**EXPERIMENT 0**

# Conversion Factors and Problem Solving

## A. Goal

The goal of this laboratory experiment is to familiarize with estimating digits and accounting for significant figures in measurements through measuring in the chemistry laboratory.d

## B. Materials

- ☐ 10ml measuring cylinder
- ☐ 50ml beaker
- ☐ any size stopper
- ☐ a spatula
- ☐ string
- ☐ set of measuring cylinders: 10, 25, 50, 100 and 250mL
- ☐ metallic cylinder
- ☐ 50mL-cylinder

## C. Background

### *Significant figures in calculations*

Two different rules allow you to express the result of calculations with the correct number of figures.

**Rule 1** $(+\ -)$ *For additions or subtractions, the results has the same number of decimal places as the number with the least decimal places in the calculation.* For example:

$$34.3451 + 34.5 = 68.8\ (+\ -\text{ less decimals})$$

If you add $34.3451 + 34.5$ you will obtain $68.8451$, however, as $34.3451$ has four decimal places (4DP) and $34.5$ has one decimal place (1DP), the result of adding both numbers will have to have only one decimal place, therefore $68.8451$ needs to be rounded to $68.8$ (1DP). Overall, we have:

$$34.3451\text{ (4DP)} + 34.5\text{ (1DP)} = 68.8\text{ (1DP)}$$

**Rule 2** $(\times\ \div)$ *For multiplications and divisions, the number of significant figures of the result should be the same as the least number of significant figures involved.* For example, if you carry the following multiplication:

$$4500 \times 342 = 1500000\ (\times\ \div\text{ less SFs})$$

the number $4500$ (2SF) has two significant figures, whereas the number $342$ (3SF) has three significant figures. If we multiply both numbers the results should contain just two significant figures. The result of multiplying $4500 \times 342$ is $1539000$ (4SF), however, this number needs to be rounded into two significant figures into 1500000 (2SF). Overall we have:

$$4500\text{ (2SF)} \times 342\text{ (3SF)} = 1500000\text{ (2SF)}$$

Sometimes we will have to add significant zeros in order to present the final result of a calculation with the correct number of digits. For example:

$$8.00\text{ (3SF)} \div 2.00\text{ (3SF)} = 4\text{ (shows in calculator)} = 4.00\text{ (3SF)}$$

### *Rounding*

The following rules indicate how to round numbers:

**Rule 1** If the digit to be removed is less than 5 then the preceding digit stays the same. For example, 1.123 rounds to 1.12.

**Rule 2** If the digit to be removed is more or equal to 5 then the preceding digit is increased by one. For example, 1.126 rounds to 1.13

**Rule 3** When rounding to a specific number of significant figures we need to look only to the first number to the right of the last significant figure. For example, 1.126 rounds to two SF as 1.1

Now, let us analyze a few use cases. Imagine we need to round the number 1234cm to two SF. The results would be 1200cm. Similarly, imagine we need to round the number 0.01264cm to two SF. The results would be 0.013cm.

Sample Problem 1

Do the following calculation with the correct number of figures.

$$\frac{88.5 - 87.57}{345.13 \times 100}$$

**SOLUTION**

We will analyze each number indicating the number of SF and Digits (DP): 88.5(3SF, 1DP), 87.57(4SF, 2DP), 345.13(6SF, 2DP) and 100(1SF, 0DP). The result of doing the addition needs to be rounded to one single decimal place: $88.5 - 87.57 = 0.93 \simeq 0.9$. After that we have only multiplications and divisions and hence we will now focus on the number of SFs:

$$\frac{0.9\ (1\text{SF})}{345.13\ (5\text{SF})\ \times 100\ (1\text{SF})}$$

The result of this operation needs to be rounded to one SF:

$$\frac{0.9}{345.13 \times 100} = 2.6077 \times 10^{-5} \simeq 3 \times 10^{5}\ (1\text{SF})$$

**STUDY CHECK**

Do the following calculation with the correct number of figures: $(24.56 + 2.433) \times 0.013$

