Chapter 2
Section 1
LAWS

EARLY PHILOSOPHY:

- Some philosophers believed that matter had an ultimate, tiny, indivisible particle
  - ✓ Leucippus and Democritus
- Other philosophers believed that matter was infinitely divisible
  - ✓ Plato and Aristotle
- Since there was no experimental way of proving who was correct, the best debater was the person assumed correct, i.e., Aristotle

Scientific Revolution

- in the late 16th century, the scientific approach to understanding nature became established; started understanding the importance of experimentation.
- Experiments preformed in the eighteenth and nineteenth centuries led to an organized atomic theory by John Dalton in the early 1800s:
  - **The law of conservation of mass** **LCM**
  - **The law of** constant **composition** **LDP**
  - **The law of multiple proportions** **LMP**

Law of Conservation of Mass

The **total mass** of substances present at the end of a chemical process is the same as the mass of substances present before the process took place.

This law was discovered by Antoine Lavoisier.

This law was one of the laws on which Dalton's atomic theory was based.

EXAMPLE

A 7.12 g sample of magnesium is heated with 1.80 g of bromine. All the bromine is used up, and 2.07 g of magnesium bromide is produced. What mass of magnesium remains unreacted?

$$\mathbf{Mg + Br_2 \rightarrow MgBr_2}$$ *unbalanced at this time is ok* **m_{Mg} = unreacted?**

7.12g 1.80 g 2.07g

LCM means $m_{products} = m_{reactans}$ therefore products mass – reactant mass = unreacted if there is leftovers = 2.07g – (7.12 + 1.80g) = 6.85 g unreacted! Since the problem states that all of the bromine was used up [FYI: 2.07 – 1.80 = 0.27 g Mg used] therefore 6.85 g of Mg was unused!

Law of Definite Proportions/Composition

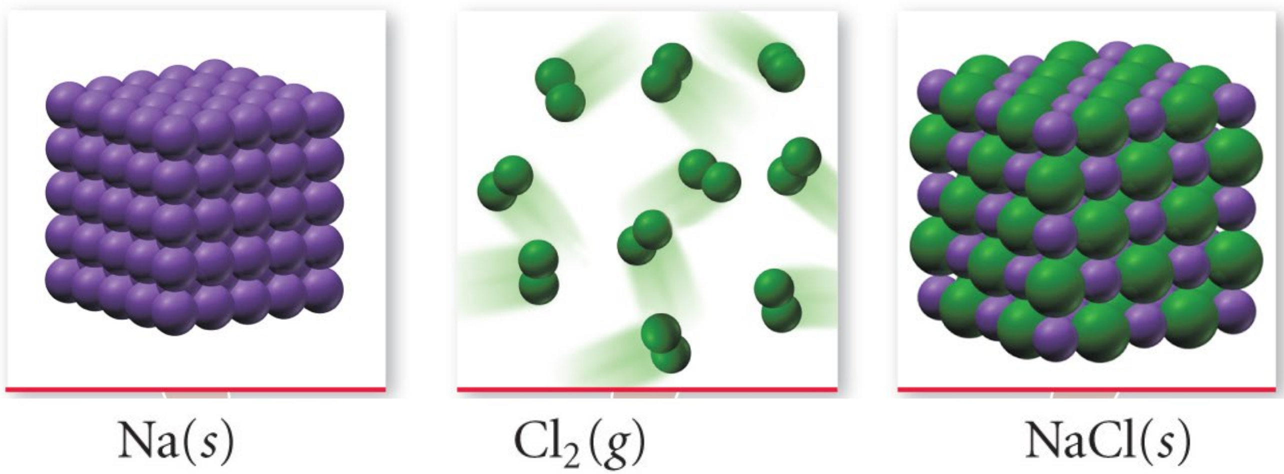
- Compounds have a definite composition. That means that the relative number of atoms of each element in the compound is the same in any sample.
- This law was discovered by Joseph Proust.
- This law was one of the laws on which Dalton's atomic theory was based.

