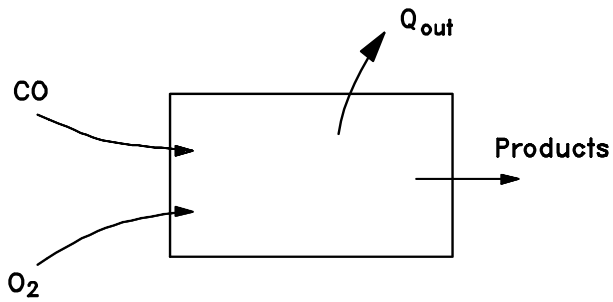
Problem: 12-24

Given: One mole of CO reacts with one mole of O_2 in a steady-flow process at 77 $°F$ and 1 atm.

Find: The heat transfer from the system when the temperature of the products is 3000 K and 2800 K



at 3000 $K = 5400\ R$

$$CO + O_2 \rightarrow aCO_2 + bCO + cO_2$$

a mass balance gives:

$$\begin{aligned} C &: \ 1 = a + b \Rightarrow b = 1 - a \\ O &: \ 1 + 2 = 2a + b + 2c \Rightarrow c = (2 - a)/2 \end{aligned}$$

$$\begin{aligned} n_{tot} &= a + b + c \\ &= (4 - a)/2 \end{aligned}$$

K-equation

$$CO_2 \rightleftharpoons CO + \frac{1}{2}O_2$$

From Table B.14, $K = 10^{-0.469} = 0.340$, or

$$K = \frac{n_{CO} n_{O_2}^{1/2}}{n_{CO_2}} \left(\frac{1}{n_{tot}}\right)^{1+1/2-1}$$

$$
\begin{aligned}
&= \frac{(1-a)\left(\frac{2-a}{a}\right)^{1/2}}{a}\left(\frac{1}{(4-a)/2}\right)^{1/2} \\
&= \frac{1-a}{a}\left(\frac{2-a}{4-a}\right)^{1/2} \\
&= 0.340
\end{aligned}
$$

Solving, gives

$$
\begin{aligned}
a &\approx 0.66 \\
b &\approx 0.35 \\
c &\approx 0.675
\end{aligned}
$$

<u>Energy balance</u>

$$
Q_{out} = \sum_{Reactants} n\hat{h} - \sum_{Products} n\hat{h}
$$

where

$$
\begin{aligned}
\hat{h}_{CO}(537\ R) &= -47517\ Btu/lbm \\
\hat{h}_{O_2}(537\ R) &= 0\ Btu/lbm \\
\hat{h}_{CO_2}(5400\ R) &= -103200\ Btu/lbm \\
\hat{h}_{CO}(5400\ R) &= -7300\ Btu/lbm \\
\hat{h}_{O_2}(5400\ R) &= 42000\ Btu/lbm
\end{aligned}
$$

which gives

$$
\begin{aligned}
Q_{out} &= [(1)(-47517) - (1)(0)] - [(0.65)(-103200) + (0.35)(-7300) + (0.675)(42000)] \\
&= \boxed{-6300\ Btu/lbm}
\end{aligned}
$$

<u>at 2800 $K = 5040\ R$</u>
use the same approach as above

$$
\begin{aligned}
k &= 0.156 \\
a &\approx 0.796 \\
b &\approx 0.204 \\
c &\approx 0.602
\end{aligned}
$$

$$
\begin{aligned}
\hat{h}_{CO}(537\ R) &= -47517\ Btu/lbm \\
\hat{h}_{O_2}(537\ R) &= 0\ Btu/lbm \\
\hat{h}_{CO_2}(5400\ R) &= -109000\ Btu/lbm \\
\hat{h}_{CO}(5400\ R) &= -10800\ Btu/lbm \\
\hat{h}_{O_2}(5400\ R) &= 38400\ Btu/lbm
\end{aligned}
$$

$$
Q_{out} = \boxed{18700\ Btu/lbm}
$$

for adiabatic flame temperature, $Q_{ad} = 0$
interpolate between 5400 R and 5040 R

$$
T_{ad} \approx 5300\ R = \boxed{2950\ K}
$$