Stoichiometry

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A branch of chemistry that deals with the amounts of reactants and products involved in a chemical reaction.

There are currently over 50 million man made compounds in the world. Aspirin, nylon and polyester in clothes, graphite tennis rackets, tires, plastics and thousands of other products you use are all synthetic.

The number of synthetic compounds has increased exponentially over the last century due to the increase in our knowledge of chemistry.

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piano keys	ivory	synthesized

So how do Chemist make compounds?

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Well... let's start out easy and work our way up!

Aluminum Sulfide

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For you to produce 1 mole of Al_2S_3, you must know how many grams of aluminum and how many grams of sulfur to react.

Use D.A. to calculate how many grams of each reactant is needed.

2 moles of aluminum

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53.96 g of Al + **96.18 g** of S would produce **150.14 g** of Al_2S_3

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53.96 g of Al + **96.18 g** of S would produce **150.14 g** of Al_2S_3

In the real world industry needs to make millions of kg of Al_2S_3.

To do so they use Mole Ratio Conversion factors.

Mole Ratio Conversion Factors

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In this reaction we know that 2 moles of Al requires 3 moles of S to make 1 mole of Al_2S_3.

From this reaction we can make 6 mole ratio conversion factors:

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relationship between Al and S:	relationship between Al and Al_2S_3:	
$\frac{2 \text{ mol Al}}{3 \text{ mol S}}$ $\frac{3 \text{ mol S}}{2 \text{ mol Al}}$		

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$$\frac{2\ mol\ Al}{1\ mol\ Al_2S_3}$$

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2 moles of Al | 3 moles of S | 1 mole of Al_2S_3

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$$\frac{2 \text{ mol Al}}{3 \text{ mol S}} \qquad \frac{3 \text{ mol S}}{2 \text{ mol Al}}$$

relationship between Al and Al_2S_3:

$$\frac{2 \text{ mol Al}}{1 \text{ mol } Al_2S_3} \qquad \frac{1 \text{ mol } Al_2S_3}{2 \text{ mol Al}}$$

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In this reaction we know that 2 moles of Al requires 3 moles of S to make 1 mole of Al_2S_3.

From this reaction we can make 6 mole ratio conversion factors:

relationship between Al and S:	relationship between Al and Al_2S_3:	relationship between S and Al_2S_3:
$\frac{2\ mol\ Al}{3\ mol\ S}$ $\frac{3\ mol\ S}{2\ mol\ Al}$	$\frac{2\ mol\ Al}{1\ mol\ Al_2S_3}$ $\frac{1\ mol\ Al_2S_3}{2\ mol\ Al}$	

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$$2Al + 3S \rightarrow Al_2S_3$$

2 moles of Al — 3 moles of S — 1 mole of Al_2S_3

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relationship between Al and Al_2S_3:

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relationship between S and Al_2S_3:

$$\frac{3 \text{ mol S}}{1 \text{ mol } Al_2S_3}$$

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2 moles of Al — 3 moles of S — 1 mole of Al_2S_3

In this reaction we know that 2 moles of Al requires 3 moles of S to make 1 mole of Al_2S_3.

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relationship between Al and Al_2S_3:

$$\frac{2\ \text{mol Al}}{1\ \text{mol}\ Al_2S_3} \qquad \frac{1\ \text{mol}\ Al_2S_3}{2\ \text{mol Al}}$$

relationship between S and Al_2S_3:

$$\frac{3\ \text{mol S}}{1\ \text{mol}\ Al_2S_3} \qquad \frac{1\ \text{mol}\ Al_2S_3}{3\ \text{mol S}}$$

Mole Ratio Conversion Factors

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relationship between Al and S:	relationship between Al and Al_2S_3:	relationship between S and Al_2S_3:
$\frac{2\text{ mol Al}}{3\text{ mol S}}$ $\frac{3\text{ mol S}}{2\text{ mol Al}}$	$\frac{2\text{ mol Al}}{1\text{ mol }Al_2S_3}$ $\frac{1\text{ mol }Al_2S_3}{2\text{ mol Al}}$	$\frac{3\text{ mol S}}{1\text{ mol }Al_2S_3}$ $\frac{1\text{ mol }Al_2S_3}{3\text{ mol S}}$

We will now use these Mole Ratio Conversion factors to do Stoichiometry!

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245.67 g	1 mol Al
1	26.98 g

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Step 1: Set up the D.A. to convert grams of Al to moles of Al.

Step 2: Write a Mole Ratio Conversion Factor to convert moles of Aluminum to moles of Aluminum sulfide.

$$\frac{245.67\ g}{1} \times \frac{1\ mol\ Al}{26.98\ g}$$

Problem 1: If you have 245.67 g of aluminum, how much aluminum sulfide could you make with an excess of sulfur?

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Step 2: Write a Mole Ratio Conversion Factor to convert moles of Aluminum to moles of Aluminum sulfide.

$$\frac{245.67\text{ g}}{1} \times \frac{1\text{ mol Al}}{26.98\text{ g}} \times \frac{1\text{ mol }Al_2S_3}{2\text{ mol Al}}$$

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2 moles of Al + 3 moles of S → 1 mole of Al_2S_3

Step 1: Set up the D.A. to convert grams of Al to moles of Al.

Step 2: Write a Mole Ratio Conversion Factor to convert moles of Aluminum to moles of Aluminum sulfide.

Step 3: Write a conversion factor that will convert moles of aluminum sulfide to grams of aluminum sulfide.

245.67 g	1 mol Al	1 mol Al_2S_3
1	26.98 g	2 mol Al

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$$\frac{245.67\text{ g}}{1} \times \frac{1\text{ mol Al}}{26.98\text{ g}} \times \frac{1\text{ mol }Al_2S_3}{2\text{ mol Al}} \times \frac{150.16\text{g }Al_2S_3}{1\text{ mol }Al_2S_3}$$

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Step 3: Write a conversion factor that will convert moles of aluminum sulfide to grams of aluminum sulfide.

Step 4: Solve for grams of aluminum sulfide produced in the reaction.

$$\frac{245.67\ g}{1} \left| \frac{1\ mol\ Al}{26.98\ g} \right| \frac{1\ mol\ Al_2S_3}{2\ mol\ Al} \left| \frac{150.16g\ Al_2S_3}{1\ mol\ Al_2S_3} \right.$$

Problem 1: If you have 245.67 g of aluminum, how much aluminum sulfide could you make with an excess of sulfur?

