CHE 1031: General Chemistry I

3. **Composition of substances & solutions**
   - **3.1: Formula mass & mole concept**
   - **3.2: Determining empirical & molecular formulas**
   - **3.3: Molarity**
   - **3.4: Other units for solution concentration**

3. Composition of substances & solutions

3.1: Formula mass &mole concept

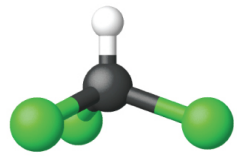
- Calculate formula masses (MW)
- Define the mole & Avogadro's number; explain the relationship between moles, atoms & molecules and convert one to another

Formula mass (aka molecular weight)

Formula mass (aka MW): *the sum of all the atomic masses in a molecule or compound*

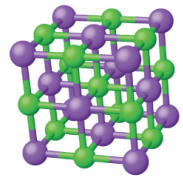
Chloroform, $CHCl_3$, was used as a surgical anesthetic & is now used as a building block for creating teflon, tetrafluoroethylene.

Element	Quantity		Average atomic mass (amu)		Subtotal (amu)
C	1	×	12.01	=	12.01
H	1	×	1.008	=	1.008
Cl	3	×	35.45	=	106.35
				Molecular mass	119.37



NaCl is common table salt.

Element	Quantity		Average atomic mass (amu)		Subtotal
Na	1	×	22.99	=	22.99
Cl	1	×	35.45	=	35.45
				Formula mass	58.44



Try these molecular compounds

Calculate the formula masses (aka molecular weights) of:

- Aspirin, $C_9H_8O_4$ (acetylsalicylic acid) 1

C	9	12.01	108.09
H	8	1.01	8.08
O	4	15.99	63.96
			180.13 amu

- Ibuprofen, $C_{13}H_{18}O_2$

C	13	12.01	156.13
H	18	1.01	18.18
O	2	15.99	31.98
			206.29 amu

Try these ionic compounds

Calculate the formula masses (aka molecular weights) of: 2

- Aluminum sulfate, $Al_2(SO_4)_3$, used to purify water & make paper

Al	2	26.98	53.96
S	3	32.06	96.18
O	12	15.99	191.88
			342.02 amu

- Calcium phosphate, $Ca_3(PO_4)_2$, used to inject DNA into cells

Ca	3	40.08	120.24
P	2	30.97	61.94
O	8	15.99	127.92
			310.10 amu

The mole

Mole: the 'counting' unit for matter on the atomic scale.

- It's like a dozen, or gross; equal to a number of objects.
- From the Latin '*moles*': mass, massive, barrier

1 mole = 6.02 E23 atoms or ions or molecules

$$\frac{1 \text{ mole}}{6.02 \text{ E}23}$$

called Avogadro's number when expressed as a conversion factor

Consider:

If you had one mole of marbles— 6.02x1023 marbles — and you spread them all over the entire surface of the Earth, how thick would the layer of marbles be?

A layer produced with a mole of marbles would be about three miles thick!

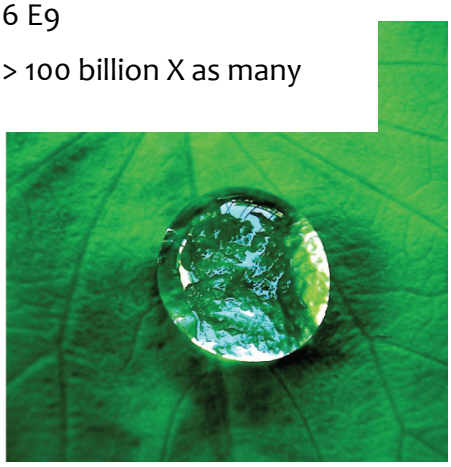
Enormous numbers are hard to 'get'

This **droplet of water** contains about 0.002275 moles of water.

$$\frac{2.275\text{ E-3 moles}}{} \quad \frac{6.02\text{ E23 molecules}}{1\text{ mole}} = 1.369\text{ E21 molecules}$$

