Methods of expression of concentrations

طرائق التعبير عن التراكيز

1-Molarity (M):

Number of Grams of molecular weight (moles) of solute per liter of solution.

المولارية :- وتعرف بأنها عدد الاوزان الجزيئية الغرامية (moles) من المادة المذابة في لتر من المحلول

$$M = \frac{number\ of\ moles}{v\ (liter)} \longrightarrow M = \frac{n}{V(liter)}$$

$$(where \quad n = \frac{Wt}{M.wt.} \longrightarrow \frac{\text{الوزن}}{\text{الوزن الجزيئي}} = \text{عدد المولات})$$

(or) $$M = \frac{no.of\ millimoles}{V\ (mL)}$$

$$\boxed{M = \frac{Wt}{M.Wt} x \frac{1000}{VmL}}$$

$$M = \frac{wt\ (gm)}{M.Wt\left(\frac{gm}{mol}\right)} / L = mole/L)$$

Wt يمثل وزن المادة المذابة بالغرام ، VmL حجم المحلول بالمليلتر .

Units: **mole/L , mmole /mL**

Ex: How many grams of 0.125 M $AgNO_3$ were used to prepare 500 ml of its solution?

(M.Wt. $_{AgNO3}$ = 169.9 g/mole)

$$M = \frac{Wt}{M.Wt} x \frac{1000}{VmL} \quad \Rightarrow \quad 0.125 = \frac{Wt}{169.9} x \frac{1000}{500}$$

$$Wt = \frac{M\ x\ M.Wtx\ Vml}{1000}$$

$$Wt = \frac{0.125\ x\ 169.9x\ 500}{1000} = 10.619\ g$$

Ex: Calculate the Molarity (M) of solution resulting from dissolving 20 g of Sodium hydroxide into 2 Liters of solution. **Na = 23, O = 16 , H = 1**

$$M = \frac{n}{V(liter)} \qquad NaOH \quad M.Wt = 23 + 16 + 1 = 40g/mol$$

$$n = \frac{Wt}{M.Wt} = \frac{20}{40} = 0.5 \text{ mole} \qquad \frac{0.5}{2} = 0.25\ M$$

حل آخر

$$M = \frac{Wt}{M.Wt} x \frac{1000}{VmL} \Rightarrow M = \frac{20}{40} x \frac{1000}{2000} = 0.25\ M$$

$$M = \frac{Wt}{M.Wt} x \frac{1}{VL} \Rightarrow M = \frac{20}{40} x \frac{1}{2} = 0.25\ M$$

2-Normality (N):

Number of grams equivalent weight of solute per liter of solution.

العيارية (النورمالية): وتعرف بأنها عدد المكافئات الغرامية من المذاب في لتر من المحلول .

$$N = \frac{number\ of\ equivalent}{V(liter)} \quad , \quad N = \frac{no.\ of\ eq}{V(liter)} \quad , \quad N = \frac{no.\ of\ meq}{V\ mL}$$

$$\frac{\text{الوزن بالغرام}}{\text{الوزن المكافئ}} = \text{عدد المكافئات الغرامية} \quad , \quad \frac{\text{عدد المكافئات الغرامية}}{\text{الحجم}} = N$$

$$N = \frac{Wt}{eq.wt} x \frac{1000}{VmL}$$

Units: **eq /L** , **meq/mL**

حيث ان :-

Wt يمثل وزن المادة المذابة بالغرام ، eq.Wt يمثل الوزن المكافئ للمادة المذابة ، VmL حجم المحلول بالمليلتر .

Ex: How many grams of 0.2 N sodium carbonate are in a 250 ml solution? (M.Wt = 106 g/mole)

$$eq.wt\ (salt) = \frac{M.wt}{no.of\ cations \times oxidation\ number\ of\ cations}$$

$$eq.wt\ Na_2CO_3 = \frac{106}{2\times1} = 53\ g/eq$$

$$N = \frac{Wt}{eq.wt} x \frac{1000}{VmL}$$

$$0.2 = \frac{Wt}{53} x \frac{1000}{250} \Rightarrow Wt = \frac{0.2x53x250}{1000} = 2.650g$$

Ex: Calculate the solution's normality (N) from dissolving 0.5 g of $Cu(OH)_2$ in 100 mL of distilled water. (Cu = 63.5 , O = 16 , H = 1)

SOL.)

