UNIT II : INTRODUCTION TO CHEMISTRY

Before you learn how to make stinks and bangs in your chemistry lab, there are a few tiny little details to attend to ... such as how to read the scales on the equipment you will be using, how to handle the units used in Chemistry 11 and how to decide how good your data is. This unit gives you the background needed for the remainder of Chemistry 11.

II.1. UNIT CONVERSIONS

This section shows how to use a mathematical method called Unit Conversions which will be used extensively in Chemistry 11 and 12. Initially, you will be solving relatively easy problems. **Avoid the temptation to solve the problems by your own method; you should learn the Unit Conversion method.** OK, let's get on with the game.

If eggs are $\frac{\$1.44}{1\text{ doz}}$, another way to say this is that eggs are $\frac{1\text{ doz}}{\$1.44}$.

> The statement "$1.44 per dozen" allows us to RELATE or CONNECT one amount ($1.44) to another amount (1 dozen). Both
>
> $$\frac{\$1.44}{1\text{ doz}} \text{ and } \frac{1\text{ doz}}{\$1.44}$$
>
> make the same connection implied by the statement:
>
> $$\$1.44 = 1\text{ doz}$$
>
> where the "=" sign here is interpreted as "**IS EQUIVALENT TO**".

Definition: A **CONVERSION FACTOR** is a fractional expression relating or connecting two different units.

Examples:

STATEMENT FORM	CONVERSION FACTORS
1 min = 60 s	$\frac{1\text{ min}}{60\text{ s}}$ and $\frac{60\text{ s}}{1\text{ min}}$
\$1 = 100 ¢	$\frac{\$1}{100\text{ ¢}}$ and $\frac{100\text{ ¢}}{\$1}$

Look at one of the conversion factors that relate "minutes" to "seconds".

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

1 min ← the TOP part
EQUALS
60 s ← the BOTTOM part

Dividing "1 min" by something **EQUAL TO** 1 min produces **a fraction with a value equal to "1".** Multiplying any expression by this conversion factor is equivalent to multiplying by "1" and therefore WILL NOT CHANGE THE VALUE of the expression. The next example shows how a conversion factor is used.

EXAMPLE: **How many minutes are there in 3480 seconds?**

$$\text{\# of minutes} = 3480\ \text{s} \times \frac{1\ \text{min}}{60\ \text{s}} = 58\ \text{min}$$

Both "60 s" and "1 min" are the same length of time (multiplying by the conversion factor didn't change the VALUE of the time). However, the units are different after using the conversion factor: the question starts with a ***large number*** of **SMALL** time units and ends up with a ***small number*** of **LARGE** time units.

> **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.

INCREDIBLY, VITALLY IMPORTANT NOTE!

In all the calculations which follow you must **ALWAYS** include the units, for they are the "major players" in the calculation. If you are tempted to omit or "forget about" the units, DON'T! The course you fail could be Chem 11!

EXAMPLES: a) **What is the cost of 2 doz eggs if eggs are $1.44/doz?**

The first thing to do is tear this problem apart and analyze the information it contains.

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

The **UNKNOWN AMOUNT and its UNIT:**

- The unknown is identified in ***the phrase which asks the question***. In this problem the UNKNOWN is the "cost".
- Since the only unit of "cost" mentioned in the problem is **dollars** ($1.44/doz), use this unit with the unknown amount.

UNKNOWN AMOUNT = # of dollars

The **INITIAL AMOUNT and its UNIT:**

- It is in a PHRASE CONNECTED OR DIRECTLY RELATED TO THE PHRASE CONTAINING THE UNKNOWN — "What is the cost ***of*** 2 doz eggs ...". Notice that in this case the word "of" connects the unknown amount to the initial amount.
- It is a number with a **SINGLE UNIT** ("doz"). The only other number mentioned, $1.44/doz, involves two units.

INITIAL AMOUNT = 2 doz

The **CONVERSION STATEMENT:**

- involves TWO DIFFERENT UNITS ("$" and "doz"), AND
- is a separate statement which does not involve a question.

