Stoichiometry

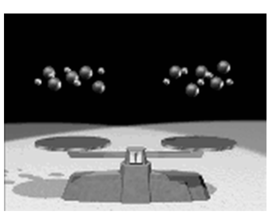
Dr. Ron Rusay

Chemical Stoichiometry

- *Stoichiometry is the study of mass in chemical reactions. It deals with both reactants and products.*
- *It quantitatively and empirically relates the behavior of atoms and molecules in a balanced chemical equation to observable chemical change and measurable mass effects.*
- *It accounts for mass and the conservation of mass, just as the conservation of atoms in a balanced chemical equation.*

Chemical Reactions

Atoms, Mass & Balance: eg. Zn(s) + S(s) ⟶



Chemical Equation

Representation of a chemical reaction:

$$\_\ C_2H_5OH + \_\ O_2 \rightarrow \_\ CO_2 + \_\ H_2O$$

Reactants *Products*

- *C=2; H =5+1=6; O=2+1* *C=1; H=2; O=2+1*
- $\_\_\_\_\_ C_2H_5OH + \_O_2 \rightarrow \_CO_2 + \_H_2O$

Chemical Equation

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

The balanced equation can be completely stated as:

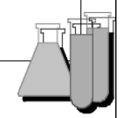
ð *1 mole of ethanol reacts with 3 moles of oxygen to produce 2 moles of carbon dioxide and 3 moles of water.*

Chemical Equation

All Balanced Equations relate on a molar mass basis. For the combustion of octane:

$\mathbf{2}\ C_8H_{18(l)} + \mathbf{25}\ O_{2(g)} \longrightarrow \mathbf{16}\ CO_{2(g)} + \mathbf{18}\ H_2O_{(l)}$

***2 moles** of octane react with **25 moles** of oxygen to produce **16 moles** of carbon dioxide and **18 moles** of water.*



QUESTION

The fuel in small portable lighters is butane (C_4H_{10}). After using a lighter for a few minutes, 1.0 gram of fuel was used. How many moles of carbon dioxide would it produce?

A. 58 moles
B. 0.077 moles
C. 1.7×10^{-24} moles
D. 0.017 moles

$?\ C_4H_{10}(g) + ?\ O_2(g) \rightarrow ?\ CO_2(g) + ?\ H_2O(g)$

The Chemical Equation: Mole & Masses

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

ð *46g (1 mole) of ethanol reacts with 3 moles of oxygen (96g) to produce 2 moles of carbon dioxide and 3 moles of water.*

ð *How many grams of carbon dioxide and water are respectively produced from 46g (1 mole) of ethanol ?*

The Chemical Equation: *Moles & Masses*

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

ð *How many grams of oxygen are needed to react with 15.3g of ethanol in a 12oz. beer ?*

NOTE: It takes approximately 1 hour for the biologically equivalent amount of oxygen available from cytochrome p450 to consume the alcohol in a human in 1 beer to a level below the legal limit of 0.08%.

Chemical Stoichiometry

ð *Epsom salt (magnesium sulfate heptahydrate) is one of five possible hydrates: mono-, di-, tri-, hexa-, or hepta- hydrate.*

ð *How can stoichiometry be used to determine, which hydrate is present in a pure unknown sample, by heating the sample in a kitchen oven at 400 ^{o} C for 45 minutes?*

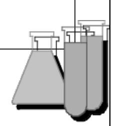
Mass Calculations

All Balanced Equations relate on a molar and mass basis. For the combustion of octane:

$$\mathbf{2}\ C_8H_{18(l)} + \mathbf{25}\ O_{2(g)} \longrightarrow \mathbf{16}\ CO_{2(g)} + \mathbf{18}\ H_2O_{(l)}$$

*228 g of octane (**2 moles**)* will react with 800 g of oxygen (**25 moles**) to produce (**16 moles**) 704 g of carbon dioxide and (**18 moles**) 324 g of water.*

***(2 moles octane x 114 g/mol = 228 g)**



Mass Calculations: *Reactants ⟶ Products*

Chemically Relate:

Something (S) ⟶ Another Thing (AT)

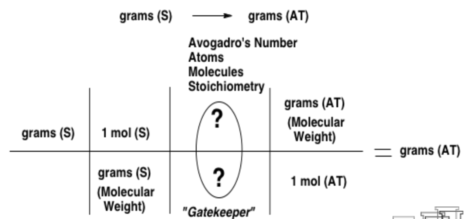
Mass (S) ⟶ Mass (AT)

grams (S) ⟶ grams (AT)

Mass Calculations: Reactants → Products

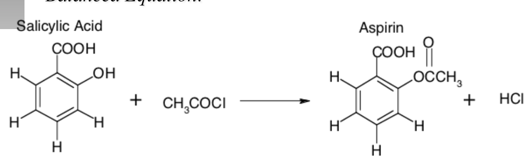
1. *Balance the chemical equation.*
2. *Convert mass of reactant or product to moles.*
3. *Identify mole ratios in balanced equation: They serve as the "Gatekeeper".*
4. *Calculate moles of desired product or reactant.*
5. *Convert moles to grams.*

