}}$$

$$\Delta_r S^\circ = 2S^\circ(H_2O_{(g)}) - 2S^\circ(H_{2(g)}) - S^\circ(O_{2(g)})$$

$$= [2(188.72) - 2(130.6) - 205.0] \text{ J mol}^{-1}\text{K}^{-1}$$

$$\boxed{\Delta_r S^\circ = -88.7_6 \text{ J mol}^{-1}\text{K}^{-1}}$$

$$\Delta_r G^\circ = \Delta_r H^\circ - T\Delta_r S^\circ = -RT\ln K$$

$$\ln K = -\frac{\Delta_r H^\circ}{RT} + \frac{\Delta_r S^\circ}{R} = \frac{1}{R}\left(-\frac{\Delta_r H^\circ}{T} + \Delta_r S^\circ\right)$$

$$K = \exp\left\{\left(\frac{\cancel{\text{mol}}\,\cancel{K}}{8.315\,\cancel{J}}\right)\left(+\left(\frac{483652\,\cancel{J}}{\cancel{\text{mol}}}\right)\left(\frac{1}{298._{15}\,\cancel{K}}\right) - \frac{88.7_6\,\cancel{J}}{\cancel{\text{mol}}\,\cancel{K}}\right)\right\}$$

$$\boxed{K = 1 \times 10^{80}}$$