Introduction to Chemistry

A. Unit Conversions

1. In Chemistry 11 and 12, a mathematical method called **Unit Conversions** will be used extensively. This method uses **CONVERSION FACTORS** to convert or change between different units.

> a **CONVERSION FACTOR** is a fractional expression relating or connecting two different units.

e.g. If **1 min = 60 s** then expressed as a fraction two conversion factors are given:

$$\frac{1\ \text{min}}{60\ \text{s}} \text{ and } \frac{60\ \text{s}}{1\ \text{min}}$$

Since the top part **EQUALS** the bottom part, **this fraction has a value equal to "1"**. Multiplying any expression by this conversion is the same as multiplying by "1" and therefore **WILL NOT CHANGE** the value of the expression.

EXAMPLE II.1	USING CONVERSION FACTORS
Problem:	How many minutes are there in 3480 seconds?
Solution:	$\# \text{ minutes} = 3480\ \text{s} \times \frac{1\ \text{min}}{60\ \text{s}} = \mathbf{58\ min}$

2. The method of unit conversions uses conversion factors to change the units associated with an expression to a different set of units.

   Every unit conversion problem has three major pieces of information which must be identified:

   i. the unknown amount and its **UNITS**,
   ii. the initial amount and its **UNITS**, and
   iii. a conversion factor which relates or connects the initial **UNITS** to the **UNITS** of the unknown.

ALL calculations must **ALWAYS** include the units.

e.g. What is the cost of 2 dozen eggs if eggs are $1.44/doz?

What is the cost	of 2 doz eggs	if eggs are $1.44/doz?
UNKNOWN AMOUNT	**INITIAL AMOUNT**	**CONVERSION**

Putting everything together completes the unit conversion.

$$\text{cost (\$)} = 2\ \text{doz} \times \frac{\$1.44}{\text{doz}} = \mathbf{\$2.88}$$

Notice that the unit “doz” cancels.

e.g. If a car can go 80 km in 1 h, how far can the car go in 8.5 h?

If a car can go 80 km in 1 h	how far can the car go	in 8.5 h?
CONVERSION	**UKNOWN AMOUNT**	**INITIAL AMOUNT**

$$\text{how far (km)} = 8.5\ \text{h} \times \frac{80\ \text{km}}{1\ \text{h}} = \mathbf{680\ km}$$

Note that the unit "h" cancels.

3. The general form of a unit conversion calculation is as follows:

(unknown amount) = (initial amount) x (conversion factor)

EXAMPLE II.2	**UNIT CONVERSION CALCULATIONS**
Problem:	If 0.200 mL of gold has a mass of 3.86 g, what is the mass of 5.00 mL of gold?
Solution:	Unknown amount and unit = mass (g) Initial amount and unit = 5.00 mL Conversion factors 0.200 mL = 3.86 g, so $\frac{0.200\ \text{mL}}{3.86\ \text{g}}$ and $\frac{3.86\ \text{g}}{0.200\ \text{mL}}$ Putting everything together $\text{mass (g)} = 5.00\ \text{mL} \times \frac{3.86\ \text{g}}{0.200\ \text{mL}} = \mathbf{96.5\ g}$

EXAMPLE II.3	**UNIT CONVERSION CALCULATIONS**
Problem:	If 0.200 mL of gold has a mass of 3.86 g, what volume is occupied by 100.0 g of gold?
Solution:	Unknown amount and unit = volume (mL) Initial amount and unit = 100.0 g Conversion factors 0.200 mL = 3.86 g, so $\frac{0.200\text{ mL}}{3.86\text{ g}}$ and $\frac{3.86\text{ g}}{0.200\text{ mL}}$ Putting everything together volume (mL) = 100.0 g x $\frac{0.200\text{ mL}}{3.86\text{ g}}$ = **5.18 mL**

4. All of the previous problems have involve a single conversion factor; however, it is possible to **two or even more conversion factors in the same calculation.**

   e.g. If eggs are $1.44/doz, and if there are 12 eggs/doz, how many individual eggs can be bought for $4.32?