▶Answer: 0.35

**Table 1 Different prefixes**

| Prefix | Symbol | Meaning | Value |
|---|---|---|---|
| exa | E | 1000000000000000000 | $1 \times 10^{18}$ |
| peta | P | 1000000000000000 | $1 \times 10^{15}$ |
| tera | T | 1000000000000 | $1 \times 10^{12}$ |
| giga | G | 1000000000 | $1 \times 10^{9}$ |
| mega | M | 1000000 | $1 \times 10^{6}$ |
| kilo | k | 1000 | $1 \times 10^{3}$ |
| hecto | h | 100 | $1 \times 10^{2}$ |
| deca | da | 10 | $1 \times 10^{1}$ |
| – | – | 1 | $1 \times 10^{0}$ |
| deci | d | 0.1 | $1 \times 10^{-1}$ |
| centi | c | 0.01 | $1 \times 10^{-2}$ |
| milli | m | 0.001 | $1 \times 10^{-3}$ |
| micro | $\mu$ | 0.000001 | $1 \times 10^{-6}$ |
| nano | n | 0.000000001 | $1 \times 10^{-9}$ |
| pico | p | 0.000000000001 | $1 \times 10^{-12}$ |
| femto | f | 0.000000000000001 | $1 \times 10^{-15}$ |
| atto | a | 0.000000000000000001 | $1 \times 10^{-18}$ |

### *Using Conversion Factors*

Unit equalities in the form of conversion factors are used to convert one unit into another. Sometimes one wants to get rid of a prefix, such as when we transform centimeter (cm) into meter (m). Sometimes, one wants to convert a prefix into another prefix. An example would be converting centimeters (cm) to millimeters (mm). Let's work on some examples.

### *Removing or adding prefixes*

Imagine that you need to remove a prefix from a unit, and convert 3 km (we will call this one the original unit) into meters (this is the final unit). First, you would need the conversion factor corresponding to the prefix (centi) from Table 1. Then you need to arrange the conversion factor by placing the prefix at the bottom of the fraction. This will cancel out the prefix in the original unit and the bottom part of the conversion factor, hence leaving the final unit on top of the conversion factor. The arrangement would be:

$$3\cancel{km} \times \frac{1 \times 10^{3} m}{1\cancel{km}} = 3000m$$

Imagine now that you need to add a prefix into a unit, and convert 4000 m in km. The same would apply for this case, but now you will have to arrange the conversion factor so that the prefix is on the top:

$$4000\cancel{m} \times \frac{1 \text{ km}}{1 \times 10^{3}\cancel{m}} = 4km$$

Sample Problem 2

The length of a textbook page is 20cm. Convert 20cm to meters, expressing the result in scientific notation.

**SOLUTION**

In order to convert 20cm into meters, we need to remove the prefix (centi) leaving the unit (meter) without any

prefix. We will use the conversion factor that relates m to cm: $\frac{1 \times 10^{-2} m}{1 cm}$ or $\frac{1 cm}{1 \times 10^{-2} m}$. We will arrange the conversion factor so that cm cancels giving m and hence we will use $\frac{1 \times 10^{-2} m}{1 cm}$:

$$20 \cancel{cm} \times \frac{1 \times 10^{-2} m}{1 \cancel{cm}} = 2 \times 10^{-1} m$$

The original units and on the bottom of the conversion factor cancel and we get meters, the final unit.

**STUDY CHECK**

Convert 100m to km, expressing the result in scientific notation.

▶Answer: $100 \cancel{m} \times \frac{km}{1 \times 10^{3} \cancel{m}} = 1 \times 10^{-1} km.$

### *Switching prefixes*

To switch a prefix into another prefix, such as transforming 30 millimeters (30 mm) into centimeters (cm), you will need two different conversion factors: the first conversion factor will remove the original unit (mm) introducing an intermediate unit, meters (m), whereas the second conversion factor will remove the intermediate meter and introduce the final unit (cm). You will get the conversion factors from Table 1. You will arrange the first conversion factor so that the original unit cancels out with the bottom of the first conversion factor, giving you an intermediate unit. You will arrange the second conversion factor so that the intermediate unit cancels out with the bottom of the second conversion factor giving the final unit. For this example:

$$30 \cancel{mm} \times \frac{1 \times 10^{-3} \cancel{m}}{1 \cancel{mm}} \times \frac{1 cm}{1 \times 10^{-2} \cancel{m}} = 3 cm$$

Sample Problem 3

The length of a textbook page is 20cm. How many mm correspond this length, expressing the result in scientific notation.

