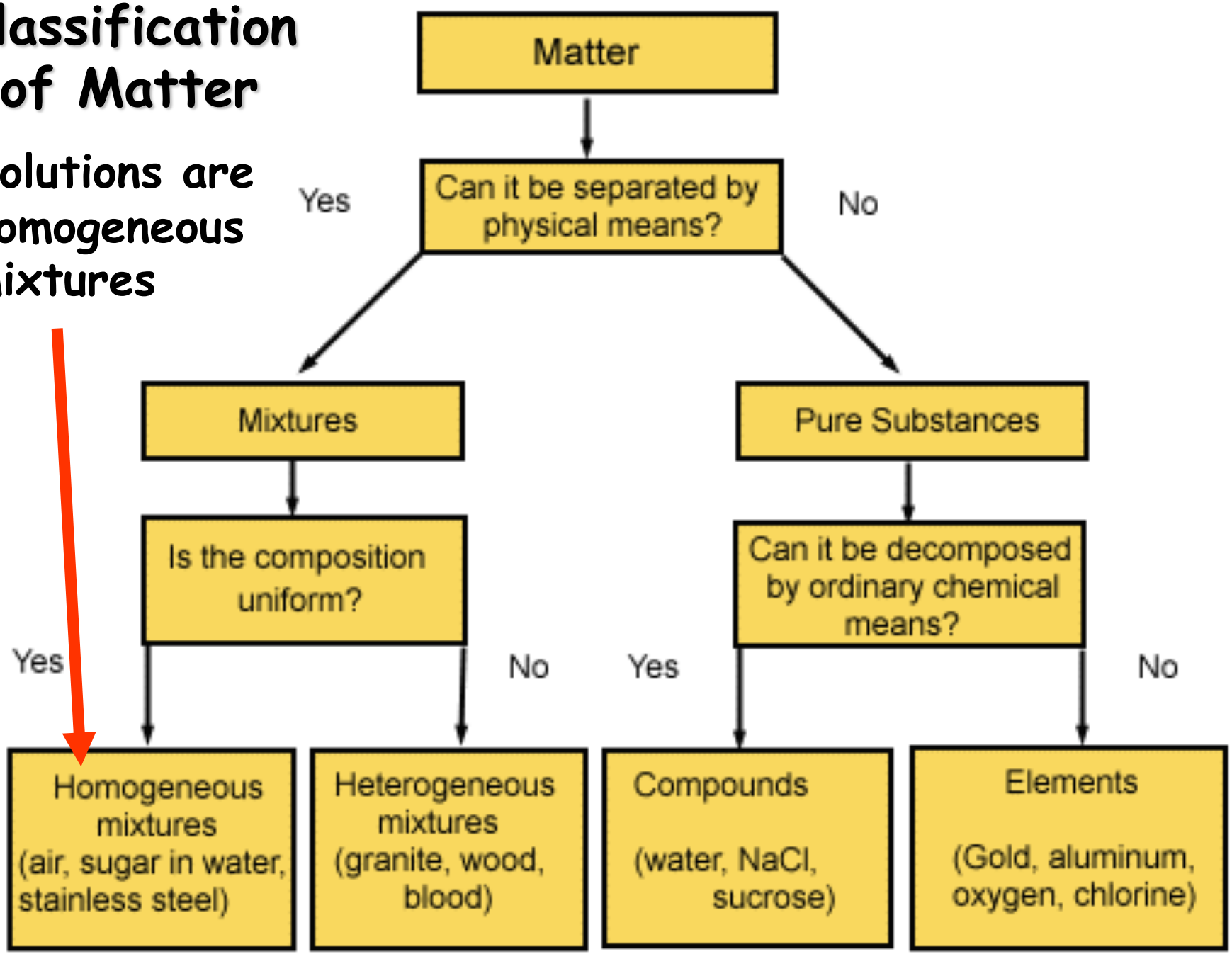
Properties of Solutions

Classification of Matter

Solutions are homogeneous mixtures



Solute

A solute is the dissolved substance in a solution.

Salt in salt water

Sugar in soda drinks

Carbon dioxide in soda drinks

Solvent

A solvent is the dissolving medium in a solution.

Water in salt water

Water in soda

Solution Concentration: Molarity

- Moles of solute per 1 liter of solution
- Describes how many molecules of solute in each liter of solution
- If a sugar solution concentration is 2.0 M,
  - 1 liter of solution contains 2.0 moles of sugar
  - 2 liters = 4.0 moles sugar
  - 0.5 liters = 1.0 mole sugar

$$\text{Molarity, M} = \frac{\text{moles of solute}}{\text{Liters of solution}}$$

Solution Concentration: Molality, m

- **Moles of solute per 1 kilogram of solvent**
  - **Defined in terms of amount of solvent, not solution**
    - **Like the others**
- **Does not vary with temperature**
  - **Because based on masses, not volumes**

$$\text{molality, m} = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

Parts Solute in Parts Solution

- Parts can be measured by mass or volume.