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Step 1: Set up the D.A. to convert grams of Al to moles of Al.

Step 2: Write a Mole Ratio Conversion Factor to convert moles of Aluminum to moles of Aluminum sulfide.

Step 3: Write a conversion factor that will convert moles of aluminum sulfide to grams of aluminum sulfide.

Step 4: Solve for grams of aluminum sulfide produced in the reaction.

$$\frac{245.67\,\cancel{g}}{1}\;\Big|\;\frac{1\,\cancel{mol\ Al}}{26.98\,\cancel{g}}\;\Big|\;\frac{1\,\cancel{mol\ Al_2S_3}}{2\,\cancel{mol\ Al}}\;\Big|\;\frac{150.16g\ Al_2S_3}{1\,\cancel{mol\ Al_2S_3}}$$

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Step 3: Write a conversion factor that will convert moles of aluminum sulfide to grams of aluminum sulfide.

Step 4: Solve for grams of aluminum sulfide produced in the reaction.

$$\frac{245.67\ \cancel{g}}{1} \times \frac{1\ \cancel{mol\ Al}}{26.98\ \cancel{g}} \times \frac{1\ \cancel{mol\ Al_2S_3}}{2\ \cancel{mol\ Al}} \times \frac{150.16g\ Al_2S_3}{1\ \cancel{mol\ Al_2S_3}} = 683.7\ g.\ Al_2S_3$$

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2 moles of Al + 3 moles of S → 1 mole of Al_2S_3

Step 1: Set up the D.A. to convert grams of Al to moles of Al.

Step 2: Write a Mole Ratio Conversion Factor to convert moles of Aluminum to moles of Aluminum sulfide.

Step 3: Write a conversion factor that will convert moles of aluminum sulfide to grams of aluminum sulfide.

Step 4: Solve for grams of aluminum sulfide produced in the reaction.

$$\frac{245.67\ \cancel{g}}{1} \times \frac{1\ \cancel{mol\ Al}}{26.98\ \cancel{g}} \times \frac{1\ \cancel{mol\ Al_2S_3}}{2\ \cancel{mol\ Al}} \times \frac{150.16g\ Al_2S_3}{1\ \cancel{mol\ Al_2S_3}} = 683.7\ g.\ Al_2S_3$$

Problem 2: How much sulfur would be required in this reaction?

Problem 1: If you have 245.67 g of aluminum, how much aluminum sulfide could you make with an excess of sulfur?

$2Al + 3S \rightarrow Al_2S_3$

2 moles of Al + 3 moles of S → 1 mole of Al_2S_3

Step 1: Set up the D.A. to convert grams of Al to moles of Al.

Step 2: Write a Mole Ratio Conversion Factor to convert moles of Aluminum to moles of Aluminum sulfide.

Step 3: Write a conversion factor that will convert moles of aluminum sulfide to grams of aluminum sulfide.

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Problem 2: How much sulfur would be required in this reaction?

246 g Al + _?_ g of S → 683.7 g Al_2S_3

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Problem 2: How much sulfur would be required in this reaction?

246 g Al + _?_ g of S → 683.7 g Al_2S_3

683.7 g Al_2S_3 - 246.67 g Al = 438.0g of S

Problem 2: You want to make 350.0 g of barium phosphide. How many grams of each of your reactants do you need?

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$$3Ba + 2P \rightarrow Ba_3P_2$$

$$\frac{350.0\ g\ Ba_3P_2}{1} \times \frac{1\ mole\ Ba_3P_2}{473.93\ g\ Ba_3P_2}$$

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Step 3: Use a Mole Ratio Conversion Factor to convert to moles of barium.

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Problem 2: You want to make 350.0 g of barium phosphide. How many grams of each of your reactants do you need?

$$3Ba + 2P \rightarrow Ba_3P_2$$

350.0 g Ba_3P_2	1 mole Ba_3P_2	3 moles Ba	137.33 g Ba
1	473.93 g Ba_3P_2	1 mole Ba_3P_2	1 mole Ba

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Step 1: Write a bal

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Step 4: Convert mo

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Step 6: Repeat the … grams of phosphorus.

Law of Conservation of Mass

350.0 g barium phosphide
-304.3 g barium
45.7 g phosphorus

$$\frac{350.0\ \cancel{g\ Ba_3P_2}}{1} \times \frac{1\ \cancel{mole\ Ba_3P_2}}{473.93\ \cancel{g\ Ba_3P_2}} \times \frac{2\ \cancel{moles\ P}}{1\ \cancel{mole\ Ba_3P_2}} \times \frac{30.97\ g\ P}{1\ \cancel{mole\ P}} = 45.7\ g\ P$$

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- The percent yield is determined by dividing the expected yield by the actual yield ideal yield and multiplying times 100 to make it a percent.

Formula: $\frac{\text{actual yield}}{\text{expected yield}} \times 100 = \text{Percent Yield}$

Problem 3: Methyl alcohol (CH_3OH) is used as a fuel, production of plastics, paints and textiles. It can be produced by reacting carbon monoxide (CO) and hydrogen gas (H_2). If 75.0 g of CO reacts to produce 68.4 g. of CH_3OH, what is the percent yield of CH_3OH?

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$$\frac{75.0\ g\ CO}{1} \times \frac{1\ mole\ CO}{28.010\ g\ CO} \times \frac{1\ mole\ CH_3OH}{1\ mole\ CO} \times \frac{32.042\ g\ CH_3OH}{1\ mole\ CH_3OH}$$

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$$\frac{68.4\ g\ of\ CH_3OH}{85.8\ g\ of\ CH_3OH} = 0.797 \times 100 = 79.7\%\ yield$$

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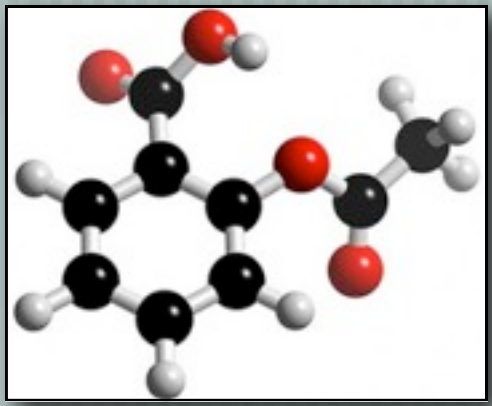
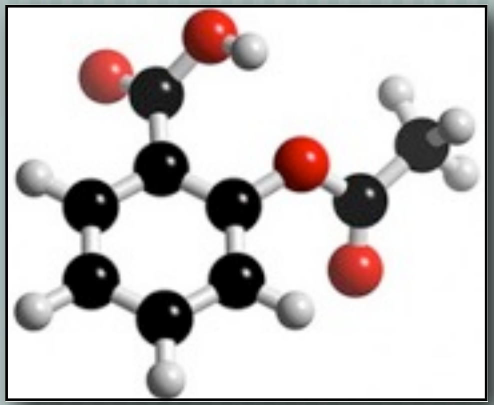
- Percent purity is especially important in the drug and food industry where impurities in the product could cause illness or death.

