**Karbala University**

**Subject Analytical Chemistry**

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**Metods Expressing analytical concentration**

**Molarity and Formality**

Both molarity and formality express concentration as moles of solute per liter of solution. There is, however, a subtle difference between molarity and formality. **Molarity** is the concentration of a particular chemical species in solution. **Formality,** on the other hand, is a substance’s total concentration in solution without regard to its specific chemical form. There is no difference between a substance’s molarity and formality if it dissolves without dissociating into ions. The molar concentration of a solution of glucose, for example, is the same as its formality.

For substances that ionize in solution, such as NaCl, molarity and formality are different. For example, dissolving 0.1 mol of NaCl in 1 L of water gives a solution containing 0.1 mol of Na+ and 0.1 mol of Cl–. The molarity of NaCl, therefore, is zero since there is essentially no undissociated NaCl in solution. The solution, instead, is 0.1 M in Na+ and 0.1 M in Cl–. The formality of NaCl, however, is 0.1 F because it represents the total amount of NaCl in solution. The rigorous definition of molarity, for better or worse, is largely ignored in the current literature, as it is in this text. When we state that a solution is 0.1 M NaCl we understand it to consist of Na+ and Cl– ions. The unit of formality is used only when it provides a clearer description of solution chemistry.

Molar concentrations are used so frequently that a symbolic notation is often used to simplify its expression in equations and writing. The use of square brackets around a species indicates that we are referring to that species’ molar concentration. Thus, [Na+] is read as the “molar concentration of sodium ions”.

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Note that it is the final volume of the solution that is important, not the starting volume of the solvent used. The final volume of the solution might be a bit larger than the volume of the solvent because of the additional volume of the solute. In practice, a solution of known molarity is prepared by weighing an appropriate amount of solute and placing it in a volumetric flask. Enough solvent is added to dissolve the solute, and further solvent is added until an accurately calibrated final volume is reached.

# Molality

**Molality (m) is used in thermodynamic calculations where a temperature independent unit of concentration is needed. Molarity, formality and normality are based on the volume of solution in which the solute is dissolved. Since density is a temperature dependent property a solution’s volume, and thus it’s molar, formal and normal concentrations, will change as a function of its temperature. By using the solvent’s mass in place of its volume, the resulting concentration becomes independent of temperature.**

**Molality is defined as mole of solute in Kg of solvent as per equation:**

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| ***EAMPLE 1*** |

**What is the molalityof solution made by dissolve 25 g of NaCl in to 2.0 Liter of water. Assume the density of water d = 1.0 g/mL (= kg/L).**

**SOLUTION**

**Molar mass of NaCl = (1 x 22.99 g/mol ) + (1 x 35.45 g/mol ) = 58.44 g**

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**http://www.chemiasoft.com/ebook/images/image109.gif**

**http://www.chemiasoft.com/ebook/images/image111.gif**

**The solution has concentration of  NaCl equals to 0.214 m**

**Normality**

**Normality is an older unit of concentration that, although once commonly used, is frequently ignored in today’s laboratories. Normality is still used in some handbooks of analytical methods, and, for this reason, it is helpful to understand its meaning. For example, normality is the concentration unit used in *Standard Methods* *for the Examination of Water and Wastewater,* and in some *Standard EPA methods* commonly used sources of analytical methods for environmental laboratories.**

**Normality makes use of the chemical equivalent, which is the amount of one chemical species reacting stoichiometrically with another chemical species. Note that this definition makes an equivalent, and thus normality, a function of the chemical reaction in which the species participates. Although a solution of H2SO4 has a fixed molarity, its normality depends on how it reacts.**

**The number of equivalents, *n,* is based on a reaction unit, which is that part of a chemical species involved in a reaction. In a precipitation reaction, for example, the reaction unit is the charge of the cation or anion involved in the reaction; thus for the reaction**

**Pb2+(*aq*) + 2I–(*aq*) http://www.chemiasoft.com/ebook/images/image076.gif PbI2(*s*)**

***n* = 2 for Pb2+ because each ion takes two electrons and *n* = 1 for I- because each ion donate only one electron.  In an acid–base reaction, the reaction unit is the number of H+ ions donated by an acid or accepted by a base. For the reaction between sulfuric acid and ammonia**

**H2SO4(*aq*)  +  2NH3(*aq*)  http://www.chemiasoft.com/ebook/images/image076.gif  2NH4+(*aq*)  +  SO42–(*aq*)**

**we find that *n* = 2 for H2SO4  because each molecule donate two ions of H+ and *n* = 1 for NH3 because each ion accept one H+. For a complexation reaction, the reaction unit is the number of electron pairs that can be accepted by the metal or donated by the ligand. In the reaction between Ag+ and NH3**

