

Stoichiometry

the study of the quantity relationships in chemical reactions.

For example, let's make turkey sandwiches. Here's the recipe:

Turkey sandwich recipe

- 2 slices bread
- 3 slices turkey
- 1 slice cheddar cheese
- 1 tomato slice

If we had the following ingredients, how many complete turkey sandwiches could we make?

- 32 slices of bread
- 49 slices of turkey
- 20 slices of cheddar cheese
- 14 tomato slices

Well, let's work this through...

this is called a ratio.
Remember that for later.

$$32 \text{ slices bread} \times \left(\frac{1 \text{ sandwich}}{2 \text{ slices}} \right) = 16 \text{ sandwiches}$$

$$49 \text{ slices turkey} \times \left(\frac{1 \text{ sandwich}}{3 \text{ slices}} \right) = 16.3 \text{ sandwiches}$$

$$20 \text{ slices cheese} \times \left(\frac{1 \text{ sandwich}}{1 \text{ slice}} \right) = 20 \text{ sandwiches}$$

$$14 \text{ slices tomato} \times \left(\frac{1 \text{ sandwich}}{1 \text{ slice}} \right) = 14 \text{ sandwiches}$$

You can only make 14 sandwiches before you run out of tomatoes!

Guess what guys?! You just did stoichiometry!

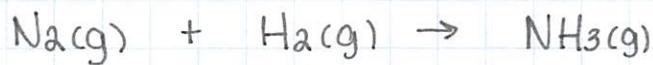
For chemistry, the process is a little more involved, but the main idea is the same. We use ratios (dimensional analysis), we call it a... mole ratio.



comes from the coefficients
in a balanced chemical equation.

$$\text{mole ratio} = \frac{\text{mol of unknown substance}}{\text{mol of given substance}}$$

Let me show you what I mean:



- balance the equation & you get the coefficients below:



- what do these coefficients tell us?

1 mol of Na(g) reacts with 3 mol of H₂(g) to produce 2 mol of NH₃(g)

- Example : (1) $\text{Na(g)} + 3\text{H}_2\text{(g)} \rightarrow 2\text{NH}_3\text{(g)}$

How many mol of ammonia (NH₃) are formed from the reaction of 12.0 mol of hydrogen with excess nitrogen ?
given extra information

use dimensional analysis -

- 1)- write down the given & the T-chart. write your unknown after the equal sign

$$\begin{array}{c|c} \underline{12.0 \text{ mol H}_2} & \\ \hline & = \end{array} \quad \underline{\text{mol NH}_3}$$

- 2) Look at the balanced equation, we are going to use it to make the mole ratio to solve the problem.

$$\text{mole ratio} = \frac{\text{mol unknown}}{\text{mol given}} = \frac{3 \text{ mol NH}_3}{2 \text{ mol H}_2}$$

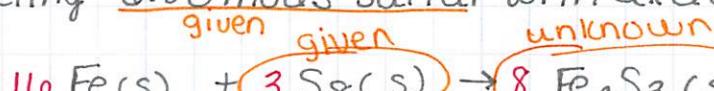
(2)

3. Put the mole ratio into the Tchart & solve. multiply any numbers on top of the horizontal line & divide by any numbers below.

$$\frac{12.0 \text{ mol H}_2}{2 \text{ mol H}_2} \left| \begin{array}{c} 3 \text{ mol NH}_3 \\ \hline \end{array} \right. = \quad 18.0 \text{ mol NH}_3$$

* Any numbers in a mole ratio have infinite significant figures. Therefore your answer has the same # significant figures as your given does.

(2) How many mols of iron (III) sulfide are produced from reacting 6.50 moles sulfur with excess iron?



$$\frac{6.50 \text{ mol S}_8}{3 \text{ mol S}_8} \left| \begin{array}{c} 8 \text{ mol Fe}_2\text{S}_3 \\ \hline \end{array} \right. = \quad 17.3 \text{ mol Fe}_2\text{S}_3$$

(3) .864 mol of tricarbon octahydride react with excess oxygen. How many mols of water vapor are produced?



$$\frac{.864 \text{ mol C}_3\text{H}_8}{1 \text{ mol C}_3\text{H}_8} \left| \begin{array}{c} 4 \text{ mol H}_2\text{O} \\ \hline \end{array} \right. = \quad 3.46 \text{ mol H}_2\text{O}$$

(4) How many moles of calcium are needed to completely react with .8105 moles of chromium(III) acetate?