- Parts are generally measured in the same units.
  - By mass in grams, kilogram, lbs, etc.
  - By volume in mL, L, gallons, etc.
  - Mass and volume combined in grams and mL

Parts Solute in Parts Solution

- **Percentage = parts of solute in every 100 parts solution**
  - **If a solution is 0.9% by mass, then there are 0.9 grams of solute in every 100 grams of solution (or 0.9 kg solute in every 100 kg solution).**

- **Parts per million = parts of solute in every 1 million parts solution**
  - **If a solution is 36 ppm by volume, then there are 36 mL of solute in 1 million mL of solution.**

PPM

- **Grams of solute per 1,000,000 g of solution**
- **mg of solute per 1 kg of solution**
- **1 liter of water = 1 kg of water**
  - **For aqueous solutions we often approximate the kg of the solution as the kg or L of water.**
    - **For dilute solutions, the difference in density between the solution and pure water is usually negligible.**

$$\text{PPM} = \frac{\text{Amount of Solute}}{\text{Amount of Solution}} \times 10^6$$

$$\text{PPM} = \frac{\text{mg of Solute}}{\text{kg of Solution}} = \frac{\text{mg of Solute}}{\text{L of Solution}}$$

Parts Per Billion Concentration

$$PPB = \frac{\text{Part (solute)}}{\text{Whole (solution)}} \times 10^9$$

Solution Concentrations: Mole Fraction, X_A

- **The mole fraction is the fraction of the moles of one component in the total moles of all the components of the solution.**
- **Total of all the mole fractions in a solution = 1.**
- **Unitless**
- **The mole percentage is the percentage of the moles of one component in the total moles of all the components of the solution.**
  - **= mole fraction × 100%**

Converting Concentration Units

1. **Write the given concentration as a ratio.**
2. **Separate the numerator and denominator.**
   - **Separate into the solute part and solution part**
3. **Convert the solute part into the required unit.**
4. **Convert the solution part into the required unit.**
5. **Use the definitions to calculate the new concentration units.**

TABLE 12.5 Solution Concentration Terms

Unit	Definition	Units
Molarity (M)	$\frac{\text{amount solute (in mol)}}{\text{volume solution (in L)}}$	$\frac{\text{mol}}{\text{L}}$
Molality (m)	$\frac{\text{amount solute (in mol)}}{\text{mass solvent (in kg)}}$	$\frac{\text{mol}}{\text{kg}}$
Mole fraction (χ)	$\frac{\text{amount solute (in mol)}}{\text{total amount of solute and solvent (in mol)}}$	None
Mole percent (mol %)	$\frac{\text{amount solute (in mol)}}{\text{total amount of solute and solvent (in mol)}} \times 100\%$	%
Parts by mass	$\frac{\text{mass solute}}{\text{mass solution}} \times \text{multiplication factor}$	
Percent by mass (%)	Multiplication factor $= 100$	%
Parts per million by mass (ppm)	Multiplication factor $= 10^6$	ppm
Parts per billion by mass (ppb)	Multiplication factor $= 10^9$	ppb
Parts by volume (%, ppm, ppb)	$\frac{\text{volume solute}}{\text{volume solution}} \times \text{multiplication factor}$ *	

*Multiplication factors for parts by volume are identical to those for parts by mass.

Calculations of Solution Concentration

Mass percent - the ratio of mass units of solute to mass units of solution, expressed as a percent

$$Mass\ percent = \left(\frac{mass\ of\ solute}{total.mass\ of\ solution} \right) x100$$

Find the mass percent of $CuSO_4$ in a solution whose density is 1.30 g/ml and whose molarity is 4.73 M.

A 41.9%

B 6.15%

C 58.1%

D 6.03%

E None of these

Calculations of Solution Concentration

Mole fraction – the ratio of moles of solute to total moles of solution

$$Mole\ fraction\ of\ A = \chi_A = \frac{n_A}{n_A + n_B}$$

What is the mole percent of ethanol (C_2H_5OH), which consists of 71.0 g of ethanol for every 14.3 g of water present?

A 66.0%

B 1.94%

C 1.52%

D 83.2%

E 34.0%

Calculations of Solution Concentration

Molality – moles of solute per kilogram of solvent

$$Molality = m = \frac{moles\ solute}{kilogram\ solvent}$$

What is the molality of solution of 33.5 g propanol ($CH_3CH_2CH_2OH$) in 152 ml water, if the density of water is 1.00 g/ml?

A 3.67 m

B 0.00367 m

C 0.273 m

D 0.557 m

E None of these

Calculations of Solution Concentration

Molarity - the ratio of moles of solute to liters of solution

$$Molarity = M = \frac{moles\ of\ solute}{Liter\ of\ solution}$$

A solution containing 481.6 g of $Mg(NO_3)_2$ per liter has a density of 1.114 g/ml. The molarity of the solution is:

A 3.247 M

B 2.915 M

C 9.740 M

D 3.617 M

E None of these