$[Cu(OH)_2]$ $M.wt = 63.5 + (2x16) + (2x1) = 97.5 g/mol_e$

$$eq.wt(base) = \frac{M.Wt}{no.of\ OH\ ions\ ready\ to\ substituted}$$

$$eq.wt = \frac{97.5}{2} = 48.75\ g/eq$$

$$N = \frac{Wt}{eq.wt}\ x\frac{1000}{VmL} \quad \Rightarrow \quad \frac{0.5}{48.75}\ x\frac{1000}{100} = 0.103N$$

3- Formality (F):

Number of grams formula weight of solute per liter of solution.

الفورمالية : هي عدد اوزان الصيغة الغرامية للمذاب في لتر من المحلول

$$F = \frac{number\ of\ formula\ weight}{V\ (liter)}$$

$$F = \frac{no.of\ milliformula\ weight}{VmL} \qquad F = \frac{\text{no. of m. fw}}{\text{VmL}}$$

$$\boxed{F = \frac{Wt}{g.\text{fw}}\ x\frac{1000}{VmL}}$$

حيث : Wt يمثل وزن المادة المذابة بالغرام , fw يمثل وزن الصيغة للمادة المذابة , VmL حجم المحلول بالملليلتر .

Units: **fw/L , m.fw/mL**

4-Molality (m):

Number of moles of solute per kilogram (1000 g) of solvent.

المولالية: تمثل عدد مولات المذاب في كيلو غرام (**1000**غم) من المذيب.

$$m = \frac{number\ \text{of moles of solute}}{Wt.solvent\ (Kg)}$$

$$m = \frac{Wt}{M.Wt} \; x \; \frac{1000}{Wt.solvent.(g)}$$

Units: Mole/kg or mmole/g

Ex: Calculate the molality (m) of the solution from dissolving 5 g of sodium hydroxide in 250 g of distilled water. (M.Wt = 40 g/mole)

$$n_{NaOH} = \frac{wt}{M.wt} = \frac{5g}{40\frac{g}{mole}} = 0.125\ mole$$

$$Kg = 1000mg \;\Rightarrow 250g = 0.250Kg$$

$$m = \frac{number\ of moles\ of\ solute}{Wt.solvent.(Kg)} = = \frac{0.125}{0.250} = 0.5m$$

or: $$m = \frac{Wt}{M.Wt} \times \frac{1000}{Wt.\ solvent\ (gm)} \qquad m = \frac{5}{40} \times \frac{1000}{250} = 0.5\ mmole/gm$$

5- Mole Fraction:

The ratio of moles of solute or solvent to the total moles of solute and solvent.

الكسر المولي: هو النسبة بين عدد مولات المذاب او المذيب الى العدد الكلي لمولات المذاب والمذيب .

$$X_1 = \frac{n_1}{n_1+n_2} \qquad X_2 = \frac{n_2}{n_1+n_2} \qquad \text{---------} \qquad (X_1+X_2 = 1)$$

X_1 يمثل الكسر المولي للمذاب، X_2 يمثل الكسر المولي للمذيب، n_1 عدد مولات المذاب ، n_2 عدد مولات المذيب

Ex: Calculate the mole fraction for A and B in its mixture if you know the number of Moles of A = 18 moles and B = 40 moles.

$$X_A = \frac{18}{18+40} = 0.310$$

$$X_B = \frac{40}{18+40} = 0.690$$

or) $X_B = 1.0 - 0.310 = 0.690$ (X_B طريقة اخرى لحساب)

6- Percentage Ratio: النسبة المئوية

A- Weight Volume Percentage (weigh to volume percent ratio):

It is the number of grams of solute in 100 ml of solution.

النسبة المئوية الوزنية الحجمية : عدد غرامات المذاب في 100 ملليلتر من المحلول .

$$\% \text{ W/V} = \frac{\text{Wt (g) of solute}}{\text{V(mL) of solution}} \times 100$$

$$100 \times \frac{\text{وزن المذاب بالغرام}}{\text{حجم المحلول بالملليلتر}} = \% \text{ W/V}$$

ملاحظة : حجم المحلول = حجم المذاب + حجم المذيب

B- Volume Percentage (volume percent ratio):

It is the number of milliliters of solute in 100 mL of solution

النسبة المئوية الحجمية : عدد ملليلترات المذاب في 100 ملليلتر من المحلول .

$$\% \text{ V/V} = \frac{\text{VmL of solute}}{\text{VmL of solution}} \times 100$$

$$100 \times \frac{\text{حجم المذاب بالملليلتر}}{\text{حجم المحلول بالملليلتر}} = \% \text{ V/V}$$

ملاحظة : حجم المحلول = حجم المذاب + حجم المذيب

C- Weight Percentage (weight percent ratio):

It is the number of grams of solute in 100 g of solution.