Global population = 7.6 billion = 7.6 E9

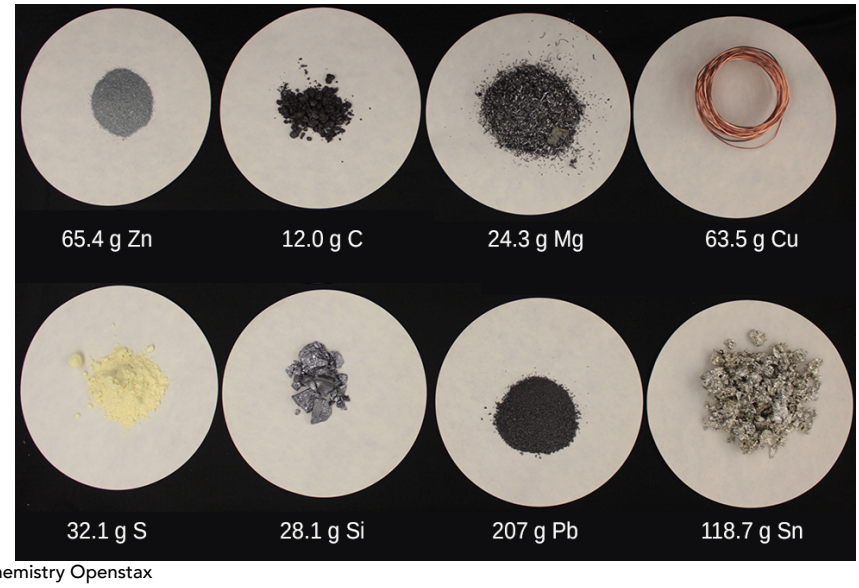
$\frac{1.369\text{ E21 molecules}}{}$ = 1.80 E11 → > 100 billion X as many 7.6 E9 people



Chemistry Openstax

Compare a mole

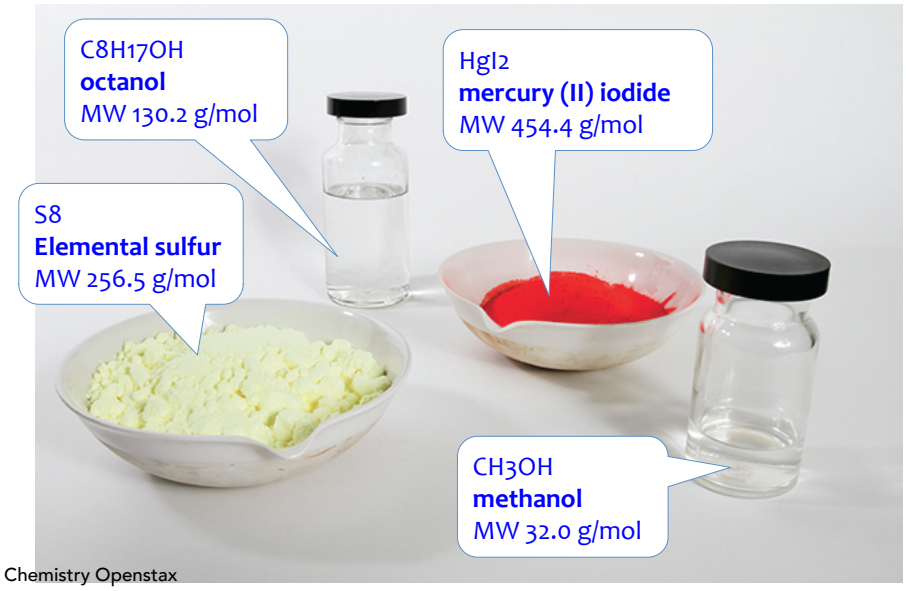
Each is a mole. So, replace amu with **grams/mole**.



Chemistry Openstax

Compare a mole

Again, each is a mole.



Chemistry Openstax

Converting mass to moles

Atomic mass or formula mass (MW) can be used to convert mass to moles (or vice versa).

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USDA nutritional guidelines suggest a daily intake of 4.7 g of potassium. What's the requirement in moles of K?

$$\frac{4.7\ \cancel{g}}{} \quad \frac{1\ \text{mole K}}{39.10\ \cancel{g}} = 0.12\ \text{mol of K}$$

Beryllium, a very light element, is used to make transparent x-ray windows for imagining devices. How many moles of Be are in a thin window that weighs 3.24 g?

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$$\frac{3.24\ \cancel{g}}{} \quad \frac{1\ \text{mole Be}}{9.01\ \cancel{g}} = 0.360\ \text{mol of Be}$$

Converting mass to atoms or molecules

Add **Avogadro's number** to convert masses of atoms or molecules into moles, an then numbers of atoms or molecules.

