Chapter 7

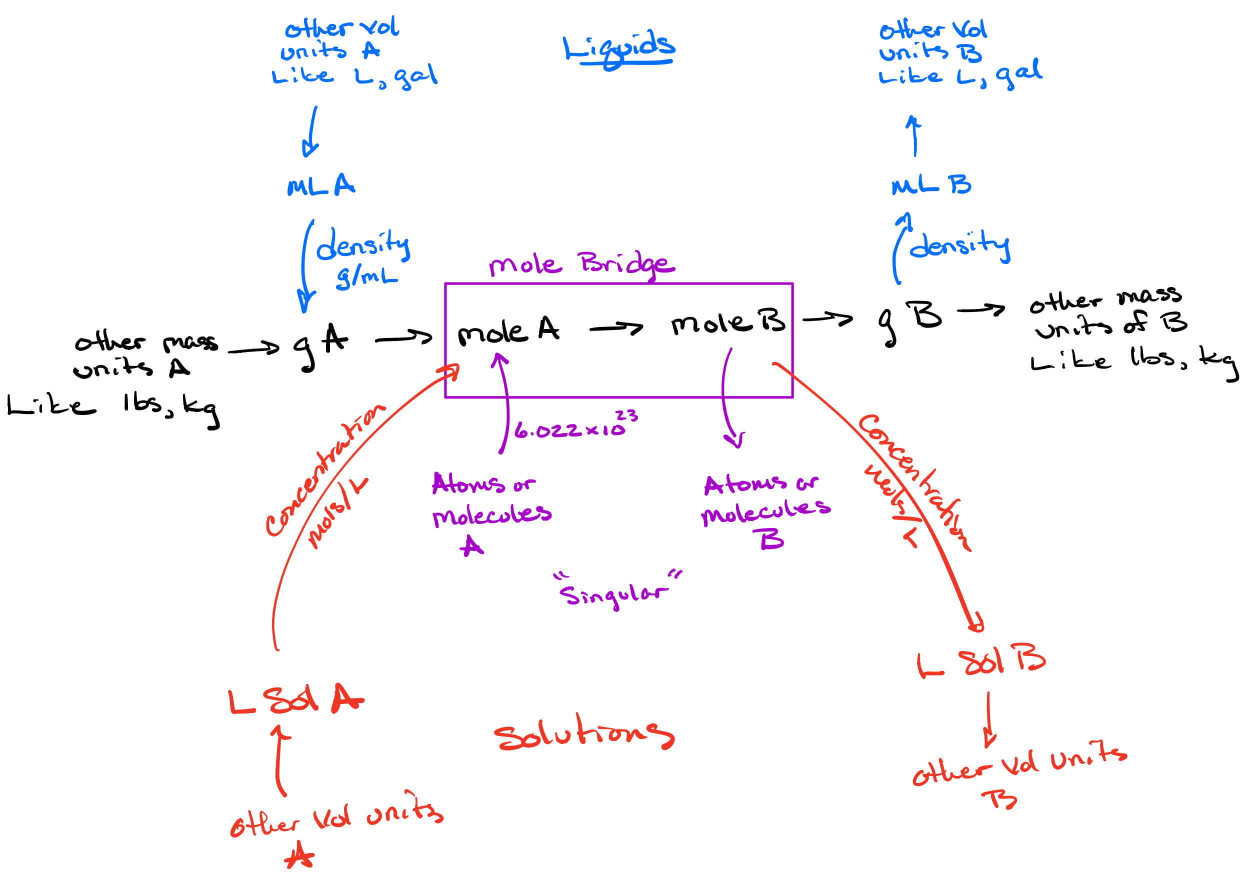
- Balancing Reactions
- Reaction types
    - Acid Base
    - Double Displacement
    - Combustion
    - Redox
- Reaction Stoichiometry
    - 3 main types of problems
        - mass → mass ✓
        - Limiting reagent ✓
        - percent yields