Percent Purity of Aspirin



Percent Purity of Aspirin

Aspirin, acetylsalicylic acid ($C_9H_8O_4$), is one of mankind's oldest drugs.
Ancient Egyptians chewed on the bark or leaves of a willow tree extracting the aspirin that was contained there.



In 1897 Felix Hoffman, working in at the Bayer lab in Germany, synthesizes aspirin.
Americans consume 50 million aspirin tablets per day.

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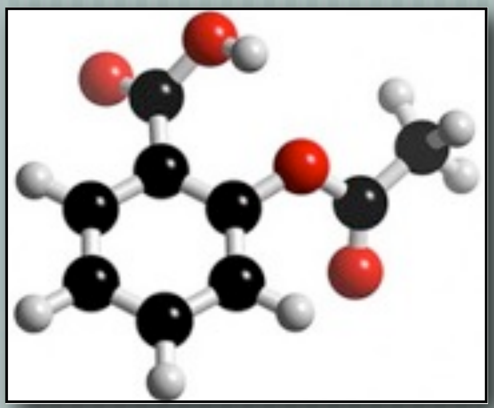

In 1897 Felix Hoffman, working in at the Bayer lab in Germany, synthesizes aspirin.

Americans consume 50 million aspirin tablets per day.

A student making aspirin produces 121.2 g of product but analysis shows that only 109.2 grams of it is aspirin. Calculate the percent purity.

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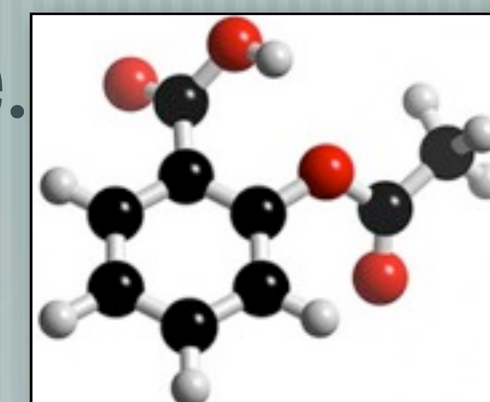

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$$\text{Percent Purity} = \frac{\text{mass of pure product}}{\text{mass of impure product}} = \frac{109.2\ \cancel{g}}{121.2\ \cancel{g}} = 0.9010 \times 100 =$$

90.10% pure

Stoichometry involving Gases

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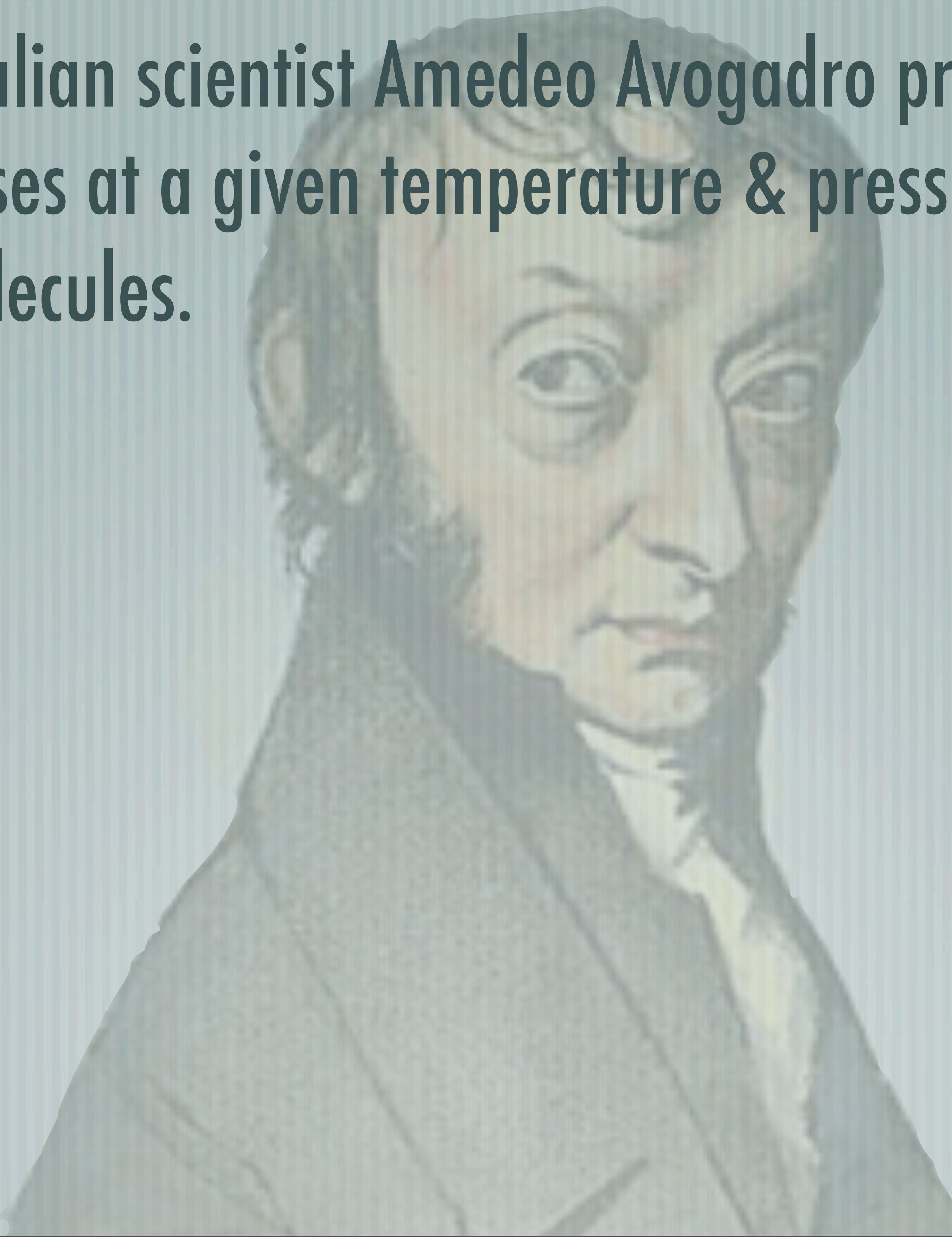
- In 1811, the Italian scientist Amedeo Avogadro proposed that equal volumes of gases at a given temperature & pressure have equal number of molecules.



