Unit 7

On completion of the unit you should be able to:

1. interpret balanced equations in terms of moles, mass units and number of particles.
2. given the number of moles (or mass or number of particles) of one substance calculate the number of moles (or mass or number of particles) of another substance in the balanced equation.
3. define limiting and excess reactants.

CALCULATIONS INVOLVING CHEMICAL REACTIONS

7.1 **Coefficients of a chemical reaction**

Today's focus.

Reading: Hebden – page 123-124

7.2 **Calculations based on chemical equations**

- **Mole-mole calculation**
- **Mass-mass calculation**
- **Mass-mole calculation**
- **Limiting reagent calculation**
- **Calculations involving neutralization reactions**

Reading: Hebden – page 125-133

PROBLEMS:
Practice Calculations

Calculations based on Chemical equations

Given moles, calculate moles

2. Mole-mole calculation
[http://nobel.scas.bcit.ca/wiki/index.php/Calculations_based_on_chemical_equations_-_mole-mole_calculation]

How many moles of oxygen gas is required to burn 3.60 moles of ethyl alcohol, C_2H_5OH?

Step 1: Identify the chemical equation involved

Step 1:

This is a combustion reaction involving a compound containing Carbon, Hydrogen and Oxygen.
The products of the reaction are carbon dioxide and water.

Step 2: Write the balanced chemical equation.

Step 2:

The balanced chemical equation is:

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$$

Calculations based on Chemical equations

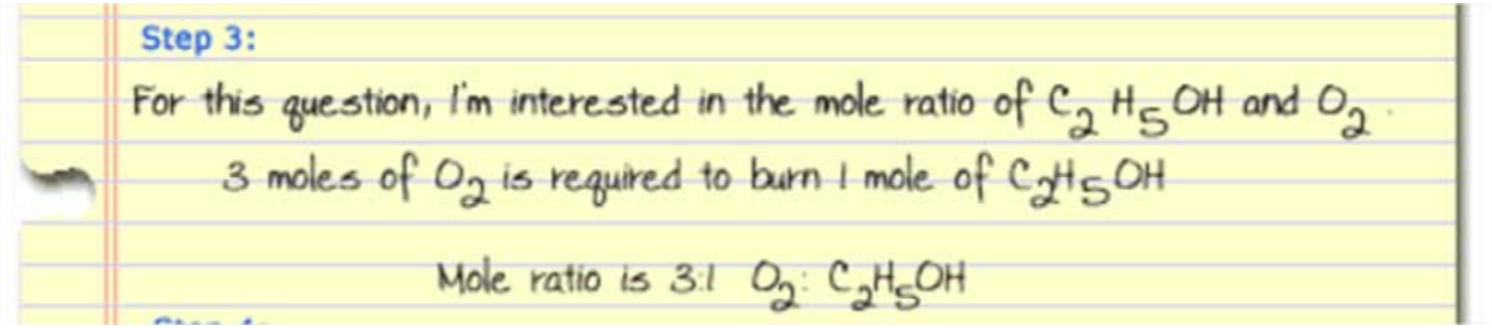
Given moles, calculate moles

2. Mole-mole calculation

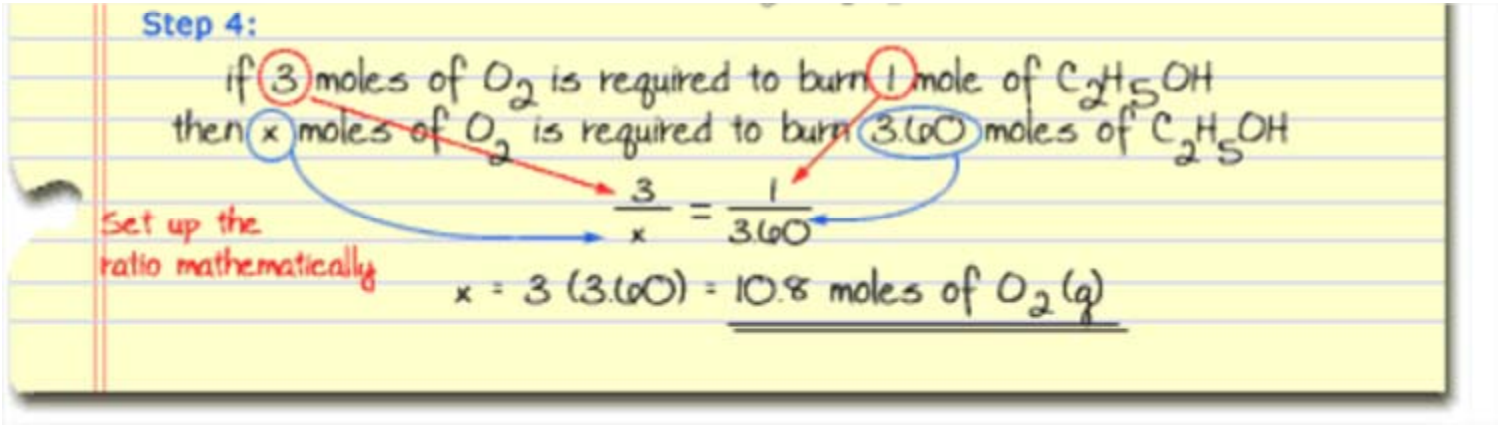
$$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l)$$

How many moles of oxygen gas is required to burn 3.60 moles of ethyl alcohol, C_2H_5OH?