Copper is used to make electrical wire. How many copper atoms are there in 5.00 g of wire? 5

Strategy: mass → moles → atoms

$$\frac{5.00\ \cancel{g}}{} \quad \frac{1\ \cancel{mole}\ Cu}{63.55\ \cancel{g}} \quad \frac{6.02\ E23\ atoms}{1\ \cancel{mole}\ Cu} = 4.74\ E22\ atoms\ Cu$$

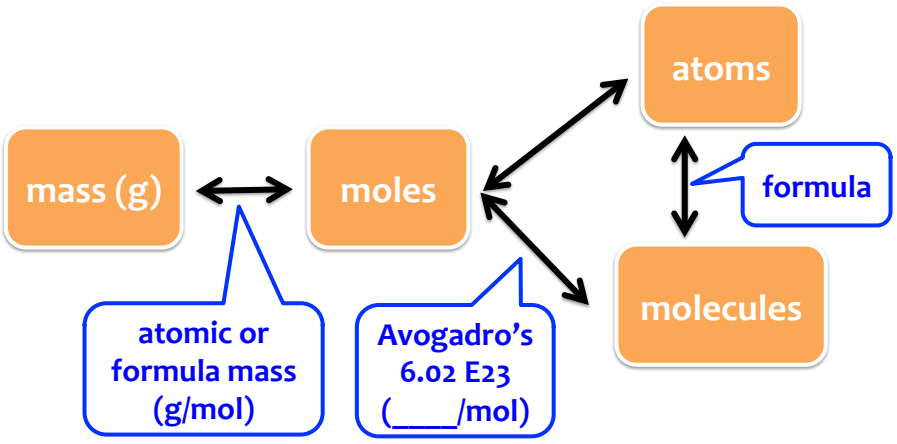
A prospector collects 15.00 g of pure gold from a river. How many gold atoms (Au) are there? 6

Strategy: mass → moles → atoms

$$\frac{15.00\ \cancel{g}}{} \quad \frac{1\ \cancel{mole}\ Au}{197.0\ \cancel{g}} \quad \frac{6.02\ E23\ atoms}{1\ \cancel{mole}\ Au} = 4.584\ E22\ atoms\ Au$$

Let's start building a mole map

By the end of this course you'll be using a bunch of conversion factors to make the change of chemistry happen. It helps to have **a map to guide your choice of conversion factors**.



Flip conversion factors to solve for your 'destination' units.

First test drive

Vitamin C has the molecular formula C6H8O6. The recommended daily dose for kids aged 4-8 years is 1.42 E-4 moles. (7)

How many grams should you give them?

MW = 176.12 g/mol

Strategy: mol $\xrightarrow{\frac{g}{mol}}$ g

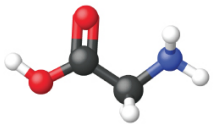
$$\frac{1.42\text{ E-4 mol}}{} \cdot \frac{176.12\text{ g}}{1\text{ mol}} = 0.0250\text{ g}$$

Longer trip

Our bodies make amino acids, the building blocks of proteins. The simplest amino acid is glycine, C2H5O2N. (8)

How many moles of glycine molecules are there in 28.35 g?

How many hydrogen atoms in the 28.35 g?



MW = 75.07 g/mol

Strategy: g $\xrightarrow{\frac{mol}{g}}$ moles $\xrightarrow{\frac{molecules}{mol}}$ molecules $\xrightarrow{\frac{atoms}{molecule}}$ atoms

$$\frac{28.35\text{ g}}{} \cdot \frac{1\text{ mol}}{75.07\text{ g}} \cdot \frac{6.02\text{ E23 molecules}}{1\text{ mol}} \cdot \frac{5\text{ atoms}}{1\text{ molecule}}$$

0.3776 mol

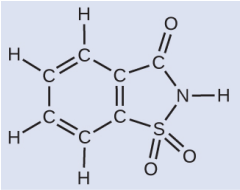
1.137 E24 atoms H

Long trip back

Saccharin, $C_7H_5NO_3S$, is the old 'pink' sugar substitute. 9

How many g of sacchirin have 9.20 E21 carbon atoms?

MW = 183.18 g/mol



Strategy: atoms $\xrightarrow{\text{formula ratio}}$ molecules $\xrightarrow{\frac{\text{mol}}{\text{molecule}}}$ moles $\xrightarrow{\frac{\text{g}}{\text{mol}}}$ g

$$\frac{9.20\text{ E21 C atoms}}{} \cdot \frac{1\text{ molecule}}{7\text{ C atoms}} \cdot \frac{1\text{ mol}}{6.02\text{ E23 molecule}} \cdot \frac{183.18\text{ g}}{1\text{ mol}}$$

= 0.400 g

Chemistry Openstax

Can you?

