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Designing simple equations to fully understand the conversions among common concentration units: An overview

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ABSTRACT

Chemists express solution concentrations in a number of ways and the beginning analytical chemist should be familiar with some of the common expressions and units of measure employed. Concentration units can be a source of confusion for students. This article presents a treatment on this topic that may help students understand the differences between these units. We have reviewed here the common concentration units that chemists use. Their use in quantitative volumetric calculations is treated in more details. We have also designed simple equations to fully understand the calculations for concentration units and conversion between them. This article provides a quick, handy solution and a practical training for chemists, technicians, scientists, students, teachers, or engineers to overcome the problem of time-consuming, difficult, and often inaccurate conversion calculations.

1. Introduction

In the study of chemistry, it is quite common to encounter both extremely large quantities and extremely small ones. Chemists traditionally express concentrations of ions or compounds in molarity (moles per liter) or molality (moles per 1000 g of solvent). This is not always so with the biochemist/life-science discipline. Their concentration is often expressed as parts per million (ppm). Water and air pollution, for example, are often expressed as ppm. When chemists and life scientists come together in meetings and chemists express an effective concentration as 2.3×10^{-4} M, the expression often has little meaning to the life scientist who thinks in terms of ppm. Inevitably, when these groups interact, one of two questions is quickly voiced, "What is that in ppm?" or "What is that in moles per liter?" On-the-spot conversion calculations are time-consuming, difficult, and often inaccurate (Sunberg, 1986). We are looking to make chemistry simple, easy for student, teacher, chemist, analyst and scientist. We are trying our best starting from small principles in chemistry. We found some chemists are making some mistakes in calculation. This simple article is a practical training for chemist, technicians or scientist for solutions calculations. There are a number of different ways of expressing solute concentration that are commonly used. Some are more useful than others in quantitative calculations. The choice of units to use in a given situation depends on the chemical, where it is located (e.g., air, water and soil/sediments) and often on how the measurement will be used (Chemiasoft, 2011; Christian *et al.*, 2014). It is therefore necessary to become familiar with the units used and methods for converting among different sets of units. We will review here the common concentration units that chemists use. Their use in quantitative volumetric calculations is treated in more detail.

This article is written to be readable by anyone who has an idea in basic principles of general chemistry and readily understood by a general audience. It will help students, teachers, chemists, scientists and engineers ... *etc* who are working in chemistry field to fully understand the calculations for concentration units and conversion between them. Here is a refresher of how concentrations by molarity (M), normality (N), percent (%), parts per thousand (ppt), parts per million (ppm), parts per billion (ppb) and parts per trillion (pptr) are calculated.

2. Definitions of common concentration units

2.1. Percent composition (%): It is also known as parts per hundred (pph) and defined as units of solute per 100 units of sample. Percent of a solution can be expressed in several ways. Three common methods are weight percent (% w/w), volume percent (% v/v) and weight-to-volume percent (% w/v).

2.1.1. Percentage by mass (%w/w): It is defined as the number of grams of solute present in 100grams of solution.

2.1.2. Percentage volume for volume (%v/v): It is defined as the number of milliliters of solute per 100 mL of solution. Normally used where the solute is a liquid.

2.1.3. Percentage weight for volume (%w/v): It is defined as the number of grams of solute per 100 mL of solution. Normally used where the solute is a solid.

2.2. Trace concentrations: Trace concentrations are usually given in smaller units, such as parts per thousand (ppt, ‰), parts per million (ppm), parts per billion (ppb), or parts per trillion (pptr).These are calculated in a manner similar to parts per hundred (Christian *et al.*, 2014).

2.2.1. Parts per thousand (ppt): It is also known as strength of a solution and defined as the amount of the solute in grams, present in one liter of the solution.

2.2.2. Parts per million (ppm): This means the mass ratios of grams of solute (grams of substance) to one million of total solution or mixture (sample). For very dilute solutions, parts per million (ppm) is a convenient way to express concentration.

2.2.3. Parts per billion (ppb): This means the mass ratios of grams of solute (grams of substance) to one billion grams of total solution or mixture (sample).

2.2.4. Parts per trillion (pptr): This means the mass ratios of grams of solute (grams of substance) to one trillion grams of total solution or mixture (Christian *et al*., 2014; Harvey, 2000; Sanagi *et al*., 2007; Skoog *et al*., 2014).

