Objectives :

After completing this unit , the student will be able to :

1-Identify concentration units and know how to use them appropriately .

2-Prepare solutions from initial ingredients and by dilution of existing solutions using various concentration units .

3- Convert one concentration unit to another e.g convert molarity to ppm or ppb or normality and vice versa …etc .

4- differentiate between molarity and normality and between molrity and activity .

5- understand how to calculate the equivalent weight of a substance .

Introduction

Solutions can be any solute, dissolved in any solvent. Very rarely do you work with any chemical in its pure solid form. Most chemical reactions, both in nature and in the laboratory, take place in a solution . Biological chemistry depends upon reactions which take place in water (as a solvent). This is especially true for reactions involving enzymes . Solutions are everywhere. They enable the body to incorporate molecules into the body systems . Medicines use solutions for good absorption, so do vitamins and supplements, food, cosmetics, stains, and paints . The relationships between the amount of solute and the amount or volume of solution is called concentration .There are two common ways to express concentration these will be the subject of this unit .

Concentration

It is a term that expresses the relationship between the amount (quantity) of solute (solu.) and often the volume of the solution (soln.) and can be expressed in one of two methods depending on the units used for the quantity of solute .

Physical Method :

In this method we use the gram and its derivatives to express the weight of solute (Wt. of solu.) :

One gram (g) = 10^3 milligram (mg)= 10^6 microgram (μg)

= 10^9 nanogram (ng) = 10^{12} picogram (pg)

And we use the liter and its derivatives to express the volume of solution (Vol. of soln.) :

Physical Method (Wt./ / V)

One liter (L) = 10^3 milliliter (mL) = 10^6 microliter (µL)
= 10^9 nanoliter (nL) = 10^{12} (picoliter (Pl)

we can use several expressions such as

$$g/L = \frac{Wt.\ of\ \ solu.(g)}{Vol.\ of\ \ soln(L)}$$

$$mg/ml = \frac{Wt.\ of\ \ solu.(mg)}{Vol.\ of\ \ soln.(mL)}$$

And so on .

Physical Method (Wt. / V)

Example : how much weight is needed to prepare 500 mL solution of 5 (g / L) of substance A ?

Solution :

$$5 \ (g/L) = \frac{x \ (g)}{500\,(mL)\,X\,10^{-3}\,(L)} \quad , \ x = 5 X 0.5 = 2.5 \ g$$

Example : 10 g of substance B have been dissolved in water and the volume is completed with water to 200 ml . calculate the concentration of B in the following terms: g/L , mg/L , µg/ml , ng/ml and pg/µL ?

Physical Method (Wt. / V)

Solution :

$$g\,/\,L = \frac{10\ (g)}{200\ (ml)\ X\ 10^{-3}\ (L)} = 50$$

$$mg\,/\,L = \frac{10\ (g)\ X\ 10^{3}\ (mg)}{200\ (ml)\ X\ 10^{-3}\ (L)} = 50\ X\ 10^{3}$$

$$\mu g\,/\,ml = \frac{10\ (g)\ X\ 10^{6}\ (\mu g)}{200\ (ml)} = 50\ X\ 10^{3}$$

$$ng\,/\,ml = \frac{10\ (g)\ X\ 10^{9}\ (ng)}{200\ (ml)} = 50\ X\ 10^{3}$$

$$pg\,/\,\mu L = \frac{10\ (g)\ X\ 10^{12}\ (pg)}{200\ X\ 10^{3}\ (\mu L)} = 50\ X\ 10^{6}$$

Physical Method (ppm)

Example : You have a solution of solute B its concentration is 10 µg B /ml . Calculate the weight of B in 5 ml of this solution ?

Solution :

$$10\,(\mu g\ B/ml) = \frac{x\,(\mu g\ B)}{5\,ml} \quad \therefore\ x = 10\,X\,5 = 50\ \mu g\ B$$

parts per million (ppm) : this expression is among the physical method which means parts of solute in a million parts of the solution . If we say 500 ppm of solute B that means 500 parts (g or mg or µg .... etc.) in a million parts (g or mg or gµ .... etc.) of the solution that means also every million parts of solution contains 500 parts of solute B . and can be expressed according to the type of solution as follows :

Physical Method (ppm)

(a) Solid solute in a solid solution : such as an element in an alloy

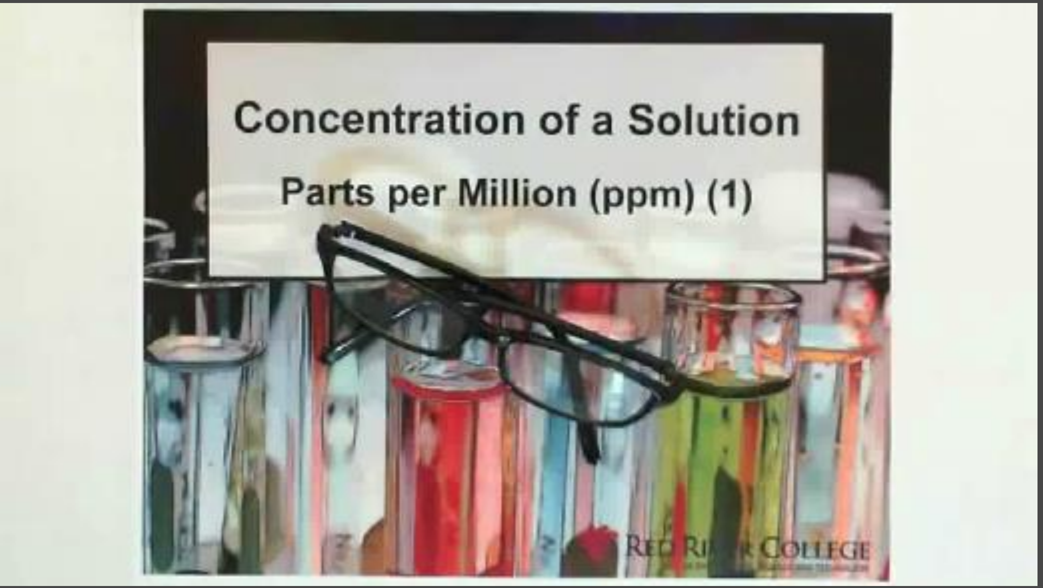
$$ppm = \frac{Wt.\,of\ solu.(g.mg...)}{Wt.\,of\ soln.(g.mg..)}\ X\ 10^6$$

where the weights of both the solute and the solution are expressed with the same unit (g or mg or µg …etc) and we multiply by 10^6

Physical Method (ppm)

Instead of multiplying by 10^6 we can use a weighing unit for the solution that is equal to million units used for the solute :

$$ppm = \frac{Wt.\,of\ solu.(mg)}{Wt.\,of\ soln.(kg)} = \frac{Wt.\,of\ solu.(\mu g)}{Wt.\,of\ soln.(g)}$$



Where we note that one kilogram (Kg) equals million milligrams (mg) and also one gram(g) equals million micrograms (μg) and so on .

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Physical Method (ppm)

(b) Liquid - liquid solution : such as dissolving an alcohol in water : Same way as before, but here we use volume units instead of the weight units and either we unite the unit of both the solute and the solution (L or mL …etc) and multiply by 10^6 thus :

$$ppm = \frac{Vol.of\ solu.(ml.L.)}{Vol.of\ soln.(ml..L..)} x\ 10^6$$

Or we use a volume unit for the solution equal million of the unit used for the solute thus :

$$ppm = \frac{Vol.of\ solu.(\mu L)}{Vol.of\ soln.(L)} = \frac{Vol.of\ solu.(nL)}{Vol.of\ soln.(mL)}$$

Physical Method (ppm)

where one liter (L) equal to million microliter (μL) and one milliliter (mL) equal to million nanoliter (nL) .

(c) solid - liquid solution : such as dissolving a salt in water . Water is a common solvent and its density is 1 g / mL at room temperature therefore one liter of water solution weigh 1000 g which is one Kilogram (Kg) assuming its density will not be affected by dissolving trace amounts of solute in it . Therefore we can deal with the solid – liquid solution in the same manner as we did with solid-solid or liquid – liquid solutions :

Physical Method (ppb)

$$ppm = \frac{Wt.of\ solu.(mg)}{Vol.\ of\ soln.(L)} \equiv \frac{mg}{Kg}$$

$$= \frac{Wt.of\ solu.(\mu g)}{Vol.of\ soln.(mL)} \equiv \frac{\mu g}{g}$$

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Con.^{n} in ppm and ppb

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Parts per billion (ppb)

The same as mentioned in the above ppm term , but instead of using 10^6 we use 10^9 or we use a unit for the solution (denominator) equal to one billion unit used for the solute (numerator) as can be seen from the following formulas:

Physical Method (ppb)

(a) Solid – solid solution :

$$ppb = \frac{Wt.\,of\ solu.(g..mg..)}{Wt.\,of\ soln.(g..mg..)}\ x\,10^9$$

Or

$$ppb = \frac{Wt.\,of\ solu.(\mu g)}{Wt.\,of\ soln.(Kg)} = \frac{Wt.\,of\ solu.(ng)}{Wt.\,of\ soln.(g)}$$

Note that one (Kg) equal to billion (µg) and one (g) equal to billion(ng) and so on .