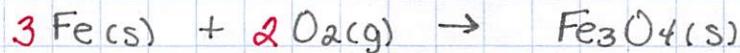
$$\frac{.8105 \text{ mol Cr(C}_2\text{H}_3\text{O}_2)_3}{2 \text{ mol Cr(C}_2\text{H}_3\text{O}_2)_3} \left| \begin{array}{c} 3 \text{ mol Ca} \\ \hline \end{array} \right. = \quad 1.216 \text{ mol Ca}$$

Now, a tiny issue we have is that we have not yet invented an instrument that measures in units of moles.

But we can measure substances using mass (g) and we know how to convert from mass to moles. Then we can use the mole ratio. It's 2 step stoichiometry time!

Examples

1. How many moles of iron(II,III) oxide (Fe_3O_4) are produced from reacting 0.456 g of iron with excess oxygen?

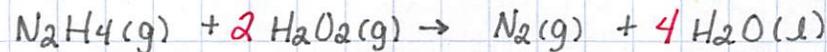


<u>0.456 g Fe</u>	<u>1 mol Fe</u>	<u>1 mol Fe_3O_4</u>	=	<u>.00272 mol Fe_3O_4</u>
	<u>55.85 g Fe</u>	<u>3 mol Fe</u>		

molar mass of Fe mole ratio from balanced equation

Remember → multiply by numbers on top of the horizontal line & divide by any numbers below the horizontal line!

2. How many moles of water are produced when 2.69 g of dinitrogen tetrahydride reacted with excess hydrogen peroxide?



<u>2.69 g N_2H_4</u>	<u>1 mol N_2H_4</u>	<u>4 mol H_2O</u>	=	<u>.336 mol H_2O</u>
	<u>32.06 g N_2H_4</u>	<u>1 mol N_2H_4</u>		

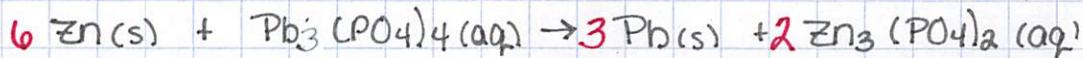
Molar Mass - N_2H_4

$$\begin{aligned} 2 N \times 14.01 g &= 28.02 g \\ 4 H \times 1.01 g &= + 4.04 g \\ &\hline 32.06 g \end{aligned}$$

unknown

3. What mass of lead is produced from the reaction of 13.00 mol of lead (IV) phosphate with excess zinc?

given



OK, so this one is different from the first 2 examples because the units for the given and unknown are switched from the previous example. But that's ok, we still have the tools to solve this!

$$\frac{13.00 \text{ mol Pb}_3(\text{PO}_4)_4}{1 \text{ mol Pb}_3(\text{PO}_4)_4} \left| \begin{array}{c} 3 \text{ mol Pb} \\ | \\ 1 \text{ mol Pb}_3(\text{PO}_4)_4 \end{array} \right| \frac{207.20 \text{ g Pb}}{1 \text{ mol Pb}} = \{ 808.1 \text{ g Pb} \}$$

↑ mole ratio from the balanced equation ↑ molar mass of Pb.

Here is a helpful guide to know which steps to use when solving stoichiometry problems.

Step A
converting mass(g)
of given to moles

1 mol given
molar mass of given

If your given
has these units:

moles

grams (g)

moles

grams (g)

Step B
the mole ratio
from the balanced
equation

moles of unknown
moles of given

And your unknown
needs this unit:

moles

moles

grams (g)

grams (g)

Step C
converting moles of
unknown to mass (g)

molar mass of unknown
1 mol unknown

Then do these
steps:

B

A $\stackrel{?}{\approx}$ B

B $\stackrel{?}{\approx}$ C

A $\stackrel{?}{\approx}$ B $\stackrel{?}{\approx}$ C

So let's try using the guide to solve some stoichiometry problems.

unknown

1. What mass of calcium chlorate is produced when 0.50 moles of calcium hydroxide react with excess chloric acid? GIVEN



Since the units for my given is moles and the units for my unknown is in mass (g), we need to use steps B & C.