**Ag+(*aq*) + 2NH3(*aq*) http://www.chemiasoft.com/ebook/images/image076.gif Ag(NH3)2+(*aq*)**

**the value of *n* for Ag+ is 2 because each ion accept pair of electrons in covalent bonds with Ammonia NH3 one electron from each covalent bond, for NH3 is *n* = 1 because each molecule of ammonia donate one electron in each covalent bond it form with Ag+. Finally, in an oxidation–reduction reaction the reaction unit is the number of electrons released by the reducing agent or accepted by the oxidizing agent; thus, for the reaction**

**2Fe3+(*aq*) + Sn2+(*aq*) http://www.chemiasoft.com/ebook/images/image076.gif Sn4+(*aq*) + 2Fe2+(*aq*)**

***n* = 1 for Fe3+ because each ion accept one electron in the reduction step and *n* = 2 for Sn2+ because each ion donate two electrons in the oxidation step. Clearly, determining the number of equivalents for a chemical species requires an understanding of how it reacts.**

**Normality is the number of equivalent weights (EW) per unit volume and, like formality, is independent of speciation. An equivalent weight is defined as the ratio of a chemical species’ formula weight (FW) to the number of its equivalents**

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**http://www.chemiasoft.com/ebook/images/image080.gif**

**http://www.chemiasoft.com/ebook/images/image082.gif**

**http://www.chemiasoft.com/ebook/images/image084.gif**

**Consequently, the following simple relationship exists between normality and molarity.**

**N = *n* ×  M**

**This equation is the simple form to fully understand the normality, you have to be able to determine the number of equivalents and calculate the molarity then use above equation to calculate the normality of the target analyte. Example 1.1 illustrates the relationship among chemical reactivity, equivalent weight, and normality.**

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| ***EXAMPLE 1*** |

**Calculate the equivalent weight and normality for a solution of 6.0 M H3PO4 given the following reactions:**

**(a) H3PO4(*aq*) + 3OH–(*aq*) http://www.chemiasoft.com/ebook/images/image076.gif PO43–(*aq*) + 3H2O(l)**

**(b) H3PO4(*aq*) + 2NH3(*aq*) http://www.chemiasoft.com/ebook/images/image076.gif HPO42–(*aq*) + 2NH4+(*aq*)**

**(c) H3PO4(*aq*) + F–(*aq*) http://www.chemiasoft.com/ebook/images/image076.gif H2PO4–(*aq*) + HF(*aq*)**

***SOLUTION***

**For phosphoric acid, the number of equivalents is the number of H+ ion donated to the base. For the reactions in (a), (b), and (c) the number of equivalents are 3, 2, and 1, respectively. Thus, the calculated equivalent weights and normalities are**

**(a) http://www.chemiasoft.com/ebook/images/image086.gif        N =  *n* x M = 3 x 6.0 = 18.0 N**

**(b) http://www.chemiasoft.com/ebook/images/image088.gif        N =  *n* x M = 2 x 6.0 = 12.0 N**

**(c) http://www.chemiasoft.com/ebook/images/image090.gif          N =  *n* x M = 1 x 6.0 = 6.0 N**

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| ***EXAMPLE 2*** |

**In standard method for Alkalinity measurement, a solution of 0.05N of Na2CO3 should be prepared based on the following titration reaction with sulfuric acid:**

**Na2CO3 (aq) + H2SO4  http://www.chemiasoft.com/ebook/images/image076.gif [H2CO3] + Na2SO4 (aq)http://www.chemiasoft.com/ebook/images/image076.gif  H2O (aq) + CO2 (gas) + Na2SO4 (aq)**

**The part [H2CO3] is an intermediate which is directly converted to H2O and CO2 gas.**

**How many grams of Na2CO3 required to prepare 1.0 Liter of 0.05N solution?**

***SOLUTION 1 By Normality Equations:***

**According to the reaction above (acid-base reaction), each molecule of Na2CO3 accept two hydrogen ions (H+) from sulfuric acid, then number of equivalents for Na2CO3 n=2.**

**Formula Weight (FW) for Na2CO3 = 105.99 g/mol**

**Equivalents Weight http://www.chemiasoft.com/ebook/images/image092.gifg/mol**

**http://www.chemiasoft.com/ebook/images/image094.gif http://www.chemiasoft.com/ebook/images/image076.gif http://www.chemiasoft.com/ebook/images/image096.gif**

