CHAPTER 1
ESSENTIAL IDEAS

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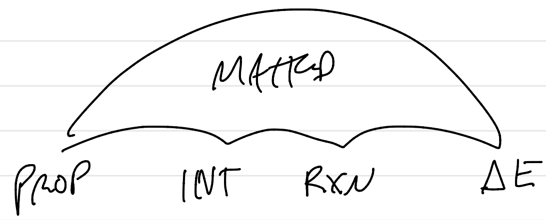
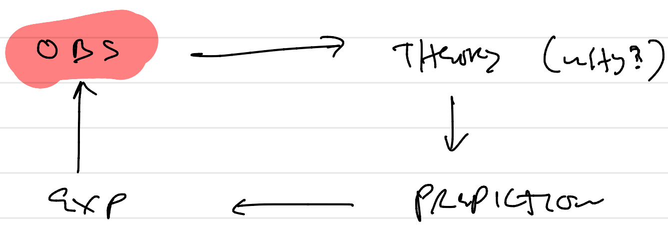
Chemistry: The Central Science



The Scientific Method



LAW - stmt of fact

The Domains Of Chemistry

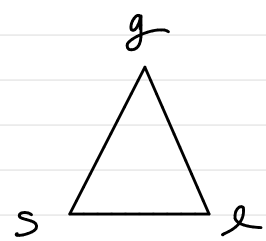
- macroscopic
- microscopic (nanoscopic)
- symbolic

Phases And Classification Of Matter [1.2]

3 States (Phases) Of Matter

Plasma - gas state, highly charged

mass - amnt of matter
weight - pull of gravity on matter



Conservation Of Matter

Atoms And Molecules

Atom — smallest STABLE particle of an element.

Molecule — combination of 2 or more atoms $O=O$, H_2O

Compound — " " " " " different " × H_2O

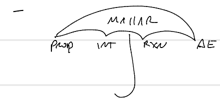
Molecule Vs. Compound

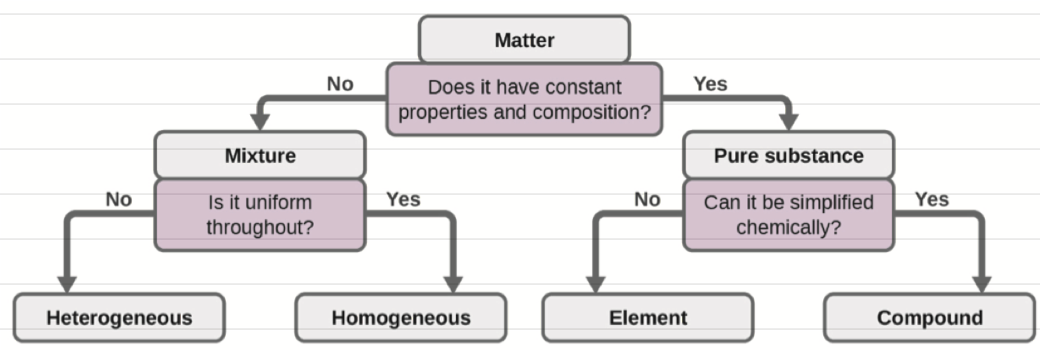
Molecule = 2+ atoms

Compound = 2+ different atoms

	Element	Compound
Atom	C, Fe	×
Molecule	O_2, H_2	H_2O

Classifying Matter: 4 Classes Of Matter





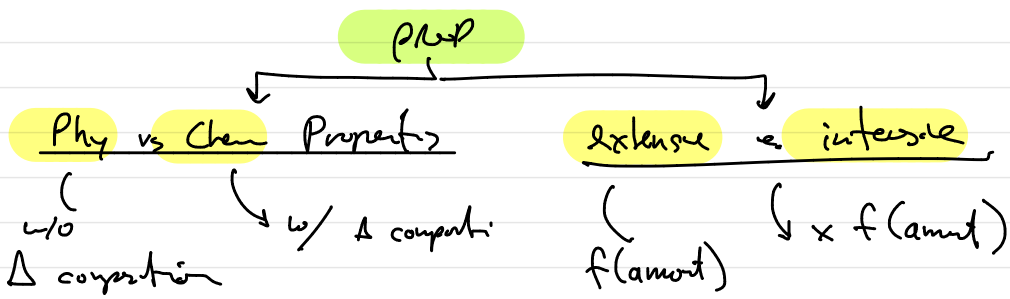
Physical And Chemical Properties [1.3]