(b) liquid – liquid solution :

$$ppb = \frac{Vol.\,of\ solu.(L..ml)}{Vol.\,of\ soln.(L..ml)}\ x\,10^9$$

Or

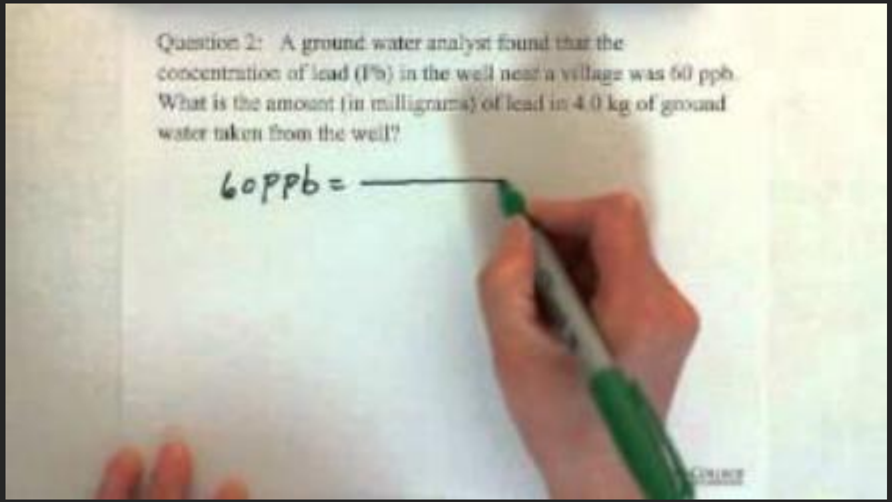
$$ppb = \frac{Vol.\,of\ solu\,(nL)}{Vol.\,of\ soln.\,(L)} = \frac{Vol.\,of\ solu\,(pL)}{Vol.\,of\ soln.\,(mL)}$$

Physical Method (ppb)

One liter (L) is equal to billion nanoliter (nL) and one milliliter (mL) is equal to billion picoliter (pL) and so on .

(C) Solid – liquid solution :

$$ppb = \frac{Wt.of\ solu.(\mu g)}{Vol.of\ soln.(L)} = \frac{Wt.of\ solu.(ng)}{Vol.of\ soln.(mL)}$$



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One liter (L) of the aqueous solution weigh one(Kg) as mentioned above which is equal to billion(μg) .Likewise

one milliliter of aqueous solution weigh one (g) which is equal to billion (ng) and so on .

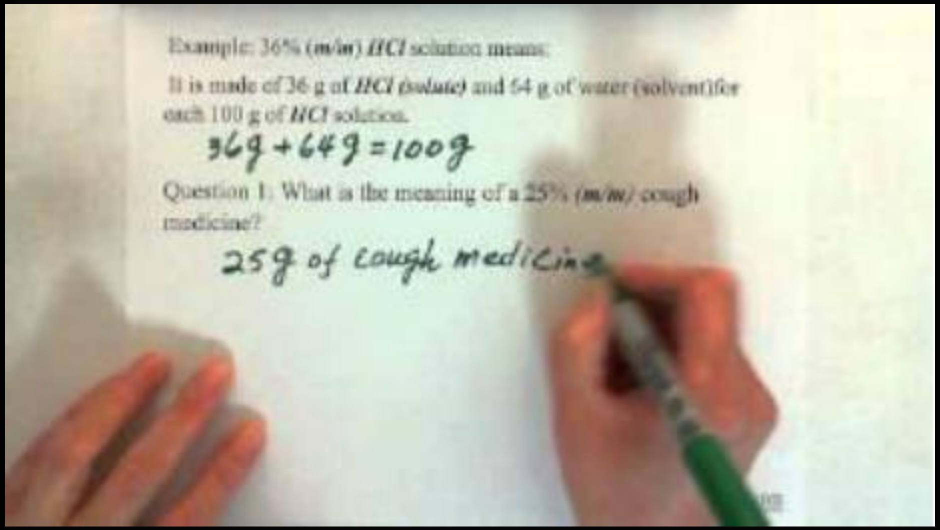
Physical Method ($\%_{w/w}$)

Percentages : Among the physical method for expressing the concentration the following percentages expressions :

(1) Weight per weigh percentage

(% w/w) : the weight of solute is divided by the weight of solution (both having the same weighing unit) and multiplying by 100 :

$$\%_{w/w} = \frac{Wt.of\ solu.(g...)}{Wt.of\ soln.(g...)} X\ 100$$



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Physical Method ($\%_{w/v}$)

This expression is used for solid – solid solution but it is common with all sorts of solutions because mass unlike volume does not change by changing temperature .

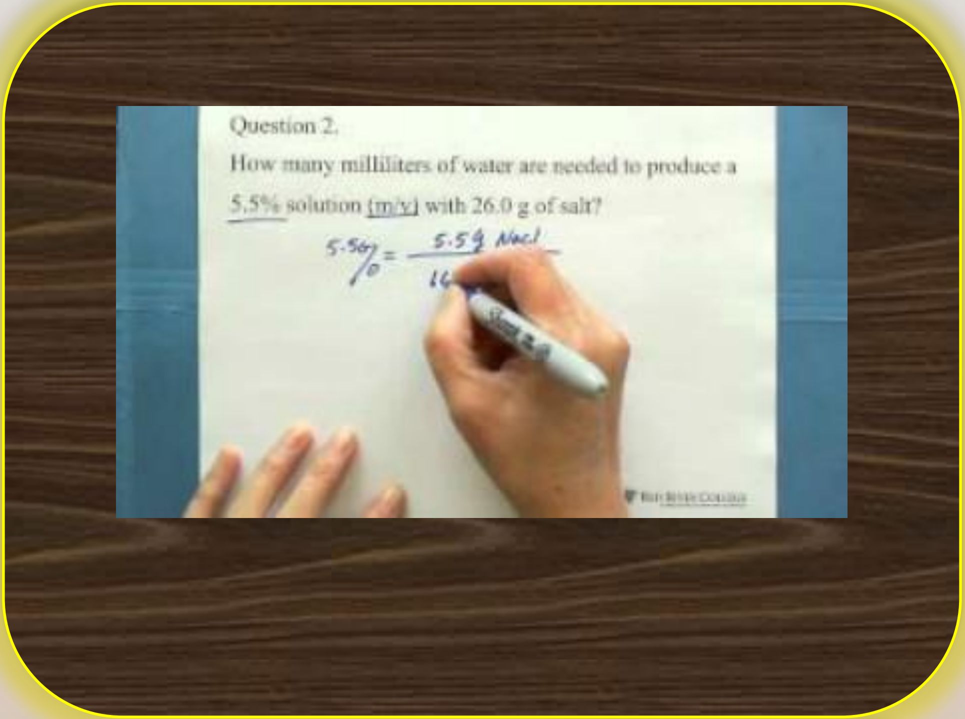
(2) weight per volume percentage ($\%_{w/v}$) :

Weight of solute usually in grams divided by volume of solution usually in milliliters multiplying by 100 :

$$\%_{w/v} = \frac{Wt.\ of\ \ solu.(g)}{Vol.\ of\ \ soln.(mL)}\ X\ 100$$

(3) Volume per volume percentage ($\%_{V/v}$) :

$$\%_{\ v/v} = \frac{Vol.of\ solu.(L..mL...)}{Vol.\ of\ \ soln.(L..mL...)}\ X\ 100$$



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Physical Method (Examples)

Example :

How many mg is required to prepare 500 mL solution of a substance B of each of the following concentration units :

(1)2000 ppb

(2) 500 ppm

(3) 5 g / L

(4) 10 $\%_{W/V}$?

Solution :

(1) $$2000\ ppb = \frac{Wt.\ of\ solu.\ (\mu g)}{500\ (mL)\ X\ 10^{-3}\ (L)}$$

$$Wt.\ of\ solu.\ (\mu g) = 2000\ X\ 500\ X\ 10^{-3} = 1000\ \mu g = 1\ mg$$

(2) $$500\ ppm = \frac{Wt.\ of\ solu.\ (mg)}{500\ (mL)\ X\ 10^{-3}\ (L)}$$

$$Wt.\ of\ solu.\ (mg) = 500\ X\ 500\ X\ 10^{-3} = 250\ mg$$

(3) $$5\ g/L = \frac{Wt. of\ solu.(g)}{500\ (mL)\ X\ 10^{-3}\ (L)}$$

$$Wt.\ of\ solu.\ (g) = 5\ X\ 500\ X\ 10^{-3} = 2.5\ g = 2500\ mg$$

(4) $$10\ \%_{w/v} = \frac{Wt. of\ solu.(g)}{500\,(mL)}\ X100$$

$$Wt.\ of\ solu.(g) = \frac{10\ X\ 500}{100} = 50$$

Physical Method (Examples)

- **Example :** 5 g of an alloy containing 10 mg of copper . Calculate the concentration of copper in ppm and ppb units in this alloy ?
- **Solution :** This is an example of solid – solid solution .

$$ppm = \frac{10(mg)}{5(g)X10^{-3}(Kg)} = \frac{10(mg)X10^{3}(\mu g)}{5(g)} = 2X10^{3}$$

$$Or \quad = \frac{10(mg)}{5(g)X10^{3}(mg)} X10^{6} = \frac{10(mg)X10^{-3}(g)}{5(g)} X10^{6} = 2X10^{3}$$

$$ppb = \frac{10(mg)X10^{3}(\mu g)}{5(g)X10^{-3}(Kg)} = \frac{10(mg)X10^{6}(ng)}{5(g)} = 2X10^{6}$$

$$Or \quad = \frac{10(mg)}{5(g)X10^{3}(mg)} X10^{9} = \frac{10(mg)X10^{-3}(g)}{5(g)} X10^{9} = 2X10^{6}$$

Physical Method (Examples)

Example : How many grams there in 50 ml of 500 ppm solution of a substance ?

Solution :

$$500\,ppm = \frac{Wt.\,of\,solu\,(mg)}{50\,(mL)\,X\,10^{-3}\,(L)}$$

$$Wt.\,of\,solu\,(mg) = 500\,X\,50\,X\,10^{-3} = 25\,mg = 0.025\,g$$

Example : 2 g of a substance have been dissolved in water and the volume was completed to 100 ml. Calculate the concentration of this substance in this solution using the following units (1) g/L (2) mg/mL (3) $\%_{w/v}$ (4) ppm (5) ppb ?