The conversion statement gives the information needed to make the conversion factor. The possible conversion factors are

$$\frac{\$1.44}{1\ \text{doz}} \text{ and } \frac{1\ \text{doz}}{\$1.44}.$$

PUTTING EVERYTHING TOGETHER completes the unit conversion. (If you follow what happens here, fine. Otherwise, don't worry; you will be shown how to "put everything together" next.)

$$\# \text{ of dollars} = 2\ \cancel{\text{doz}} \times \frac{\$1.44}{1\ \cancel{\text{doz}}} = \mathbf{\$2.88}$$

Notice that the unit "doz" cancels

b) If a car can go 80 km in 1 h, how far can the car go in 8.5 h?

Again, dissect the sentence.

If a car can go 80 km in 1 h,	how far can the car go	in 8.5 h?
CONVERSION STATEMENT	UNKNOWN AMOUNT	INITIAL AMOUNT

The **UNKNOWN AMOUNT and its UNIT:** The part of the sentence which asks the question ("how far can the car go") implies that the unknown is a distance. Since the only unit of distance mentioned is "km" ("80 **km** in one hour"), use this as the distance unit.

UNKNOWN AMOUNT = # of kilometres

The **INITIAL AMOUNT and its UNIT:** The initial amount, 8.5 h, is connected directly to the unknown — "how far can the car go ***in*** 8.5 h" — and has a single unit ("h").

INITIAL AMOUNT = 8.5 h

The **CONVERSION STATEMENT:** This statement is recognized because it

- makes a statement involving a number with no question asked or implied, AND
- mentions two different units (km and h).

The possible conversion factors are

$$\frac{80\text{ km}}{1\text{ h}} \text{ and } \frac{1\text{ h}}{80\text{ km}}.$$

PUTTING EVERYTHING TOGETHER in a complete unit conversion:

$$\# \text{ of kilometers} = 8.5\ \cancel{\text{h}} \times \frac{80\text{ km}}{1\ \cancel{\text{h}}} = \mathbf{680\ km}.$$

Again, note that the unit "h" cancels.

EXERCISE:

1. For each of the following problem statements identify
   - the unknown amount and its unit,
   - the initial amount and its unit, and
   - the conversion factors and their units.

   (You aren't required to put everything together and solve the problem yet... that comes next.)

   a) If a chemical costs $50 per gram, what is the cost of 100 g of the chemical?
   b) Computer disks cost $6.00 for 10 disks. How many disks can you buy for $36.00?
   c) Cork has a density of 0.35 g/mL. What is the volume of 20 g of cork?
   d) If 3 kiwi fruit sell for $1, how many kiwi fruit can you buy for $5?
   e) If 4 bims are worth 5 tuds, how many bims can you buy for 30 tuds?
   f) A farmer trades 2 cows for 7 goats. At this rate, how many goats can he get for 10 cows?
   g) One mole of oxygen has a mass of 32 g. What is the mass of 5.5 moles of oxygen?
   h) One molecule of sulphur contains 8 sulphur atoms. How many sulphur molecules can be made from 104 sulphur atoms?
   i) How long must an electrical current of 35 coulombs/s flow in order to deliver 200 coulombs?
   j) What temperature increase is caused by 100 kJ of heat if 4.18 kJ of heat causes a 1 $^{\circ}$C increase in temperature?

HOW TO PUT EVERYTHING TOGETHER

The method of unit conversions may seem a little awkward at first, but later it will allow you to solve some complicated problems **in one line. Also, it is "SELF-CHECKING", allowing you to check the "correctness" of your results!**

The general form of a unit conversion calculation is shown below.

(UNKNOWN AMOUNT) = (INITIAL AMOUNT) X (CONVERSION FACTOR)

EXAMPLES: a) **If 0.200 mL of gold has a mass of 3.86 g, what is the mass of 5.00 mL of gold?**

The **UNKNOWN AMOUNT and its UNIT**: The question asks "What is the mass", which suggests finding "# of grams".

The **INITIAL AMOUNT and its UNIT** is "5.00 mL", which is tied to the unknown amount ("What is the mass") by the connector "of".

The **CONVERSION STATEMENT** is "If 0.200 mL of gold has a mass of 3.86 g". The amounts being connected are 0.200 mL and 3.86 g.

Now to solve the problem. Put the **unknown amount** on the **left** side of an "=" sign to identify what you are trying to find.

# of grams =

Then put the **initial amount and unit** on the **right** side of the "=" sign.

# of grams = 5.00 mL

Next multiply the initial value by a conversion factor. Construct the conversion factor from the conversion statement as follows.

