SOME IMPORTANT PHYSICAL PROPERTIES

$$M = \frac{n}{V}$$

Some important physical properties of foods

- Density
- Specific heat
- Viscosity

physical properties of foods **change in certain limits** depending on the chemical and physical properties of foods

Chemical comp. → Physical property

CHANGES → CHANGES

Physical properties of foods;

- The most accurate way → **EXPERIMENT** to determine the physical property

- In practice, app. determined using equations developed for this purpose

CONCENTRATION

- Concentration is a measure of the amount of **dissolved solute** per unit of volume or weight of solution.

- Molarity
- Normality
- Molality

- ppm
- ppb
- Mass fraction-mass ratio
- Mole fraction-mole ratio

Concentrations based on volume

Dissolved solute

a) Molarity (M) : Mole of dissolved solute per L of solution (mol/L)

For calculation;

- Need to know MA/AA of dissolved solute.

b) Normality (N) :

Dissolved solute

$$N = \frac{\text{Equivalents}}{\text{1 L solution}}$$

To calculate the normality, we need to know :

- The weight of dissolved solute
- Its equivalent weight

How to calculate equivalent weight ?

$NaOH$ — f =1

H_2SO_4 — f =2

H_3PO_4 — f =3

f : the equivalence factor: the number of replaceable H^+ or OH^- per molecule

Concentrations based on volume:

Dissolved solute

c) Molality (*m*) : Mole number / 1000 g solvent (molal, m)

Example 1: Calculate the molality of concentrated stock HCL solution (28%).

Answer : 10.65 m

Concentrations based on volume:

d) Parts per million (ppm) :

Dissolved solute

mg of solute / kg of solution (or food)

(This concentration unit is used for **dilute aqueous solutions**)

1 g = 10^3 mg = 10^6 µg = 10^9 ηg = 10^{12} pg

- $ppm = \dfrac{mg}{kg} = \dfrac{\mu g}{g} = \dfrac{\eta g}{mg} = \dfrac{pg}{\mu g}$

- **Example 2 :** Calculate the concentration of Ca^{++} ions in water in ppm.

a) 1 mg Ca^{++} ions in 1 L water.

b) 1 mg Ca^{++} ions in 100 mL water.

c) 1 mg Ca^{++} ions in 80 mL water.

Concentrations based on volume:

e) Parts per billion (ppb) :

Dissolved solute

μg of a solute / kg of solution (or food)

(This concentration unit is used **dilute aqueous solutions**)

$$ppb = \frac{\mu g}{kg}$$

Example 3 : Calculate the concentration of Ca^{++} ions in water in ppb.

a) 1 mg Ca^{++} ions in 1 L water.

b) 1 mg Ca^{++} ions in 100 mL water.

c) 1 mg Ca^{++} ions in 80 mL water.

- **Example 16:** Calculate the English equivalent of 8 Pa.

  (lb_f = 4.44823 N)

- **Example 16:** Calculate the English equivalent of 8 Pa without using «lb_f = 4.44823 N» conversion.

Concentrations based on volume:

f) Weight / Volume Percent (*%w/v*) :

Dissolved solute

g solute / 100 mL solution

For example; 10% (w/v) sugar solution means 10 g sugar in 100 mL of sugar solution

Concentrations based on weight:

a) Weight / Weight Percent (*%w/w*) :

Dissolved solute

g solute / 100 g solution

- The concentrations of many commercial acids (HCl, H_2SO_4) are given in terms of w/w%.
- In order to calculate the volume of the stock solution, we need to know the density of stock solution.

- **Example 4 :** Describe the preparation of 2 L of 0.4 M HCl starting with a concentrated HCl solution (28% w/w, ρ=1.15 g/cm^3).

Answer: 90.7 mL stock HCl solution needed

- Measure out 90.7 mL of stock HCl solution
- Add slowly onto app 1800 mL of distilled water in iced-water bath.
- Acid should be added onto water slowly and the formation of excessive heat should be avoided.
- Final volume volumetric flask (2 L) was brought to 2 L with distilled water.
- The content of volumetric flask is mixed by turning upside-down of the flask content by 180^{o} for 10 times.

