Quantitative Chemical Analysis

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Welcome to Analytical Chemistry

The textbook for this course is

Quantitative Chemical Analysis
Seventh Edition

by Dan Harris

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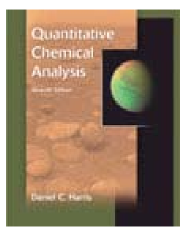

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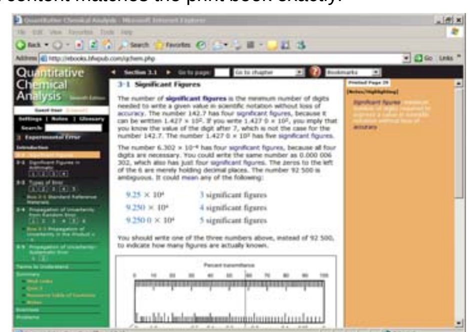

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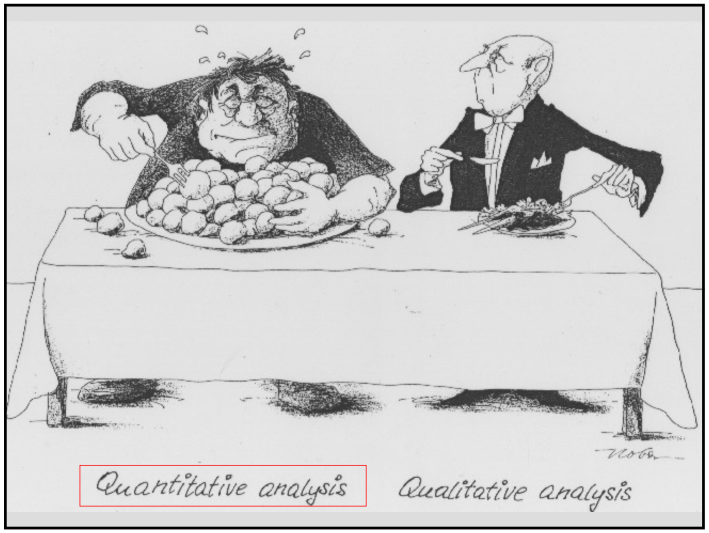
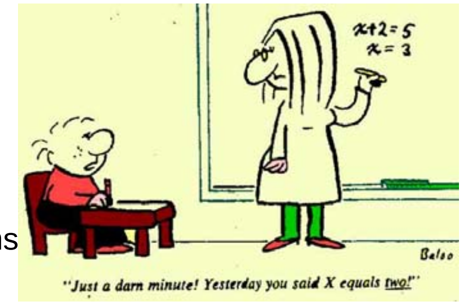
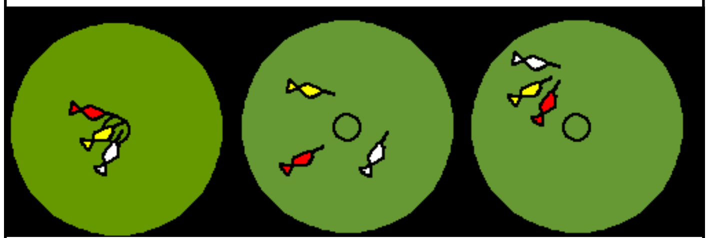


Numbers count

Required math skills:

- Add
- Subtract
- Multiply
- Divide
- Powers
- Logarithms





ACCURATE PRECISE	ACCURATE NOT precise	NOT Accurate PRECISE
	Random error	systematic error

- Orders of magnitude
- Estimation
- Units
- Conversions
- Powers of 10
- Prefixes
- Errors
- Statistics

Estimation and orders of magnitude:

What is the national debt?

Estimation and orders of magnitude:

How many piano tuners are there in Chicago?

Estimation and orders of magnitude:

What is the world population?

Estimation and orders of magnitude:

How many water molecules in 1000 droplets?