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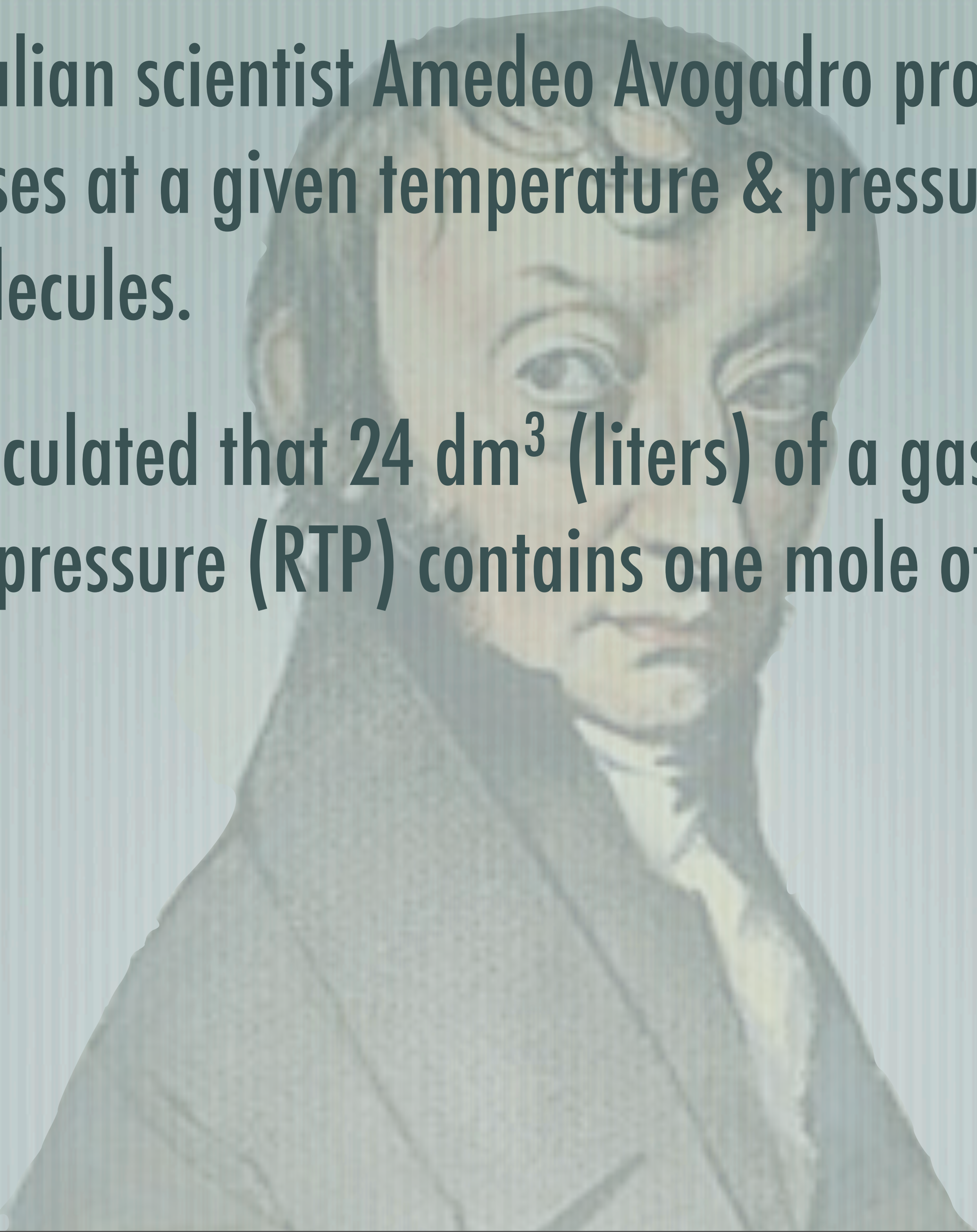

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- So... instead of trying to mass a mole of a gas (which would be especially difficult with lighter than air gases), scientists measure out a mole of gas by volume: 24 L @ room temperature & pressure
- When dealing with gases, 1 mole = 24 dm^3 at RTP.

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135 dm^3 of CO_2 gas

Limiting Reagent

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Suppose your foreman comes in and says that there is a problem: termites got into the wood shafts and destroyed all but 2000 of them.

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Chemical reactions are the same. If you run out of one reagent (reactant) but have plenty of the other reagents, the whole reaction shuts down and you cannot produce more product.

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The reactant(s) that run out and cause the reaction to stop is called the limiting reagent (reactant).

To determine which of your reactants are the limiting reagent you will use your mole ratio conversion factor to determine how much of each reactant is required for the reaction.

Limiting Reagent: Mg + P

Magnesium burns bright in phosphorus to produce magnesium phosphide. If 37.6 g of Mg is reacted with 37.6 g of P, which is the limiting reagent?

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37.6 g of Mg	1 mole of Mg	2 moles of P	30.97 g of P
1	24.31 g of Mg	3 moles of Mg	1 mole of P

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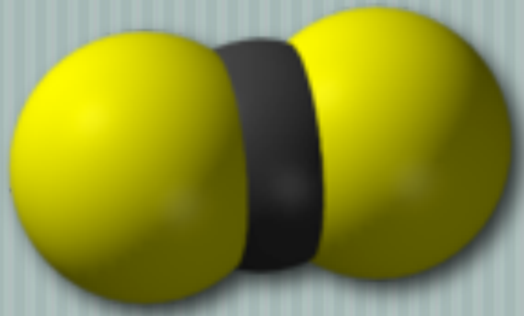
Since it requires only 31.9 g of phosphorus and you have 37.9 g, you will have an excess of 6.0 grams of P when you run out of magnesium.
So magnesium is the limiting reagent.

