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Stoichiometry

Joe's favorite word!

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Our toolbox

We've now filled our toolbox with the basic tools required to discuss real chemistry:

1. Nomenclature
2. Conversion factors - Units! Units! Units
3. Significant figures/accuracy
4. Atomic Theory
5. Moles! Moles! Moles!

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Real Chemistry

Real Chemistry is all about doing chemical reactions.

Chemistry is about making or breaking bonds in order to rearrange atoms and make new compounds.

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Real Chemistry

Real Chemistry obeys Joe's 2 Rules of Chemistry:

1. UNITS! UNITS! UNITS!
2. MOLES! MOLES! MOLES!

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Chemical Equations

A chemical equation is a recipe for making a molecule.

This can be written in "shopping list" format:
$H_2 + O_2 \rightarrow H_2O$

But this doesn't help with specific amounts

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Balanced Chemical Equations

Chemical equations are most useful when **balanced** – meaning that all atoms are accounted for, there are the same number of each atom on both sides of the reaction arrow.

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

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Balancing Chemical Equations

There's no trick to balancing equations, but there are a few helpful hints:

1. Atoms that appear by themselves, on either side, should be done last.
2. Atoms that appear in one place on either side should be done first.
3. Practice makes perfect.

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Practice Problems

#11 Balance the following equations:

a) $CO + O_2 \rightarrow CO_2$
b) $N_2O_5 + H_2O \rightarrow HNO_3$
c) $CH_4 + Cl_2 \rightarrow CCl_4 + HCl$
d) $Al_4C_3 + H_2O \rightarrow Al(OH)_3 + CH_4$

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$CO + O_2 \rightarrow CO_2$

Which atom should we do first?
C – O occurs by itself on the left, so we can always balance it using the pure O_2
$CO + O_2 \rightarrow CO_2$ (Carbon is balanced)

$CO + ½ O_2 \rightarrow CO_2$ (balances O, but we like integers)

$2CO + O_2 \rightarrow 2 CO_2$

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$N_2O_5 + H_2O \rightarrow HNO_3$

Which first?

N or H – shouldn't matter

$N_2O_5 + H_2O \rightarrow 2HNO_3$ (I did N first)
$N_2O_5 + H_2O \rightarrow 2\ HNO_3$ (H second)
$N_2O_5 + H_2O \rightarrow 2\ HNO_3$ (turns out O is already done!)

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$CH_4 + Cl_2 \rightarrow CCl_4 + HCl$

Which first?

Either C or H. Cl should definitely be last

$CH_4 + Cl_2 \rightarrow CCl_4 + 4\ HCl$ (H first, C done already)

$CH_4 + 4\ Cl_2 \rightarrow CCl_4 + 4\ HCl$

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$Al_4C_3 + H_2O \rightarrow Al(OH)_3 + CH_4$

$Al_4C_3 + H_2O \rightarrow 4\ Al(OH)_3 + CH_4$

$Al_4C_3 + H_2O \rightarrow 4\ Al(OH)_3 + 3\ CH_4$

$Al_4C_3 + 12\ H_2O \rightarrow 4\ Al(OH)_3 + 3\ CH_4$

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Balanced Equations

Once I have a balanced equation, I have a very specific recipe:

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

This balanced equation indicates the exact relative amounts of all the chemical species. The numbers are called **stoichiometric coefficients.**

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$2\ H_2 + O_2 \rightarrow 2\ H_2O$

2 moles H_2:1 mole O_2:2 moles H_2O

This is essentially 6 different ratios:

$\frac{2 \text{ mol } H_2}{1 \text{ mol } O_2}$ $\frac{1 \text{ mol } O_2}{2 \text{ mol } H_2O}$ $\frac{2 \text{ mol } H_2O}{2 \text{ mol } H_2}$

$\frac{1 \text{ mol } O_2}{2 \text{ mol } H_2}$ $\frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2}$ $\frac{2 \text{ mol } H_2}{2 \text{ mol } H_2O}$

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Stoichiometric Ratios

These ratios are the relative stoichiometry and are, therefore, called **stoichiometric ratios**.

Like any other ratios, these are conversion factors – in this case converting one chemical substance into another.