Estimation and orders of magnitude: powers of 10

Estimation and orders of magnitude:

A cube – 1” on a side → $(2.6)^3$ cm^3 ~ 18 cc

18 cc = 18 cc (1 g/1 cc) = 18 g

18 g = 18 g (1 molecule/ (18 x 1.66×10^{-24} g)) = 6.022×10^{23} molecules

Table 1-3 Prefixes

Prefix	Symbol	Factor	Prefix	Symbol	Factor
yotta	Y	10^{24}	deci	d	10^{-1}
zetta	Z	10^{21}	centi	c	10^{-2}
exa	E	10^{18}	milli	m	10^{-3}
peta	P	10^{15}	micro	μ	10^{-6}
tera	T	10^{12}	nano	n	10^{-9}
giga	G	10^{9}	pico	p	10^{-12}
mega	M	10^{6}	femto	f	10^{-15}
kilo	k	10^{3}	atto	a	10^{-18}
hecto	h	10^{2}	zepto	z	10^{-21}
deca	da	10^{1}	yocto	y	10^{-24}

Table 1-3
Quantitative Chemical Analysis, Seventh Edition

Table 1-1 Fundamental SI units

Quantity	Unit (symbol)	Definition
Length	meter (m)	One meter is the distance light travels in a vacuum during $\frac{1}{299\,792\,458}$ of a second.
Mass	kilogram (kg)	One kilogram is the mass of the prototype kilogram kept at Sèvres, France.
Time	second (s)	One second is the duration of 9 192 631 770 periods of the radiation corresponding to a certain atomic transition of ^{133}Cs.
Electric current	ampere (A)	One ampere of current produces a force of 2×10^{-7} newtons per meter of length when maintained in two straight, parallel conductors of infinite length and negligible cross section, separated by 1 meter in a vacuum.
Temperature	kelvin (K)	Temperature is defined such that the triple point of water (at which solid, liquid, and gaseous water are in equilibrium) is 273.16 K, and the temperature of absolute zero is 0 K.
Luminous intensity	candela (cd)	Candela is a measure of luminous intensity visible to the human eye.
Amount of substance	mole (mol)	One mole is the number of particles equal to the number of atoms in exactly 0.012 kg of ^{12}C (approximately $6.022\,141\,5 \times 10^{23}$).
Plane angle	radian (rad)	There are 2π radians in a circle.
Solid angle	steradian (sr)	There are 4π steradians in a sphere.

Table 1-1
Quantitative Chemical Analysis, Seventh Edition

Table 1-4 Conversion factors

Quantity	Unit	Symbol	SI equivalent[a]
Volume	liter	L	$*10^{-3} m^3$
	milliliter	mL	$*10^{-6} m^3$
Length	angstrom	Å	$*10^{-10} m$
	inch	in.	*0.025 4 m
Mass	pound	lb	*0.453 592 37 kg
	metric ton		*1 000 kg
Force	dyne	dyn	$*10^{-5} N$
Pressure	bar	bar	$*10^{5} Pa$
	atmosphere	atm	*101 325 Pa
	torr (= 1 mm Hg)	Torr	133.322 Pa
	pound/in.^{2}	psi	6 894.76 Pa
Energy	erg	erg	$*10^{-7} J$
	electron volt	eV	$1.602\,176\,53 \times 10^{-19} J$
	calorie, thermochemical	cal	*4.184 J
	Calorie (with a capital C)	Cal	*1000 cal = 4.184 kJ
	British thermal unit	Btu	1 055.06 J
Power	horsepower		745.700 W
Temperature	centigrade (= Celsius)	°C	*K − 273.15
	Fahrenheit	°F	*1.8(K − 273.15) + 32

a. An asterisk (*) indicates that the conversion is exact (by definition).

Table 1-4
Quantitative Chemical Analysis, Seventh Edition

Table 1-2 SI-derived units with special names

Quantity	Unit	Symbol	Expression in terms of other units	Expression in terms of SI base units
Frequency	hertz	Hz		l/s
Force	newton	N		$m \cdot kg/s^2$
Pressure	pascal	Pa	N/m^2	$kg/(m \cdot s^2)$
Energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg/s^2$
Power, radiant flux	watt	W	J/s	$m^2 \cdot kg/s^3$
Quantity of electricity, electric charge	coulomb	C		$s \cdot A$
Electric potential, potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg/(s^2 \cdot A)$
Electric resistance	ohm	Ω	V/A	$m^2 \cdot kg/(s^2 \cdot A^2)$
Electric capacitance	farad	F	C/V	$s^4 \cdot A^2/(m^2 \cdot kg)$

