Percentage Concentration

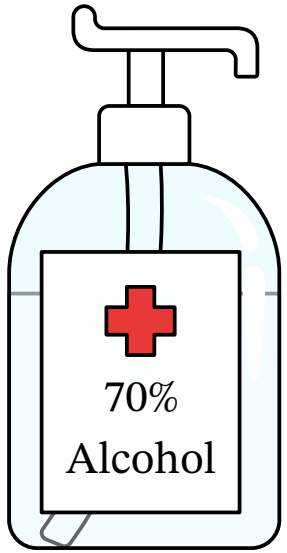
Lesson Objectives

You will be able to

- explain how a solution can be defined as a percentage by volume or mass,
- explain the difference between percentage concentration by volume and by mass,
- recall and use equations to calculate percentage concentration by volume or mass,
- calculate the percentage by volume (% (v/v)) or mass (% (m/m)) of a solution,
- calculate the percentage by volume or mass when two different percentage solutions are mixed together,
- calculate the percentage mass by volume, % (m/v), of a solution.

Explaining the Notation on Commercial Bottles Labels

Have you ever noticed on the label of a tube of ointment, a medicine bottle, bleach, or a hand sanitizer that the ingredients are followed by the notation %, % (v/v), or % (m/m)?



This notation describes the *percentage concentration* of the ingredients and is often used for solutions. You may be familiar with the term concentration. Concentration is a measure of the amount of solute dissolved in a given amount of solution.

Definition: Concentration

Concentration is a measure of how much solute is dissolved in a given amount of solution.

Concentration Equation

We can measure the concentration of a solution quantitatively using different units. The amount of solute and solution can be expressed in grams, millilitres, litres, cubic decimetres, or moles:

$$\text{concentration of a solution} = \frac{\text{amount of solute } (\text{g}, \text{mL}, \text{ or moles})}{\text{amount of solution } \left(\text{g}, \text{mL}, \text{L}, \text{ or } \text{dm}^3\right)}.$$

Definition: Percentage Concentration

Percentage concentration is a measure of the amount of solute dissolved in every 100 units of solution.

The General Equation for Percentage Concentration

Consider the following equation:

$$\text{percentage concentration of a solution} = \frac{\text{amount of solute } (\text{g, mL, or L})}{\text{amount of solution } \left(\text{g, mL, L, or } \text{dm}^3\right)} \times 100\%.$$

The mass of the solution is equal to the sum of the masses of the solute and solvent.

The Equation for Mass Percentage Concentration

Consider the following equation:

$$\text{mass percentage concentration (\%m/m)} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%.$$

Example 1: Calculating the Percent by Mass Concentration

A sugar solution was made by mixing 12 g of glucose with 100 g of water. What is the percentage concentration by mass of the glucose in the solution? Give your answer to one decimal place.

A. 12.0% (m/m)
B. 8.3% (m/m)
C. 13.6% (m/m)
D. 10.7% (m/m)
E. 11.4% (m/m)

Answer

In this example, we are given the mass of the solute (12 g of glucose), but we are not given the mass of the solution. However, as we are given the mass of the solvent in the question (100 g of water), we can calculate the mass of the solution.

Example 1 (Continued)

To calculate the mass percentage concentration, we can use the following equation:

$$\text{mass percentage concentration } (\%\text{m/m}) = \frac{\text{mass of solute } (\text{g})}{\text{mass of solute } (\text{g}) + \text{mass of solvent } (\text{g})} \times 100\%.$$

We can substitute the values for the mass of the solute and the mass of the solvent into the equation:

$$\begin{aligned}\text{mass percentage concentration} &= \frac{12\ \text{g}}{12\ \text{g} + 100\ \text{g}} \times 100\% \\ &= \frac{12\ \text{g}}{112\ \text{g}} \times 100\% \\ &= 10.7\%\,(\text{m/m})\,.\end{aligned}$$

Example 2: Calculating the New Percent by Mass When Two Different Percent Solutions Are Mixed Together

50 g of a 26% (m/m) solution was mixed together with 130 g of a 17% (m/m) solution. What is the percentage concentration by mass of the new solution?

A. 19.5% (m/m)
B. 15% (m/m)
C. 5% (m/m)
D. 43% (m/m)
E. 35% (m/m)

Answer

We can start by calculating the total solution mass by adding the two solution masses together as follows

$$\begin{aligned}\text{total solution mass} &= \text{mass of solution 1} + \text{mass of solution 2} \\ &= 50\,\text{g} + 130\,\text{g} \\ &= 180\,\text{g}.\end{aligned}$$

Example 2 (Continued)

In solution 1, the mass of the solute can be calculated by substituting the data we have for solution 1 into the mass percent equation.

$$\%\ \text{m/m} = \frac{\text{mass of solute 1}}{\text{mass of solution 1}} \times 100\%$$

$$26\% = \frac{\text{mass of solute 1}}{50\ \text{g}} \times 100\%$$

We then rearrange the equation to solve for the mass of the solute.

$$\text{Mass of solute 1} = \frac{26\% \times 50\ \text{g}}{100\%}$$

$$\text{Mass of solute 1} = 13\ \text{g}$$

We can do the same for solution 2, using the data we have for it.

$$17\% = \frac{\text{mass of solute 2}}{130\ \text{g}} \times 100\%$$

We then rearrange the equation to solve for the mass of the solute.