**SOLUTION**

We want to convert 20 cm into mm, that is, we are switching prefixed. In order to do this, you need two conversion factors: $\frac{1 \times 10^{-2} m}{1 cm}$ and $\frac{1 \times 10^{-3} m}{1 mm}$. You will have to arrange the number (20cm) and the two conversion factors in the following form:

$$20 \cancel{cm} \times \frac{1 \times 10^{-2} \cancel{m}}{1 \cancel{cm}} \times \frac{1 mm}{1 \times 10^{-3} \cancel{m}} = 2 \times 10^{2} mm$$

**STUDY CHECK**

Convert 100mm to km, expressing the result in scientific notation.

▶Answer: $100 \cancel{mm} \times \frac{1 \times 10^{-3} \cancel{m}}{1 \cancel{mm}} \times \frac{1 km}{1 \times 10^{3} \cancel{m}} = 1 \times 10^{-4} km.$

### *Units of volume and area*

How big is your apartment? You might be living in a $750 ft^2$ loft in Brooklyn or a larger house Upstate. Often times we encounter cubic or square units such as cubic centimeters ($cm^3$) or square feet ($ft^2$). The equivalencies for cubic or square units should take into account the unit power (power of two or power of three). If $1 cm = 1 \times 10^{-2} m$, for square units the relation should be squared and $1 cm^2 = 1 \times (10^{-2})^2 m^2 = 1 \times 10^{-4} m^2$. Another example, for the case of mm

and $mm^3$:

$$\boxed{\frac{1mm}{1\times10^{-3}m} \quad \text{and} \quad \frac{1mm^3}{1\times10^{-9}m^3}}$$

Let us work on an example in which we want to convert $30m^2$ into $m^2$:

$$30\cancel{m^2}\times\frac{1cm^2}{1\times10^{-4}\cancel{m^2}}=3\times10^5cm^2$$

**Sample Problem 4**

How many $m^2$ is $20cm^2$, expressing the result in scientific notation.

**SOLUTION**

In order to convert $20cm^2$ to square meters, we need to remove the centi prefix and that will give us the unit square meter without any prefix. We will use the conversion factor that relates $m^2$ to $cm^2$: $\frac{1\times10^{-4}m^2}{1cm^2}$ or $\frac{1cm^2}{1\times10^{-4}m^2}$.

$$20\cancel{cm^2}\times\frac{1\times10^{-4}m^2}{1\cancel{cm^2}}=2\times10^{-3}m^2$$

**STUDY CHECK**

Convert $100m^3$ to $dm^3$, expressing the result in scientific notation.

Answer: $100\cancel{m^3}\times\frac{1dm^3}{1\times10^{-3}\cancel{m^3}}=1\times10^5dm^3$.

**Table 2 Table containing some common unit equalities**

| Unit | Equality |
|---|---|
| Inches (in)-centimeters (cm) | $2.54^{\dagger}$ cm $=1$ in |
| miles (mi)-meters ($m$) | 1 mi $=1609.34$m |
| minutes (min)-hours (h) | 60 min $=1$ h |
| minutes (min)-seconds (s) | 60 s $=1$ min |
| pound (lb)-grams (g) | 454 g $=1$ lb |
| cubic centimeter ($cm^3$)-mililiters (mL) | 1 mL $=1$cm$^3$ |
| quart ($qt$)-milliliters (mL) | 1 qt $=946.353$mL |
| Liter (L)-cubic decimeters ($dm^3$) | 1 L $=1$dm$^3$ |
| drops-mililiters* (mL) | 1 mL $=15$ drops |

* There are several definitions of a drop

† the number is exact

### *Liters and milliliters*

Units such as L or mL are units of volume. As volume is a three-dimensional property, those units somehow have to be related to the units of length. One liter is the same as one $dm^3$ and one ml is the same as one $cm^3$ (See Figure **??**). In the allied health field, the units *mL* are also written as *cc* as in cubic centiliters.

$$\boxed{1L=1dm^3 \text{ and } 1mL=1cm^3(cc)}$$

Let us work on an example in which we want to convert $30cm^3$ into L:

$$30\cancel{cm^3}\times\frac{1\cancel{mL}}{1\cancel{cm^3}}\times\frac{1\times10^{-3}L}{1\cancel{mL}}=3\times10^{-2}L$$

Sample Problem 5

Convert 30 $m^3$ into L, expressing the result in scientific notation.

