3.10 – 3.11 Stoichiometry, Limiting Reactants

Sep 21-6:56 AM

Stoichiometry

Def: Study of quantitative relationships between reactants used and products formed.

Allows us to calculate exactly how much product a chemical reaction makes, or how much reactant is needed to produce a certain amount.

All stoichiometric calculations MUST begin with a balanced chemical equation.

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Mole Ratios

Mole Ratio: Way of comparing the amountsof any two substances in a balanced reaction.

1. Mole Ratio Example

Consider the reaction: $2\ K + Br_2 \longrightarrow 2\ KBr$

Depending on what is being calculated, any two components could be compared in a mole ratio.

Make four mole ratios for potassium:

$\frac{2\ mol\ K}{2\ mol\ KBr}$ or: $\frac{2\ mol\ KBr}{2\ mol\ K}$ or: $\frac{2\ mol\ K}{1\ mol\ Br_2}$ or: $\frac{1\ mol\ Br_2}{2\ mol\ K}$

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Calculation Format

When converting from one molar value to another, use this process:

$$Moles\ Known \bullet \frac{Moles\ Seeking}{Moles\ Known} = Moles\ Seeking$$

Given in Problem | Mole Ratio from Balanced Equation | What You're Looking For

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2. Which Ratio to Use?

$2\ K + Br_2 \longrightarrow 2\ KBr$

How many moles of Br_2 are needed to generate 156.3 moles of KBr?

Mole Ratio (from balanced equation): $\frac{1\ mol\ Br_2}{2\ mol\ KBr}$

$$156.3\ mol\ KBr \bullet \frac{1\ mol\ Br_2}{2\ mol\ KBr} = \boxed{78.15\ mol\ Br_2}$$

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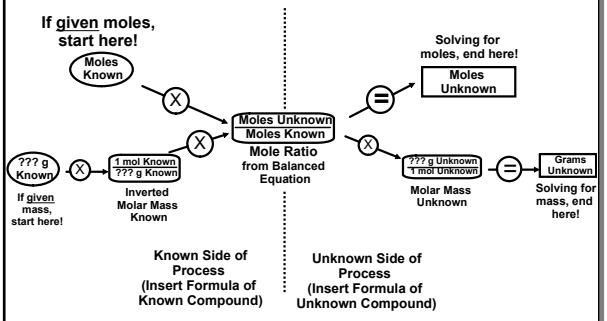
Stoichiometry Process Flow Chart

Template:



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3. Mass to Mass Guided Example

Calcium carbide (CaC_2) and water react, producing acetylene (C_2H_2) and calcium hydroxide ($Ca(OH)_2$). How many grams of acetylene can be produced by reacting 2.50 grams of calcium carbide with water?

Step 0. – Balance the reaction:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

What is given? 2.50 g CaC_2.

What do you seek? Mass C_2H_2

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Mass to Mass

Note Color Coding!

$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$

A. Insert molar mass of CaC_2 (64.10 g/mol):

B. Insert mole ratio from mol CaC_2 to mol C_2H_2:

$$\frac{1\,mol\,C_2H_2}{1\,mol\,CaC_2}$$

C. Insert molar mass C_2H_2 (26.04 g/mol):

Finally, cancel units and compute.

$$2.50\,g\,CaC_2 \bullet \frac{1\,mol\,CaC_2}{64.10\,g\,CaC_2} \bullet \frac{1\,mol\,C_2H_2}{1\,mol\,CaC_2} \bullet \frac{26.04\,g\,C_2H_2}{1\,mol\,C_2H_2} = 1.02\,g\,C_2H_2$$

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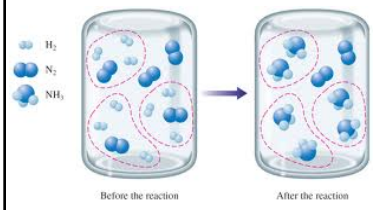
Limiting Reactant

Def : The reactant consumed first in a reaction. When it runs out, the reaction **stops**.
The opposite is an excess reactant.

We must calculate the limiting reactant because it is used to determine the amount of product formed.



Which is limiting?