   UNKNOWN AMOUNT = how many eggs (eggs)

   INITIAL AMOUNT = $4.32

   CONVERSION FACTORS:

   Ideally, we would like

   $$(\$) \rightarrow (\text{eggs})$$

but since we don't have this conversion factor we must first convert

$$(\$) \rightarrow (\text{doz})$$

and then

$$(\text{doz}) \rightarrow (\text{eggs})$$

Putting it all together,

$$\text{how many eggs (eggs)} = \$4.32 \times \frac{\text{doz}}{\$1.44} \times \frac{12\text{ eggs}}{1\text{doz}} = \textbf{36 eggs}$$

EXAMPLE II.4	MULTIPLE UNIT CONVERSION CALCULATIONS
Problem:	The automobile gas tank of a Canadian tourist holds 39.5 L of gas. If 1 L of gas is equal to 0.264 gal in the United States and gas is \$1.26/gal in Dallas, Texas, how much will it cost the tourist to fill his tank in Dallas?
Solution:	Unknown amount and unit = cost (\$) Initial amount and unit = 39.5 L Conversion factors 1 L = 0.264 gal and \$1.26/gal Putting everything together $\text{cost (\$)} = 39.5\text{ L} \times \frac{0.264\text{ gal}}{1\text{L}} \times \frac{\$1.26}{1\text{ gal}} = \textbf{\$13.1}$

B. SI Units

1. The International System (SI) of metric units has numerous “base units”. A “base unit” is a basic unit of measurement; all other units are multiples of the base units or combinations of base units.

Base Units

QUANTITY	WRITTEN UNIT	UNIT SYMBOL
length	metre	m
mass	gram	g
time	second	s
amount of substance	mole	mol
volume	litre	L
mass	tonne	t

2. Multiples of base units are produced by multiplying the base unit by some factor of 10 or its exponential equivalent.

Multiples Of Base Units

WRITTEN PREFIX	PREFIX SYMBOL	EQUIVALENT EXPONENTIAL
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deka	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}

OTHER IMPORTANT EQUIVALENCES

$$1 \text{ mL} = 1 \text{ cm}^3$$

$$1 \text{ m}^3 = 10^3 \text{ L}$$

$$1 \text{ t} = 10^3 \text{ kg}$$

EXAMPLE II.5	**PREFIXES, UNIT SYMBOLS, AND EXPONENTS**
Problem:	Re–write the expression “5 kilograms” using (a) Prefix and Unit symbol and (b) Exponential Equivalent.
Solution:	(a) 5 kilogram = **5 kg** (b) Since the exponential equivalent of “kilo” and “k” is “10^3” 5 kilogram = **5 x 10^3 g**

EXAMPLE II.6	**PREFIXES, UNIT SYMBOLS, AND EXPONENTS**
Problem:	Re–write the expression “2 ms” using (a) Written Prefix and Unit and (b) Exponential Equivalent.
Solution:	(a) 2 ms = **2 milliseconds** (b) Since the exponential equivalent of “milli” and “m” is “10^{-3}” 2 ms = **2 x 10^{-3} g**

EXAMPLE II.7	**PREFIXES, UNIT SYMBOLS, AND EXPONENTS**
Problem:	Re–write the expression “2.7 x 10^{-2} m” using (a) Written Prefix and Unit and (b) Prefix and Unit symbol.
Solution:	(a) Since “10^{-2}” is equivalent to “centi” and “m” = metre 2.7 x 10^{-2} m = 2.7 centimetre (b) 2.7 x 10^{-2} m = 2.7 cm

3. The following multiples are used far less frequently.

WRITTEN PREFIX	PREFIX SYMBOL	EQUIVALENT EXPONENTIAL
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-12}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

C. Metric Conversions

1. Metric conversions involve using unit conversions between prefix symbols and exponential equivalents.

   e.g. (a) Write a conversion statement between **cm** and **m**.

   since "c" stands for "10^{-2}" then $1 \text{ cm} = 10^{-2} \text{ m}$

   (b) Write a conversion statement between **ms** and **s**.