All of the above start by calculating the fractional composition and then multiplied by representative quantity as shown below.

$$\frac{\text{amount of solute}}{\text{amount of solution}} \times \text{ representative quantity} \begin{Bmatrix} 10^2 \\ 10^3 \\ 10^6 \\ 10^9 \\ 10^{12} \end{Bmatrix} \begin{matrix} \rightarrow \text{ parts per hundred, pph (\%)} \\ \rightarrow \text{ parts per thousand, ppt (‰)} \\ \rightarrow \text{ parts per million, ppm} \\ \rightarrow \text{ parts per billion, ppb} \\ \rightarrow \text{ parts per trillion, pptr} \end{matrix}$$

2.3. Ity concentrations: It represents the concentration units ending with suffix "ity" such as molarity (M), normality (N), formality (F), and molality (m). We will only discuss molarity and normality in this tutorial article.

2.3.1. Molarity: A very useful means of expressing concentration in the laboratory is **molarity (M)**, the number of moles of solute dissolved per liter of solution.

2.3.2. Normality: it is defined as the number of equivalents of solute per liter of solution.

3. Common relative expressions of concentration units

We can report the results of analysis in many ways, and the beginning analytical chemist should be familiar with some of the common expressions and units of measure employed. Results will nearly always be reported as *concentration*, on either a weight or a volume basis: the quantity of analyte per unit weight or per volume of sample (Christian *et al*., 2014). The units used for the analyte will vary as shown in Table 1.

Table 1

Common relative expressions of concentration units

Expression	Abbreviation	w/w	w/v	v/v
Parts per hundred	pph (%)	g/100g	g/100mL	mL/100mL
Parts per thousand	ppt (‰)	g/kg	g/L	mL/L
		mg/g	mg/mL	µL/mL
		µg/mg	µg/µL	nL/µL
		ng/µg	ng/nL	pL/nL
		pg/ng	pg/pL	
Parts per million	ppm	mg/kg	mg/L	µL/L
		µg/g	µg/mL	nL/mL
		ng/mg	ng/µL	pL/µL
		pg/µg	pg/nL	
Parts per billion	ppb	µg/kg	µg/L	nL/L
		ng/g	ng/mL	pL/ml
		pg/mg	pg/µL	
Parts per trillion	pptr*	ng/kg	ng/L	pL/L
		pg/g	pg/mL	

*pptr is used instead of ppt to avoid confusion.

We shall first review the common units of weight and volume in the metric system and then describe methods of expressing results. The gram (g) is the basic unit of mass and is the unit employed most often in macro analyses. For small samples or trace constituents, chemists use smaller units. The milligram (mg) is 10^{-3} g, the microgram *(µg)* is 10^{-6} g, the nanogram (ng) is 10^{-9} g, and the picogram (pg) is 10^{-12} g. The basic unit of volume is the liter (L). The milliliterr (mL) is 10^{-3} L and is used commonly in volumetric analysis. The microliter (*µ*L) is 10^{-6} L (10^{-3} mL), the nanoliter (nL) is 10^{-9} L (10^{-6} mL), and the picoliter (pL) is 10^{-12} L (10^{-9} mL) (Christian *et al*., 2014: Harvey, 2000: Sanagi *et al*., 2007: Skoog *et al*., 2014). Fig.1 shows the relationships between metric conversions.

Practices:

1. A 2.6 g sample of plant tissue was analyzed and found to contain 3.6 µg zinc. What is the concentration of zinc in the plant in ppt, ppm, ppb, and pptr?

To answer this question, use the information in Table 1 and Fig. 1.

a. Concentration in ppt (ppt = mg/g, g/kg, µg/mg, ng/µg, or pg/ng)

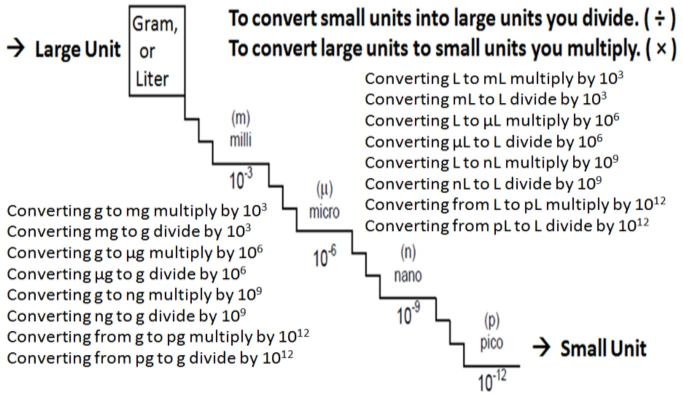

Fig. 1. Relationships among metric conversions

$$Cppt = \frac{3.6 \times 10^{-3}\text{mg}}{2.6 \text{ g}} = 1.3846\times 10^{-3} \text{ mg/g} = 1.4\times 10^{-3}\text{ppt, or}$$

$$Cppt = \frac{3.6 \times 10^{-6}\text{g}}{2.6\times 10^{-3}\text{ kg}} = 1.3846 \times 10^{-3} \text{ g/kg} = 1.3846\times 10^{-3}\text{ppt} \approx 1.4 \times 10^{-3} \text{ ppt, or}$$

