

Concentration Terms from Wikipedia, the free encyclopedia.

Concentration is a very common concept used in chemistry and related fields. It is the measure of how much of a given substance there is mixed with another substance. This can apply to any sort of chemical mixture, but most frequently is used in relation to solutions, where it refers to the amount of *solute* dissolved in a *solvent*.

To **concentrate** a solution, one must add more solute, or reduce the amount of solvent (for instance, by selective evaporation). By contrast, to **dilute** a solution, one must add more solvent, or reduce the amount of solute.

There exists a concentration at which no further solute will dissolve in a solution. At this point, the solution is said to be saturated. If additional solute is added to a saturated solution, it will not dissolve. Instead, phase separation will occur, leading to either coexisting phases or a suspension. The point of saturation depends on many variables such as ambient temperature and the precise chemical nature of the solvent and solute.

Concentration may be expressed both qualitatively ('informally') and quantitatively ('numerically').

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1 Qualitative notation: Qualitatively, solutions of relatively low concentration are described using adjectives such as "dilute," or "weak," while solutions of relatively high concentration are described as "concentrated," or "strong." As a rule, the more concentrated a chromatic solution is, the more intensely coloured it is.



Diluted ←————→ **Concentrated**

These glasses containing red dye demonstrate qualitative changes in concentration. The solutions on the left are "weaker" (or more dilute), compared to the "stronger" (or more concentrated) solutions on the right.

2 Quantitative notation: Quantitative notation of concentration is far more informative and useful from a scientific point of view. There are a number of different ways to quantitatively express concentration; the most common are listed below.

Note: Many units of concentration require measurement of a substance's volume, which is variable depending on ambient temperature and pressure. Unless otherwise stated, all the following measurements are assumed to be at standard state temperature and pressure (that is, 25 degrees Celsius at 1 atmosphere).

- 2.1 Mass percentage:** denotes the mass of a substance in a mixture as a percentage of the mass of the entire mixture. For instance: if a bottle contains 40 grams of ethanol and 60 grams of water, then it contains 40% ethanol by mass. Commercial concentrated aqueous reagents such as acid and bases are often labeled in concentrations of weight percentage with the specific gravity also listed. In older texts and references this is sometimes referred to as weight-weight percentage (abbreviated as w/w).
- 2.2 Mass-volume percentage, (sometimes referred to as weight-volume percentage and often abbreviated as % m/v or % w/v):** denotes the mass of a substance in a mixture as a percentage of the volume of the entire mixture. Mass-volume percentage is often used for solutions made from solid reagents. It is the mass of the solute in grams multiplied by one hundred divided by the volume of solution in milliliters.
- 2.3 Volume-volume percentage or % (v/v):** describes the volume of the solute in mL per 100 mL of the resulting solution. This is most useful when a liquid - liquid solution is being prepared. For example, beer is about 5% ethanol by volume. This means every 100 mL beer contains 5 mL ethanol (ethyl alcohol).
- 2.4 Molarity (M):** denotes the number of moles of a given substance per litre of solution. For instance: 4.0 litres of liquid, containing 2.0 moles of dissolved particles, constitutes a solution of 0.5 M. Such a solution may be described as "0.5 molar." (Working with moles can be highly advantageous, as they enable measurement of the absolute number of particles in a solution, irrespective of their weight and volume. This is often more useful when performing stoichiometric calculations.). See molar solution for further information.
- 2.5 Molality (m):** denotes the number of moles of a given substance per kilogram of solvent. For instance: 2.0 kilograms of solvent, containing 1.0 moles of dissolved particles, constitutes a molality of 0.5 mol/kg. Such a solution may be described as "0.5 molal." The advantage of molality is, it does not change with the temperature, as it deals with the mass of solvent rather than the volume of solution. Volume increases with increase in temperature resulting in decrease in molarity. Molality of a solution is always constant irrespective of the physical conditions like temperature and pressure.
- 2.6 Normality:** *Normality* is a concept related to *molarity*, usually applied to acid-base solutions and reactions. For acid-base reactions, the equivalent is the mass of acid or base that can accept or donate exactly one mole of protons (H^+ ions). Normality is also used for redox reactions. In this case the equivalent is the quantity of oxidizing or reducing agent that can accept or furnish one mole of electrons. Whereas molarity measures the number of particles per litre of solution, normality measures the number of equivalents per litre of solution. In practice, this simply means one multiplies the molarity of a solution by the valence of the ionic solute. A bit more complex for redox reactions.
Note: The normality is always equal to, or greater than the molarity for acid-base reactions. However, for redox reactions the normality is typically equal to or less than the molarity.