Step 3: Determine the mole ratio of the substances that you are working with specifically between ethyl alcohol and oxygen.



Step 4: Calculate the number of moles of oxygen by making the ratio specifically for 3.60 moles of ethyl alcohol.



Calculations based on Chemical equations

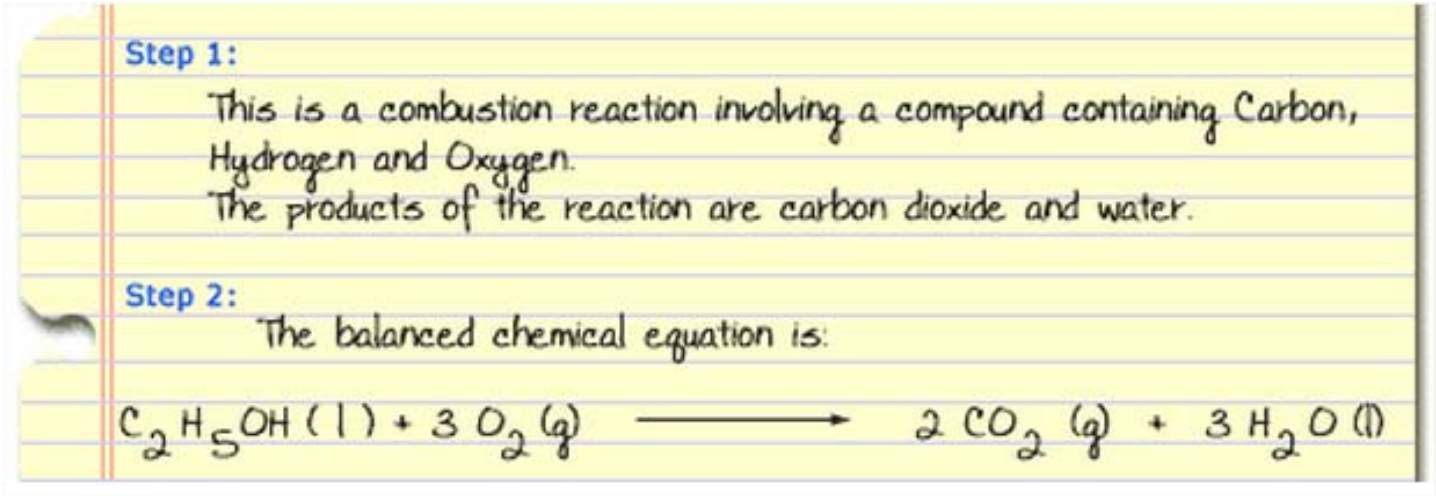
Given mass, calculate mass

3. Mass-mass calculation
[http://nobel.scas.bcit.ca/wiki/index.php/Calculations_based_on_chemical_equations_-_mass-mass_calculation]

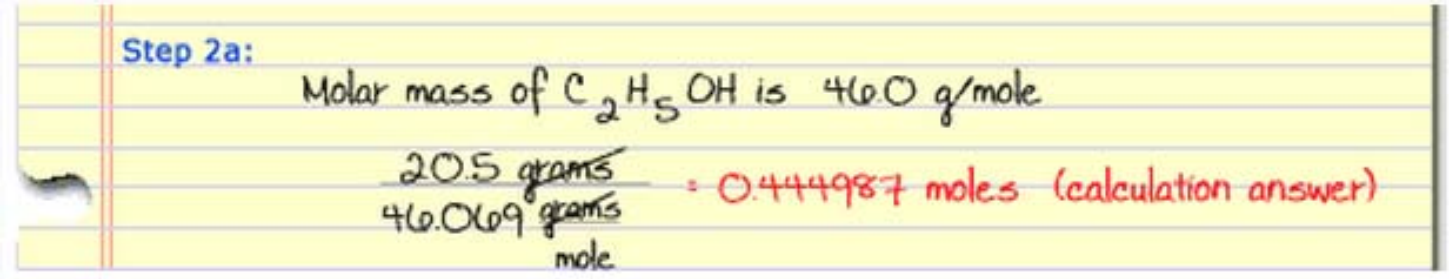
How many grams of oxygen gas is required to burn 20.5 grams of ethyl alcohol, C_2H_5OH?

Step 1: Identify the chemical equation involved: a combustion reaction.

Step 2: Write the balanced chemical equation.



Step 2a: Convert the mass of C_2H_5OH to moles of C_2H_5OH.