- carbon combines with oxygen to form two different compounds, carbon monoxide and carbon dioxide
- carbon monoxide contains 1.33 g of oxygen for every 1.00 g of carbon
- carbon dioxide contains 2.67 g of oxygen for every 1.00 g of carbon
- since there are twice as many oxygen atoms per carbon atom in carbon dioxide than in carbon monoxide, the oxygen mass ratio should be 2

$$\frac{\text{mass of oxygen that combines with 1 g of carbon in carbon dioxide}}{\text{mass of oxygen that combines with 1 g of carbon in carbon monoxide}} = \frac{2.67\text{ g}}{1.33\text{ g}} = 2$$

Reaction of Sodium with Chlorine to Make Sodium Chloride

- the mass of sodium and chlorine used is determined by the number of atoms that combine
- since only whole atoms combine and atoms are not changed or destroyed in the process, the mass of sodium chloride made must equal the total mass of sodium and chlorine atoms that combine together

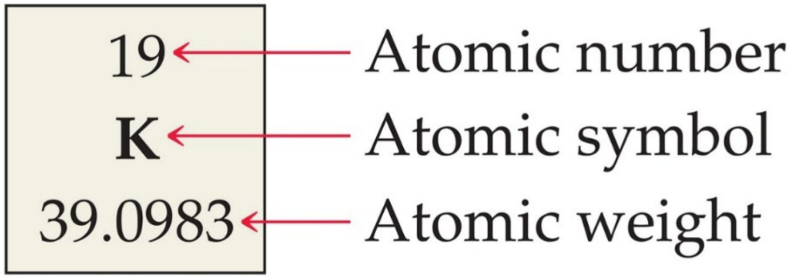


$$7.7 \text{ g Na} + 11.9 \text{ g } Cl_2 \rightarrow 19.6 \text{ g NaCl}$$

Reading the Periodic Table

Boxes on the periodic table list the atomic number **Above** the symbol.

The atomic weight of an element is listed below the symbol on the periodic table.



Experimental Proportions in Sodium Chloride

a 100.0 g sample of sodium chloride contains 39.3 g of sodium and 60.7 g of chlorine