النسبة المئوية االوزنية : عدد غرامات المذاب في 100غرام من المحلول .

$$\%\text{W/W} = \frac{\text{Wt (g) of solute}}{\text{Wt (g) of solution}} \times 100$$

$$100 \times \frac{\text{وزن المذاب بالغرام}}{\text{وزن المحلول بالغرام}} = \%\text{W/W}$$

ملاحظة : وزن المحلول = وزن المذاب + وزن المذيب

Ex1: Calculate the percentage ratio for solution result from dissolving 5 g of Sodium hydroxide in 0.25 L of solution

$$\%W/V = \frac{\text{Wtg of solute}}{\text{VmL of solution}} \times 100 = \frac{5}{250} \times 100 = 2\ \%$$

Ex2: Calculate the percentage ratio for the solution resulting from the addition of 200 mL of Methanol to 400 mL distilled water.

$$\%\ V/V = \frac{\text{VmL of solute}}{\text{VmL of solution}} \text{ x } 100$$

$$\%\ V/V = \frac{200}{200 + 400} \text{ x } 100 = 33.333\%$$

Ex3: Calculate the No. of grams of glucose solution in 800 mL of industrial solution, if its percentage ratio is 15 %

$$\%W/V = \frac{\text{Wtg of solute}}{\text{VmL of solution}} \text{x}100$$

$$15 = \frac{\text{Wt}_g \text{ of glucose}}{800} \text{ x } 100 = 120 \text{ g}$$

7- Parts per thousand (ppt) **جزء لكل الف جزء**

$$\text{ppt} = \frac{\textbf{\textit{Wt. of solute}}(\text{وزن المذاب})}{\textbf{\textit{Wt. of solution}}(\text{وزن المحلول})} \times 10^3$$

$$(\text{or}) \quad \text{ppt} = \frac{\textbf{\textit{Wt of solute (g)}}}{\textbf{\textit{Volume of solution (L)}}} = \frac{\textbf{\textit{mg}}}{\textbf{\textit{mL}}}$$

8- Parts per million (ppm) **جزء لكل مليون جزء**

$$\textbf{ppm} = \frac{\textbf{\textit{Wt.of solute}}(\text{وزن المذاب})}{\textbf{\textit{Wt.of solution}}(\text{وزن المحلول})} \times 10^6$$

(or) $\text{ppm} = \frac{Wt\ of\ solute\ (mg)}{Volume\ of\ solution\ (L)} = \frac{\mu g}{mL}$

9- (Parts per billion) ppb جزء لكل بليون جزء

$$\text{ppb} = \frac{Wt\ of\ solute(\text{وزن المذاب})}{Wt\ of\ solution(\text{وزن المحلول})} \times 10^9$$

(or) $\text{ppb} = \frac{Wt\ of\ solute\ (\mu g)}{Volume\ of\ solution\ (L)} = \frac{ng}{mL}$

Gram (g) = 1000 Milligram (mg)

Milligram (mg) =1000 Microgram (µg)

Microgram (µg) = 1000 Nangram (ng)

Liter (L) = 1000 Milliliter (mL)

Milliliter (mL) = 1000 Microliter (µL)

Microliter(µL) = 1000 Nanoliter (nL)

part	liquid in liquid	Solid in liquid	Solid in solid
ppt	mL/L = µL/mL	g/L = mg/mL	g/kg = mg/g
ppm	µL/L = nL/mL	mg/L = µg/mL	mg/kg = µg/g
ppb	nL/L	µg/L = ng/mL	µg/kg = ng/g

10- يمكن استخدام القوانين الاتية لإيجاد تراكيز المحاليل السائلة من معرفة نسبتها المئوية ووزنها النوعي :

$$\mathbf{M} = \frac{\% \times sp.gr \times 1000}{M.wt.} \qquad \frac{\text{النسبة المئوية} \times \text{الوزن النوعي} \times 1000}{\text{الوزن الجزيئي}} = M$$

$$N = \frac{\% \times sp.gr \times 1000}{eg.wt} \qquad \frac{\text{الوزن النوعي} \times \text{النسبة المئوية} \times 1000}{\text{الوزن المكافئ}} = N$$

$$F = \frac{\% \times sp.gr \times 1000}{g.fw} \qquad \frac{\text{الوزن النوعي} \times \text{النسبة المئوية} \times 1000}{\text{وزن الصيغة}} = F$$

Also these laws:

$$N_1 V_1 = N_2 V_2 \quad , \quad M_1 V_1 = M_2 V_2 \quad , \quad F_1 V_1 = F_2 V_2$$

$$\text{Density (d)} = \frac{Wt\ (g)}{V(mL)} \quad \text{(UNIT: g / mL or Kg /L)} \qquad \left(\text{الكثافة} = \frac{\text{الكتلة بالغرام}}{\text{الحجم بالملليلتر}} \right)$$

$$\text{Specific gravity (sp. gr)} = \frac{density\ of\ substance}{density\ of\ water}$$

