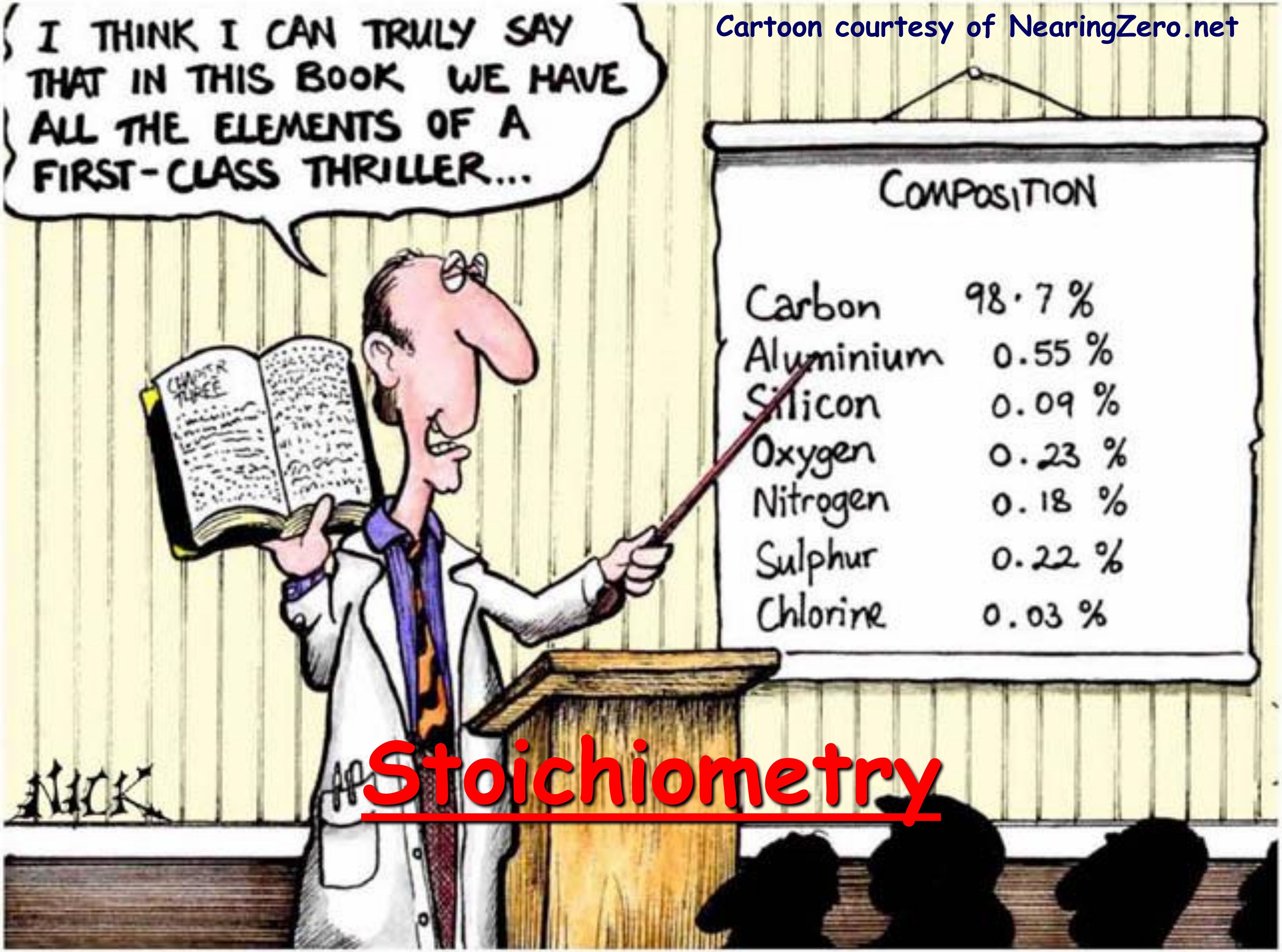
Stoichiometry



Cartoon courtesy of NearingZero.net

Stoichiometry

"In solving a problem of this sort, the grand thing is to be able to reason backward. This is a very useful accomplishment, and a very easy one, but people do not practice it much."

Sherlock Holmes, in Sir Arthur Conan Doyle's *A Study in Scarlet*

Stoichiometry - The study of quantities of materials consumed and produced in chemical reactions.