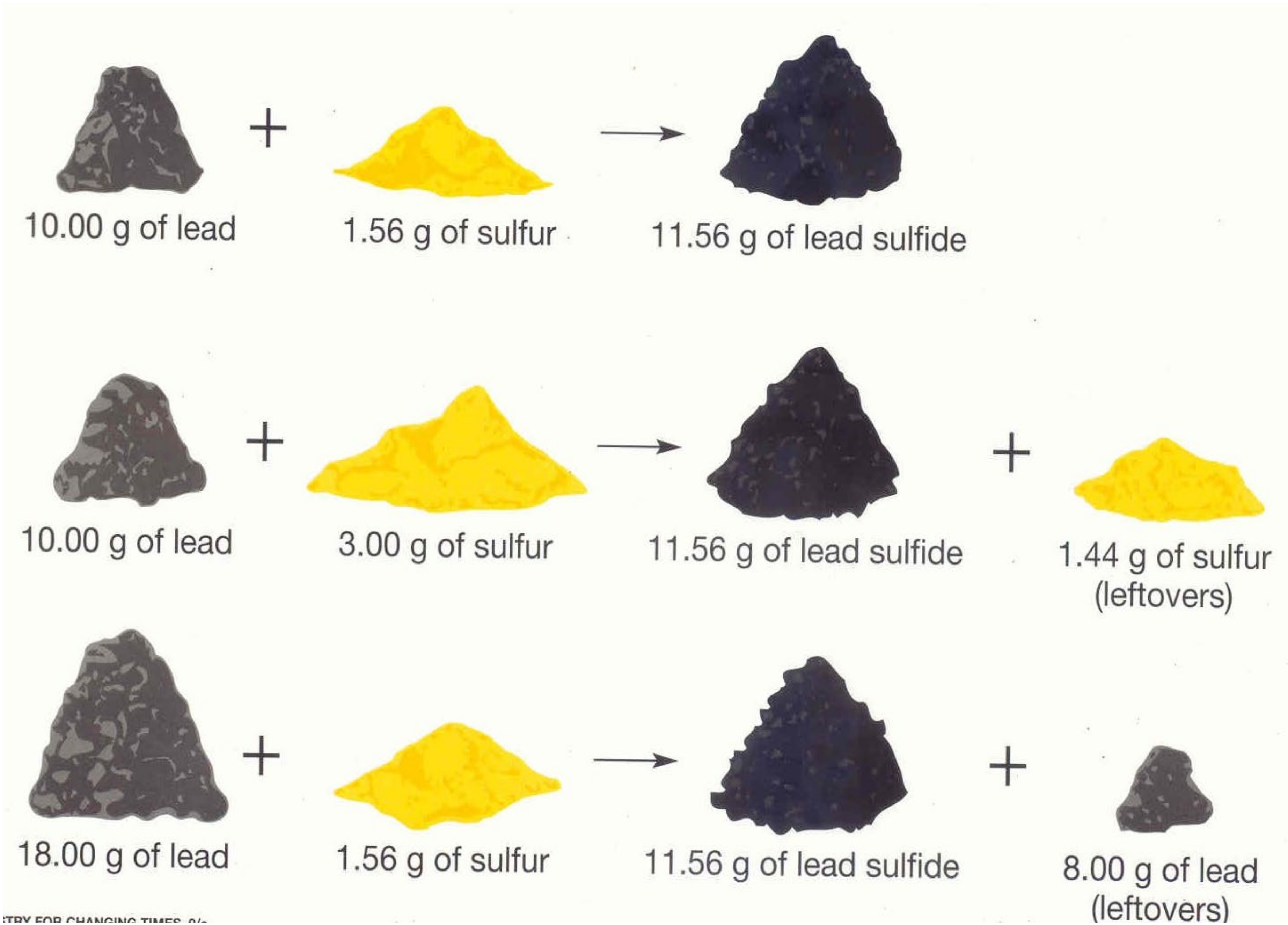
$$\frac{\text{mass of Cl}}{\text{mass of Na}} = \frac{60.7\ \text{g}}{39.3\ \text{g}} = 1.54$$

