Theoretical and Percent Yield

Today's Tasks

Task 1: Introduction Quiz on Socrative: RAJASEKARAN

Task 2.1: Show work on paper and send me image of your work by email: Renuka.Rajasekaran@henry.k12.ga.us

Task 2.2: Show work on paper and send me image of your work by email: Renuka.Rajasekaran@henry.k12.ga.us

Task 3.1: Show work on paper and send me image of your work by email: Renuka.Rajasekaran@henry.k12.ga.us

Task 3.2: Show work on paper and send me image of your work by email: Renuka.Rajasekaran@henry.k12.ga.us

Task 4: End-of Lesson Quiz on Socrative: RAJASEKARAN1

Standard

SC3. Obtain, evaluate, and communicate information about how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.

SC3d. Use mathematics and computational thinking to identify and solve different types of reaction stoichiometry problems (i.e., mass to moles, mass to mass, moles to moles, and percent yield) using significant figures.

Learning Goals for Lesson 1

1. I can define "Yield"
2. I can distinguish between Theoretical Yield and Actual Yield
3. I can determine the Percent Yield from the given values of Actual Yield and Theoretical yield.
4. I can list the alternate names for Actual Yield.
5. I can determine Theoretical Yield from a Balanced Equation and given mass of a reactant.
6. I can determine Percent Yield from a Balanced Equation and given masses of a reactant and the corresponding product

Task 1: Read the following content and take a quiz on Socrative: ROOM: RAJASEKARAN (You need to peruse the Standard SC3e as well to take this quiz)

In a chemical manufacture process, the amount of products obtained is referred to as, "Yield."
"Yield" is a term used in agricultural production of crops. The amount of produce harvested is called "Yield."
The same term is used in chemical manufacturing processes as well for the amount of products harvested from a chemical reaction.
Yield can be of two types: Theoretical Yield and Actual Yield. Theoretical Yield is the Expected Yield, which is normally obtained by Calculations. Actual Yield is the yield, which one actually gets from the manufacture process.
As in agriculture, in chemical manufacturing processes, it is a convention to report Yield as "Percent Yield", which is given by the following equation:

Formula for Percent Yield

$$\text{Percent yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

Very often, Actual Yield is also referred to as Experimental Yield or Practical Yield.
IT should be remembered that "Percent Yield" applies to all products of a reaction, even though different products are formed in different masses. So, if two products are formed in reaction and one product has been determined to have a 75.6% means, the other product also has a percent yield of 75.6%
Why masses of different products differ for the same percent yield needs to be understood from the fact that different substances have different formula masses.

Example 1 shows a simple calculation for Percent Yield (Type 1 Problems in Percent Yield).

Example 1: In a particular experiment 10.0 g of sugar should be produced but only 0.664 g is produced. What is the percentage yield?

$$\% \text{ yield} = \frac{\text{Experimental yield}}{\text{theoretical yield}} \times 100$$

$$= \frac{0.664\ g}{10.0 g} \times 100$$

$$= 6.64\ \%$$

Task 2: Determination of Theoretical Yield

Percent Yield Problems in chemistry are little more detailed than Example 1. You are required to determine the Theoretical Yield yourself from the given data and then you need to proceed to the determination percent yield. Therefore, you are first required to master the Determination of Theoretical yield. You need the Balanced Chemical Equation, the Periodic Table and a calculator. Math involved is very simple.

Example 2: For the given balanced equation, if the reaction involved 20.7 grams of $CaCO_3$ what is the Theoretical Yield of CaO?

$1\ CaCO_3 \rightarrow 1\ CaO + 1\ CO_2$

Solution for Example 2:

Step 1: Calculate the Formula Mass (aka Molar Mass) of the two chemicals involved in the problem, namely, $CaCO_3$ and CaO.