Review: The Mole

	divide by MM →		multiply by 6.022×10^{23} →	
grams		**moles**		**molecules**
	← multiply by MM		← divide by 6.022×10^{23}	

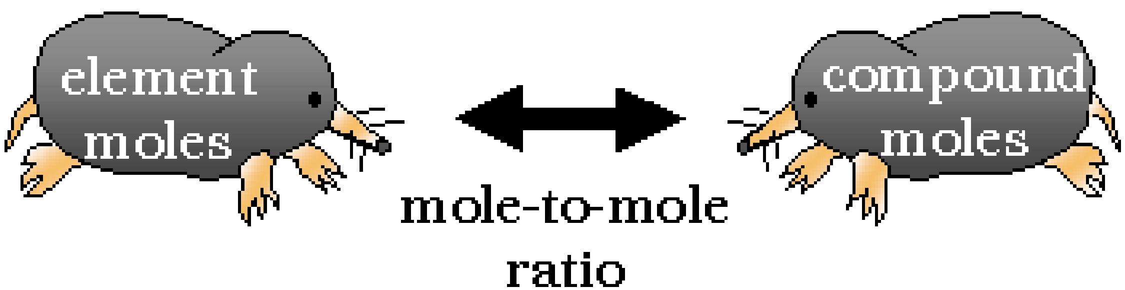
- The number equal to the number of carbon atoms in exactly 12 grams of pure ^{12}C.

- 1 mole of anything = 6.022×10^{23} units of that thing

Using Chemical Formulas:

Element & compound masses

- problems that convert one substance to another require mole-to-mole ratios!



How many grams of H_2 can be obtained from the electrolysis of 100.0 g of H_2O?

How many grams of CuO can be made from a piece of copper wire weighing 0.2134 g?

Review: Molar Mass

A substance's molar mass (molecular weight) is the mass in grams of one mole of the compound.

CO_2 = 44.01 grams per mole

H_2O = 18.02 grams per mole

$Ca(OH)_2$ = 74.10 grams per mole

Review: Chemical Equations

Chemical change involves a reorganization of the atoms in one or more substances.

$$C_2H_5OH \quad + \quad 3O_2 \rightarrow 2CO_2 \quad + \quad 3H_2O$$

reactants products

When the equation is balanced it has quantitative significance:

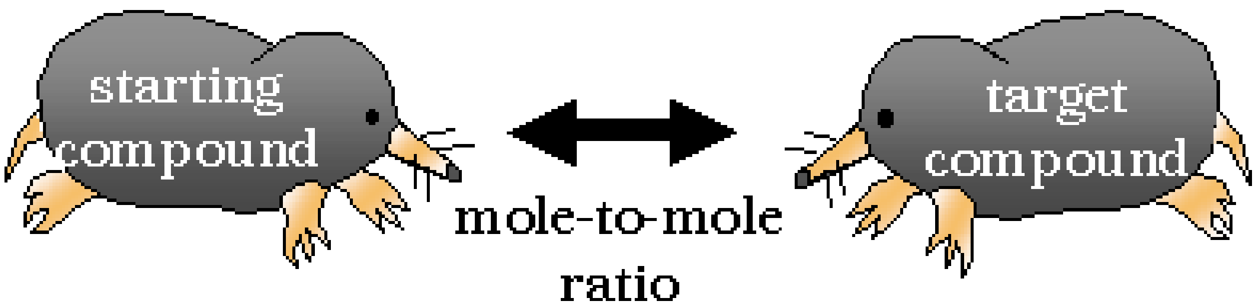
1 mole of ethanol reacts with 3 moles of oxygen to produce 2 moles of carbon dioxide and 3 moles of water

Mole Relations from Chemical Equations

- ratios of balanced coefficients = mole ratios

$$C_6H_{12}O_6(s) + 6\ O_2(g) = 6\ CO_2(g) + 6\ H_2O(l)$$

$$\frac{1\ \text{mol}\ C_6H_{12}O_6}{6\ \text{mol}\ O_2} \qquad \frac{1\ \text{mol}\ C_6H_{12}O_6}{6\ \text{mol}\ CO_2} \qquad \frac{1\ \text{mol}\ C_6H_{12}O_6}{6\ \text{mol}\ H_2O}$$



how many grams of oxygen are required to burn exactly 1 kg of glucose?

Calculating Masses of Reactants and Products

1. Balance the equation.
2. Convert mass to moles.
3. Set up mole ratios.
4. Use mole ratios to calculate moles of desired substituent.
5. Convert moles to grams, if necessary.