$$Cppt = \frac{3.6\ \mu g}{2.6\times 10^{3}\text{ mg}} = 1.3846 \times 10^{-3}\ \mu\text{g/mg} = 1.3846 \times 10^{-3} \text{ ppt} \approx 1.4 \times 10^{-3} \text{ ppt, or}$$

$$Cppt = \frac{3.6 \times 10^{3}\text{ng}}{2.6\times 10^{6}\ \mu g} = 1.3846\times 10^{-3}\text{ng}/\mu\text{g} = 1.3846\times 10^{-3} \text{ ppt} \approx 1.4 \times 10^{-3} \text{ ppt, or}$$

$$Cppt = \frac{3.6 \times 10^{6}\text{pg}}{2.6\times 10^{9}\text{ ng}} = 1.3846\times 10^{-3} \text{ pg/ng} = 1.3846\times 10^{-3} \text{ ppt} \approx 1.4\times 10^{-3} \text{ ppt}$$

b. Concentration in ppm (ppm = µg/g, mg/kg, ng/mg, or pg/µg)

$$Cppm = \frac{3.6\ \mu g}{2.6 \text{ g}} = 1.384.6\ \mu\text{g/g} = 1.384.6 \text{ ppm} \approx 1.4 \text{ ppm, or}$$

$$Cppm = \frac{3.6 \times 10^{-3}\text{mg}}{2.6 \times 10^{-3}\text{ kg}} = 1384.6 \text{ mg/kg} = 1.384.6 \text{ ppm} \approx 1.4 \text{ ppm, or}$$

$$Cppm = \frac{3.6 \times 10^{3}\text{ng}}{2.6 \times 10^{3}\text{mg}} = 1384.6 \text{ ng/mg} = 1.384.6 \text{ ppm} \approx 1.4 \text{ ppm, or}$$

$$Cppm = \frac{3.6 \times 10^{6}\text{ pg}}{2.6 \times 10^{6}\ \mu g} = 1384.6 \text{ pg}/\mu\text{g} = 1.384.6 \text{ ppm} \approx 1.4 \text{ ppm}$$

c. Concentration in ppb (ppb = ng/g, µg/kg, or pg/mg)

$$Cppb = \frac{3.6 \times 10^{3}\text{ng}}{2.6 \text{ g}} = 1384.6 \text{ ng/g} = 1384.6 \text{ ppb} \approx 1.4 \times 10^{3} \text{ ppb, or}$$

$$Cppb = \frac{3.6\ \mu g}{2.6\ \times 10^{-3}\text{ kg}} = 1384.6\ \mu\text{g/kg} = 1384.6 \text{ ppb} \approx 1.4 \times 10^{3} \text{ ppb, or}$$

$$Cppb = \frac{3.6 \times 10^{6}\text{ pg}}{2.6\times 10^{3}\text{ mg}} = 1384.6 \text{ pg/mg} = 1384.6 \text{ ppb} \approx 1.4 \times 10^{3} \text{ ppb}$$

d. Concentration in pptr (pptr = ng/kg, or pg/g)

$$Cpptr = \frac{3.6 \times 10^{3}\text{ng}}{2.6 \times 10^{-3}\text{ kg}} = 1384.6 \text{ ng/kg} = 1384615.4 \text{ pptr} \approx 1.4 \times 10^{6} \text{ pptr, or}$$

$$Cpptr = \frac{3.6 \times 10^{6}\text{pg}}{2.6 \text{ g}} = 1384.6 \text{ pg/g} = 1384615.4 \text{ pptr} \approx 1.4 \times 10^{6} \text{ pptr}$$

3.1. Approximate conversions between trace concentrations and percent

Fig. 2. shows the relationships among percent composition %, ppt, ppm, ppb, and pptr. Chemists frequently express concentrations in terms of percent (parts per hundred). The percent is the basic unit of concentration and is the unit employed most often in macro analyses which express concentration as units of solute per 100 units of sample in terms of weight percent (% w/w), volume percent (% v/v) and weight-to-volume percent (% w/v). Trace concentrations are usually given in smaller units, such as parts per thousand (ppt, ‰), parts per million (ppm), parts per billion (ppb), or parts per trillion (pptr). These are

calculated in a manner similar to parts per hundred (Christian *et al*., 2014; Harvey, 2000; Sanagi *et al*., 2007; Skoog *et al*., 2014).

In case of dealing with solid dissolved in liquid (usually diluted solutions), Table 2 shows approximate conversions between trace concentrations (ppt, ppm, ppb, pptr) and percent (%). Simple designed equations are used to convert between percent (%) and trace units.