**Number of EWs solute = 0.05 N x 1.0 L = 0.05 mol**

**http://www.chemiasoft.com/ebook/images/image080.gif    http://www.chemiasoft.com/ebook/images/image076.gif**

**Weight of solute =  Number of EWs solute × Equivalent Weight (EW) = 0.05 mol × 52.995 g/mol = 2.65 g**

**To prepare 0.05N of Na2CO3 weigh 2.65 g of Na2CO3 and dissolve and complete to volume 1.0 L.**

***SOLUTION 2 By Molarity Equations:***

**Convert the normality concentration to molarity the make all calculations by molarity equations**

**N = *n*  x  M   http://www.chemiasoft.com/ebook/images/image076.gif   http://www.chemiasoft.com/ebook/images/image098.gifof Na2CO3**

**http://www.chemiasoft.com/ebook/images/image052.gif**

**Moles of solute = 0.025 M   X  1.0 L = 0.025 mol of Na2CO3**

**http://www.chemiasoft.com/ebook/images/image056.gif    http://www.chemiasoft.com/ebook/images/image076.gif**

**Weight of solute (g) = Moles of solute X Molecular Weight (g/mol)**

**Weight of solute (g) = 0.025 mol X 105.99 (g/mol) = 2.65 g of Na2CO3**

**Weight, Volume, and Weight-to-Volume Ratios**

**Weight percent (% w/w), volume percent (% v/v) and weight-to-volume percent (% w/v) express concentration as units of solute per 100 units of solution. A solution in which a solute has a concentration of 23% w/v contains 23 g of solute per 100 mL of solution. Parts per million (ppm) and parts per billion (ppb) are mass ratios of grams of solute to one million or one billion grams of sample, respectively. For example, a steel that is 450 ppm in Mn contains 450 mg of Mn for every kilogram of steel. If we approximate the density of an aqueous solution as 1.00 g/mL, then solution concentrations can be expressed in parts per million or parts per billion using the following relationships. For gases a part per million usually is a volume ratio. Thus, a helium concentration of 6.3 ppm means that one liter of air contains 6.3 mL of He.**

**Table 1.2 explain most common equations used in calculations of weight and volume ratios units. Note that the ppm of ppb units can be used as (w/w) or (w/v), for solutions if unit is not specified as (w/v) or (w/w) then (w/v) is assumed as default.**

**most common equations used in calculations of weight and volume ratios units.**

| **Concentration Unit** | **Equations** |
| --- | --- |
| **% w/w** | **http://www.chemiasoft.com/ebook/images/image113.gif** |
| **%v/v** | **http://www.chemiasoft.com/ebook/images/image115.gif** |
| **%w/v** | **http://www.chemiasoft.com/ebook/images/image117.gif** |
| **Part per million (ppm)**  **w/v** | **http://www.chemiasoft.com/ebook/images/image119.gif** |
| **Part per million (ppm)**  **w/w** | **http://www.chemiasoft.com/ebook/images/image121.gif** |
| **Part per billion (ppb)**  **w/v** | **http://www.chemiasoft.com/ebook/images/image123.gif** |
| **Part per billion (ppb)**  **w/w** | **http://www.chemiasoft.com/ebook/images/image125.gif** |

**w/w: Weight by weight**

**w/v:  Weight by volume**

**v/v:   Volume by volume**

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| ***EXAMPLE 1*** |

**How many grams of NaCl required to prepare each of the following solutions:**

**a) 2500 ppm (w/v) NaCl 250 mL solution.**

**b) 10% (w/v) NaCl in 250 mL solution.**

**c) 20% (w/w) NaCl in 250 g solution.**

**SOLUTION**

**a) 2500 ppm (w/v) NaCl**

**http://www.chemiasoft.com/ebook/images/image128.gif http://www.chemiasoft.com/ebook/images/image076.gif  mg of solute = Conce. (ppm) × Volume of Solution(L)**

**mg of NaCl = 2500 ppm X 0.250 L = 625 mg = 0.625 g of NaCl.**

**b)  10% (w/v) NaCl**

**http://www.chemiasoft.com/ebook/images/image130.gif   http://www.chemiasoft.com/ebook/images/image076.gif   http://www.chemiasoft.com/ebook/images/image132.gif**

**http://www.chemiasoft.com/ebook/images/image134.gif**

**c) 20% (w/w) NaCl**

**http://www.chemiasoft.com/ebook/images/image136.gif  http://www.chemiasoft.com/ebook/images/image076.gif   http://www.chemiasoft.com/ebook/images/image138.gif**