The conversion statement connects "0.200 mL" and "3.86 g"; possible conversion factors are

$$\frac{0.200\text{ mL}}{3.86\text{ g}} \text{ and } \frac{3.86\text{ g}}{0.200\text{ mL}}.$$

Use the conversion factor which has "0.200 mL" on the bottom. **THE PURPOSE OF PLACING "0.200 mL" ON THE BOTTOM OF THE FRACTION IS TO ALLOW THE UNIT "mL" TO *CANCEL*.**

$$\#\text{ of grams} = 5.00\ \cancel{\text{mL}} \times \frac{3.86\text{ g}}{0.200\ \cancel{\text{mL}}}$$

Finally, carry out the multiplication and finish the problem.

$$\#\text{ of grams} = 5.00\ \cancel{\text{mL}} \times \frac{3.86\text{ g}}{0.200\ \cancel{\text{mL}}} = \mathbf{96.5\text{ g}}$$

This problem started with the unit "mL" and eventually **converted** to the unit "g"; hence the term "***Unit Conversion***". To show that everything has been done properly, notice that the procedure started with "# of grams" on the left, and found 96.5 g as an answer.

The conversion statement allows you to make two possible conversion factors:

$$\frac{0.200\text{ mL}}{3.86\text{ g}} \text{ and } \frac{3.86\text{ g}}{0.200\text{ mL}}.$$

The required conversion factor was BUILT by arranging the fraction in such a way as to cancel the initial unit "mL". If the other conversion factor had been used (that is, the fraction was built upside–down), the calculation would have given:

$$\text{\# of grams} = 5.00\ \text{mL} \times \frac{0.200\ \text{mL}}{3.86\ \text{g}} = 0.259\frac{(\text{mL})^2}{\text{g}} = \text{a mess!!!}$$

Therefore, whenever you multiply the initial value by a conversion factor you have to ask yourself:

> "WHICH WAY DO I HAVE TO WRITE THE CONVERSION FACTOR IN ORDER TO ALLOW THE INITIAL UNITS TO CANCEL PROPERLY?"

b) **If 0.200 mL of gold has a mass of 3.86 g, what is the volume occupied by 100.0 g of gold?**

The **UNKNOWN AMOUNT and its UNIT**: The question asks "what is the volume", which suggests finding "# of millilitres".

The **INITIAL AMOUNT and its UNIT** are "100.0 g", which is tied to the unknown amount ("what is the volume") by the connector "occupied by".

As in the previous example, the **CONVERSION STATEMENT** is "If 0.200 mL of gold has a mass of 3.86 g". The amounts being connected are 0.200 mL and 3.86 g.

Now to solve the problem. Start with the **unknown amount** on the **left** side of an "=" sign.

$$\text{\# of millilitres} =$$

Then put the **initial amount and unit** on the **right** side of the "=" sign.

$$\text{\# of millilitres} = 100.0\ \text{g}$$

Construct a conversion factor from the conversion statement such that the starting unit "g" is cancelled by having "3.86 g" on the bottom.

$$\text{\# of millilitres} = 100.0\ \cancel{\text{g}} \times \frac{0.200\ \text{mL}}{3.86\ \cancel{\text{g}}}$$

Finally, carry out the multiplication and finish the problem:

$$\text{\# of millilitres} = 100.0\ \cancel{\text{g}} \times \frac{0.200\ \text{mL}}{3.86\ \cancel{\text{g}}} = \mathbf{5.18\ mL}$$

Again, notice that the problem tried to find "# of millilitres" and found 5.18 mL as an answer. Also, note that the conversion factor used in this problem, 0.200 mL/3.86 g, was the inverse of the conversion factor used in the problem above, 3.86 g/0.200 mL. **The way the conversion factor is used depends on which unit is to be cancelled.**

SUMMARY OF THE PROCEDURE TO BE USED WITH UNIT CONVERSIONS

1. Identify the unknown amount and its unit. Write these down on the left–hand side of an "=" sign.
2. Identify the initial amount and its unit. Write these down on the right–hand side of the "=" sign.
3. Identify the conversion factor. Multiply the initial amount by the conversion factor in such a way that one of the units in the conversion factor cancels the unit of the initial amount.
4. Complete the problem by multiplying and/or dividing the amounts on the right–hand side.