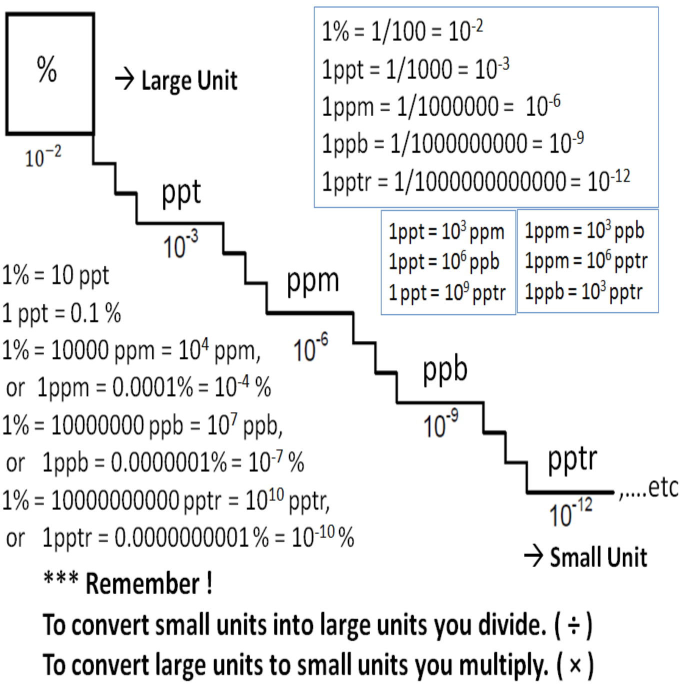

Fig. 2. Conversions among common relative concentration units.

Table 2
Approximate conversions between trace concentrations and percent for diluted solutions. (see examples 1, 2 and 3)

Conversion	Designed equation
Converting (%) to (ppt) multiply by 10	Cppt = C% * 10
Converting (ppt) to (%) divide by 10	C% = Cppt / 10
Converting (%) to (ppm) multiply by 10^4	Cppm = C% * 10^4
Converting (ppm) to (%) divide by 10^4	C% = Cppm / 10^4
Converting (%) to (ppb) multiply by 10^7	Cppb = C% * 10^7
Converting (ppb) to (%) divide by 10^7	C% = Cppb / 10^7
Converting (%) to (pptr) multiply by 10^{10}	Cpptr = C% * 10^{10}
Converting (pptr) to (%) divide by 10^{10}	C% = Cpptr / 10^{10}

Notes: C represents concentration value, e.g. Cppt means concentration in parts per thousand ...etc. Because the solution is so dilute, it is reasonable to assume that its density (d) is 1.00 g/mL. Therefore, the density is ignored in the above equations.

In case of dealing with **high concentrated** liquid materials such as acids and ammonia the density (d) of liquids must be considered. Table 3 shows approximate conversions between trace concentrations (ppt, ppm, ppb, pptr) and percent (pph). Simple designed equations are used to convert between percent (%) and trace units.

Table 3
Approximate conversions between trace concentrations and percent for concentrated liquids such as acids and ammonia. (see examples 4 and 5)

Conversion	Designed equation
Converting (%) to (ppt) multiply by (d * 10)	Cppt = C% * d * 10
Converting (ppt) to (%) divide by (d * 10)	C% = Cppt / d *10
Converting (%) to (ppm) multiply by (d $*$ 10^4)	Cppm = C% * d * 10^4
Converting (ppm) to (%) divide by (d $*$ 10^4)	C% = Cppm / d * 10^4
Converting (%) to (ppb) multiply by (d $*$ 10^7)	Cppb = C% * d * 10^7
Converting (ppb) to (%) divide by (d $*$ 10^7)	C% = Cppb / d *10^7
Converting (%) to (pptr) multiply by (d * 10^{10})	Cpptr = C% * d * 10^{10}
Converting (pptr) to (%) divide by (d * 10^{10})	C% = Cpptr / d * 10^{10}

Note: Because the solution is so concentrate, the density will vary. Therefore, the density is not ignored.

Practices:

1. A sample of Mollusks was analysed for cadmium (Cd) and found to contain 677 μg/kg. Express this as %?

Converting (ppb) to (%) divide by 10^7

C% = 677 / 10^7 = 6.77×10^{-5}%

2. A sample of Mollusks was analyzed for cadmium (Cd) and found to contain 6.77 x 10^{-5} %. Express this as ppb?

Converting (%) to (ppb) multiply by 10^7

Cppb = $6.77\times 10^{-5} \times 10^7$ = 677 μg/kg (ppb)

3. A solution of NaCl has a concentration of 8.0%. Calculate the concentration in ppt of NaCl solution in which 6.8 g of NaCl has been dissolved making a solution with a volume of 85 mL?