Step 1.1: Formula Mass of $CaCO_3$
(1 x Avg. At. Mass of Ca) + (1 X Avg. At. Mass of C) + (3 x Avg. At. Mass of O) g
(1 x 40.078) + (1 X 12.011) + (3 x 15.999) g
= 100.086 g

Step 1.2: Formula Mass of CaO
(1 x Avg. At. Mass of Ca) + (1 X Avg. At. Mass of O)
(1 x 40.078) + (1 X 15.999) g
= 56.007 g

Step 2: Calculate theoretical yield of CaO using

1. **The Coefficients in the BALANCED equation,**
2. **Formula Masses of $CaCO_3$ and CaO,**
3. **The given mass of $CaCO_3$**

Solution

Theoretically, $1 CaCO_3$ gives 1 CaO
That is, 1 x 100.086 g of $CaCO_3$ gives 1 x 56.007 g of CaO
So, 20. 7 g of $CaCO_3$ will give how much of CaO in g?, let us set this as *x*
Math Process: Cross Multiplication and Division (treat this as a proportion problem)

$$x = \frac{20.7\ g \times 1 \times 56.007\ g}{1 \times 100.086\ g} = \frac{b}{a} = \frac{20.7\ g \times 56.007\ g}{100.086\ g} = \frac{c}{} = 11.583487201 = 11.6\ g \text{ (in correct sigfig)}$$

Answer: Theoretical Yield = 11.6 g

Since CO_2 is not questioned in the problem, you do not have to bother about CO_2

Sigfig

In this calculation, 20.7 is the number with least sigfigs (3 sigfigs). Therefore, your answer should be in three sigfigs.

This is simply a Proportion Problem

Ratios and Proportions

From the word problem, set up two equal ratios to form a proportion

$$a : b = c : d$$

Rewrite the ratios as fractions

$$\frac{a}{b} = \frac{c}{d}$$

In this problem,
a = 1 x 100.086
b = 1 x 56.007
c = 20.7
d = *x*

Cross Multiply

$$\frac{a}{b} \times \frac{c}{d}$$

$$ad = bc \quad \text{or } d = bc/a$$

Task 2 Continued: Your Turn: Independent Practice 2.1 (Two Steps; First Step has two Substeps): Follow Example 2 and Solve the Following Problem (2.1)

In the reaction represented by the folowing balanced equation, determine the theoretical yield of hydrogen, if 7.3 g of hydrochloric acid was used. For your quick reference, for one mole, the average atomic mass of H is 1.008 g; the average atomic mass of Cl is 35.453 g. $Zn + 2\ HCl(aq) \rightarrow ZnCl_2 + H_2(g)$

Solution for Independent Practice 2.1:

Step 1: Calculate the Formula Mass (aka Molar Mass) of the two chemicals involved in the problem, namely, HCl and H_2

Step 1.1: Formula Mass of HCl
(1 x Avg. At. Mass of H) + (1 X Avg. At. Mass of Cl) g
= g
= g

Step 1.1: Formula Mass of H_2
(2 x Avg. At. Mass of H)
= g
= g

Step 2: Calculate theoretical yield of H_2 using

1. **The Coefficients in the BALANCED equation,**
2. **Formula Masses of HCl and H_2 (these are the answers from Step 1.1 and 1.2 respectively)**
3. **The given mass of HCl**

Solution

Theoretically, 2 HCl gives 1 H_2

That is, 2 x …… g of HCl gives 1 x …… g of H_2

7.3 g of HCl will give how much of H_2 in g?, let us set this as *x*

Math Process: Cross Multiplication and Division

$$x = \frac{7.3\ g \times 1 \times \ldots\ldots\ g}{2 \times \ldots\ldots\ g} = = \frac{7.3\ g \times \ldots\ldots\ldots\ldots g}{\ldots\ldots\ldots\ldots\ g} = \ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ g \text{ (in correct sigfig)}$$

Answer: Theoretical Yield of H_2= ---------- g

Sigfig

In this calculation, 7.3 is the number with least sigfigs (2 sigfigs). Therefore, your answer should be in two sigfigs.

Task 2 Continued: Your Turn: Independent Practice 2.2 (Two Steps; First Step has two Substeps). Follow Example 2.