  Today

- Quantitative Chemical Analysis
    - Titration Acid/Base
    - Gravimetric

  Skip for now

Stoichiometry Overview to date



Our experience has been limited to looking at a single compound

$82g \; C_{12}H_{22}O_{11} \longrightarrow$ # g of Carbon

$1 \text{ mole } C_{12}H_{22}O_{11} = 12 \text{ mole } C$

molar relationships

$\Longrightarrow$ Subscripts are molar relationships

Balanced Chemical Equation

$$2\, C_8H_{18} + 25\, O_2 \longrightarrow 16\, CO_2 + 18\, H_2O$$

molar Coefficients

$$2 \text{ mole } C_8H_{18} = 25 \text{ mole } O_2$$

$$25 \text{ mole } O_2 = 16 \text{ mole } CO_2$$

$$2 \text{ mole } C_8H_{18} = 16 \text{ mole } CO_2$$

Ex

The balanced chemical eq for octane is given

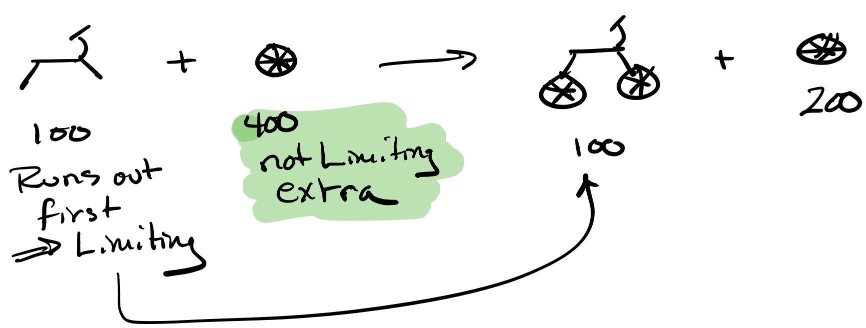
$$2\,C_8H_{18\,(l)} + 25\,O_{2\,(g)} \rightarrow 16\,CO_{2\,(g)} + 18\,H_2O_{(l)}$$

If 1000. g of C_8H_{18} were combusted with excess oxygen, How many grams of CO_2 would be produced?