**SOLUTION**

In order to convert $m^3$ into L we just need to remember that the L actually refers to $dm^3$, therefore is connected to meter. We will first convert $m^3$ into $dm^3$ and then $dm^3$ into L.

$$30\cancel{m^3} \times \frac{1\cancel{dm^3}}{1 \times 10^{-3}\cancel{m^3}} \times \frac{1L}{1\cancel{dm^3}} = 3 \times 10^4 L$$

**STUDY CHECK**

Convert 40L to $cm^3$, expressing the result in scientific notation.

▶Answer: $40\cancel{L} \times \frac{1\cancel{mL}}{1 \times 10^{-3}\cancel{L}} \times \frac{1cm^3}{1\cancel{mL}} = 4 \times 10^4 cm^3$.

### *Using other equalities*

How many hours are 300 minutes, or how many centimeters is 2 inches? Some of the units conversion is not based on a power of ten relationships and do not contain prefixes such as kilo or centi. Table 2 lists some of the common equalities that can be easily converted into conversion factors. As an example, the unit equivalency between hours and minutes is $60min = 1h$ and the conversion factor would be $\frac{60min}{1h}$ or $\frac{1h}{60min}$.

Sample Problem 6

Convert 20 in to cm, expressing the result in scientific notation.

**SOLUTION**

We want to convert 20 inches into centimeters. The relationship between Inch and centimeter is given in Table 2. In order to do this, you need the conversion factor: $\frac{1in}{2.54cm}$ or $\frac{2.54cm}{1in}$. You will have to arrange the number (20 in) and the conversion factor in the following form:

$$20\cancel{in} \times \frac{2.54cm}{1\cancel{in}} = 5.080 \times 10^1 cm$$

**STUDY CHECK**

Convert 200mL to drops, expressing the result in scientific notation.

▶Answer: $200\cancel{mL} \times \frac{15drops}{1\cancel{mL}} = 3000drops = 3 \times 10^3 drops$

## D. Procedure

**1. Significant figures in additions and subtractions** The goal of this mini-experiment is to familiarize with the use of significant figures in basic calculations. When faced with an addition or subtraction calculation, the rule says that the final number has to have the same number of decimal places as the number with the fewest decimal places. Carry the following calculations and give the result with the correct number of decimal places or significant figures.

*Step 1:* – Analyze each number separately and among all numbers identify the less number of decimal places.

*Step 2:* – Analyze each number separately and among all numbers identify the less number of significant figures (SFs).

*Step 3:* – Write down the final result with the correct number of decimals or SFs using the rounding rules (If the number you are rounding is followed by 5, 6, 7, 8, or 9, round the number up)

**2. Significant figures in multiplications and divisions** The goal of this mini-experiment is, again, to familiarize with the use of significant figures in basic calculations. When faced with multiplications and divisions, the rule says that the final number has to have the same number of SFs as the number with the fewest SFs. Carry the following calculations and give the result with the correct number of decimal places or significant figures.

*Step 1:* – Analyze each number separately and among all numbers identify the less number of decimal places.

*Step 2:* – Analyze each number separately and among all numbers identify the less number of significant figures (SFs).

*Step 3:* – Write down the final result with the correct number of decimals or SFs using the rounding rules (You can replace a digit by zero to eliminate significant figures: 123(3SF)≈100(1SF))

**3. Measuring volume** In this mini-experiment learn how to properly compute volume using the right number of SF's.

*Step 1:* – Obtain a rectangular wood piece from the lab. Obtain one piece per team.

*Step 2:* – With a ruler measure the length of the sides of the rectangular piece of wood in cm.

