Reaction Stoichiometry
Parallel Reactions

Problem 4-93

The manufacture of ethyl alcohol, C_2H_5OH, yields diethyl ether, $(C_2H_5)_2O$, as a by-product. The complete combustion of a 1.005-g sample of the product of this process yields 1.963 g CO_2. What must be the mass percents of C_2H_5OH and of $(C_2H_5)_2O$ in this sample?

First, write the parallel reaction equations:

$$C_2H_5OH + 5\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$$

$$(C_2H_5)_2O + 7\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$$

And for simplicity, let's define some abbreviations:

$$C_2H_5OH = EA \quad \text{and} \quad (C_2H_5)_2O = DE$$

$$M_{\text{EA}} = 46.068\ \text{g/mol} \qquad M_{\text{DE}} = 74.122\ \text{g/mol} \qquad M_{\text{CO}_2} = 44.01\ \text{g/mol}$$

$$m_{\text{sample}} = m_{\text{EA}} + m_{\text{DE}}$$

$$m_{\text{CO}_2} = m_{\text{CO}_2\ \text{from EA}} + m_{\text{CO}_2\ \text{from DE}}$$

$$m_{\text{CO}_2\ \text{from EA}} = \left(m_{\text{EA}} / M_{\text{EA}} \right) \times \frac{2\ \text{mol CO}_2}{1\ \text{mol EA}} \times M_{\text{CO}_2} \quad \text{and} \quad m_{\text{CO}_2\ \text{from DE}} = \left(m_{\text{DE}} / M_{\text{DE}} \right) \times \frac{4\ \text{mol CO}_2}{1\ \text{mol DE}} \times M_{\text{CO}_2}$$

so....

$$m_{\text{CO}_2} = \left(m_{\text{EA}} / M_{\text{EA}} \right) \times \frac{2\ \text{mol CO}_2}{1\ \text{mol EA}} \times M_{\text{CO}_2} + \left(m_{\text{DE}} / M_{\text{DE}} \right) \times \frac{4\ \text{mol CO}_2}{1\ \text{mol DE}} \times M_{\text{CO}_2}$$

$$m_{\text{CO}_2} = M_{\text{CO}_2} \left[\left(m_{\text{EA}} / M_{\text{EA}} \right) \times \frac{2\ \text{mol CO}_2}{1\ \text{mol EA}} + \left(m_{\text{DE}} / M_{\text{DE}} \right) \times \frac{4\ \text{mol CO}_2}{1\ \text{mol DE}} \right]$$

$$m_{\text{CO}_2} / M_{\text{CO}_2} = \left(m_{\text{EA}} / M_{\text{EA}} \right) \times \frac{2\ \text{mol CO}_2}{1\ \text{mol EA}} + \left(m_{\text{DE}} / M_{\text{DE}} \right) \times \frac{4\ \text{mol CO}_2}{1\ \text{mol DE}}$$

$$1.963\ \text{g CO}_2 / 44.01\ \text{g CO}_2/\text{mol CO}_2 = \left(\frac{m_{\text{EA}}}{46.068\ \text{g EA}/\text{mol EA}} \right) \times \frac{2\ \text{mol CO}_2}{1\ \text{mol EA}} + \left(\frac{m_{\text{DE}}}{74.122\ \text{g DE}/\text{mol DE}} \right) \times \frac{4\ \text{mol CO}_2}{1\ \text{mol DE}}$$

$$m_{\text{DE}} = m_{\text{sample}} - m_{\text{EA}} = 1.005\ \text{g} - m_{\text{EA}}$$

$$0.04460 \text{ mol } CO_2 = \left(\frac{m_{EA}}{46.068 \, ^{\text{g EA}}/_{\text{mol EA}}} \right) \times \frac{2 \text{ mol } CO_2}{1 \text{ mol EA}} + \left(\frac{1.005 \text{ g} - m_{EA}}{74.122 \, ^{\text{g DE}}/_{\text{mol DE}}} \right) \times \frac{4 \text{ mol } CO_2}{1 \text{ mol DE}}$$

$$0.04460 \text{ mol } CO_2 = 0.043414 \frac{\text{mol } CO_2}{\text{g EA}} \times m_{EA} + 0.054235 \text{ mol } CO_2 - 0.053965 \frac{\text{mol } CO_2}{\text{g DE}} \times m_{EA}$$

$$\text{-}0.009635 \text{ mol } CO_2 = -0.010551 \frac{\text{mol } CO_2}{\text{g EA}} \times m_{EA}$$

$$m_{EA} = 0.9132 \text{ g EA}$$

$$\%C_2H_5OH = \frac{0.9132 \text{ g EA}}{1.005 \text{ g sample}} \times 100 = 90.9\% \; C_2H_5OH$$

$$\%(C_2H_5)_2O = 100 - 90.9\% = 9.1\% \; (C_2H_5)_2O$$