limiting and excess reactants pogil

Understanding Limiting and Excess Reactants: A Comprehensive POGIL Guide

limiting and excess reactants pogil principles are fundamental to stoichiometry, the quantitative study of chemical reactions. Mastering these concepts allows chemists to predict the yield of a reaction and understand the efficiency of a process. This article delves into the core ideas behind identifying and calculating limiting and excess reactants, exploring how these concepts impact chemical synthesis and analysis. We will cover the definition of each, methods for identification, calculations involved, and practical implications, providing a thorough understanding for students and professionals alike. The journey through limiting and excess reactants will equip you with essential skills for comprehending chemical transformations.

- Practice Problems and Strategies

Introduction to Limiting and Excess Reactants

The concept of limiting and excess reactants is central to understanding the outcomes of chemical reactions. When reactants are combined in a chemical process, they rarely combine in perfect stoichiometric ratios. This imbalance leads to one reactant being completely consumed before the others, thereby dictating the maximum amount of product that can be formed. Identifying this crucial reactant, known as the limiting reactant, is paramount for accurate prediction and control in chemistry. Conversely, reactants that are not fully used up are termed excess reactants. This section will lay the groundwork for comprehending these vital stoichiometric concepts and their significance in chemical reactions.

Defining Limiting Reactant

The limiting reactant, often referred to as the limiting reagent, is the reactant in a chemical reaction that is entirely consumed first. Once this reactant is exhausted, the reaction stops, and no more product can be formed, regardless of how much of the other reactants are still present. Think of it like baking cookies: if a recipe calls for 2 cups of flour and you only have 1 cup, the flour will be your limiting ingredient, determining how many cookies you can make, even if you have plenty of sugar and eggs. In chemical terms, the limiting reactant dictates the theoretical yield of the product.

Defining Excess Reactant

In contrast to the limiting reactant, the excess reactant, or excess reagent, is any reactant present in an amount greater than that required to react completely with the limiting reactant. These reactants will have some amount remaining after the reaction has ceased because the limiting reactant has been fully consumed. In our cookie baking analogy, the sugar and eggs would be the excess ingredients if the flour was the limiting one. The amount of excess reactant remaining can be calculated and is often a measure of the efficiency of a chemical process or the presence of unreacted starting materials.

The Importance of Identifying Limiting and Excess Reactants

Understanding which reactant is limiting and which is in excess is crucial for several reasons in chemistry. Firstly, it allows for the prediction of the maximum possible amount of product that can be synthesized, known as the theoretical yield. This is vital for planning experiments, optimizing reaction conditions, and determining the efficiency of a synthesis. Secondly, it helps in understanding the composition of the reaction mixture after completion, as the presence of unreacted excess reactants might need to be accounted for in subsequent steps or analyses. Finally, in industrial settings, identifying excess reactants can help in cost-effectiveness by ensuring that expensive reagents are not wasted and that reactants are utilized as efficiently as possible. Accurately determining limiting and excess reactants prevents wasted materials and ensures reproducible results in both laboratory and industrial applications.

Methods for Determining Limiting Reactants

There are several reliable methods to identify the limiting reactant in a chemical reaction. The most common approach involves converting the given masses of reactants into moles. Once the moles are determined, the mole ratios from the balanced chemical equation are used to compare how much of each reactant is available relative to the stoichiometric requirements. A systematic comparison based on these mole ratios will reveal which reactant will be completely consumed first.

Stoichiometric Calculations: The Cornerstone

At the heart of determining limiting and excess reactants lies stoichiometry. Stoichiometry uses the balanced chemical equation to establish the quantitative relationships between reactants and products. The coefficients in a balanced equation represent the relative number of moles of each substance involved in the reaction. Without a properly balanced equation, any calculations regarding reactant quantities will be inaccurate. Therefore, the first and most critical step in any limiting reactant problem is to ensure the chemical equation is correctly balanced.

Calculating Moles of Reactants

To begin any quantitative analysis, we must first express the amounts of reactants in moles. This conversion is typically done using the molar mass of each substance, which is found by summing the atomic masses of all atoms in a chemical formula, usually expressed in grams per mole (g/mol). The formula for converting mass to moles is straightforward: moles = mass (g) / molar mass (g/mol). Performing this calculation for each reactant provides the starting point for determining their relative amounts in terms of the reaction's stoichiometric needs.

