

Name _____ Pd _____ Date _____

Chemistry Scientific Measurement Guided Inquiry *Teacher's Notes*

Work with your group using your prior knowledge, the textbook (2.1 – 2.7), internet research, and class discussion to complete this handout.

1. ALL measurements MUST include numbers and units .

SI Units – scientists all over the world have agreed on a single measurement system called Le Systeme International d'Unites or SI Units for short

Base Quantities & Units – the 7 quantities that can be measured directly and their SI unit. Complete the table below. [Hint: you won't find all of these in the textbook.]

Base Quantity	Quantity Symbol	SI Unit Name	SI Unit Abbreviation
length	l	<i>meter</i>	<i>m</i>
mass	m	<i>kilogram</i>	<i>kg</i>
time	t	<i>second</i>	<i>s</i>
temperature	T	<i>Kelvin</i>	<i>K</i>
amount of substance	n	<i>mole</i>	<i>mol</i>
electric current	I	<i>ampere</i>	<i>A</i>
luminous intensity	I_v	<i>candela</i>	<i>cd</i>

Derived Quantities & Units – all other quantities are derived from combinations of multiplying or dividing base quantities and their units. Complete the table below for some of the important derived units in chemistry.

Derived Quantity	Quantity Symbol	SI Unit name	SI Unit Abbreviation
Area	A	<i>square meter</i>	<i>m²</i>
Volume	V	<i>cubic meter</i>	<i>m³</i>
Density	D	<i>kilograms per cubic meter</i>	<i>kg/ m³</i>
Molar Mass	M	<i>kilogram per mole</i>	<i>kg/mol</i>
Concentration	c	<i>moles per cubic meter</i>	<i>mol/m³</i>
Molar Volume	V_m	<i>cubic meters per mole</i>	<i>m³/mol</i>
Pressure	P	<i>pascal</i>	<i>Pa</i>

Summarize

2. Why are units important?

Units represent agreed upon standards for the measured quantities.

3. Why do scientists use the SI units?

The international community of scientists agreed to use SI Units so all scientific research and literature would use a common set of units.

4. Compare and contrast base quantities and derived quantities.

Base quantities are quantities that can be measured directly, such as mass and length. Derived quantities are quantities that are calculated by multiplying or dividing combinations of base units.

Scientific Notation (aka Exponential Notation) – is a convenient way to write very large or very small numbers. Also, a convenient way to show the number of significant figures in a measurement that has non-significant trailing zeros.

Numbers are written in the form $M \times 10^n$

where, M is a number greater than or equal to 1 but less than 10

n is an integer

Examples

- Write 6.5×10^4 km in “normal” notation.

The exponent is positive so move the decimal 4 places to the right adding zeros as necessary, 6 5 0 0 0. km.

- Write 2.49×10^{-3} cm in “normal” notation.

The exponent is negative so move the decimal 3 places to the left adding zeros as necessary, 0.00249 m

- Write 210400 g in scientific notation.

Move the decimal so the number is greater than or equal to 1 but less than ten, 2 1 0 4 0 0 g. Since the decimal moves 5 places to the left the scientific notation is 2.10400×10^5 g.

- Write 0.0000502 in scientific notation.

Move the decimal so the number is greater than or equal to 1 but less than ten, 0.0000502 g. Since the decimal moves 5 places to the right the scientific notation is 5.02×10^{-5} cm.

Keep the “M” number equal to and greater than 1 but less than 10! In the third example above 21.0400×10^4 g would be wrong and so would 0.210400×10^6 g.

Convert the following quantities into scientific notation, include the units:

5. $0.00012 \text{ mm} = 1.2 \times 10^{-4} \text{ mm}$

7. $35.908 \text{ kg} = 3.5908 \times 10^1 \text{ kg}$

6. $89630000 \text{ s} = 8.963 \times 10^7 \text{ s}$

8. $0.23007 \text{ g} = 2.3007 \times 10^{-1} \text{ g}$

Convert the following quantities from scientific notation to “normal” notation, include the units:

9. $3.044 \times 10^{-2} \text{ m} = 0.03044 \text{ m}$

11. $5.20006 \times 10^4 \text{ cm} = 52\,000.6 \text{ cm}$

10. $9.9559 \times 10^2 \text{ m} = 995.59 \text{ m}$

12. $2.10 \times 10^{-9} \text{ kg} = 0.000\,000\,002\,10 \text{ kg}$

Scientific Notation and Calculators – Most calculators are able to handle scientific notation. The Texas Instrument calculators have the EE button; Casio calculators have the EXP button. To enter a number in scientific notation simply enter the “M” number, press the EE or EXP button, and then enter the “n” number.

