

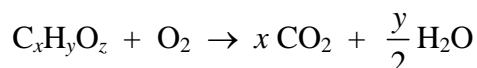
Percentage Composition and the Empirical Formula

Ibuprofen is a carbon-hydrogen-oxygen compound used in painkillers. When a 2.174-g sample is burned completely, it yields 6.029 g CO₂ and 1.709 g H₂O.

- (a) What is the percent composition, by mass, of ibuprofen?
(b) What is the empirical formula of ibuprofen?

Solution:

Start by writing a model chemical equation:



Realizing that the total amount, in moles, of carbon in the CO₂ formed comes from the ibuprofen as does the H in H₂O, it is possible to calculate quantities, in moles and grams, of both C and H:

$$n_C = 6.029 \text{ g CO}_2 \times \frac{1 \text{ mol}}{44.01 \text{ g}} \times \frac{1 \text{ mol C}}{1 \text{ mol CO}_2} = 0.13699 \text{ mol C}$$

$$m_C = 0.13699 \text{ mol C} \times 12.01 \frac{\text{g}}{\text{mol}} = 1.6453 \text{ g C}$$

$$n_H = 1.709 \text{ g H}_2\text{O} \times \frac{1 \text{ mol}}{18.015 \text{ g}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = 0.18973 \text{ mol H}$$

$$m_H = 0.18973 \text{ mol H} \times 1.00794 \frac{\text{g}}{\text{mol}} = 0.19124 \text{ g H}$$

Now that the masses of C and H in the 2.174 g sample are known, it's a simple matter to calculate the percentage composition of those two elements:

$$\%C = \frac{1.6453 \text{ g C}}{2.174 \text{ g ibuprofen}} \times 100 = \boxed{75.68\%C}$$

$$\%H = \frac{0.19124 \text{ g H}}{2.174 \text{ g ibuprofen}} \times 100 = \boxed{8.797\%H}$$

The text of the problem said that ibuprofen contains C, H, and O so the percentage composition oxygen is simply the remaining percentage:

$$\%O = 100 - (75.68\%C + 8.797\%H) = \boxed{15.52\%O}$$

Finally, use the simple algorithm for determining the empirical formula from percentage composition:

$$\% \text{C} = 75.68\% \text{C}$$

$$\% \text{H} = 8.797\% \text{H}$$

$$\% \text{O} = 15.52\% \text{O}$$

Assume 100 g of ibuprofen and convert the masses into molar quantities:

$$n_{\text{C}} = 75.68 \text{ g C} / 12.011 \frac{\text{g}}{\text{mol}} = 6.301 \text{ mol C}$$

$$n_{\text{H}} = 8.797 \text{ g H} / 1.0079 \frac{\text{g}}{\text{mol}} = 8.727 \text{ mol H}$$

$$n_{\text{O}} = 15.52 \text{ g O} / 16.00 \frac{\text{g}}{\text{mol}} = 0.970 \text{ mol O}$$

Normalize to 1 mol O by dividing each by 0.970 mol:

$$n_{\text{C}} = 6.496 \text{ C}$$

$$n_{\text{H}} = 8.997 \text{ H}$$

$$n_{\text{O}} = 1.00 \text{ O}$$

Normalize again to increase the fraction ~6.5 C by multiplying by 2:

$$n_{\text{C}} = 13 \text{ C}$$

$$n_{\text{H}} = 18 \text{ H}$$

$$n_{\text{O}} = 2 \text{ O}$$

$$\boxed{\text{Empirical formula} = \text{C}_{13}\text{H}_{18}\text{O}_2}$$