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$2 H_2 + O_2 \rightarrow 2 H_2O$

If I have 2.5 moles of hydrogen – how much oxygen do I need to completely react the hydrogen?

$$2.5 \text{ mol } H_2 * \frac{1 \text{ mol } O_2}{2 \text{ mol } H_2} = 1.25 \text{ mol } O_2$$

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$2 H_2 + O_2 \rightarrow 2 H_2O$

If I reacted 2.5 moles of hydrogen – how much water did I create?

$$2.5 \text{ mol } H_2 * \frac{2 \text{ mol } H_2O}{2 \text{ mol } H_2} = 2.5 \text{ mol } H_2O$$

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Life as Conversion Factors

So, once again we see the power of conversion factors.

In this case, the stoichiometry is the conversion factor between different chemical species!

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Moles is better, Grams is easier

…to measure!

The reactions are all written in terms of molecules (or moles) interacting.

It is easier to measure grams in the laboratory!

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A more typical problem

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

What mass of oxygen is required to react with 5.0 g H_2?

Where do we start? What do we do?

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A more typical problem

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

What mass of oxygen is required to react with 5.0 g H_2?

$$5.0\text{ g } H_2 * \frac{1\text{ mol } H_2}{2.016\text{ g } H_2} * \frac{1\text{ mol } O_2}{2\text{ mol } H_2} * \frac{32.0\text{ g } O_2}{1\text{ mol } O_2} = 39.6\text{ g } O_2$$

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Joe's 1st Dance of Chemistry

GRAMS TO MOLES
MOLES TO MOLES
MOLES TO GRAMS

This is the most common calculation in all of chemistry!

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A more typical problem

$2\,H_2 + O_2 \rightarrow 2\,H_2O$

What masses of oxygen and hydrogen are required to create 5.0 g H_2O?

Where do we start? What do we do?
Grams to moles, moles to moles, moles to grams

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A more typical problem

$2\,H_2 + O_2 \rightarrow 2\,H_2O$

What masses of oxygen and hydrogen are required to create 5.0 g H_2O?

$$5.0\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18.016\text{ g } H_2O} \times \frac{1\text{ mol } O_2}{2\text{ mol } H_2O} \times \frac{32.0\text{ g } O_2}{1\text{ mol } O_2} = 4.44\text{ g } O_2$$

$$5.0\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18.016\text{ g } H_2O} \times \frac{2\text{ mol } H_2}{2\text{ mol } H_2O} \times \frac{2.016\text{ g } H_2}{1\text{ mol } H_2} = 0.56\text{ g } H_2$$

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A more typical problem

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

What masses of oxygen and hydrogen are required to create 5.0 g H_2O?

4.44 g O_2

0.56 g H_2

Both are required! Doesn't matter how much oxygen you have if you don't have any hydrogen!

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1 cup flour + 2 eggs → 1 cake

How many cakes can you make with 4 cups of flour?

None – unless you have 8 eggs!

How many cakes can you make with a million eggs?

None – unless you have half a million cups of flour.

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Problems

Ammonia can be made by the gas-phase reaction of nitrogen and hydrogen:

$H_2 + N_2 \rightarrow NH_3$

15.32 g of hydrogen are mixed with an excess of nitrogen. How much ammonia can be manufactured?

A.129 g

B.173 g

C. 153 g

D. 86 g

E.15 g

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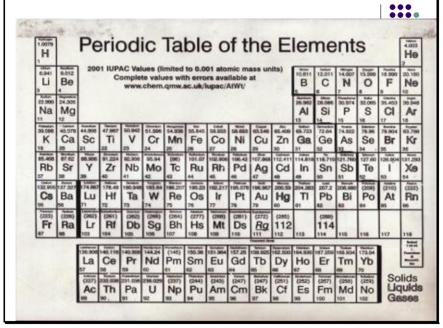

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$H_2 + N_2 \rightarrow NH_3$

1st you need to balance the equation:

$3\ H_2 + N_2 \rightarrow 2\ NH_3$

$15.32\ g\ H_2 * \frac{1\ mol}{2.016\ g\ H_2} * \frac{2\ mol\ NH_3}{3\ mol\ H_2} * \frac{17\ g\ NH_3}{1\ mol\ NH_3} = 86\ g\ NH_3$