Example – Enter 6.022×10^{23} in your calculator.

Texas Instruments: 6. 0 2 2 2nd EE 2 3

Casio: 6. 0 2 2 EXP 2 3

If your calculator doesn't allow you to enter numbers in scientific notation you can enter it using exponents HOWEVER, you must always enclose the entire number in parentheses, otherwise you may get a wrong answer.

Example – Enter 6.022×10^{23} in your calculator → (6 . 0 2 2 X 1 0 ^ 2 3)

Use your calculator to perform the following calculations. Keep the numbers in scientific notation and write your answer with the correct units.

13. $(2.76 \times 10^2 \text{ m}) \times (1.09 \times 10^1 \text{ m}) = 3.0084 \times 10^3 \text{ m}^2$

14. $(9.00005 \times 10^2 \text{ m}) \times (5.993 \times 10^{-3} \text{ m}) = 5.393729965 \times 10^0 \text{ m}^2$

15. $(5.55 \times 10^3 \text{ m}) / (1.50 \times 10^2 \text{ s}) = 3.7 \times 10^1 \text{ m/s}$

16. $(2.33 \times 10^2 \text{ m}) / (5.9 \times 10^{-2} \text{ s}) = 3.949152542 \times 10^3 \text{ m/s}$

17. $(9.655 \times 10^3 \text{ s}) + (5.50 \times 10^2 \text{ s}) = 1.0205 \times 10^4 \text{ s}$

18. $(3.26 \times 10^1 \text{ s}) + (1.77 \times 10^{-1} \text{ s}) = 3.2777 \times 10^1 \text{ s}$

19. $(3.5 \times 10^{-3} \text{ s}) - (5.50 \times 10^{-1} \text{ s}) = -5.465 \times 10^{-1} \text{ s}$

Summarize

20. Why do we use scientific notation?

We use scientific notation to make it easier to write very large and very small numbers. It also allows us to write numbers when some of the trailing zeros are significant.

21. How do you convert “normal” numbers into scientific notation?

Move the decimal point to the left or to the right of the normal until the number is greater than or equal to 1 and less than 10. The number of places the decimal moved represents the exponent of 10. Moving the decimal to the left creates a positive exponent. Moving the decimal place to the right creates a negative exponent.

22. How do you convert numbers written in scientific notation into “normal” numbers?

Move the decimal point the number of places as the exponent of 10. If the exponent is negative move the decimal to the left. If the exponent is positive move the decimal to the right. Use zeros as placeholders as necessary.

Rounding Numbers to a Specific Digit

Your car’s odometer reads 95,357 miles. If someone asks you how many miles you have on your car do you say, “ninety five thousand three hundred fifty seven miles” or do you say, “ninety five thousand miles”? If you were born on February 28, 1998 and someone asks you how old you are do you say, “fifteen point five years” or do you say, “fifteen years”? Both situations are examples of rounding numbers to a specific digit. In the case of the car’s odometer reading if you said “ninety five thousand miles” you were rounding the mileage to the thousands digits. In the case of your age if you said “fifteen years” you were rounding your age to the ones digit.

Scientists have a specific way of rounding numbers:

7.745882 rounded to the ...

- tenths digit would be 7.7
- ones digit it would be 8
- hundredths digit it would be 7.75

73, 493 rounded to the ...

- tens digit would be 73,490
- hundreds digit would be 73, 500
- thousands digit would be 73,000

To round a number to a specific digit look at the next digit to the right; if it is 5 or higher, make the number in your “rounding digit” one higher; and if it is 4 or lower, leave the number in your rounding digit the same. An easy way to remember this rounding rule is “4 or below leave it go, 5 and above give it a shove.”

