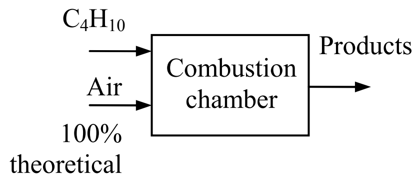
15-18 n-Octane is burned with stoichiometric amount of air. The mass fraction of each product, the mass of water in the products and the mass fraction of each reactant are to be determined.

Assumptions **1** Combustion is complete. **2** The combustion products contain CO_2, H_2O, O_2, and N_2 only.

Properties The molar masses of C, H_2, O_2 and air are 12 kg/kmol, 2 kg/kmol, 32 kg/kmol, and 29 kg/kmol, respectively (Table A-1).

Analysis The reaction equation for 100% theoretical air is



$$C_8H_{18} + a_{th}[O_2 + 3.76N_2] \longrightarrow B\,CO_2 + D\,H_2O + E\,N_2$$

where a_{th} is the stoichiometric coefficient for air. The coefficient a_{th} and other coefficients are to be determined from the mass balances

Carbon balance: $B = 8$

Hydrogen balance: $2D = 18 \longrightarrow D = 9$

Oxygen balance: $2a_{th} = 2B + D \longrightarrow a_{th} = 0.5(2 \times 8 + 9) = 12.5$

Nitrogen balance: $a_{th} \times 3.76 = E \longrightarrow E = 12.5 \times 3.76 = 47$

Substituting, the balanced reaction equation is

$$C_8H_{18} + 12.5[O_2 + 3.76N_2] \longrightarrow 8\,CO_2 + 9\,H_2O + 47\,N_2$$

The mass of each product and the total mass are

$$m_{CO2} = N_{CO2}M_{CO2} = (8\text{ kmol})(44\text{ kg/kmol}) = 352\text{ kg}$$
$$m_{H2O} = N_{H2O}M_{H2O} = (9\text{ kmol})(18\text{ kg/kmol}) = 162\text{ kg}$$
$$m_{N2} = N_{N2}M_{N2} = (47\text{ kmol})(28\text{ kg/kmol}) = 1316\text{ kg}$$
$$m_{total} = m_{CO2} + m_{N2} + m_{H2O} = 352 + 162 + 1316 = 1830\text{ kg}$$

Then the mass fractions are

$$\text{mf}_{CO2} = \frac{m_{CO2}}{m_{total}} = \frac{352\text{ kg}}{1830\text{ kg}} = \mathbf{0.1923}$$
$$\text{mf}_{H2O} = \frac{m_{H2O}}{m_{total}} = \frac{162\text{ kg}}{1830\text{ kg}} = \mathbf{0.0885}$$
$$\text{mf}_{N2} = \frac{m_{N2}}{m_{total}} = \frac{1316\text{ kg}}{1830\text{ kg}} = \mathbf{0.7191}$$

The mass of water per unit mass of fuel burned is

$$\frac{m_{H2O}}{m_{C8H18}} = \frac{(9 \times 18)\text{ kg}}{(1 \times 114)\text{ kg}} = \mathbf{1.421\,kg\,H_2O/kg\,C_8H_{18}}$$

The mass of each reactant and the total mass are

$$m_{C8H18} = N_{C8H18}M_{C8H18} = (1\text{ kmol})(114\text{ kg/kmol}) = 114\text{ kg}$$
$$m_{air} = N_{air}M_{air} = (12.5 \times 4.76\text{ kmol})(29\text{ kg/kmol}) = 1725.5\text{ kg}$$
$$m_{total} = m_{C8H18} + m_{air} = 114 + 1725.5 = 1839.5\text{ kg}$$

Then the mass fractions of reactants are

$$\text{mf}_{C8H18} = \frac{m_{C8H18}}{m_{total}} = \frac{114\text{ kg}}{1839.5\text{ kg}} = \mathbf{0.0620}$$
$$\text{mf}_{air} = \frac{m_{air}}{m_{total}} = \frac{1725.5\text{ kg}}{1839.5\text{ kg}} = \mathbf{0.9380}$$