   since "m" stands for "10^{-3}" then $1 \text{ ms} = 10^{-3} \text{ s}$

EXAMPLE II.8	**METRIC CONVERSIONS**
Problem:	How many micrometres are there in 5 cm?
Solution:	**UNKNOWN AMOUNT** = how many micrometres (μm) **INITIAL AMOUNT** = 5 cm **CONVERSION:** (cm) → (m) → (μm) $1 \text{ cm} = 10^{-2} \text{ m}$ $1 \mu\text{m} = 10^{-6} \text{ m}$ Putting it all together $(\mu\text{m}) = 5 \text{ cm} \times \frac{10^{-2} \text{ m}}{1 \text{ cm}} \times \frac{1 \mu\text{m}}{10^{-6} \text{ m}} = 5 \times 10^{4} \mu\text{m}$ Notice that all the given prefix symbols are directly related to the "base unit". In order to connect two metric prefixes, connect them to the base unit first.

EXAMPLE II.9	**METRIC CONVERSIONS**
Problem:	How many milligrams is 8 kg?
Solution:	**UNKNOWN AMOUNT** = how many milligrams (mg) **INITIAL AMOUNT** = 8 kg **CONVERSION:** $(kg) \rightarrow (g) \rightarrow (mg)$ $1\ kg = 10^3\ g$ $1\ mg = 10^{-3}\ g$ Putting it all together $(mg) = 8\ kg \times \frac{10^3\ g}{1\ kg} \times \frac{1\ mg}{10^{-3}\ g} = 8 \times 10^6\ mg$

EXAMPLE II.10	**METRIC CONVERSIONS**
Problem:	Express 5 Mg/mL in kilograms/litre
Solution:	**UNKNOWN AMOUNT** = how many kilograms/litre (kg/L) **INITIAL AMOUNT** = 5 Mg/mL **CONVERSION:** (Mg) → (g) → (kg) 1 Mg = 10^6 g 1 kg = 10^3 g (mL) → (L) 1 mL = 10^{-3} L Putting it all together, $\frac{\text{kg}}{\text{L}} = \frac{5\text{ Mg}}{1\text{mL}} \times \frac{10^6\text{ g}}{1\text{ Mg}} \times \frac{1\text{ kg}}{10^3\text{ g}} \times \frac{1\text{ mL}}{10^{-3}\text{ L}} = 5 \times 10^6\text{ kg/L}$

D. Derived Quantities

1. A **DERIVED QUANTITY** is a number made by combining two or more other values. A **DERIVED UNIT** is a unit which is made by combining two or more other units.

   e.g. The heat change occurring when the temperature of a water sample increases is given by

$$\Delta H = c \bullet m \bullet \Delta T$$

   where: ΔH = the change in heat; "Δ" is the Greek letter "delta" and is used to indicate "the change in" (ΔH is measured in joules, **J**).

   m = the mass of water being heated (**g**).

   ΔT = the change in temperature of the water (**°C**)

   and c = a derived quantity called the specific heat capacity, which can be calculated by rearranging the above equation.

$$c = \frac{\Delta H}{m \text{ x } \Delta T}$$

   The units of **c** are derived by substituting the units of each symbol into the equation. For example, using the values: $\Delta H = 4.02 \text{ x } 10^4$ J, m = 175 g, and ΔT = 55.0 °C gives

$$c = \frac{4.02 \text{ x } 10^4 \text{ J}}{175 \text{ g x } 55.0 \text{ °C}} = 4.18 \frac{\text{J}}{\text{g x °C}}$$

   Therefore, ***c*** is a **derived quantity**, having **derived units**, found by combining three other quantities (*ΔH, m,* and *ΔT*) and their units.

E. Density

1. Density is derived quantity that describes the mass contained in a given volume. Mass is the quantity of matter in an object.

$$d = \frac{m}{V}$$

where: d = density

m = mass

V = volume

If mass is measured in grams (g) and volume in litres (L), the units of density are:

$$d = \frac{mass\ (g)}{Volume\ (L)} = \frac{g}{L}$$

2. Density calculations involve substituting information into the density equation after rearranging the equation to solve for the unknown.