Round the numbers below to the specified digit:

23. 4.499 to the ones digit

4

24. 17.5 to the ones digit

18

25. 17.5 to the tens digit

20

26. 39,909 to the tens digit

39 910

27. 39,909 to the thousands digit

40 000

28. 0.0573 to the tenths digit

0.1

29. 0.0573 to the hundredths digit

0.06

30. 0.0573 to the thousandths digit

0.057

Complete the following POGIL activities before moving on to the next section:

- Significant Digits and Measurement
- Significant Zeros

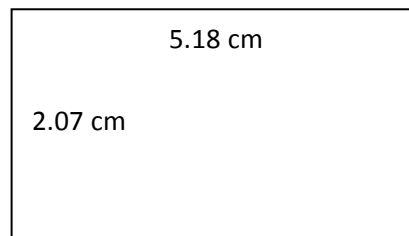
Using Sig Figs in Math Operations

In the previous two POGIL activities we learned about measurements and significant figures (aka significant digits). Scientists use significant figures to indicate the amount of certainty they have in a measured quantity. Scientists routinely use measurements they gather during their investigations in calculations. The calculated quantities also need to indicate the amount of certainty the scientist has in the number. **After all, a calculated number can't have any more certainty than the numbers that were used to calculate it!**

Let's look at an example of calculating the area of a rectangle that is 5.18 cm by 2.07 cm.

31. What answer does your calculator give you when you multiply the two distances to get the area?

$$10.7226 \text{ cm}^2$$



32. Based on what we know about significant figures underline the digits in the number above that we supposedly know with certainty.

$$\underline{1} \underline{0} . \underline{7} \underline{2} \underline{2} \underline{6} \text{ cm}^2$$

Do we really know the digits with certainty down to the ten-thousandth of a square centimeter? Let's take a closer look at our length and width numbers.

33. Underline the digits that we know with certainty in both numbers.

$$\underline{5} . \underline{1} 8 \text{ cm}$$

$$\underline{2} . \underline{0} 7 \text{ cm}$$

34. List all the valid measurements for the length and the width.

$$5.17 \text{ cm}$$

$$5.18 \text{ cm}$$

$$5.19 \text{ cm}$$

$$2.06 \text{ cm}$$

$$2.07 \text{ cm}$$

$$2.08 \text{ cm}$$

35. Using the valid length and width measurements above calculate the smallest area of the rectangle and the largest area of the rectangle.

$$\text{Smallest: } 5.17 \text{ cm} \times 2.06 \text{ cm} = 10.6502 \text{ cm}^2$$

$$\text{Largest: } 5.19 \text{ cm} \times 2.08 \text{ cm} = 10.7952 \text{ cm}^2$$

36. Based on these two extremes, which digits of the area do we know with certainty?

The tens and ones digits.

37. Which is the first digit that has some uncertainty?

The tenths (0.1) digit

38. Using significant figures, how should we write the number for the area so it indicates the correct amount of certainty we have in the number?

$$10.7 \text{ cm}^2$$

39. How does the number of significant figures in the answer compare to the number of significant figures in the values used to calculate the answer?

They all have three significant figures.

Let's look at some other examples of multiplying measured numbers:

Calculation:	14.10×15.97	13578×8.9	45.1×104.8	0.6×8
Calculator Answer	225.177	120844.2	4726.48	4.8
Range of possible answers using valid measurements	$14.09 \times 15.96 = 224.8764$ $14.11 \times 15.98 = 225.4778$	$13577 \times 8.8 = 119477.6$ $13579 \times 9.0 = 122211$	$45.0 \times 104.7 = 4711.5$ $45.2 \times 104.9 = 4741.48$	$0.5 \times 7 = 3.5$ $0.7 \times 9 = 6.3$
Certain digits	Hundreds, tens and ones	Hundred-thousands	Thousands and hundreds	none
Answer w/ sig figs	225.2	120000	4730	5

Here are examples of dividing measured numbers:

Calculation	$17.1 \div 0.977$	$82950 \div 45.5$	$82950. \div 45.50$	$82950.0 \div 45.500$
Calculator Answer	17.50255885	1823.076923	1823.076923	1823.076923
Range of possible answers using valid measurements	$17.0 \div 0.978 = 17.38241309$ $17.2 \div 0.976 = 17.62295082$	$82940 \div 45.6 = 1818.859649$ $82960 \div 45.4 = 1827.312775$	$82949 \div 45.51 = 1822.654362$ $82951 \div 45.49 = 1823.49967$	$82949.9 \div 45.501 = 1823.034659$ $82950.1 \div 45.499 = 1823.119189$
Certain digits	tens and ones	Thousands and hundreds	Thousands, hundreds and tens	Thousands, hundreds, tens and ones
Answer w/ sig figs	17.5	1820	1823	1823.1

40. In both the tables above look at the number of significant figures in the measurements being used in the calculations and the number of significant figures in the answers. Look for a pattern and in your own words write the rule for multiplying and dividing with significant figures.