**http://www.chemiasoft.com/ebook/images/image140.gif**

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| **EXAMPLE 2** |

**What is the concentration of MgSO4 the following prepared solution, express concentrations in ppm, %(w/v) and (w/w) concentrations units. Assume solution density is 1.0 g/mL**

**30 g of MgSO4 dissolved in 500 mL distilled water.**

**SOLUTION**

**http://www.chemiasoft.com/ebook/images/image143.gif**

**http://www.chemiasoft.com/ebook/images/image145.gif**

**When solution density 1.0 g/mL then**

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**http://www.chemiasoft.com/ebook/images/image151.gif**

## 

# Dilution of Concentrated Solutions

**Dilution is one of the main preparation processes which used daily in all laboratories; any chemist should be familiar with dilution calculations to prepare a correct diluted solution.**

**For convenience, chemicals are sometimes bought and stored as concentrated solutions that must be diluted before use. Aqueous hydrochloric acid, for example, is sold commercially as a 12.0 M solution, yet it is most commonly used in the laboratory after dilution with water to a final concentration of 6.0 M or 1.0 M.**

**Concentrated Solution + Solvent  http://www.chemiasoft.com/ebook/images/image076.gif Diluted Solution**

**The key fact to remember when diluting a concentrated solution is that the number of moles of solute is constant; only the volume is changed by adding more solvent. Because the number of moles of solute can be calculated by multiplying molarity times volume, we can set up the following equation:**

**Moles of solute (constant) = Molarity   ×   Volume**

**= Mi  × Vi = Mf  ×  Vf**

**where Mi is the initial molarity, Vi is the initial volume, Mf is the final molarity, and Vf is the final volume after dilution. Rearranging this equation into a more useful form shows that the molar concentration after dilution (Mf) can be found by multiplying the initial concentration (Mi) by the ratio of initial and final volumes (Vi/Vf):**

**http://www.chemiasoft.com/ebook/images/image195.gif**

**Part (Vf/Vi) called dilution factor:**

**http://www.chemiasoft.com/ebook/images/image197.gif  http://www.chemiasoft.com/ebook/images/image199.gif   http://www.chemiasoft.com/ebook/images/image201.gif**

**Where DF (Dilution Factor) = http://www.chemiasoft.com/ebook/images/image203.gif**

**Suppose, for example, that we dilute 50.0 mL of a solution of 2.00 M to a volume of 200.0 mL. The solution volume increases by a factor of four (from 50 mL to 200 mL), so the concentration of the solution must decrease by a factor of four (from 2.00 M to 0.500 M):**

**http://www.chemiasoft.com/ebook/images/image205.gif**

**Dilution Factor DF = http://www.chemiasoft.com/ebook/images/image207.gif**

**Dilution factor of value 4 means the solution concentration has been diluted by factor of 4, i.e the original solution concentration is equal four times the new concentration of the diluted solution**

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| ***EXAMPLE 1*** |

**How would you prepare 500.0 mL of 0.2500 M NaOH solution starting from a concentration of 1.000 M?**

***SOLUTION***

**The problem gives initial and final concentrations (Mi and Mf) and final volume (Vf) and asks for the initial volume (Vi) that we need to dilute. Rewriting the equation as gives the answer.**

**http://www.chemiasoft.com/ebook/images/image195.gif  http://www.chemiasoft.com/ebook/images/image199.gif  http://www.chemiasoft.com/ebook/images/image212.gif**

**http://www.chemiasoft.com/ebook/images/image214.gif**

**This mean to prepare solution with concentration of 0.2500 M NaOH you have to transfer 125 mL from initial solution (1.000 M) and complete with solvent to 500.0 mL.**

***Note about the dilution roles:***

* **The volume units for both final volume (Vf) and initial volume (Vi) should be same, i.e if Vi is in (mL) unit then Vf is also in (mL) unit. If Vi is in Liter unit, also Vf should also have Liter unit…etc.**
* **The concentration (Mi) and (Mf) are not limited to molarity only, it could be generalized for any concentration unit, but under one condition they have to be same unit. The following equation used as general:**

**http://www.chemiasoft.com/ebook/images/image195.gifhttp://www.chemiasoft.com/ebook/images/image199.gif http://www.chemiasoft.com/ebook/images/image216.gif**

**Where Ci is initial concentration, Cf is final concentration.**

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# More Examples

**For best practice and help you understand more about chemical solution preparations, we include more examples below:**

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| **EXAMPLE** |

**How many grams of Sodium Persulfate (Na2S2O8) required to prepare a 1 L solution of Sodium Persulfate with concentration of 10% (w/v). This solution is widely used as oxidizing reagent for Total Organic Carbon analyzer (TOC).**