Concentrations based on weight:

b) **Degrees brix (°Bx)** ***:***

Dissolved solute in water

g solute / 100 g aqueous solution

(or food)

- **Example 5 :** In 74 g of pomegranate juice, there are 11.65 g of sugar, 1.05 g of organic acid and 0.17 g of salts of organic acids. Find out the brix of pomegranate juice.

Answer: 17.39°Brix

Dimensionless concentration forms:

Mass fraction

$$\textbf{Mass fraction (X)} = \frac{\text{weight of solute}}{\text{weight of solution}}$$

$$\textbf{Mass fraction } (X_1) = \frac{W_1}{W_1 + W_2}$$

Mass ratio

$$\textbf{Mass ratio} = \frac{\text{wt of solute in sol.}}{\text{wt of another solute in sol.}}$$

$$\textbf{Mass ratio:} = \frac{W_1}{W_3}$$

Mole fraction

$$\textbf{Mole fraction (Y)} = \frac{\text{\# of moles of solute in sol.}}{\text{total \# of moles in solution}}$$

$$\textbf{Mole fraction } (Y_1) = \frac{n_1}{n_1 + n_2}$$

Mole ratio

$$\textbf{Mole ratio} = \frac{\text{\# of moles of solute in sol.}}{\text{\# of moles of another solute in sol.}}$$

$$\textbf{Mole ratio} = \frac{n_1}{n_3}$$

- **Example 6 :** Calculate the mole fraction of HCl in concentrated stock HCL solution (28%).

Answer : 0.161

- **Example 7 :** Calculate the mass and mole fractions of the air with the following composition. (21%O_2 and 79%N_2)

Mean molecular weight (of gas mixtures):

a) The mole fractions :

$$\overline{MW} = Y_A\, MW_A + Y_B\, MW_B + .. + Y_i\, MW_i = \sum Y_i\, MW_i$$

b) The mass fractions :

$$\frac{1}{\overline{MW}} = \frac{X_A}{MW_A} + \frac{X_B}{MW_B} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + \frac{X_i}{MW_i} = \sum \frac{X_i}{MW_i}$$

Example 8 : Calculate the mean molecular weight of air using:

a) Mass fraction

b) Mole fraction

Answer :

$\overline{M_W} = 28.75$ g/gmol

Example 9 : The density of sugar solution prepared by dissolving 43 kg sucrose in 100 kg water is 1127 kg/m^3. Calculate the following terms;

a) Mass fraction of sugar,

b) Mass/volume fraction of sugar in sugar syrup,

c) Mole fraction of sucrose,

d) Molal concentration.

Answers

a) Mass fraction of sugar = **0.30**

b) Mass/volume fraction of sugar = **0.3889**

c) Mole fraction of sucrose = **0.022**

d) Molal concentration = **1.257 m**

Homework : Calculate the mean molecular weight of the gas mixture with the following composition.

- 15% oxygen (O_2)
- 65% nitrogen (N_2)
- 10% sulfur dioxide (SO_2)
- 10% carbon monoxide (CO)

Homework 2: Develop a spreadsheet on a computer to calculate concentration units for a sugar solution. The sugar solution is prepared by dissolving 10 kg of sucrose in 90 kg of water. The density of this sugar solution is 1040 kg/m^3. Determine:

- Concentration, weight per unit weight (w/w)
- Concentration, weight per unit volume (w/v, kg/L)

- °Brix
- molarity
- mole fraction
- molality
- Using the spreadsheet, recalculate the concentration values from the spreadsheet you formed if a) sucrose solution contains 20 kg of sucrose in 80 kg of water, and the density of the solution is 1,083 kg/m^3, b) sucrose solution contains 30 kg of sucrose in 70 kg of water, and the density of the solution is 1,129 kg/m^3.

Density:

$$\rho = \frac{m}{V}$$

ρ : Density, kg/m^3,

m : The mass of the substance, kg,

V : The volume of the substance, m^3.