The answer will have the same number of significant figures as the measurement with the least significant figures.

41. Notice in the last three division calculations above the calculator answer is exactly the same in all three instances, but the answer with significant figures is different. Explain why.

As we know the measurements with more certainty we also know the calculated answer with more certainty.

What happens when we add and subtract measured numbers? Here are examples of adding measurements:

Calculation:	$\begin{array}{r} 187.0 \\ + 72.9 \\ + 2.5 \end{array}$		$\begin{array}{r} 187 \\ + 72.9 \\ + 2.5 \end{array}$		$\begin{array}{r} 187 \\ + 73 \\ + 3 \end{array}$		$\begin{array}{r} 187.00 \\ + 72.900 \\ + 2.5 \end{array}$	
Calculator Answer	262.4		262.4		263		262.400	
Range of possible answers using valid measurements	$\begin{array}{r} 186.9 \\ + 72.8 \\ + 2.4 \\ \hline 262.1 \end{array}$	$\begin{array}{r} 187.1 \\ + 73.0 \\ + 2.6 \\ \hline 262.7 \end{array}$	$\begin{array}{r} 186 \\ + 72.8 \\ + 2.4 \\ \hline 261.2 \end{array}$	$\begin{array}{r} 188 \\ + 73.0 \\ + 2.6 \\ \hline 263.6 \end{array}$	$\begin{array}{r} 186 \\ + 72 \\ + 2 \\ \hline 260 \end{array}$	$\begin{array}{r} 188 \\ + 74 \\ + 4 \\ \hline 266 \end{array}$	$\begin{array}{r} 186.99 \\ + 72.899 \\ + 2.4 \\ \hline 262.289 \end{array}$	$\begin{array}{r} 187.01 \\ + 72.901 \\ + 2.6 \\ \hline 262.511 \end{array}$
Certain digits	Hundreds, tens and ones		Hundreds and tens		Hundreds and tens		Hundreds, tens and ones	
Answer w/ sig figs	262.4		262		263		262.4	

Here are examples of subtracting measurements:

Calculation:	$\begin{array}{r} 38.01 \\ - 17.95 \end{array}$		$\begin{array}{r} 110 \\ - 57 \end{array}$		$\begin{array}{r} 110. \\ - 57 \end{array}$		$\begin{array}{r} 110.5 \\ - 57.000 \end{array}$	
Calculator Answer	20.06		53		53		53.5	
Range of possible answers using valid measurements	$\begin{array}{r} 38.00 \\ - 17.96 \\ \hline 20.04 \end{array}$	$\begin{array}{r} 38.02 \\ - 17.94 \\ \hline 20.08 \end{array}$	$\begin{array}{r} 100 \\ - 58 \\ \hline 42 \end{array}$	$\begin{array}{r} 120 \\ - 56 \\ \hline 64 \end{array}$	$\begin{array}{r} 109 \\ - 58 \\ \hline 51 \end{array}$	$\begin{array}{r} 111 \\ - 56 \\ \hline 55 \end{array}$	$\begin{array}{r} 110.4 \\ - 57.001 \\ \hline 53.399 \end{array}$	$\begin{array}{r} 110.6 \\ - 56.999 \\ \hline 53.601 \end{array}$
Certain digits	Tens, ones and tenths		none		Tens		Tens and ones	
Answer w/ sig figs	20.06		50		53		53.5	

42. In both the tables above look at the number of significant figures in the measurements being used in the calculations and the number of significant figures in the answers. Look for a pattern and in your own words write the rule for adding and subtracting with significant figures. [Hint: the rule is different than the rule for multiplying and dividing.]

The smallest digit of the answer will be the smallest digit that all the measurements in the calculation have in common.

43. Notice in the middle two subtraction calculations above the calculator answer is exactly the same in both instances, but the answer with significant figures is different. Explain why.

As we know the measurements with more certainty we also know the calculated answer with more certainty.

Exact Numbers - An Exception to Sig Fig Rules

If you are using an “exact number” in calculations you do not have to account for it when determining the number of significant figures in your answer. An exact number is a value that is:

- counted instead of measured, or
- defined rather than measured.