Solution :

$$(1)\quad g/L = \frac{2(g)}{100\,(mL)\,X10^{-3}\,(L)} = 20$$

Physical Method (Examples)

(2) $$mg/mL = \frac{2\,(g)\,X\,10^3\,(mg)}{100} = 20\,(mg/mL)$$

(3) $$\%_{w/v} = \frac{2\,(g)}{100\,(mL)}\,X\,100 = 2$$

(4) $$ppm = \frac{2\,(g)\,X\,10^3\,(mg)}{100\,(mL)\,X\,10^{-3}\,(L)} = 20\,X\,10^3$$

(5) $$ppb = \frac{2\,(g)\,X\,10^6\,(\mu g)}{100\,(mL)\,X\,10^{-3}\,(L)} = 20\,X\,10^6$$

Measurement Units and Concentration Analogies

What is Parts Per Million (ppm)?

1 PPM in water chemistry represents 1 milligram/liter or 1 mg/l

PPM Analogies

1 second in 11.5 days

1 pounds in ~ 120,000 gallons of water

What is Parts Per Billion (ppb)?

1 PPB in water chemistry represents 1 microgram/liter or 1 ug/l

PPB Analogies

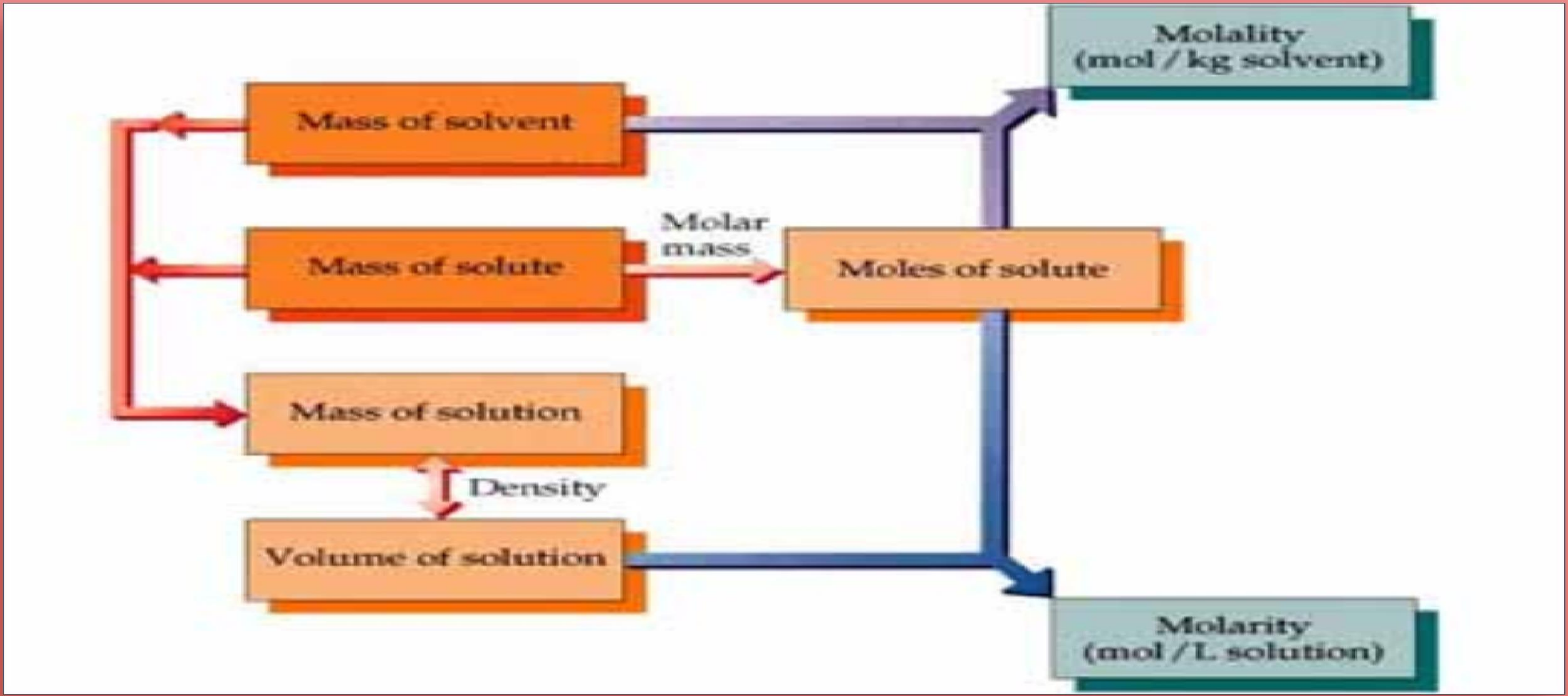
1 second in nearly 32 years

1 pounds in 120 million gallons of water

Chemical Method

Chemical method for expressing concentration In this method we use chemical units to express the quantity of solute instead of the gram and its derivatives as we saw in the physical method . The chemical units for the molar concentration are , mole and millimole (mmole) , and for the normal concentration are , equivalent weight (eq.wt.) and milliequivalent weight (meq.wt.) . Note that one mole = 10^3 mmoles and one eq.wt.=10^3 meq.wt. . With regard to the volume of the solution we use the same units as in the physical method i.e the liter and its derivatives .

Chemical Method

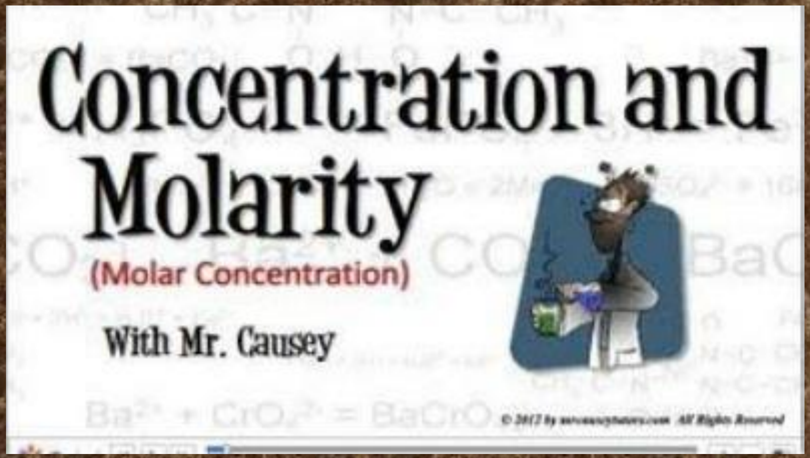


Chemical Method (Molarity)

Molarity or Molar Concentration (M) :

The molar concentration can be expressed either : by the number of moles of solute [moles = Wt. of solute (g) / molecular weight of solute (mw)] in one liter of the solution and can be calculated by dividing the number of moles of solute on the volume of the solution in liters as indicated by the following formula :

$$Molar\ concentration\,(M) = \frac{no.of\ moles\,of\ solu.}{Vol.of\ soln.(L)} = \frac{[\frac{Wt.of\ solu.(g)}{mw\ of\ solu.}]}{Vol.of\ soln.(L)}$$



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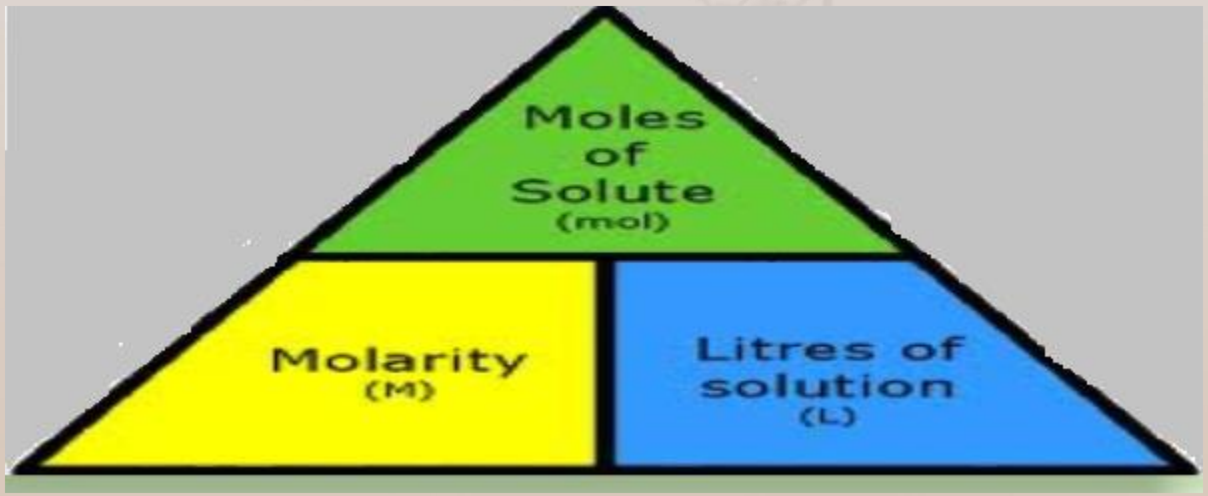
Chemical Method (Molarity)

Or by the number of mmoles of solute
[mmoles = Wt. of solute (mg) / mw of solute] in one mL of the solution and can be calculated by dividing the number of mmoles of solute on the volume of solution in mL as indicated by the following formula :