Phosphorus reacts with bromine to form phosphorus tribromide. If 35.0 grams of bromine was reacted, what is the theoretical yield? $2\ P_{(s)} + 3\ Br_{2\ (l)} \rightarrow 2\ PBr_{3(g)}$ .For your quick reference, for one mole, the average atomic mass of P is 30.974 g; the average atomic mass of Br is 79.904 g. **Show work on Paper and send me image of your work**. Renuka.Rajasekaran@henry.k12.ga.us

Solution for Independent Practice 2.2

Step 1: Calculate the Formula Mass (aka Molar Mass) of the two chemicals involved in the problem, namely, Br_2 and PBr_3

Step 1.1: Formula Mass of Br_2
(2 x Avg. At. Mass of Br)
= **g**
= **g**

Step 1.1: Formula Mass of PBr_3
(1x Avg. At. Mass of P) + (3 x avg. At. Mass of Br)
= **g**
= **g**

Step 2: Calculate theoretical yield of PBr_3 using

1. **The Coefficients in the BALANCED equation,**
2. **Formula Masses of Br_2 and PBr_3 (these are the answers from Step 1.1 and 1.2 respectively)**
3. **The given mass of Br_2**

Solution

Theoretically, 3 Br_2 gives 2 PBr_3

That is, 3 x …… g of Br_2 gives 2 x …… g of PBr_3

So, 35.0 g of Br_2will give how much of PBr_3 in g?, let us set this as *x*

Math Process: Cross Multiplication and Division

$$x = \frac{35.0\ g \times 2 \times \ldots\ldots\ g}{3 \times \ldots\ldots\ g} = = \frac{35.0\ g \times \ldots\ldots\ldots\ldots g}{\ldots\ldots\ldots\ldots\ g} = \ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ g \text{ (in correct sigfig)}$$

Answer: Theoretical Yield of H_2= ---------- g

SIgfig

In this calculation, 35.0 is the number with least sigfigs (3 sigfigs). Therefore, your answer should be in three sigfigs.

In problem 2.2, the Coefficients and formulas are different. That is the only difference. You need to slow down. If needed, please extra time.

Example 3 (Three Steps):Calculation of Percent Yield with in-built calculation of Theoretical Yield (Totally Three Steps – First Step has two substeps).

For the balanced equation shown below, if the reaction of 72.3 grams of CuS produces 93.2 grams of $CuCl_2$, what is the percent yield? For your quick reference, Average Atomic Mass of the required elements for one mole are: Cu = 63.546 g; S = 32.065 g; Cl = 35.450 g

$CuS_{(s)} + 2HCl_{(aq)} \rightarrow CuCl_{2(aq)} + H_2S_{(g)}$

Example 3 is a Combination of Example 2 and Example 1

Solution for Independent Practice 2.1:

Step 1: Calculate the Formula Mass (aka Molar Mass) of the two chemicals involved in the problem, namely, CuS and $CuCl_2$

Step 1.1: Formula Mass of CuS
(1 x Avg. At. Mass of Cu) + (1 X Avg. At. Mass of S) g
= (1 x 63.546) + (1 x 32.065) g
= 63.546 + 32.065 = 95.611 g

Step 1.1: Formula Mass of $CuCl_2$
(1 x Avg. At. Mass of Cu) + (2 x Avg. At. Mass of Cl)
= (1 x 63.546) + (2 x 35.450) g
= 63.546 + 70.90 = 134.456 g

Step 2: Calculate theoretical yield of $CuCl_2$ using
1. **The Coefficients in the BALANCED equation,**
2. **Formula Masses of CuS and $CuCl_2$ (these are the answers from Step 1.1 and 1.2 respectively)**
3. **The given mass of CuS, given in the problem**

Solution
Theoretically, 1 CuS gives 1 $CuCl_2$
That is, 1 x 95.611 g of CuS gives 1 x 134.456 g of $CuCl_2$
72.3 g of CuS will give how much of $CuCl_2$ in g?, let us set this as *x*
Math Process: Cross Multiplication and Division

$$x = \frac{72.3 \text{ g} \times 1 \times 134.456 \text{ g}}{1 \times 95.611 \text{ g}} = \frac{72.3 \text{ g} \times 134.456 \text{ g}}{95.611 \text{ g}} = 101.674167198 = \mathbf{102 \text{ g (in correct sigfig)}}$$

Answer: Theoretical Yield of H_2= 102 g

SIgfig
In this calculation, 72.3 is the number with least sigfigs (3 sigfigs). Therefore, your answer should be in three sigfigs.