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Determining the Limiting Reactant

Step 0: Balance the reaction!
Step 1: Convert mass to moles for each reactant.
Step 2: Make a mole ratio of available reactants, then set it up as a proportion: divide the top value by the bottom and writing the result over 1 mol.
Step 3: Make a mole ratio of reactants from the balanced equation – position reactants as you did in step 2. If necessary, make a proportion so 1 mol is on bottom - divide top by bottom, and rewrite with that number as numerator, and 1 mol as denominator.

$$\frac{3\,mol\,X}{2\,mol\,Y} = \frac{1.5\,mol\,X}{1\,mol\,Y}$$

Step 4: Compare the two ratios: if the top value of what is available is less than what the top number of the balanced reaction ratio is, then that chemical is the limiting reactant. Otherwise, it's excess.

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4. Which is Limiting?

Chlorine gas (Cl_2) and sulfur (S_8) react to form disulfur dichloride (S_2Cl_2). Which will run out first if you start with 100.0 g of chlorine and 100.0 g of sulfur?

Step 0. Balance the reaction!

$$\_4\_\ Cl_2 + \_\_\_\ S_8 \rightarrow \_4\_\ S_2Cl_2$$

Step 1: Convert mass to moles for each reactant.

Chlorine: $100.0\,g\,Cl_2 \times \frac{1\,mol\,Cl_2}{70.91\,g\,Cl_2} = 1.41\,mol\,Cl_2$

Sulfur: $100.0\,g\,S_8 \times \frac{1\,mol\,S_8}{256.5\,g\,S_8} = 0.39\,mol\,S_8$

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4. Which is Limiting?

Step 2: Make a mole ratio of available reactants,

$$\frac{1.41\,mol\,Cl_2}{0.39\,mol\,S_8}$$

then set it up as a proportion: divide top value by the bottom and write it thusly:

$$\frac{1.41\,mol\,Cl_2}{0.39\,mol\,S_8} = \frac{3.62\ mol\,Cl_2}{1.00\,mol\,S_8}$$

Step 3: Make a mole ratio of reactants from the balanced equation – position reactants (top & bottom) as you did in step 2.

$$4\ Cl_2 + S_8 \rightarrow 4\ S_2Cl_2 \qquad \frac{4\,mol\,Cl_2}{1\,mol\,S_8}$$

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4. Which is Limiting?

Step 4: Compare the two ratios:

Available Reactants: $\frac{3.62\,mol\,Cl_2}{1.0\,mol\,S_8}$

Balanced Formula: $\frac{4.0\,mol\,Cl_2}{1.0\,mol\,S_8}$

Which reactant is limiting? Vote!

Chemocracy	
Cl_2	S_8

Chlorine is limiting – only 3.62 mol Cl_2 are available instead of the 4 mol Cl_2 that's needed.

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5. Product Example

$$4\,Cl_2 + S_8 \rightarrow 4\,S_2Cl_2$$

Calculate the mass of S_2Cl_2 produced, if the 100.0 grams of Cl_2 react completely.

Since LIMITING reactant (Cl_2) determines yield, we must start with it.

We already calculated moles of Cl_2 available, so:

$$1.41\,mol\,Cl_2 \times \frac{4\,mol\,S_2Cl_2}{4\,mol\,Cl_2} \times \frac{135\,g\,S_2Cl_2}{1\,mol\,S_2Cl_2} = \boxed{190.4\,g\,S_2Cl_2}$$

Actual Chlorine Amount

Mole Ratio From Bal. Equation

Molar Mass of S_2Cl_2

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Percent Yield

Chemical reactions are not 100%complete: something is always unreacted.

Chemists calculate the percent yield of reactions to predict product amount.

$$Percent\,Yield = \frac{Actual\,Yield}{Theoretical\,Yield} \bullet 100\%$$

Actual Yield: measured mass of product.

Theoretical Yield: maximum product mass possible assuming all limiting reactant gets consumed: **use stoichiometry to determine this.**

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6. Percent Yield Example

If the reaction of chlorine and sulfur is only 75.3% efficient, how much actual yield could an industrial chemist expect, using the 100.0 grams of Cl_2?

$$\%\,Yield = \frac{Actual\,Yield}{Theoretical\,Yield} \bullet 100\%$$

$$Actual\,Yield = \frac{\%\,Yield \bullet Theoretical\,Yield}{100\%}$$

$$= 0.753 \bullet 190.4\,g\,S_2Cl_2 = \boxed{143\,g\,S_2Cl_2}$$

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Homework

Read 4.1 - 4.????

3.10 - 3.11 Problems in your Booklet
Due: Next Class.

Study for Balancing Equations Quiz

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Attachments

- NI3 one.MOV
- NI3 two.MOV