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

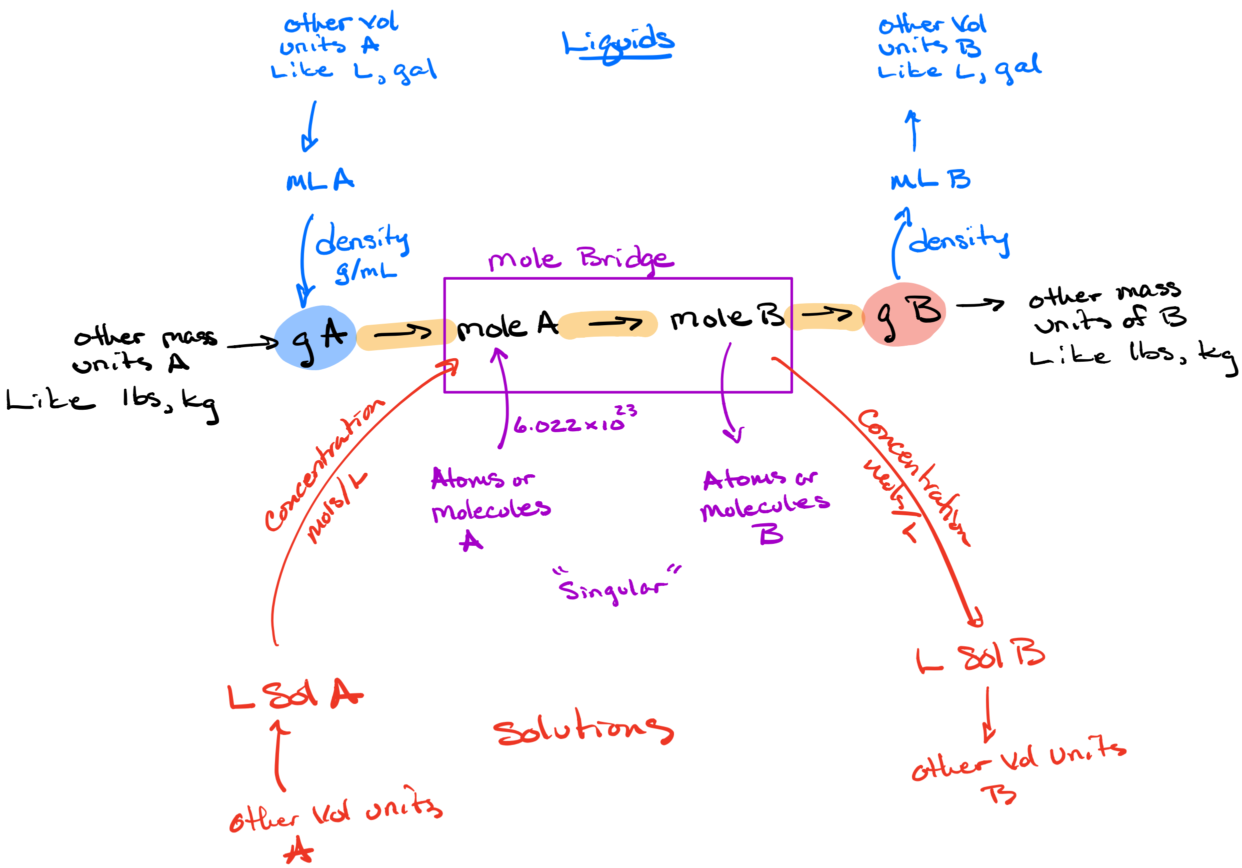
1000. g   excess   ? g

$$\begin{array}{ccc} 1000.\ g & & ?\ g \\ \downarrow & & \uparrow \\ \text{mole } C_8H_{18} & \longrightarrow & \text{mole } CO_2 \end{array}$$



Road Map

$$g\ C_8H_{18} \xrightarrow{\text{molar mass } C_8H_{18}} \text{mole } C_8H_{18} \xrightarrow{\text{molar coef}} \text{mole } CO_2 \xrightarrow{\text{molar mass } CO_2} g\ CO_2$$



Required

$$\text{molar Mass } C_8H_{18} = \overset{C}{8\times 12.01} + \overset{H}{18\times 1.008} = $$

$$= 114.224 \text{ g/mole}$$

$$= \boxed{114.22 \text{ g/mol } C_8H_{18}}$$

$$\text{molar Mass } CO_2 = 12.01 + 2\times 16.00$$

$$= \boxed{44.01 \text{ g/mole } CO_2}$$

$$\text{molar Coef } \boxed{2 \text{ mole } C_8H_{18} = 16 \text{ mole } CO_2}$$

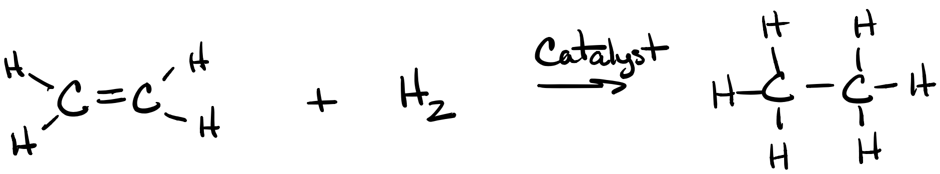
g C_8H_{18} $\longrightarrow$ mole C_8H_{18} $\longrightarrow$ mole CO_2 $\longrightarrow$ g CO_2

Exact Counted

$$\overset{4}{1000.}\ \cancel{g\ C_8H_{18}} \times \frac{1\ \cancel{mole\ C_8H_{18}}}{\underset{5}{114.22}\ \cancel{g\ C_8H_{18}}} \times \frac{16\ \cancel{mole\ CO_2}}{2\ \cancel{mole\ C_8H_{18}}} \times \frac{\overset{4}{44.01}\ g\ CO_2}{1\ \cancel{mole\ CO_2}} =$$

$$= 3082.4724\ g\ CO_2$$

$$= \boxed{3082\ g\ CO_2\ \text{produced}}$$



$C_2H_4 + H_2 \longrightarrow C_2H_6$

If 3.72 g of ethylene (C_2H_4) is to be converted into ethane (C_2H_6), How many grams of H_2 are required?