Calculations based on Chemical equations

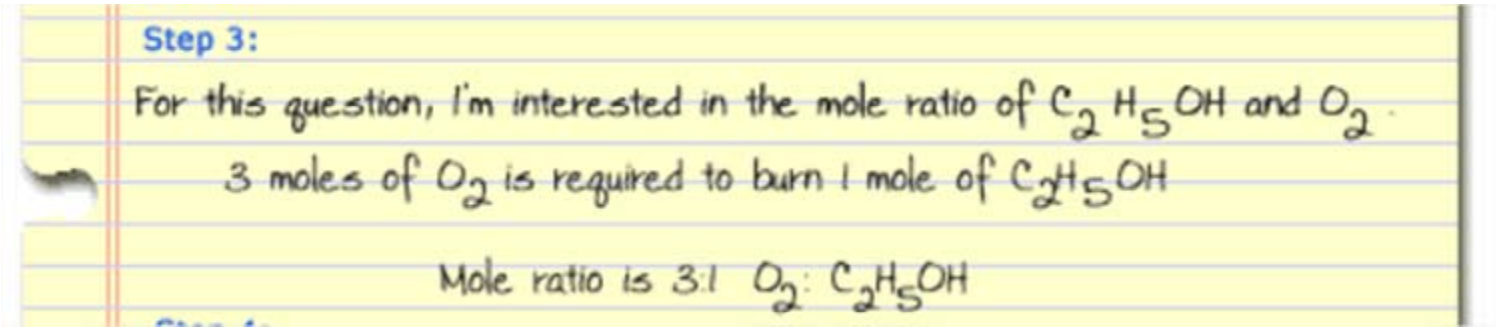
Given mass, calculate mass

3. Mass-mass calculation

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$$

How many grams of oxygen gas is required to burn 20.5 grams of ethyl alcohol, C_2H_5OH?

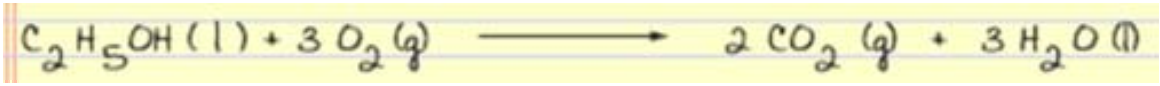
Step 3: Determine the mole ratio of the substances that you are working with specifically between ethyl alcohol and oxygen.