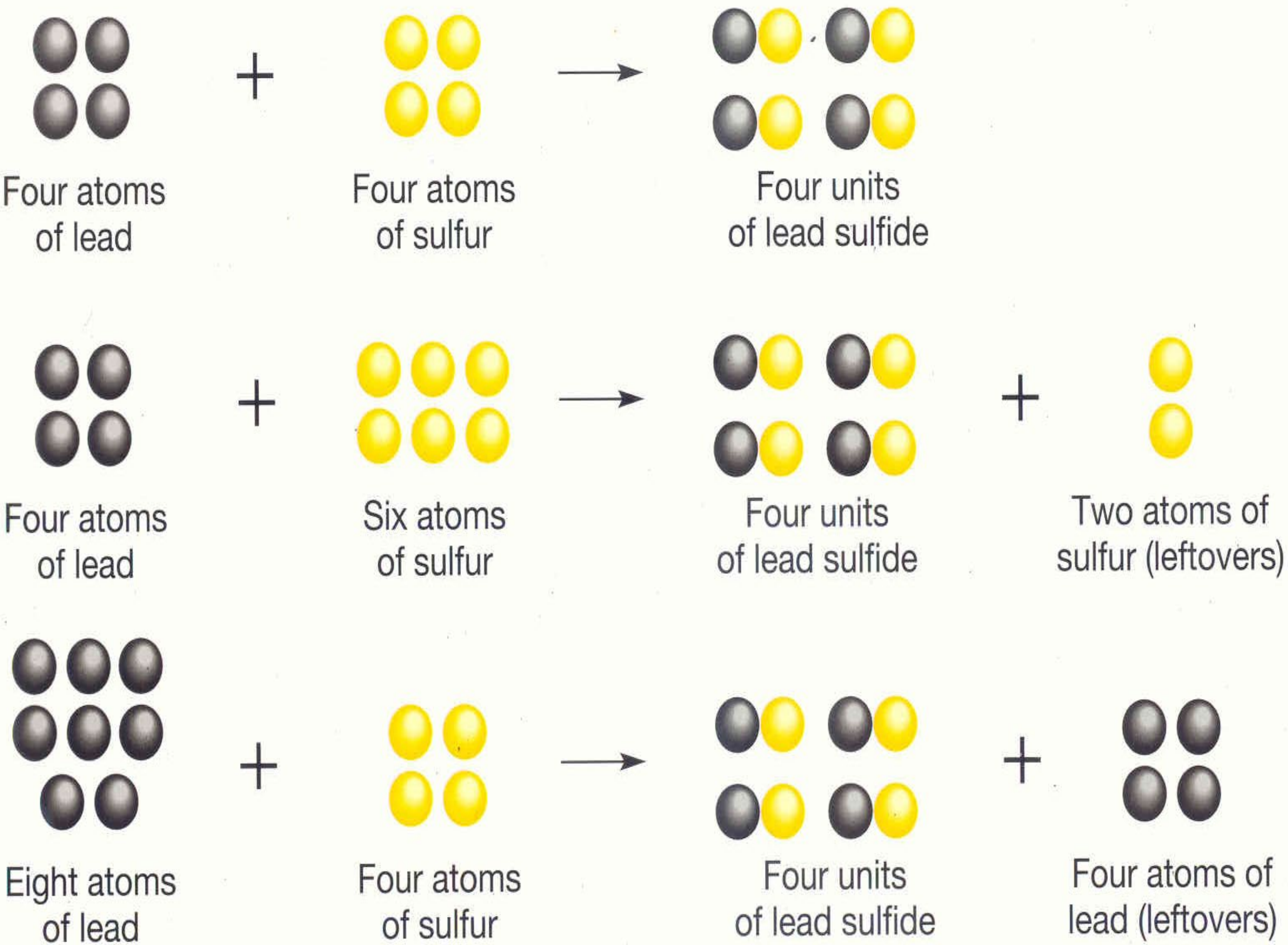
a 200.0 g sample of sodium chloride contains 78.6 g of sodium and 121.4 g of chlorine

$$\frac{\text{mass of Cl}}{\text{mass of Na}} = \frac{121.4\ \text{g}}{78.6\ \text{g}} = 1.54$$

a 58.44 g sample of sodium chloride contains 22.99 g of sodium and 35.44 g of chlorine

$$\frac{\text{mass of Cl}}{\text{mass of Na}} = \frac{35.44\ \text{g}}{22.99\ \text{g}} = 1.541$$


10.00 g of lead
1.56 g of sulfur
11.56 g of lead sulfide
10.00 g of lead
3.00 g of sulfur
11.56 g of lead sulfide
1.44 g of sulfur
(leftovers)
18.00 g of lead
1.56 g of sulfur
11.56 g of lead sulfide
8.00 g of lead
(leftovers)


Four atoms of lead
Four atoms of sulfur
Four units of lead sulfide
Four atoms of lead
Six atoms of sulfur
Four units of lead sulfide
Two atoms of sulfur (leftovers)
Eight atoms of lead
Four atoms of sulfur
Four units of lead sulfide
Four atoms of lead (leftovers)

EXAMPLES

1) A 0.100 g sample of magnesium, when combined with oxygen, yields 0.166 g of magnesium oxide. What masses of magnesium and oxygen must be combined to make exactly 2.00 g of magnesium oxide?