Step 3: Calcultion of Percent Yield from
(1) Theoretical Yield of $CuCl_2$ (Answer from Step2) = 102 g
(2) Actaula yield of $CuCl_2$(given in the problem) = 93.2 g

$$\text{Percent Yield} = \frac{\text{Actual yield} \times 100}{\text{Theoretical Yield}} = \frac{93.2 \times 100}{102}$$

Step 2 Answer

Answer: Percent Yield = 91.372549019... 91.4 %

SIgfig
Report your answer in three sigfigs to give precise value for the percent yield.

Your Turn: Independent Practice 3.1: (Three Steps):Calculation of Percent Yield with in-built calculation of Theoretical Yield (Totally Three Steps – First Step has two substeps). **Show work on Paper and send me image of your work**. Renuka.Rajasekaran@henry.k12.ga.us

For the balanced equation shown below, if the reaction of 0.112 grams of H_2 produces 0.745 grams of H_2O, what is the percent yield of water?

$Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$

For your quick reference, Average Atomic Mass of the required elements for one mole are: H = 1.008 g; O = 15.999 g

Answer for Percent Yield = 74.5%

Example 3 is a Combination of Example 2 and Example 1

Solution for Independent Practice 2.1:

Step 1: Calculate the Formula Mass (aka Molar Mass) of the two chemicals involved in the problem, namely, H_2 and H_2O

Step 1.1: Formula Mass of H_2
(2 x Avg. At. Mass of H) g
= g
= g

Step 1.1: Formula Mass of H_2O
(2 x Avg. At. Mass of H) + (1 x Avg. At. Mass of O)
= g
= g

Step 2: Calculate theoretical yield of H_2O using
1. **The Coefficients in the BALANCED equation,**
2. **Formula Masses of (these are the answers from Step 1.1 and 1.2 respectively)**
3. **The given mass of H_2, given in the problem , 0.112 g**

Solution
Theoretically, 4 H_2 gives 4 H_2O
That is, 4 x …… g of H_2 gives 4 x …….. g of H_2O
0.112 g of H_2 will give how much of H_2O in g?, let us set this as *x*
Math Process: Cross Multiplication and Division

$$x = \frac{0.112 \text{ g} \times 4 \times \ldots\ldots \text{ g}}{4 \times \ldots\ldots \text{ g}} = \frac{0.112 \text{ g} \times \ldots\ldots \text{g}}{\ldots\ldots \text{ g}} = \ldots\ldots = \ldots\ldots \text{ g (in correct sigfig)}$$

Answer: Theoretical Yield of H_2O = ---------- g

SIgfig
In this calculation, 0.112 is the number with least sigfigs (3 sigfigs). Therefore, your answer should be in three sigfigs.

Step 3: Calcultion of Percent Yield from
(1) Theoretical Yield of H_2O (Answer from Step2)
(2) Actaula yield of H_2O (given in the problem) = 0.745 g

$$\text{Percent Yield} = \frac{\text{Actual yield} \times 100}{\text{Theoretical Yield}}$$

Step 2 Answer

Answer: Percent Yield = %

SIgfig
Report your answer in three sigfigs to give precise value for the percent yield.

Your Turn: Independent Practice: 3.2 (Three Steps):Calculation of Percent Yield with in-built calculation of Theoretical Yield

For the balanced equation shown below, if the reaction of 77.0 grams of $CaCN_2$ produces 27.1 grams of NH_3, what is the percent yield of NH_3? For your quick reference, Average Atomic Mass for the required elements are: Ca = 40.078 g; N = 14.007 g; C = 12.011 g: H = 1.008 g. **Show work on Paper and send me image of your work**. Renuka.Rajasekaran@henry.k12.ga.us

$CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$ Answer for Percent Yield = 83.0%

Example 3 is a Combination of Example 2 and Example 1

Solution for Independent Practice 2.1:

Step 1: Calculate the Formula Mass (aka Molar Mass) of the two chemicals involved in the problem, namely, $CaCN_2$ and NH_3