Stoichiometry MAP

$$\text{Grams of A} \; \frac{\text{1 mole A}}{\text{MW A}} \; \frac{\#B}{\#A} \; \frac{\text{MW B}}{\text{1mole B}} \; \text{Grams B}$$

A is the starting material given in the problem not always the reactant

B is the desired material in the problem needed

#B / #A is the mole ratio from the balanced equation

Solving Problems

Problem Type	Use Steps
Grams A → Grams B	All Three
Grams A → Moles B	1 & 2
Moles A → Grams B	2 & 3
Moles A → Moles B	JUST 2

Working a Stoichiometry Problem

6.50 grams of aluminum reacts with an excess of oxygen. How many grams of aluminum oxide are formed.

1. Identify reactants and products and write the balanced equation.

$$4\ Al + 3\ O_2 \longrightarrow 2\ Al_2O_3$$

a. Every reaction needs a yield sign!

b. What are the reactants?

c. What are the products?

d. What are the balanced coefficients?

Working a Stoichiometry Problem
gram A to gram B

100.0 grams of aluminum reacts with an excess of oxygen. How many grams of aluminum oxide are formed?

$$4\,Al + 3\,O_2 \rightarrow 2Al_2O_3$$

100.0 g Al	1 mol Al	2 mol Al_2O_3	101.96 g Al_2O_3	= ? g Al_2O_3
	26.98 g Al	4 mol Al	1 mol Al_2O_3	

189.0 g Al_2O_3

Grams A to Moles B

$4\ Al + 3\ O_2 \rightarrow 2Al_2O_3$

- 3. 55.00 **grams** of aluminum oxide formed, how many **moles** of oxygen reacted?

- 55.0 g Al_2O_3

55.0 g Al_2O_3	1 mole	3 mole O_2
	101.96	2 moles Al_2O_3

0.809 moles O_2

Moles A to Grams B

$4\ Al + 3\ O_2 \rightarrow 2Al_2O_3$

5. 0.750 **moles** of aluminum reacted, how many **grams** of oxygen are required to react?

- 0.750 molesAl

0.750 molesAl	3 mole O_2	32.0 g
	4 moles Al	1 mol O_2

18.0 grams O_2

Moles A to Moles B

$4\,Al + 3\,O_2 \rightarrow 2Al_2O_3$

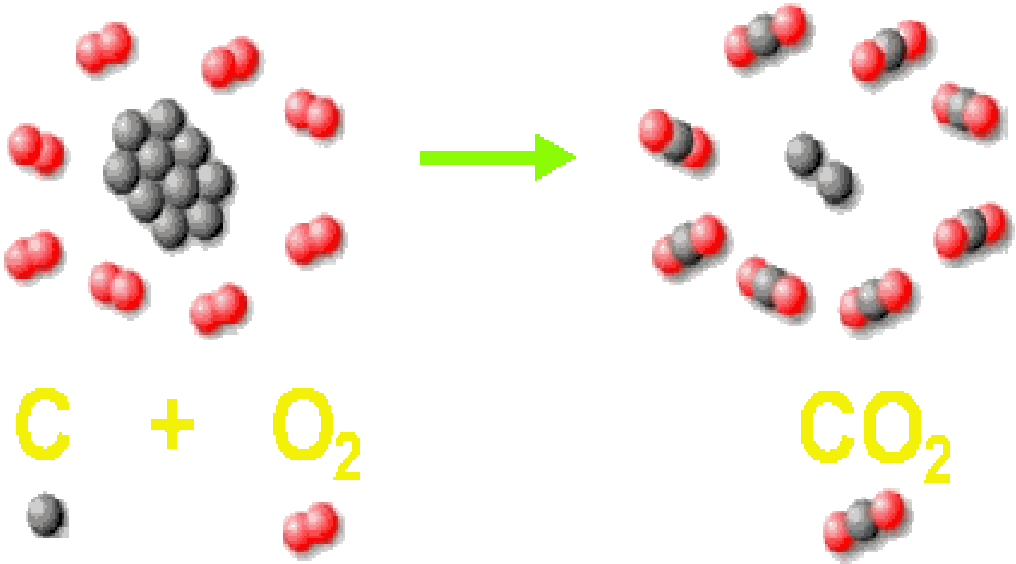
- 0.750 **moles** of aluminum oxide formed, how many **moles** of oxygen reacted?

$$0.750\ \text{moles}Al_2O_3 \times \frac{3\ \text{mole}\ O_2}{2\ \text{moles}\ Al_2O_3}$$

1.12 moles O_2

Limiting Reactant or Reagent

The limiting reactant is the reactant that is consumed first, limiting the amounts of products formed.