(1) Calculate a formula mass or molecular mass (aka molar mass or molecular weight, MW)?

(2) Understand just how massive Avogadro's number is?

(3) Understand how and why a mole of different elements and compounds can have radically different masses?

(4) Use atomic mass, molar mass, Avogadro's number and formula subscripts as conversion factors to convert mass to moles to molecules to atoms?

(5) Use a '*mole map*' to help you choose conversion factors and the number of steps for conversion problems?

3. Composition of substances & solutions

3.2: Determining empirical & molecular formulas

- Compute the percent composition of a compound
- Determine the empirical formula of a compound
- Determine the molecular formula of a compound

Unknown compound?

What can you do to figure out what it is?

- What elements does it contain?
- What percent of the substance's mass is made up of each element (ie **percent composition**)

For example, a gas is found to contain only carbon and hydrogen. Analysis of a 10.0-g sample finds 2.5 g are C & 7.5 g are H. *What's the compound's percent composition?* 10

$$\% C = \frac{2.5 \text{ g C}}{10.0 \text{ g}} (100) = 25\%$$

$$\% H = \frac{7.5 \text{ g C}}{10.0 \text{ g}} (100) = 75\%$$

$$\Sigma = 100\%$$

Try this

A 12.04-g sample of an unknown liquid is analyzed & found to contain 7.34 g C, 1.85 g H and 2.85 g N.
Calculate its percent composition.

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$$\% C = \frac{7.34 \text{ g C}}{12.04 \text{ g}} (100) = 61.0\%$$

$$\% H = \frac{1.85 \text{ g C}}{12.04 \text{ g}} (100) = 15.4\%$$

$$\% N = \frac{2.85 \text{ g C}}{12.04 \text{ g}} (100) = 23.7\%$$

$$\Sigma = 100.1\%$$

Calculate % composition from formulas

To add nitrogen to a crop, farmers can use several different fertilizers: ammonia (NH_3); ammonium nitrate ($(NH_4)(NO_3)$); or urea (CH_4N_2O). If prices were equal, which delivers the most N per formula weight?

12

Strategy: 1. Calculate formula mass of each
2. Calculate N's % composition for each

What would you guess and why?

NH_3 = 17.04 g/mol

$$\% N = \frac{14.01 \text{ g/mol}}{17.04 \text{ g/mol}} (100) = 82.22\%$$

$(NH_4)(NO_3)$ = 79.02 g/mol

$$\% N = \frac{28.02 \text{ g/mol}}{79.02 \text{ g/mol}} (100) = 35.46\%$$

CH_4N_2O = 60.06 g/mol

$$\% N = \frac{28.02 \text{ g/mol}}{60.06 \text{ g/mol}} (100) = 46.65\%$$

Try this

Aspirin's formula is $C_9H_8O_4$. *Calculate its percent composition.*

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Strategy: 1. Calculate formula mass
2. Express the mass of each element as a % of the formula mass

C 9 x 12.01 = 108.09
H 8 x 1.01 = 8.08
O 4 x 15.99 = 63.96
180.13 g/mol

$$\% C = \frac{108.09 \text{ g/mol}}{180.13 \text{ g/mol}} (100) = 60.0\%$$

$$\% H = \frac{8.08 \text{ g/mol}}{180.13 \text{ g/mol}} (100) = 4.5\%$$

$$\% O = \frac{63.96 \text{ g/mol}}{180.13 \text{ g/mol}} (100) = 35.5\%$$

Working it the other way

How can we work this process the other way and use percent composition to calculate empirical formula?

A sample contains 1.71 g of C and 0.287 g of H.
What's its empirical formula?

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Strategy: 1. Convert grams to moles
2. Use mole ratios as formula subscripts
Ratios must be small, whole numbers!
3. Divide all moles by the smallest; multiply if needed.

C $\frac{1.71 \text{ g}}{12.01 \text{ g}} \frac{1 \text{ mol}}{} = 0.142 \text{ mol}$ / 0.142 = 1

So, formula is CH_2

H $\frac{0.287 \text{ g}}{1.01 \text{ g}} \frac{1 \text{ mol}}{} = 0.284 \text{ mol}$ / 0.142 = 2

Try this

A sample contains 5.31 g of Cl and 8.40 g of O. 15
What's its empirical formula?