[org chart]

Intensive vs. Extensive Properties

Chemical vs. Physical Properties

Density: intensive property which is defined by extensive properties



(EX) ID Type of Property

¿Identify the following as Physical only, Chemical only, or Both:

- Ice melts at ° C
- Propane burns to CO_2 + H_2O
- Pb is a dense metal
- Milk turns sour
- Leaves turn color in Fall
- Gallium melts in your hand
- Scramble an egg
- A nut rusts onto a bolt
- Strike a match
- Au is inert (is not very reactive)

The Periodic Chart

- tends to group materiasl by similiar properties …
- some by chemical properties (groups)
- some by physical properties (eg., s, l, g)

Measurements [1.4]

Measurement = # + unit

← prefix letter

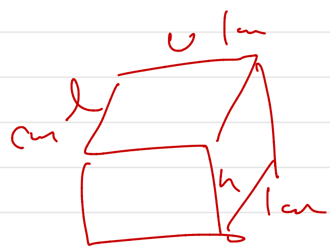
unit

SI Base Units

m	length
Kg	mass
s	time
K	temp
mol	amt (6.02×10^{23})
A	electr
cd	luminosity

Derived SI Units

“mL” is a derived unit — it is derived from three length measurements



} 1 mL

$1\ cm^3$ → 1 cc

7 Prefixes You Need To Memorize

M	mega	1,000,000
K	kilo	1,000
d	deci	1/10
c	centi	1/100
m	milli	1/1000
μ	micro	1/1,000,000
n	nano	1/1,000,000,000

Density

$$D = \frac{m}{V} \quad \left(\frac{g}{mL} \text{ or } \frac{g}{cm^3} \text{ or } \frac{g}{cc}\right)$$

density – ratio of mass of sample to its volume
↪ physical property ↪ intensive
↪ ex: water = 1.0 g/mL ; wood : 0.60 - 0.90 ; Hg = 13.6 ; Au = 19.
↪ d < 1.0 , floats on water ; d > 1.0 , sinks

problem solving – density problems can be solved algebraically , or by DA (no +/-)

* WILL RETURN TO DENSITY PROBLEM AFTER WE TAKE UP DA , SHORTLY

Measurement Uncertainty, Accuracy, And Precision [1.5]

Accuracy and Precision provided indications of ‘uncertainty’

Accuracy — ability to hit the bullseye

Precision — tight grouping… ability to hit the same spot every time… to not “spray” the data.

Determining and Expressing Uncertainty

In this course, there are basically three levels of questions regarding 'uncertainty' calculations:

(1) SINGLE NUMBER: Det'n the Sig Figs and Places of a single number

(2) SINGLE OPERATION: Det'n the Sig Figs and Places of the answer resulting from a (x/÷), or a (+/—), mathematical operation.

(3) MIXED OPERATION: Det'n the Sig Figs and Places of the answer resulting from a problem involving both (x/÷) and (+/—) operations.

12.030

12.030
+ 0.40

$$\frac{12.030 + 0.40}{0.200}$$

CAVEAT!!!
Determining SigFigs and Places is a CORE CONCEPT in this class… it is highly probably that every test will have at least one "SigFig" question on it… SigFig questions will also be on the final exam… and they will be graded on every lab report submitted… in short, SigFigs is not "going away."

Uncertainty: Single Number

The Box-and-Dot Method: How to count Sig Figs and Places

(1) Box from the first thur the last non-zero digits
(2) IF, and only if, you see a “dot”, draw a box around any TRAILING zeros
(3) all digits in the box(es) are significant, the others are not
… furthermore, the right-most boxed digit provides the “place” to which the number is precise

	sf	Places
3040	3	10's
3040.0	5	1 dp
304.0	4	1 dp
0.00304	3	5 dp
3.01×10^3	3	2 dp
100	1	100's
100.	3	1's
	x/÷	+/−

The Box-and-Dot Method: A Simple Strategy for Counting Significant Figures

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When test time arrives many students struggle to correctly assign significant figures to numbers. They confuse (or forget altogether) simple rules previously memorized, making the rules difficult or impossible to apply under pressure situations.