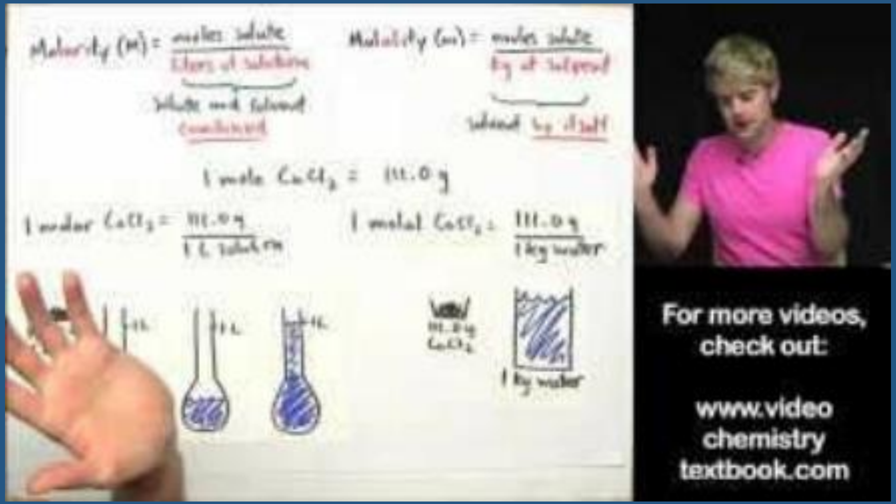
$$Molar\ Concentration\,(M) = \frac{no.of\ mmoles\ of\ solu.}{Vol.of\ soln.(mL)}$$

$$= \frac{\left[\dfrac{Wt.of\ solu.(mg)}{mw\ of\ solu.}\right]}{Vol.of\ soln.(mL)}$$



Chemical Method (Molality)

There is a concentration expression called molality (m) which is equal to the number of moles of solute in one Kg of solvent .This tem is not commonly used in analytical chemistry .



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Chemical Method (Molarity Examples)

Example : Describe the preparation of 500 mL of 5.0 M HNO_3 from the concentrated commercial reagent that is 70 $\%_{w/w}$ and has a specific gravity of 1.4 g/mL ? mw (HNO_3) = 63

Solution : Suppose we have 1000 mL (one liter) of the concentrated solution so its weight will be 1000 X 1.4 = 1400 g/L . First we calculate the weight of HNO_3 in one liter of this concentrated solution by applying the following usual formula :

$$70\%_{w/w} = \frac{Wt.of\ HNO_3\ (g/L)}{1400\ (g/L)}\ X\ 100 \qquad Wt.of\ HNO_3\ (g/L) = \frac{70\ X\ 1400}{100} = 980\ g/L$$

Then we calculate the molarity of the concentrated solution :

Chemical Method (Molarity Examples)

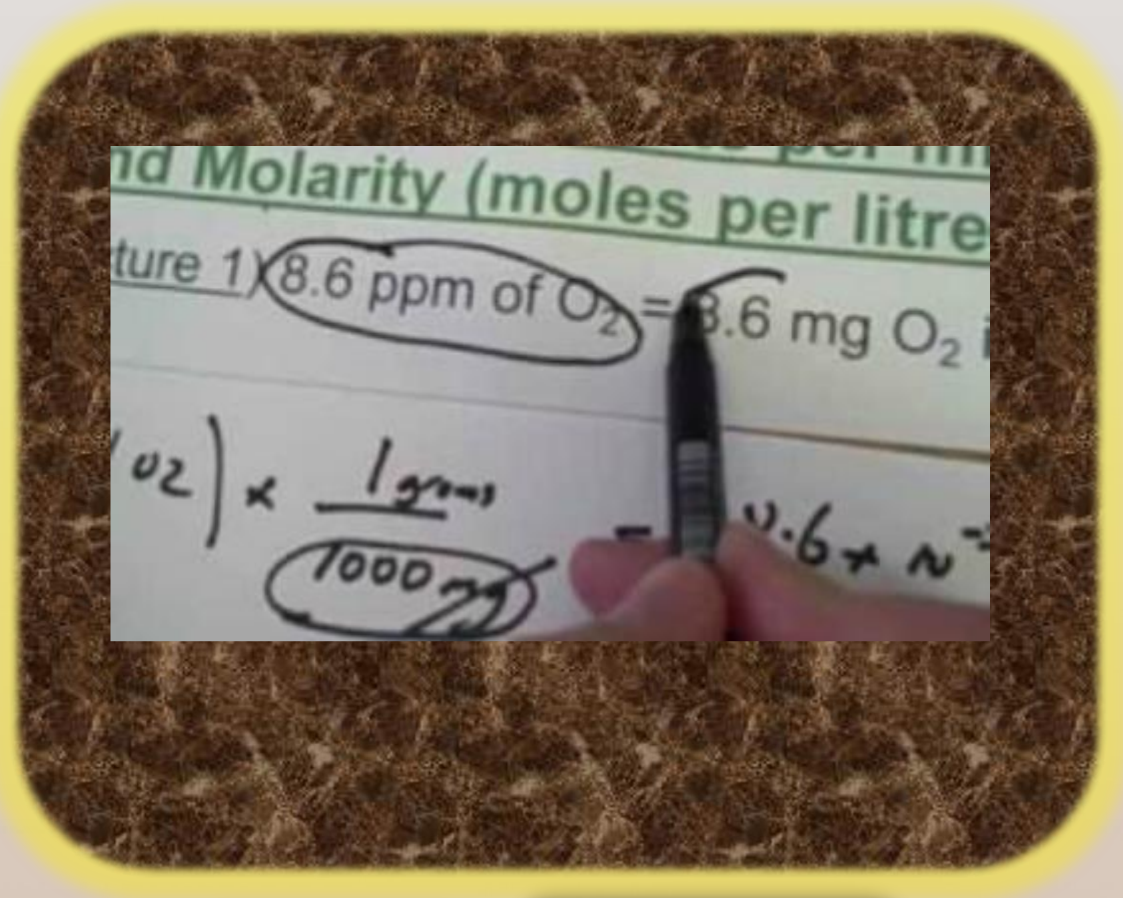
$$M_{HNO_3} = \frac{moles\ of\ HNO_3 / L}{V_L} = \frac{\frac{980}{63}}{1} = 15.6\ M$$

After that we apply the dilution formula :

$$M_1 \quad X \; V_1 \quad = \quad M_2 \quad X \quad V_2$$

$$15.6 \quad X \; V_1 \quad = \; 5 \; X \; 500 \; (\ mL)$$

$$V_1 = 160.26 \; \ mL$$



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Chemical Method (Molarity Examples)

Example : Calculate the number of grams of NaCl (mw = 58.5) in 50 ml of 0.25 M NaCl ?

Solution :

$$M = \frac{no.\ of\ moles}{Vol.\ (L)} = \frac{\frac{Wt.\ (g)}{mw}}{Vol.\ (L)}$$

$$0.25 = \frac{[\frac{Wt.\ (g)}{58.5}]}{50\ (mL)\ X\ 10^{-3}\ (L)}$$

$$Wt.\ (g) = 0.73\ g$$

Example : 1.3 g of $AgNO_3$ (mw = 170) was dissolved in water and the volume was completed with water to 250 mL . Calculate the molar concentration of $AgNO_3$ in this solution ?

Solution :

$$M = \frac{[\frac{1.3\ (g)}{170}]}{250\ (mL)\ X\ 10^{-3}\ (L)} = 0.03\ M$$

Chemical Method (Molarity Examples)

Example : How many mL you should take from 0.1 M solution of Na_2SO_4 compound (mw = 142) to obtain 5 g of Na_2SO_4 ?

Solution :

$$0.1 = \frac{\left[\frac{5\,(g)}{142}\right]}{V_l}$$

$$V_l = 0.352\ (l) = 352\ ml$$

Example: Calculate the concentration of K^+ (aw = 39.1) in g/L unit in a solution resulting from mixing 200 mL of 0.1 M of K_2SO_4 with 100 mL of 0.25 M of KCl ?

Solution : Note that the number mmoles of K^+ is equal to twice the number of mmoles of K_2SO_4 because each one mmole of K_2SO_4 contains 2 mmoles of K^+, while each one mmole of KCl contains one mmole of K^+. Therefore, the following equation can be written :

mmoles K^+ /300 mL= mmoles KCl + 2 x mmoles K_2SO_4

= 100 x 0.25 + 2 X 200 X 0.1

= 65 mmoles K^+ / 300 mL

$$g\,K^+/L = \frac{65 X 10^{3} X 391}{300} X 10^{3} = 8.47$$

Chemical Method (Molarity Examples)

Example : Calculate the weight of Na_2SO_4(mw = 106) required to prepare 250 ml solution of 0.1 M Na^+ using a Na_2SO_4 reagent that has a purity of $90\%_{w/w}$?

Solution : Note that each one mmole of Na_2SO_4 contains 2 mmoles of Na^+ . Therefore, the following equation can be written :

$$mmoles\ \ Na_2SO_4 = \frac{mmoles\ \ Na^+}{2} = \frac{250\ x\ 0.1}{2} = 12.5$$

Wt. Pure Na_2SO_4 = 12.5 X 106 = 1325 mg = 1.325 g

$$Wt.\ of\ (90\%_{w/w}\ Na_2SO_4) = \frac{100\ X\ 1.325}{90} = 1.47\ g$$

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Molarity

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Chemical Method (Molarity Examples)

Example : Calculate the molar concentration of 2000 ppm of Pb^{2+} (aw = 207) ?