Liquid carbon disulfide is extremely flammable and burns in oxygen to produce carbon dioxide gas and sulfur dioxide gas.



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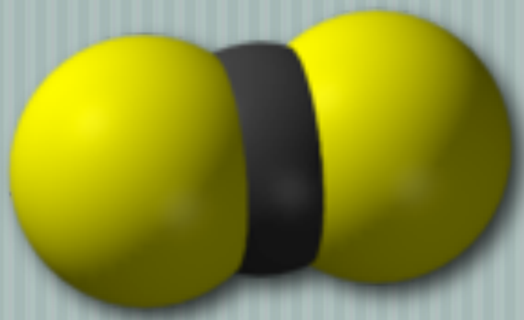

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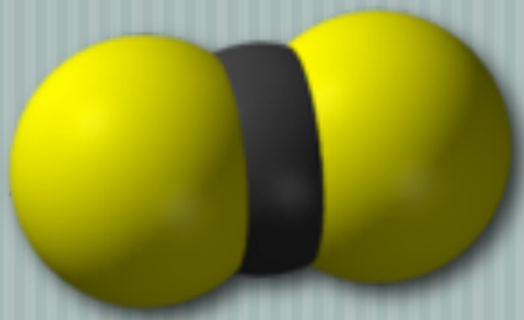

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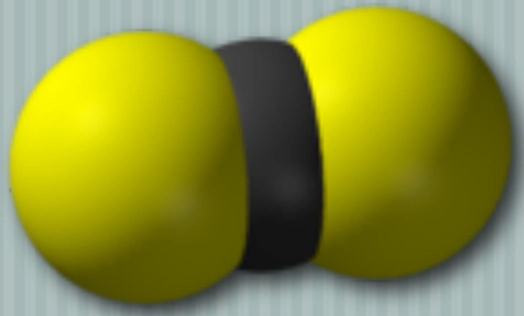

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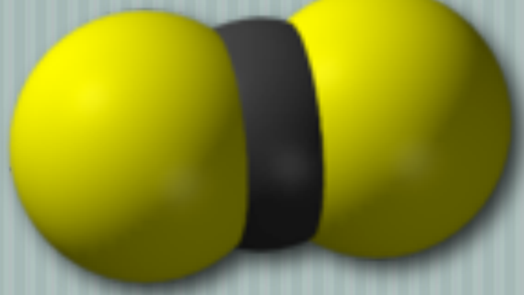

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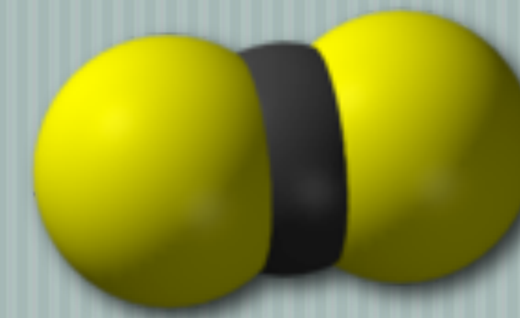

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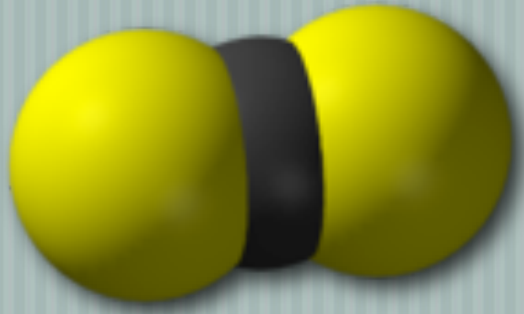

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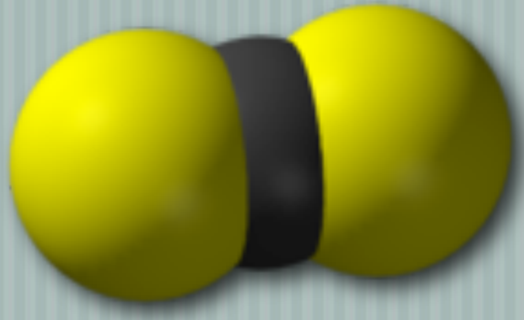

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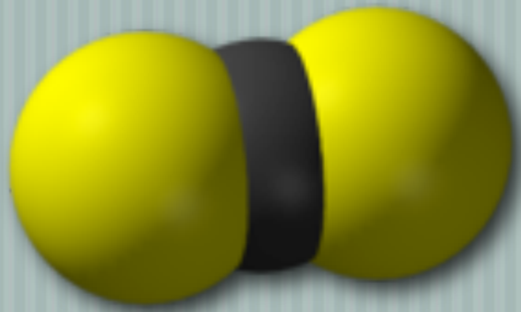

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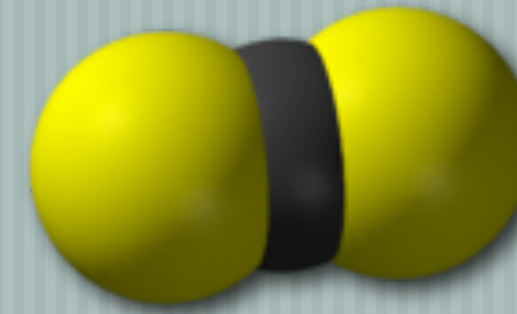

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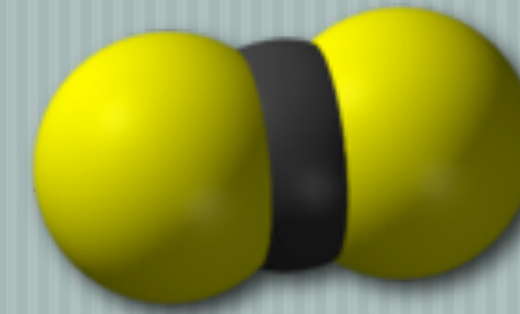