Calculations based on Chemical equations

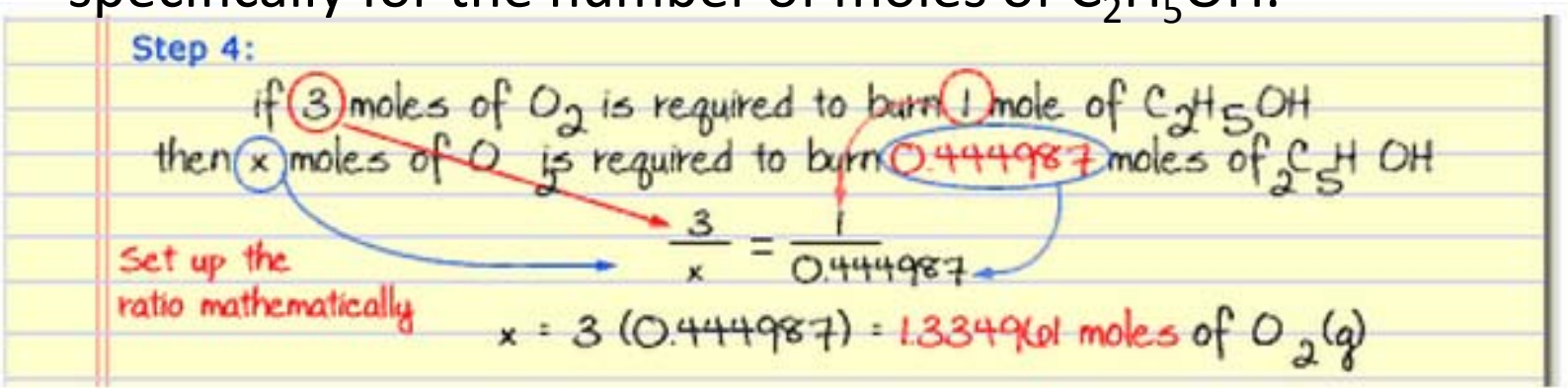
Given mass, calculate mass

3. Mass-mass calculation

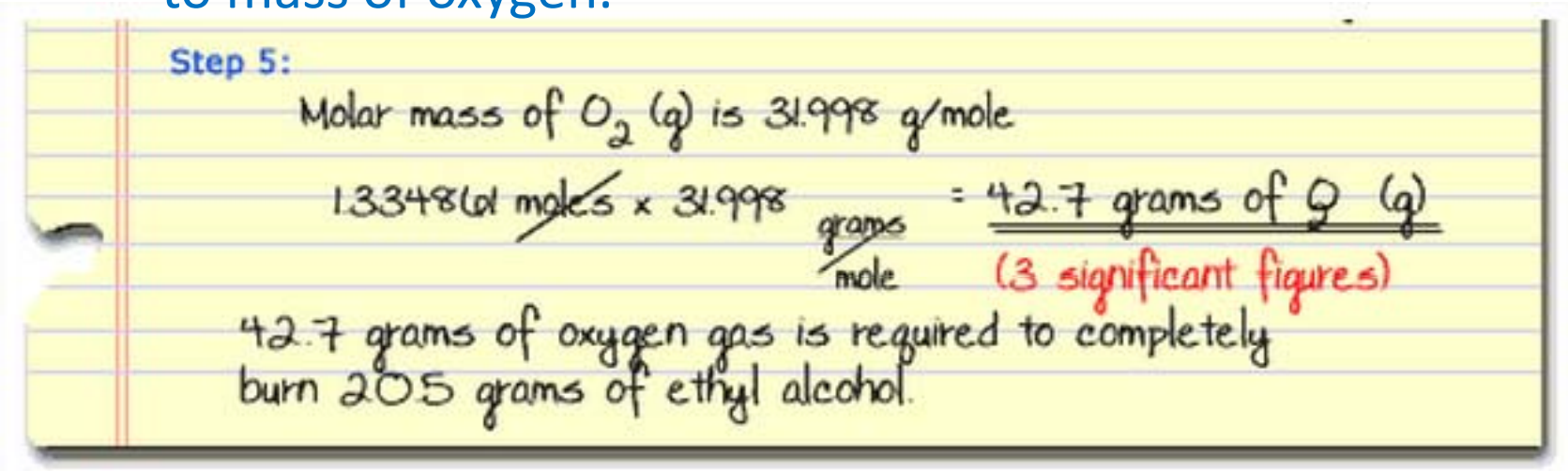


How many grams of oxygen gas is required to burn 20.5 grams of ethyl alcohol, C_2H_5OH?

Step 4: Calculate the number of moles of oxygen by making the ratio specifically for the number of moles of C_2H_5OH.



Step 5: Convert the number of moles of oxygen obtained in step 4 to mass of oxygen.



Calculations based on Chemical equations

Given mass, calculate mole

$$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l)$$

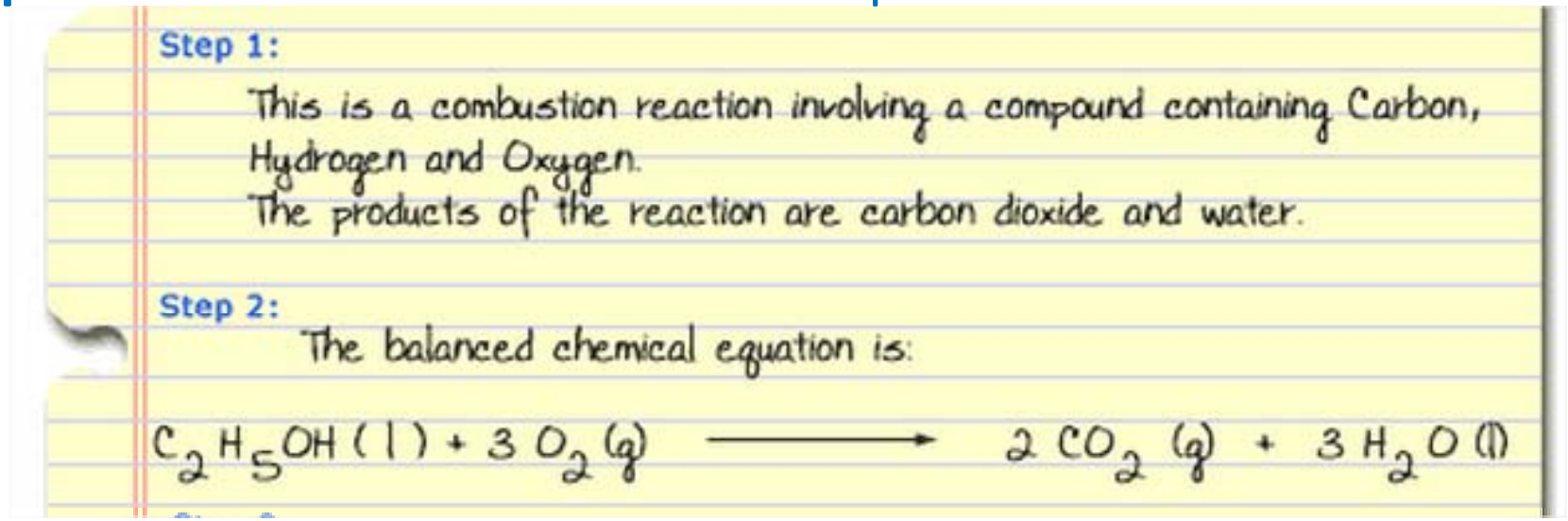
4. [Mass-mole calculation]

[http://nobel.scas.bcit.ca/wiki/index.php/Calculations_based_on_chemical_equations_-_mass-mole_calculation]

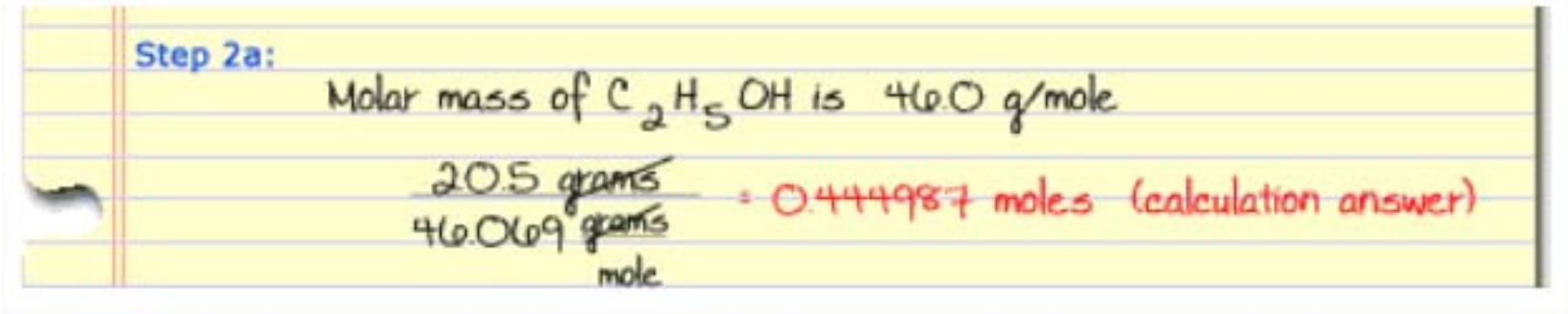
How many moles of CO_2 gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, is burned?

