

Combining Percentage Composition, Concentration, and Equilibrium

Problem 16-33

A particular vinegar is found to contain 5.7% acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$, by mass. What mass of the vinegar should be diluted with water to produce 0.750 L of a solution with $\text{pH} = 4.52$?

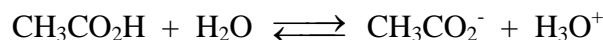
Solution:

This integrative problem requires quite a bit of information management to get to an answer.

Let's start by getting the one thing we really know, $[\text{H}_3\text{O}^+]$:

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-4.52} = 3.02 \times 10^{-5} \text{ M}$$

Now, we can calculate the $[\text{CH}_3\text{CO}_2\text{H}]$ necessary to obtain that $[\text{H}_3\text{O}^+]$:



$$K_a = 1.75 \times 10^{-5} = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{CO}_2^-]}{[\text{CH}_3\text{CO}_2\text{H}]}$$

But, we know that $[\text{H}_3\text{O}^+] = [\text{CH}_3\text{CO}_2^-]$ by stoichiometry, so...

$$1.75 \times 10^{-5} = \frac{(3.02 \times 10^{-5})^2}{C_{\text{CH}_3\text{CO}_2\text{H}} - 3.02 \times 10^{-5}} \quad \text{Do the algebra,}$$

$$C_{\text{CH}_3\text{CO}_2\text{H}} = 8.23 \times 10^{-5} \text{ M CH}_3\text{CO}_2\text{H}$$

The problem stipulates 0.750 L of the diluted solution, so we can calculate the quantity, in moles, of acetic acid in the solution:

$$n_{\text{CH}_3\text{CO}_2\text{H}} = 8.23 \times 10^{-5} \text{ M} \times 0.750 \text{ L} = 6.17 \times 10^{-5} \text{ mol CH}_3\text{CO}_2\text{H}$$

We get that acetic acid from the 5.7% ^{w/w} solution of vinegar. We need only to calculate the mass of 5.7% acetic acid that contains that number of moles of acetic acid:

$$m_{\text{CH}_3\text{CO}_2\text{H}} = \frac{6.17 \times 10^{-5} \text{ mol CH}_3\text{CO}_2\text{H}}{\left(\frac{0.057 \frac{\text{g CH}_3\text{CO}_2\text{H}}{\text{g vinegar}}}{60.05 \frac{\text{g}}{\text{mol}}} \right)} = 0.065 \text{ g vinegar}$$