Mass Calculations: Reactants → Products



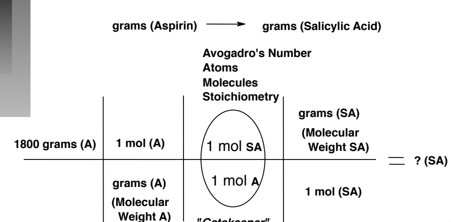
Mass Calculations: Reactants → Products

- *How many grams of salicylic acid are needed to produce 1.80 kg of aspirin?*
- *Balanced Equation:*



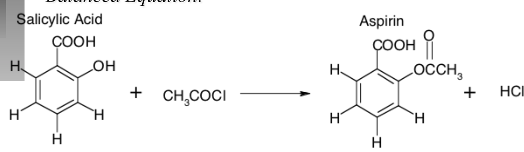
$C_7H_6O_3$	C_2H_3OCl	$C_9H_8O_4$	HCl
MW = 138.12	MW = 78.49	MW = 180.15	MW= 36.45

Mass Calculations: Reactants → Products



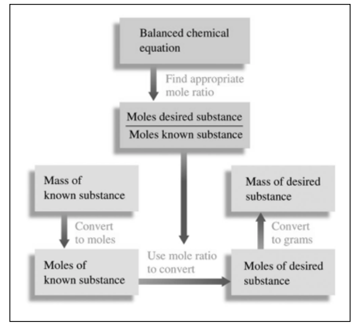
Mass Calculations: How many grams of salicylic acid are needed to produce 1.80 kg of aspirin?

- *Balanced Equation:*



1 $C_7H_6O_3$ MW = 138.12	C_2H_3OCl MW = 78.49	1 $C_9H_8O_4$ MW = 180.15	HCl MW= 36.45

Mass Calculations: Reactants ⟶ Products



QUESTION

The fuel in small portable lighters is butane (C_4H_{10}). After using a lighter for a few minutes, 1.0 gram (0.017 moles) of fuel was used. How many grams of carbon dioxide would it produce?

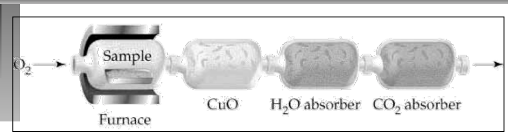
$$2\,C_4H_{10}(g) + 13\,O_2(g) \rightarrow 8\,CO_2(g) + 10\,H_2O(g)$$

How many grams of carbon dioxide would this produce?

A.) 750 mg B.) 6.0 g

C) 1.5 g D.) 3.0 g

Combustion Analysis



- $C_xH_y + (x + y/4)\,O_2 \rightarrow x\,CO_2 + y/2\,H_2O$

Molecules with oxygen in their formula are more difficult to solve for O_Z knowing only the respective masses of $C_xH_yO_z$ sample, CO_2 and H_2O.

- $C_xH_yO_z + (x + y/4 - z)\,O_2 \rightarrow x\,CO_2 + y/2\,H_2O$

SEE: **COMPARISON to wt % CALCULATIONS**

Combustion Analysis Calculation

Ascorbic Acid (Vitamin C)

- *Combustion of a 6.49 mg sample in excess oxygen, yielded 9.74 mg CO_2 and 2.64 mg H_2O*
- *Calculate it's Empirical formula!*

- *C: 9.74 x10^{-3}g CO_2 x(12.01 g C/44.01 g CO_2)*
  *= ? **g C***
- *H: 2.64 x10^{-3}g H_2O x (2.016 g H_2/18.02 gH_2O)*
  *= **? g H***
- *Mass Oxygen = 6.49 mg - 2.65 mg - 0.30 mg*
  *= **3.54 mg O***

Vitamin C: Calculation

(continued)

- *C = 2.65 x 10^{-3} g C / (12.01 g C / mol C) =*
  *= **2.21 x 10^{-4} mol C***
- *H = 0.295 x 10^{-3} g H / (1.008 g H / mol H) =*
  *= **2.92 x 10^{-4} mol H***
- *O = 3.54 x 10^{-3} g O / (16.00 g O / mol O) =*
  *= **2.21 x 10^{-4} mol O***
- ***Divide each by 2.21 x 10^{-4}***
- *C = 1.00 Multiply each by 3 = 3.00 = 3.0*
- *H = 1.32 = 3.96 = 4.0*
- *O = 1.00 = 3.00 = 3.0*

$C_3H_4O_3$

QUESTION

Erythrose contains carbon, hydrogen and oxygen (*MM* = 120.0 g/mol). It is an important sugar that is used in many chemical syntheses.

Combustion analysis of a 700.0 mg sample yielded 1.027 g CO_2 and 0.4194 g H_2O. Mass Spectrometry produced a molecular ion @ 120 mass units (m/z). What is the molecular formula of erythrose?

A) CH_2O
B) $C_6H_{12}O_6$
C) $C_3H_6O_3$
D) $C_4H_8O_4$