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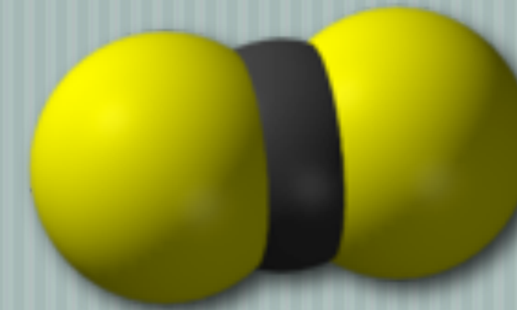

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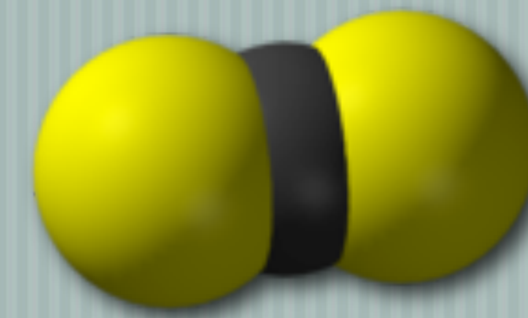

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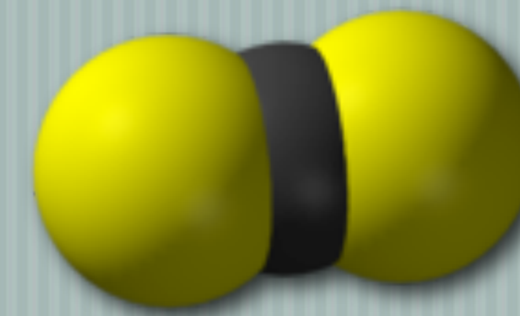
$$\frac{152.28\text{ g }CS_2}{1} \times \frac{1\text{ mole }CS_2}{76.14\text{ g }CS_2} \times \frac{3\text{ moles }O_2}{1\text{ mole }CS_2} \times \frac{31.998\text{ g }O_2}{1\text{ mole }O_2} \times \frac{24\text{ dm}^3\ O_2}{31.998\text{ g }O_2}$$

Liquid carbon disulfide is extremely flammable and burns in oxygen to produce carbon dioxide gas and sulfur dioxide gas.



If 152.28 g of carbon disulfide and 120 dm^3 of O_2 are reacted, which is the limiting reagent?

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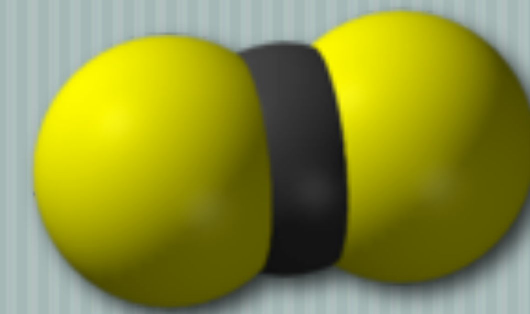

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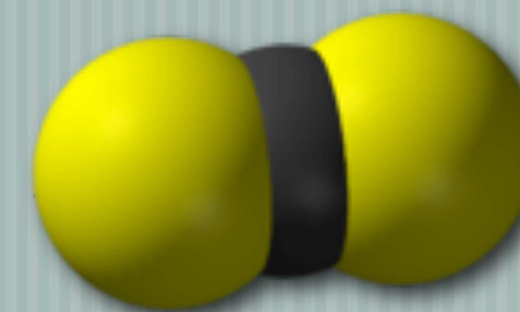

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Oxygen is the limited reagent since you need 144 dm^3 (6 moles) of O_2 in this reaction but only have 120 dm^3 (5 moles).

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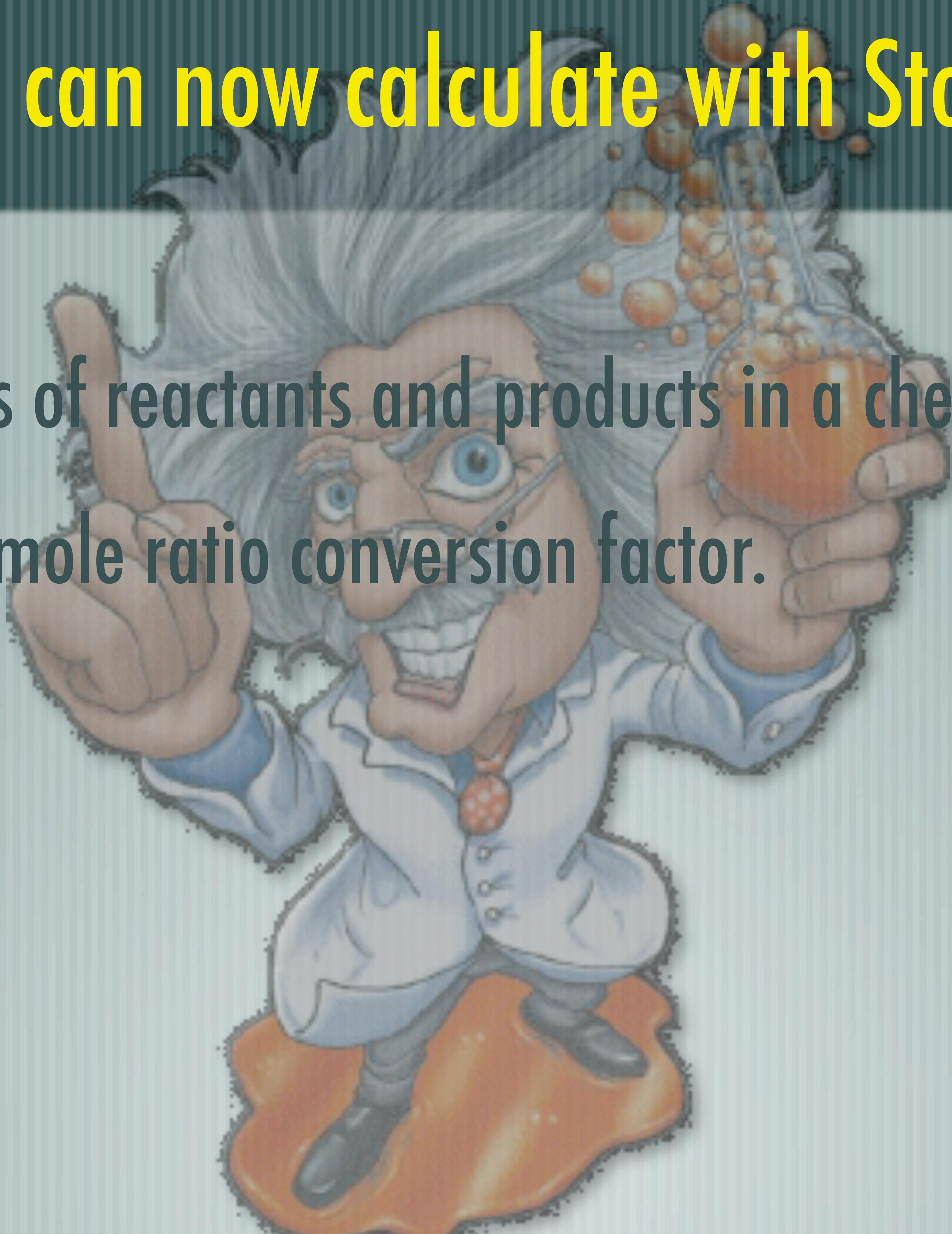