EXERCISE:

2. Solve the following using the method of unit conversions.
   a) If there are 6.02×10^{23} atoms in 1 mol of atoms, how many atoms are there in 5.5 mol of atoms?
   b) If one mole of a gas has a volume of 22.4 L, how many moles are there in 25.0 L of gas?
   c) If one mole of nitrogen has a mass of 28 g, how many moles of nitrogen gas are in 7.0 g of nitrogen gas?
   d) How many seconds must an electrical current of 35 coulombs/s flow in order to deliver 200.0 coulombs?
   e) A quiet sound exerts a pressure of 4×10^{-8} kPa ("kPa" = kilopascals, an SI pressure unit). What is this pressure in atmospheres if 1 atmosphere is 101.3 kPa?
   f) A large nugget of naturally occurring silver metal has a mass of 3.20×10^{4} troy ounces. What is the mass in kilograms if 1 troy ounce is equivalent to 0.0311 kg?
   g) A reaction is essentially complete in 5.0×10^{-4} s. If one millisecond (1 ms) equals 10^{-3} s, how many milliseconds does the reaction take?
   h) If 1 mol of octane produces 5450 kJ of heat when burned, how many moles of octane must be burned to produce 15 100 kJ of heat?
   i) Our fingers can detect a movement of 0.05 micron. If 1 micron is 10^{-3} mm, what is this movement expressed in millimetres (mm)?
   j) If concentrated hydrochloric acid has a concentration of 11.7 mol/L, what volume of hydrochloric acid is required in order to have 0.0358 mol of hydrochloric acid?

MULTIPLE UNIT CONVERSIONS

So far, hopefully, so good. All of the problems above involve a single conversion factor, which leads to the question "What happens when there is ***more than one*** conversion factor involved in a problem?" In fact, you have already run into such problems in everyday life if you have ever tried to solve a problem such as "How many seconds are there in 1 day?" Consider the following examples.

EXAMPLES: (a) **If eggs are \$1.44/doz, and if there are 12 eggs/doz, how many individual eggs can be bought for \$4.32?**

Analyzing this problem —

The UNKNOWN AMOUNT is "how many individual eggs can be bought".

The INITIAL AMOUNT is \$4.32.

There are two conversion statements: "eggs are \$1.44/doz", and "there are 12 eggs/doz".

The overall connection which is required is **(\$) ⟶ (eggs).**

The first conversion statement, \$1.44 = 1 doz, makes the connection

(\$) ⟶ (doz).

The second conversion statement, 12 eggs = 1 doz, makes the connection

(doz) ⟶ (eggs).

Combining the conversion statements gives the overall connection

(\$) ⟶ (doz) ⟶ (eggs)

which is the connection required (in bold, above).

To start, set up the problem as usual.

$$\# \text{ of eggs} = \$4.32$$

Now, apply the first conversion factor, which cancels the unit "$".

$$\# \text{ of eggs} = \cancel{\$}4.32 \times \frac{1 \text{ doz}}{\cancel{\$}1.44}$$

So far, cancelling the unit "$" on the right side leaves the unit "doz". The unit change ($) ⟶ (doz) is accomplished. Now apply the second conversion factor, which cancels the unit "doz" and accomplishes the unit change (doz) ⟶ (eggs).

$$\# \text{ of eggs} = \cancel{\$}4.32 \times \frac{1 \cancel{\text{doz}}}{\cancel{\$}1.44} \times \frac{12 \text{ eggs}}{1 \cancel{\text{doz}}} = \mathbf{36 \text{ eggs}}$$

Notice that both the units "$" and "doz" are cancelled.

(b) 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 ("gal" is the symbol for "gallon", a measure of volume used in the U.S.), and gas is $1.26/gal in Dallas, Texas, how much will it cost the tourist to fill his gas tank in Dallas?

UNKNOWN AMOUNT = # of dollars

INITIAL AMOUNT = 39.5 L

Required connection: (L) ⟶ ($)

Conversion statements available: 1 L = 0.264 gal and 1 gal = $1.26

Connections available through the conversion statements:

(L) ⟶ (gal) and (gal) ⟶ ($)

Using the conversion statements together gives the required overall connection.

