Environmental Health

Solution Basics

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Where Do Solution "Recipes" Come From?

- Original Scientific Literature
- Lab Manuals (professional)
- Handbooks
- Manufacturers and suppliers

- Make their way into instructional Lab manuals

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Interpreting Recipes

DEFINITIONS:

- **SOLUTES** -- substances that are dissolved
- **SOLVENTS** -- substance in which solutes are dissolved (usually water)
- **AMOUNT** -- how much

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Concentration Versus Amount

CONCENTRATION -- amount / volume

- ***Fraction*** where:
  - Numerator, the amount of solute
  - Denominator, usually volume of entire solution
    - solvent + solute(s)

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Each star represents 1 mg of NaCl.

What is the total <u>amount</u> of NaCl in the tube? _____

What is the <u>concentration</u> of NaCl in the tube (in mg/mL)? _____

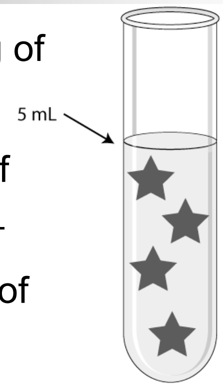

Figure 1.

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Each star represents 1 mg of NaCl.

What is the total amount of NaCl in the tube?

<u>4 mg</u>

What is the concentration of NaCl in the tube (in mg/mL)?

$$\frac{4\ \text{mg}}{5\ \text{mL}} = \frac{?}{1\ \text{mL}}$$

? = 0.8 mg,so the

concentration is *<u>0.8 mg/mL</u>*

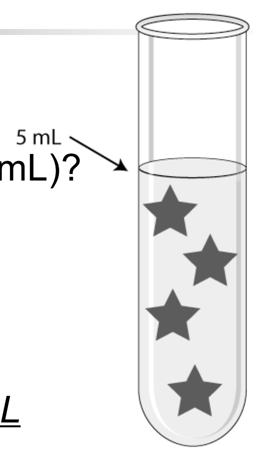

Figure 1.

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Ways To Express Concentration Of Solute

- Source of confusion: more than one way to express concentration of solute in a solution

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Concentration Expressions (Most Common)

- **WEIGHT PER VOLUME**
- **MOLARITY**
- **PERCENTS (Three kinds)**
  - a. Weight per Volume % (w/v %)
  - b. Volume per Volume % (v/v %)
  - c. Weight per Weight % (w/w %)

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More
Concentation Expressions

- **PARTS** (Common in environmental sciences, for example)

Amounts of solutes expressed as "parts"

a. Parts per Million (ppm)
b. Parts per Billion (ppb)
c. Might see parts per Thousand (ppt)
d. Percents are same category (pph %)

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Still More
Concentration Expressions

TYPES NOT COMMON IN BIOLOGY MANUALS:

- **MOLALITY**
- **NORMALITY**
  - We remember that for NaOH and HCl, molarity = normality, however, this is not true for all solutes

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Weight / Volume

Means a fraction with:

weight of solute in numerator

total volume in denominator

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Example:

- 2 mg/mL proteinase K
  - Means 2 mg of proteinase K in each mL of solution.
- Example: How much proteinase K is required to make 50 mL of solution at a concentration of 2 mg/mL?

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Can Solve as A Proportion Problem

$$\frac{2 \text{ mg proteinase K}}{1 \text{ mL solution}} = \frac{X}{50 \text{ mL solution}}$$

X = 100 mg
= amount proteinase K needed.

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Molarity

- **Molarity** is: number of moles of a solute that are dissolved per liter of total solution.
- **By definition: A 1 M solution contains 1 mole of solute per liter total volume.**

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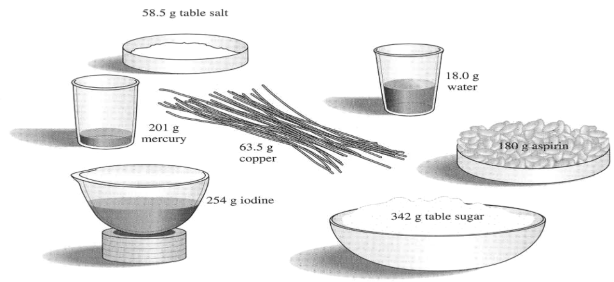
Mole

- How much is a mole?