Counted Number Example - We are asked to find the average mass of a sample of steel pellets. We counted 4 steel pellets and measured their total mass to be 237.1 grams. Because we counted the pellets we know there are 4, not 3 or 5, not 3.9 or 4.1, but exactly 4 pellets. Since we used a device such as a scale to measure the mass the 237.0 grams is a measured number. It could be anywhere from 236.9 to 237.1 grams. The range of valid answers for the average mass of the steel pellets would be

$$\text{Low: } \frac{236.9 \text{ g}}{4 \text{ pellets}} = 59.225 \text{ g} \quad \text{Mid: } \frac{237.0 \text{ g}}{4 \text{ pellets}} = 59.25 \text{ g} \quad \text{High: } \frac{237.1 \text{ g}}{4 \text{ pellets}} = 59.275 \text{ g}$$

We know the tens, ones and tenths digits with certainty. Our answer, 59.25 grams, has 4 sig figs, which is the same number of sig figs as the measured mass. The answer will have the same amount of certainty as the measured value with the least amount of certainty..

Defined Number Example – We are asked to convert the distance 2.45 km to meters. Our calculation is ...

$$2.45 \text{ km} \times \frac{1000 \text{ m}}{1 \text{ km}} = 2450 \text{ m}$$

We multiply the kilometers by the conversion factor $\frac{1000 \text{ m}}{1 \text{ km}}$ because one kilometer is defined as 1000 meters. Neither of these numbers is measured. Exactly 1 kilometer equals exactly 1000 meters. So our final answer is limited by the number of sig figs in the distance 2.45 km, which is 3 sig figs. The conversion factor does not affect the number of sig figs in the answer.

If you aren't sure whether a number is exact or not, ask yourself, “did we get this number by measuring something, counting something or by definition?”

Summarizer

44. Why do we need to know if a value is a measured number or an exact number?

So we know if we need to consider it when determining the number of sig figs in an answer.

Rounding with Sig Figs – Look at the digit to the right of the last significant digit and “if it's 4 or below leave it go, 5 and above give it a shove.”

Examples – Round each number to 2 sig figs.

3.06 m rounds to 3.1 m

99.6 km rounds to 1.0×10^2 km

3.0499 m rounds to 3.0 m

2549 g rounds to 2500 g

Round the numbers below to the specified number of sig figs.

45. 77.076 to 4 sig figs

77.08

47. 0.0044476 to 2 sig figs

0.0044

46. 1002 to 2 sig figs

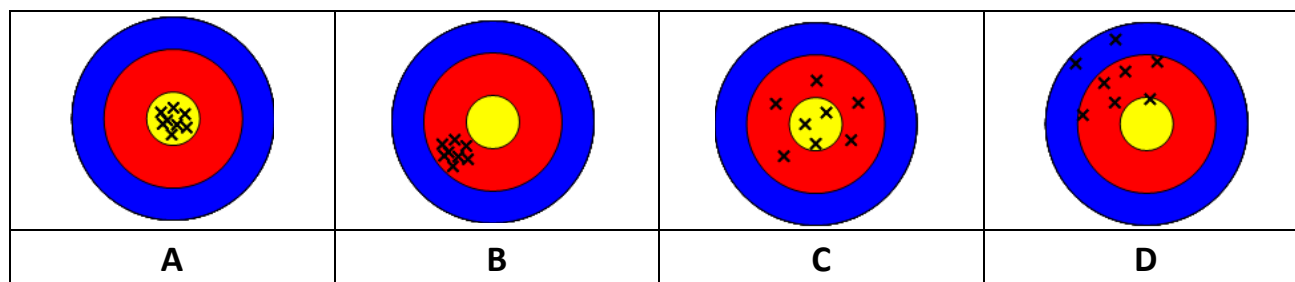
1.0×10^3

48. 0.0044476 to 3 sig figs

0.00445

Precision, Accuracy & Percent Error

Accuracy and precision – they aren't the same thing! The model below shows four archery targets each containing eight arrows.



49. Compare and contrast targets A and B.

The arrows are bunched close together on both targets; but target A has all bulls-eyes, whereas target B has no bulls-eyes.

50. Compare and contrast targets A and C.

Both targets have bulls-eyes; but the arrows are bunched together in the bulls-eye circle on target A, whereas the arrows are spread out in target B and some arrows missed the bulls-eye.

51. Compare and contrast targets B and C.

Target C has the arrows spread out, but has some bulls-eyes. Target B has the arrows bunched close together, but there are no bulls-eyes.

52. Compare and contrast targets B and D.

Neither target has any bulls-eyes, but target B has the arrows bunched close together, whereas the arrows are spread out in target D.