Determining the Limiting Reactant Using Mole Ratios

Once the moles of each reactant are known, the next step is to compare them using the mole ratios from the balanced chemical equation. One effective method is to choose one reactant and calculate how many moles of the other reactant would be required to react with it completely. If the amount of the other reactant available is less than what is required, then that other reactant is the limiting one. Alternatively, you can divide the moles of each reactant by its stoichiometric coefficient in the balanced equation. The reactant that yields the smallest resulting value is the limiting reactant. This comparison highlights which reactant will be fully consumed first.

Calculating Theoretical Yield

The theoretical yield represents the maximum amount of product that can be formed in a chemical reaction, assuming complete conversion of the limiting reactant. To calculate the theoretical yield, you use the moles of the limiting reactant and the mole ratio between the limiting reactant and the desired product from the balanced chemical equation. This value is then typically converted back into grams using the molar mass of the product. The theoretical yield is a crucial benchmark for evaluating the success of an experimental reaction.

Calculating the Amount of Excess Reactant Remaining

After the limiting reactant has been identified and the reaction is assumed to have gone to completion, you can determine the amount of excess reactant that remains. This is done by first calculating how much of the excess reactant was consumed by reacting completely with the limiting reactant. You use the moles of the limiting reactant and the mole ratio between the limiting reactant and the excess reactant for this calculation. Once the moles of consumed excess reactant are found, subtract this amount from the initial moles of the excess reactant to find the moles remaining. This remaining amount can then be converted back to mass if needed.

Real-World Applications of Limiting and Excess Reactants

The principles of limiting and excess reactants are not confined to theoretical chemistry problems; they have widespread practical applications across various scientific and industrial fields. Understanding these concepts is essential for efficient and effective chemical operations.

Chemical Synthesis

In the synthesis of new chemical compounds, whether in academic research or pharmaceutical development, controlling the amounts of reactants is vital. Chemists use limiting reactant calculations to ensure they maximize the yield of their desired product and minimize the formation of unwanted byproducts. By carefully choosing which reactant is limiting, they can optimize the reaction for efficiency and purity.

Industrial Processes

Large-scale chemical manufacturing heavily relies on precise stoichiometric control. Industries producing everything from plastics and fertilizers to fuels and pharmaceuticals must manage reactant quantities meticulously. Identifying the limiting reactant helps companies optimize resource allocation, reduce waste, and ensure consistent product quality. For instance, in the Haber-Bosch process for ammonia synthesis, managing the ratio of nitrogen and hydrogen is critical for efficient ammonia production.

Laboratory Experiments

Across all levels of chemistry education and research, laboratory experiments frequently involve reactions where reactants are not mixed in perfect stoichiometric proportions. Students learn to identify limiting reactants to predict the outcome of experiments and to calculate percent yield. Researchers use these concepts to design experiments, troubleshoot issues, and interpret results accurately. For example, when performing a titration, understanding the limiting reactant helps in determining the concentration of an unknown solution.

Common Pitfalls and How to Avoid Them

Students often encounter difficulties when first learning about limiting and excess reactants. Awareness of common mistakes can significantly improve understanding and accuracy.

- **Using Masses Instead of Moles:** A very common error is attempting to compare reactant quantities directly using their masses. Chemical reactions occur based on the number of moles (or molecules/atoms), not their mass. Always convert masses to moles first using molar masses.
- **Not Balancing the Chemical Equation:** The stoichiometric coefficients in a balanced equation are essential for determining correct mole ratios. If the equation is not balanced, all subsequent calculations will be incorrect. Always balance the equation before proceeding.
- **Confusing Limiting and Excess Reactants:** Ensure a clear understanding of the definitions. The limiting reactant is the one that runs out first and determines product yield. The excess reactant is the one left over.
- **Incorrectly Calculating Theoretical Yield:** Theoretical yield should always be calculated based on the limiting reactant, not any other reactant.
- **Calculation Errors:** Simple arithmetic mistakes can lead to the wrong answer. Double-check your calculations, especially when performing divisions and multiplications with multiple numbers.

