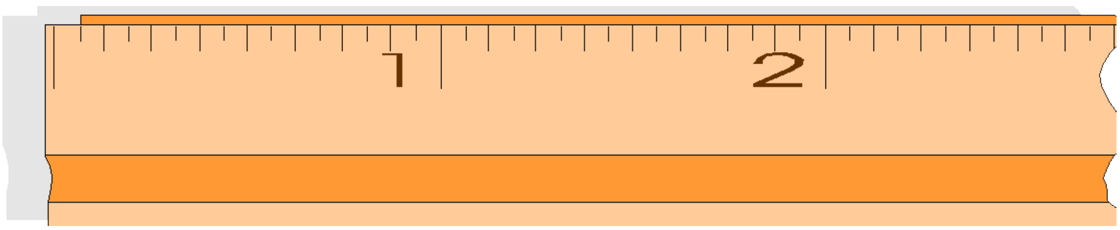
College of the Canyons: "Introduction to Biotechnology" Custom Lab Exercises



Metric System, Dimensional Analysis and Introduction to Solution Chemistry

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- **The metric system is a decimal system of measurement of such features as: length, mass, area, and other physical conditions of objects.**
- **Dimensional analysis is the conversion of one unit of measurement to a different unit of measurement (i.e. inches to centimeters.)**
- **The conversion is accomplished using equalities and proportions.**
- **Metric familiarity is less common in the U.S., where the British System is still in use. As a result, students of science should make an effort to make themselves more aware of metric units by assessing their surrounding with respect to "metric awareness".**
- **Proper dimensional analysis uses conversions factors that are equal to one, the units cancel accordingly.**
- **Solution preparation involves conversion factors, volumetric transfer and familiarity with molar equations.**
- **These topics are further explored in supplementary reading and assignments.**
- ***The Molarity and Dilutions and Serial Dilutions exercises (at the back of this handout) should be completed after doing the Concentration Calculations and Expressions lab (due February 3/see syllabi)***

For more information on College of the Canyons' Introduction Biotechnology course, contact Jim Wolf, Professor of Biology/Biotechnology at (661) 362-3092 or email: jim.wolf@canyons.edu. Online versions available @ www.canyons.edu/users/wolfj

I. **Objectives**:

1. To become familiar with key metric units and relate their values to common British equivalents.
2. Become familiar with steps involved in basic and compound conversions using dimensional analysis.
3. Begin to understand link of molecular formula to solution preparation.
4. Become proficient at calculating solution concentrations using a variety of methods (molarity, percent solution, serial dilution, pH calibration, etc.)
5. Reference previous and future labs to help complete all exercises as noted.

II. **Background**:

Accurate measurement is the cornerstone of modern science. It is important to understand that certain features of scientific measurement have become standard methods or practices that are accepted as being *the* way a certain process or procedure is done. One such standard in science is the use of the metric system, which is a decimal system of measurement of such features as: length, mass, area and other physical conditions of objects.

In the metric system, larger and smaller units are easily expressed by changes in the prefix of the name of the unit of measure. These prefixes reflect changes in multiples of 10, making all measurements easily converted by movement of the decimal point.

While there are many prefixes in the metric system the following table shows those most commonly used:

Conversion factor	Prefix	Symbol
1,000,000,000 = 1.0×10^{9}	giga	G
1,000,000 = 1.0×10^{6}	mega	M
1,000 = 1.0×10^{3}	kilo	K
100 = 1.0×10^{2}	hecto	H
1 = 1		
0.1=1.0×10^{-1}	deci	D
0.01 = 1.0×10^{-2}	centi	C
0.001 = 1.0×10^{-3}	milli	M
0.000001 = 1.0×10^{-6}	micro	μ
0.00000001 = 1.0×10^{-9}	nano	n

The prefixes mentioned above are attached to base values. These values define the type of measurement, i.e., length, mass, etc. By convention prefixes greater than one are often capitalized and those less than one are often lower case when used without the unit.

length	=	**meter (M)**
mass	=	**gram (g)**
liquid volume	=	**liter (l)**
temperature	=	**Kelvin/Celsius**

So a centimeter is $1/100^{th}$ of a meter while a kilometer is 1000 meters, and a millimeter is $1/1000^{th}$ of a meter. By simply changing the prefix, you are able to create measurements with vastly different units.