Accuracy and precision are scientific terms used to describe experimental data. Accuracy refers to how close the data are to the acceptable value. In everyday language we use words like “correct”, “accurate” and “right on” to describe data that have high accuracy. We use “incorrect”, “inaccurate” and “way off” to describe data that have low accuracy. Precision refers to how close the data are to each other. In everyday language we use words like “consistent”, “close together” and “precise” to describe data that have high precision. We use “inconsistent”, “scattered” and “imprecise” to describe data that have low precision.

Accuracy and precision are not connected or related to each other. Accurate data is not always precise; and precise data is not always accurate.

53. Which archery target has ...

a. High accuracy and low precision?

target C

b. High accuracy and high precision?

target A

c. Low accuracy and high precision?

target B

d. Low accuracy and low precision?

target D

Four lab groups performed an experiment to determine the boiling point of water. Each group performed four trials. Their data are shown below:

	Boiling Point, °C			
Group	A	B	C	D
Trial 1	99.8	102.5	98.9	100.2
Trial 2	99.0	103.3	99.4	100.0
Trial 3	101.1	100.9	99.2	99.9
Trial 4	100.6	99.8	99.2	100.1

54. Describe the accuracy and precision of each lab group's data.

Group A's data is accurate but not precise. Group B's data is neither accurate nor precise. Group C's data is precise but not accurate. Group D's data is accurate and precise.

Systematic errors cause inaccurate data. Systematic errors are usually a result of the experimental design. There may be one or more steps in the procedure that introduce error or the equipment used to carry out the experiment may have some limitations to its accuracy that are creating the error. Reproducibility errors cause imprecise data. Reproducibility errors are often a result of human error, such as slight differences in the way each trial is performed, or mistakes in measuring results.

55. What might be a source of error in group B's data?

The person was not very careful in reading the thermometer or a different thermometer was used for each trial.

56. What might be a source of error in group C's data?

The thermometer was inaccurate.

Percent Error – Is a measure of how accurate experimental values are. A low percent error means the experimental value is close to the accepted value. A large percent error means the experimental value is much different than the accepted value. Here is the formula for calculating percent error:

$$\text{Percent error} = \frac{\text{Value}_{\text{accepted}} - \text{Value}_{\text{experimental}}}{\text{Value}_{\text{accepted}}} \times 100$$

If you have a hard time remembering if it's the accepted value minus the experimental value or vice versa just remember "a comes before e, which means accepted minus experimental."

57. Calculate the percent errors for the data below (show your work):

Experimental Value	Accepted Value	Percent error
3.45 g	3.49 g	$\frac{3.49\text{g} - 3.45\text{g}}{3.49\text{g}} \times 100 = 1.15\%$
105 m	101 m	$\frac{101\text{m} - 105\text{m}}{105\text{m}} \times 100 = -3.81\%$

Equalities, Conversion Factors & Dimensional Analysis

Often we need to convert a measured quantity from one unit to another unit. For example, we measured the mass of an object as 454.3 grams, but we need the measurement in kilograms. We can use the factor label method to do the conversion.

Factor Conversion Method Steps

- Write an equality equation for the two units, i.e. 1 kilogram = 1000 grams
- Create two conversion factors from this equality, i.e. $\frac{1000\text{ g}}{1\text{ kg}}$ and $\frac{1\text{ kg}}{1000\text{ g}}$
- Start with the original measurement and unit, i.e. 454.3 g
- Pick the conversion factor that has the original unit in the denominator (on the bottom) and multiply it by the original measurement, i.e. $454.3\text{ g} \times \frac{1\text{ kg}}{1000\text{ g}}$
- Cancel out units that appear in both the numerator (top) and denominator (bottom), i.e. $454.3\text{ g} \times \frac{1\text{ kg}}{1000\text{ g}}$
- Perform the calculation and include the units that aren't cancelled, i.e. $454.3\text{ g} \times \frac{1\text{ kg}}{1000\text{ g}} = 0.4543\text{ kg}$