Step 1: Identify the chemical equation involved: a combustion reaction.

Step 2: Write the balanced chemical equation.



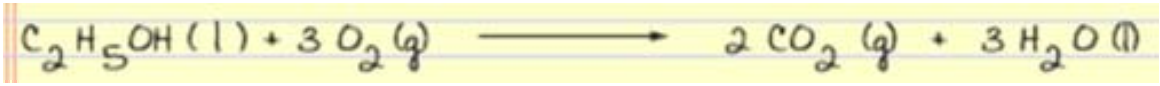
Step 2a: Convert the mass of C_2H_5OH to moles of C_2H_5OH.



Calculations based on Chemical equations

Given mass, calculate mole

4. Mass-mole calculation



How many moles of CO_2 gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, is burned?

Step 3: Determine the mole ratio of the substances that you are working with specifically between ethyl alcohol and oxygen.

Step 3: *Mole ratio of* $CO_2 : C_2H_5OH$ *is* 2:1.

Calculations based on Chemical equations

Given mass, calculate mole

4. Mass-mole calculation

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$$

How many moles of CO_2 gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, is burned?

Step 4: Calculate the number of moles of CO_2 by making the ratio specifically for the number of moles of C_2H_5OH from step 2a.

Step 4:

if 2 moles of CO_2 is produced for 1 mole of C_2H_5OH burned,
then x moles of CO_2 is produced for 0.444987 moles of C_2H_5OH burned

Set up the ratio mathematically

$$\frac{2}{x} = \frac{1}{0.444987}$$

$x = 2(0.444987) = 0.890$ moles of $CO_2(g)$

(3 significant figures)

0.890 moles of carbon dioxide is produced when 20.5 grams of ethyl alcohol is burned

Calculations based on Chemical equations

One reactant is in excess and the other is used up.

5. Limiting reagent calculation

[http://nobel.scas.bcit.ca/wiki/index.php/Limiting_Reactant_Calculations]

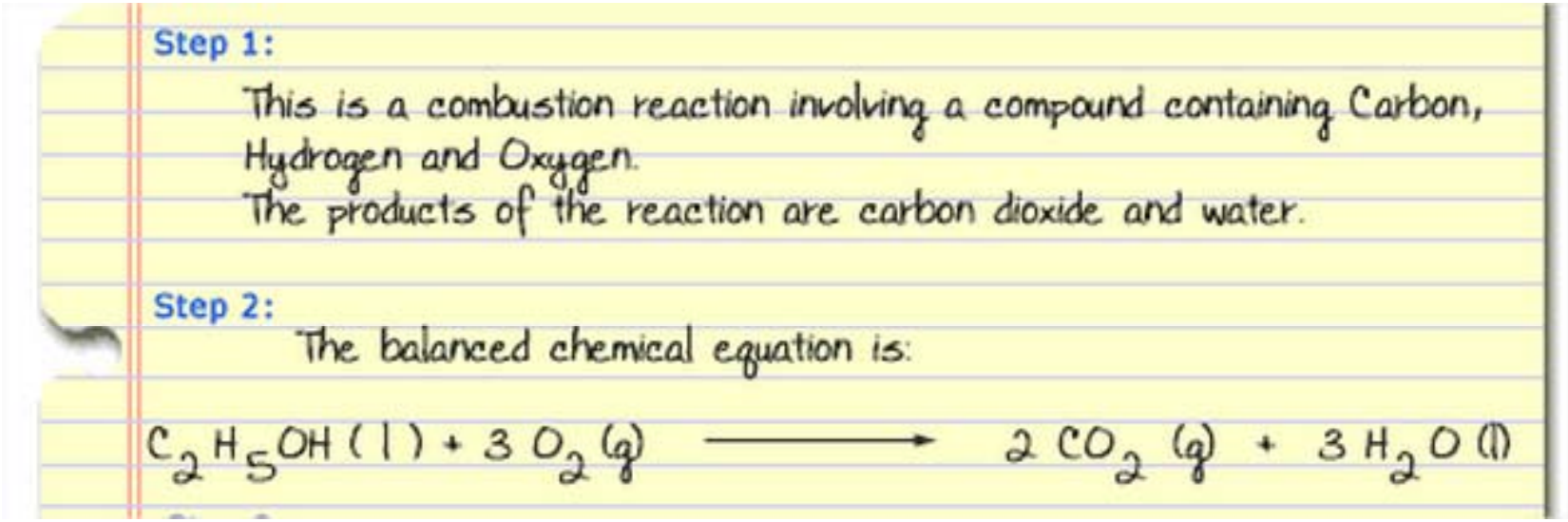
$$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l)$$

(a) How many grams of carbon dioxide gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, burns with 100.0 grams of oxygen, O_2?

