Thermodynamics - Pressure and Temperature - Combustion of Methane and air

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The total reaction of interest is,

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

The heat of combustion for methane and diatomic oxygen is $\triangle H = -891\frac{\mathrm{kJ}}{\mathrm{mol}}$. Determine the amount of energy that can be used as work from this reaction per mol consumed.

Solution:

The measured and tabulated values for one mole of each species are,

Chemical	Entropy
H_2O	$70\frac{\mathrm{J}}{\mathrm{K}}$
O_2	$205\frac{\mathrm{J}}{\mathrm{K}}$
CH_4	$187\frac{\mathrm{J}}{\mathrm{K}}$
CO_2	$214\frac{\mathrm{J}}{\mathrm{K}}$

The entropy sum for the above reaction is

$$\triangle S = 214\frac{\mathrm{J}}{\mathrm{K}} + 2 \cdot 70\frac{\mathrm{J}}{\mathrm{K}} - 187\frac{\mathrm{J}}{\mathrm{K}} - 2 \cdot 205\frac{\mathrm{J}}{\mathrm{K}} = -243\frac{\mathrm{J}}{\mathrm{K}}.$$

The system's entropy decreases by this amount. The maximum amount of heat that can enter the system is therefore

$$T\triangle S = (298\mathrm{K})\left(-243\frac{\mathrm{J}}{\mathrm{K}}\right) = -72.45\mathrm{kJ}.$$

The amount of energy that must enter as electrical work is,

$$\triangle G = \triangle H - T\triangle S = -891\mathrm{kJ} - (-72.45\mathrm{kJ}) = -819\mathrm{kJ}$$

This is the change in the system's Gibb's free energy; it is the minimum "other" work required to make the reaction go. This is the amount of work possible for every methane and 2 diatomic oxygen molecules consumed.

A combustion process without heat loss or gain is adiabatic. At 1atm, the minimum temperature of the adiabatic flame front is 2223K. Reactants enter the combustion process at 298K and 1atm pressure. The products leaves the process at 1atm pressure combustion is stoichiometric without any excess air. Excess air will reduce the adiabatic flame temperature and is often introduced to avoid flame temperatures exceeding limits sets by the materials in the combustion system.[1]

[1] http://www.engineeringtoolbox.com/adiabatic-flame-temperature-d_996.html