**Mole Fraction**
The mole fraction of a component substance \( A \) \( (X_A) \) in a solution is defined as the moles of component substance divided by the total moles of solution (moles of solute plus solvent).

\[
X_A = \frac{\text{moles of substance } A}{\text{total moles of solution}}
\]

**Example. Calculating the Mole Fractions of Components**
What are the mole fractions of glucose and water in a solution containing 5.67 g of glucose, \( \text{C}_6\text{H}_{12}\text{O}_6 \), dissolved in 25.2 g of water?

**Solution**
Here, 5.67 g of glucose equals 0.0315 mol of glucose. The moles of water in the solution are
\[
(25.2 \text{ g H}_2\text{O})(1 \text{ mol H}_2\text{O}/18.0 \text{ g H}_2\text{O} = 1.40 \text{ mol H}_2\text{O})
\]
and the total moles of solution are
\[
1.40 \text{ mol } + 0.0315 \text{ mol } = 1.432 \text{ mol}
\]
(retain an extra figure in the answer for further computation.)

Finally, you get:
Mole fraction glucose = \( 0.0315 \text{ mol}/1.432 \text{ mol} = 0.02199 = 0.0220 \)
Mole fraction \( \text{H}_2\text{O} \) = \( 1.40 \text{ mol}/1.432 \text{ mol} = 0.978 \)

Check: note that the sum of the mole fractions is 1.000.

**Calculating Molality**
What is the molality of a solution that contains 5.67 g of glucose (180.2 g/mol) dissolved in 25.2 g of water? Glucose is \( \text{C}_6\text{H}_{12}\text{O}_6 \).

**Solution.** Molality = \( m = \frac{\text{mols solute}}{\text{kg solvent}} \)
First, calculate mols solute (glucose): mols glucose = \( (5.67 \text{ g})(1 \text{ mol glucose}/180.2 \text{ g}) = 0.0315 \text{ mol} \)

Next, calculate kg solvent: kg solvent = \( (25.2 \text{ g water})(1 \text{ kg water}/1000 \text{ g water}) = 25.2 \times 10^{-3} \text{ kg} \)
molality = \( (0.0315 \text{ mol glucose})/( 25.2 \times 10^{-3} \text{ kg water}) = 1.25 \text{ m glucose} \)

**Example. Converting Molality to Mole Fractions**
An aqueous solution is 0.120 m in glucose, \( \text{C}_6\text{H}_{12}\text{O}_6 \). What are the mole fractions of each component in the solution?

**Solution**
A 0.120 m glucose solution contains 0.120 mol of glucose in 1.00 kg of water. The moles of \( \text{H}_2\text{O} \) in 1.00 kg of water are \( (1.00 \times 10^3 \text{ g H}_2\text{O})(1 \text{ mol H}_2\text{O}/18.0 \text{ g H}_2\text{O}) = 55.6 \text{ mol H}_2\text{O} \)

So, mole fraction glucose = \( (0.120 \text{ mol})/(0.120 + 55.6) \text{ mol}) = 0.00215 \)
and mole fraction water = \( (55.6 \text{ mol})/(0.120 + 55.6) \text{ mol}) = 0.998 \)

**Example. Converting Mole Fractions to Molality**
A solution is 0.150 mole fraction glucose, \( \text{C}_6\text{H}_{12}\text{O}_6 \) and 0.850 mole fraction water. What is the molality of glucose in the solution?
Example. Converting Mole Fractions to Molality –Solution

Assume exactly 1.000 mol of solution, so one mole of solution contains 0.150 mol of glucose and 0.850 mol of water. The mass of this amount of water is \((0.850 \text{ mol } \text{H}_2\text{O})(18.0 \text{ g H}_2\text{O/mol H}_2\text{O}) = 15.3 \text{ g H}_2\text{O} \) (or, 0.0153 kg H\(_2\)O).