Step 1.1: Formula Mass of $CaCN_2$
(1 x Avg. At. Mass of Ca) + (1 X Avg. At. Mass of C) + (2 x Avg. At. Mass of N) g
= + + g
= g

Step 1.1: Formula Mass of NH_3
(1 x Avg. At. Mass of N) + (3 x Avg. At. Mass of H)
= + g
= g

Step 2: Calculate theoretical yield of H_2 using
1. **The Coefficients in the BALANCED equation,**
2. **Formula Masses of $CaCN_2$ and NH_3 (these are the answers from Step 1.1 and 1.2 respectively)**
3. **The given mass of $CaCN_2$ given in the problem = 77.0**

Solution
Theoretically, 1 $CaCN_2$ gives 3 NH_3
That is, 1 x …… g of $CaCN_2$ gives 2 x …… g of NH_3
77.0 g of $CaCN_2$ will give how much of NH_3 in g?, let us set this as *x*
Math Process: Cross Multiplication and Division

$$x = \frac{77.0 \text{ g} \times 2 \times \ldots\ldots \text{ g}}{1 \times \ldots\ldots \text{ g}} = \frac{77.0 \text{ g} \times \ldots\ldots \text{g}}{\ldots\ldots \text{ g}} = \ldots\ldots = \ldots\ldots \text{ g (in correct sigfig)}$$

Answer: Theoretical Yield of NH_3 ---------- g

SIgfig
In this calculation, 77.0 is the number with least sigfigs (3 sigfigs). Therefore, your answer should be in three sigfigs.

Step 3: Calcultion of Percent Yield from
(1) Theoretical Yield of NH_3 (Answer from Step2)
(2) Actaula yield of NH_3 (given in the problem) = 27.1 g

$$\text{Percent Yield} = \frac{\text{Actual yield} \times 100}{\text{Theoretical}} = \frac{27.1 \times 100}{32.7}$$

Step 2 Answer

SIgfig
Report your answer in three sigfigs to give precise value for the percent yield.

Review & Summarization

1. In Chemistry, “Yield” refers to the quantity of products formed.
2. Since no reaction is 100% complete, reactions never have 100% yield.
3. Therefore, we have two different types of Yields in Chemistry; they are: Theoretical yield and Actual Yield.
4. Actual Yield is also often referred to as Practical yield and Experimental Yield.
5. Yield of chemical reactions are to be reported as Percent Yield.
6. Percent Yield is given by the following formula
7. Percent Yield = (Actual Yield x 100)/Theoretical yield
8. Theoretical Yield is determined by calculations using the Balanced Chemical Equation for the reaction and the formula mass of the chemical substances involved. The formula mass of substances are multiplied by the respective coefficient in the balanced equation. A proportion based calculation is made to arrive at the Theoretical Yield.
9. Formula Mass of the substances is calculated by using the molecular formula and average atomic mass (from the Periodic Table.; Average Atomic Mass of each element (present in the given substance) is multiplied by its subscript in the formula and this product is calculated for all the elements in that formula. These products are then added up to get the formula mass in grams.
10. Percent Yield applies to all products in the reaction. Different products cannot have different percent yield even though they may have different masses.
11. Three types of mathematical problem solving are involved in percent yield calculations:

    Type 1: Both Theoretical Yield and Actual Yield are provided, and you are asked to determine the Percent Yield

    Type 2: Balanced Equation and mass of one reactant is provided and you are asked to determine the Theoretical Yield.

    Type 3: Balanced Equation and mass of a reactant and the corresponding mass of a product are given and you are asked to determine the Percent yield. Type 3 Problems are a combination of Type 2 and Type 1

12. There are additionally derived problems, which will be discussed in the next class

End of Lesson Quiz on Socrative: RAJASEKARAN 1

I am available for Google Meet during the following time periods:

Period 2: 9.15 to 9.45 am

Period 3 and 4: 10.50 to 11.20 am

Period 5: 1.10 to 1.40 pm

Periods 7 and 8: 2.45 to 3.15 PM

The code for the google meet signup will be posted on my website just before the google meet time begins. Please meet me live with your questions and doubts about the content and processes.