Practice Problems and Strategies

Consistent practice is key to mastering limiting and excess reactant calculations. When approaching a problem:

1. **Write and Balance the Chemical Equation:** This is the non-negotiable first step.
2. **Convert Given Quantities to Moles:** Use molar masses to convert grams (or other units) of each reactant into moles.
3. **Determine the Limiting Reactant:** Use the mole ratio method discussed earlier.
4. **Calculate the Theoretical Yield:** Use the moles of the limiting reactant and the mole ratio to the product.
5. **Calculate the Amount of Excess Reactant Remaining:** Determine how much of the excess reactant was consumed and subtract it from the initial amount.

Work through a variety of problems, starting with simpler examples and progressing to more complex ones involving multiple steps. Don't be afraid to revisit the definitions and calculation methods whenever you encounter difficulties.

Frequently Asked Questions

What is the definition of a limiting reactant in a chemical reaction?

The limiting reactant is the substance that is completely consumed first in a chemical reaction and therefore determines the maximum amount of product that can be formed.

How do you identify the limiting reactant given the amounts of multiple reactants?

To identify the limiting reactant, you calculate the moles of product that can be formed from each reactant individually, assuming the other reactant is in excess. The reactant that produces the least amount of product is the limiting reactant.

What is the significance of the excess reactant?

The excess reactant is the substance that is not completely consumed in a chemical reaction. Some amount of it will be left over after the reaction has finished.

What is theoretical yield, and how does it relate to the limiting reactant?

Theoretical yield is the maximum amount of product that can be formed in a chemical reaction, calculated based on the amount of the limiting reactant. It represents the ideal outcome if the reaction goes to completion with no losses.

What is percent yield, and how is it calculated?

Percent yield is a measure of the efficiency of a chemical reaction. It's calculated as (actual yield / theoretical yield) 100%, where actual yield is the experimentally obtained amount of product.

Why is it important to determine the limiting reactant in stoichiometry?

Determining the limiting reactant is crucial in stoichiometry because it dictates the quantity of product that can actually be formed and helps predict the amount of excess reactant remaining.

What are common units used when working with limiting and excess reactants problems?

Common units include grams (for mass), moles (for amount of substance), and sometimes liters or molarity for solutions. Calculations often involve converting between these units.

How does an unbalanced chemical equation affect the determination of limiting reactants?

An unbalanced chemical equation does not provide the correct mole ratios between reactants and products. Therefore, it's impossible to accurately determine the limiting reactant or calculate yields from an unbalanced equation.

What are some real-world applications where understanding limiting and excess reactants is important?

Real-world applications include industrial chemical synthesis, pharmaceutical manufacturing, food production, and even biological processes like metabolism, where optimizing product formation and minimizing waste are critical.

What is the relationship between moles, molar mass, and mass in limiting reactant calculations?

The relationship is that moles = mass / molar mass. You use molar mass to convert between the mass of a substance and the number of moles, which are essential for stoichiometric calculations involving limiting reactants.

Additional Resources

Here are 9 book titles related to limiting and excess reactants, along with short descriptions:

1. The Art of Stoichiometry: Mastering Limiting Reactants
This practical guide delves into the foundational principles of stoichiometry, with a specific focus on identifying and calculating limiting reactants. It offers a step-by-step approach to solving complex reaction problems, emphasizing the importance of mole ratios and theoretical yield. The book includes numerous worked examples and practice exercises designed to build confidence and proficiency in this crucial chemical concept.

2. Beyond the Balanced Equation: Understanding Excess and Limiting
Moving beyond simply balancing chemical equations, this text explores the real-world implications of reactions where reactants are not present in perfect stoichiometric ratios. It clearly defines excess and limiting reactants and explains how their presence affects the amount of product formed. The book provides insightful analogies and visual aids to solidify comprehension for a variety of learners.

3. Chemical Quantities: A Limiting Reactant Workbook
Designed as a hands-on workbook, this resource is dedicated to reinforcing the concepts of limiting and excess reactants through targeted problem-solving. Each chapter presents a new type of problem, gradually increasing in difficulty, with detailed solutions and explanations. It's an ideal companion for students seeking to practice and master quantitative calculations in chemistry.

4. The Molecular Balance: Predicting Reaction Outcomes
This book offers a deeper dive into how the relative amounts of reactants dictate the outcome of chemical reactions. It uses molecular models and visual representations to illustrate the process of identifying limiting reactants and predicting the maximum possible yield of products. The text also touches upon experimental techniques used to determine these quantities in a laboratory setting.