Tend to be: expensive, rare, or toxic reagent

Excess Reagent

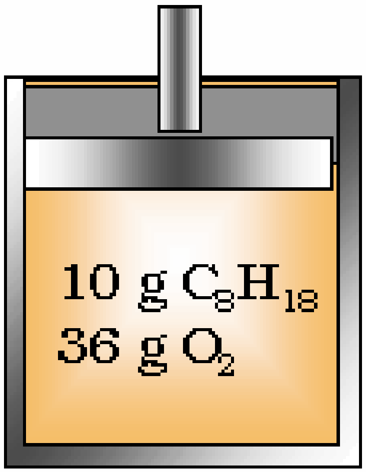
- The more abundant reactant. Does not run out at the end of the experiment. If a chemist has a choice it will
- Tend to be cheaper,
- abundant,
- non-toxic

Methane combusts to give a lot of heat and energy.

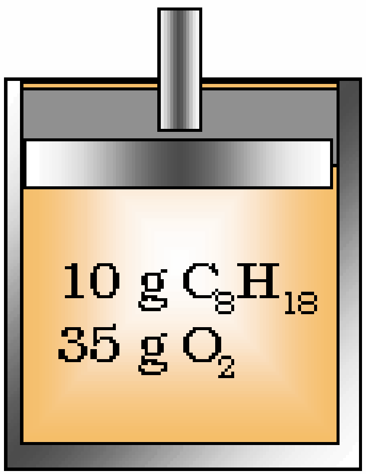
What reagent do you think a chemist would hold as the limiting reagent? Why?

Limiting Reagents

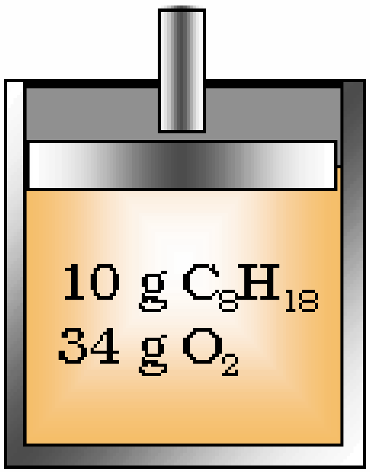
$$2\ C_8H_{18}(l) + 25\ O_2(g) = 16\ CO_2(g) + 18\ H_2O(l)$$



octane is limiting
engine stalls



optimal



oxygen is limiting
dirty exhaust

Determine the Limiting Reagent

- *Compare the amount each reagent can produce the one that produces the least is the limiting reagent. For the problem below solve 2 gram to gram problems and evaluate:* $4\ Al + 3\ O_2 \rightarrow 2Al_2O_3$

Given 50.00 **grams** of aluminum and 50.00 **grams** of oxygen what is the maximum **mass** of aluminum oxide that may be produced? What is the limiting reagent?

	1mol Al	2 Al_2O_3	101.96 g	
50.0 g Al	27.0 grams	4 Al	1moles Al_2O_3	= 94.4 g Al_2O_3

	1mol O_2	2 Al_2O_3	101.96 g	
50.0g O_2	32.0 grams	3 O_2	1moles Al_2O_3	= 106. g Al_2O_3

Therefore only 94.4 grams can be made!

How much oxygen remains?

Determine the leftover amount of excess reagent

- Subtract what was produced from what could have been produced and send backwards:
  - $4\ Al + 3\ O_2 \rightarrow 2Al_2O_3$
- 106.0 grams- 94.4 grams = 11.6 grams

$$11.6\ g \times \frac{1mol\ Al_2O_3}{101.96\ grams} \times \frac{3\ O_2}{2\ Al_2O_3} \times \frac{32.0g\ O_2}{1\ mole\ Al} =$$

5.46 grams of Oxygen leftover

Percent Yield

- Find the theoretical amount or (Mathematical result)
- Divide what was obtained (Lab or Actual) by the theoretical
- Multiply by 100
- Yields are seldom 100% due to four factors:

  Poor Collection,

  Impure reagents,

  Incomplete reactions,

and Competing side reactions

Percent Yield

Cindy reacts **4.00 grams of aluminum** with an excess of oxygen and **formed 7.05 grams** of aluminum oxide. Please calculate her percent yield.

Calc Theo:

- 4.00 g Al

1mol Al	2 Al_2O_3	101.96 g
27.0 g	4 Al	1 molAl_2O_3

Should get: 7.55 grams Al_2O_3

% Yield = 7.05 / 7.55 x 100 =

93.4%