Strategy: 1. Convert grams to moles
2. Use mole ratios as formula subscripts
Ratios must be small, whole numbers!
3. Divide all moles by the smallest; multiply if needed.

Cl $\frac{5.31\text{ g}}{35.45\text{ g}} \frac{1\text{ mol}}{} = 0.150\text{ mol} \;/\; 0.150 = 1 \;\; \times 2 = 2$

O $\frac{8.40\text{ g}}{15.99\text{ g}} \frac{1\text{ mol}}{} = 0.525\text{ mol} \;/\; 0.150 = 3.5 \;\; \times 2 = 7$

So, formula is Cl_2O_7

Now, put these pieces together

Yeast are used to ferment grain and produce alcohol. 16
Fermentation also produces a gas whose percent composition is 27.29% C and 72.71% O. *What's the empirical formula of the gas?*

Strategy: 1. Change % sign to grams
2. Convert grams to moles
3. Use mole ratios as formula subscripts
Ratios must be small, whole numbers!
4. Divide all moles by the smallest; multiply if needed.

C $\frac{27.29\text{ g}}{12.01\text{ g}} \frac{1\text{ mol}}{} = 2.272\text{ mol} \;/\; 2.272 = 1$

So, formula is CO_2

O $\frac{72.71\text{ g}}{15.99\text{ g}} \frac{1\text{ mol}}{} = 4.547\text{ mol} \;/\; 2.272 = 2$

What about molecular formulas?

With one more piece of information, formula mass or MW, we can determine the **molecular formula** too.

Nicotine, responsible for the addictive nature of cigarettes is 74.02% C, 8.710% H, 17.27% N. And 40.57 g contains 0.2500 moles. *What is the molecular formulas of nicotine?*

17

Strat: 1. Solve for empirical formula and calculate EW.
2. Divide MW by EW to create a factor.
3. Multiply subscripts by that factor

C $\frac{74.02\text{ g}}{12.01\text{ g}} \frac{1\text{ mol}}{} = 6.163\text{ mol}$ / 1.233 = 5

H $\frac{8.710\text{ g}}{1.01\text{ g}} \frac{1\text{ mol}}{} = 8.624\text{ mol}$ / 1.233 = 7

N $\frac{17.27\text{ g}}{14.01\text{ g}} \frac{1\text{ mol}}{} = 1.233\text{ mol}$ / 1.233 = 1

EF = C_5H_7N

EW = 81.13 g/mol

MW = $\frac{40.47\text{ g}}{0.2500\text{ mol}}$ = 162.3 g/mol

$\frac{MW}{EW} = \frac{162.3}{81.13} = 2$

MW = $C_{10}H_{14}N_2$

Try this

What's the molecular formula of a compound with 49.47 % C, 5.201 % H, 28.84 % N and 14.48% O. The formula mass is 194.2 g/mol.

18

Strat: 1. Solve for empirical formula and calculate EW.
2. Divide MW by EW to create a factor.
3. Multiply subscripts by that factor

C $\frac{49.47\text{ g}}{12.01\text{ g}} \frac{1\text{ mol}}{} = 4.119\text{ mol}$ / 1.031 = 4

H $\frac{5.201\text{ g}}{1.01\text{ g}} \frac{1\text{ mol}}{} = 5.150\text{ mol}$ / 1.031 = 5

N $\frac{28.84\text{ g}}{14.01\text{ g}} \frac{1\text{ mol}}{} = 2.059\text{ mol}$ / 1.031 = 2

O $\frac{16.48\text{ g}}{15.99\text{ g}} \frac{1\text{ mol}}{} = 1.031\text{ mol}$ / 1.031 = 1

EF = $C_4H_5N_2O$

EW = 97.10 g/mol

$\frac{MW}{EW} = \frac{194.20}{97.10} = 2$

MW = $C_8H_{10}N_4O_2$

Can you?

(1) Calculate percent composition of a compound if given masses of each element in the compound?

(2) Calculate percent composition from a molecular formula?
List the steps needed to do it?

(3) Calculate empirical formula from percent composition?
List the steps needed to do this?

(4) Calculate molecular formula from percent composition?
List the steps needed and the extra piece of information?