**SOLUTION 1 By Equations:**

**http://www.chemiasoft.com/ebook/images1/image130.gif http://www.chemiasoft.com/ebook/images1/image042.gif http://www.chemiasoft.com/ebook/images1/image131.gif**

**http://www.chemiasoft.com/ebook/images1/image132.gif**

**SOLUTION 2 By Conversions:**

**1 L = 1000 mL**

**http://www.chemiasoft.com/ebook/images1/image135.gif**

**Reagent is prepared by dissolving 100 g of Sodium Persulfate in solvent and complete to 1 L with solvent.**

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| **EXAMPLE 1.8.2** |

**What is the concentration of Hydrochloric Acid (HCl) bottle in Molarity unit (M), if the following information written on the bottle:**

**M.Wt = 36.46 g/mol , d= 1.18 g/cm3, 37% (w/w)**

**SOLUTION**

**Molarity unit (M) is equal to mol/L by using conversion factor starting from information we have:**

**http://www.chemiasoft.com/ebook/images1/image137.gif http://www.chemiasoft.com/ebook/images1/image042.gif**

**http://www.chemiasoft.com/ebook/images1/image139.gif**

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| **EXAMPLE 1.8.3** |

**How to prepare a 500 mL solution of 2.0 N Sulfuric acid (H2SO4) from concentrated bottle of Sulfuric acid. If the following information written on Sulfuric acid bottle:**

**M.Wt = 98.08 g/mol, d= 1.84 g/cm3, 97% (w/w).**

**SOLUTION**

**In this example we have to dilute from concentrated bottle of Sulfuric acid (97% (w/w)) to lower concentration of 2.0 N.**

**1- The first step we have to find out the concentrated bottle concentration in unit Molarity.**

**2- Convert concentration from Molarity to Normality**

**3- Use dilution role to calculate the volume required from the concentrated bottle**

**To find the concentration of the concentrated bottle we start from information we have:**

**Density = 1.84 g/cm3 = 1.84 g/mL**

**http://www.chemiasoft.com/ebook/images1/image141.gif http://www.chemiasoft.com/ebook/images1/image042.gif**

**http://www.chemiasoft.com/ebook/images1/image143.gif**

**The concentration of H2SO4 is 18.197 M**

**To convert this unit to Normality we have to find out the number of equivalents for H2SO4, Sulfuric acid is strong acid and always donate two hydrogen ions in all reactions for example:**

**H2SO4 + 2NaOH http://www.chemiasoft.com/ebook/images1/image042.gif 2H2O + Na2SO4**

**In this case we say the number of equivalents for Sulfuric acid equals two (n=2). By substitute in Molarity to Normality equation:**

**N = n × M**

**N = 2 × 18.197 = 36.394 N of H2SO4**

**Now we found the concentration of the Sulfuric acid and have to make dilutions by using dilution role:**

**Initial Concentration (Ci) = 36.394 N**

**Final Concentration (Cf) = 2.0 N**

**Final Volume (Vf) = 500 mL**

**Initial Volume (Vi) = ?**

**http://www.chemiasoft.com/ebook/images1/image127.gif http://www.chemiasoft.com/ebook/images1/image042.gif http://www.chemiasoft.com/ebook/images1/image144.gif**

**This mean to prepare a solution of 2.0 N you have to transfer exactly 27.5 mL from concentrated bottle and dilute with solvent to total volume 500.0 mL.**

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| **EXAMPLE 1.8.4** |

**If we need to prepare a solution of NaOH with concentration of 20% (w/w) with total weight of solution equals to 2.0 Kg, how many grams of Sodium Hydroxide required.**

**SOLUTION**

**By using conversion factors starting from information we have:**

**http://www.chemiasoft.com/ebook/images1/image146.gif**

**1Kg of solution = 1000 g of solution http://www.chemiasoft.com/ebook/images1/image042.gif**

**http://www.chemiasoft.com/ebook/images1/image147.gif**

**To prepare solution by dissolving 400.0 g of NaOH in suitable amount of solvent and dilute to 2.0 Kg.**

**Note:**

**To prepare solution in lab in practical work the process done by taking initial weight of the container need to prepare the solution in then transfer some solvent and 400.0 g of NaOH, shake and mix until all dissolved, then add solvent and complete to final weight on balance where:**