(L) ⟶ (gal) ⟶ ($)

Using both conversion statements solves the problem. One statement, 1 L = 0.264 gal, allows the cancelling of the initial unit, "L". The other statement, 1 gal = $1.26, allows the cancelling of the unit "gal" which was introduced by the first conversion factor.

$$\# \text{ of dollars} = 39.5 \cancel{\text{L}} \times \frac{0.264 \cancel{\text{gal}}}{1 \cancel{\text{L}}} \times \frac{\$1.26}{1 \cancel{\text{gal}}} = \mathbf{\$13.1}$$

At the end, the units "L" and "gal" have been cancelled, leaving the required unit, "$".

EXERCISES:

3. An old barometer hanging on the wall of a mountain hut has a reading of 27.0 inches of mercury. If 1 inch of mercury equals 0.0334 atm ("atmospheres") and 1 atm = 101.3 kPa ("kilopascals"), what is the pressure reading of the barometer, in kilopascals?
4. It requires 334 kJ of heat to melt 1 kg of ice.
   (a) The largest known iceberg had a volume of about 3.1×10^{13} m^3. How much heat was required to melt the iceberg if 1 m^3 of ice has a mass of 917 kg?
   (b) The explosive "TNT" releases 1.51×10^4 kJ of energy for every kilogram of TNT which explodes. Provided that all the energy of an explosion went into melting the ice, how many kilograms of TNT would be needed to melt the iceberg in part (a) of this question?
5. Sugar costs $0.980/kg. 1 t = 1000 kg. How many tonnes ("t") of sugar can you buy for $350?
6. The Cullinan diamond, the largest diamond ever found, had an uncut volume of 177 mL. If 1 mL of diamond has a mass of 3.51 g and 1 carat = 0.200 g, how many carats was the Cullinan diamond?

7. How many kilometres ("km") will a car travelling at 120 km/h go in: (a) 0.25 h? (b) 12 min?
8. Solve the following, using the fact that beakers cost $8.40 per dozen.
   (a) Harry drops 3 dozen beakers. How much will the Chemistry teacher charge Harry?
   (b) Harry drops another 5 dozen beakers (clumsy!). If Burger Bob's hamburgers cost $1.50 each, how many hamburgers could clumsy Harry have bought for the same amount of money as he has to pay for the second batch of beakers?
   (c) Harry does not learn very quickly, and breaks a third batch of beakers. If he has to pay $13.30, what is the number of beakers he breaks the third time? (Express your answer in actual numbers of beakers, rather than in "dozens of beakers".)
9. An ancient Celtic chicken farmer wished to purchase a gift for his wife. The gift was worth 2 horses. At the local market, 3 horses were worth 5 cows, 1 cow was worth 4 hogs, 3 hogs were worth 4 goats, and 1 goat cost 9 chickens. How much was the gift going to cost the farmer, who had to pay in chickens?
10. If 1 yard = 3 feet, 1 foot = 12 inches and 1 centimetre = 0.3937 inch, how many centimetres are there in 5 yards?

In addition to the above, there is a specialized type of unit conversion which you must be able to perform: METRIC CONVERSIONS. Before starting on these conversions, let's review metric usage.

II.2. SI UNITS

The International System (SI) of metric units has numerous "base units", although only a few are used in Chemistry 11. A "base unit" is a basic unit of measurement; all other units are multiples of the base units, or combinations of base units.

A. SOME SELECTED BASE UNITS IN THE INTERNATIONAL SYSTEM (SI)

Quantity	Written Unit	Unit Symbol
length	metre	m
mass	gram *	g *
time	second	s
amount of substance	mole	mol

* The actual base unit for mass in the SI system is the kilogram (kg), which is an inconsistent base unit, but for the purposes of Chemistry 11 the gram (g) is considered to be the base unit.

B. SOME ADDITIONAL UNITS USED

Quantity	Written Unit	Unit Symbol
volume	litre	L
mass	tonne	t

C. MULTIPLES OF BASE UNITS

Written Prefix	Prefix symbol	Equivalent exponential
mega	M	10^6
* kilo	k	10^3
deci	d	10^{-1}
* centi	c	10^{-2}
* milli	m	10^{-3}
micro	μ	10^{-6}

(The prefixes preceded by a "*" are those used most frequently in Chemistry 11.)

