SOLUTIONS-2
SOLUTION CONCENTRATIONS

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There are a number of ways one can measure concentration of solute in solutions.

- Molarity – commonly used since volumes of solutions are easy to measure
- Mole fraction – used for gases and vapor pressures of solutions
- Molality – temperature independent
- Percent by Mass – temperature independent and need not know molar masses
- Conversion between units requires the use of density if any mass to volume or volume to mass conversion in needed.
## VARIOUS UNITS OF SOLUTIONS

- **Molarity (mol/L)**
  \[ M = \frac{\text{moles of solute}}{\text{liters of solution}} \]

- **Mass percent (mass/mass; mass/vol; vol/vol – the denominator is solution)**
  \[
  \text{Mass percentage of solute} = \frac{\text{grams of solute}}{\text{grams of solution}} \times 100%
  \]

- **Molality (mol/Kg)**
  \[ m = \frac{\text{moles of solute}}{\text{kilograms of solvent}} \]

- **Mole fraction**
  \[ X = \frac{\text{moles of solute}}{\text{total moles of solution}} \]

- **Parts per million**
  \[ ppm = \frac{\text{mass* of solute}}{\text{mass* of solution}} \times 10^6 \]

- **Parts per billion**
  \[ ppb = \frac{\text{mass* of solute}}{\text{mass* of solution}} \times 10^9 \]
EXAMPLE: MASS PERCENT

An experiment calls for 36.0 g of a 5.00% aqueous solution of potassium bromide. Describe how you would make up such a solution.

Solution:
A 5.00% aqueous solution of KBr has 5.00 g KBr per 100. g solution. The remainder of the 100. g is water: 95 g.

We can use this ratio to determine the mass of KBr in 36.0 g solution:

\[
36.0 \text{ g solution} \times \frac{5.00 \text{ g KBr}}{100. \text{ g solution}} = 1.80 \text{ g KBr}
\]

Since 1.80 g KBr is required for 36.0 g of solution, the remainder consists of 34.2 g water.

We make the solution by mixing 1.8 g KBr in 34.2 g water.
EXAMPLE: MOLALITY

Iodine dissolves in a variety of organic solvents. For example, in methylene chloride, it forms an orange solution. What is the molality of a solution of 5.00 g iodine, I$_2$, in 30.0 g of methylene chloride, CH$_2$Cl$_2$?

Solution:

Mass of solute = 5.00 g I$_2$

Mass of solvent = 30.0 g CH$_2$Cl$_2$

Calculate mols of the solute and convert the mass of solvent into Kg.

\[
m = \frac{5.00 \text{ g } I_2}{30.0 \text{ g solvent}} \times \frac{1 \text{ mol } I_2}{253.8 \text{ g } I_2} \times \frac{10^3 \text{ g}}{1 \text{ kg}} = 0.657 \text{ mol/Kg}
\]
EXAMPLE: MOL FRACTION

A solution of iodine, I\(_2\), in methylene chloride, CH\(_2\)Cl\(_2\), contains 5.00 g I\(_2\) and 56.0 g CH\(_2\)Cl\(_2\). What is the mole fraction of each component in this solution?

Solution:

Mass of solute = 5.00 g I\(_2\)

Mass of solvent = 56.0 g CH\(_2\)Cl\(_2\)

Find moles of both; add the moles and then calculate mol fraction of each.

Moles solute = \(\frac{5.00 \text{ g I}_2 \times 1 \text{ mol I}_2}{253.8 \text{ g I}_2}\) = 0.01970 mol

Moles solvent = \(\frac{56.0 \text{ g I}_2 \times 1 \text{ mol CH}_2\text{Cl}_2}{84.93 \text{ g CH}_2\text{Cl}_2}\) = 0.6594 mol

Total moles = 0.01970 mol + 0.6594 mol = 0.6791 mol

\(X_{\text{I}_2} = \frac{0.01970 \text{ mol I}_2}{0.6791 \text{ mol total}} = 0.0290\)

\(X_{\text{CH}_2\text{Cl}_2} = \frac{0.6594 \text{ mol CH}_2\text{Cl}_2}{0.6791 \text{ mol total}} = 0.971\)
A bottle of bourbon is labeled 94 proof, meaning that it is 47% by volume of alcohol in water. What is the mole fraction of ethyl alcohol, $C_2H_5OH$, in the bourbon? The density of ethyl alcohol is 0.80 g/mL.

**Solution:**

When no volume is given – assume it is 1L. So there is 470 mL alcohol and 530 mL water. Find masses of both; convert to mols and find mol fractions.

\[
470\text{mL} \times \frac{0.80\text{ g}}{1\text{mL}} \times \frac{1\text{mol}}{46.08\text{ g}} = 8.16\text{ mol}
\]

\[
530\text{mL} \times \frac{1.00\text{ g}}{1\text{mL}} \times \frac{1\text{mol}}{18.02\text{ g}} = 29.4\text{ mol}
\]

Total moles = 8.16 mol + 29.4 mol = 37.6 mol

\[
X_{\text{ethanol}} = \frac{8.16\text{ mol } C_2H_5OH}{37.6\text{ mol total}} = 0.22
\]
EXAMPLE: UNIT CONVERSION; MOLALITY TO MOLARITY

Citric acid, HC₆H₇O₇, is often used in fruit beverages to add tartness. An aqueous solution of citric acid is 2.331 \( m \) HC₆H₇O₇. What is the molarity of the solution? The density of the solution is 1.1346 g/mL.

Solution:

2.331 \( m \) means – 2.331 mols of citric acid in 1.000 Kg SOLVENT; molarity is mols over L of SOLUTION.

Strategy: convert mols citric acid to mass -\( \rightarrow \) mass of solution -\( \rightarrow \) use d to find L of solution.

\[
\text{Mass solute} = 2.331 \text{mol} \times \frac{192.14 \text{g}}{1 \text{mol}} = 447.88 \text{g}
\]

\[
\text{Mass of solution} = 447.88 \text{g} + 1000.00 \text{g} = 1447.88 \text{g}
\]

\[
\text{Liters solution} = 1447.88 \text{g} \times \frac{1 \text{mL}}{1447.88 \text{g}} \times \frac{10^{-3} \text{L}}{\text{mL}} = 1.267 \text{L}
\]

\[
M = \frac{2.331 \text{mol}}{1.2761 \text{L}} = 1.827 \frac{\text{mol}}{\text{L}}
\]
KEY CONCEPTS

• Know all the units of solutions
• Convert one unit of concentration to another.