**Final weight = Initial weight + Total Solution Volume (2.0 Kg)**

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| **EXAMPLE 1.8.5** |

**A solution has been prepared by transfer 60 mL from Ortho-phosphoric acid 85 % (v/v) H3PO4 and dilute to 1.0 L, what is the concentration of the new solution.**

**SOLUTION**

**By using dilution role:**

**1.0 L = 1000 mL**

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**Note: This solution is generally used as a second oxidizing agent in Total Organic Carbon analyzer (TOC).**

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| **EXAMPLE 1.8.6** |

**A Total Petroleum Hydrocarbon (TPH) standard solution is prepared by dissolving amount of mineral oil (motor oil) in organic solvent like n-hexane or chloroform. Explain how to prepare TPH standard in 100 mL volume with concentration of 50,000 ppm (w/v).**

**SOLUTION**

**By using conversion factor starting from information we have:**

**http://www.chemiasoft.com/ebook/images1/image151.gif**

**100 mL = 0.100 L**

**http://www.chemiasoft.com/ebook/images1/image153.gif**

**To prepare TPH standard weigh exactly 5.0 g of mineral oil and complete to total volume 100 mL.**

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| **EXAMPLE 7** |

**How many moles Sodium Sulfate Na2SO4 exists in a 250 mL solution have concentration 15% (w/v).**

**SOLUTION**

**Molecular Weight of Na2SO4 = (22.99 × 2) + 32.07 + (16.0 × 4) = 142.04 g/mol**

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| **EXAMPLE 1.8.8** |

**How to prepare 200 mL of solution with concentration of 1% (w/v) NaOH starting from NaOH 20 % (w/v).**

**SOLUTION**

**In this example you have a simple dilution process, use dilution equation to calculate the amount required:**

**http://www.chemiasoft.com/ebook/images1/image158.gif**

**Where in this case:**

**Cf = 1 % (w/v) NaOH**

**Ci = 20% (w/v) NaOH**

**Vf = 250 mL**

**Vi = Volume required from 20% NaOH solution**

**Substitute above values in equation:**

**http://www.chemiasoft.com/ebook/images1/image159.gif**

**Volume of 10 mL required, to prepare the solution transfer exactly 10 mL from 20% (w/v) NaOH solution to 200 mL volumetric flask and dilute with solvent to the mark.**

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**How to prepare 500 g solution of 5 % (w/w) NaOH starting from 50% (w/w) NaOH solution.**

**SOLUTION**

**In this example dilution equation will be used but instead of put volume we will put weight**

**http://www.chemiasoft.com/ebook/images1/image161.gif**

**Where in this case:**

**Cf = 5 % (w/w) NaOH**

**Ci = 50% (w/w) NaOH**

**Wf = 500 g of 5 % (w/w) solution**

**Wi = Volume required from 50% (w/w) NaOH solution**

**Substitute above values in equation:**

**http://www.chemiasoft.com/ebook/images1/image162.gif**

**Weight of 50 g from 50%(w/w) NaOH required to prepare solution of 5% (w/w) NaOH.**

## 

# Ionic Standard Solutions

## Ionic Compounds:

**Ionic compounds are basically defined as being compounds where two or more ions are held next to each other by electrical attraction. One of the ions has a positive charge (called a "cation") and the other has a negative charge ("anion"). Cations are usually metal atoms and anions are either nonmetals or polyatomic ions (ions with more than one atom).**

**Ions can be single atoms, as the sodium and chloride in common table salt sodium chloride, or more complex groups such as the carbonate in calcium carbonate. But to be considered an ion, they must carry a positive or negative charge. Thus, in an ionic bond, one 'bonder' must have a positive charge and the other a negative one. By sticking to each other, they resolve, or partially resolve, their separate charge imbalances. Positive to positive and negative to negative ionic bonds do not occur.**

**Ionic standard solutions are mostly used in analysis of all kind of ions, anions such as chloride (Cl-), bromide (Br-), sulfate (SO42-) or cations such as sodium (Na+), magnesium (Mg2+) and potassium (K+). The analysis procedure is either in wet-chemistry by titration or by using instrument like ion-chromatography or spectrophotometer or else. But regardless of the procedure used in the analysis the accuracy in the analysis depends on the accuracy of standards.**

**To prepare stock standard solution of ion analyte, first we have to find a salt starting reagent either in liquid or solid state contain such ion then make sure the salt is fully dissociated in water such as sodium chloride (NaCl) and sodium sulfate (Na2SO4).**

