Example 3

$$2HOOCC_6H_4OH + C_4H_6O_3 \longrightarrow 2HOOCC_6H_4O_2C_2H_3 + H_2O$$

salicylic acid — acetic anhydride — acetyl salicylic acid

Calculate the theoretical yield of acetyl salicylic acid that can be made from 35.0 g salicylic acid and 50.0 g acetic anhydride. If the percent yield of the reaction is 92%, what is the actual yield of acetyl salicylic acid?

Solution: It is a limiting-reactant problem.

$n(\text{salicylic acid}) = \left(\frac{35.0}{138}\right) = 0.254 \text{ mol}$

$n(\text{anhydride}) = \left(\frac{50.0}{102}\right) = 0.490 \text{ mol}$

$M_r(\text{salicylic acid}) = 138 \text{ g mol}^{-1}$

$M_r(\text{anhydride}) = 102 \text{ g mol}^{-1}$

$M_r(\text{acetyl sal. acid}) = 180 \text{ g mol}^{-1}$

ratio moles of the reactants:

$$r_{\text{theoretical}} = \frac{n(\text{salicylic acid})}{n(\text{anhydride})} = \frac{2}{1} = 2.0$$

$$r_{\text{experimental}} = \frac{n(\text{salicylic acid})}{n(\text{anhydride})} = \frac{0.254}{0.490} = 0.52$$

$r_{\text{experimental}} < r_{\text{theoretical}}$
$(0.52) \quad (2.0)$

This is due to the numerator is small (salicylic acid = Limiting reactant), whereas the denominator is big (anhydride - excess)

$n_{\text{acetyl product}} = n_{\text{salicylic acid}} \quad (\because n_{\text{acetyl}} : n_{\text{salicylic acid}} = 2:2)$

$= 0.254 \text{ mol}$

$m_{\text{acetyl product}} = (0.254 \times 180 \text{ g mol}^{-1}) = \underline{45.72 \text{ g}}$ (theoretical yield)

Actual yield $= (\%\text{ yield})(\text{theoretical yield}) \div 100$

$= \left(\frac{92 \times 45.72}{100}\right) \text{g} = \underline{42.09 \text{ g}}$ (Ans)

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