Cppt = C% * 10= 8.0% * 10 = 80 g/L, or

$Cppt = \frac{g}{L} = \frac{6.8g}{0.085L} = 80g/L$

4. If the following information was written on sulfuric acid bottle: Fw = 98 g/mol, d = 1.84 g/ml, 96% H_2SO_4. Calculate the concentration of sulfuric acid in ppt?

Cppt = C% * d * 10 = 96 * 1.84 * 10 =1766 g/L ≈ 1.8 $*$ 10^3g/L

5. Calculate the percent (%) of sulfuric acid whether the following information was written on sulfuric acid bottle: Fw = 98 g/mol, d =1.84 g/ml, 1766.4 g/L H_2SO_4?

$C\% = \frac{Cppt}{d * 10} \rightarrow C\% = \frac{1766.4}{1.84 * 10} = 96\%$

3.2. Conversions among trace concentrations

The formulated equations are simply designed by using Fig. 2. Table 4 shows simple designed equations that are used to convert among trace concentrations.

Table 4
Conversions among trace units

Conversion	Designed equation
Converting (ppt) to (ppm) multiply by 10^3	Cppm = Cppt * 10^3
Converting (ppm) to (ppt) divide by 10^3	Cppt = Cppm/10^3
Converting (ppt) to (ppb) multiply by 10^6	Cppb = Cppt * 10^6
Converting (ppb) to (ppt) divide by 10^6	Cppt = Cppb/10^6
Converting (ppt) to (pptr) multiply by 10^9	Cpptr = Cppt * 10^9
Converting (pptr) to (ppt) divide by 10^9	Cppt = Cpptr/10^9
Converting (ppm) to (ppb) multiply by 10^3	Cppb = Cppm * 10^3
Converting (ppb) to (ppm) divide by 10^3	Cppm = Cppb/10^3
Converting (ppb) to (pptr) multiply by 10^3	Cpptr = Cppb * 10^3
Converting (pptr) to (ppb) divide by 10^3	Cppb = Cpptr/10^3
Converting (ppm) to (pptr) multiply by 10^6	Cpptr = Cppm * 10^6
Converting (pptr) to (ppm) divide by 10^6	Cppm = Cpptr/10^6

Practices:

1. Find the concentration in ppt, ppm, ppb and pptr of a solution in which 0.1 g of NaCl has been dissolved making a solution with a volume of 2 L?

a. Concentration in ppt → $Cppt = \frac{g}{L} = \frac{0.1g}{2L} = 0.05\frac{g}{L}$ (ppt), or

$Cppt = \frac{0.1g}{2 * 10^3} \times 10^3 = 0.05$ mg/mL (ppt)

b. Concentration in ppm → Cppm = Cppt * 10^3 = 0.05 * 10^3 mg/L = 50 ppm, or

$Cppm = \frac{0.1g}{2 * 10^3} \times 10^6 = 50$ μg/mL = 50 ppm

c. Concentration in ppb → Cppb = Cppt * 10^6 = 0.05 * 10^6 = 50000 μg/L = 5 $*$ 10^4 ppb, or

$Cppb = \frac{0.1g}{2 * 10^3} \times 10^9 = 50000$ ng/mL = 5 $*$ 10^4 ppb

d. Concentration in pptr → Cpptr = Cppt * 10^9 = 0.05 * 10^9 = 50000000 ng/L = 5 $*$ 10^7 pptr, or

$Cpptr = \frac{0.1g}{2 * 10^3} \times 10^{12} = 50000000$ pg/mL = 5 $*$ 10^7 pptr

2. A sample of canned tuna fish was analysed for mercury (Hg) and found to contain 0.55 mg/kg. Express this as pptr?

Converting (mg/kg = ppm) to (pptr) multiply by 10^6

Concentration in pptr = Cppm*10^6 = 0.55 ppm $* \ 10^6 = 5.5 * 10^5 \, ng/kg$ (pptr)

3. A sample of kelp was analyzed for arsenic (As) and found to contain 25 µg/g. What is the concentration of arsenic (As) in ppt?

Converting (ppm) to (ppt) divide by 10^3

$$\text{Cppt} = \frac{\text{Cppm}}{10^3} \rightarrow \text{Cppt} = \frac{25}{10^3} = 0.025 = 2.5 \times 10^{-2} \, \frac{\text{mg}}{\text{g}} \text{ (ppt)}$$

3.3. Conversion among molarity, normality and percent

The basic concentration units in laboratory are molarity, normality, and percent. Some students are facing little difficulty to convert between them. Here is a solution to that problem.

3.3.1 Converting from molarity (M) to normality (N) and vice versa

The following simple relationship exists between normality and molarity.

