SI Chemistry - Full Discipline Demo

Limiting Reactants

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Nitrogen and hydrogen react to form ammonia:

$$\mathrm{N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)}$$

Identify the limiting reactant (hydrogen or nitrogen) in each of the following combinations of starting chemicals.

- 0.75 moles of nitrogen and 2.5 moles of hydrogen
- 1.0 mole of nitrogen and 1.0 mole of hydrogen
- 1.0 mole of nitrogen and 4.0 moles of hydrogen
- 10.0 grams of nitrogen and 10.0 grams of hydrogen

Limiting Reactant: Hydrogen	Limiting Reactant: Nitrogen
1	2

Correct answers:

1 1.0 mole of nitrogen and 1.0 mole of hydrogen

2 0.75 moles of nitrogen and 2.5 moles of hydrogen

1.0 mole of nitrogen and 4.0 moles of hydrogen

10.0 grams of nitrogen and 10.0 grams of hydrogen

Label each type of reaction.

- Combination
- Decomposition
- Double displacement
- Single displacement

$Al_2(SO_4)_3\,(aq) + 6NaOH\,(aq) \rightarrow 2Al(OH)_3\,(s) + 3Na_2SO_4\,(aq)$

1 [ ]

$2KClO_3\,(s) \rightarrow 2KCl\,(s) + 3O_2\,(g)$

2 [ ]

$4Fe\,(s) + 3O_2\,(g) \rightarrow 2Fe_2O_3\,(s)$

3 [ ]

$Cl_2\,(g) + 2NaI\,(aq) \rightarrow 2NaCl\,(aq) + I_2\,(aq)$

4 [ ]

Correct answers:

1 Double displacement 2 Decomposition 3 Combination

4 Single displacement

Move the terms to complete each statement.

Chemical equation | Law of conservation of mass | Limiting reactant | Reactant | Stoichiometry

A [1] describes a reaction that occurs between two or more chemical substances.

A chemical substance that participates and undergoes change in a chemical reaction is called a [2].

[3] can be used to determine how much of each reactant is needed to produce a specific amount of each product.

The reactant that is consumed first is referred to as the [4].

The [5] states that the total mass, in a closed system, does not change as the result of reactions between its parts.

Correct answers:

1 Chemical equation 2 Reactant 3 Stoichiometry

4 Limiting reactant 5 Law of conservation of mass

Exploration

The substances that interact in a reaction are called reactants, while the substances produced from the reaction are called products.

- True ✔
- False

Typesetting math: 100%

The proportion of reactants to products can be calculated using a balanced chemical equation and stoichiometry.

- [x] True ✔
- [ ] False

A _____ reaction occurs when an uncombined element displaces an element in a compound.

- [ ] decomposition
- [ ] combination
- [x] single displacement ✔
- [ ] double displacement

In a chemical reaction, the reactant that is consumed first is referred to as the _____.

- [ ] stoichiometry
- [ ] smaller reactant
- [x] limiting reactant ✔
- [ ] balanced equation
- [ ] limiting product

In the chemical equation $2\mathrm{Ca} + \mathrm{O}_2 \rightarrow 2\mathrm{CaO}$, if calcium is the limiting reactant, then _____ will be in excess.

- [ ] Ca
- [x] O_2 ✔
- [ ] CaO
- [ ] no substances

The law of conservation of mass states that _____.

- the total mass, in an open system, does not change as the result of reactions between its parts
- the total mass, in a closed system, does not change as the result of reactions between its parts ✔
- particles at rest tend to stay at rest
- the total energy of an isolated system cannot change

Exercise 1

From your calculations, which reaction experiment had closest to stoichiometric quantities? How many moles of $NaHCO_3$ and $HC_2H_3O_2$ were present in this reaction?

Reaction 3 had the closest stoichiometric quantities. There were 0.0042 mol of $NaHCO_3$ and 0.0042 mol of $HC_2H_3O_2$.

The chemical reaction you investigated is a two-step reaction. What type of reaction occurs in each step? How did you determine your answer?

Step 1 of the reaction is a double displacement reaction and Step 2 is a decomposition reaction. Each student should explain how they determined their answer.

As the reaction was theoretically performed in a closed system, there should be no change in mass before and after the reaction. What are possible sources of error in your experiment reactions?

The only reaction that validated the law of conservation of mass was reaction #1, where there was not a mass difference in the closed system between the total mass before the reaction and the reaction. Once the reactions commenced, the bubbling in the test tubes

continued until it ceased and a mass recording was taken. For the reactions in test tubes #3 and #4, the bubbling continued for over one hour. In reaction #3, the 1:1 stoichiometry showed that all the $NaHCO_3$ reacted with the 5% $HC_2H_3O_2$ to produce CO_2 (g). Possible sources of error include: $NaHCO_3$ getting trapped between the latex material of the balloon and the test tube exterior and the loss of CO_2 (g) to the environment via either a hole in the balloon and/or a non-tight seal between the mouth of the balloon and the test tube glass.