$$\begin{array}{ccccc} C_2H_4 & + & H_2 & \longrightarrow & C_2H_6 \\ 3.72\ g & & ?\ g & & \\ \downarrow & & \uparrow & & \\ \text{mole } C_2H_4 & \longrightarrow & \text{mole } H_2 & & \end{array}$$

Road map

g C_2H_4 $\longrightarrow$ mole C_2H_4 $\longrightarrow$ mole H_2 $\longrightarrow$ g H_2

<u>molar mass</u> C_2H_4 $\quad 2 \times 12.01 + 4 \times 1.008 = 28.05\,g/mole$

$H_2 = 2.016\,g/mole$

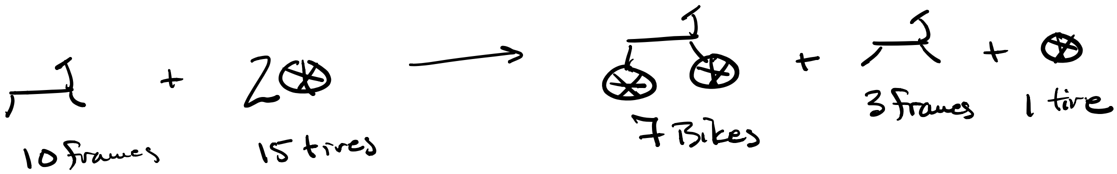
$$\overset{3}{3.72\,g\,C_2H_4} \times \frac{1\text{ mole }C_2H_4}{\underset{4}{28.05\,g\,C_2H_4}} \times \frac{\overset{\text{Exact}}{1\text{ mole }H_2}}{1\text{ mole }C_2H_4} \times \frac{\overset{4}{2.016\,g\,H_2}}{1\text{ mole }H_2} =$$

$$= 0.26736226608\,g\,H_2$$

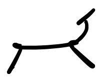
$$= \boxed{0.267\,g\,H_2\text{ Required}}$$

Limiting Reagents

How many bikes can we make? What is limiting?

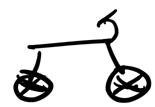


Set up 2 Stoiciometry calculations & look for smallest # of products.



10 frames

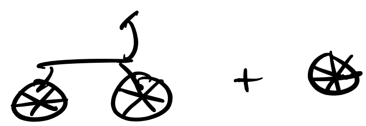
1 frame : 1 Bike



10 Bikes

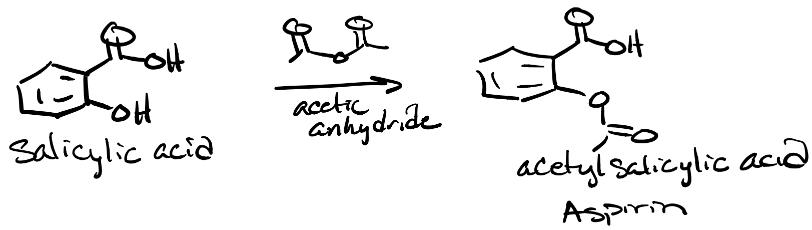
15 tires
Limiting

2 tires : 1 Bike



7 Bikes

Smaller



$$\underset{1.02\,g}{1\, C_7H_6O_3} + \underset{1.72\,g}{1\, C_4H_6O_3} \rightarrow \underset{?\,g}{1\, C_9H_8O_4}$$

If 1.02g of Salicylic acid are combined with 1.72g of acetic anhydride, how many grams of aspirin can be formed?

$$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4$$

Smaller?

Road Maps

Salicylic Acid $g\, C_7H_6O_3 \rightarrow mole\, C_7H_6O_3 \rightarrow \boxed{mole\, C_9H_8O_4 \rightarrow g\, C_9H_8O_4}$

acetic anhydride $g\, C_4H_6O_3 \rightarrow mole\, C_4H_6O_3 \rightarrow \boxed{mole\, C_9H_8O_4 \rightarrow g\, C_9H_8O_4}$