(i) Equation to convert from molarity to normality and vice versa; N = $n_{(H,^+ OH,^- e^-,....etc)}$ * M, where n is the number of reacting units. The number of reacting units denoted by *n* depends on the chemical reaction. It may vary most often in redox reactions, when different products are obtained. For acids and bases, the number of reacting units is based on the number of protons (i.e., hydrogen ions) an acid will furnish or a base will react with. For oxidation–reduction reactions it is based on the number of electrons an oxidizing or reducing agent will take on or supply (Christian *et al*., 2014: Harvey, 2000).

Practices: Convert the following Molarities to Normalities.

1. **1.5 M HCl** → N = $n_{(H^+)}$ * M =1.0 * 1.5 = **1.5 N**
2. **0.2 M $Ca(OH)_2$** → N = $n_{(OH^-)}$ * M = 0.2 * 2.0 = **0.4 N**

(ii) Equation to convert from normality to molarity**;**

$$M = \frac{N}{n_{(H,^+ OH,^- e^-,...etc)}}$$

Practices: Convert the following Normalities to Molarities.

1. **2.4 N H_2SO_4** → $M = \frac{N}{n_{(H^+)}} = \frac{2.4\text{ N}}{2.0} =$ **1.2 M**
2. **1.0 N NaOH** → $M = \frac{N}{n_{(OH^-)}} = \frac{1.0\text{ N}}{1.0} =$ **1.0 M**

3.3.2 Conversion between percent and molarity or normality

In order to convert percent to molarity or normality, there are two types of equations to simplify the conversion. One of these types is used when dealing with solid dissolved in liquid (low concentration) and the other one is used when dealing with liquids such as acids and ammonia (high concentration).

In case of dealing with solid dissolved in liquid, which usually prepared in **low concentration**. Because the solution is so dilute, it is reasonable to assume that its density is 1.00 g/mL. Therefore, the density is ignored in the below equations. In order to convert percent to normality or molarity, simple equations are designed to simplify the conversions between them as seen in Table 5.

Table 5
Conversions between *percent and normality or molarity in diluted solutions*

Conversion	Designed equation
Converting from % to N	N = C% * 10 / Ew
Converting from N to %	C% = N * Ew / 10
Converting from % to M	M = C% * 10 / Fw
Converting from M to %	C% = M * Fw / 10
General equation for converting from % to N and vice versa	N * Ew = C% * 10
General equation for converting from % to M and vice versa	M * Fw = C% * 10

Note: Ew represents equivalent weight and Fw represents formula weight, because the solution is so dilute, it is reasonable to assume that its density is 1.00 g/mL. Therefore, the density is ignored in the above equations.

Practices:

1. Find the % percentage, molarity and normality of a solution in which 6.8 g of NaCl has been dissolved making a solution with a volume of 85 mL?

Calculating percent:

$$(\text{w/v})\% = \frac{\text{amount of solute in (g)}}{\text{total volume of solution in (ml)}} \times 100 = \frac{6.8\text{ g}}{85\text{ ml}} \times 100 =$$

8.0%(w/v) NaCl

Calculating molarity:

$$M = \frac{C\% * 10}{\text{Fw}} = \frac{8.0 * 10}{58.44} = 1.37\text{ M} \approx 1.4\text{ M, or}$$

$$M = \frac{g}{\text{VL} * \text{Fw}} = \frac{6.8\text{ g}}{0.085\text{L} * 58.44\text{ g/mol}} = 1.37\text{ mol/L} \approx 1.4\text{ M}$$

Calculating normality:

$$N = \frac{C\% * 10}{\text{Ew}} = \frac{8.0 * 10}{58.44} = 1.37\text{ N} \approx 1.4\text{ N, or}$$

$$N = \frac{g}{\text{VL} * \text{Ew}} = \frac{6.8\text{ g}}{0.085\text{L} * 58.44\text{ g/eq}} = 1.37\text{ eq/L} \approx 1.4\text{ N}$$

2. A solution of NaCl has a concentration of 1.37M. What %(w/v) of NaCl solution in which 6.8 g of NaCl has been dissolved making a solution with a volume of 85 mL?

$$C\% = \frac{M * \text{Fw}}{10} = \frac{1.37 * 58.44}{10} = 8.0\% \text{ (w/v) NaCl}$$

Similarly, when dealing with liquids such as acids and ammonia, which usually purchased in **high concentration**. Because the solution is so concentrate, the density of solution will vary. Therefore, the density is not ignored in the below equations. There is some information written on the bottle of liquid in laboratory such as percent (%), density (d), and formula weight (Fw). This information is used to convert percent to other concentration units. Table 6 shows simple equations that are used to convert percent to molarity or normality and vice versa.