Solution : 200 ppm = 2000 mg / L

$$M = \frac{[(2000\ mg/L)\ X\ 10^{-3}\ g/L}{207} = 0.01\ moles/L$$

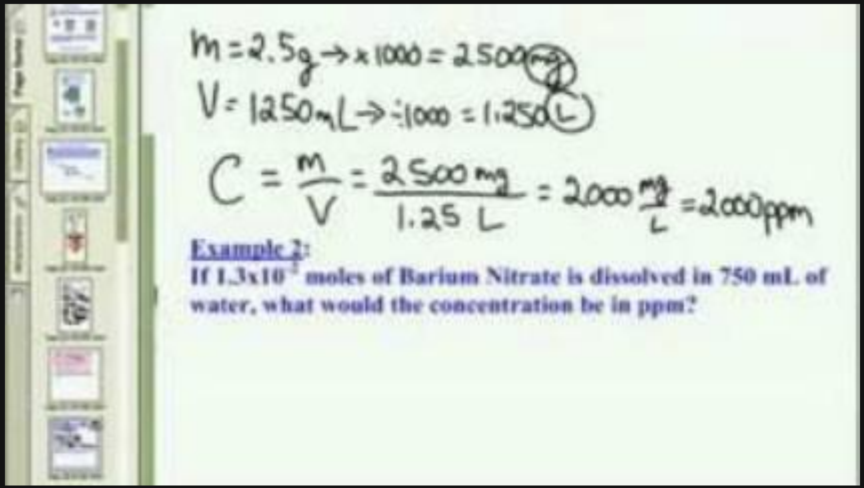
Example : Calculate the concentration in ppm unit of o.1 M Pb^{2+} solution?

Solution :

Ppm = 0.1 (moles / L) X 207 (g/L) X 10^3 (mg/L)

= 0.1 (moles / L) X 207 (g/L) X 10^3 (mg/L)

= 2070 mg/L



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Chemical Method (Normality)

Normality or Normal concentration (N) :

The normal concentration reflects either:

1- the number of equivalent weights (eq.wts.) of a solute in one liter of a solution and can be obtained by dividing the number of eq. wts. of solute on the volume of the solution in liters as indicated by the following formula :

$$N = \frac{\text{no. eq.wts of solu.}}{\text{Vol. of soln.}(L)} = \frac{\left(\dfrac{Wt.\,of\,solu.(g)}{eq.wt.of\,solu.}\right)}{Vol.of\,soln.(L)}$$

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Chemical Method (Normality)

2- Or the number of milliequivalent weights (meq. Wts.) of a solute in one mL of a solution and can be obtained by dividing the number of meq. wts. of a solute on the volume of the solution in mL as indicated by the following formula :

$$N = \frac{\text{no.meq.wts of solu}}{\text{Vol.of soln.(mL)}} = \frac{\left(\dfrac{Wts.of\ solu.(mg)}{eq.wt.of\ solu.}\right)}{Vol.of\ soln.(mL)}$$

Note that we can calculate the number of equivalent weights of a solute by dividing its weight in grams on its equivalent weight and also we can calculate the number of meq.wts. of a solute by dividing its weight in mg on its equivalent weight as expressed in the above formulas .

Chemical Method (Normality)

Equivalent Weight (eq.wt.) : Equivalent weight of a substance can be calculated by dividing its molecular weight on the number of active units in one molecule of this substance (h) thus :

$$eq.\ wt.\ of\ solu. = \frac{mw\ \ of\ solu.}{no.\ of\ active\ units\ in\ one\ molecule\ of\ solu.(h)}$$

The active units in the acid – base reactions are the number of H^+ ions liberated by a single molecule of an acid or reacted with a single molecule a of a base as shown by the following formulas .

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Chemical Method (Normality)

$CH_3COOH \leftrightarrow H^+ + CH_3COO^-$: (eq. wt. of CH_3COOH = mw / 1)

$H_2SO_4 \leftrightarrow 2H^+ + SO_4^{2-}$: (eq. wt. of H_2SO_4 = mw / 2)

$Ba(OH)_2 + 2H^+ \leftrightarrow Ba^{2+} + 2H_2O$: (eq. wt. of $Ba(OH)_2$ = mw / 2)

$NaOH + H^+ \leftrightarrow Na^+ + H_2O$: (eq. wt. of NaOH = mw / 1)

$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$: (eq. wt. of NH_3 = mw / 1)

$Na_2CO_3 + H^+ \leftrightarrow HCO_3^- + 2\,Na^+$: (eq. wt. of Na_2CO_3 = mw / 1)

$Na_2CO_3 + 2H^+ \leftrightarrow H_2CO_3 + 2\,Na^+$ - : (eq. wt. of Na_2CO_3 = mw / 2)

$H_3PO_4 \leftrightarrow H_2PO_4^- + H^+$: (eq. wt. of H_3PO_4 = mw / 1)

$H_3PO_4 \leftrightarrow HPO_4^{2-} + 2H^+$: (eq. wt. of H_3PO_4 = mw / 2)

$H_3PO_4 \leftrightarrow PO_4^{3-} + 3H^+$: (eq. wt. of H_3PO_4 = mw / 3)

Chemical Method (Normality)

The active units in the oxidation - reduction reactions is the number of electrons (e) that has been transfered during the reaction as shown by the following formulas :

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Chemical Method (Molarity Examples)

$Sn^{4+} + 2e \leftrightarrow Sn^{2+}$: (eq. wt. of Sn = aw / 2)

$Fe^{3+} + e \leftrightarrow Fe^{2+}$: (eq. wt. of Fe = aw / 1)

$MnO_4^- + 5e + 8H^+ \leftrightarrow Mn^{2+} + 4\,H_2O$: (eq. wt of MnO_4^- = mw / 5)

$NO_3^- + 2e \leftrightarrow NO_2^-$: (eq. wt. of NO_3^- = mw / 2)

$Cr_2O_7^{2-} + 14\,H^+ + 6e \leftrightarrow 2Cr^{3+} + 7\,H_2O$ (eq.wt. of $Cr_2O_7^{2-}$ = mw/6)

For information on the active units in the precipitation reactions and the complex- formation reactions sea reference 1. However, the malor concentration is overshadowing the normal concentration, which is rarely used now .

Chemical Method (Molarity and Normality)

The Relationship between M and N for the same solute in the same solution :

$$\because\ M = \frac{\frac{Wt.}{mw}}{V} \qquad \therefore\ mw = \frac{Wt.}{M\ X\ V} \qquad and \qquad \because\ N = \frac{\frac{Wt.}{eq.wt.}}{V} \qquad \therefore\ eq.wt. = \frac{Wt.}{N\ X\ V}$$

By substituting mw and eq.wt. from the above equations in the following equation

$$eq.wt. = \frac{mw}{h}$$

we get :

$$\boxed{N = M\ X\ h}$$

Since $h \geq 1$ therefore $N \geq M$

Chemical Method (Normality Examples)

Example : Calculate the normality of 0.53 g / 100 mL solution of Na_2CO_3 (mw = 106) when reacted as follow :

$$Na_2CO_3 + 2\ H^+ \rightarrow H_2CO_3 + 2\ Na$$

$$= \frac{5(mg)}{5(g)\,X 10^3\,(mg)} X\,10^6 = \frac{5(mg)\,X 10^{-3}\,(g)}{5(g)} X\,10^6$$

Solution :

$$eq.wt.\ of\ Na_2CO_3 = \frac{106}{2} = 53$$

$$N = \frac{\dfrac{0.53\ X\ 1000\ (mL)}{100\,(mL)}(g/L)}{53} = 0.1$$

Example : In the last example calculate the normality of a solution of Na_2CO_3 prepared by dissolving 2.5 g of Na_2CO_3 in water and completing the volume with water to 200 mL ?

Solution :

$$N = \frac{\dfrac{2.5(g)}{53}}{200(mL)\ X\ 10^{-3}\ (L)} = 0.24\ N$$

Chemical Method (Normality)

Example : Calculate the normality of 5.267 g /L solution of $K_2Cr_2O_7$ (mw= 294.2) when $K_2Cr_2O_7$ is reduced to Cr^{3+}

Solution :

$$eq.\,wt.\ of\ K_2Cr_2O_7 = \frac{294.2}{6} = 49.03$$

$$N = \frac{5.267\ (g)}{49.03} = 0.1074\ N$$

Example : In the last example if the concentration of $K_2Cr_2O_7$ solution is 0.5 M , calculate its normality ?

Solution : N = 0.5 X 6 = 3.0

VIDEO Molality

VIDEO My Channel

Preparation by dilution

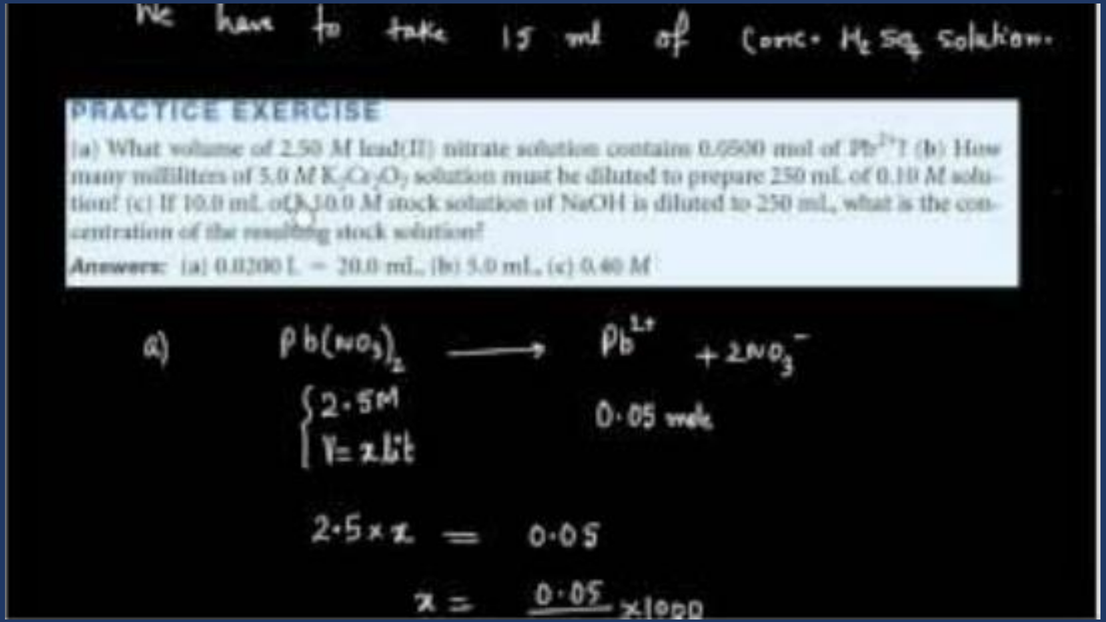
Dilution is a reduction in the concentration of a chemical . It is the process of reducing the concentration of a solute in solution, usually simply by mixing with more solvent. To dilute a solution means to add more solvent without the addition of more solute. The resulting solution is thoroughly mixed so as to ensure that all parts of the solution are identical. For example, if there are 10 grams of salt (the solute) dissolved in 1 liter of water (the solvent), this solution has a certain salt concentration/molarity. If one adds 1 liter of water to this solution the salt concentration is reduced. The diluted solution still contains 10 grams of salt (i.e.0.171 moles of NaCl).Mathematically this relationship can be shown in the equation:

$$C_1 \times V_1 = C_2 \times V_2$$

Where , C_1 = Initial concentration or molarity , V_1 = Initial volume , C_2= Final concentration or molarity , V_2 = Final Volume .

Preparation by dilution

The main reason for preparing high concentrated stock solution is that it is more accurate to weigh large amount than to weigh very small amount . Note that the balance error is constant whether you weigh large or small quantity .



VIDEO
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VIDEO
Expressing Con.^{n}

VIDEO
You Tube

VIDEO
My Channel

Active Concentration or activity (a)

The activity a_x represents the concentration of the species **x** that reacted where as [x] represent the added concentration i.e the molar concentration . Depending on the ionic strength not necessary all added ions react with each other i.e $a_x < [x]$ The relationship between a_x and [x] is as follows : $a_x = f_x [x]$

Where f_x is the activity coefficient of the species x and depends on the ionic strength of the solution thus : $\log f_x = 0.5 Z_x^{2} \sqrt{\mu}$

and μ is the ionic strength of the solution Where Z_x is the charge on the species x and can be calculated from the following equation : $\mu = 1/2 \sum [i] Z_i^{2}$

Where [i] and Z_i are the molar concentration and the charge on each species i present in the solution .In analytical chemistry we use very dilute concentrations in which $\mu \approx$ zero and accordingly $f_x = 1$ and $a_x = [x]$. Therefore in analytical chemistry we use [x] instead of a_x to facilitate the calculations . For more details on the activity see references 1 , 5 and 6 .

Summary

We discussed the two main methods for expressing concentration namely , physical and chemical methods . The student has been trained to prepare a stock solution using various units such as molarity , normality , ppm , ppb , $\%_{w/w}$, $\%_{w/v}$ and $\%_{v/v}$.

The student has been taught , the relationship between activity and molarity , how to convert a concentration unit to another unit and how to prepare a stock standard solution and other dilute standard solution by dilution from the stock solution .

We used some videos and pictures to illustrate some of the concepts of the subject of this unit .

Tutorial

Exercise 1 : Calculate the molarity of 69 $\%_{w/v}$ solution of HNO_3 (mw = 63 , specific gravity = 1.42 g/mL) . Calculate the volume of this solution needed for the preparation of 500 mL solution of 0.1 M HNO_3 ?

Your answer :

Our answer next slide

Tutorial

Answer 1 :

$Wt.HNO_3 = 979.8\ g/L$

$\text{Molarity of } HNO_3 = 979.8 / 63 = 15.6$

$500 \times 0.1 = 15.6 \times V_{mL}$

$V_{mL} = 3.2\ mL$

Tutorial

Exercise 2 : How many grams of K (aw = 39) are contained in 100 mL solution of 0.5 M of K_2SO_4 ?

Your answer :

Our answer next slide

Tutorial

Answer 2 :

0.5 M = 0.5 (moles K_2SO_4 / L) equivalent to 2 X 0.5 (moles K / L)

g K / L = 2 X 0.5 x 39.1 (g K / L)

$$g\ K/L = \frac{2\,X\,0.5\,X\,39.1(g\,K/L)\,X\,100}{1000} = 3.91\,(g\,K/100\,mL)$$

Tutorial

Exercise 3 : How many grams of Na_2CO_3 (mw = 106) are required for the preparation of 500 mL of 0.1 M of Na^+ ?

Your answer :

Our answer next slide

Tutorial

Answer 3 :

$$mmoles\ Na_2CO_3\ required = \frac{mmoles\ Na}{2} = \frac{500\ X\ 0.1}{2} = 25$$

$$Wt.\ Na_2CO_3 = 25\ X\ 106 = 2.65\ mg = 0.00265\ g$$

Tutorial

Exercise 4 : How many grams of a solute in 20 mL solution of 10 $\%_{w/w}$ of the solute (the specific gravity of this solution is 2 g / mL) ?

Your answer :

Our answer next slide

Tutorial

Solution 4 :

$$10 = \frac{Wt.\ of\ \ solu.\,(g/20\,mL)}{20\ \ X\ \ 2\ (g\ so\ln./20\,mL)}\ X\ 100$$

$$Wt.\ of\ \ solu. = 4\ (g\ /\ 20\ mL)$$

Tutorial

EXERCISE 5 : What is the concentration of 0.1 M Na_3PO_4 (mw = 164) solution in ppb unit ?

Your answer :

Our answer next slide

Tutorial

Solution 5 :

$$0.1\,M = 0.1\,(moles/L) = 0.1\ X\ 164\ (g/L)$$

$$= 0.1\,X\ 164\ X\ 10^{3}\ (mg/L)$$

$$= 16400\ ppm$$

$$= 16400000\ \mu g/L = 16400000\ ppb$$

Tutorial

Exercise 6 : You have 100 ml of a solution of a substance containing 2 g of this substance . Calculate its concentration in ppb and ppm units ?

Your answer :

Our answer next slide

Tutorial

Answer 6 :

$$ppb = \frac{2\,(g)\ X\ 10^{6}\,(\mu g)}{100\ (mL)\ X\ 10^{-3}\,(L)} = 20000000\,(\mu g / L)$$

$$ppm = \frac{2\,(g)\ X\ 10^{3}\,(mg)}{100\,(mL)\ X\ 10^{-3}\,(L)} = 20000\ (mg / L)$$

Tutorial

Exercise 7 : Calculate the concentration of Na^+ (aw = 23) in ppm units in a solution resulting from mixing 150 mL of 0.2 M of Na_2SO_4 with 200 mL of 0.15 M of NaCl

Your answer :

Our answer next slide

Tutorial

Answer 7 :

$$mmoles\ \ Na = mmoles\ \ NaCl\ + 2\ X\ mmoles\ \ Na_2SO_4$$

$$= \ 200\ \ X\ 0.15\ \ + 2\ X\ 150\ X\ 0.2 = 90\ (mmoles\ \ Na\ /\ 350\ \ mL)$$

$$ppm\ \ Na\ \ = \frac{90\ \ (mmoles\ \ Na\ \ / 350\ \ mL\ )\ X\ 23\ \ (mg\ \ Na\ \ / 350\ \ mL)\ X\ 10^{3}}{350\ \ mL}$$

$$= 5914.3\ (mg\ \ Na / L)$$

Tutorial

Exercise 8 : 120 mg /100 mL solution of substance A (mw = 60) has been prepared . Calculate the followings :

(a) The molar concentration of substance A in the solution ?

(b) The concentration of substance A in ppm units in the solution ?

(c) The concentration of substance A in $\%_{w/v}$ units in the solution ?

(d) If the solution has a specific gravity of 1.2 g/mL calculate the concentration of A in $\%_{w/w}$ units in the solution ?

Your answer :

Our answer next slide

Tutorial

Answer 8 :

$$(a)\ M_A = \frac{mmoles\ A}{Vol.(mL)} = \frac{\frac{120(mg)}{60}\ (mmoles/100\,mL)}{100\,mL} = 0.02\ M$$

$$(b)\ ppm_A = \frac{120(mg)}{100(mL)\ X\ 10^{-3}\ (L)} = 1200\ (mg_A/L)$$

$$(c)\ \%_{w/v} = \frac{Wt.of\ solu.(g)}{Vol.of\ soln.(mL)}\ X\ 100 = \frac{120\ (mg)\ X\ 10^{-3}(g)}{100(mL)}\ X\ 100$$

$$= 1.2\ X\ 10^{-3}\ \%$$

$$(d)\ \%_{w/w} = \frac{Wt.of\ solu.(g)}{Wt.of\ soln.(g)}\ X\ 100 = \frac{120(mg)\ X\ 10^{-3}(g)}{100(mL)\ X\ 1.2(g)}\ X\ 100$$

$$= 0.1\ \%$$

Tutorial

Exercise 9 : How many mL of pure ethanol in 250 mL of 50 $\%_{v/v}$ solution of ethanol ?

Your answer :

Our answer next slide

Tutorial

Answer 9 :

$$\%_{v/v} = \frac{Vol.of\ solu.(mL)}{Vol.of\ soln.(mL)}\ X\ 100$$

$$50\ \%_{v/v} = \frac{Vol.of\ ethanol\,(mL)}{250\,(mL)}\ X\ 100$$

$$Vol.of\ \ pure\,ethanol = 125\ (mL)$$

Tutorial

Exercise 10 : How many grams of substance A (mw = 50) in 100 mL solution of 0.1 M of substance A ?