**NaCl     http://www.chemiasoft.com/ebook/images/image275.gif      Na+ +  Cl-**

**Na2SO4   http://www.chemiasoft.com/ebook/images/image275.gif   2Na+   +   SO42-**

**Sodium chloride dissociate in water into one sodium cation (Na+) and one chloride anion (Cl-) as per  equation above. Sodium sulfate dissociate into two sodium cations and one sulfate anion.**

**After find the starting reagent to prepare standard solution check the chemical formula of the substance and find how many ion(s) are produced from dissociation of single molecule. Example each molecule of NaCl produces one sodium ion (Na+) but each molecule of Na2SO4 produce two sodium ions. Use the conversion factor equation to make calculations.**

**We consider some examples below will show how to prepare and make calculations for different kinds of ionic standard solutions.**

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| **EXAMPLE 2.2.1** |

**Calculate amount required to prepare 500 mL solution of 1000 ppm (mg/L) Na starting from sodium chloride (NaCl).**

**SOLUTION**

**We will use conversion factor and we will start with conversion we will prepare:**

**Molecular weight for NaCl = 58.44 g/mol**

**Atomic weight for Na = 22.99 g/mol**

**Each 58.44 g of NaCl contain 22.99 g of Na by convert grams to milligrams**

**Each 58.44 mg of NaCl contain 22.99 mg of Na**

**http://www.chemiasoft.com/ebook/images/image278.gif**

**Good Practice: Calculate amount required to prepare 1000 mL of 2000 ppm (mg/L) Na starting from Na2SO4.**

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| **EXAMPLE 2.2.2** |

**Calculate how to prepare sulfate (SO42-) stock standard solution 1000 ppm (mg/L) in 1 Liter starting from magnesium sulfate hexahydrate (MgSO4.7H2O).**

**SOLUTION**

**First will calculate the molecular weight for starting reagent formula and for sulfate ion**

**Molecular weight for MgSO4.7H2O = 246.48 g/mol**

**Formula weight for sulfate ion (SO42-) = 96.06 g/mol**

**From starting reagent formula MgSO4.7H2O each molecule produce after dissociate in water one sulfate anion (SO42-) i.e each 246.48 grams of MgSO4.7H2O have 96.06 grams of sulfate anion. Use this relation to write the conversion factor. Start always from the concentration we need to prepare 1000 ppm (mg/L).**

**http://www.chemiasoft.com/ebook/images/image281.gif**

**To prepare stock solution dissolve 2.5659 grams of MgSO4.7H2O in small amount of solvent then complete to total volume 1 Liter.**

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| ***EXAMPLE 2.2.3*** |

**Nitrate (NO3-) anion solution prepared by dissolving 3.0 g of KNO3 in 250 mL of water. What is the concentration of Nitrate ion, express the concentration in Molarity and ppm.**

**SOLUTION**

**Molecular weight of KNO3 = 101.10 g/mol**

**Formula weight of NO3- = 62.00 g/mol**

**Starting from the information we have:**

**http://www.chemiasoft.com/ebook/images/image284.gif**

**http://www.chemiasoft.com/ebook/images/image286.gif**

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| ***EXAMPLE 2.2.4*** |

**A student needs to prepare mixed anion standard solution 1 Liter to be used in Ion Chromatography contains the following:**

1. **Sulfate (SO42-) 10,000 ppm**
2. **Nitrate (NO3-) 1,000 ppm**
3. **Bromide (Br-) 1,000 ppm**

**Student has the following reagent in his lab, Aluminum sulfate hexadecahydrate Al2(SO4)3.16H2O, Sodium bromide NaBr, Calcium nitrate Ca(NO3)2.**

**Explain to the student how to prepare stock standard.**

**SOLUTION**

**First we have to find a source for each ion as per the following table:**

| **Ion** | **Source** | **Concentration (ppm)** | **Number of ion in each molecule** |
| --- | --- | --- | --- |
| **Sulfate (SO42-)** | **Aluminum sulfate hexadecahydrate Al2(SO4)3.16H2O** | **10,000** | **3** |
| **Nitrate (NO3-)** | **Calcium nitrate Ca(NO3)2** | **1,000** | **2** |
| **Bromide (Br-)** | **Sodium bromide NaBr** | **1,000** | **1** |

**Above table shows each ion in stock standard and it's starting reagent source and concentration in ppm (mg/L). The last column shows number of ions produced from each molecule of starting reagents after dissociation in water.**

**To calculate the amount required we assume all starting reagents are pure 100 % w/w. Start calculate from the target concentration:**