Table 6
Conversions between percent and normality or molarity in concentrated liquids

Conversion	Designed equation
Converting from % to N	N = C% * d * 10 / Ew
Converting from N to %	C% = N * Ew / d * 10
Converting from % to M	M = C% * d * 10 / Fw
Converting from M to %	C% = M * Fw / d * 10
General equation for converting from % to N and vice versa	N * Ew = C% * d * 10
General equation for converting from % to M and vice versa	M * Fw = C% * d * 10

Notes: Ew represents equivalent weight, because the solution is so concentrate, the density of solution will vary. Therefore, the density is written in the above equations.

Practices:

1. If the following information was written on the sulfuric acid bottle: Fw = 98 g/mol, d =1.84 g/ml, 96% H_2SO_4. Calculate the molarity and normality of concentrated sulfuric acid?

Solution:

M * Fw = C% * d * 10

$$M = \frac{C\% * d * 10}{\text{Fw}} = \frac{96 * 1.84 * 10}{98} = 18.02 \approx 18\text{ mol/L (M)}$$

N * Ew = C% * d * 10

$$N = \frac{C\% * d * 10}{\text{Ew}} = \frac{96 * 1.84 * 10}{49} = 36.04 \approx 36\text{ eq/L (N)}$$

2. Calculate the percent (%) of concentrated sulfuric acid? If the following information was written on volumetric flask contained the acid: Fw = 98 g/mol, d =1.84 g/ml, 18.02M H_2SO_4?

$$C\% = \frac{M * \text{Fw}}{d * 10} = \frac{18.02 * 98}{1.84 * 10} = 96\%$$

3.4. Conversion between trace concentrations and molarity or normality

3.4.1. Conversion between trace concentrations and molarity

In order to convert between trace units (*ppt, ppm, ppb, and pptr*) and molarity (*M*), new equations need to be designed to simplify the conversions between them as shown in Table 7.

Practices:

1. Convert 0.025M of Na_2CO_3 to ppt, ppm, ppb, and pptr?

Concentration in ppt = M * Fw = 0.025 M * 106 g/mol = 2.65 g/L (ppt)

Concentration in ppm = M * Fw * 10^3 = 0.025 M * 106 g/mol * 10^3 = 2650 mg/L ≈ 2.65 * 10^3 ppm

Concentration in ppb = M * Fw * 10^6 = 0.025 M * 106 g/mol * 10^6 = 2650000 μg/L ≈ 2.65 * 10^6 ppb

Concentration in pptr = M * Fw * 10^9 = 0.025 M * 106 g/mol * 10^9 = 2650000000 ng/L ≈ 2.65 * 10^9 pptr

Table 7
Conversions between trace units and molarity

Conversion	Designed equation
Converting from M to ppt	Cppt = M * Fw
Converting from ppt to M	M = Cppt / Fw
Converting from M to ppm	Cppm = M * Fw * 10^3
Converting from ppm to M	M = Cppm / Fw * 10^3
Converting from M to ppb	Cppb = M * Fw * 10^6
Converting from ppb to M	M = Cppb / Fw * 10^6
Converting from M to pptr	Cpptr = M * Fw * 10^9
Converting from pptr to M	M = Cpptr / Fw * 10^9

Note: The relationship between any trace concentrations and molarity (M) units depends on the formula weight (Fw) which represents the atomic or molecular weight of the substance.

2. Calcium ion has a concentration of 0.01 M. What is the concentration of calcium ion in ppm?

Concentration in ppm = M * Fw * 10^3 = 0.010M * 40.08 g/mol * 10^3 = 400.8 mg/L ≈ 400 ppm ≈ 4.0 ∗ 10^2 ppm

3. Calculate the molar concentration (molarity) of 1.00 mg/L of Pb^{2+}?

$$M = \frac{\text{Cppm}}{\text{Fw} * 10^3} = \frac{1.00\ \text{ppm}}{207 * 10^3} = 4.83 * 10^{-6}\ \text{M}$$

4. Convert 2650 ppm of Na_2CO_3 to M?

$$M = \frac{\text{Cppm}}{\text{Fw} * 10^3} = \frac{2650\ \text{ppm}}{106 * 10^3} = 0.0250\ \text{M}$$

5. A solution of NaCl has a concentration of 1.37 M. What is the concentration of NaCl solution in ppt?

Concentration in ppt = M * Fw = 1.37 mol/L * 58.44g/mol = 80.06 g/L ≈ 80.0 g/L (ppt)

6. A solution of NaCl has a concentration of 80 ppt. What is the molarity of NaCl solution in which 6.8 g of NaCl has been dissolved making a solution with a volume of 85 mL?

$$M = \frac{\text{Cppt}}{\text{Fw}} = \frac{\frac{80\text{g}}{\text{L}}}{\frac{58.44\text{g}}{\text{mol}}} = 1.3689 \approx 1.4\ \frac{\text{mol}}{\text{L}}\ \text{(M), or}$$

$$M = \frac{\text{g}}{\text{Fw} * \text{L}} = \frac{6.8\ \text{g}}{\frac{58.44\text{g}}{\text{mol}} * 0.085\text{L}} = 1.4\ \frac{\text{mol}}{\text{L}}\ \text{(M)}$$

3.4.2. Conversion between trace concentrations and normality

Some students and technicians are facing difficulty to correlate between trace units (*ppt, ppm, ppb, and pptr*) and normality (N). Table 8 shows simple new equations to simplify the conversions between them. The simple formulated equations will simply work in practice.