EXAMPLE II.11	**DENSITY CALCULATIONS**
Problem:	(a) An iron bar has a mass of 19 600 g and volume of 2.50 L. What is the iron's density? (b) If mercury has a density of 13 600 g/L, what volume of (in mL) is occupied by 425 g of mercury?
Solution:	(a) Substitute into the density equation. $d = \frac{m}{V} = \frac{19600 \text{ g}}{2.50 \text{ L}} = 7.84 \times 10^3 \text{ g/L}$ (b) Rearrange density equation to solve for V $V = 425 \text{ g} \times \frac{\text{L}}{13600 \text{ g}} \times \frac{1000 \text{ mL}}{\text{L}} = \mathbf{31.3 \text{ mL}}$

IMPORTANT FACT

for water at 4 °C, the density = 1000.0 g/l or 1.0000 g/ml

note that measuring the volume of a sample of water allows you to immediately know its mass, and vice versa. so for water at 4 °C,

1 g = 1 ml

LESS DENSE LIQUIDS AND OBJECTS WILL FLOAT ON LIQUIDS HAVING A GREATER DENSITY

Objects will sink in a liquid if $\mathbf{d_{OBJECT} > d_{Liquid}}$

Objects will float in a liquid if $\mathbf{d_{OBJECT} < d_{Liquid}}$

F. Significant Figures

1. When **COUNTING** a small number of objects it is not difficult to find the **EXACT** number of objects; however, when a property such as mass, volume, time, or length is **MEASURED** it is **impossible** to find the exact value because **all measurements have a certain amount of "uncertainty"** associated with them. Measurements will have a certain number of **SIGNIFICANT FIGURES** or **SIGNIFICANT DIGITS.**

A **SIGNIFICANT FIGURE** is a **measured** or **meaningful digit**

All of the digits in a measurement are considered **certain** with the **final digit considered uncertain** or a "best guess". Collectively, all the certain digits PLUS the first uncertain digit are counted as significant figures.

e.g. If a stopwatch is used to time an event and the elapsed time is **35.2** s, then the measurement has 3 significant figures (3, 5, and 2).

e.g. A balance gives a reading of 97.53 g when a beaker is placed on it. This reading has 4 significant figures since it contains 4 digits.

2. When a measurement is reported it is usual to assume that numbers such as

10, 1100, 120, 1000, 12 500

any zeroes at the end are not significant **when no decimal point is shown**. That is, we assume the last digits are zeroes because they are rounded off to the nearest 10, 100, 1000, etc.

10 (1 sf), 1100 (2 sf), 120 (2 sf), 1000 (1 sf), 12 500 (3 sf)

Furthermore, SI usage dictates that a decimal point cannot be used without a following digit. For example,

10.0 and 100.0

are proper examples of SI usage with 3 and 4 significant figures, but

100. and 1000.

are "improper" ways of showing numbers. If you need to show that a number has been measured to 3 significant figures and has a value of 100 or that the number 1000 has 4 significant figures, then it must be written in exponential notation.

$1.00 \times 10^2 = 100$ (to 3 significant figures)

$1.000 \times 10^3 = 1000$ (to 4 significant figures)

EXAMPLE II.12	**SIGNIFICANT FIGURES**
Problem:	How many significant figures do each of the following measurements have? 52.3 g, 1800 mL, 0.09835 m, 12.574 cm, 2.480 x 10^5 ms
Solution:	3 sf, 2 sf, 4 sf, 5 sf, 4 sf

3. Measurements are often described as **ACCURATE** or **PRECISE**. These two terms are often used interchangeably; however, they do not mean the same thing.

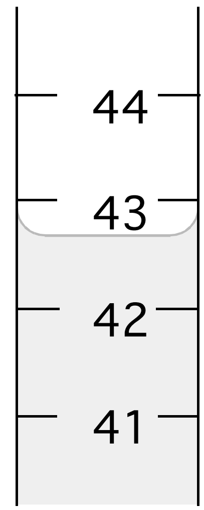
An **ACCURATE** measurement is one that is **close to the correct or accepted value.** (The closer to the correct/accepted value, the more accurate the measurement.)

A **PRECISE** measurement is a **reproducible** measurement. In general, the more precise a measurement, the more significant digits it has.