ملاحظة : الوزن النوعي للمادة خالي من الوحدات

$$\text{الوزن النوعي} = \frac{\text{كثافة المادة}}{\text{كثافة الماء}}$$

Ex1: Calculate the normality (N) of the solution resulting from the dilution of 100 mL of 0.25 N Nitric Acid to 250 mL

$$N_1 V_{10.} = N_2 V_2$$

$$0.25 \times 100 = N_2 \times 250 \quad \Rightarrow \quad N_2 = 0.1\ N$$

Ex2: How can you prepare 0.1 N of 250 mL Sulfuric Acid if you know Sp.Gr. 1.84, percentage ratio 96 %, and M.Wt. 98 g/mole

$$eq.wt(acid) = \frac{M.Wt}{no.\ of\ H\ ions\ ready\ to\ substituted}$$

$$\frac{98}{2} = 49$$

$$N = \frac{\%\ x\ sp.gr\ x\ 1000}{eq.wt} = \frac{0.96\ x\ 1.84\ x\ 1000}{49} = 36.049N$$

$N_1 V_1 = N_2 V_2$

$36.049 \times V_1 = 0.1 \times 250$

$V_1 = 0.694$ mL

By adding 0.694 mL of acid in a 250 mL volumetric flask then complete the volume up to the mark with distilled water

Q(خارجي) How can you prepare 0.5 N of 500 mL Hydrochloric Acid if you know Sp. Gr. 1.184, percentage ratio 37% and A.Wt. H=1 Cl=35.5

Solved questions on concentrations

Q1- What is the formal concentration of NaCl solution (M.Wt 58.5 g/mole) if 0.1753 g of the salt is dissolved in a sufficient amount of water to give 240 mL of solution?

$$F = \frac{Wt}{g.\text{fw}} x \frac{1000}{VmL}$$

$$F = \frac{0.1735}{58.5} x \frac{1000}{240}$$

$$= 0.0125\ F\ (mfw/mL)$$

Q2- Calculate the molality (m) of a solution which is 10 % by weight NaOH (M.Wt 40 g/mole), supposing that we take 100 gm of solution.

Sol.

In 100 g of solution: 10 g NaOH + 90 g H_2O

$$m = \frac{Wt}{M.Wt}\ x\ \frac{1000}{Wt.solvent.(g)}$$

$$\frac{10}{40} \times \frac{1000}{90} = 2.778\ m(mmole/g)$$

Q3- Calculate the molarity and normality of a solution containing 10.6 g of sodium carbonate Na_2CO_3 (M.Wt 106 g/mole) in one liter of the aqueous solution.

$$M = \frac{n}{V(Liter)}$$

$$n = \frac{wt}{Mwt} = \frac{10.6}{106} = 0.1\ mole$$

$$M = \frac{0.1}{1} = 0.1\ M\ (\frac{mole}{l})$$

حل آخر

$$M = \frac{wt}{Mwt} \times \frac{1000}{V(ml)}$$

$$M = \frac{10.6}{106} \times \frac{1000}{1000} = 0.1\ M\ (mmole/mL)$$

$$eq.wt(salt) = \frac{M.wt}{no.of\ cations\ x\ oxidation\ number\ of\ cations}$$

eq.wt $(Na_2CO_3) = \frac{106}{2\times1} = 53g/eq$

$$N = \frac{no.ofeq}{V(liter)}, \qquad no.ofeq = \frac{Wt}{eq.wt} = \frac{10.6}{53} = 0.2\ eq$$

$$N = \frac{0.2}{1} = 0.2\ N(eq/L)$$

(or)

$$N = \frac{Wt}{eq.wt}\ x\frac{1000}{VmL} = \frac{10.6}{53}\ x\frac{1000}{1000} = 0.2N(meq/mL)$$

Q4- 16 grams of KNO_3 dissolved in 84 g of water, give 16 % (w/w) KNO_3 solution express the concentration in ppm.

$$ppm = \frac{wt\ of\ soluute}{wt\ of\ solution} \times 10^6$$

$$ppm = \frac{16}{84} \times 10^6 = 0.1905\ ppm\ (\frac{\mu g}{g})$$

Q5- Calculate the number of grams of solute in:

a- 1 liter of 0.2 N $Ba(OH)_2$ solution.

b- 5 liters of 0.2 N (NaOH) solution.