From *Basic Laboratory Methods for Biotechnology: Textbook and Laboratory Reference,* Seidman and Moore, 2000

Example: Sulfuric Acid

For a particular compound, add the atomic weights of the atoms that compose the compound.

H_2SO_4:

2 hydrogen atoms	2 X 1.00 g =	2.00 g
1 sulfur atom	1 X 32.06 g =	32.06 g
4 oxygen atoms	4 X 16.00 g =	64.00 g
		98.06 g

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Example Continued

- A 1M solution of sulfuric acid contains 98.06 g of sulfuric acid in 1 liter of total solution.
- Observe that "mole" is an expression of amount
- “Molarity" is an expression of concentration.

Definitions

- "Millimolar", mM, millimole/L.
  - A millimole is 1/1000 of a mole.
- "Micromolar", µM, µmole/L.
  - A µmole is 1/1,000,000 of a mole.

Formula

HOW MUCH SOLUTE IS NEEDED FOR A SOLUTION OF A PARTICULAR MOLARITY AND VOLUME?

FW x molarity x volume = g solute needed

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Example

- How much solute is required to make 300 mL of 0.8 M $CaCl_2$?

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Answer

Substituting into the formula:

$$\left(\frac{111.0\ g}{mole}\right)\left(\frac{0.8\ mole}{L}\right)(0.3\ L) = 26.64\ g$$

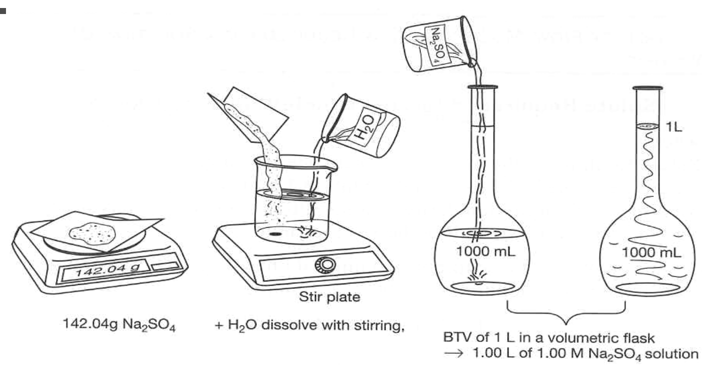

Figure 21.4. A 1 *M* Solution of Sodium Sulfate (Na_2SO_4). The *FW* of Na_2SO_4 is

From *Basic Laboratory Methods for Biotechnology: Textbook and Laboratory Reference,* Seidman and Moore, 2000

To Make Solution Of Given Molarity And Volume:

- Find the FW of the solute, usually from label.
- Determine the molarity desired.
- Determine the volume desired.
- Determine how much solute is necessary by using the formula.

Procedure Cont.

- Weigh out the amount of solute.
- Dissolve the solute in less than the desired final volume of solvent.
- Place the solution in a volumetric flask or graduated cylinder. Add solvent until exactly the required volume is reached, "Bring To Volume", "BTV".

Percents

X % is a fraction

numerator is X
denominator is 100

Three variations on this theme.

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Weight/volume %

TYPE I:

- Grams of solute
- 100 mL total solution
- Most common in biology but seldom used in chemistry manuals
  - Technically, the units should be the same in the numerator and denominator

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Example

20 g of NaCl in
100 mL of total solution

= 20% (w/v) solution.

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Example: By Proportions

- How would you prepare 500 mL of a 5 % (w/v) solution of NaCl?

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Answer, By Proportions

By definition: 5 % = $\frac{5\text{ g}}{100\text{ mL}}$

$$\frac{5\text{ g}}{100\text{ mL}} = \frac{?}{500\text{ mL}}$$

? = 25 g = amount of solute
BTV 500 mL

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By Equation

How would you prepare 500 mL of a 5 % (w/v) solution of NaCl?

1. Total volume required is 500 mL.
2. 5% = 0.05
3. (0.05) (500 mL) = 25

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% Example Continued

4. 25 is the amount of solute required in grams.