D. SOME IMPORTANT EQUIVALENCES

1 mL = 1 cm^3
1 m^3 = 10^3 L
1 t = 10^3 kg

EXAMPLES: **(a) Re–write the expression "5 kilograms" using**
- **PREFIX and UNIT SYMBOLS, and**
- **an EXPONENTIAL EQUIVALENT.**

The ***prefix symbol*** which stands for "kilo" is "k" and the ***unit symbol*** which stands for "grams" is "g".

Therefore: 5 kilograms = 5 kg.

The ***exponential equivalent*** of "kilo" and "k" is "10^3"

Therefore: 5 kilograms = 5 x 10^3 g.

(b) Re–write the expression "2 ms" using
- **a WRITTEN PREFIX and UNIT, and**
- **an EXPONENTIAL EQUIVALENT.**

The ***written prefix*** which is equivalent to "m" is "milli" and the ***written unit*** which is equivalent to "s" is "seconds".

Therefore: 2 ms = 2 milliseconds.

The ***exponential equivalent*** of "milli" and "m" is "10^{-3}"

Therefore: 2 ms = 2 x 10^{-3} s.

(c) Re–write the expression "2.7 x 10^{-2} m" using
- **a WRITTEN PREFIX and UNIT, and**
- **a PREFIX SYMBOL .**

The ***written prefix*** equivalent to "10^{-2}" is "centi", and the ***written unit*** which is equivalent to "m" is "metres".

Therefore: 2.7 x 10^{-2} m = 2.7 centimetres.

The ***prefix symbol*** which stands for "10^{-2}" is "c"

Therefore: 2.7 x 10^{-2} m = 2.7 cm.

The following multiples are used very infrequently and do not have to be memorized. They are only included for the purpose of completeness. (Like, you never can tell when they might come in handy.)

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}
hecto	h	10^{2}
deka	da	10^{1}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

EXERCISES:

11. Re–write the following using PREFIX and UNIT SYMBOLS, and EXPONENTIAL EQUIVALENTS.
    (a) 2.5 centimetres (b) 1.3 kilograms (c) 25.2 millimoles (d) 5.1 decigrams (e) 0.25 megalitres (f) 6.38 micrograms
12. Re–write the following using WRITTEN PREFIXES and UNITS, and EXPONENTIAL EQUIVALENTS.
    (a) 2.5 mm (b) 6.5 dL (c) 1.9 kmol (d) 4 Mt (e) 9.94 cg (f) 1.25 μs
13. Re–write the following using PREFIX SYMBOLS, and WRITTEN PREFIXES and UNITS.
    (a) 4.5×10^{-3} mol (b) 1.6×10^{3} m (c) 0.50×10^{-6} L (d) 2.68×10^{-1} g (e) 8.85×10^{6} t (f) 7.25×10^{-2} m
14. Express (a) 50 cm^3 in millilitres (b) 22.5 t in kilograms (c) 0.125 m^3 in litres

II.3. METRIC CONVERSIONS

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

EXAMPLES: (a) Write a conversion statement between **cm** and **m**.

Since "c" stands for "10^{-2}" then 1 cm = 10^{-2} m.

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

Since "m" stands for "10^{-3}" then 1 ms = 10^{-3} s.

EXERCISE:

15. Write conversion statements between each of the following.
    (a) kg and g (b) Mm and m (c) μL and L (d) dm and m (e) cs and s (f) mmol and mol (g) kL and L (h) μs and s (i) Mg and g (j) cL and L (k) dmol and mol (l) mg and g

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EXAMPLE: **How many micrometres are there in 5 cm?**

Unknown amount = # of μm

Initial amount = 5 cm

You can write your own conversion statements between μm and m, and cm and m because the prefixes ***micro*** (μ) and ***centi*** (c) are mentioned in the problem statement.

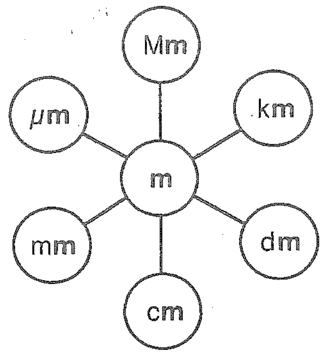
1 μm = 10^{-6} m These statements can be combined to make the connections below.