Table 1-2
Quantitative Chemical Analysis, Seventh Edition

Chemical concentrations

Molarity = Moles of solute/Liters of Solution (M)

Molality = Moles of solute/Kg of Solvent (m)

Mole Fraction = Moles solute/total number of moles

Mass % = Mass solute/total mass x 100

Volume % = volume solute/total volume x 100

ppm = parts per million *
ppb = parts per billion *

* *mass for solutions, volume for gasses*

Chemical concentrations

Molarity = Moles of solute/Liters of Solution (M)

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Mass % = Mass solute/total mass x 100

Volume % = volume solute/total volume x 100

ppm = parts per million *
ppb = parts per billion *

* *mass for solutions, volume for gasses*

A sample of $NaNO_3$ weighing 8.5 grams is placed in a 500 ml volumetric flask and distilled water was added to the mark on the neck of the flask. Calculate the Molarity of the resulting solution.

Convert the given grams of solute to moles of solute by dividing by the molecular weight of $NaNO_3$: 1 mole $NaNO_3$ = Molecular mass of $NaNO_3$ expressed in grams = 23 + 14 + 3(16) = 85 grams

(8.5 grams $NaNO_3$) X (1 mole NaNO3 / 85 grams NaNO3) = 0.1 mole NaNO3

Convert given ml of solution to liters by dividing by 1000: 1 liter = 1000 ml

(500 ml) X (1 liter / 1000 ml) = 0.500 liters

Apply the definition for Molarity: Molarity = moles $NaNO_3$ / volume of the solution in liters

M = 0.1 mole / .500 liters = 0.200 Molar $NaNO_3$

Chemical concentrations

Molarity = Moles of solute/Liters of Solution (M)

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Mass % = Mass solute/total mass x 100

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Mass % = Mass solute/total mass x 100

Volume % = volume solute/total volume x 100

ppm = parts per million *
ppb = parts per billion *

* *mass for solutions, volume for gasses*

Determine the molality of 3000 grams of solution containing 37.3 grams of Potassium Chloride KCl.

1. Convert grams KCl to moles KCl using the molecular weight of KCl
(37.3 grams KCl) X (1 mole KCl / 74.6 grams KCl) = 0.5 mole KCl

2. Determine the grams of pure solvent from the given grams of solution and solute
Total grams = 3000 grams = Mass of solute + Mass of solvent
Mass of pure solvent = (3000 - 37.3) gram
= 2962.7 gram

3. Convert grams of solvent to kilograms
(2962.7 grams solvent) X (1 kg / 1000 grams) = 2.9627 kg

Chemical concentrations

Molarity = Moles of solute/Liters of Solution (M)

Molality = Moles of solute/Kg of Solvent (m)

Mole Fraction = Moles solute/total number of moles

Mass % = Mass solute/total mass x 100

Volume % = volume solute/total volume x 100

ppm = parts per million *
ppb = parts per billion *

** mass for solutions, volume for gasses*

Determine the molality of 3000 grams of solution containing 37.3 grams of Potassium Chloride KCl.

4. Apply the definition for molality
molality = moles of KCl / kilograms of solvent =
0.5 / 2.9627 = <u>0.169 m</u>

Determine the mole fraction of KCl in 3000 grams of aqueous solution containing 37.3 grams of Potassium Chloride KCl.

1. Convert grams KCl to moles KCl using the molecular weight of KCl
(37.3 grams KCl) X (1 mole KCl) / (74.6 grams KCl) = 0.5 mole KCl

2. Determine the grams of pure solvent water from the given grams of solution and solute
Total grams = 3000 grams = Mass of solute + Mass of water
Mass of pure solvent = (3000 - 37.3) gram
= 2962.7 gram

Determine the mole fraction of KCl in 3000 grams of aqueous solution containing 37.3 grams of Potassium Chloride KCl.

