# Solutions and Colligative Properties

# TOPICS COVERED

- Solution
- Concentration Expression
  - Mass Percentage or Percentage Expression
  - % Concentration - % w/w, % v/v, % w/v, % v/w
  - Parts per Million (ppm) and Parts per Billion (ppb)
  - Molarity (*M*)
  - Molality (m)
  - Normality
  - Mole Fraction (*X*)

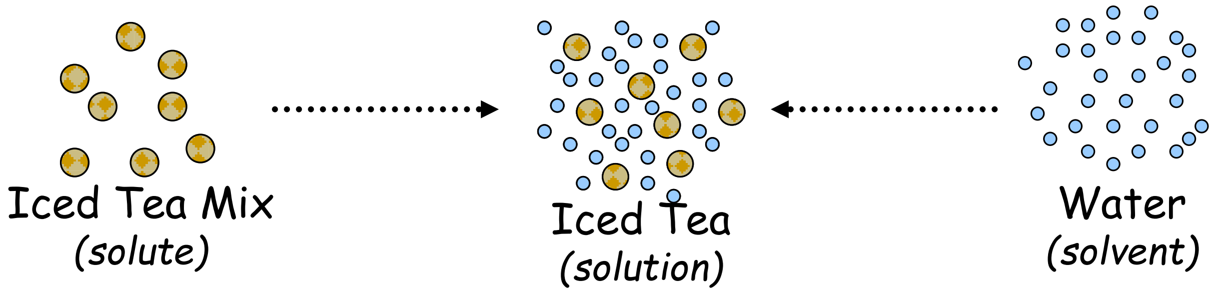
# Solution

- Solution: a mixture of two or more substances that is identical throughout (homogeneous)
- can be physically separated
- composed of *solutes* and *solvents*

Salt water is considered a solution. How can it be physically separated?

the substance being dissolved

the substance that dissolves the solute



# Definitions

- A solution is a homogeneous mixture of two or more substances

OR

- A solution is a homogenous mixture of solute and solvent.

OR

- A solution is a homogenous mixture of two substances but consisting of one phase.
- A solute is dissolved in a solvent.
- solute is the substance being dissolved
- solvent is the liquid in which the solute is dissolved
- an *aqueous* solution has water as solvent

- **Binary solution:** A homogenous mixture consisting of one phase and containing only two components i.e. one solute and one solvent e.g. Solution of NaCl in water.

- **Dilute Solutions:** A solution containing relatively small quantity of solute as compared with the amount of solvent.

- **Concentrated Solution:** A solution containing large amount of solute in the solution than that in dilute solution.

- **Un-saturated solution:** a solution in which more solute can be dissolved at a given temperature is called as an unsaturated solution.

# Types of Solutions: Based on physical states of solute and solvent:

**TABLE 13.1 Examples of Solutions**

| State of Solution | State of Solvent | State of Solute | Example |
|---|---|---|---|
| Gas | Gas | Gas | Air |
| Liquid | Liquid | Gas | Oxygen in water |
| Liquid | Liquid | Liquid | Alcohol in water |
| Liquid | Liquid | Solid | Salt in water |
| Solid | Solid | Gas | Hydrogen in palladium |
| Solid | Solid | Liquid | Mercury in silver |
| Solid | Solid | Solid | Silver in gold |
| Gas | Gas | Solid | Smoke in air |
| Gas | Gas | liquid | Water vapours in air |

# Concentration Expression

- **5 ways of expressing concentration**

- **Mass percent**: (mass solute / mass of solution) * 100
- **Molarity(M)**: moles solute / Liter solution
- **Molality* (m)** - moles solute / Kg solvent
- **Normality (N)**- gram equivalent of solute/ liter solution
- **Mole Fraction(cA)** - moles solute / total moles solution

*** Note that molality is the only concentration unit in which denominator contains only solvent information rather than solution.**

# Mass Percentage or Percentage Expression

- $\text{Mass \% of A} = \dfrac{\text{mass of A in solution}}{\text{total mass of solution}} \times 100$

- **Determine the mass percentage of hexane in a solution containing 11 g of butane in 110 g of hexane.**
    - $\text{Mass \% of the component} = \dfrac{\text{mass of the component in solution}}{\text{total mass of solution}} \times 100$

$$= \frac{110\text{ g}}{110\text{ g} + 11\text{g}} \times 100 = 91\%$$

## % Concentration

- $\% \text{ (w/w)} = \dfrac{\text{mass solute}}{\text{mass solution}} \times 100$
- $\% \text{ (w/v)} = \dfrac{\text{mass solute}}{\text{volume solution}} \times 100$
- $\% \text{ (v/v)} = \dfrac{\text{volume solute}}{\text{volume solution}} \times 100$

## % w/w

- It expresses the no. of grams of the solute per 100 gram of the solution.
- e.g. a 10 % w/w aqueous glycerine solution means 10 g of glycerine dissolved in sufficient water to make overall 100 gram of the solution.