What is the relationship between the limiting reactant and theoretical yield of CO_2?

The limiting reactant dictates the theoretical yield of the product, CO_2 (g). As was observed in a direct comparison between balloon #3, which was a 1:1 stoichiometrically correct ratio of $NaHCO_3$ to $HC_2H_3O_2$, and balloon #4, which contained an excess of $NaHCO_3$ (i.e., 0.15 g excess reagent), the reactions resulted in balloons of almost identical size. The reaction only proceeds until the limiting reagent is consumed. In the case of balloon #4, excess $NaHCO_3$ was left on the bottom of the test tube at the conclusion of the reaction.

After the reactions occurred, did the largest balloon size match the largest theoretical yield you calculated in Data Table 4? Use your experimental results to explain your answer. If not, what sources of error do you think caused the discrepancy?

The answer to the first part of the question will be different for each student, depending on how well they were able to complete the calculations. Possible sources of error include human error in measuring and the $NaHCO_3$ not completely leaving the balloon to react with the $HC_2H_3O_2$. The largest balloon sizes were seen for reaction #3 and reaction #4. These reactions had identical theoretical yields for CO_2 (g). In reaction #3, the stoichiometrically correct ratio of $NaHCO_3$ to $HC_2H_3O_2$ required 0.35 g $NaHCO_3$ for 5 mL of 5% $HC_2H_3O_2$. In reaction #4, there was an excess of $NaHCO_3$. As the $HC_2H_3O_2$ is the limiting reactant, this reaction stopped once all the $HC_2H_3O_2$ had reacted with the $NaHCO_3$. The inflated balloon sizes for reaction #3 and reaction #4 were very similar as predicted by the calculations.

Data Table 1: Conservation of Mass – Initial Mass
(SAMPLE ANSWER BELOW)

Reaction #	Mass of test tube and 5.0% $HC_2H_3O_2$ (g) (A)	Mass of $NaHCO_3$ (g) (B)	Mass of balloon and $NaHCO_3$ (g) (C)	Total mass before reaction (g) (D = A + C)
1	11.23	0.10	1.37	11.60
Typesetting math: 100%		0.20	1.39	11.50

3	10.14	0.35	1.59	11.73
4	10.49	0.50	1.80	12.29

Data Table 2: Moles of HC2H3O2
(SAMPLE ANSWER BELOW)

Reaction #	Volume of 5.0% Vinegar (mL)	Mass of $HC_2H_3O_2$ (g)	Moles of $HC_2H_3O_2$
1	5.0	0.25	0.0042
2	5.0	0.25	0.0042
3	5.0	0.25	0.0042
4	5.0	0.25	0.0042

Data Table 3: Moles of NaHCO3
(SAMPLE ANSWER BELOW)

Reaction #	Mass of $NaHCO_3$ (g)	Moles of $NaHCO_3$
1	0.10	0.0012
2	0.20	0.0024
3	0.35	0.0042
4	0.50	0.0060

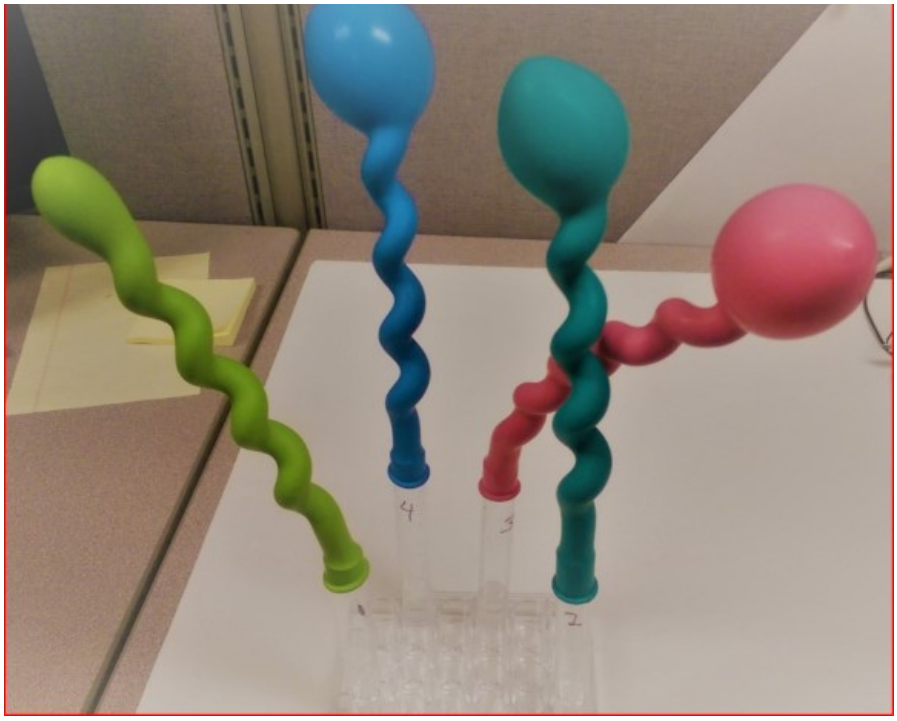
Data Table 4: Theoretical Yield of CO2
(SAMPLE ANSWER BELOW)