3. Convert grams of solvent H_2O to mols
(2962.7 grams water) X (1 mol / 18.0 grams) = 164.6 mols H_2O

4. Apply the definition for mole fraction mole fraction = moles of KCl / Total mols of KCl and water =
0.5 / (0.5 + 164.6) = 0.5 / 165.1 = 0.00303

Determine the mass % of a NaCl solution if 58.5 grams of NaCl was dissolved in 50 ml of water (assume the density of water to be 1 g/ml)

Convert ml of water to grams
mass = (50 ml) X (1 g/ml) = 50 grams water

Determine total mass of solution
Mass of solution = mass of solute + mass of solvent = 58.5 + 50 = 108.5 g

Apply the definition of mass percent mass % = 58.5 (100) / 108.5 = 53.9% NaCl

Chemical concentrations

Molarity = Moles of solute/Liters of Solution (M)

Molality = Moles of solute/Kg of Solvent (m)

Mole Fraction = Moles solute/total number of moles

Mass % = Mass solute/total mass x 100

Volume % = volume solute/total volume x 100

ppm = parts per million *
ppb = parts per billion *

** mass for solutions, volume for gasses*

Chemical concentrations

Molarity = Moles of solute/Liters of Solution (M)

Molality = Moles of solute/Kg of Solvent (m)

Mole Fraction = Moles solute/total number of moles

Mass % = Mass solute/total mass x 100

Volume % = volume solute/total volume x 100

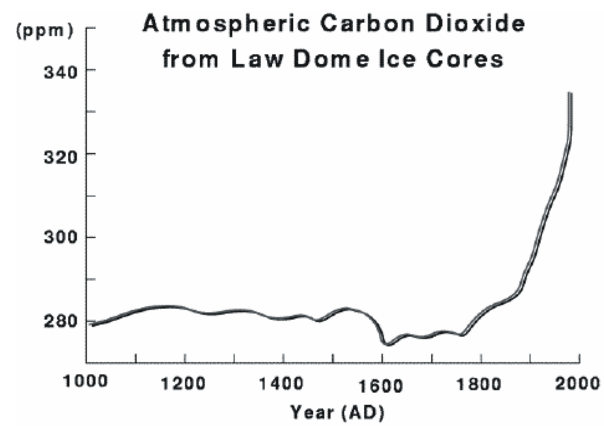
ppm = parts per million *
ppb = parts per billion *

** mass for solutions, volume for gasses*

Assuming the density of water to be 1 g/mL we approximate the density of a dilute aqueous solution to be 1 g/mL

→ 1 ppm = 1 μg/mL = 1 mg/L

→ 1 ppb = 1 ng/mL = 1 μg/L



Determine the ppm of a NaCl solution if 58.5 grams of NaCl was dissolved in 50 ml of water (assume the density of water to be 1 g/ml)

Convert ml of water to grams

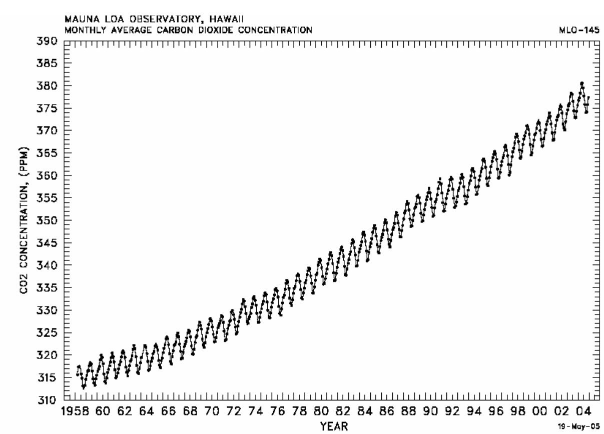
mass = (50 ml) X (1 g/ml) = 50 grams water