The Metric System Equalities

Prefix	Unit Abbreviation	Exponential Factor	Meaning	Example
tera	T	10^{12}	1 000 000 000 000	1 Tm = 1×10^{12} m
giga	G	10^9	1 000 000 000	1 Gm = 1×10^9 m
mega	M	10^6	1 000 000	1 Mm = 1×10^6 m
kilo	k	10^3	1 000	1 km = 1 000 m
hecto	h	10^2	100	1 hm = 100 m
deka	da	10^1	10	1 dam = 10 m
		10^0	1	1 meter (m), gram (g)
deci	d	10^{-1}	1/10	10 dm = 1 m
centi	c	10^{-2}	1/100	100 cm = 1 m
milli	m	10^{-3}	1/1000	1 000 mm = 1 m
micro	μ (mu)	10^{-6}	1/1 000 000	$1 \times 10^6\text{ }\mu\text{m} = 1\text{ m}$
nano	n	10^{-9}	1/1 000 000 000	$1 \times 10^9\text{ nm} = 1\text{ m}$
pico	P	10^{-12}	1/1 000 000 000 000	$1 \times 10^{12}\text{ pm} = 1\text{ m}$

***** MUST MEMORIZE nano to kilo prefixes**

English & English-Metric Equalities

Mass & Weight	1 lb = 453.6 g	1 oz = 28.35 g	1 kg = 2.2 lb
Length	1 in = 2.54 cm	1 ft = 12 in	1 yd = 3 ft
	1 km = 0.62 miles	1 mile = 1.6 km	
Volume	1 qt = 0.946 L	1 L = 1.06 qt	$1\text{ cm}^3 = 1\text{ mL}$
	1 gallon = 4 quarts = 8 pints = 128 oz		
Time	60 s = 1 min	60 min = 1 hr	24 hr = 1 day
			365 days = 1 year

Use the factor-label method to calculate the unit conversions. Show your work including the correct sig figs.

58. 500. mL = _____ L

$$500.\cancel{\text{mL}} \times \frac{1\text{L}}{1000\cancel{\text{mL}}} = 0.500\text{L}$$

64. 0.22 km = _____ m

$$0.22\cancel{\text{km}} \times \frac{1000\text{m}}{1\cancel{\text{km}}} = 220\text{m}$$

59. 400. mg = _____ kg

$$400.\cancel{\text{mg}} \times \frac{1\cancel{\text{g}}}{1000\cancel{\text{mg}}} \times \frac{1\text{kg}}{1000\cancel{\text{g}}} = 0.000400\text{kg}$$

65. 1.25 km = _____ yds

$$1.25\cancel{\text{km}} \times \frac{1000\cancel{\text{m}}}{1\cancel{\text{km}}} \times \frac{100\cancel{\text{cm}}}{1\cancel{\text{m}}} \times \frac{1\cancel{\text{in}}}{2.54\cancel{\text{cm}}} \times \frac{1\text{yd}}{36\cancel{\text{in}}} = 1\,370\text{yd}$$

60. 3500. s = _____ hr

$$3500.\cancel{\text{s}} \times \frac{1\cancel{\text{min}}}{60\cancel{\text{s}}} \times \frac{1\text{hr}}{60\cancel{\text{min}}} = 0.9722\text{hr}$$

66. 2400 mm³ = _____ cm³

$$2400\cancel{\text{mm}^3} \times \frac{(1\cancel{\text{m}})^3}{(1000\cancel{\text{mm}})^3} \times \frac{(100\cancel{\text{cm}})^3}{(1\cancel{\text{m}})^3} = 2.4\text{cm}^3$$

61. 1.5 yr = _____ s

$$1.5\cancel{\text{yr}} \times \frac{365\cancel{\text{day}}}{1\cancel{\text{yr}}} \times \frac{24\cancel{\text{hr}}}{1\cancel{\text{day}}} \times \frac{60\cancel{\text{min}}}{1\cancel{\text{hr}}} \times \frac{60\text{s}}{1\cancel{\text{min}}} = 4.7 \times 10^7\text{s}$$

67. 14.33 m³ = _____ dm³

$$14.33\cancel{\text{m}^3} \times \frac{(10\cancel{\text{dm}})^3}{(1\cancel{\text{m}})^3} = 14\,330\text{dm}^3$$

62. 15 m = _____ mm

$$15\cancel{\text{m}} \times \frac{1000\text{mm}}{1\cancel{\text{m}}} = 15\,000\text{mm}$$

68. 9722 μm = _____ hm

$$9722\cancel{\mu\text{m}} \times \frac{1\cancel{\text{m}}}{1\,000\,000\cancel{\mu\text{m}}} \times \frac{1\text{hm}}{100\cancel{\text{m}}} = 9.722 \times 10^{-5}\text{hm}$$

63. 4.2 L = _____ cm³

$$4.2\cancel{\text{L}} \times \frac{1000\cancel{\text{mL}}}{1\cancel{\text{L}}} \times \frac{1\text{cm}^3}{1\cancel{\text{mL}}} = 4200\text{cm}^3$$

Summarizer

69. How do you set up the 2 conversion factors for an equality equation between two units?

You put one number and its unit from one side of the equality in the numerator and the number and its unit from the other side of the equality in the denominator. To get the second conversion factor you flip flop the numerator and denominator.