4. Recall,

The **number** of significant figures is equal to all the certain digits PLUS the **first uncertain** digit.

In the figure at right, the liquid level is somewhere between 42 mL and 43 mL. We know it is at least 42 mL, so we are certain about the first 2 digits. We might estimate that the volume is 42.6 mL; it could be between 42.5 mL or 42.7 mL. The final digit is a guess and is therefore uncertain. Collectively, the 2 certain and 1 uncertain digit are significant. The measurement 42.6 mL has 3 significant figures.



Whenever you are given a measurement without being told something about the device used to obtain the measurement, assume that the **LAST DIGIT GIVEN IS SOMEWHAT UNCERTAIN.**

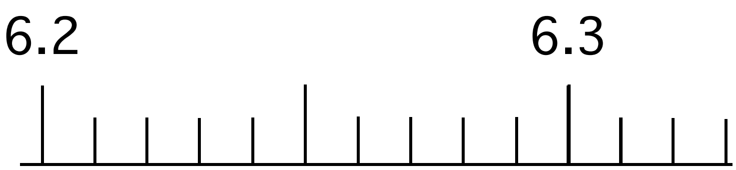
5. **"DEFINED"** numbers and **"COUNTING"** numbers are assumed to be **PERFECT** so that they are **"exempt"** from the rules applying to significant figures (i.e., they have no uncertainty).

e.g. When "1 book" or "4 students" is written, it means exactly "1 book" or "4 students", not 1.06 books or 4.22 students.

The conversion factor 1 kg = 1000 g defines an exact relationship, so the numbers are assume to be perfect.

6. When reading a measurement from a scale, each unnumbered division is **CALIBRATED** or **“marked off”** at regular intervals. The value of each unnumbered is equal to the difference between the numbered divisions divided by the number of subdivisions.

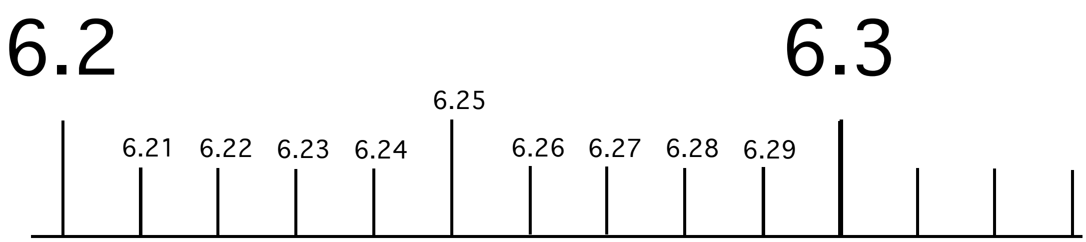
Consider the following scale:



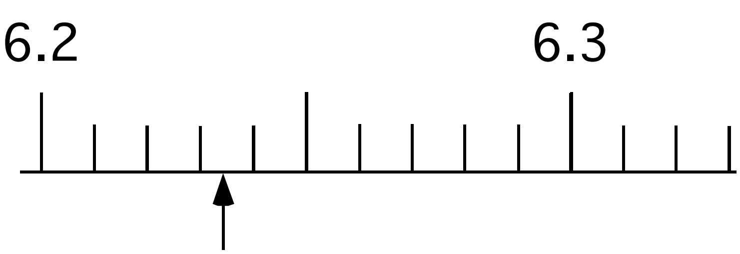
There are 10 subdivisions between 6.2 and 6.3, so each subdivision has a value of

$$\text{subdivision} = \frac{0.1}{10} = 0.01$$

Therefore, we can imagine the subdivisions to be as follows:

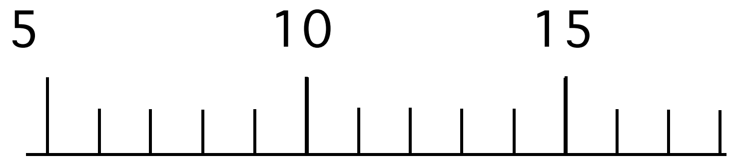


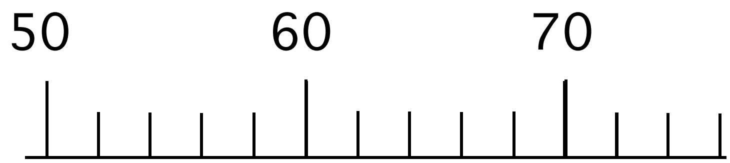
When reading a measurement from a scale, the final digit should be estimated at $^{1}/_{10}$ of the smallest division or subdivision on the scale.

