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):

$$C_{P,CH_4} = 55.42, \quad C_{P,O_2} = 32.53, \quad C_{P,N_2} = 30.37, \quad C_{P,CO_2} = 48.65, \quad C_{P,H_2O} = 36.94.$$

Solution The combustion reaction of methane is

$$CH_4 + 2O_2 = CO_2 + 2H_2O.$$

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:

2.4

$$\frac{79}{21}(2.2) = 9.02857.$$

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_2O	
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_{Pi}	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 $T_{in} = 40\ °C = 313.15$ K, $T_{out} = 1000\ °C = 1273.15$ K, $T_0 = 25\ °C = 298.15$ K, we have:

$$\begin{aligned}\Delta H^\circ_{rxn}(T_0) &= (-1)(-75,520) + (-2)(0) + (1)(-393,509) + (2)(-241,818)\\ &= -801,625 \text{ J},\end{aligned}$$

$$\begin{aligned}\sum_{\text{inlet}} \int_{T_{in}}^{T^\circ} n_{i0} C_{Pi}\, dT &= \Big((1)(55.42) + (2.4)(32.53) + (9.02857)(30.37)\Big)(298.15 - 313.15)\\ &= -6,115.35 \text{ J},\end{aligned}$$

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