1. **Sulfate (SO42-)**

**Molecular weight of Al2(SO4)3.16H2O = 630.40 g/mol**

**http://www.chemiasoft.com/ebook/images/image289.gif**

1. **Nitrate (NO3-)**

**Molecular weight of Ca(NO3)2 = 164.09 g/mol**

**http://www.chemiasoft.com/ebook/images/image291.gif**

1. **Bromide (Br-)**

**Molecular weight of NaBr = 102.89 g/mol**

**http://www.chemiasoft.com/ebook/images/image293.gif**

**To prepare standard we weigh exactly 21.8752 g, 1.3233 g and 1.2877 g from Al2(SO4)3.16H2O , Ca(NO3)2 and NaBr respectively and transfer all to same 1 liter volumetric flask then add solvent (water) to dissolve all substances then we complete to marked volume with solvent.**

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| **EXAMPLE 2.2.5** |

**A solution prepared by add 5.0 g of KNO3 and 5.0 g of Hg(NO3)2 in 1 L volumetric flask and complete with water to volume, what is the concentration of Nitrate anion (NO3-) in the final solution? Express concentration in Molarity unit.**

**SOLUTION**

**First we calculate how many grams or how many moles of nitrate ion in the solution from each source reagent, we start always from the information we know:**

**Molecular weight of KNO3 = 101.10 g/mol**

**http://www.chemiasoft.com/ebook/images/image296.gif**

**Molecular weight of Hg(NO3)2  = 324.60 g/mol**

**http://www.chemiasoft.com/ebook/images/image298.gif**

**Total number of moles of nitrate ions from both source =**

**49.46 mmoles + 30.80 mmoles =  80.26 mmoles = 0.08026 moles NO3-**

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| **EXAMPLE 2.2.6** |

**Sulfide (S2-) ion solution prepared from sodium sulfide Na2S solid with purity of 30% (w/w). How many grams of sodium sulfide required to prepare 500 mL of 2,000 ppm sulfide (S2-) stock standard solution.**

**SOLUTION**

**Purity of starting reagent is important, 30% w/w  means for each 100 grams of sodium sulfide powder there are 30 grams of sodium sulfide, we will start calculations from the target concentration 2,000 ppm:**

**http://www.chemiasoft.com/ebook/images/image303.gif**

**http://www.chemiasoft.com/ebook/images/image305.gif**

**To prepare standard weigh exactly 8.1125 g of Na2S powder dissolved it in water then complete to total volume 500 mL.**

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| **EXAMPLE 2.2.7** |

**A solution prepared by mixing 50 mL from 0.5 M orthophosphate (PO43-) and 35 mL from 5,000 ppm (mg/L) PO43- solutions then completed to 250 mL total volume. What is the final concentration of phosphate anion PO43- in both ppm and molarity.**

**SOLUTION**

**First we calculate number of moles of orthophosphate ion we took from each solution:**

* **50 mL of 0.5 M PO43- solution (M = mol/L)**

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* **35 mL of 5,000 ppm PO43- solution (ppm = mg/L)**

**http://www.chemiasoft.com/ebook/images/image310.gif**

**Total number of moles = 0.025 + 0.00184 = 0.02684 mol PO43-**

**Calculate concentration of final solution in Molarity (M):**

**http://www.chemiasoft.com/ebook/images/image312.gif**

**Calculate concentration in ppm(mg/L):**

**http://www.chemiasoft.com/ebook/images/image314.gif**

**Final concentration of solution is 0.1074 M or 10,195.97 ppm PO43-**

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| **EXAMPLE 2.2.8** |

**Nitrite anion (NO2-) stock solution prepared from Sodium nitrite NaNO2, the concentration of nitrite are expressed in terms of nitrogen element. For example if we said Nitrite-N 1,000 ppm mg N/L means 1 liter of the solution contains one thousand milligrams of nitrogen element sourced from nitrite anion.**

**Notice: Express nitrite and nitrate anions concentrations by nitrogen element source make it easy for comparison between them; most of national environmental protection agencies for water in many countries around the world are expressing thus kind of ions by nitrogen element. Standard Methods for Examination of Water and Wastewater book is also using this expression.**

**How many grams of Sodium nitrite NaNO2 powder required to prepare 1 liter of Nitrite-N solution with concentration of 1,000 mg N/L if the purity of NaNO2 powder is 97.1 % w/w.**

**SOLUTION**

**Calculation is depend on nitrogen element in Sodium nitrite, there is only on nitrogen atom produced from each molecule of Sodium nitrite**

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**= 5.0758 g of NaNO2 powder**

**Good practice: resolve example 2.8 but change Sodium nitrite (NaNO2) with Ammonium nitrite (NH4NO2).**

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