70. How do you determine which conversion factor to use in your unit conversion calculation?

Use the conversion factor that cancels out the starting units and leaves the same units that are needed for the answer.

Dimensional Analysis

Often we need to convert from one quantity to another quantity to solve a problem. For example, we need to figure out the volume of gas we can put in the car if we have \$20.00 and gas costs \$3.929 per gallon. We use the factor-label method for these types of calculations.

Steps for Dimensional Analysis with Factor-Label Method

- Look at the original units, the units for the answer, and find an equality equation between the two. Note that there may not be one equation that relates the two; rather you may need to use several equality statements to go from your starting units to your final units. In our example, we are starting with dollars and need an answer in gallons. We have an equality 1 gallon = \$3.929
- Create two conversion factors from this equality, i.e. $\frac{\$3.929}{1 \text{ gal}}$ and $\frac{1 \text{ gal}}{\$3.929}$
- Start with the original measurement and unit, i.e. \$20.00
- Pick the conversion factor that has the original unit in the denominator (on the bottom) and multiply it by the original measurement, i.e. $\$20.00 \times \frac{1 \text{ gal}}{\$3.929}$
- Cancel out units that appear in both the numerator (top) and denominator (bottom), i.e. $\$20.00 \times \frac{1 \text{ gal}}{\$3.929}$
- Perform the calculation and include the units that aren't cancelled, i.e. $\$20.00 \times \frac{1 \text{ gal}}{\$3.929} = 5.090 \text{ gal}$.

Note that the 1 gallon and \$3.929 are exact numbers so our answer is limited to the number of sig figs in \$20.00, which are 4.

Use dimensional analysis and the factor-label method to solve these problems. Show your work and include the correct units and sig figs in your answer.

71. Mr. Good drives 50.0 miles round trip to school each day. There are 5 school days per week, his car averages 32.1 miles per gallon and gasoline costs \$3.929 per gallon. How much money does Mr. Good spend on gasoline each week?

$$\frac{50.0 \text{ mi}}{1 \text{ day}} \times \frac{5 \text{ day}}{1 \text{ wk}} \times \frac{1 \text{ gal}}{32.1 \text{ mi}} \times \frac{\$3.929}{1 \text{ gal}} = \$30.60/\text{wk}$$

72. The ladle at an iron foundry can hold 4500 kg of molten iron; 446 metric tons of iron is needed to make rails. How many ladleful's of iron will it take to make 446 metric tons of iron? (1 metric ton = 1000 kg)

$$446 \text{ metric tons} \times \frac{1000 \text{ kg}}{1 \text{ metric ton}} \times \frac{1 \text{ ladle}}{4500 \text{ kg}} = 99 \text{ ladles}$$

73. A baker uses 1.75 tsp of vanilla extract in each cake. How much vanilla extract in liters should the baker order to make 600 cakes? (1 tsp = 5 mL)

$$600 \text{ cakes} \times \frac{1.75 \text{ tsp}}{1 \text{ cake}} \times \frac{5 \text{ mL}}{1 \text{ tsp}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 5.25 \text{ L}$$

74. A person drinks six glasses of water each day, and each glass contains 300 mL. How many liters of water will that person consume in a year? What is the mass of this volume of water in kilograms? (Assume one year has 365 days and the density of water is 1.00 kg/L.)

$$\frac{6 \text{ glasses}}{1 \text{ day}} \times \frac{365 \text{ day}}{1 \text{ yr}} \times \frac{300 \text{ mL}}{1 \text{ glass}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1.00 \text{ kg}}{1 \text{ L}} = 657 \frac{\text{kg}}{\text{yr}}$$

Summarizer

75. What are the three key steps to solving problems with dimensional analysis and the factor-label method?

- *Determine the units you are starting with and determine the units for the final answer.*
- *Find one or more equalities that relate your quantities and units to each other*
- *Use one or more conversion factors to cancel out units that aren't part of the final answer and leave the units that are in the final answer.*

76. How do you determine how many equality statements you need to convert from one quantity to another quantity?

You need as many equality statements as it takes to go from your starting quantity and units to the quantity and units for your answer.