Determination Empirical Formula by Combustion Analysis

The organic solvent thiophene is a carbon-hydrogen-sulfur compound that yields CO_2, H_2O, and SO_2 on complete combustion. When subjected to combustion analysis, a 1.086-g sample of thiophene produces 2.272 g CO_2, 0.465 g H_2O, and 0.827 g SO_2. What is the empirical formula of thiophene?

Solution:

The goal of the problem is to determine the simplest formula for $C_xH_yS_z$. One way to approach the problem is to determine the percentage composition of C, H, and S. Alternatively, the mole quantity of each element can simply be calculated using the mass of each product.

$$n_{\mathrm{C}} = \left(2.272 \text{ g } \mathrm{CO_2} \Big/ 44.01 \tfrac{\text{g}}{\text{mol}} \right) \times \frac{1 \text{ mol C}}{1 \text{ mol } \mathrm{CO_2}} = 0.05162 \text{ mol C}$$

$$n_{\mathrm{H}} = \left(0.465 \text{ g } \mathrm{H_2O} \Big/ 18.015 \tfrac{\text{g}}{\text{mol}} \right) \times \frac{2 \text{ mol H}}{1 \text{ mol } \mathrm{H_2O}} = 0.05162 \text{ mol H}$$

$$n_{\mathrm{S}} = \left(0.827 \text{ g } \mathrm{H_2O} \Big/ 64.06 \tfrac{\text{g}}{\text{mol}} \right) \times \frac{1 \text{ mol S}}{1 \text{ mol } \mathrm{SO_2}} = 0.01291 \text{ mol S}$$

Now, normalize to the least common multiple (*i.e.,* divide by the smallest *n*)....

$x = 4$

$y = 4$

$z = 1$

so the empirical formula is C_4H_4S