5. Weigh out 25 g of NaCl. Dissolve it in less than 500 mL of water.

6. In a graduated cylinder or volumetric flask, bring the solution to 500 mL.

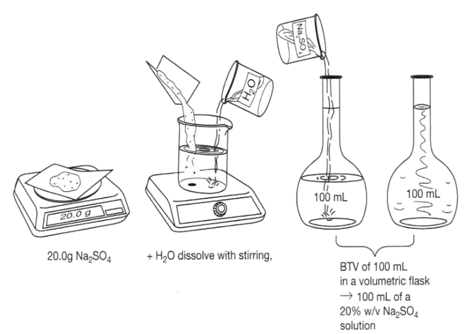

Figure 21.5. A 20% Weight per Volume Percent Solution of Sodium Sulfate (Na_2SO_4).

From *Basic Laboratory Methods for Biotechnology: Textbook and Laboratory Reference,* Seidman and Moore, 2000

Two Other Forms Of %

v/v $\frac{\text{mL solute}}{\text{100 mL solution}}$

w/w $\frac{\text{g solute}}{\text{100 g solution}}$

Note: in w/w the denominator can also be a solid substance (g of lead (Pb) in 100g of soil)

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Weight/weight

- How would you make 500 g of a 5% solution of NaCl by weight (w/w)?

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Answer

- Percent strength is 5% w/w, total weight desired is 500g.
- 5% = 5g/100g
- $\frac{5\text{g}}{100\text{ g}}$ X 500 g = 25 g = NaCl needed
- 500 g – 25 g = 475 g = amount of solvent needed
- Dissolve 25 g of NaCl in 475 g of water.

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Parts

- Parts may have any units but must be the same for all components of the mixture.

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Example:

A solution is 3:2:1 ethylene:chloroform:isoamyl alcohol

Might combine:

3 liters ethylene
2 liters chloroform
1 liter isoamyl alcohol

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Ppm And Ppb

- **ppm:** The number of parts of solute per 1 million parts of total solution.
- **ppb:** The number of parts of solute per billion parts of solution.

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Ppm Example:

- 5 ppm chlorine = 5 g of chlorine in 1 million g of solution,
- or 5 mg chlorine in 1 million mg of solution,
- or 5 pounds of chlorine in 1 million pounds of solution

Conversions

To convert ppm or ppb to simple weight per volume expressions:

5 ppm chlorine = $\frac{\text{5 g chlorine}}{10^6 \text{ g water}} = \frac{\text{5 g chlorine}}{10^6 \text{ mL water}}$

= **5 mg/1 L water**

= 5 X 10^{-6} g chlorine/ 1 mL water

= **5 micrograms/mL**

PPM To Micrograms/ml

For any solute:

$$1 \text{ ppm in water} = \frac{1 \text{ microgram}}{\text{mL}}$$

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Each star represents 1 mg of dioxin.
What is the concentration of dioxin in tube expressed as ppm (parts per million)?

____

What is the total amount of dioxin in beaker?

____

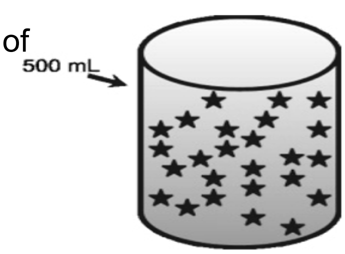

Figure 5

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Each star represents 1 mg of dioxin.

What is the total amount of dioxin in tube? 25 mg

What is the concentration of dioxin in tube expressed as ppm? ____________

1 ppm in water = 1 μg / mL

25 mg/500 mL

= 0.05 mg/mL= 50 μg/mL

so the concentration is 50 ppm

Figure 5

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A Comparison of Methods of Expressing the Concentration of a Solute

Concentration of Solute (Na2SO4)	Amount of Solute	Amount of Water
1M	142.04 g Na_2SO_4	BTV1L with water
1m	142.04 g Na_2SO_4	Add 1.00kg of water
1N	71.02 g Na_2SO_4	BTV1L with water
1%	10g Na_2SO_4	BTV1L with water
1 ppm	1mg	BTV1L