step B step C

$$\frac{0.50 \text{ mol Ca(OH)}_2}{1 \text{ mol Ca(OH)}_2} \times \frac{206.98 \text{ g Ca(ClO}_3)_2}{1 \text{ mol Ca(ClO}_3)_2} = 103.49 \text{ g}$$

$$= 1.0 \times 10^2 \text{ g Ca(ClO}_3)_2$$

molar mass - $\text{Ca(ClO}_3)_2$

$$\begin{aligned} 1 \text{ Ca} \times 40.08 \text{ g} &= 40.08 \text{ g} \\ 2 \text{ Cl} \times 35.45 \text{ g} &= 70.90 \text{ g} \\ 6 \text{ O} \times 16.00 \text{ g} &= + 96.00 \text{ g} \\ &= 206.98 \text{ g} \end{aligned}$$

unknown

2. What mass of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) can a plant produce through photosynthesis when 150.0 g of water reacts with excess carbon dioxide? GIVEN



Ok, the given has units of grams and so does the unknown, so we have to use steps A & B & C. It's ok guys, we can do this!

step A step B step C

$$\frac{150.0 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \times \frac{1 \text{ mol C}_6\text{H}_{12}\text{O}_6}{18.02 \text{ g H}_2\text{O}} \times \frac{180.18 \text{ g C}_6\text{H}_{12}\text{O}_6}{6 \text{ mol H}_2\text{O}} = \{ 250.0 \text{ g C}_6\text{H}_{12}\text{O}_6 \}$$

Molar Mass - H_2O

$$\begin{aligned} 2 \text{ H} \times 1.01 \text{ g} &= 2.02 \text{ g} \\ 1 \text{ O} \times 16.00 \text{ g} &= 16.00 \text{ g} \\ &= 18.02 \text{ g} \end{aligned}$$

molar mass - $\text{C}_6\text{H}_{12}\text{O}_6$

$$\begin{aligned} 6 \text{ C} \times 12.01 \text{ g} &= 72.06 \text{ g} \\ 12 \text{ H} \times 1.01 \text{ g} &= 12.12 \text{ g} \\ 6 \text{ O} \times 16.00 \text{ g} &= + 96.00 \text{ g} \\ &= 180.18 \text{ g} \end{aligned}$$

UNKNOWN

3. What mass of oxygen can the plant produce through photosynthesis when 88.02g of carbon dioxide reacts with excess water?

GIVEN



What steps should we use for this problem? Well the given is in units of grams so is the unknown (mass is grams, right?) so we will use all 3 steps again: A & B & C.

step A step B step C

<u>88.02g CO₂</u>	<u>1 mol CO₂</u>	<u>6 mol O₂</u>	<u>32.00g O₂</u>	<u>= (64.00 g O₂)</u>
	<u>44.01g CO₂</u>	<u>6 mol CO₂</u>	<u>1 mol O₂</u>	

molar mass - CO₂

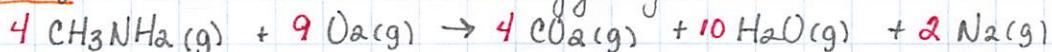
$$\begin{aligned} 1 \text{ C} \times 12.01 \text{ g} &= 12.01 \text{ g} \\ 2 \text{ O} \times 16.00 \text{ g} &= \underline{32.00 \text{ g}} \\ &\quad 44.01 \text{ g} \\ &\quad \text{UNKNOWN} \end{aligned}$$

molar mass - O₂

$$2 \text{ O} \times 16.00 \text{ g} = 32.00 \text{ g}$$

4. How many moles of water are produced when 36.0g of methylamine (CH_3NH_2) reacted with excess oxygen gas?

GIVEN



The given has units of grams and the unknown's unit is moles. So we should use steps A & B.

step A

<u>36.0g CH₃NH₂</u>	<u>1 mol CH₃NH₂</u>	<u>10 mol H₂O</u>	<u>= (2.90g H₂O)</u>
	<u>31.07g CH₃NH₂</u>	<u>4 mol CH₃NH₂</u>	

molar mass - CH₃NH₂

$$\begin{aligned} 1 \text{ C} \times 12.01 \text{ g} &= 12.01 \\ 5 \text{ H} \times 1.01 \text{ g} &= 5.05 \\ 1 \text{ N} \times 14.01 \text{ g} &= \underline{14.01} \\ &\quad 31.07 \text{ g} \end{aligned}$$