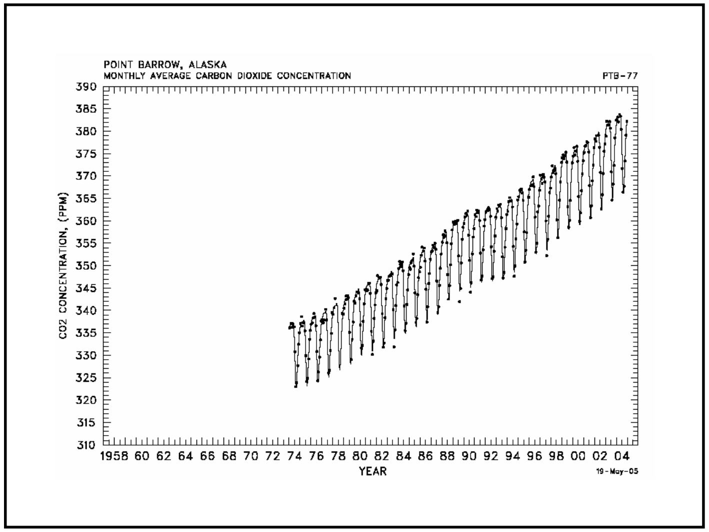
Determine total mass of solution

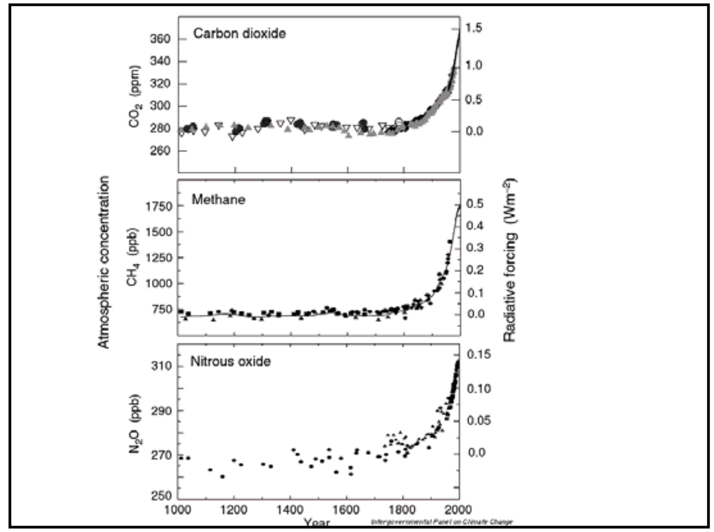
Mass of solution = mass of solute + mass of solvent = 58.5 + 50 = 108.5 g

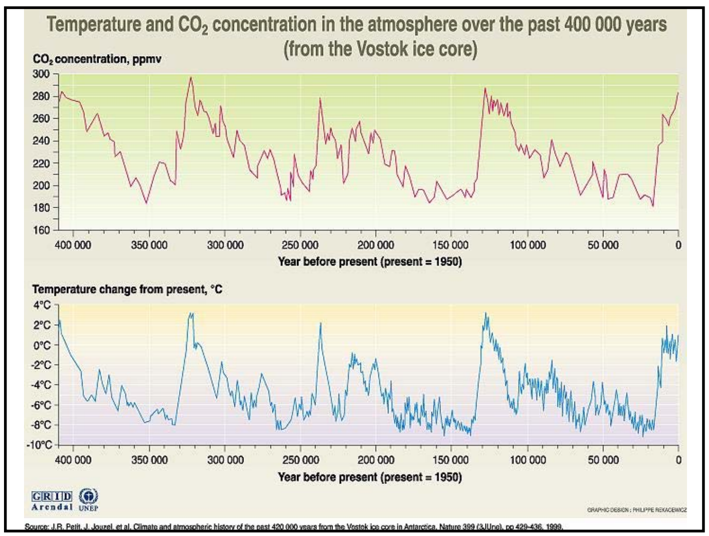
Apply the definition of ppm

$58.5 (10^6) / 108.5 = \underline{5.39 \times 10^5 \text{ ppm NaCl}}$




POINT BARROW, ALASKA
MONTHLY AVERAGE CARBON DIOXIDE CONCENTRATION
PTB-77
CO2 CONCENTRATION, (PPM)
YEAR
19-May-05


Carbon dioxide
Methane
Nitrous oxide
Atmospheric concentration
Radiative forcing (Wm^{-2})
CO_2 (ppm)
CH_4 (ppb)
N_2O (ppb)
Year


Temperature and CO_2 concentration in the atmosphere over the past 400 000 years
(from the Vostok ice core)
CO_2 concentration, ppmv
Year before present (present = 1950)
Temperature change from present, °C
Year before present (present = 1950)
Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.