1 cm = 10^{-2} m (μm) ⟶ (m) ⟶ (cm)

The conversion is now straightforward.

$$\#\text{ of } \mu m = 5\text{ cm} \times \frac{10^{-2}\text{ m}}{1\text{ cm}} \times \frac{1\ \mu m}{10^{-6}\text{ m}} = 5 \times 10^{4}\ \mu m$$

The diagram below shows the manner in which a given base unit (for example, meters) is related to the important prefix symbols.



As can be seen, all the prefix symbols are directly related to the "central" base unit. (The central unit "m" also could be any other base unit such as g, s or mol.) In order to connect any two metric prefixes, first connect the initial prefix symbol to the base unit and then connect the base unit to the prefix symbol of the unknown.

EXAMPLE: **Express 8 kg in milligrams.**

Unknown amount = # of mg

Initial amount = 8 kg

Since the prefix symbols "k" (kilo) and "m" (milli) are mentioned in the problem statement, write down the conversion statements.

$1\text{ kg} = 10^3\text{ g}$
$1\text{ mg} = 10^{-3}\text{ g}$

These statements can be combined to make the connections below.

(kg) ⟶ (g) ⟶ (mg)

Carry out the conversion.

$$\#\text{ of mg} = 8\text{ kg} \times \frac{10^3\text{ g}}{1\text{ kg}} \times \frac{1\text{ mg}}{10^{-3}\text{ g}} = \mathbf{8 \times 10^6\text{ mg}}$$

EXAMPLE: **Express 5 Mg/mL in kilograms/litre.**

$$\text{Unknown amount} = \#\text{ of } \frac{\text{kg}}{\text{L}}$$

$$\text{Initial amount} = \frac{5\text{ Mg}}{\text{mL}}$$

This problem requires the conversion of both the numerator and the denominator. Again, write conversion statements for each metric prefix mentioned.

$1\text{ kg} = 10^3\text{ g}$
$1\text{ Mg} = 10^6\text{ g}$
$1\text{ mL} = 10^{-3}\text{ L}$

Treat the top and bottom of the initial fraction separately.

- to convert the top: (Mg) ⟶ (g) ⟶ (kg)
- to convert the bottom: (mL) ⟶ (L)

Depending on how comfortable you are with conversion factors, you can carry out the overall conversion in two ways.

a) ***The 3–step method***:

1st: Convert the top (ignoring the bottom).

$$\# \text{ of kg} = 5 \text{ Mg} \times \frac{10^6 \text{ g}}{1 \text{ Mg}} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 5 \times 10^3 \text{ kg}$$

2nd: Convert the bottom (ignoring the top).

$$\# \text{ of L} = 1 \text{ mL} \times \frac{10^{-3} \text{ L}}{1 \text{ mL}} = 1 \times 10^{-3} \text{ L}$$

3rd: Divide the converted top amount by the converted bottom amount.

$$\# \text{ of } \frac{\text{kg}}{\text{L}} = \frac{5 \times 10^3 \text{ kg}}{1 \times 10^{-3} \text{ L}} = 5 \times 10^6 \frac{\text{kg}}{\text{L}}$$

b) ***The 1–step method***: Simply convert the top and then the bottom (or vice versa), applying all the conversion factors one after another.

- arbitrarily, first convert **Mg** to **g** : $\# \text{ of } \frac{\text{kg}}{\text{L}} = \frac{5 \text{ Mg}}{1 \text{ mL}} \times \frac{10^6 \text{ g}}{1 \text{ Mg}}$
- then immediately convert **g** to **kg** : $\# \text{ of } \frac{\text{kg}}{\text{L}} = \frac{5 \text{ Mg}}{1 \text{ mL}} \times \frac{10^6 \text{ g}}{1 \text{ Mg}} \times \frac{1 \text{ kg}}{10^3 \text{ g}}$
- then convert the BOTTOM by cancelling the **mL** on the bottom of the initial amount with **mL** in the top of a final conversion factor

$$\# \text{ of } \frac{\text{kg}}{\text{L}} = \frac{5 \text{ Mg}}{1 \text{ mL}} \times \frac{10^6 \text{ g}}{1 \text{ Mg}} \times \frac{1 \text{ kg}}{10^3 \text{ g}} \times \frac{1 \text{ mL}}{10^{-3} \text{ L}} = \mathbf{5 \times 10^6 \frac{kg}{L}}$$

Sneaky Short–Cut

Situations which simply require changing from prefix symbol form to base unit form can use a direct substitution of the exponential equivalent for the prefix symbol. This procedure helps to eliminate writing one conversion factor in longer problems.