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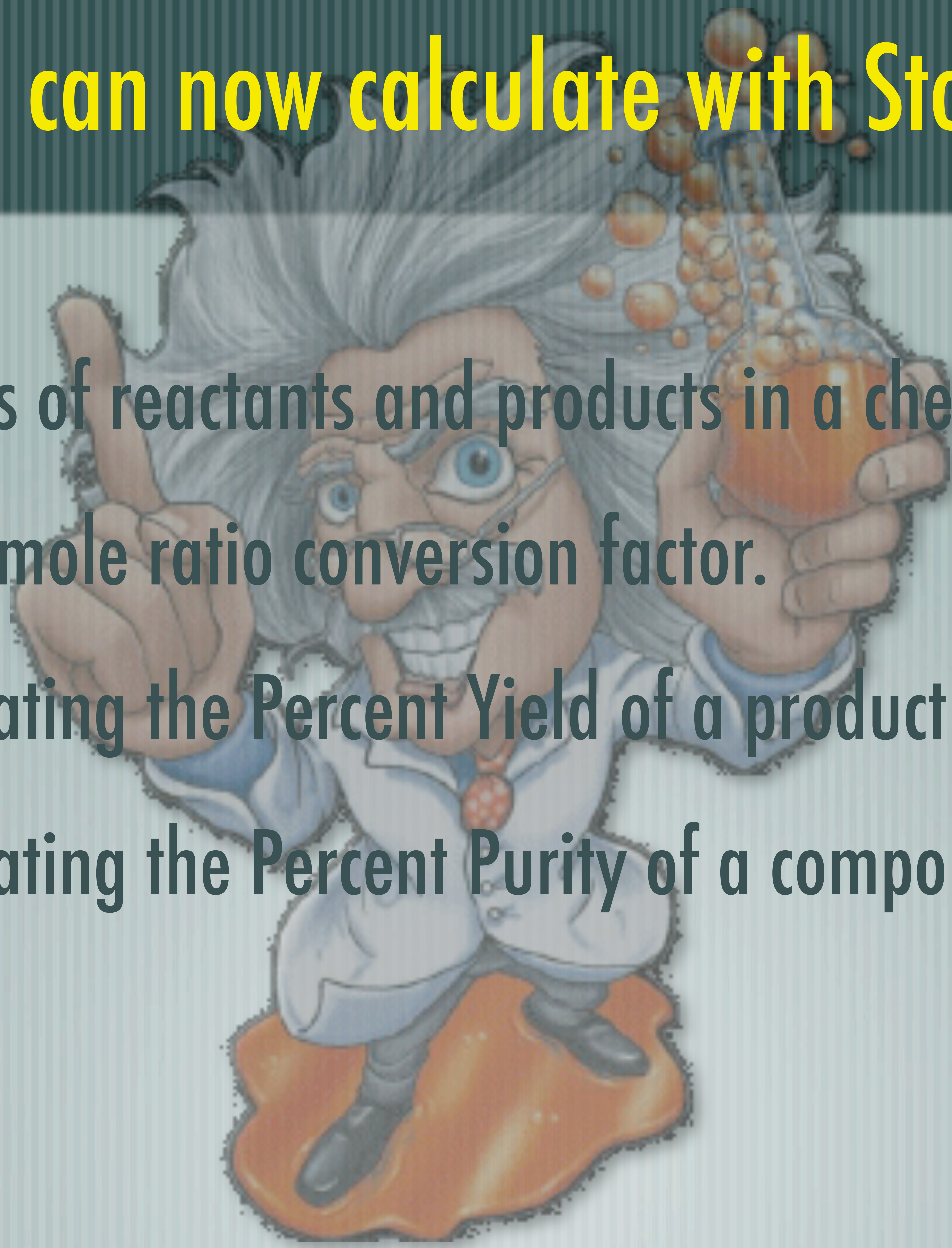

