Lab Investigation 5 - What is the optimum mole ratio for a reaction?

AN INVESTIGATION OF MOLE RATIOS AND LIMITING REACTANTS

Guiding Question

What is the optimum mole ratio for the formation of CO_2 from the reaction of sodium bicarbonate and acetic acid?

INTRODUCTION

You have already learned how to balance chemical equations in terms of molecules, for example see the following equations.

1 Unbalanced:

$$C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l) \tag{1}$$

2 Balanced:

$$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l) \tag{2}$$

This equation can be interpreted as 1 molecule of C_3H_8 reacts with 5 molecules of O_2 to produce 3 molecules of CO_2 and 4 molecules of H_2O. This information can also be interpreted in terms of moles (of molecules).

$$\text{1 mole of } C_3H_8 \text{ reacts with 5 moles of } O_2 \text{ to produce 3 moles of } CO_2 \text{ and 4 mols of } H_2O \tag{3}$$

Why is this useful? With a balanced equation we can predict the moles of products that a given amount of reactants (in moles) will produce. When moles are used, we are then able to count the number of molecules produced by weighing (in grams). Predicting the amount of product formed or determining the amount of reactants needed for a reaction to occur is called stoichiometry.

Most stoichiometry calculations are performed using exact mole ratios of reactants and products. In real life, however, many commercial processes for preparing compounds are carried out using an excess amount of one reactant (and thus a limiting amount of the other). For example, if you mix 2.5 moles of O_2 with 1 mole of C_3H_8, 3 moles of CO_2 will not be produced because there is not enough O_2 added to 'use up' all of the C_3H_8. Once the O_2 is consumed, no more products can be formed, even though some C_3H_8 remains. In this situation, because the amount of O_2 limits the amount of product that can be formed, it is called the *limiting reactant* or *limiting reagent.*

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Therefore, if two reactants are not mixed in the correct mole ratio, the reaction will not go to completion and you will have less product produced and one or more left over reagents.

THE PROBLEM

When bicarbonate is mixed with acid, it breaks down into CO_2 and H_2O. Your task is to design and carry out an investigation to determine the optimum mole ratio for the formation of CO_2 by mixing various amounts of sodium bicarbonate and acetic acid. By comparing the amount of carbon dioxide generated when varying amounts of sodium bicarbonate react with a given amount of acetic acid, you should be able to determine the optimum mole ratio of sodium bicarbonate and acetic acid and be able to identify the limiting reactant in the other reactions.

MATERIALS AVAILABLE FOR USE

1.00 M Acetic Acid ($HC_2H_3O_2$)

Sodium Bicarbonate ($NaHCO_3$)

Graduated cylinders (1000 mL & 25 mL)

Plastic tray

Electronic balance

Beaker (400 mL)

Side-arm flask w/ tubing

Ring Stands/Rings

Eye droppers

SAFETY PRECAUTIONS

CAUTION: Handle acetic acid with care.

CAUTION: Wear goggles at all times, as pressure is built up in this reaction.

GETTING STARTED

You will need to collect gas by water displacement in order to measure the amount of CO_2 produced after the mixing of acetic acid and sodium bicarbonate in different molar ratios. Once you have determined the amount of sodium bicarbonate you will need to use in each reaction, conduct your experiments. Be sure to keep in mind the goals of the investigation.

1 Determine the optimum mole ratio of sodium bicarbonate and acetic acid.

2 Write the balanced equation based on your data.

3 Identify the limiting reactant in the each of the reactions.

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NOTE: It may be helpful to prepare a graph of mL of CO_2 vs. moles of $NaHCO_3$.

INTERACTIVE POSTER SESSION

Once your group has completed your work, prepare a whiteboard that you can use to share and justify your ideas. See the handout provided for details on this process.

REPORT

Once you have completed your research, you will need to prepare an ***investigation report*** that consists of three sections. Your report should answer these questions in 2 pages or less. This report must be typed and any diagrams, figures, or tables should be embedded into the document. Generally, you need one page for the first two sections and the second page for third section.

Section 1: What concept were you investigating? Relate this concept to the guiding question. Discuss limiting reagents and mole ratios?

Section 2: How did you go about your work and why? This is NOT the details of your procedure, but discussion of the processes. For example, describe the method for collecting gas and why this was necessary to answer the guiding question.

Section 3: What is your argument? You should include the mole and mass calculations table with mL of CO_2 added for each reaction. Discuss the validity and reliability of your data. Make clear your reasoning from mL of CO_2 to mole ratio. This is where you not only present your data, but **use** the values you obtain as evidence in your reasoning.

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