3. Composition of substances & solutions

3.3: Molarity

- Describe the fundamental properties of solutions
- Calculate solution concentration using molarity
- Perform dilution calculations using the dilution equation

Solutions

Remember that **solutions** are homogenous mixtures. Solutions can occur in all physical states, but we'll be focusing on liquid and gaseous solutions.

Liquid solutions can be described as mixtures of:
solutes: the compound present in lesser amounts; &
solvents: the compound present in larger amounts.

On our planet, the dominant solvent is **water**. Solutions made by **dissolving** solutes in water are called **aqueous**.

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Molarity

Concentration is a measure of the amount of solute in solvent.

Molarity (M) is a unit that we'll use to express solution concentration.

$$\textbf{molarity (M)} = \frac{\text{mol solute}}{1\text{ L solution}}$$

Note that M uses the volume of solutions, not solvents. Why?

A 335-mL soft drink contains 0.133 mol of sucrose (table sugar). *What is the molar concentration of sucrose in the drink?* 19

$$\frac{0.133\text{ mol}}{335\text{ mL}} \cdot \frac{1\text{ E3 mL}}{1\text{ L}} = 0.397\text{ M}$$

Try this

A teaspoon of sugar has 0.01 mol of sucrose. *What's the molarity of sucrose if the sugar is dissolved in a cup of tea with a volume of 200 mL?* 20

$$\frac{0.01\ \text{mol}}{200\ \cancel{\text{mL}}} \cdot \frac{1\ \text{E3}\ \cancel{\text{mL}}}{1\ \text{L}} = 0.05\ \frac{\text{mol}}{1\ \text{L}} = \text{M}$$

A sip of tea has a volume of 10 mL. *How many moles of sucrose are there in one sip?* 21

$$\frac{10\ \cancel{\text{mL}}}{} \cdot \frac{1\ \cancel{\text{L}}}{1\ \text{E3}\ \cancel{\text{mL}}} \cdot \frac{0.05\ \text{mol}}{1\ \cancel{\text{L}}} = 5\ \text{E-4 mol sucrose}$$

Now add a step

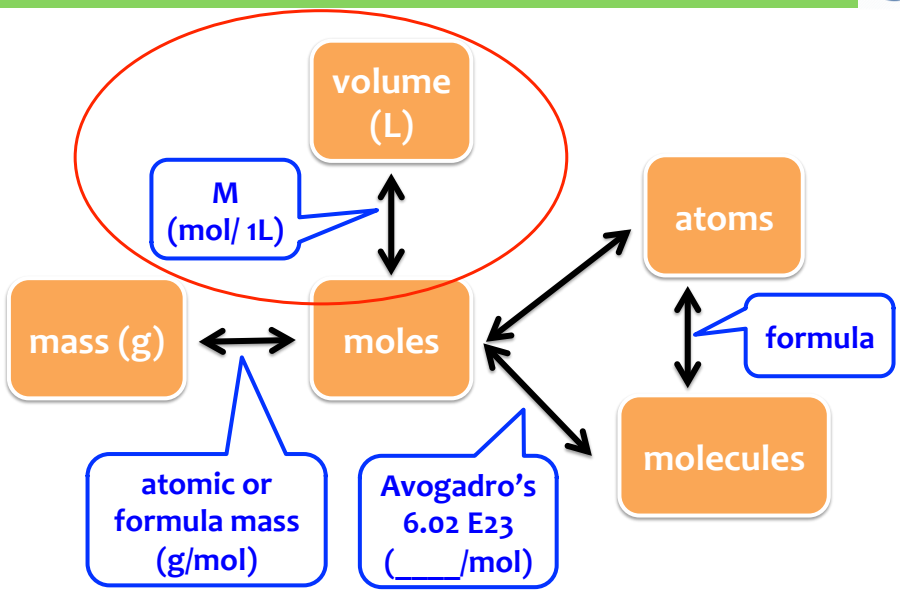
Distilled white vinegar is a solution of acetic acid (CH_3COOH) in water. A 0.500-L solution of vinegar contains 25.2 g of acetic acid. *What is the concentration (M) of acetic acid in the vinegar?*

Strategy: g → mol → M 22

$\frac{\text{mol}}{\text{g}}$ L MW = 60.04 g/mol

$$\frac{25.2\ \cancel{\text{g}}}{} \cdot \frac{1\ \text{mol}}{60.04\ \cancel{\text{g}}} \cdot \frac{}{0.500\ \text{L}} = \frac{0.839\ \text{mol}}{1\ \text{L}} = \text{M}$$

Add molarity to the mole map



Flip conversion factors to solve for your 'destination' units.