- 2.7 Formal:** The *formal* (F) is yet another measure of concentration similar to molarity. It is used rarely. It is calculated based on the formula weights of chemicals per litre of solution. The difference between formal and molar concentrations is that the formal concentration indicates moles of the original chemical formula in solution, without regard for the species that actually exist in solution. Molar concentration, on the other hand, is the concentration of species in solution. For example: if one dissolves sodium carbonate (Na_2CO_3) in a litre of water, the compound dissociates into the Na^+ and CO_3^{2-} ions. Some of the CO_3^{2-} reacts with the water to form HCO_3^- and H_2CO_3 . If the pH of the solution is low, there is practically no Na_2CO_3 left in the solution. So, although we have added 1 mol of Na_2CO_3 to the solution, it does not contain 1 M of that substance. (Rather, it contains a molarity based on the other constituents of the solution.) However, one can still say that the solution contains 1 F of Na_2CO_3 .
- 2.8 "Parts-per" notation:** The *parts-per* notation is used for extremely low concentrations. This is often used to denote the relative abundance of trace elements in the Earth's crust, trace elements in forensics or other analyses, or levels of pollutants in the environment.
- 2.8.1 Parts per hundred (denoted by '%' and very rarely 'pph'):** - denotes one particle of a given substance for every 99 other particles. This is the common percent. 1 part in 10^2 .
- 2.8.2 Parts per thousand (denoted by '‰' [the per mil symbol], and occasionally 'ppt'):** denotes one particle of a given substance for every 999 other particles. This is roughly equivalent to one drop of ink in a cup of water, or one second per 17 minutes. 'Parts per thousand' is often used to record the salinity of seawater. 1 part in 10^3 .
- 2.8.3 Parts per million ('ppm'):** denotes one particle of a given substance for every 999,999 other particles. This is roughly equivalent to one drop of ink in a 40 gallon drum of water, or one second per 280 hours. 1 part in 10^6 .
- 2.8.4 Parts per billion ('ppb'):** denotes one particle of a given substance for every 999,999,999 other particles. This is roughly equivalent to one drop of ink in a canal lock full of water, or one second per 32 years. 1 part in 10^9 .
- 2.8.5 Parts per trillion ('ppt'):** denotes one particle of a given substance for every 999,999,999,999 other particles. This is roughly equivalent to one drop of ink in an Olympic-sized swimming pool, or one second every 320 centuries. 1 part in 10^{12} .
- 2.8.6 Parts per quadrillion ('ppq'):** denotes one particle of a given substance for every 999,999,999,999,999 other particles. This is roughly equivalent to a drop of ink in a medium-sized lake, or one second every 32,000 millennia. There are no known analytical techniques that can measure with this degree of accuracy; nevertheless, it is still used in some mathematical models of toxicology and epidemiology. 1 part in 10^{15} .

Regarding wikipedia's statement 2.8.6, October 2005: on a daily basis, SEASTAR's Quality Control routinely works in the ppq range with elements such as Uranium, Thorium, the Rare Earth Elements. Sample instrumental data, from Aug 23, 2005, our High Resolution Mass Spectrometer's Limits of Detection: 22 of 74 isotopes detected @<100ppq, 18 of 74 isotopes detected @<50ppq, 4 of 74 isotopes detected @<10ppq. Approximately 40% of those figures are within quantifiable limits. Our Method Detection Limits routinely put these values in the sub ppq, or sub Parts per quadrillion range.