a) **eq. Wt $Ba(OH)_2 = \frac{171}{2}$ = 85.5 g / eq**

$$N = \frac{Wt}{eq.wt} x \frac{1000}{VmL} \Rightarrow Wt = \frac{N\ x\ eq.wt\ x\ Vml}{1000}$$

$$Wt = \frac{0.2\ x\ 85.5x\ 1000}{1000} = 17.1\ g$$

b) $$\text{eq.wt (base)} = \frac{M.Wt}{no.of\ hydroxide\ atoms\ ionized(OH^-)}$$

$$\text{eq.wt NaOH} = \frac{40}{1} = 40\ g/eq$$

$$N = \frac{Wt}{eq.wt} x \frac{1000}{VmL} \Rightarrow Wt = \frac{N\ x\ eq.wt\ x\ Vml}{1000}$$

$$Wt = \frac{0.2\ x\ 40x\ 5000}{1000} = 40\ g$$

Q6- How can you prepare:

a- 250 mL of 0.25 F HCl, if the sp. gravity of HCl a=1.184 and containing about 37 % HCl by weight.

b- 250 ml of 0.1 M H_2SO_4. if the sp. Gravity = 1.84 and containing about 96 % H_2SO_4 .

a-

$$F = \frac{\%\ x\ sp.gr\ x\ 1000}{g.fw} = \frac{0.37\ x\ 1.184\ x\ 1000}{36.5} = 12.002F$$

هذا يمثل تركيز الحامض الاصلي ولتحضير محلول مخفف منه تطبق قانون التخفيف وكما يلي :-

$F_1V_1 = F_2V_2$

$12.002 \times V_1 = 0.25 \times 250$

$$v_1 = \frac{0.25 \times 250}{12.002} = 5.207\ mL$$

By adding 5.207 mL of acid and in 250 mL volumetric flask then complete the volume up to the mark with distilled water.

b-

$$M = \frac{\% \; x \; sp.gr \; x \; 1000}{M.Wt} = \frac{0.96 \; x \; 1.84 \; x \; 1000}{98} = 18.024M$$

$M_1V_1 = M_2V_2$

$18.024 \times V_1 = 0.1 \times 250$

$$v_1 = \frac{25 \times 250}{18.024} = 1.387 \; mL$$

By adding 1.378 mL of acid in a 250 mL volumetric flask then complete the volume up to the mark with distilled water.

Q7- Calculate the normality (N) of a 500 ml solution containing 20 g of NaOH (M.Wt 40 g/mole).

$$N = \frac{Wt}{eq.wt} \; x \frac{1000}{VmL} = \frac{20}{40} \; x \frac{1000}{500} = 1N(meq/mL)$$

Q8- Find the molarity (M) of NaCl solution if 1.17 % (W/V), M.Wt = 58.5 g/mole

Sol.

% W/V = No. of grams of solute (1.17 g) in 100 ml of solution

$$M = \frac{Wt}{M.Wt} \; x \frac{1000}{VmL}$$

$$M = \frac{1.17}{58.5} \; x \frac{1000}{100}$$

M = 0.2 M (mmole/mL)

Q9- Calculate the mole fraction of 15 % by weight of aqueous sugar solution (15 % (w/w) $C_6H_{12}O_6$).

Sol.

M.Wt: $C_6H_{12}O_6$ = 180 g/mole, H_2O = 18 g/mole

In 100 g of solution: 15g $C_6H_{12}O_6$ + 85 g H_2O

$$mole\ fraction\ of\ sugar(X_1) = \frac{No.\ of\ moles\ of\ sugar}{No.\ of\ moles\ of\ sugar + No.\ of\ moles\ of\ water}$$

$$mole\ fraction\ of\ water(X_2) = \frac{No.\ of\ moles\ of\ water}{No.\ of\ moles\ of\ sugar + No.\ of\ moles\ of\ water}$$

Numbers of mole of $C_6H_{12}O_6$ (n_1) =

$$n_1 = \frac{Wt}{M.Wt} = \frac{15}{180} = 0.083\ mole$$

Numbers of the mole of water (n_2) =

$$n_2 = \frac{Wt}{M.Wt} = \frac{85}{180} = 4.722\ mole$$

$$X_1 = \frac{n_1}{n_1 + n_2} = \frac{0.083}{4.805} = 0.017\ (\text{mole fraction of sugar})$$

$$X_2 = \frac{n_2}{n_1 + n_2} = \frac{4.722}{4.805} = 0.983\ (\text{mole fraction of water})$$

$$X_1 + X_2 = 1$$

$$0.017 + 0.983 = 1$$