Reaction #	Limiting Reactant	Theoretical yield of CO_2 (moles)	Theoretical yield of CO_2 (g)
1	$NaHCO_3$	0.0012	0.052
2	$NaHCO_3$	0.0024	0.11
3	$NaHCO_3 = HC_2H_3O_2$	0.0042	0.18
4	$HC_2H_3O_2$	0.0042	0.18

Panel 1: Hypothesis
(SAMPLE ANSWER BELOW)

Students should hypothesize that balloons 3 and 4 will be the largest and of equal size in support of the calculations recorded in Data Table 3.

Photo 1: Reaction Results
(SAMPLE ANSWER BELOW)



Data Table 5: Conservation of Mass

(SAMPLE ANSWER BELOW)

Reaction #	Total Mass after Reaction (g) (E)	Mass Difference (g) (F = D - E)
1	11.60	0

2	11.43	0.07
3	11.61	0.12
4	12.00	0.29

Competency Review

In the chemical equation $4\mathrm{Fe} + 3\mathrm{O}_2 \rightarrow 2\mathrm{Fe}_2\mathrm{O}_3$, 4Fe is considered a _____.

- reactant ✔
- product
- compound

Stoichiometry can be applied to a chemical equation to calculate _____.

- the half-life of an element
- significant digits based on SI units
- activation energy in relation to chemical reactivity
- the proportion of reactants and products ✔

When chlorine reacts with sodium iodide to form sodium chloride and iodine, a _____ reaction takes place.

- combination
- decomposition
- single displacement ✔
- double displacement

Typesetting math: 100%

Consider a closed system in which aluminum sulfate and sodium hydroxide react to form aluminum hydroxide and sodium sulfate. If aluminum sulfate is the limiting reactant, what other information can be concluded about the substances?

- the reaction rate will decrease
- the sodium hydroxide will be found in excess ✔
- the reverse reaction will be favored
- a single displacement reaction will proceed

The law of conservation of mass states that the total mass, in a closed system, does not change as the result of reactions between its parts.

- True ✔
- False

The law of conservation of mass states that the total mass in a closed chemical system does not change. In a student experiment, initial mass might differ from final mass due to experimental error.

- True ✔
- False

$$\mathrm{NaHCO_3(s)} + \mathrm{HC_2H_3O_2(aq)} \rightarrow \mathrm{C_2H_3O_2Na(aq)} + \mathrm{H_2CO_3(aq)}$$
$$\mathrm{H_2CO_3(aq)} \rightarrow \mathrm{H_2O(l)} + \mathrm{CO_2(g)}$$

If 0.00416 mols of $HC_2H_3O_2$ are reacted with 0.00595 mols of $NaHCO_3$, _____ is/are considered a limiting reactant.

- $HC_2H_3O_2$ and $NaHCO_3$
- $NaHCO_3$
- $HC_2H_3O_2$ ✔
- the products
- no chemicals

Percent yield can be calculated by dividing actual yield by theoretical yield and multiplying by 100.

- [x] True
- [ ] False

Extension Questions

$2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$

a. Determine the volume (mL) of 15.0 M sulfuric acid needed to react with 45.0 g of aluminum to produce aluminum sulfate.

b. Determine the % yield if 112 g of aluminum sulfate is produced under the above conditions.

(SAMPLE ANSWER BELOW)

a. Molar masses: Al = 26.98g and $Al_2(SO_4)_3$ = 341.96g
45.0g x (1mol Al / 26.98 g) x (3mol H_2SO_4 / 2mol Al) x (1L H_2SO_4 / 15.0 mol) x (1000mL / L) = 167mL H_2SO_4

45.0g x (1mol Al / 26.98 g) x (1 mol $Al_2(SO_4)_3$ / 2 mol Al) x (341 g $Al_2(SO_4)_3$ / 1 mol $Al_2(SO_4)_3$) = 285g $Al_2(SO_4)_3$

b. Percent Yield = 112g/285g x 100% = 39.3%