(b) Identify the limiting reagent and how much of the other reactant is left over?

Step 1: Identify the chemical equation involved: a combustion reaction.

Step 2: Write the balanced chemical equation.



Step 1:

This is a combustion reaction involving a compound containing Carbon, Hydrogen and Oxygen.
The products of the reaction are carbon dioxide and water.

Step 2:

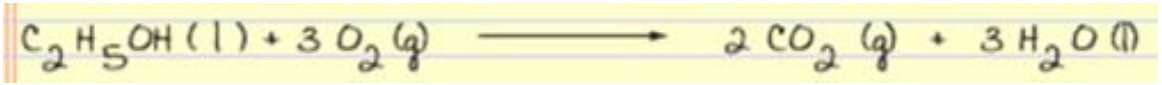
The balanced chemical equation is:

$$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l)$$

Calculations based on Chemical equations

One reactant is in excess and the other is used up.

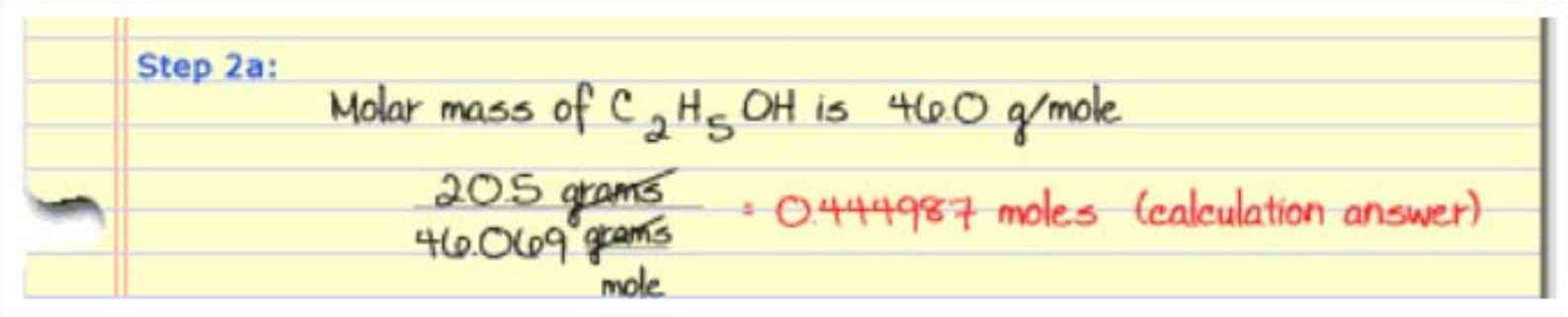
5. Limiting reagent calculation



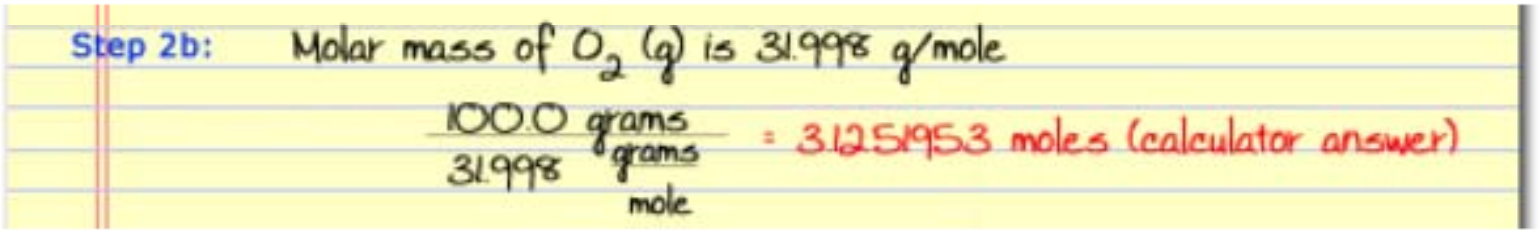
(a) How many grams of carbon dioxide gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, burns with 100.0 grams of oxygen, O_2?

(b) Identify the limiting reagent and how much of the other reactant is left over?

Step 2a: Convert the mass of C_2H_5OH to moles of C_2H_5OH.



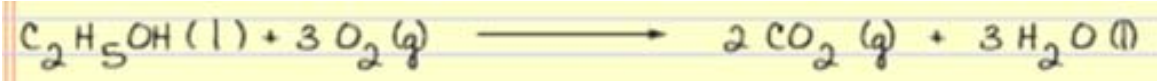
Step 2b: Convert the mass of O_2 to moles of O_2.



Calculations based on Chemical equations

One reactant is in excess and the other is used up.

5. Limiting reagent calculation



(a) How many grams of carbon dioxide gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, burns with 100.0 grams of oxygen, O_2?

(b) Identify the limiting reagent and how much of the other reactant is left over?

Step 3: Determine the mole ratio of the substances that you are working with.

Step 3: *Mole ratio of the substances that you are working with, specifically:*

- *between* C_2H_5OH *and* O_2 1:3
- *between* C_2H_5OH *and* CO_2 1:2
- *between* O_2 *and* CO_2 3:2

Calculations based on Chemical equations

One reactant is in excess and the other is used up.