Molar Mass

Salicylic acid $C_7H_6O_3 = 7 \times 12.01 + 6 \times 1.008 + 3 \times 16 = 138.12$ g/mole

acetic anhydride $C_4H_6O_3 = 4 \times 12.01 + 6 \times 1.008 + 3 \times 16 = 102.09$ g/mole

aspirin $C_9H_8O_4 = 9 \times 12.01 + 8 \times 1.008 + 4 \times 16 = 180.15$ g/mole

#1

Salicylic Acid g $C_7H_6O_3 \rightarrow$ mole $C_7H_6O_3 \rightarrow$ mole $C_9H_8O_4 \rightarrow$ g $C_9H_8O_4$

$$\overset{3}{1.02\text{ g } C_7H_6O_3} \times \frac{1 \text{ mole } C_7H_6O_3}{\underset{5}{138.12}\text{ g } C_7H_6O_3} \times \overset{\text{exact}}{\frac{1 \text{ mole } C_9H_8O_4}{1 \text{ mole } C_7H_6O_3}} \times \frac{\overset{5}{180.15}\text{ g } C_9H_8O_4}{1 \text{ mole } C_9H_8O_4} =$$

Limiting

1.33038866 g $C_9H_8O_4$

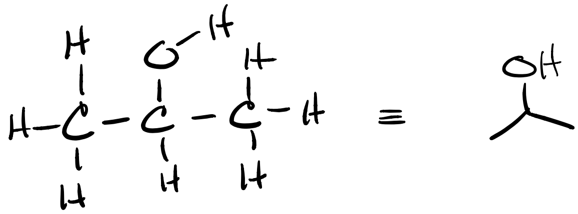
#2

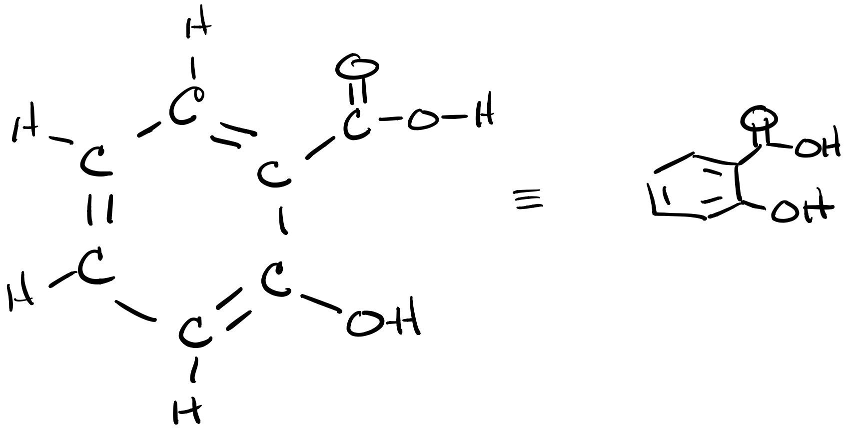
acetic anhydride g $C_4H_6O_3 \rightarrow$ mole $C_4H_6O_3 \rightarrow$ mole $C_9H_8O_4 \rightarrow$ g $C_9H_8O_4$

$$1.72\text{ g } C_4H_6O_3 \times \frac{1 \text{ mole } C_4H_6O_3}{102.09\text{ g } C_4H_6O_3} \times \frac{1 \text{ mole } C_9H_8O_4}{1 \text{ mole } C_4H_6O_3} \times \frac{180.15\text{ g } C_9H_8O_4}{1 \text{ mole } C_9H_8O_4} =$$

3.03514546 g $C_9H_8O_4$

$\boxed{1.02\text{ g } C_7H_6O_3 \text{ is limiting and produces } 1.33\text{ g } C_9H_8O_4}$





Percent Yield

$$\text{Precent Yield} = \frac{\overbrace{\text{actual Yield}}^{\text{Part}}}{\underbrace{\text{Theoretical Yield}}_{\text{whole}}} \times 100$$

actual Yield = mass obtained in an experiment

Theoretical Yield = Calculated mass from Stoichiometry ⇒ what you could make if it ran in 100%

$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

2.67 g of Sodium metal are reacted with excess chlorine gas. If 6.23g of NaCl is actually produced, what is the % yield of the reaction?