Your answer :

Our answer next slide

Tutorial

Answer 10

$$0.1M_A = 0.1(mmoles/L) = 0.1\,X\,50(g_A/L)$$

$$= \frac{0.1\,X\,50(g_A/L)}{1000}\,X\ 100 = 0.5\ (g_A/100\,mL)$$

$$Or$$

$$mmoles\,A = 100\,X\,0.1(mmoles\,A/100\,mL)$$

$$g_A/100\ mL = 100\,X\,0.1\,X\,50\ (mg_A/100\,mL)\,X\,10^3\,(g/L)$$

$$= 0.5\,g/100\,mL$$

Tutorial

Exercise 11 : Calculate the molar concentration of substance A in 2000 ppm solution of substance A (mw = 50) ?

Your answer :

Our answer next slide

Tutorial

Answer 11 :

2000 ppm = 2000 (mg/L) = 2000 X10^{-3} (g/L)

$$= \frac{2000\ X\ 10^{-3}\ (g/L)}{50\ (mw)}\ (moles/L) = 0.04\ M$$

Tutorial

Exercise 12 : Calculate the normal concentration (N) of o.1 M solution of NO_3^- which has been reduced to NO_2^- ?

Your answer :

Our answer next slide

Tutorial

Answer 12: The oxidation state of nitrogen in NO_3^- is 5+ while in NO_2^- is 3+ , so the number of active units h is equal to 2 :

$$N = M \times h = 0.1 \times 2 = 0.2\ N$$

Tutorial

Exercise 13 : 4.9 g of H_3PO_4 (mw = 98) has been dissolved in water and the volume has been completed to one liter . If this acid was participated in a neutralization reaction and was converted to HPO_4^{2-} , calculate the normality N of the solution ?

Your answer :

Our answer next slide

Tutorial

Answer 13 : In this neutralization reaction H_3PO_4 liberated 2 H^+ , therefore h = 2

$$eq.wt._{H_3PO_4} = \frac{mw_{H_3PO_4}}{h} = \frac{98}{2} = 49$$

$$N = \frac{no.\ eq.wts}{Vol.\ (l)} = \frac{\frac{4.9}{49}}{1} = 0.1\ N$$

Tutorial

Exercise 14 : 2.5 g of Na_2SO_4 (mw = 106) has been dissolved in water and the volume was completed to 500 mL , calculate the followings :

1- The molar concentration of Na_2SO_4 ?

2- The molar concentration of Na^+ ?

3- The concentration of Na^+ in ppm units ?

Your answer :

Our answer next slide

Tutorial

Answer 14 :

(1) $$M_{Na_2SO_4} = \frac{\dfrac{2.5(g)}{106\,(mw)}}{500\ mL\ X\ 10^{-3}\ (L)} \approx 0.05M$$

(2) $$M_{Na} = M_{Na_2SO_4}\ X\ 2 = 0.05\ X\ 2 = 0.1\,M$$

(3) $$\text{Na (ppm)} = M_{Na}\ X\ aw_{Na}\ (g/L)\ \ X\ 10^3\ (\,mg/L\,)$$

$$= 0.1\ \text{X}\ 23\ \text{X}\ 10^3 = 2300\ \text{mg/L}$$

Tutorial

Exercise 15 : 2.5 g of Na_2SO_4 (mw = 106) has been dissolved in water and the volume was completed to 500 mL , calculate the followings :

1- The concentration of Na_2SO_4 in g/L unit ?

2- The concentration of Na_2SO_4 in $\%_{w/v}$ unit ?

Your answer :

Our answer next slide

Tutorial

Answer 15 :

(1) $$Na_2SO_4\,(g/L) = M_{Na_2SO_4}\ X\ mw_{Na_2SO_4} = 0.047\ X\ 106$$

$$\approx 5\ (g/l)$$

$$or\ Na_2SO_4\ (g/L) = \frac{2.5\,(g)}{500\,(mL)\,X10^{-3}\,(L)} = 5\ (g/L)$$

(2) $$Na_2SO_4\,(\%_{w/v}) = \frac{2.5\ (g)}{500\ (mL)}\ X\ 100 = 0.5\ \%$$

Tutorial

Exercise 16 : 2.5 g of Na_2SO_4 (mw = 106) has been dissolved in water and the volume was completed to 500 mL , calculate the followings :

1- The concentration of Na_2SO_4 in ppb unit ?

2- Number of mmoles of Na^+ in 100 mL of this solution ?

Your answer :

Our answer next slide

Tutorial

Answer 16 :

(1)

$$Na_2SO_4 \ (\text{ ppb }) = \frac{2.5\,(g)\ X\ 10^6\ (\mu g)}{500\ (mL)\ X\ 10^{-3}\ (L)}$$

$$= 5\,X\,10^6\,(\mu g/L)$$

(2)

$$\text{No. mmoles Na in 100 mL} = M_{Na}\ X\ \text{Vol. (mL)}$$

$$= 0.1\ X\ 100 = 10$$

Tutorial

Exercise 18 : Describe the preparation of 500 mL of 0.5 M of a solute solution from 2 M solution of this solute ?

Your answer :

Our answer next slide

Tutorial

Answer 18 :

This is an example of preparing a dilute solution from a concentrated one for the same solute :

$$500 \times 0.5 = 2 \times V_{ml}$$

$$V_{ml} = 125 \text{ ml}$$

125 mL of 2 M solution can be diluted to 500 mL to get 0.5 M solution

Tutorial

Exercise 19 : Calculate the number of mmoles of KIO_3 (mw = 214) present in 0.5 g of pure KIO_3 ?

Your answer :

Our answer next slide

Tutorial

Answer 19 :

$$KIO_3\ (mmoles) = \frac{0.5(g)\,X\,10^3\,(mg)}{214(mw)} = 2.3\ mmoles$$

Tutorial

Exercise 20 : 0.5 g of a sample contain 0.5 mg of Cr_2O_3 . Express the concentration of Cr_2O_3 in this sample using the following units : (1) $\%_{w/w}$ unit (2) ppm unit

Your answer :

Our answer next slide

Tutorial

Answer 20 :

(1) $$Cr_2O_3\ (\%_{w/w}) = \frac{0.5\ (mg)}{0.5\ (g)\ X\ 10^3\ (mg)}\ X\ 100 = 0.1$$

(2) $$Cr_2O_3\ (ppm) = \frac{0.5\ (mg)}{0.5\ (g)\ X\ 10^3\ (mg)}\ X\ 10^6 = 1000$$

or

$$Cr_2O_3\ (ppm) = \frac{0.5\ (mg)}{0.5\ (g)\ X\ 10^{-3}\ (kg)} = 1000$$

Tutorial

Exercise 21 : Describe the preparation of one liter solution of 0.001 M Cl^- from a solution of KCl that is 250 ppm K^+ ?

Your answer :

Our answer next slide

Tutorial

Answer 21 :

$$aw_K = 39$$

$$M_K = M_{Cl} = M_{KCl}$$

$$= \frac{250\left(mg/L\right) X\, 10^{-3}\left(g/L\right)}{39\left(aw\right)} = 6.4\, X\, 10^{-3}\ M$$

$$0.001 M\ X\, 1000\left(mL\right) = 6.4\, X\, 10^{-3}\ M\ X\ V_{mL}$$

$$V_{mL} = 156.25\ mL$$

$$156.25\, mL\ of\ KCl\ solution\ will\ be\ diluted\ to\ one\ liter\,.$$

Tutorial

Exercise 22 : How many grams of K^+ (aw = 39) are contained in 500 ppm of $KClO_3$ (mw = 122.5) solution ?

Your answer :

Our answer next slide

Tutorial

Answer 22 :

$$M_{KClO_3} = \frac{500\left(mg/L\right)X\,10^{-3}\left(g/L\right)}{122.5\left(mw\right)} = 4.1\,X\,10^{-3}\ M\ = M_K$$

$$g\ \ K/L = \ 4.1\,X\,10^{-3}\ X\ 39\left(aw\right) = \ 0.1599\ \left(g/L\right)$$

Tutorial

Exercise 23 : 20 mL of a concentrated solution of a solute were diluted to 100 mL in order to prepare 0.2 M of this solute . What is the molar concentration of the concentrated solution ?

Your answer :

Our answer next slide

Tutorial

Answer 23 :

$$0.2 \times 100 = 20 \times M$$

$$M = 1.0\ M$$

Tutorial

Exercise 24 : Calculate the equivalent weight of $H_2C_2O_4$ (mw = 90) :

(a) When used in a neutralization reaction ($H_2C_2O_4 \rightarrow 2\,H^+ + C_2O_4^{2-}$).

(b) When used as a reducing agent ($C_2O_4^{2-} - 2e \rightarrow 2\,CO_2$) ?

Your answer :

Our answer next slide

Tutorial

Answer 24 :

(a)

$$H_2C_2O_4 \rightarrow 2\,H^+ + C_2O_4^{2-}$$

$$\text{equivalent weight} = \text{mw}/2 = 90 / 2 = 45$$

(b)

$$C_2O_4^{2-} - 2e \rightarrow 2\,CO_2$$

$$\text{equivalent weight} = \text{mw}/2 = 90 / 2 = 45$$

Tutorial

Exercise 25 : In the last question if we dissolved 0.5 g of $H_2C_2O_4$ in water and completed the volume to 500 mL calculate its normality as is used in (a) and as is used in (b) ?

Your answer :

Our answer next slide

Tutorial

Answer 25 :

In both cases (a) and (b) :
$$N = \frac{\dfrac{0.5(g)}{45(eq.wt.)}}{500\ (mL)\ X\ 10^{-3}\ (L)} = 0.02\ N$$

Tutorial

:**Exercise 26** Calculate the concentration of Na^+ in ppm units in 0.3 M solution of Na_2SO_4 ?