Step 1: write an equation:

Step 2: fill out table

Mg	$+$	O_2	$\rightarrow$	MgO
0.10g		0.066 g		0.166g
?		?		2.00 g

In this case you can set up a ratio. According to the L.D.P. compounds combine in set ratios therefore irrespective if starting material, the ratios of one atom to the next are related!

$$\frac{0.10}{?} = \frac{0.166}{2.00}$$

$? = [(0.10)(2.00)] / 0.166$

$? = 1.2048$ g of Mg

for $O_2 = 2.00 - 1.2048 = 0.7952$ g

or

$$\frac{0.066\text{g}}{x} = \frac{0.166}{2.00}$$

$x = [(0.066)(2.00)] / 0.166$

$x = 0.7952$ g of O_2

for $Mg = 2.00 - 0.7952 = 1.2048$g Mg

So no matter where you start, you will end up in the same place. In a 2.00 g sample of MgO, there are 1.21 g of Mg and 0.795 g of O

EXAMPLES

2) Galena, a mineral of lead and sulfur contained 2.030 g of lead in a 2.345 g sample.

(a) calculate the mass of sulfur in the sample.

(b) calculate the mass fraction of lead.

(c) calculate the mass percent of lead.

(d) How much reactant is needed to produce 15.000 g of product, galena?

Step 1: label galena (Pb_xS_y) and then write an equation:

Step 2: fill out table:

Pb_xS_y	$\rightarrow$ Pb	+ S
2.345g	2.030g	0.315 g
15.000 g	?	?

(a) L.C.M.

(b) Mass fraction = mass Pb /mass Pb_xS_y = 2.030 g / 2.345 g = 0.86567 This semester we will be using fractions rather than percentages to avoid excess unnecessary calculations!

(c) Simply multiply the fraction by 100 to get percent: (2.030 g / 2.345 g) 100 = 86.66%

(d) Again, you can set up a ratio. According to the L.D.P. compounds combine in set ratios therefore irrespective if starting material, the ratios of one atom to the next are related!

$$\frac{2.030g}{?} = \frac{2.345g}{15.000}$$

? = [(2.030)(15.000)] / 2.345

?= 12.985g of Pb

for S = 15.000g – 12.985g = 2.01483 g

In 15g of galena, there are 12.99g of Pb and 2.015 g S

So in the last two problems we learned experimentally that:

a 2.00 g sample of MgO is composed of 1.21 g of Mg for every 0.715 g of O,
or
in a 0.166g sample is made up of 0.10 g Mg for every 0.066 g of O.

In a 2.345g sample of galena, 2.030 g of it are made up of Pb atoms with 0.31 g of S atoms
or
in a 15g sample of galena, for every 2.015 g of S there must be 12.99g of Pb present.

Many ways to say the same thing! **Law of Definite Proportions**

So how could you determine the formula for galena if you knew, according to the periodic table, Pb weighs 207 amu and S weighs 32 amu?

Compounds have FIXED COMPOSITION.

From above experimental:

2.030g/2.345g = 0.8657 & 12.99 g/ 15.00g = 0.8657

so from the periodic table; Pb is 207amu

then

(Pb / Pb_xS_y) = fraction → 207 amu/ T = 0.8657

Rearrange → T = 207/0.8657→ T=239amu

now subtract Pb from total; 239 – 207 = 32 amu (??? That's S!)

so there is a 1:1 ratio by mass or PbS

When using the periodic table amu values we are dealing with theoretical!

EXAMPLE

3) When 10.00 g of marble chips, calcium carbonate, are treated with 50.0 mL of hydrochloric acid (d = 1.096 g/mL), the marble chips dissolve resulting in a solution and releasing the gas carbon dioxide. The final solution weighed 60.4 g. A) How many liters of carbon dioxide was released if the density of the gas is 1.798 g/L? B) How many grams of carbon are in both carbon dioxide and calcium carbonate in this example?

Step 1:	$CaCO_3$ +	HCl $\rightarrow$	CO_2	+	solution (everything but CO_2)
Step 2:	10 g	50 mL			60.4 g
		1.096g/mL	1.798g/L		

A)

Step 3: common units dV = m (1.096g/mL)(50mL) = 54.8g HCl NOW use LCM!