This situation is largely remedied with the use of a visual approach I refer to as the box-and-dot method. The method uses the device of "boxing" significant figures based on two simple rules, then counting the number of digits in the box(es).

The three steps of the box-and-dot method are detailed below; additional examples show the method's ease of use.

Box-and-Dot Basics

The box-and-dot method consists of three simple steps for determining the significant figures in any real number (except zero). The steps must be followed explicitly.

Step 1

Draw a box around all nonzero digits, beginning with the leftmost nonzero digit and ending with the rightmost nonzero digit in the number.

For example, drawing a box around the nonzero digits in the number 0.0123012300 gives $0.0\boxed{1230123}00$. Any zero(s) trapped or "sandwiched" between nonzero digits will necessarily be included in the box.

For convenience, a digit or number surrounded by a box may be referred to as a "boxed" digit or "boxed" number, respectively.

Step 2

If a dot is present, draw a box around any trailing zeros.

Continuing with the above example, a dot (decimal point) is present in the expression $0.0\boxed{1230123}00$; therefore, trailing zeros[1] are boxed, which gives $0.0\boxed{1230123}\boxed{00}$.

Step 2 uses the term *dot* in lieu of *decimal point* for reasons of brevity and ease of recall. "Box-and-decimal point method" possesses neither the pith nor lilt of "box-and-dot".

The position of a decimal point within a number is irrelevant—the only test for boxing trailing zeros is the mere presence of a dot.

Because method steps are followed explicitly, it is understood that trailing zeros should *not* be boxed when a dot is *not* present. In other words, draw a box around trailing zeros if and only if a dot is present.

Step 3

Consider any and all boxed digits significant.

Boxed digits are significant, whereas digits that are not boxed are not significant. Continuing the example from Step 2, the expression $0.0\boxed{1230123}\boxed{00}$ reveals nine digits surrounded by boxes. Therefore, there are nine significant figures. Specifically, the significant figures are: 1, 2, 3, 0, 1, 2, 3, 0, and 0.

Note that the box-and-dot method does not expressly address leading zeros.[2] There is no need. Leading zeros, which are never significant, always lie to the left of the box drawn in Step 1 and are therefore excluded from consideration as significant figures by virtue of the explicitness of Steps 1 and 2. Those steps provide criteria for boxing (and thus rendering significant) trapped and trailing zeros only, to the exclusion of all other zeros.

In general, at least one, but not more than two, boxes will be associated with any given number. Step 1 always requires that a box be drawn. Step 2 only allows for a (second) box to be drawn when two conditions are met: (i) a decimal point is present, and (ii) one or more trailing zeros are present.

Typically, none of the steps requires more than a few seconds to complete.

Worked Examples of the Box-and-Dot Method

Several examples follow, in the form of sample questions. For convenience, each of the three steps discussed above is represented with a chevron (»). The number prior to the first chevron in each example is the number for which significant figures are to be determined. To demonstrate the ease of use and visual nature of the box-and-dot method, little or no explanation is provided. Deriving the correct answer becomes second nature after working only a few problems.

Question 1

How many significant figures are in the number 123.01230?

Answer: 123.01230 » $\boxed{123.0123}0$ (nonzero digits are boxed) » $\boxed{123.0123}\boxed{0}$ (dot present, so the trailing zero is boxed) » eight numbers are boxed, therefore the number has eight significant figures.

Question 2

How many significant figures are in the number 12301230?

Answer: 12301230 » $\boxed{1230123}0$ » no dot is present (so the trailing zero is not boxed) » seven significant figures.

Question 3

How many significant figures are in the number 123.0123?

Answer: 123.0123 » $\boxed{123.0123}$ » no trailing zeros » seven significant figures.

Question 4

How many significant figures are in the number 10100?

Answer: 10100 » $\boxed{101}00$ » no dot (so no trailing box) » three significant figures.