*Step 3:* – Compute the volume by multiplying the length, heigh and depth using the right number of SF's and digits.

*Step 4:* – Compare your result with the other students in the team and write them down below. Do you get the same result?

**4. Simple conversion factors** This mini-experiment will help you out learn how to carry simple conversion factors. In particular, how to remove and add a prefix.

*Step 1:* – Fill the gap in the calculations displayed in the results section. Remember to place 1 in front of the unit with prefix (cm) and the corresponding power of ten in from of the unit (m).

**5. Non-metric conversions** This mini-experiment deals with non-metric units and their conversion to metric-based units. An example of this is inches which are 2.54cm. One can convert from non-metric In into centimeter–a metric-based unit. Below is a list of a few non-metric units

$$\boxed{1\text{in} = 2.54cm \quad 1\text{lb} = 454g \quad 1\text{qt} = 946mL}$$

*Step 1:* – Using a metric-based ruler and a string, measure the size of your wrist in cm. Write down your results in the table below.

*Step 2:* – Using an inch-based ruler and a string, measure the length of your wrist in In. Write down your results in the table below.

*Step 3:* – Set up the conversion factor below to convert cm into inches.

$$\_\_\_\_cm \times \frac{\_\_\_\_}{\_\_\_\_} = \_\_\_\_in$$

*Step 4:* – Write down the results in the table below.

*Step 5:* – Calculate the percent error using the formula (make sure you use absolute value). Write down your results in the table below:

$$\%\ \text{Error} = \left| \frac{\textcircled{2} - \textcircled{1}}{\textcircled{1}} \right| \times 100$$

*Step 6:* – Compare your error with the other students in the team and write them down below. Do you get similar errors?

**6. Non-metric conversions for volume** This mini-experiment deals with non-metric volume units and their conversion to metric-based units. One can convert from non-metric qt (quart) into L–a metric-based unit. Below is a list of a few non-metric units

$$\boxed{1\text{L} = 1.057qt}$$

*Step 1:* – Measure 1qt of water and transfer it to a 1L graduated cylinder.

*Step 2:* – Read the volume meaurement from the 1L graduated cylinder.

*Step 3:* – Set up the conversion factor below to convert qt into L.

$$\_\_\_\_qt \times \frac{\_\_\_\_}{\_\_\_\_} = \_\_\_\_L$$

*Step 4:* – Write down the results in the table below.

*Step 5:* – Calculate the percent error using the formula (make sure you use absolute value). Write down your results in the table below:

$$\%\text{ Error} = \left|\frac{(2)-(1)}{(1)}\right| \times 100$$

*Step 6:* – Compare your error with the other students in the team and write them down below. Do you get similar errors?

**STUDENT INFO**

Name: _____ Date: _____

**Pre-lab Questions**

# Conversion Factors and Problem Solving

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1. Fill in the gaps for the following conversion equalities:

| | | |
|---|---|---|
| 1 Kg | = | _____g |
| _____ Km | = | $10^3$m |
| 1 cm | = | _____m |
| _____ dm | = | $10^{-1}$m |
| 1 Tb | = | _____b |
| _____ $\mu$L | = | $10^{-6}$L |

2. Fill in the gaps for the following conversion factors:

$$\frac{1fs}{\qquad s} \qquad \frac{\qquad cm}{10^{-2}m} \qquad \frac{1nm}{\qquad m} \qquad \frac{1Kcal}{\qquad cal}$$

3. Round the following numbers to the indicated number of decimal places or significant figures. Mind, the rules for rounding say that if the first digit to be dropped is more or equal to five (0.262) the value of the retained digit should be increased by one ($\approx 0.3$ one decimal place).

| | | | |
|---|---|---|---|
| 157.68 | $\approx$ | _____ | (one decimal place) |
| 47.807 | $\approx$ | _____ | (two decimal places) |
| 1200 | $\approx$ | _____ | (one significant figure) |

4. Do the following calculations with the correct number of significant figures. Mind when adding or substring numbers the results has to have the same number of digits as the number in the calculation with the fewest decimal places.

| | | |
|---|---|---|
| 123.1+34.58 | = | _____ |
| 45.567+2.24 | = | _____ |

5. Do the following calculations with the correct number of significant figures. Mind when multiplying or dividing numbers the results has to have the same number of significant figures as the number in the calculation with the number of significant figures.