It is often necessary to convert one unit of measure to another, i.e. one that is either larger or smaller. This is done using **dimensional analysis**, a process that employs **conversion factors** as part of a methodical approach to the solution of the problem. Dimensional analysis requires that you define the units to be converted from and those to which this value will be converted. Determine the value relationship of each and then make up an appropriate conversion factor; for instance, if one wishes to determine the number of meters in 12.5 kilometers, the first step is to determine the correct conversion factor for kilometers to meters. Since there are 1000 meters in one kilometer the conversion factor would be:

[ ] Conversion factors can also be flipped, so… [ ]

Note: The conversion factor does equal one, as any value over its equal does equal one!
The actual dimensional analysis is:

$$12.5\text{ km}\quad \frac{(1000\text{ m})}{(1\text{ km}\quad)} = 12{,}5000$$

As a general rule for dimensional analysis always put the unit you start in on the bottom of the next conversion factor. Just as in a typical math equation you can now cross cancel the units on the top and bottom (In this case you could cancel out "the unit you are in"):

$$\underline{\text{The unit you are in}} \quad X \quad \frac{\text{the unit you want to convert to}}{\text{The unit you are in}}$$

THERE ARE TWO GOLDEN RULES OF Dimensional Analysis:

1. **Make sure that the conversion factors are valid** (example: 1 inch = 2.540cm).
2. **Ensure that the units cancel**. As you proceed, the respective numerators and denominators should cancel nicely. This idea is especially crucial in multi-unit conversions (example problem set 2.)

When it comes to general dimensional analysis, there are three types to be concerned with.

1. **Single unit conversion**: As the name implies, these are the simplest of the conversions. The above is an example and here are a few more:

With the knowledge that: ***** 1 gallon = 3.85 liters, 1 ounce =28 grams, 1 meter =39 inches
<u>Lets try some:</u>
How many liters in 3.5 gallons?

How many grams in 2.6 ounces?

3.5 gallons $\frac{(3.85 \text{ liters})}{(1 \text{ gallon})}$ = 13.48 liters

2.6 ounces $\frac{(28 \text{ grams})}{(1 \text{ ounce})}$ = 72.0 grams

Notice that both golden rules of dimensional analysis are being adhered to! Make sure you clearly understand these examples before moving on to example set 2, as they will get a little more complex.

2. **Multiple unit conversions**: While this sounds more intimidating, it is really just a series of single unit conversions put back to back. <u>The golden rules are especially crucial here as your chances of messing up are compounded by the multiple conversions</u>. Also, multiple unit conversions help you by not requiring you to memorize every possible conversion factor. Instead you can use a series of more familiar conversion factors and link them together. Let's try the example mentioned below.

<u>How many micro-liters in a 2.5 pints?</u>

Start by verifying the accuracy of the simple conversion units.
1 pint = 0.5 quarts 1 quart = 0.962 liters 1 liter = 10^6 micro-liters

Please note, these conversion factors are either common knowledge, or can be calculated by knowledge of previously given conversion factors and/or the metric conversions. There are many routes to this answer, but for brevity, the shortest has be provided.

2.5 pints $\frac{(0.5 \text{ quarts})}{(1 \text{ pint})}$ $\frac{(0.962 \text{ liters})}{(1 \text{ quart})}$ $\frac{(1\text{x}10^6 \text{ microliters})}{(1 \text{ liter})}$ = $1.203\text{x}10^7$ microliters

Notice that the units all cancel and that each individual conversion is valid.

3. Multi-dimensional analysis: This level of analysis is again just a more complex form of dimensional analysis. The golden rules still apply; you just need to ensure that the conversion factors are valid. Also, some of the conversion factors are more sophisticated in the fact that they can be used to convert one unit of measure to another. The reason for this is that the metric system has been designed to allow this. For instance, 1 ml of water weighs one gram and takes up 1 cubic centimeter of space (1ml = 1cm^3). Using this conversion factor we can go from liquid volume (ml) to the volume of a solid (cm^3). These observations are contingent on a few realities. For instance, the water must be pure, at about room temperature and at atmospheric conditions.

Despite the qualifications, these conversion factors can be very powerful. If you use them, just ensure that the conditions of the solution do not deviate substantially from the above mention conditions (e.g. not to warm, concentrated (i.e. too salty, etc.))

How many microliters are in 1.6 lbs of water?

