

Solutions

Solutions are homogeneous mixtures that can be made using all three phases of matter: liquids and gases dissolve in gases, solids and liquids and gases dissolve in liquids, and solids and liquids dissolve in solids.

Solute: solution component that is dissolved.

Solvent: solution component that does the dissolving.

When two liquids make a solution, the solute is the lesser quantity and the solvent is the greater quantity.

Polar molecules make polar solvents. Polar solvents dissolve polar solutes. Examples of polar molecules are water, methanol, ethanol, acetone, formic acid, and acetic acid.

Nonpolar molecules make nonpolar solvents. Nonpolar solvents dissolve nonpolar solutes. Examples of nonpolar molecules are hexane, heptane, toluene, carbon tetrachloride, chloroform, and ethyl ether.

The two rules above give rise to the **like dissolves like rule**. For example, toluene dissolves well in hexane, but not in acetone. Acetic acid dissolves well in water, but not in carbon tetrachloride.

Two liquids that dissolve completely in each other are **miscible** liquids. Those that do not are **immiscible** liquids. Toluene and hexane would be miscible liquids. Acetone and water would be miscible liquids. Toluene and acetone would be immiscible liquids. Water and hexane would be immiscible liquids.

The like dissolves like rule applies also to solutions made from the same or different phases of matter. Ionic solids (salts) dissolve in water but not in hexane. Polar molecules like sugar dissolve in water but not in hexane. Nonpolar compounds like naphthalene dissolve in hexane but not in water.

Dissolving occurs because solvent molecules have a greater attraction to solute molecules than solute molecules do for each other. When polar molecules dissolve in polar solvents, the negative and positive ends of solvent and solute molecules orient to maximize attractions between opposite charges.

Concentration Units

Mass percent and **molarity** are the two units we will use to tell the concentration of a solution. Concentrated and dilute solutions are imprecise terms that describe concentration.

$$\begin{aligned}\text{Mass percent} &= 100\% * \text{mass solute} / \text{solution} \\ &= 100\% * \text{mass solute} / (\text{mass solute} + \text{mass solvent})\end{aligned}$$

Example: Calculate the mass percent of dextrose in a solution made from 3.4g of dextrose and 45.5g of water.

Answer: Water is commonly the solvent for solutions. The mass percent of dextrose is $100\% * 3.4 / (3.4 + 45.5) = 7.0\%$ dextrose.

The mass percent, 7.0% dextrose, can be written as several unit factors:

$$\frac{7.0\text{g dextrose}}{100\text{g solution}}, \quad \frac{7.0\text{g dextrose}}{93\text{g water}}, \quad \frac{93\text{g water}}{100\text{g solution}}$$

$$\frac{100\text{g solution}}{7.0\text{g dextrose}}, \quad \frac{93\text{g water}}{7.0\text{g dextrose}}, \quad \frac{100\text{g solution}}{93\text{g water}}$$

Example: Calculate the mass of 7.0% dextrose solution that contains 18g of dextrose.

Answer: $18\text{g dextrose} * (100\text{g solution} / 7.0\text{g dextrose}) = 260\text{g solution (2SD)}$, so 260g of solution contains 18g of dextrose.

Molarity is one of the most common units of concentration.

$$\text{Molarity} = \text{moles solute} / \text{L solution}$$

Example: Calculate the molarity of 21.0g of KOH in 455mL of solution.

Answer: The volume of the solution in liters is $455\text{mL} (1 \times 10^{-3}\text{L}/1\text{mL}) = 0.455\text{L}$. The moles of solute is $21.0\text{g KOH} (\text{mol KOH}/56.105\text{gKOH}) = 0.374298\text{mol KOH}$, where we use the molar mass of KOH to convert grams KOH to moles KOH. Calculate the molarity by using the definition: $0.374298\text{mol KOH}/0.455\text{L} = 0.823\text{M KOH}$.

The molarity, 0.823M KOH, can be written as unit factors:

$$\frac{0.823\text{ mol KOH}}{\text{L solution}} \quad \text{and} \quad \frac{\text{L solution}}{0.823\text{ mol KOH}}$$

Example: Calculate the mass of KOH in 25.0mL of a 0.823M KOH solution.

Answer: Start the problem with the lab measurable, 25.0mL. To use molarity, the volume must be in liters. $0.0250\text{L} * (0.823\text{ mol KOH} / \text{L}) * (56.105\text{g KOH} / \text{mol KOH}) = 1.15\text{g KOH}$. Use the molar mass of KOH to convert moles KOH to the mass in grams.

Example: Calculate the volume of 0.823M KOH solution that contains 41.0g of KOH.

Answer: Start with the lab measurable, 41.0g KOH. Convert to moles with the molar mass of KOH. Use the molarity to calculate volume. $41.0\text{g KOH} * (\text{mol KOH} / 56.105\text{g KOH}) * (\text{L} / 0.823\text{mol KOH}) = 0.888\text{L}$ or 888mL of solution.

Dilutions of Solutions

Diluting solutions is an easy process in the laboratory. The equation to dilute solutions is:

$$M_{\text{concentrated}} * V_{\text{concentrated}} = M_{\text{diluted}} * V_{\text{diluted}}$$

$M_{\text{concentrated}}$ is the molarity of the concentrated solution.

$V_{\text{concentrated}}$ is the volume of the concentrated solution

M_{diluted} is the molarity of the diluted solution

V_{diluted} is the volume of the diluted solution.

Example: What volume of 9.00M KOH needs to be diluted to prepare 5.00L of a 1.25M KOH solution?

Answer: Plug the numbers into the dilution equation to calculate $V_{\text{concentrated}}$.

$$9.00\text{mol KOH/L} * V_{\text{concentrated}} = 1.25\text{mol KOH/L} * 5.00\text{L}. V_{\text{concentrated}} = 0.694\text{L} = 694\text{mL}.$$