Sig Figs In Single Mathematical Operation: (x/÷) or (+/—)

Every number has both SIG FIGS and PLACES

4 operations

x/÷ → sf: # digits in box(es)

+/− → places: place of far-right digit

	sf	places	
45.60	4	2 dp	45.60
x 1.4	2	1 dp	+ 1.4
63.84 → 64			47.00 → 47.0

REMEMBER…
- Trust the calculator's DIGITS, not it's NUMBER
- When determining the correct number: "Choose one: either SF or PLACES
- Apply the "weakest link" rule

(EX) Sig Figs In Mathematical Operations: (x/÷) and (+/—)

sf places

44.56 x 0.140 ———	44.56 + 0.140 ———

For Mixed Operations problems, use the “3-Box approach”

(EX) Mixed Operations: single problem with both +/– AND (x/÷) operations

How NOT do get the correct answer: punch all the numbers out on you calculator in one step

$$\% \text{Error} = \frac{98-94}{94} \times 100 = 4.25532$$

% = exact

from calculator

How TO get the correct answer: use the 3-column approach

(1) write the entire equation to be solved in Column1	(2) solve only the add/sub (+/–), then write the entire new equation in Column2	(3) solve the mul/div (x/÷), then write the entire new equation in Column3
$\frac{98-94}{94} \times 100$	$\frac{4}{94} \times 100$	

+/–

$$\begin{array}{r} 99 \\ +2 \\ \hline 101 \end{array}$$

Remember the way to work mixed problems

(1) write the entire equation to be solved in Column1	(2) solve only the add/sub (+/–), then write the entire new equation in Column2	(3) solve the mul/div (x/÷), then write the entire new equation in Column3

$$\begin{array}{r} 100 \\ +\ 1 \\ \hline 101 \end{array}$$

100's

1's

100

Exact Numbers (can ignore when determining SigFig's)

1. Conversions between units within the English System are exact.
   ~e.g. 12 in = 1 ft or 12 in/1 ft (In this conversion, 12 and 1 are both exact.)

2. Conversions between units within the Metric System are exact.
   ~e.g. 1 m = 100 cm or 1 m/100 cm (In this conversion, 1 and 100 are both exact.)

3. Conversions between English and Metric system are generally NOT exact. Exceptions will be pointed out to you.
   ~e.g. 1 in = 2.54 cm exactly (1 and 2.54 are both exact.)
   ~e.g. 454 g = 1 lb or 454 g/1 lb (454 has 3 sig. fig., but 1 is exact.)

4. "Per" means out of exactly one.
   ~e.g. 45 miles per hour means 45 mi = 1 hr or 45 mi/1 hr. (45 has 2 sig. fig. but 1 is exactly one.)

5. "Percent" means out of exactly one hundred.
   ~e.g. 25.9% means 25.9 out of exactly 100 or 25.9/100 (25.9 has 3 sig. fig., but 100 is exact.)

6. Counting numbers are exact. Sometimes it is hard to decide whether a number is a "counting number" or not. In most cases it would be obvious. Ask when in doubt.
   ~e.g. There are 5 students in the room. (5 would be an exact number because you cannot have a fraction of a student in the room.)
   ~e.g. subscripts in a formula, and coefficients in a balanced equation, are considered "counting numbers" and are exact

7. Mathematical constants are exact. The symbol is exact; however, the number 3.14 has only three significant figures, while 3.1416 has five. In a mathematical formula, such as V = (4/3)pr 3 , or P.E. = ½ mv 2 , the fractions are exact numbers.

8. The conversions between Celsius, Fahrenheit, and Kelvin temperatures are exact. This means the fractions (5/9 or 9/5) and the number 32 are exact. The number 273.15, in the Celsius to Kelvin temperature conversion, is also exact.

9. Speed of light in a vacuum is exact, and is equal to 299,792,458 m/s

(see also PDF on Bb)

Math Operations, Measured Numbers, and Exact Numbers

$$\begin{array}{r} 100 \\ \times\ \ 2 \\ \hline \end{array}$$

$$\begin{array}{r} 100 \\ +\ \ 2 \\ \hline \end{array}$$

$$\begin{array}{r} 100 \\ +\ \ 2 \\ \hline \end{array}$$

$$\begin{array}{r} 100 \\ \times\ \ 2 \\ \hline 200 \end{array}$$

200 (1 s.f.) ← 200

1 sf, 100's

1 sf, 1's

$$\begin{array}{r} 100 \\ +2 \\ \hline 102 \end{array}$$

102 → 100 (100's place)

Measured vs. Exact Numbers In Calculations

sf if 9 is measured   sf if 9 is exact

47.2
x 9

47.2
x 9

REMEMBER…

- for purposes of SIG FIGS and PLACES, ignore Exact Numbers
- Exact Numbers are infinitely precise (“perfect”), so they can never be the least precise number
- often can NOT tell if an integer is Measured or Exact just by looking — must know situation.