Two more variations

How many grams of NaCl are there in 0.250 L of a 5.30 M solution? 23

Strategy: L → mol → g

$M = \frac{mol}{L} \quad \frac{g}{mol}$ MW = 58.44 g/mol

$$\frac{0.250\ \cancel{L}}{} \cdot \frac{5.30\ \cancel{mol}}{1\ \cancel{L}} \cdot \frac{58.44\ g}{1\ \cancel{mol}} = 77.4\ g$$

What volume (mL) of this salt solution contains 20.0 g of NaCl? 24

Strategy: g → mol → L → mL

$$\frac{20.0\ \cancel{g}}{} \cdot \frac{1\ \cancel{mol}}{58.44\ \cancel{g}} \cdot \frac{\cancel{1\ L}}{5.30\ \cancel{mol}} \cdot \frac{1\ E3\ ml}{1\ \cancel{L}} = 64.6\ mL$$

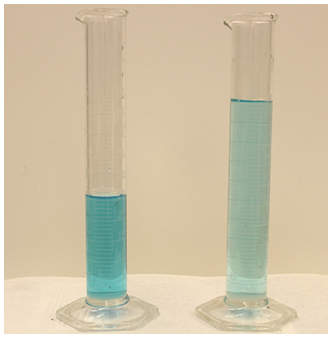
Dilution

Dilution: *the process of adding more solvent to decrease the concentration of a solution*

- Also the process of preparing solutions at the desired concentration from more concentrated **stock solutions** or from dry (solid) compounds

n = (M)(L) *where n = moles*

M1L1 = M2L2 *where 1 & 2 are sol'ns of different concentrations*



concentrated ***dilute***

Both contain the same mass of copper.

Chemistry Openstax

Apply the dilution 'formula'

If 0.850 L of a 5.00 M solution of copper (II) nitrate is diluted to a volume of 1.80L by the addition of water, what is the molarity of the diluted solution?

25

M1L1 = M2L2

(5.00 M)(0.850 L) = (M2)(1.80L)

$$\frac{(5.00\ M)(0.850\ L)}{1.80\ L} = (M_2)(\cancel{1.80L})$$

M2 = 2.36 M

Sanity check: should the M increase or decrease?

A different angle

What volume of 0.12 M HBr can be prepared from 11 mL of 0.45 M solution?

26

$M_1L_1 = M_2L_2$

$(0.45\ M)(11\ mL) = (\cancel{0.12\ M})(L_2)$

$$\frac{(0.45\ M)(11\ mL)}{0.12\ M} = (L_2)$$

$L_2 = 41\ mL$

Sanity check: should the volume increase or decrease?

Note that volume can take <u>any units</u> as long as they are the same on both sides.

Can you?

(1) Define the terms solution, solute, solvent, dissolve, aqueous, concentration, molarity and dilution?

(2) Calculate molarity from moles or mass and volume?

(3) Use molarity as a conversion factor?

(4) Use the dilution 'formula'?

3. Composition of substances & solutions

3.4: Other units for solution concentrations

- Define the concentration units of mass percentage, volume percentage, mass-volume percentage, parts per million (ppm), & parts per billion (ppb)
- Perform calculations relating a solution's concentration and its components' volume and / or masses with these units

Mass percentage

Mass percentage: *the ratio of solute mass to solution mass, multiplied by 100*

- % mass or % (w/w)

The label of a bottle of bleach lists its active ingredient, sodium hypochlorite (NaOCl), as 7.4%.

- So, 100.0 grams of bleach would contain 7.4 g of NaOCl.

A 5.0-g sample of spinal fluid contains 3.75 mg of glucose. *What is the percent by mass of glucose in spinal fluid?* 27

$$\frac{3.75\ \cancel{mg}\ \ \cancel{1\ g}}{1\ E3\ \cancel{mg}\ \ 5.0\ \cancel{g}}(100) = 0.075\%\ (w/w)$$

Using mass percentage

Concentrated hydrochloric acid is a 37.2% aqueous solution with a density of 1.19 g/mL. What mass of HCl is there in 0.500 L of concentrated HCl solution? 28