Tablo 2.2 The unit of density in various systems

System	**Unit**
SI	kg/m^3
English	lb_m/ft^3
mks	kg/L
cks	g/cm^3 (g/mL)

In almost all of the substances;

- The density varies depending on the temperature!
- Temperature ↑ Volume ↑ Density ↓
- While the density of a substance is given, the **temperature should also be defined**!!
- It is more important in gases!! (0°C and 760 mmHg)

In Gases:

Temperature ↑ Pressure ↓

Volume ↑ Density ↓

Example 10 : Calculate the density at 12°C of pure water by using Tablo 2.2, according to :

- SI,
- EES unit systems.

Relation between temperature and density of pure water

Temperature (°C)	ρ (g/cm^3)
0	0.99987
3.98	1.00000
5	0.99999
10	0.99973
15	0.99913
40	0.99224
80	0.97183
100	0.95838

Answers

- 999.49 kg/m^3
- $$62.40 \frac{lb_m}{ft^3}$$

INTERPOLATION

A method

which is not found in a table

for the calculation of a value

by taking into consideration of changing trend of values.

Determination of density in foods :

- The only way → EXPERIMENT

- Developed equations for this purpose have not given true result.

- The density of foods depends on;
  - ✓ Its composition (especially water)
  - ✓ Soluble solid content.

Density of food

- Decreases with increasing fat content

- Increases with increasing protein, sugar and salt contents

There are also other factors!!

- Intracellular spaces
- Intercellular spaces

Therefore, the densities of fruits and vegetables are **less than that of water**.

Density

Disregards all the pore spaces!!

Solid density

Particle density

Accounts for the presence of internal pores in the food particles!!

Bulk density

Accounts for the all void spaces !!

- The solid density of most food particles is 1.4–1.6 g/cm^3 (or 1400–1600 kg/m^3), **except for fat (0.9 g/cm^3) and salt (2.16 g/cm^3).**
- If the type of the density is not specified, then the given density is taken as **solid density**.

Solid density

$$\text{Solid density} = \frac{\text{Mass of a particle}}{\text{Volume (disregarding all space)}}$$

Particle density

$$\text{Particle density} = \frac{\text{Mass of a particle}}{\text{Volume (including the internal pores in particles, disregarding the pores between particles)}}$$

Bulk density

$$\text{Bulk density} = \frac{\text{Mass of a particle}}{\text{Volume (including the internal pores in particles and the pores between particles)}}$$

Tablo 2.2 Solid densities of major food ingredients

Ingredient	g/cm^3		Ingredient	g/cm^3
Glucose	1.56		Citric acid	1.54
Sucrose	1.59		Fat	0.90
Starch	1.50		Salt	2.16
Cellulose	1.27–1.61		Water	1.00
Protein	1.4		Ethyl alcohol	0.79

Example 11 : Calculate the density of apple in SI unit with the following composition.

- 85% water
- 14.4% sugar
- 0.4% fat
- 0.2% protein

$\rho_{apple} = 1057\ kg/m^3$

Calculated density (1057 kg/m^3) is higher than the density of water (1000 kg/m^3), but apples stay on the water.

Which density are we talking about?

Answer: Of course, the **solid density**!!!

However, apples stay on the water because apples contain high amount of air in both intercellular and intracellular.

During **storage** of fruit and vegetable, the **bulk density** is taken into account for calculating of the storage volume.

Specific gravity (sp-gr):

- The ratio of the density of a given substance at 4°C to the density of water at the same temperature.

- The density of water is the highest at 3.98°C (1 g/cm^3 or 1000 kg/m^3).

- Specific gravity = $\dfrac{\text{Density of a material at a given temperature}}{\text{Density of water at the same temperature}}$

- Specific gravity is dimensionless since it is the ratio of densities.

- In the calculation of specific gravity of gases, air is taken as reference, not water.

- **Example 12 :** The density of ammonia is 0.769 kg/m^3. Calculate the specific gravity of this gas.

Note: The density of dry air is 1.293 kg/m^3 under standard conditions (0°C and 760 mm-Hg)