10g + 54.8 g = 64.8 g <u>reactants total</u> so 64.8g – 60.4 g = 4.4 g of CO_2 <u>products</u>

So V = m/d V = 4.4g / 1.798 g/L = 2.45 L of CO_2 gas was produced!

B)

We will use theoretical values from the periodic table. C =12amu, O = 16amu, Ca = 40amu

CO_2 = C + 2O = 12amu + 2(16amu) = 44 amu so according to the LDP,
Mass fraction = 12/44 = .2727 therefore 4.4 g of CO_2 * 0.2727 = 1.199g C in CO_2 collected.

$CaCO_3$ = Ca + C+ 3O = 40amu + 12amu + 3(16amu) = 100amu

Mass fraction = 12 amu/100amu = 0.12 therefore in 10g of $CaCO_3$ * 0.12 = 1.20g C start!

Law of Multiple Proportions

- If two elements, A and B, form more than one compound, the masses of B that combine with a given mass of A are in the ratio of small whole numbers.
- John Dalton discovered this law while developing his atomic theory.
- When two or more compounds exist from the same elements, they can **not** have the same relative number of atoms.

Law of Multiple Proportions

1) The following data were obtained for compounds of iodine and fluorine:

Compound	Mass of Iodine (g)	Mass of Fluorine (g)
A	1.000	0.1497
B	0.500	0.2246
C	0.750	0.5614
D	1.000	1.0480
E	0.250	0.1871

If the formula for compound A is IF, what are the formulas for compounds B, C, D and E?

Step 1: we need to determine if they are the same compound or different compounds.

So let's set up some ratios.

Step 2: we need some relationships. Let's set all masses of I_2 the same.

UK		M_{I2}(g)	M_{F2}(g)	ratio	M_{F2}(1g I_2)
A		1.000	0.1497	6.680	-
B	2x	0.500	0.2246	2.226	0.4492
C	1.33x	0.750	0.5614	1.336	0.7485
D		1.000	1.0480	0.954	1.0480
E	4x	0.250	0.1871	1.336	0.7485

~~So sample C&E are the same substance.~~

Repeat this process to achieve:

UK	M_{I2}(g)	M_{F2}(g)	M_{F2}(1g I_2)	
A	1.000	0.1497	-	IF
B	0.500	0.2246	0.4492	IF_3
C	0.750	0.5614	0.7485	IF_5
D	1.000	1.0480	1.0480	IF_7
E	0.250	0.1871	0.7485	IF_5

Now all masses of iodine are the same. Note that sample A = IF, so 1 F atom weighs 0.1497 g. We can use this relationship. $\frac{1F}{0.1497} = \frac{?F}{0.4492}$?F = 3 so the formula for B = IF_3

INDIVIDUAL QUIZ #4A on LAWS

Aluminum metal reacts with bromine, a red-brown liquid with a noxious odor. The reaction is vigorous and produces aluminum bromide, a white crystalline material. A sample of 27.062 g of aluminum yields 266.705 g of aluminum bromide. How many grams of bromine will react with 15.00 g of Al?

LECTURE QUIZ #4B on LAWS (in-person show all work)

1. A sample of chloroform is found to contain 12.00 g of carbon, 106.40 g of chlorine, and 1.010 g of hydrogen. If a second sample of chloroform is found to contain 30.00 g of carbo, what is the total mass of chloroform in the 2nd sample?

2. Two elements, R & Q, combine to form two binary compounds. The first compound has 14.00 g of R combining with 3.00 g of Q. In the second compound it took 7.00 g of R to combine with 4.50 g of Q. If the formula of the second compound was RQ, what is the formula for the first compound?

GROUP QUIZ #2 on LAWS (show all work)

1. When 1.445g of silver was heated in sulfur, 1.661 g of silver sulfide (Ag_2S) was produced.

   a) what is the mass of sulfur needed to produce 1.661 g of silver sulfide (Ag_2S) ?

   b) If a student started with 43.776 g of sulfur, how much silver would be needed to use up all of the sulfur?

2. How many grams of CuO can be obtained from 1.80 g of copper?