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Honors Chemistry
Stoichiometry experimental design

Abstract

In the stoichiometry lab, scientists designed an experiment to test the amount of CO_2 produced from a baking soda and vinegar reaction. The following equation represents the reactants and products of the reaction: $C_2H_40_2 + NaHCO_3$ ---> $NaC_2H_3O_2$ + H2O + CO_2
Scientists used stoichiometry to find the limiting reactant, which was then used to find the anticipated amount of CO_2 produced. The experiment yielded results very similar to those that were anticipated.

Introduction and purpose

Stoichiometry is the mathematical examination of chemical reactions. It can be used before and after experiments to determine limiting reactants as well as the amount of product produced. In this experiment, scientists use stoichiometry to determine how much Carbon Dioxide (CO_2) can be produced based on the given reactants: a combination of 34 g of vinegar (1.7 g acetic acid, $C_2H_40_2$) and 10 g of baking soda ($NaHCO_3$).

Hypothesis

(For full stoichiometry calculations, see **figure 1**).

The first step in stoichiometry is balancing an equation. From there, one can use dimensional analysis to find the amount of each reactant *present* (in moles). Then, one uses mole ratios to solve for the amount of each reactant *needed*. From the results, a "have" versus "need" chart can be created (**figure 2,** below).

Substance	Have	Need
$C_2H_4O_2$	0.028305971 moles	0.119037699 moles
$NaHCO_3$	0.119037699 moles	0.028305971 moles

Based on the table, vinegar is the limiting reactant. The amount the scientist has of vinegar is then multiplied by the molar mass of CO_2. Therefore, the amount of CO_2 to be released from 10 g of $NaHCO_3$ and 1.7 g of $C_2H_40_2$ is 1.24 g.

Procedure

1. Separately measure out 10 g of baking soda and 34 grams of vinegar using an electronic balance. Add the masses and record the sum in the data table.
2. Slowly stir to add baking soda into a beaker of vinegar.
3. Measure and record new mass after reaction.
4. Calculate the difference between original and new mass; this represents escaped CO_2.
5. Record amount of escaped CO_2 in data table.
6. Repeat three times.

Data

The following data table shows the amount of CO_2 produced in relation to the amount predicted through stoichiometry.

Trial #	Theoretical yield	Mass of reactants before reaction	Mass of reactants after reaction	Amount of CO_2 produced	% yield
1	1.24 g	44 g	42.61 g	1.39 g	112.1%
2	1.24 g	44 g	42.75 g	1.25 g	100.8%
3	1.24 g	44 g	42.72 g	1.28 g	103.2%

Analysis/Results

All data points fell within 0.15 g of the theoretical yield with no significant outliers. The average amount of CO_2 produced was 1.31 grams. The average percent yield was 105.4%. The most accurate trial, trial #2, produced 1.25 g of CO_2 with 100.8% yield.

Conclusion

This reaction yielded, on average, 1.31 grams of CO_2. Because the procedure was followed closely, the produced amount of CO_2 was very similar to that which was theorized through stoichiometry. In all three trials, only slightly more CO_2 than predicted was produced. This slight difference could be due to human error: using slightly too much of either reactant, stirring more or less than needed. Overall, the results were both accurate and precise and were supported by the stoichiometry.

Figure 1: Stoichiometric calculations

Step 1: Determine the amount of each reactant *present* in moles

$$1.7\text{ g } C_2H_40_2 \times \frac{1\text{ mol } C_2H_40_2}{60.058\text{ g } C_2H_40_2} = 0.028305971\text{ mol } C_2H_40_2$$

$$10\text{ g } NaHCO_3 \times \frac{1\text{ mol NaHCO}}{84.007\text{ g } NaHCO_3} = 0.119037699\text{ mol } NaHCO_3$$

Step 2: Determine the amount of each reactant *needed* in moles

$$0.028305971\text{ mol } C_2H_40_2 \times \frac{1\text{ mol } NaHCO_3}{1\text{ mol } C_2H_40_2} = 0.028305971\text{ mol } NaHCO_3$$

$$0.119037699\text{ mol } NaHCO_3 \times \frac{1\text{ mol } C_2H_40_2}{1\text{ mol } NaHCO_3} = 0.119037699\text{ mol } C_2H_40_2$$

Step 3: Create a "have" versus "need" chart to find limiting reactant. (See **figure 2**)

Step 4: Using a mole ratio, find the amount of moles of CO_2.

$$0.028305971\text{ mol } C_2H_40_2 \times \frac{1\text{ mol CO2}}{1\text{ mol C2H4O2}} = 0.028305971\text{ mol } CO_2$$

Step 5: Convert this amount to grams. This is the anticipated amount of CO_2 to be produced.

$$0.028305971\text{ mol } CO_2 \times \frac{44.01\text{ g } CO_2}{1\text{ mol } CO_2} = 1.244896561\text{ g } CO_2$$