5. Stoichiometry Unveiled: From Theory to Practical Application
This comprehensive text unravels the intricacies of stoichiometry, dedicating significant attention to the practical application of limiting and excess reactant calculations. It bridges the gap between theoretical understanding and real-world scenarios, such as industrial chemical synthesis. The book includes case studies and discussions on how these concepts are vital in various scientific and engineering fields.

6. The Chemist's Compass: Navigating Limiting Reactant Problems
This book serves as a reliable guide for students tackling challenging limiting and excess reactant problems. It breaks down the problem-solving process into manageable steps, offering strategies for identifying key information and avoiding common pitfalls. The "compass" metaphor highlights how the book provides direction and clarity in navigating these complex calculations.

7. Quantitative Chemistry: The Limiting Reactant Framework
This focused text establishes a clear framework for understanding and solving quantitative chemistry problems, with a particular emphasis on limiting reactants. It systematically introduces the concepts, provides clear definitions, and offers a structured approach to calculations. The book is designed to build a solid foundation in this essential area of chemistry.

8. Reaction Ratios: Decoding Limiting and Excess
This engaging book uses clear language and relatable examples to decode the often-confusing concepts of limiting and excess reactants. It emphasizes the importance of reaction ratios in

determining which reactant will be consumed first and how much product can be formed. The text aims to demystify these calculations for students at various levels.

9. The Yield Game: Optimizing Reactions with Limiting Reactants
This book frames the concept of limiting reactants as a "game" where understanding and correctly identifying them is key to optimizing reaction yields. It explores the practical implications of maximizing product formation by understanding reactant limitations. The text includes discussions on efficiency and cost-effectiveness in chemical processes where reactant amounts are critical.

Limiting And Excess Reactants Pogil

Limiting and Excess Reactants POGIL

Name: Mastering Stoichiometry: A Deep Dive into Limiting and Excess Reactants

Outline:

Introduction: What is stoichiometry? Defining limiting and excess reactants. The importance of understanding these concepts in chemistry and real-world applications.
Chapter 1: Understanding Mole Ratios and Stoichiometric Calculations: Review of mole concepts, molar mass, and balanced chemical equations. Calculating mole ratios from balanced equations. Performing stoichiometric calculations to determine the amount of product formed from given reactants.
Chapter 2: Identifying Limiting and Excess Reactants: Developing strategies to identify the limiting reactant in a chemical reaction. Different approaches to solving limiting reactant problems. Practice problems with varying complexities.
Chapter 3: Calculating Theoretical Yield, Actual Yield, and Percent Yield: Defining theoretical yield, actual yield, and percent yield. Understanding the factors that affect percent yield. Calculations involving theoretical, actual, and percent yield. Real-world examples.
Chapter 4: Applications of Limiting Reactants in Real-World Scenarios: Examples from various industries (e.g., pharmaceuticals, manufacturing) showcasing the practical application of limiting reactant calculations. Discussion of the economic implications of efficient reactant utilization.
Conclusion: Summary of key concepts. Emphasis on the importance of mastering limiting and excess reactant calculations for further studies in chemistry.

Mastering Stoichiometry: A Deep Dive into Limiting

and Excess Reactants

Stoichiometry, the cornerstone of quantitative chemistry, deals with the relative amounts of reactants and products involved in chemical reactions. A crucial aspect of stoichiometry is understanding the concepts of limiting and excess reactants. These concepts are not merely theoretical exercises; they are essential for optimizing chemical processes in various fields, from industrial manufacturing to pharmaceutical production. This article delves into the intricacies of limiting and excess reactants, providing a comprehensive understanding of their significance and practical applications.

Chapter 1: Understanding Mole Ratios and Stoichiometric Calculations

Before tackling limiting and excess reactants, a solid grasp of mole ratios and stoichiometric calculations is paramount. The mole, a fundamental unit in chemistry, represents Avogadro's number (6.022×10^{23}) of particles (atoms, molecules, ions). Molar mass, the mass of one mole of a substance, is crucial for converting between mass and moles.

Balanced chemical equations provide the quantitative relationship between reactants and products. For example, consider the combustion of methane:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

This equation tells us that one mole of methane reacts with two moles of oxygen to produce one mole of carbon dioxide and two moles of water. The coefficients in the balanced equation represent the mole ratios, providing the basis for stoichiometric calculations.