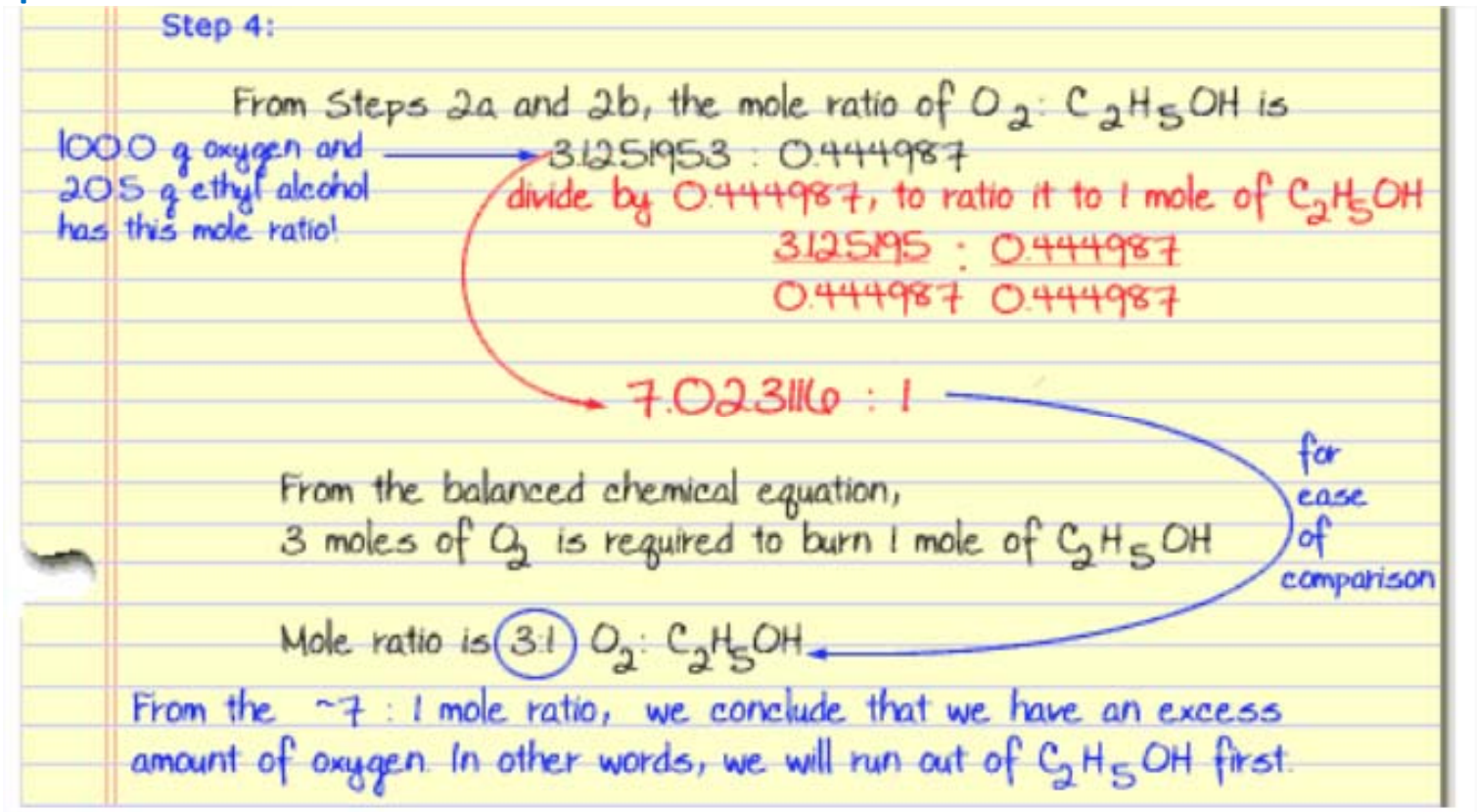
5. Limiting reagent calculation

$$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l)$$

(a) How many grams of carbon dioxide gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, burns with 100.0 grams of oxygen, O_2?

(b) Identify the limiting reagent and how much of the other reactant is left over?

Step 4: Determine which is present as the limiting reagent and which is present in excess.



Calculations based on Chemical equations

One reactant is in excess and the other is used up.

5. Limiting reagent calculation

$$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l)$$

(a) How many grams of carbon dioxide gas is produced when 20.5 grams of ethyl alcohol, C_2H_5OH, burns with 100.0 grams of oxygen, O_2?

(b) Identify the limiting reagent and how much of the other reactant is left over?

Step 5: Calculate the amount of reactant that is left over.