Table 8
Conversions *between trace units and normality*

Conversion	Designed equation
Converting from N to ppt	Cppt = N * Ew
Converting from ppt to N	N = Cppt / Ew
Converting from N to ppm	Cppm = N * Ew * 10^3
Converting from ppm to N	N = Cppm / Ew * 10^3
Converting from N to ppb	Cppb = N * Ew * 10^6
Converting from ppb to N	N = Cppb / Ew * 10^6
Converting from N to pptr	Cpptr = N * Ew * 10^9
Converting from pptr to N	N = Cpptr / Ew * 10^9

Note: The relationship between any trace concentration and normality (N) units depends on the equivalent weight (Ew) of the substance.

Practices:

1. Convert 0.05N of Na_2CO_3 to ppt, ppm, ppb, and pptr?

a. Concentration in ppt = N * Ew = 0.05 N * 53 g/eq = 2.65 g/L (ppt)

b. Concentration in ppm = N * Ew * 10^3 = 0.05 N * 53 g/eq * 10^3 = 2650 mg/L = 2.65 * 10^3 ppm

c. Concentration in ppb = N * Ew * 10^6 = 0.05 N * 53 g/eq * 10^6 = 2.65 * 10^6 μg/L (ppb)

d. Concentration in pptr = N * Ew * 10^9 = 0.05 N * 53 g/eq * 10^9 = 2.65 * 10^9 ng/L (pptr)

2. Convert 2650 ppm of Na_2CO_3 to N?

$$N = \frac{\text{Cppm}}{\text{Ew} * 10^3} = \frac{2650\text{ppm}}{53 * 10^3} = 0.050\ \text{N}$$

3. Calculate the normal concentration (normality) of 1.00 mg/L of Pb^{2+} ?

$$N = \frac{\text{Cppm}}{\text{Ew} * 10^3} = \frac{1.00\ \text{ppm}}{103.5 * 10^3} = 9.66 * 10^{-6}\ \text{N}$$

4. A solution of NaCl has a concentration of 80 ppt. What is the normality of NaCl solution in which 6.8 g of NaCl has been dissolved making a solution with a volume of 85 mL?

$$N = \frac{\text{Cppt}}{\text{Ew}} = \frac{\frac{80\text{g}}{\text{L}}}{\frac{58.44\text{g}}{\text{eq}}} = 1.4\ \frac{\text{eq}}{\text{L}}\ \text{(N), or}$$

$$N = \frac{\text{g}}{\text{Ew} * \text{L}} = \frac{6.8\ \text{g}}{\frac{58.44\text{g}}{\text{eq}} * 0.085\text{L}} = 1.4\ \frac{\text{eq}}{\text{L}}\ \text{(N)}$$

4. Conclusion

We have successfully designed simple equations to fully understand the calculations for common concentration units and conversion between them. This review article is written to be readable by anyone who has an idea in basic principles of general and analytical chemistry. This simple article is a practical training for chemists, technicians, scientists, students, teachers, or engineers for rapid solution of complicated conversion calculations.

References

Chemiasoft. (2011) Guide to preparation of stock standard solutions (1st ed.). Amman, Jordan: Author; pp 6-26. Retrieved from:http://www.chemiasoft.com/CHEMIASOFT_STOCK_STANDARDS_1st_ED__2011.pdf. (Accessed Feb 3, 2016).

Christian, G.D., Purnendu, K.D., & Kevin, A.S. (2014) Analytical chemistry (7th ed.). NY: John Wiley & Sons; pp. 149-172.

Harvey, D.T. (2000) Modern analytical chemistry (1st ed.). Boston: McGraw-Hill Companies; pp. 15-19.

Sanagi, M.M., Sulaiman, A., & Ibrahim, W.A.W. (2007) Principles of chemical analysis (2nd ed.). Johor Bahru: UTM Press; pp. 10-17.

Skoog, D.A., West, D.M., Holler, F.J., & Stanley, R.C. (2014) Fundamentals of analytical chemistry (9th ed.). NY: Brooks/Cole, Cengage Learning; pp 62-72.

Sunberg, R.J. (1986) A simple procedure to convert parts per million (PPM) to molarity (M). *Journal of Chemical Education.* 63(8), pp. 714.