$100 \times 12$ = _____

$0.34/3.56$ = _____

**STUDENT INFO**

Name: _____ Date: _____

**Results**
**EXPERIMENT**

# Conversion Factors and Problem Solving

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## 1. Significant figures in additions and subtractions

| Calculation | Fewest # of SFs | Fewest # of decimals | Result |
|---|---|---|---|
| $45.3 + 12.63$ | | | |
| $45.3 + 12.23$ | | | |
| $45.33 + 12.456$ | | | |
| $45 + 12.12 - 23.2$ | | | |

## 2. Significant figures in multiplications and divisions

| Calculation | Fewest # of SFs | Fewest # of decimals | Result |
|---|---|---|---|
| $1700/123$ | | | |
| $0.1245 \times 2.00 \times 0.0367$ | | | |
| $54.87 \times 4.56/0.4$ | | | |

## 3. Measuring volume

| Length | Height | Depth | Volume, $cm^3$ |
|---|---|---|---|
| | | | |

## 4. Simple conversion factors

$$20m \times \frac{1cm}{\quad m} = 2000cm \qquad 76g \times \frac{1Kg}{\quad g} = 0.076Kg$$

$$40L \times \frac{1mL}{\quad L} = 4 \times 10^4 mL \qquad 200\mu L \times \frac{10^{-6}L}{\quad \mu L} = 2 \times 10^{-4} L$$

$$5m \times \frac{\quad cm}{\quad m} = 500cm \qquad 1000g \times \frac{\quad Kg}{\quad g} = 1Kg$$

$$0.4cm \times \frac{\quad m}{\quad cm} = 4 \times 10^{-3} m \qquad 100g \times \frac{\quad Kg}{\quad g} = 0.1Kg$$

$300Gb \times \frac{\quad b}{\quad Gb} = \quad b$ $200mm \times \frac{\quad m}{\quad mm} = \quad m$

$50m \times \frac{\quad dm}{\quad m} = \quad dm$ $5g \times \frac{\quad Kg}{\quad g} = \quad Kg$

$300nm \times \frac{\quad}{\quad} = \quad m$ $500Kg \times \frac{\quad}{\quad} = \quad g$

$70Tb \times \frac{\quad}{\quad} = \quad b$ $500mL \times \frac{\quad}{\quad} = \quad L$

**5. Non-metric conversions**

| **Measured Length (cm)** | **Measured Length (in)** | **Converted Length (in)** | **% Error** |
|---|---|---|---|
| | (1) | (2) | |

**6. Non-metric conversions for volume**

| **Measured volume (qt)** | **Measured volume (L)** | **Converted volume (L)** | **% Error** |
|---|---|---|---|
| | (1) | (2) | |

**STUDENT INFO**

Name: _____ Date: _____

**Post-lab Questions**

# Conversion Factors and Problem Solving

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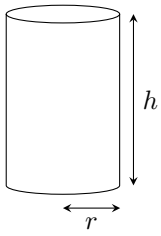
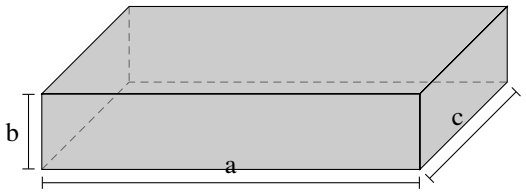
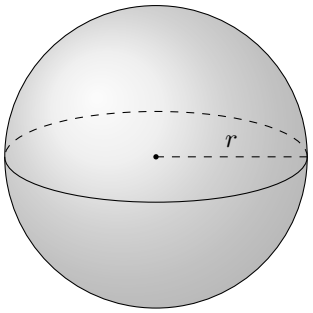
1. Convert $100\mu L$ into L.

2. Using a ruler in cm, calculate the volume of the following object with the correct number of digits or SFs:




$$v_{cylinder} = \pi r^2 \times h \qquad v_{cube} = a \times b \times c \qquad v_{sphere} = \frac{3}{4} \times \pi r^3$$