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How Solutions are Prepared, Topics:

- Preparing Dilute Solutions from Concentrated Ones ($C_1V_1=C_2V_2$)
- Biological Buffers
- Assuring the Quality of a Solution
- Preparing Solutions with More Than One Solute (another Power Point)

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Preparing Dilute Solutions From Concentrated Ones

- Concentrated solution = stock solution
- Use this equation to decide how much stock solution you will need: $C_1V_1=C_2V_2$
  - C_1 = concentration of stock solution
  - C_2 = concentration you want your dilute solution to be
  - V_1 = how much stock solution you will need
  - V_2 = how much of the dilute solution you want to make

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Example

- **How would you prepare 1000 mL of a 1 M solution of Tris buffer from a 3 M stock of Tris buffer?**
  - The concentrated solution is 3 M, and is C_1.
  - The volume of stock needed is unknown, ?, and is V_1.

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Example Cont…

The final concentration required is
1 M, and is C_2.
The final volume required is 1000 mL and is V_2.

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Substituting Into The Equation:

$C_1 \quad V_1 = C_2 \; V_2$

3 M (?) = 1 M (1000 mL)

? = 333.33 mL

So, take 333.33 mL of the concentrated stock solution and BTV 1 L.

"X" Solutions

- The concentration of a stock solution is sometimes written with an "X".
- The "X" is how many more times the stock is than normal.
- You generally want to dilute such a stock to 1X, unless told otherwise.

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Example

- A can of frozen orange juice is labeled 4X. How would you dilute it to make 1L of drinkable juice?
- Using the $C_1V_1=C_2V_2$ equation:

  $C_1 \;\; V_1 \;=\; C_2 \;\; V_2$

  4X (?) = 1X (1L)

  ? = 0.25 L

Use 0.25 L of orange juice, BTV 1L.

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Biological Buffers

- Laboratory buffers

  solutions to help maintain a biological system at proper pH
- pKa of a buffer

  the pH at which the buffer experiences little change in pH with addition of acids or bases = the pH at which the buffer is most useful

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Temperature

- Some buffers change pH as their temperature and/or concentration changes
- Tris buffer, widely used in molecular biology, is very sensitive to temperature

Dilution

- Some buffers are sensitive to dilution
- Phosphate buffer is sensitive to dilution

Adjusting the pH of a Buffer

- This is done to set the buffer to a pH value which is...
  - somewhat close to its pKa
  - useful for the biological system the buffer is to be used with
- Often adjust pH using NaOH or HCl
  - Note: these are not appropriate for adjusting the pH of phosphate buffer

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Bringing a Solution to the Proper pH

- Adjust the pH when the solution is at the temperature at which you plan to use it.
- Mix the solute(s) with most, but not all, the solvent. Do not bring the solution to volume.
- Stir solution.

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- Check the pH.
- Add a small amount of acid or base.
  - The recipe may specify which to use.
  - If not, HCl and NaOH are commonly used.
- Stir again and then check the pH.

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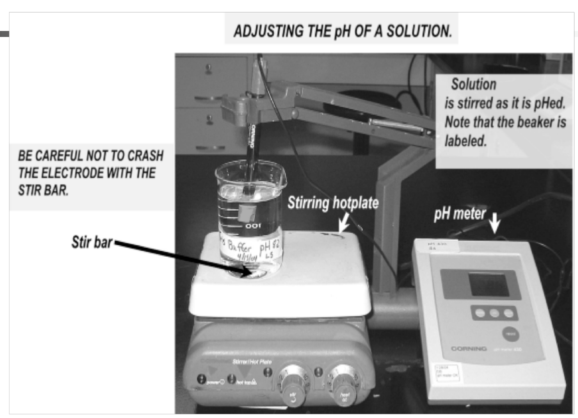

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- Repeat until the pH is correct, but don’t overshoot.
- Bring the solution to volume and recheck the pH.

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Assuring The Quality Of A Solution

- Documentation, labeling, recording what was done
- Traceability
- Standard Operating Procedures (SOPs)
- Maintenance and calibration of instruments
- Stability and expiration date recorded
- Proper storage

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