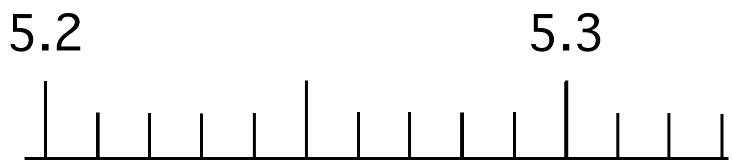


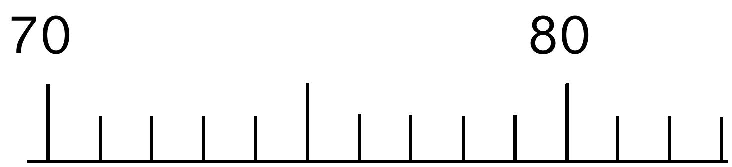
This should be read as 6.23**4** cm

e.g. Read the following measurements









7. When determining the number of significant figures a measurement has, **LEADING ZEROES** are **NOT SIGNIFICANT** but **TRAILING ZEROES** are **SIGNIFICANT**.

0.0**253** kg has **3** significant figures
67.90 cm has **4** significant figures
0.0**870** mm has **3** significant figures

To avoid confusion express numbers in scientific notation in which case **all digits in the number portion are significant.**

2.53 x 10^{-2} kg has **3** significant figures
6.790 x 10^{1} cm has **4** significant figures
8.70 x 10^{-2} mm has **3** significant figures

8. After **MULTIPLYING** or **DIVIDING** numbers, round off the answer to the **LEAST NUMBER OF SIGNIFICANT** contained in the calculation.

2.53 x 3.1675 = **8.01**3775

When multiplying two numbers like

5.0 x 20.0 = **10**0 is wrong (1 significant figures)
5.0 x 20.0 = **1.0** x 10^{2} is correct (2 significant figures)

When there are more than 2 numbers in a calculation, **round off the answer to the fewest number of significant figures used in the calculation.**

$$\frac{15.55 \times 0.0\mathbf{12}}{24.6} = 0.0075853659 = 0.00\mathbf{76}$$

$$\frac{2.56 \times 10^{5}}{\mathbf{8.1} \times 10^{8}} = 3.1604938 \times 10^{-4} = \mathbf{3.2} \times 10^{-4}$$

Always perform calculations to the **maximum number of significant figures** allowed by your calculator and only your **FINAL ANSWER** should be rounded to the correct number of significant figures. Rounding off immediate answers will often lead to rounding errors and incorrect answers.

9. When **ADDING** or **SUBTRACTING** numbers, round off the answer to the **LEAST NUMBER OF DECIMAL PLACES** contained in the calculation.

12.5 | 6 cm + 125.8 | cm ——————— 138.3 | 6 cm	This answer should be rounded to **1** decimal place, so the answer is **138.4 cm**
41.037 6 | g - 41.037 5 | 84 g ——————— 0.000 0 | 16 g	This answer should be rounded to **4** decimal places, so the answer to the correct sig figs is **0.0000 g**

$$1.234 \times 10^6 \ \ x \ \ 4.568 \times 10^7 = ?$$

Since the exponents are different, **the smaller exponent must be changed to equal the larger exponent.**

$$0.1234 \times 10^7 + 4.\mathbf{568} \times 10^7 = 4.\mathbf{691}4 \times 10^7$$

$$= 4.691 \times 10^7$$

When **multiplying** or **dividing** two numbers, the result is **rounded off to the least number of significant figures** used in the calculation.

When **adding** or **subtracting** two numbers, the result is **rounded off to the least number of decimal places** used in the calculation.