Stoichiometry
Mole-Mole Relationship

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YALE UNIVERSITY
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Chemical Equations

What do they tell us?

What does it mean to be “balanced”?

How do we balance chemical equations?

What do chemical equations tell us?

- Formulas for the reactants (left side)
- Formulas for the products (right side)
- Phases, most of the time
- **<u>Relative</u>** amounts of reactants of reactants and products

$$\text{REACTANT} \rightarrow \text{PRODUCTS}$$

What does it mean to be “balanced”?

- Same number of each type of atom on the left (reactants) and right (products) side.
- **<u>Law of Conservation of Mass</u>**

REACTANT $\rightarrow$ PRODUCTS

How do we balance chemical equations?

- Mainly trial-and-error (some general strategies though).
- Make sure you have the same number of each type of atom on both sides of the equation.
- Do <u>NOT</u> balance by changing subscripts! Seriously, don't.
- Balance the most complicated molecule *first*.

REACTANT $\rightarrow$ PRODUCTS

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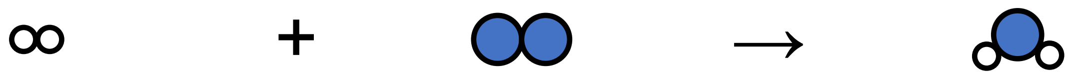
(drawings)



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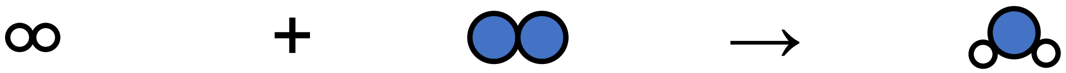

Reactants	Products
2 H atoms	2 H atoms
2 O atoms	1 O atoms

Q: Why am I missing an O atom in the products?

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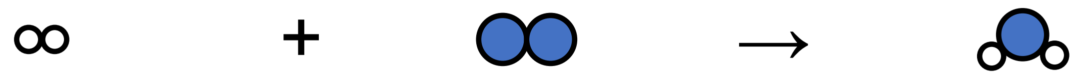

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Q: Why am I missing an O atom in the products?

A: We need to balance this equation!

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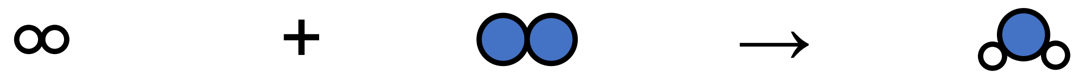

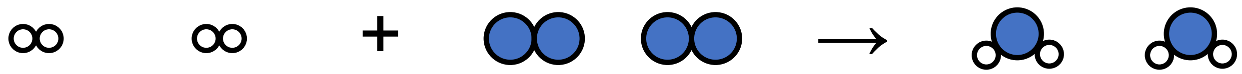

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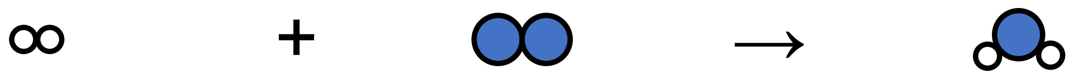

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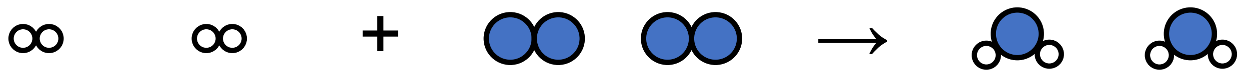

Reactants	Products
4 H atoms	4 H atoms
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Great!
Now we're all good!

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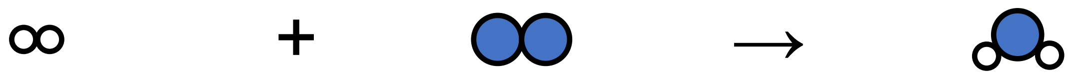
(drawings) 

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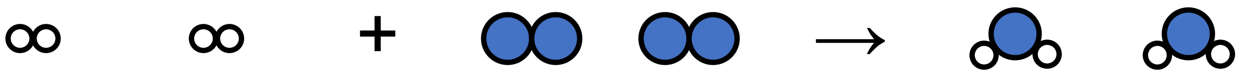

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Pictures aren't always convenient though…

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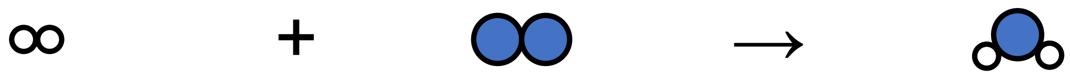

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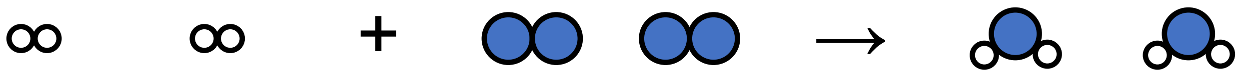

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(equation) $2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (g)$

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How do I read a chemical equation?

COEFFICIENTS
Tell us the *relative* amounts of reactants/products

SUBSCRIPTS
Tell us the # of atoms in a molecule

PHASES
Tell us the nature of reactants/products

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- Subscripts are not conserved!
- Coefficients have no real meaning by themselves…
- RATIO of coefficient is what's important.
- Read it like a recipe:

  "For every 2 H_2 molecules, we need 1 O_2 molecule to produce 2 H_2O molecules."

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"To make 2 moles NH_3, we need 1 mole N_2 and 3 moles H_2."

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Q: Mioy, I don't understand how you knew what reactants and products to write though?