Step 5:

Recap from Step 4 - C_2H_5OH is the limiting reagent
O_2 is in excess

-20.5 grams ethyl alcohol is 0.444987 moles of ethyl alcohol (step 2a)
-100.0 g of oxygen is 3.1251953 moles of oxygen (step 2b)

The balanced chemical equation tells us that
the ratio of $O_2 : C_2H_5OH$ is 3 : 1

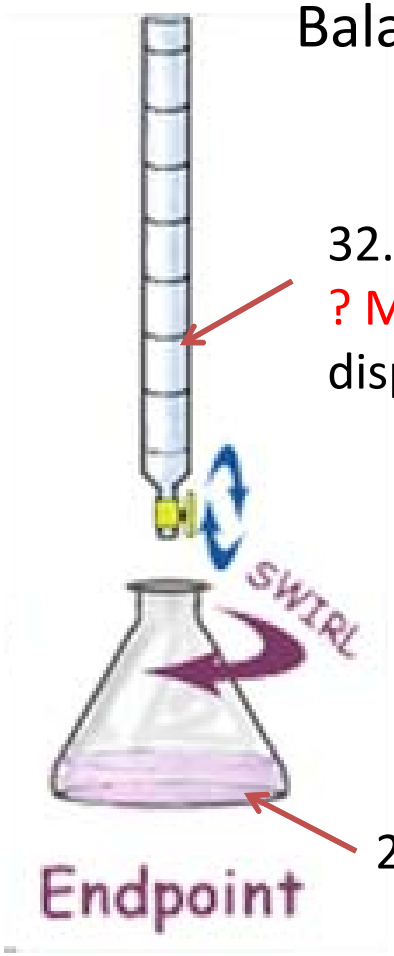
Therefore,
0.444987 x 3 = 1.33496 moles of oxygen was used up
to produce the CO_2

At the start of the reaction, we had 3.1251953 moles of oxygen (100.0 g)

What remains must be

3.1251953 moles - 1.33496 moles = 1.79 moles
(3 significant figures)

Q: A student performs a titration to determine the concentration of a LiOH solution. 20.00 mL of a 0.0820 M H_3PO_4 solution was used in the titration. The student observed that when 32.45 mL of the base is added, the phenolpthalein colour indicator turned pale pink. What is the concentration of the LiOH solution?



Balanced chemical reaction:

$$H_3PO_4\,(aq) + 3\,LiOH\,(aq) \rightarrow Li_3PO_4(aq) + 3H_2O\,(l)$$

32.45 mL
? M LiOH
dispensed

Mole ratio of H_3PO_4 : LiOH

$$\frac{1}{0.001640} = \frac{3}{x}$$

x = 0.004920 moles LiOH

Concentration of LiOH = $\dfrac{0.004920\ \text{moles}}{0.03245\text{L}}$ = **0.152 M**

20.00 mL of a 0.0820 M H_3PO_4 ➤ 0.02000 L x 0.0820 moles/L
= 0.001640 moles H_3PO_4

Q: 25.00 mL of a 0.243 M *acetic acid* solution is combined with 12.75 mL of a 0.250 M KOH solution.

(a) What are the products of the reaction?

(b) How many moles of each product are formed?

(c) Is the final solution acidic or basic?

(d) What volume of which solution is needed to neutralize the solution in (c)?

(a) This is a neutralization reaction. Products are KCH_3COO (aq) + H_2O (l)

$$CH_3COOH\ (aq) + KOH\ (aq) \rightarrow KCH_3COO\ (aq) + H_2O\ (l)$$

25.00 mL of a 0.243 M H_3PO_4

0.02500 L x 0.243 moles/L = 0.00608 moles CH_3COOH

12.75 mL of a 0.250 M KOH

0.01275 L x 0.250 moles/L = 0.00319 moles KOH

This is the limiting reagent.

(b) 0.00319 moles KCH_3COO

(b) 0.00319 moles H_2O

(c) Since acetic acid is in excess, the solution is acidic.

0.00608 – 0.00319 = 0.002888 moles CH_3COOH left.

0.002888 moles KOH is needed to neutralize the acid.

(d) $0.002888\ \text{mole} \cdot \dfrac{1\ \text{L}}{0.250\ \text{mole}} = 11.6\ \text{mL}$

Q: 25.00 mL of a 0.243 M *sulfuric acid* solution is combined with 12.75 mL of a 0.250 M KOH solution.

(a) What are the products of the reaction?

(b) How many moles of each product are formed?

(c) Is the final solution acidic or basic?

(d) What volume of which solution is needed to neutralize the solution in (c)?

(a) This is a neutralization reaction. Products are K_2SO_4 (aq) + H_2O (l)

$$H_2SO_4\,(aq) + 2\,KOH(aq) \rightarrow K_2SO_4\,(aq) + 2\,H_2O\,(l)$$

25.00 mL of a 0.243 M H_2SO_4

0.02500 L x 0.243 moles/L = 0.00608 moles H_2SO_4

12.75 mL of a 0.250 M KOH

0.01275 L x 0.250 moles/L = 0.00319 moles KOH

This is the limiting reagent.

(Note: only need 0.00158 moles H_2SO_4 to use it up)

0.00608 – 0.00158 = 0.00450 moles H_2SO_4 left.

(b) 0.00158 moles K_2SO_4

(b) 0.00319 moles H_2O

(c) Since sulfuric acid is in excess, the solution is acidic.

(d) $0.00900\ \text{mole} \cdot \dfrac{1\,\text{L}}{0.250\ \text{mole}} = 36.0\ \text{mL}$

0.00450 x 2 = 0.00900 moles KOH is needed to neutralize the acid.

Try some practice problems in Maple TA.

Use Dimensional Analysis in ALL your calculations!!