To perform stoichiometric calculations, we use the mole ratios from the balanced equation as conversion factors. For instance, if we have a certain number of moles of methane, we can use the mole ratio (1 mol CH_4 : 2 mol O_2) to determine the moles of oxygen required for complete combustion. Similarly, we can calculate the moles of products formed. These calculations often involve converting between grams and moles using molar mass.

Chapter 2: Identifying Limiting and Excess Reactants

In most real-world reactions, the reactants are not present in the exact stoichiometric ratios indicated by the balanced equation. One reactant will be completely consumed before the others, limiting the amount of product formed. This reactant is known as the limiting reactant. The other reactants, present in greater amounts than required, are called excess reactants.

Identifying the limiting reactant involves comparing the mole ratios of the reactants to the stoichiometric ratios from the balanced equation. Several approaches can be used:

Method 1: Comparing Mole Ratios: Calculate the moles of each reactant. Then, divide the moles of each reactant by its stoichiometric coefficient from the balanced equation. The reactant with the smallest result is the limiting reactant.

Method 2: Multiple Calculations: Assume each reactant is the limiting reactant separately and calculate the amount of product formed in each case. The reactant that produces the least amount of product is the limiting reactant.

Chapter 3: Calculating Theoretical Yield, Actual Yield, and Percent Yield

The theoretical yield is the maximum amount of product that can be formed from a given amount of reactants, assuming 100% conversion. It's calculated using stoichiometry, based on the limiting reactant. The actual yield is the amount of product actually obtained in a reaction. It's always less than or equal to the theoretical yield due to various factors like incomplete reactions, side reactions, and loss during purification.

The percent yield expresses the efficiency of the reaction and is calculated as:

Percent Yield = (Actual Yield / Theoretical Yield) x 100%

A high percent yield indicates a more efficient reaction. Factors affecting percent yield include:

Incomplete Reactions: Some reactions don't go to completion.
Side Reactions: Unwanted reactions can consume reactants and reduce the yield of the desired product.
Loss during Purification: Some product may be lost during separation and purification steps.

Chapter 4: Applications of Limiting Reactants in Real-World Scenarios

The concept of limiting reactants is crucial in various industrial processes:

Pharmaceutical Industry: Precise stoichiometric control is vital in drug synthesis to ensure the desired product is formed with high purity and yield. Limiting reactant calculations help optimize reaction conditions and minimize waste.

Manufacturing: In manufacturing processes, controlling the amounts of reactants is essential for efficiency and cost-effectiveness. Using the correct ratio of reactants minimizes waste and maximizes product output.

Environmental Chemistry: Understanding limiting reactants is crucial for modeling and predicting the outcome of environmental reactions, such as pollutant degradation or nutrient cycling.

Efficient reactant utilization, guided by limiting reactant calculations, directly impacts the economic viability of industrial processes. Minimizing waste and maximizing product yield contribute significantly to profitability and sustainability.

Conclusion

Mastering the concepts of limiting and excess reactants is fundamental for anyone pursuing studies or a career in chemistry or related fields. This article provided a comprehensive guide to understanding, identifying, and applying these concepts in various contexts. By understanding stoichiometry and the role of limiting reactants, we can optimize chemical processes for efficiency, sustainability, and cost-effectiveness.

FAQs

1. What is the difference between a limiting reactant and an excess reactant? The limiting reactant is completely consumed in a reaction, determining the maximum amount of product formed. The excess reactant is present in a greater amount than required and some remains unreacted after the reaction is complete.

2. How do I identify the limiting reactant in a chemical reaction? Compare the mole ratios of the reactants to the stoichiometric ratios from the balanced equation. The reactant with the smallest ratio is the limiting reactant.

3. What is theoretical yield? The maximum amount of product that can be formed from a given amount of reactants, assuming 100% conversion.

4. What is actual yield? The amount of product actually obtained in a reaction.

5. What is percent yield? A measure of the efficiency of a reaction, calculated as (Actual Yield / Theoretical Yield) x 100%.

6. What factors affect percent yield? Incomplete reactions, side reactions, and loss during purification.

7. How are limiting reactants relevant to industrial processes? They are crucial for optimizing reaction conditions, minimizing waste, and maximizing product yield.

