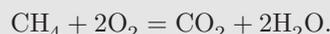


to carbon dioxide and water. For simplicity, assume the heat capacities of the species to be constant and equal to the values given below (in J/mol):

$$C_{P,\text{CH}_4} = 55.42, \quad C_{P,\text{O}_2} = 32.53, \quad C_{P,\text{N}_2} = 30.37, \quad C_{P,\text{CO}_2} = 48.65, \quad C_{P,\text{H}_2\text{O}} = 36.94.$$

Solution The combustion reaction of methane is



For stoichiometric combustion we need 2 mol of oxygen. The actual amount of oxygen is 20% above the stoichiometric requirement, or, $2 + (0.2)(2) = 2.4$ mol. Assuming air to be 21% oxygen and 79% nitrogen, the inlet stream contains nitrogen in the amount $(79/21)$ times the amount of oxygen:

$$\frac{79}{21} (2.4) = 9.02857.$$

Even though nitrogen does not participate in the reaction, it is a component of the mixture and must be included in the mole and energy balance. We now construct the stoichiometric table:

	CH ₄	O ₂	N ₂	CO ₂	H ₂ O	
ν_i	-1	-2	0	1	2	
n_{i0}	1	2.4	9.02857	0	0	mol
n_i	$1 - \xi$	$2.4 - 2\xi$	9.02857	ξ	2ξ	mol
H_{298}°	-75520	0	0	-393509	-241818	J/mol
C_{P_i}	55.42	32.53	30.37	48.65	36.94	J/mol K

For complete combustion of methane, $\xi = 1$.

The assumptions behind eq. (14.13) are acceptable in this problem: mixing effects can be neglected as products and reactants are close to the ideal-gas state at 2 bar and at the temperatures of this problem; in addition, no phase changes take place in bringing the inlet species from inlet conditions (40 °C, 2 bar) to standard conditions at 25 °C, 1 bar, or the outlet species from standard conditions to 1000 °C, 2 bar. Therefore, eq. (14.13) may be used. With $T_{\text{in}} = 40 \text{ °C} = 313.15 \text{ K}$, $T_{\text{out}} = 1000 \text{ °C} = 1273.15 \text{ K}$, $T_0 = 25 \text{ °C} = 298.15 \text{ K}$, we have:

$$\Delta H_{\text{rxn}}^\circ(T_0) = (-1)(-75,520) + (-2)(0) + (1)(-393,509) + (2)(-241,818) = -801,625 \text{ J},$$

$$\sum_{\text{inlet}} \int_{T_{\text{in}}}^{T_0} n_{i0} C_{P_i} dT = \left((1)(55.42) + (2.4)(32.53) + (9.02857)(30.37) \right) (298.15 - 313.15) = -6,115.35 \text{ J},$$

$$\sum_{\text{outlet}} \int_{T_0}^{T_{\text{out}}} n_i C_{P_i} dT = \left((0.4)(32.53) + (9.02857)(30.37) + (1)(48.65) + (2)(36.94) \right) \times (1,273.15 - 298.15) = 399,496 \text{ J}.$$