Mathematical Treatment Of Measurement Results [1.6]

Two Methods Of Calculation

(1) Algebraically (this is probably the way you have solved problems throughout your school career)
(2) Dimensional Analysis, aka Factor Label Method… ELIMINATES the need for ALGEBRA)

(1) Algebraically (plug-into-formula)

¿The density of 55.64 g of a material is 21.4 g/mL. What is its volume?

$$D = \frac{m}{V} \rightarrow V = \frac{m}{D} = \frac{55.64\,g}{21.4\,g/mL} = \boxed{2.60\,mL}$$

① write equation ② re-arrange equation ③ plug in numbers, & solve

(2) Dimensional Analysis

DA mindset — Think units first, and numbers last

DA Generic Formula:

answer	=	given	×	CF
(□ unit)		("data")		(simple ratio of 2 items)

(EX) Dimensional Analysis

¿If 2 loaves of bread cost $4.28, how much do 17 loaves cost?

CF: $\left(\frac{\$4.28}{2\text{ loaves}}\right)$ or $\left(\frac{2\text{ loaves}}{\$4.28}\right)$

$$\frac{\$\,\square}{1} = \frac{\$4.28}{2\text{ loaves}} \times \frac{17\text{ loaves}}{} = \$36.38$$

$$\frac{£\,\square}{1} = \frac{\$4.28}{2\text{ loaves}} \times \frac{17\text{ loaves}}{} \times \frac{£1.00}{\$1.25} \times \frac{¥}{£}$$

¥

(EX) Dimensional Analysis

¿Your Ford Mustang has a 5.00 L engine. What is the engine size in units of "in³"?

$$\frac{\square \ in^3}{1} = \frac{5.00\ L}{1}\left|\frac{1000\ mL}{1\ L}\right|\frac{1\ cm^3}{1\ mL}\left|\frac{1^3\ in^3}{(2.54)^3\ cm^3}\right. = \boxed{305\ in^3}$$

$(2.54)^3 = 16.387$

(EX) Dimensional Analysis… REDUX: Density Question Previous Page:
¿The density of 55.64 g of a material is 21.4 g/mL. What is its volume?

$\left(\frac{21.4\,g}{mL}\right)$ CF

The Hard Way

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

algebraically

$D = \frac{m}{V} \rightarrow V = \frac{m}{D} = \frac{55.64\,g}{21.4\,g/mL} = \boxed{2.60\,mL}$

① write equation ② re-arrange equation ③ plug in numbers, & solve

The Easy "No-algebra" Way

$$\frac{\square\, g}{mL} =$$

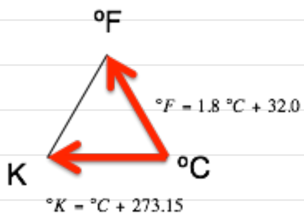
dimensional analysis

$$\frac{\square\, mL}{1} = \frac{1\, mL}{21.4\, g}\frac{55.64\, g}{1} = 2.60\, mL$$

$= \frac{m}{D}$

GOOD NEWS: DA will work on equations that are all (x/÷) … which probably turns out to be over 90% of the equations you will use in this course.

Conversion Of Temperature Units



$$°F = 1.8\ °C + 32.0$$

$$°K = \quad °C + 273.15$$

exact numbers

CAVEAT: canNOT use DA with temperature conversions.
¿Why not?
Because temp conv. formulas have a (+) or (–) operation.

(EX) Temp Conversion

¿Convert 373 K to °F?

K → °C → °F

$K = °C + 273.15$

$°C = K - 273.15$

$= 373 - 273.15$

$= 100.$

$°F = 1.8\,°C + 32.0$ ($\frac{9}{5}$)

$= (1.8)(100.) + 32.0$

$= 180 + 32.0$

$= 212\ °F$

$°F = 1.8\ °C + 32.0$

$°K = °C + 273.15$

exact numbers