## % v/v

- It expresses the no. of milliliters of the solute per 100 milliliters of the solution.
- e.g. a 10 % v/v aqueous ethanolic solution means 10 ml of ethanol dissolved in sufficient water to make overall 100 mls of the solution.

## % w/v

- It expresses the no. of grams of the solute per 100 mls of the solution.
- e.g. a 10 % w/v aqueous NaCl solution means 10 g of NaCl dissolved in sufficient water to make overall 100 mls of the solution.

**% v/w**

- It expresses the no. of mls of the solute per 100 gram of the solution.
- e.g. a 10 % v/w aqueous glycerine solution means 10 ml of glycerine dissolved in sufficient water to make overall 100 gram of the solution.

**Parts per Million and Parts per Billion**

This is another way to expressing concentration, particularly those of very dilute solutions. e.g. to express the impurities of substances in water.

- ppm denotes the amount of given substance in a total amount of 1,000,000 of solution e.g. one milligram per kilogram. 1 part in $10^{6}$
- ppb denotes the amount of given substance in a total amount of 1,000,000,000 of solution e.g. 0.001 milligram per kilogram. 1 part in $10^{9}$

# Parts per Million (ppm) and Parts per Billion (ppb)

**Parts per Million (ppm)** **Parts per Billion (ppb)**

- $$\text{ppm} = \frac{\text{mass of A in the solution}}{\text{total mass of solution}} \times 10^6$$ $$\text{ppb} = \frac{\text{mass of A in the solution}}{\text{total mass of solution}} \times 10^9$$

- **If 3.6 mg of Na+ is detected in a 200g sample of water from Lake Erie, what is its concentration in ppm?**

$$\text{ppm} = \frac{\text{mass of A in the solution}}{\text{total mass of solution}} \times 10^6$$

$$\text{ppm} = \frac{3.6\text{ mg}}{200\ g} = \frac{0.0036\text{ g}}{200\ g} \times 10^6 = 18\text{ ppm}$$

# Molarity (*M*)

- It expresses the no. of moles of solute dissolved per liter of the solution.

$$\% \text{ (w/w)} = \frac{\text{mole of solute}}{\text{L of solution}}$$

- molarity= Given weight / molecular weight substance x 1/ volume of solution in liters
- e.g.1 mole of Nacl= 58.5 gm of Nacl
- No. of moles= Given weight / molecular weight substance.
- Because volume is temperature dependent, molarity can change with temperature.

## Molality (*m*)

- It expresses the no. of moles of solute dissolved per kg of the solvent.

$$\% \text{ (w/w)} = \frac{\text{mole of solute}}{\textit{kg of solvent}}$$

- Because both moles and mass do not change with temperature, molality (unlike molarity) is *not* temperature dependent.

➢ **A solution is made by dissolving 4.35 g glucose ($C_6H_{12}O_6$) in 25.0 mL of water at 25°C. Calculate the molality of glucose in the solution.**

molar mass of glucose, 180.2 g/mol

$$\text{Mol } C_6H_{12}O_6 = (4.35 \text{ g } C_6H_{12}O_6)\left(\frac{1 \text{ mol } C_6H_{12}O_6}{180.2 \text{ g } C_6H_{12}O_6}\right) = 0.0241 \text{ mol } C_6H_{12}O_6$$

water has a density of 1.00 g/mL, so the mass of the solvent is

$$(25.0\ \text{mL})(1.00\ \text{g/mL}) = 25.0\ \text{g} = 0.0250\ \text{kg}$$

$$\text{Molality of } C_6H_{12}O_6 = \frac{0.0241\ \text{mol } C_6H_{12}O_6}{0.0250\ \text{kg } H_2O} = 0.964\ m$$

**Normality (N)**

- It expresses the no. of gram equivalent of solute dissolved per liter of the solution.

$$N = \frac{\textit{Number of gram equivalent of } \text{solute}}{\textit{L of solution}}$$

- Normality = Given weight / equivalent weight x 1/ volume of solution in liters

## Mole Fraction (*X*)

- The ratio of the number of the moles of that component to the total number of moles of all the components of the solution

$$X_A = \frac{moles\ of\ A}{total\ moles\ in\ solution}$$

The sum of the mole fractions of all the components is always equal to unity i.e. 1

# References

**Text Books**

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THANK YOU