Solution for Problem T14

(a) Conservation of atoms:

Carbon: $A = C$ | $C = A$ (1)

Hydrogen: $1.95A = 2D$ | $D = \frac{1.95}{2}A$ (2)

Oxygen: $2B = 2C + D + 2E$ | $E = B - A - \frac{1.95}{4}A$ (3)

Nitrogen: $3.76 \times 2B = 2F$ | $F = 3.76\,B$ (4)

Impose 1 kg of reactants:

$$13.95\,A + \underbrace{(32 + 3.76 \times 28)}_{137.3}\,B = 1000 \qquad (5)$$

Impose $f = 0.03$:

$$\frac{13.95\,A}{(32 + 3.76 \times 28)\,B} = 0.03 \qquad (6)$$

Combine (6) and (5): $13.95\left(1 + \frac{1}{0.03}\right) = 1000$ $\boxed{A = 2.088\ \frac{\text{mole Kero.}}{\text{kg}}}$

and then $B = \dfrac{13.95 \times 2.088}{0.03 \times 137.3}$ $\boxed{B = 7.072\ \frac{\text{mole air}}{\text{kg}}}$

The other coefficients follow from (1)-(4), with the result

$$\boxed{2.088\ CH_{1.95} + 7.072\,(O_2 + 3.76\,N_2) \rightarrow 2.088\ CO_2 + 2.036\ H_2O + 3.3665\ O_2 + 26.5915\ N_2} \qquad (7)$$

(b) For a first approximation, $\dot{m}_f h = \dot{m}_a c_p (T - T_{in})$, or

$$T = T_{in} + f\,\frac{h}{c_p} \qquad (8)$$

Using $h = 43 \times 10^6$ J/kg fuel, $c_p \simeq 1005$ J/kg/K (as pure air), we find

$$T = 600 + 0.03\,\frac{43 \times 10^6}{1005} \qquad \boxed{T = 1884\ K}$$

A more realistic estimate of c_p would be that for heated air, for which $\gamma = 1.3$ is sometimes assumed. This means

$c_p = \frac{1.3}{0.3}\,\frac{8.314}{0.0288} = 1249$ J/kg/K. With this c_p, $\underline{T = 1632K}$.