EXAMPLE: If aluminum is worth \$0.00116/g, what is the cost of 725 kg of aluminum?

$$\# \text{ of dollars} = 725 \times 10^3 \text{ g} \times \frac{\$0.00116}{\text{g}} = \mathbf{\$870}$$

"725 kg" is simply written as "725 x 10^3 g", eliminating the conversion factor $\frac{10^3 \text{ g}}{1 \text{ kg}}$.

EXERCISES:

16. (a) If 1 mg = 10^{-3} g and 1 Mg = 10^6 g, how many milligrams are there in 0.25 Mg?
    (b) If 1 μs = 10^{-6} s and 1 cs = 10^{-2} s, how many centiseconds are there in 10 μs?
    (c) If 1 mm = 10^{-3} m and 1 cm = 10^{-2} m, how many millimetres are there in 15.8 cm?
    (d) If 1 kg = 10^3 g and 1 mg = 10^{-3} g, how many kilograms are there in 250 mg?
    (e) If 1 dL = 10^{-1} L and 1 kL = 10^3 L, how many decilitres are there in 0.5 kL?

17. Convert the following

(a) 3 s into milliseconds
(b) 50.0 mL into litres
(c) 2 L into microlitres
(d) 25 kg into grams
(e) 3 Mm into metres
(f) 2 L into decilitres
(g) 7 μs into milliseconds
(h) 51 kg into milligrams
(i) 3125 μL into kilolitres
(j) 1.7 μg into centigrams
(k) 1 year into seconds
(l) 1 mg/dL into grams per litre
(m) 1 cm/μs into kilometres/second
(n) 1 cg/mL into decigrams/litre
(o) 5 cg/ds into milligrams/second

18. Light travels at a rate of 3.00×10^8 m/s.
    (a) It takes light 8.3 min to travel from the surface of the sun to the earth. What is the distance of the earth from the sun?
    (b) The moon is 3.8×10^5 km from the earth. What time will pass between the instant an astronaut on the moon speaks and the instant his voice is heard on earth? (His voice travels by modulated laser beam at the speed of light.)
    (c) A robot vehicle is travelling on the surface of Mars while Mars and Earth are at their closest approach (7.83×10^7 km). Suddenly, a video camera on the robot shows a yawning crevasse dead ahead! How many minutes will it take for an electronic signal travelling at the speed of light to go from Earth to Mars in order to tell the robot to stop immediately?

19. (Care: Nasty!) A measurement is given as 9.0 lb/in^3. If 1 kg = 2.2 lb and 1 m = 39 in, convert the measurement into kg/m^3.

OPTIONAL EXERCISES:

20. If sugar is $9.80 for 10 kg, what is the cost of: (a) 90.0 kg of sugar? (b) 6.00 tonnes of sugar?

21. If 1 inch = 2.54 cm, what is the length, in centimetres, of a 20.0 inch rod? What is the length, in metres, of a 36 inch ruler?

22. Express 90 μg in centigrams.

23. A car travels at a constant speed of 105 km/h.
    (a) How many hours does it take to go 450 km?
    (b) How many seconds does it take to go 2.0×10^2 m?
    (c) How many kilometres are travelled in 10.0 min?
    (d) How many centimetres are travelled in 1.00 ms?

24. If 1 L of granite has a mass of 5.50 kg,
    (a) what is the mass of 7.00 L of granite?
    (b) what is the volume occupied by 22 kg of granite?
    (c) what is the mass, in grams, of 5.00 mL of granite?

25. The SI unit of energy is the joule (unit symbol = J). If 0.334 kJ of energy is required to melt 1.00 g of ice and 1 kJ = 1000 J then:
    (a) what mass of ice can be melted by 10.0 kJ of heat?
    (b) how many kilojoules of heat are required to melt 50.0 g of ice?
    (c) how many joules of heat are required to melt 2.00 kg of ice?

26. Express 80.0 Mg in micrograms.

27. Express 2 cL/ms in kilolitres/second.

28. Express 50.0 mL/min in microlitres/second.