A: Good point! How did I know?
When we "burn" a hydrocarbon (a compound with C, H, and/or O atoms), it ***always*** reacts with O_2 gas in the air to form CO_2 and H_2O gases as products.

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Now balance the chemical equation above. Can you do it?

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1. Use molar mass of CH_4 to convert from mass to moles.

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2. *Use 2:1 H_2O:CH_4 mole-mole ratio to find moles of H_2O.*

$$0.311_7\text{ mol }CH_4 \times \frac{2\text{ mol }H_2O}{1\text{ mol }CH_4} = 0.623_4\text{ mol }H_2O$$

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3. Use molar mass of H_2O to convert from moles to mass.

$$0.623_4\ \text{mol}\ H_2O \times \frac{18.02\ \text{g}\ H_2O}{1\ \text{mol}\ H_2O} = 11.2\ \text{g}\ H_2O$$

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How many moles of oxygen gas are required to react completely with 2.0 moles of sugar crystals, $C_{12}H_{22}O_{11}$?

Write out the core of the equation from the description:

$$\underline{\ 1\ }\ C_{12}H_{22}O_{11}\,(s) + \underline{\ 12\ }\ O_2\,(g) \rightarrow \underline{\ 12\ }\ CO_2\,(g) + \underline{\ 11\ }\ H_2O\,(g)$$

Balance the equation above.

How many moles of oxygen gas are required to react completely with 2.0 moles of sugar crystals, $C_{12}H_{22}O_{11}$?

The balanced chemical equation is:

$$\underline{\ 1\ }\ C_{12}H_{22}O_{11}\ (s) + \underline{\ 12\ }\ O_2\ (g) \rightarrow \underline{\ 12\ }\ CO_2\ (g) + \underline{\ 11\ }\ H_2O\ (g)$$

"For every 1 mol $C_{12}H_{22}O_{11}$, we need to react with 12 mol O_2 to produce 12 mol CO_2 and 11 mol H_2O."

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REMEMBER : We only care about the **ratio** of coefficients, so we can still use the mole-mole ratio to "go backwards."

$$2.0 \text{ mol } C_{12}H_{22}O_{11} \times \frac{12 \text{ mol } O_2}{1 \text{ mol } C_{12}H_{22}O_{11}} = 24 \text{ mol } O_2$$

Pouring an aqueous solution of hydrochloric acid onto a solid block of magnesium metal produces an aqueous solution of magnesium chloride and hydrogen gas.

___ + ___ → ___ + ___

A) Given 3.00 g Mg, how many moles of hydrochloric acid do we need?

B) If we produce 5.00 g H_2 gas, what mass of $MgCl_2$ solution is produced?

C) If we produce 4.00 g H_2 gas, what mass of HCl did we need?

REMEMBER : We only care about the **ratio** of coefficients, so we can use mole-mole ratios to go between reactants-to-reactants, reactants-products, products-to-reactants, or products-to-products.

Pouring an aqueous solution of hydrochloric acid onto a solid block of magnesium metal produces an aqueous solution of magnesium chloride and hydrogen gas.

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$\underline{\ 1\ }$ Mg (s) + $\underline{\ 2\ }$ HCl (*aq*) → $\underline{\ 1\ }$ $MgCl_2$ (*aq*) + $\underline{\ 1\ }$ H_2 (*g*)

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A) Given 3.00 g Mg, how many moles of hydrochloric acid do we need?

$$3.00\ \text{mol Mg} \times \frac{2\ \text{mol HCl}}{1\ \text{mol Mg}} = 6.00\ \text{mol HCl}$$

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$$5.00\ \mathrm{g\ H_2} \times \frac{1\ \mathrm{mol\ H_2}}{2.016\ \mathrm{g\ H_2}} \times \frac{1\ \mathrm{mol\ MgCl_2}}{1\ \mathrm{mol\ H_2}} \times \frac{95.21\ \mathrm{g\ MgCl_2}}{1\ \mathrm{mol\ MgCl_2}} = 236\ \mathrm{g\ MgCl_2}$$

C) If we produce 4.00 g H_2 gas, what mass of HCl did we need?

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$$4.00\ \text{g H}_2 \times \frac{1\ \text{mol H}_2}{2.016\ \text{g H}_2} \times \frac{2\ \text{mol HCl}}{1\ \text{mol H}_2} \times \frac{36.46\ \text{g HCl}}{1\ \text{mol HCl}} = 145\ \text{g HCl}$$

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REMEMBER THIS?

THE MOLE IS CENTRAL

use: $\dfrac{6.022\times10^{23}\ \text{“thing”}}{1\ \text{mol}}$ or $\dfrac{1\ \text{mol}}{6.022\times10^{23}\ \text{“things”}}$

 # ATOMS
– or –
 # MOLECULES

$\longleftrightarrow$

 # MOLES

$\longleftrightarrow$

MASS (in grams)

use molar masses from periodic table: $\dfrac{12.01\ \text{g C}}{1\ \text{mol C}}$ or $\dfrac{1\ \text{mol C}}{12.01\ \text{g C}}$

SUMMARIZING STOICHIOMETRY RELATIONSHIPS

THE MOLE IS ***STILL*** CENTRAL

MASS
VOLUME
MOLES

BALANCED CHEMICAL EQUATION

mole$_1$ $\longrightarrow$ **mole$_2$**

MASS
VOLUME
MOLES

GIVEN
reactant or product

LOOKING FOR
reactant or product

I hope now you understand why I say to convert to moles before you do anything else. It's because a balanced chemical equation gives us ***mole-to-mole ratios*** *that we can use to convert between one reactant/product to another reactant/product.*