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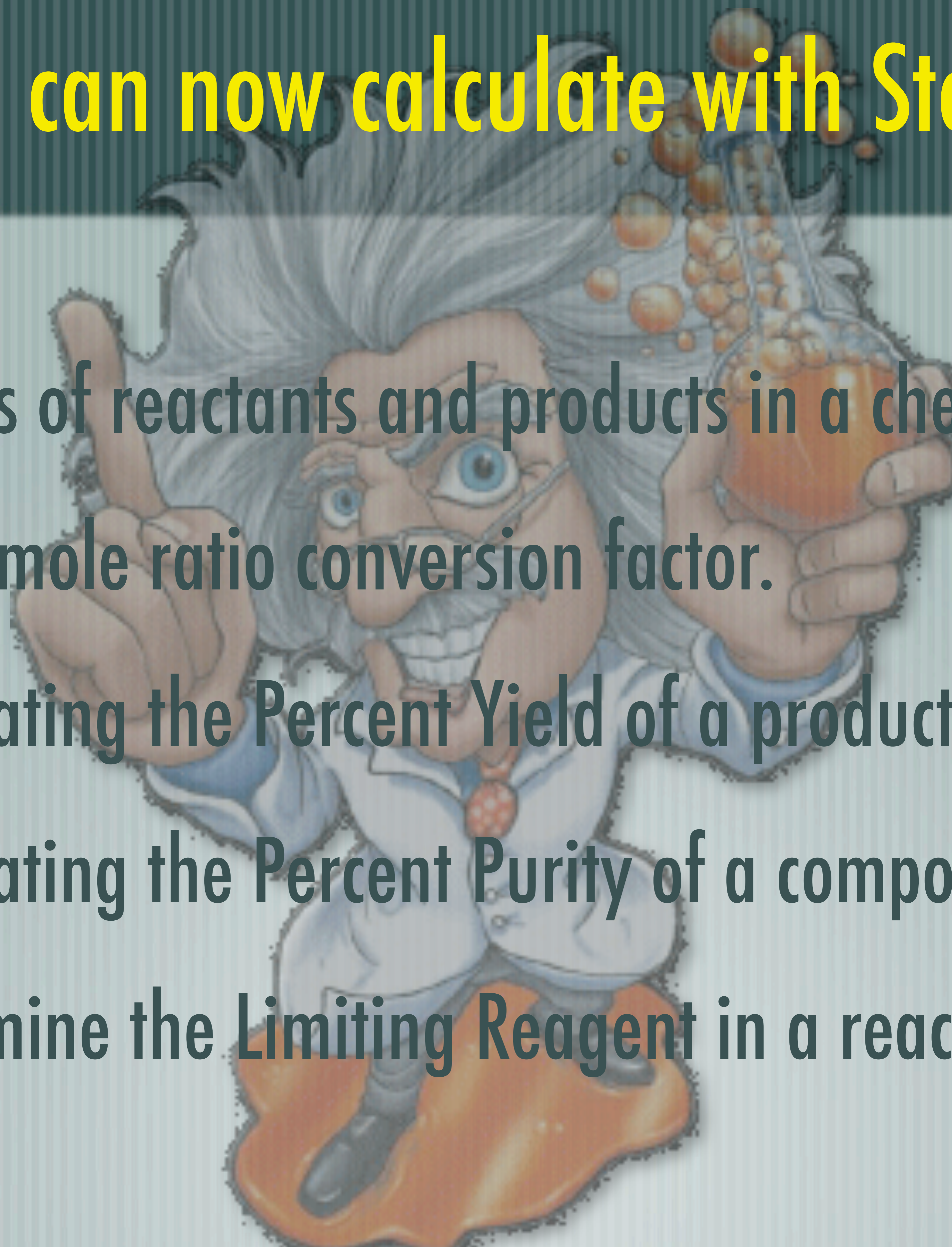

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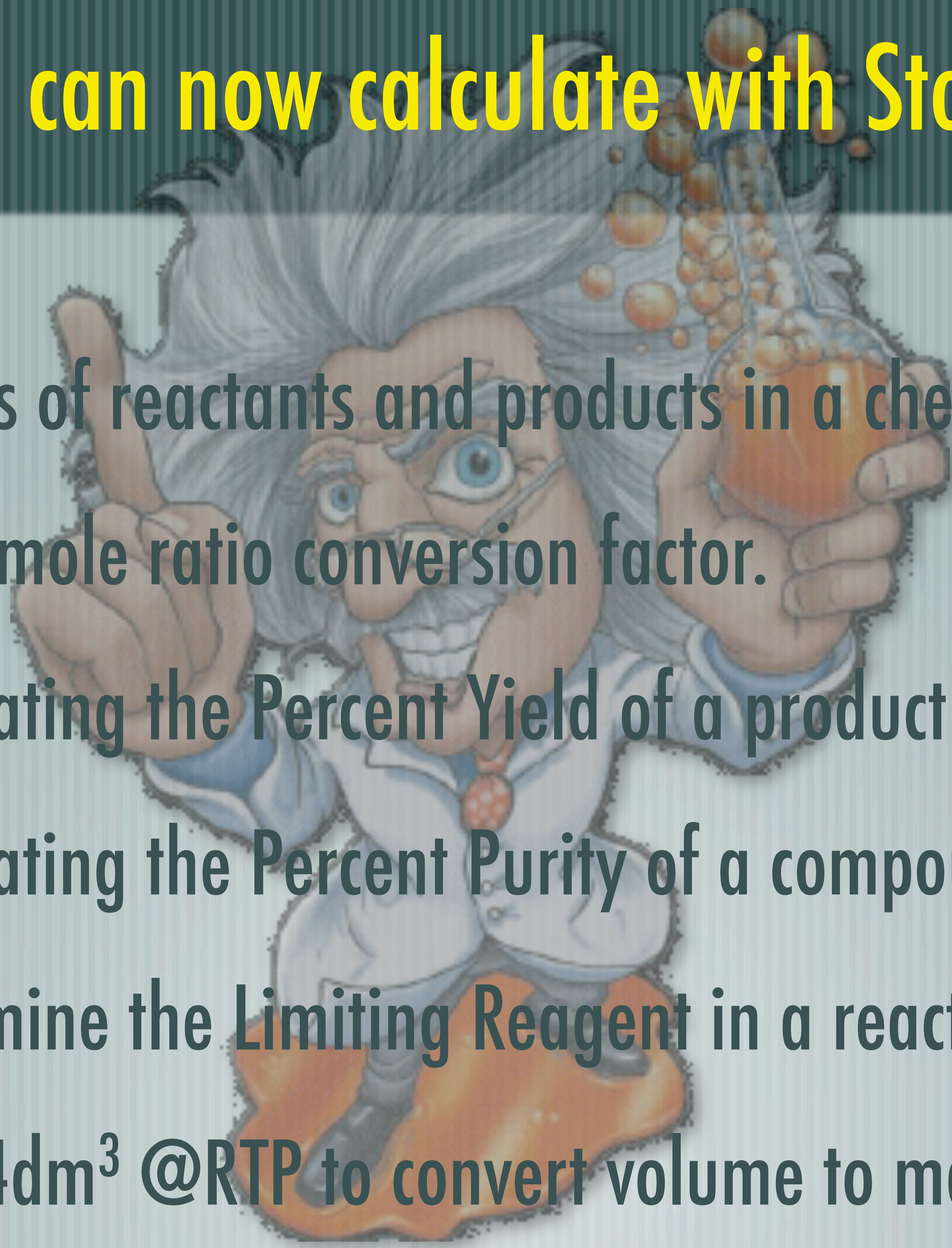

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- Use 24dm^3 @RTP to convert volume to mass of gases.