Strategy: volume → mass → mass HCl
mL/g %

$$\frac{0.500\ \cancel{L}}{} \cdot \frac{1\ E3\ \cancel{mL}}{1\ \cancel{L}} \cdot \frac{1.19\ \cancel{g}}{1\ \cancel{mL}} \cdot \frac{37.2\ g\ HCl}{100\ \cancel{g}\ sol'n} = 222\ g\ HCl$$

Volume percentage

Volume percentage: *expresses the concentration of a liquid solute dissolved in a liquid solvent, % (v/v)*

$$\%\ (v/v) = \frac{\text{volume solute}}{\text{volume solution}} (100)$$

Rubbing alcohol (isopropanol) is usually sold as a 70% (v/v) aqueous solution. If the density of isopropanol is 0.785 g/mL, how many grams of isopropyl alcohol are present in 355 mL of rubbing alcohol? 29

Strategy: volume → volume → g isopropyl alcohol
sol'n iso
% density

$$\frac{355\ \cancel{mL}}{} \cdot \frac{70\ \cancel{mL}\ HCl}{100\ \cancel{mL}\ sol'n} \cdot \frac{0.785\ g}{1\ \cancel{mL}} = 195\ g\ \text{isopropyl alcohol}$$

Mass-volume percentage

Mass-volume percentage: *expresses the ratio of a solute's mass to the solution's volume as a percentage*

$$\% \text{ (w/v)} = \frac{\text{g solute}}{\text{100 mL sol'n}}$$

saline sol'n = 0.9% (w/v) NaCl

Fasting blood glucose should be 70-100 mg/dL

Chemistry Openstax

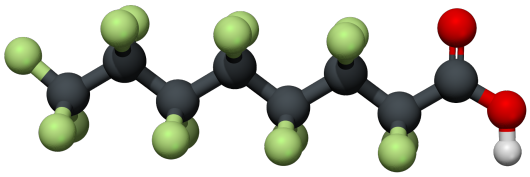
ppm & ppb

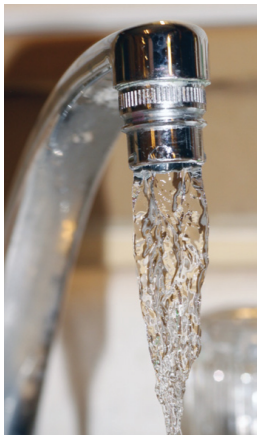
Very low solute concentrations are often expressed as **parts per million (ppm)** or **parts per billion (ppb)**.

$$\text{ppm} = \frac{\text{mass solute}}{\text{mass sol'n}} \text{ (1 E6) ppm}$$

$$\text{ppb} = \frac{\text{mass solute}}{\text{mass sol'n}} \text{ (1 E9) ppb}$$

Some wells in Vermont are contaminated with PFOA (perfluorooctanoic acid). Vermont has set safe levels at 20 ppt, parts per trillion.





Chemistry Openstax; https://en.wikipedia.org/wiki/Perfluorooctanoic_acid
http://www.healthvermont.gov/health-environment/drinking-water/perfluorooctanoic-acid-pfoa

Try this

EPA rules say that if lead levels in drinking water reach 15 ppb, remedies must be taken.

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(a) Convert this to ppm.

(b) What mass of lead (ug) would be in a 300-mL glass of water?

(a) $\frac{15\ \cancel{ppb}\ \ 1\ E6\ ppm}{1\ E9\ \cancel{ppb}} = 0.015\ ppm$

(b) $ppb = \frac{mass\ solute}{mass\ sol'n}(1\ E9) \rightarrow mass\ solute = \frac{(\cancel{ppb})(mass\ sol'n)}{1\ E9\ \cancel{ppb}}$

$mass\ solute = \frac{(15\ \cancel{ppb})(300\ \cancel{mL}\ \ 1.0\ g/\cancel{mL})}{1\ E9\ \cancel{ppb}} = 4.5\ E\text{-}6\ g\ lead$

Can you?

(1) Define the terms mass percentage, volume percentage, ppm and ppb?

(2) Use mass percentage, volume percentage and mass-volume percentage 'equations' in calculations?

(3) Convert ppm and ppb to other units of concentration?

Lecture 3, Composition… Terms to know

aqueous solution
Avogadro's number
concentrated
concentration
dilute
dilution
dissolved
empirical formula mass
formula mass
mass percentage
mass-volume percentage
molar mass
molarity (M)
mole
parts per billion (ppb)
parts per million (ppm)
percent composition
solute
solvent
volume percentage