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 °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.

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

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

$$\#\text{ of grams} = 5.00\text{ mL}$$

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.

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

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.

# 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).

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

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 $3.1 \times 10^{13}\ m^3$. 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