$$\text{Mass of solute 2} = \frac{17\% \times 130\ \text{g}}{100\%}$$

$$\text{Mass of solute 2} = 22.1\ \text{g}$$

Example 2 (Continued)

$$\begin{aligned}\text{Total solute mass} &= \text{mass of solute 1} + \text{mass of solute 2}\\ &= 13\,\text{g} + 22.1\,\text{g}\\ &= 35.1\,\text{g}\end{aligned}$$

Now, we can calculate the new combined solution concentration:

$$\begin{aligned}\text{mass percentage concentration } (\%\text{m/m}) &= \frac{\text{mass of solute } (\text{g})}{\text{mass of solution } (\text{g})} \times 100\%\\ &= \frac{35.1\,\text{g}}{180\,\text{g}} \times 100\%\\ &= 19.5\%.\end{aligned}$$

The Equation for Volume-by-Volume Percentage Concentration

Consider the following equation:

$$\text{volume percentage concentration (\%v/v)} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%.$$

Example 3: Calculating the Volume of Solute from a Percentage v/v Concentration

A 0.75 L bottle of vinegar contains 4% (v/v) of ethanoic acid. What volume of ethanoic acid does the bottle of vinegar contain?

Answer

To determine the volume of the solute, we need to use the percentage concentration (v/v) equation:

$$\text{volume percentage concentration (\%v/v)} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%.$$

We are told the volume percentage concentration (4%), and we are told the volume of the solution (0.75 L). We can substitute these values into the equation:

$$4\% = \frac{\text{volume of solute}}{0.75\ \text{L}} \times 100\%$$

$$\text{volume of solute} = \frac{4\% \times 0.75\ \text{L}}{100\%}$$

$$= 0.03\ \text{L}.$$

Example 4: Calculating the Volume of Water Added to Dilute a Solution to a Desired Concentration

What volume of water must be added to a 125 mL solution of ethanol to change its percentage volume from 40% (v/v) to 35% (v/v)? Give your answer to the nearest whole number.

A. 18 mL

B. 143 mL

C. 50 mL

D. 44 mL

E. 107 mL

Answer

We need to calculate how much water must be added to the initial volume to decrease the concentration from 40% (v/v) to 35% (v/v).

Example 4 (Continued)

We can begin by calculating how much ethanol is in the initial solution, and this will also be the amount of ethanol in the diluted solution. To calculate this, we use the following equation:

$$\begin{aligned}
\text{volume percentage concentration } (\%\text{v/v}) &= \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\% \\
40\% &= \frac{\text{volume of solute}}{125\ \text{mL}} \times 100\% \\
\text{volume of solute} &= \frac{40\% \times 125\ \text{mL}}{100\%} \\
&= 50\ \text{mL}.
\end{aligned}$$

Example 4 (Continued)

This value of 50 mL is also the volume of ethanol in the dilute solution. So, we can calculate the volume of the dilute solution as follows:

$$\begin{aligned}\text{volume percentage concentration } (\%\text{v/v}) &= \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\% \\ 35\% &= \frac{50\text{ mL}}{\text{volume of solution}} \times 100\% \\ \text{volume of solution} &= \frac{50\text{ mL} \times 100\%}{35\%} \\ &= 142.86\text{ mL}.\end{aligned}$$

Finally, we need to determine how much water was added to the initial solution during dilution:

$$\begin{aligned}\text{volume of water added} &= \text{volume of dilute solution} - \text{volume of initial solution} \\ &= 142.86\text{ mL} - 125\text{ mL} \\ &= 17.86\text{ mL} \\ &\approx 18\text{ mL}.\end{aligned}$$

Definition: Mass-by-Volume Percentage Concentration (%m/v)

It is a concentration unit for the mass of the solute (in grams) in 100 volume units (usually millilitres) of solution.

The Equation for Mass-by-Volume Percentage Concentration

Consider the following equation:

$$\text{mass-by-volume percentage concentration } (\%\text{m/v}) = \frac{\text{mass of solute } (\text{g})}{\text{volume of solution } (\text{mL})} \times 100\%.$$

Example 5: Calculating the Mass-by-Volume Percentage Concentration of a Solution

A saline solution was prepared by dissolving 9 g of NaCl in water to produce a solution with a total volume of 1 000 mL. What is the mass/volume percentage concentration, %(m/v), of the saline solution?

Answer

We know that the mass of the solute (NaCl) is 9 g.

We also know that the volume of the solution is 1 000 mL.

We can substitute these values into the equation below to determine the %m/v:

$$\begin{aligned} \%\text{m/v} &= \frac{\text{mass of solute (g)}}{\text{volume of solution (mL)}} \times 100\% \\ &= \frac{9\ \text{g}}{1\,000\ \text{mL}} \times 100\% \\ &= 0.9\%. \end{aligned}$$

Key Points

- The concentration of a solution is a measure of how much solute is dissolved in a given amount of solution.
- Percentage concentration is a measure of how much solute is dissolved in every 100 units of solution.
- Percentage concentration can be calculated in three ways, using the following equations:

$$\text{mass percentage concentration (\%m/m)} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%,$$

$$\text{volume percentage concentration (\%v/v)} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%,$$

$$\text{mass-by-volume percentage concentration (\%m/v)} = \frac{\text{mass of solute (g)}}{\text{volume of solution (mL)}} \times 100\%.$$