Warning: although 'ppt' is usually used to denote 'parts per trillion', it is also on occasion used to denote 'parts per thousand'. If there is any chance of ambiguity, one should describe the abbreviation in full.

According to the U.S. National Institute of Standards and Technology (NIST) *Guide for the Use of the International System of Units (SI)*, "the language-dependent terms part per million, part per billion, and part per trillion ... are not acceptable for use with the SI to express the values of quantities." [1] which lists examples of alternative expressions.

Notes for clarity:

The indication given above is that parts per notation refers to numbers of particles (equivalent to moles), whereas in the last column of the chart below it is given by mass (grams per kilogram). Those using the notation need to state their usage to avoid confusion.

In atmospheric chemistry the parts per notation is commonly expressed with a *v* following, such as **ppmv** (or **ppvm** is some usages), to indicate parts per million by volume. In gases ppmv is equivalent to ppm by particles (Avogadro's law). This works fine for gases, but may have problems with cloud droplets and smoke or other atmospheric particulate matter.

Table of concentration measures

Frequently used standards of concentration

Measurement	Notation	Generic formula	Typical units
Mass percentage	-	$\left(\frac{\text{grams solute} \times 100}{\text{grams solution}} \right)$	%
Mass-volume percentage	-	$\left(\frac{\text{grams solute} \times 100}{\text{millilitres solution}} \right)$	% <i>though strictly</i> %kg/L
Volume-volume percentage	-	$\left(\frac{\text{millilitres solute} \times 100}{\text{millilitres solution}} \right)$	%
Molarity	M	$\left(\frac{\text{moles solute}}{\text{litres solution}} \right)$	mol/L (or M)
Molinity	-	$\left(\frac{\text{moles solute}}{\text{kilograms solution}} \right)$	mol/kg
Molality	m	$\left(\frac{\text{moles solute}}{\text{kilograms solvent}} \right)$	mol/kg (or m)
Molar fraction	χ (chi)	$\left(\frac{\text{moles solute}}{\text{moles solution}} \right)$	(fraction)
Formal	F	$\left(\frac{\text{moles undissolved solute}}{\text{litres solution}} \right)$	mol/L (or F)
Normality	N	$\left(\frac{\text{moles solute}}{\text{litres solution}} \times \text{valence of solute} \right)$	N

Table of concentration measures - continued
Frequently used standards of concentration

Parts per hundred	% (or pph)	$\left(\frac{\text{dekagrams solute}}{\text{kilograms solution}} \right)$	da.g/kg
Parts per thousand	‰ (or ppt*)	$\left(\frac{\text{grams solute}}{\text{kilograms solution}} \right)$	g/kg
Parts per million	ppm	$\left(\frac{\text{milligrams solute}}{\text{kilograms solution}} \right)$	mg/kg
Parts per billion	ppb	$\left(\frac{\text{micrograms solute}}{\text{kilograms solution}} \right)$	µg/kg
Parts per trillion	ppt*	$\left(\frac{\text{nanograms solute}}{\text{kilograms solution}} \right)$	ng/kg
Parts per quadrillion	ppq	$\left(\frac{\text{picograms solute}}{\text{kilograms solution}} \right)$	pg/kg

* Although 'ppt' is usually used to denote 'parts per trillion', it is on occasion used for 'parts per thousand'. Sometimes 'ppt' is also used as an abbreviation for precipitate. Beware any ambiguity in usage.

Note (1) : The table above is described in terms of solvents and solutes; however the units given often also apply to other types of mixture.

Note (2) : The use of billion, trillion, quadrillion above follows the short scale usage of these words.

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