(1 lb = 454 grams) (1 gram=1 milliliter)

$$1.6 \text{ lbs} \frac{(454 \text{ grams})(1 \text{ milliliter})(1000 \text{ µl})}{(1 \text{ lb})(1 \text{ gram})(1 \text{ ml})} = 7.26\text{x}10^{+5} \text{ µl}$$

Ready for a really scary one? Try this one on for size. A cube of water, 0.6 meters on side is filled with salty water of a density of 1.045 grams/ milliliter. What is the weight of this cube in ounces? Come see me if you want to check your answer, need hints, etc…

Metric Conversions Worksheet

A. Which metric unit and prefix would be used to measure the following (if no prefix is used write "none")

length = ________________	inches = __________________
weight = ________________	pounds = __________________
temperature = _____________	ounces = __________________
liquid volume = ___________	feet = ________________
yards = __________________	gallons = ________________
pints = __________________	miles = ________________

B. Circle the larger unit of measurement.

m or cm	dl or l	kg or µg
µm or m	ml or µl	mg or g
µm or cm	µl or cl	µg or mg
dm or m	l or ml	g or kg

C. Write the two golden rules of dimensional analysis:

1.

2.

D. Complete the following relationships. Show the dimensional analysis and write very neatly, show canceled units and needed conversions (s).

1 m = ______________________ cm	1.3 l = ______________________ ml
10 µl = ______________________ ml	0.27 gm = ______________________ ug
4 mg = ______________________ g	3.33 mg = ______________________ ug
0.5 m = ______________________ mm	0.5 ml = ______________________ kl

6.13 l = ____________________ ml	27 km= ____________________ mm
115 cm = ____________________ m	3045 mm = ____________________ m
7.57 g = ____________________ µg	5,045 l = ____________________ kl
2.3 ml = ____________________ µl	2,082,099 ul= ____________________ km

E. Answer the following questions using dimensional analysis. Where applicable, start with a British unit and convert to metric, vice versa, etc. Do as little or as much as you need to do to feel comfortable with and feel free to ask if you do not know a conversion (i.e. 454 grams = 1 lb, 1 qt = 1.09 liters, 2.54 cm = 1 inch).

1. What is your height in m? cm?

2. What is your ideal weight in g? kg, lbs?

3. At what temperature does water boil in Celsius? In Kelvin?

4. How far is COC from your home in km? m?

5. What is the average speed you drive to COC in km/hr? m/hr?

6. How much coffee/tea do you drink in a day in µl? ml?

7. What is room temperature in Celsius?

8. How big of a steak (or tofu patty if you are a vegetarian) do you like to eat in g? In mg?

9. What is your body temperature in Celsius?

10. What is the length of your hand in mm? km?

11. A 12 ounce can of soda has how many ml? ul?

12. 6.7 liters of fresh water weights how many kg?

13. How many gallons does your gas tank hold? Liters?

14. How many mm longs is the class textbook? Cm?

15. About many liters does a gel box hold? ml?

16. How many meters tall is the ceiling in the lab? mm?

17. 127 liters of freshwater weight how many kg? grams?

18. 127 liters of saltwater weight how many kg? grams? *Approximately*.

19. A cube, 3 cm on side is equal to how m? any cubic mm?

20. A cube, 29 inches on side holds how many liters?

21. A block of wood 2 cm x 3 cm x 6 cm weighs 35 grams. What is its density? Density FYI is mass/grams.

22. Pizza cooks at 450 degrees Fahrenheit. What is the temperature in ^{o}C

23. A pizza weigh 1.2 lbs. How many grams is this? Kg?

24. Assume an average shower last 15 minutes and uses 3 galloons per minute. How liters of waters are used?

25. How many square cm does a 8/5 x 11 inch piece of copy paper have?

B. During the course of the semester you will be working with very small volumes. To prepare you for this, do the following conversions for liquid measurements and indicate which instrument you would use to measure each volume (choose from micro-pipette, transfer pipet, serological pipette or volumetric glass ware). Take a minute to review the actual equipment to help you with your decisions. For most answers, there is one best choice, with some latitude. In a subsequent labs you will be working extensively with volumetric equipment and additionally conduct a lab designed to help you decide what piece of volumetric equipment to use if more than one device will measure the volume.

	Volume	Instrument
1.	10 µl = ?ml	
2.	250 µl = ?ml	
3.	514 µl = ?ml	
4.	25 µl = ?ml	
5,	4 µl = ?ml	

6. 3 L = ?ml

7. 4 µl = ?ml

8. 1.2 ml = ? µl

9. 150 L = ? µl

10. .08 ml = ? µl

11. 20 ml = ? µl

12. 12 ml = ? µl

C. Molecular Weights and Formula Weights

Write the atomic weights for the following elements.