Therefore, the molality of glucose, \(C_6\text{H}_{12}0_6\), in the solution is
\[
m = \frac{(0.150 \text{ mol } C_6\text{H}_{12}0_6)}{(0.0153 \text{ kg H}_2\text{O})} = 9.80 \frac{C_6\text{H}_{12}0_6}{\text{mol H}_2\text{O}} = 9.80 \text{ m } C_6\text{H}_{12}0_6.
\]

Example. Converting Molality to Molarity

An aqueous solution is 0.273 \(\text{m } \text{KCl}\). What is the molar concentration of potassium chloride, \(\text{KCl}\)? The density of the solution is 1.011 \(\times \text{10}^3\) g/L.

Solution. Here, there is 0.273 mol KCl per kg of water. To calculate the molarity, you must first find the volume of solution for a given mass of solvent. Assume an amount of solution containing 1.000 kilogram of water (1.000 \(\times \text{10}^3\) g H\(_2\)O). The mass of potassium chloride in this quantity of solution is
\[
g \text{ KCl} = (0.273 \text{ mol } \text{KCl})( 74.6 \text{ g KCl} /1 \text{ mol KCl}) = 20.4 \text{ g KCl}
\]
Next, the total mass of the solution equals the mass of water plus the mass of potassium chloride, so
\[
g \text{ solution} = 1.000 \times \text{10}^3 \text{ g} + 20.4 \text{ g} = 1.020 \times \text{10}^3 \text{ g}
\]
The volume of solution equals its mass divided by the density of the solution:
\[
\text{Volume of solution} = \frac{(1.020 \times \text{10}^3 \text{ g})}{(1.011 \times \text{10}^3 \text{ g/L})} = 1.009 \text{ L}
\]
and the molarity (\(M\)) of the solution = \(0.273 \text{ mol KCl}/1.009 \text{ L solution}\) = 0.271 \(\text{M KCl}\).

Note that the molarity and the molality of this solution are approximately equal. This is generally true when solutions are dilute and their density is about 1 g/mL.

Example. Converting Molarity to Molality

An aqueous solution is 0.907 \(\text{M } \text{Pb(NO}_3\text{)}_2\). What is the molality of lead \(\text{Pb(NO}_3\text{)}_2\), in this solution? The density of the solution is 1.252 g/mL.

Solution. There is 0.907 mol \(\text{Pb(NO}_3\text{)}_2\) per liter of solution. Begin by assuming 1 L (= 1.000 \(\times \text{10}^3\) mL) of solution and calculate its mass. You can then calculate the mass of \(\text{Pb(NO}_3\text{)}_2\) and then find the mass of water by difference, where mass of solution = density \(\times\) volume:
\[
g \text{ solution} = (1.252 \text{ g/mL})(1.000 \times \text{10}^3 \text{ mL}) = 1.252 \times \text{10}^3 \text{ g}
\]
The mass of \(\text{Pb(NO}_3\text{)}_2\) is
\[
g \text{ Pb(NO}_3\text{)}_2 = (0.907 \text{ mol } \text{Pb(NO}_3\text{)}_2)(331.2 \text{ g Pb(NO}_3\text{)}_2/\text{mol}) = 3.00 \times \text{10}^2 \text{ g Pb(NO}_3\text{)}_2
\]
The mass of the water in this solution is
\[
\text{mass of } \text{H}_2\text{O} = \text{mass of solution} - \text{mass of } \text{Pb(NO}_3\text{)}_2 = 1.252 \times \text{10}^3 \text{ g} - 3.00 \times \text{10}^2 \text{ g} = 9.52 \times 10^2 \text{ g} (= 0.952 \text{ kg})
\]

molality of \(\text{Pb(NO}_3\text{)}_2\) = \(0.907 \text{ mol } \text{Pb(NO}_3\text{)}_2/0.952 \text{ kg } \text{H}_2\text{O}\) = \textbf{0.953 m } \text{Pb(NO}_3\text{)}_2