Your answer :

Our answer next slide

Tutorial

Answer 26 :

$$0.3M\ (Na_2SO_4) = 0.3\ (\text{ moles } Na_2SO_4 / L)$$

this equivalent to 2 X 0.3 (mmoles Na/L)

$$\text{ppm Na} = 2 \times 0.3\ (\text{ mmoles Na / L }) \times 23\ (\text{ mg Na / L })$$

$$= 13.8(\text{ mg Na / L })$$

Tutorial

Exercise 27 : What weight of Na_3PO_4 (mw = 164) is required to prepare 200 mL solution of 0.1 M of Na^+ ?

Your answer :

Our answer next slide

Tutorial

Answer 27 :

$$mmoles\ Na_3PO_4 = \frac{mmoles\ Na}{3} = \frac{200\ X\ 0.1}{3} = 6.7$$

$$Wt.\ Na_3PO_4 = 6.7\ X\ 164 = 1098.8\ (mg) \approx 1.099\ (g)$$

Tutorial

Exercise 28 : When mixing 100 mL of 0.2 M Na_2SO_4 with 200 mL of 0.1 M Na_3PO_4 Calculate the molar concentration of Na^+ and also the concentration of Na^+ in g/L unit in the mixture ?

Your answer :

Our answer next slide

Tutorial

Answer 28 :

$$mmoles_{Na}/300\,mL = 2\ X\ mmoles_{Na_2SO_4} + 3\ X\ mmoles_{Na_3PO_4}$$

$$= 2\ X\ 100\,X\,0.2 + 3\ X\ 200\ X\ 0.1$$

$$= 100\ (mmoles_{Na}/300\ mL)$$

$$M_{Na} = \frac{100}{300} = 0.33M$$

Tutorial

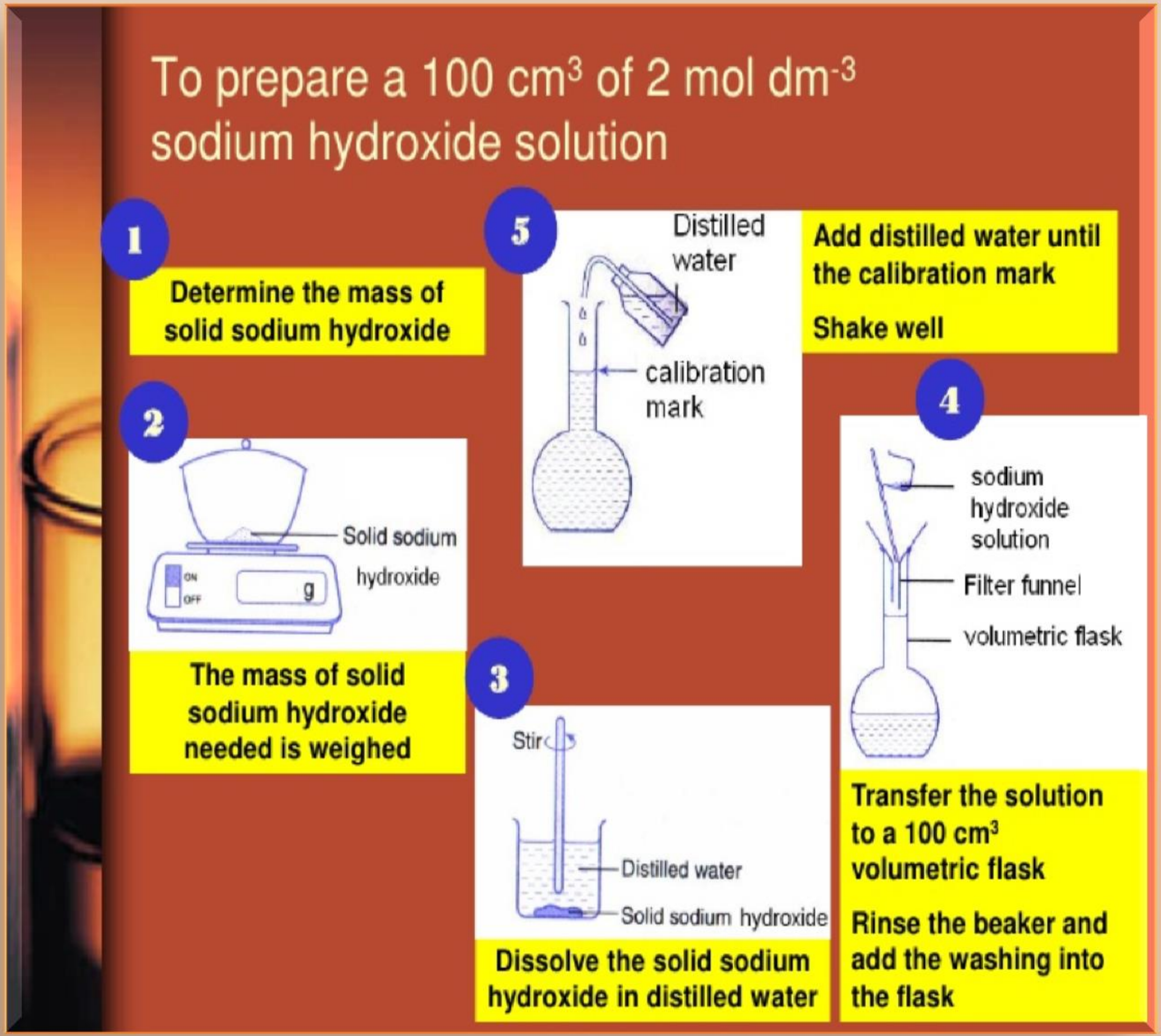
Exercise 29 : How to prepare 100 mL solution of 2M NaOH ?

Your answer :

Our answer next slide

Tutorial

Answer 29 : See the procedures on the picture on your right .



Tutorial

Exercise 30 : A stock solution containing Ba^{2+} ions was prepared by dissolving 23.0 g of pure barium metal in HNO_3 and diluting to 2.0 L . Calculate the molar concentration of Ba^{2+} in the stock solution and in the dilute solution if 125 mL of the stock solution was diluted to 500 mL ?

Your answer :

Our answer next slide

Tutorial

Answer 30 : See the answer on this video .

VIDEO Library

VIDEO You Tube

5) A stock solution containing Ba^{2+} ions was prepared by dissolving 23.0 grams of pure barium metal in nitric acid and diluting to a final volume of 2.000 L. Calculate the concentrations of Ba^{2+} ions in the stock solution and the diluted solution if 125 mL of the stock solution was diluted to 500.0 mL.

FIRST, You need to create the STOCK solution from the information given:

- 23 grams of Barium metal (dissolved in nitric acid)
- The Barium Ions are then placed in a volumetric flask
- Water is added to make a 2.000 liter solution

So, convert the mass to moles:

$23.0\ g\ Ba \quad 1\ mol\ Ba^{+2}$

Tutorial

Look at these videos and ask me or your instructor about any thing that are not clear to you .

VIDEO
Preparat^{n} of Std. Soln. of Na_2CO_3

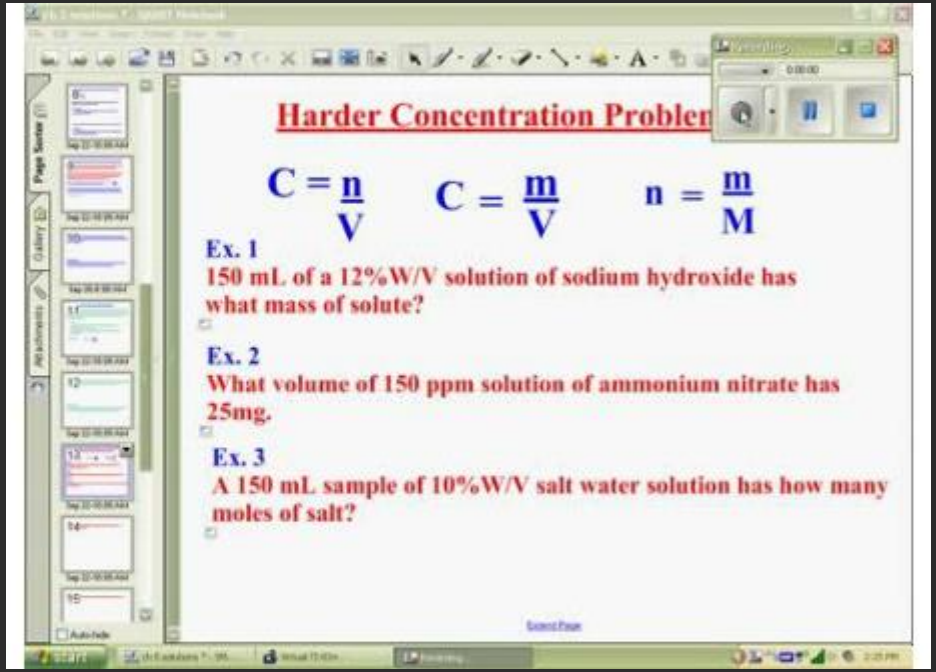
VIDEO
You Tube

VIDEO
Library

PREPARATION OF SOLUTIONS (CONCENTRATIONS)

Tutorial

Look at these videos and ask me or your instructor about any things that are not clear to you .



VIDEO
Molarity

VIDEO
You Tube

VIDEO
Library

على الراغبين الاستماع الى محاضرات الاستاذ الدكتور/ ابراهيم زامل الزامل باللغة العربية عن هذا الموضوع الرجوع الى الروابط التالية :

تحضير المحاليل ٥

تحضير المحاليل٣

تحضير المحاليل

تحضير المحاليل ٧

تحضير المحاليل ٦

تحضير المحاليل ٤

تحضير المحاليل ٢