Calcium	Oxygen
Carbon	Magnesium
Sulfur	Potassium
Helium	Phosphorous
Iron	Hydrogen
Sodium	Chloride

D. Calculate the formula weights for the following compounds. (Show your work.)

Water

Carbon Dioxide

Sodium Chloride

Sodium Hydroxide

Hydrochloric Acid

H_2SO_4

Na_2HPO_4

KH_2PO_4

$MgCl_2$

$NaHCO_3$

E. Solutions
Calculate how many grams of a compound would be needed to make the following solutions. NOTE: Depending on you comfort with this material, you may want to reference the lab on Concentration Expressions and Calculations.

1 L of 10% Sodium Chloride

1 L of 28% Calcium

50ml of 3% Tris-Cl

20ml of 0.02% Phenol Red

50ml of 0.9% Agarose gel

50ml of 0.3% Agarose gel

F. Calculate how many grams of a compound would be needed to make the following solutions. NOTE: Depending on you comfort with this material, you may want to reference the lab on Concentration Expressions and Calculations.

1 L of 2M NaOH

1L of 0.5M HCl

250ml of 5M NaCl

30ml of 2M KCI

1 L of 15mM Na_2CO_3

1 L of 71mM NaCl

500ml of 3.1mM NaN_3

100ml of 35mM $NaHCO_3$

Molarity and Dilutions: **NOTE: Depending on you comfort with this material, you may want to reference the lab on Concentration Expressions and Calculations to help with your calculations. The pH meters, bicarbonate, et. will be out during the next few labs to give you time to complete the lab**

Protocol

Calculate the amount of NaHCO3 (in grams) needed to make 10mls of solutions with the following molarities:

10.0 M		**10 mM**		**10 μM**	
Pr:	Sd:	Pr:	Sd:	Pr:	Sd:

1.0 M		**1 mM**		**1 µM**	
Pr:	Sd:	Pr:	Sd:	Pr:	Sd:
0.1 M		**0.1 mM**		**0.1 µM**	
Pr:	Sd:	Pr:	Sd:	Pr:	Sd:

FYI: These are solutions of baking soda and are both harmless and sink friendly…

- Make 10 mls each of the above solutions (using DI water) in 50 ml centrifuge tubes (check to see if the pH meter probe will fit into the tube prior to making solutions.) Also, take a minute to review the SOP for pH meter use and recall the dialog covered in the pH lecture and lab quiz. <u>Please note</u>, it is not an oversight that some of the solutions reagents cannot be weighed using our scales. If this is not possible, do not attempt to prepare the solution with the direct preparation method. Move on the serial dilution part and compare the pH of the solutions that can be prepared.

- Record the pH of each of the solutions. Write the value next to the above pH. Use the subscript "Pr" to denote these vales as being determined from the solutions you prepared.

- Calculate how the same solutions could be generated by using the process of serial dilution.

- Now generate a new set of solutions using serial dilution. For the first solution in the series, start with the solution that fully solubilizes (e.g. dissolves completely)

- Record the pH of these solutions next to above pH values with subscript "Sd" to denote serial dilutions.

Questions

Which process of generating the set of solutions was least time consuming?

Is there any difference in the pH values when the two sets are compared. Look at your table, and look for inconsistencies in the data. You will be graphing this information later FYI.

Which process was the most accurate? Why?

Serial Dilutions: NOTE: Depending on you comfort with this material, you may want to reference the lab on Concentration Expressions and Calculations to help with your calculations. The lab handout itself should be completed by the fourth lab meeting.

Serial dilutions are dilutions made in a series that for the most part have the same dilution factor (how is that for elucidating the obvious!) A diagram of the process and additional explanation are on the next page FYI. For the following problems show the serial dilutions you would make to arrive at the final concentration. Assume that the original stock solution is a 1 molar concentration and you want 50 mls of the final solution. FYI, dilutions rarely exceed 1:100 as this may contribute to substantial measurement errors. In the dilution series, state each solutions' amount and molarity. FYI…a key for this lab is available upon request…but try it first yourself!

1 µM NaCl

10 nM Phosphate Buffered Saline

0.05 M glucose (hint, start off with 2.5 mls of 1 M stock glucose)

0.15 mM albumin

Note the general process: Start with a concentrated solution (usually 1 or 10 molar). From this starter solution, dilute using 1 to 10 to 1 to 1000 (larger dilutions can be error prone). You may need multiple dilutions. Keep track of the effects of each dilution on the vials (see below) and once you are within range of the final dilution, simply complete it and note the final concentration. You will need to employ a C1V1 = C2V2 dilution to get the 50 ml volume and / or the concentration that is not decimal unit different from 1 (i.e. 1.0 to .075).