$$\underset{2.67g}{2Na} + Cl_2 \rightarrow \underset{6.23g \Leftarrow \text{actual}}{2NaCl}$$

$$\%\text{ yield} = \frac{\text{actual}}{\text{Theoretical}} \times 100 = \frac{6.23g\ NaCl}{2.67g\ Na \rightarrow mol\ Na \rightarrow mole\ NaCl \rightarrow g\ NaCl} \times 100$$

$g\ Na \rightarrow mole\ Na \rightarrow mole\ NaCl \rightarrow g\ NaCl$

$$\overset{3}{2.67}\ \cancel{g\ Na} \times \frac{1\ \cancel{mole\ Na}}{\underset{4}{22.99}\ \cancel{g\ Na}} \times \frac{\overset{Exact}{2}\ \cancel{mole\ NaCl}}{2\ \cancel{mole\ Na}} \times \frac{\overset{4}{58.44}\ g\ NaCl}{1\ \cancel{mole\ NaCl}} =$$

6.78|707264 g NaCl

6.79 g NaCl Theoretical

$$\%\ yield = \frac{\overset{3}{6.23\ g\ NaCl}}{\underset{3}{6.79\ g\ NaCl}} \times 100 = 91.7|525773\ \%$$

$$\boxed{\%\ yield = 91.8\%}$$

$$A + B \rightarrow \underbrace{C}_{\%\ yield} + \underbrace{D + E}_{\text{Side products}}$$

byproducts
subtract from the possible yield

$$A + B \rightleftharpoons C$$

Equilibrium

$$2Na + Cl_2 \rightarrow NaCl$$

excess $\quad 0.62g$

Reaction runs to produce a 79.2% isolated yield. How much NaCl was produced?

Theoretical

$g\ Cl_2 \rightarrow mole\ Cl_2 \rightarrow mole\ NaCl \rightarrow g\ NaCl$

PT

$Cl_2\ 2 \times 35.45 = 58.44$

$$79.2\% = \frac{actual}{Theoretical}$$

$$actual = 79.2\% \times Theoretical$$

$Cl = 35.45 g/mole$

$Cl_2 = 2 \times 35.45$

$= 70.90\ g/mole$

$$2Na + Cl_2 \rightarrow 2NaCl$$

excess $\quad 0.62g$

$Cl\ 1 \times 35.45 = 35.45$

$Na\ 1 \times 22.99 = 22.99$

$58.44\ g/mole$

molar mass

Molar Coefficients

$$0.62g\ Cl_2 \times \frac{1\ mole\ Cl_2}{70.90\ Cl_2} \times \frac{2\ mole\ NaCl}{1\ mole\ Cl_2} \times \frac{58.44g\ NaCl}{1\ mole\ NaCl} =$$

$1.0220818\ g\ NaCl$

Theoretical

actual = % yield × Theoretical

$$= \frac{79.2 \text{ g of NaCl actually}}{100 \text{ g of NaCl Theo}} \times 1.0 \text{ g NaCl} =$$

$$= \boxed{0.79 \text{ g NaCl can be made}}$$

3 Types of Reactions you Should Know

⇒ Double Displacement

$$A^{+}B^{-} + C^{+}D^{-} \rightarrow AD + CB$$

$$3NaOH + FeCl_3 \rightarrow Fe(OH)_3 + 3NaCl$$

⇒ Acid Base Neutralization

$$H^{+}A^{-} + B^{+}OH^{-} \rightarrow AB + H_2O$$

$$HCl + NaOH \rightarrow NaCl + H_2O$$

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + H_2O$$

⇒ Combustion

$$C_xH_yO_z + \underbrace{O_2 \rightarrow CO_2 + H_2O}_{\text{always the same}}$$

$$2\left[C_8H_{18} + \tfrac{25}{2}O_2 \rightarrow 8\,CO_2 + 9\,H_2O\right]$$

C	8	$\cancel{1}$ 8
H	18	$\cancel{2}$ 18
O	$\cancel{2}$ 25	$\cancel{3}$ $\cancel{17}$ 25

$$\boxed{2C_8H_{18} + 25O_2 \rightarrow 16\,CO_2 + 18\,H_2O}$$