8. Can a reaction have more than one limiting reactant? No, only one reactant will be completely consumed first.

9. How do I convert grams of reactant to moles? Divide the mass in grams by the molar mass of the reactant (grams/mol).

Related Articles

1. Stoichiometry Basics: A foundational introduction to stoichiometric calculations and mole concepts.

2. Molar Mass Calculations: A detailed guide to calculating molar masses of various compounds.

3. Balancing Chemical Equations: Techniques and strategies for balancing complex chemical equations.

4. Types of Chemical Reactions: An overview of different types of chemical reactions and their stoichiometry.

5. Gas Stoichiometry: Calculations involving gases in chemical reactions.

6. Solution Stoichiometry: Calculations involving solutions in chemical reactions.

7. Limiting Reactant Problems: Worked Examples: A collection of solved problems illustrating different approaches to limiting reactant calculations.

8. Percent Yield and its Significance: A deeper discussion on factors affecting percent yield and its implications.

9. Real-World Applications of Stoichiometry: Case studies showcasing the applications of stoichiometry in various industries.

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limiting and excess reactants pogil: Chemistry Education in the ICT Age Minu Gupta Bhowon, Sabina Jhaumeer-Laulloo, Henri Li Kam Wah, Ponnadurai Ramasami, 2009-07-21 th th The 20 International Conference on Chemical Education (20 ICCE), which had rd th "Chemistry in the ICT Age" as the theme, was held from 3 to 8 August 2008 at Le Méridien Hotel, Pointe aux Piments, in Mauritius. With more than 200 participants from 40 countries, the conference featured 140 oral and 50 poster presentations. th Participants of the 20 ICCE were invited to submit full papers and the latter were subjected to peer review. The selected accepted papers are collected in this book of proceedings. This book of proceedings encloses 39 presentations covering topics ranging from fundamental to applied chemistry, such as Arts and Chemistry Education, Biochemistry and Biotechnology, Chemical Education for Development, Chemistry at Secondary Level, Chemistry at Tertiary Level, Chemistry Teacher Education, Chemistry and Society, Chemistry Olympiad, Context Oriented Chemistry, ICT and Chemistry Education, Green Chemistry, Micro Scale Chemistry, Modern Technologies in Chemistry Education, Network for Chemistry and Chemical Engineering Education, Public Understanding of Chemistry, Research in Chemistry Education and Science Education at Elementary Level. We would like to thank those who submitted the full papers and the reviewers for their timely help in assessing the papers for publication. th We would also like to pay a special tribute to all the sponsors of the 20 ICCE and, in particular, the Tertiary Education Commission (http://tec.intnet.mu/) and the Organisation for the Prohibition of Chemical Weapons (http://www.opcw.org/) for kindly agreeing to fund the publication of these proceedings.

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limiting and excess reactants pogil: Barriers and Opportunities for 2-Year and 4-Year STEM Degrees National Academies of Sciences, Engineering, and Medicine, National Academy of Engineering, Policy and Global Affairs, Board on Higher Education and Workforce, Division of Behavioral and Social Sciences and Education, Board on Science Education, Committee on Barriers and Opportunities in Completing 2-Year and 4-Year STEM Degrees, 2016-05-18 Nearly 40 percent of the students entering 2- and 4-year postsecondary institutions indicated their intention to major in science, technology, engineering, and mathematics (STEM) in 2012. But the barriers to students realizing their ambitions are reflected in the fact that about half of those with the intention to earn a STEM bachelor's degree and more than two-thirds intending to earn a STEM associate's degree fail to earn these degrees 4 to 6 years after their initial enrollment. Many of those who do obtain a degree take longer than the advertised length of the programs, thus raising the cost of their education. Are the STEM educational pathways any less efficient than for other fields of study? How might the losses be stemmed and greater efficiencies realized? These questions and others are at the heart of this study. Barriers and Opportunities for 2-Year and 4-Year STEM Degrees reviews research on the roles that people, processes, and institutions play in 2-and 4-year STEM degree production. This study pays special attention to the factors that influence students' decisions to enter, stay in, or leave STEM majorsâ€quality of instruction, grading policies, course sequences, undergraduate learning environments, student supports, co-curricular activities, students' general academic preparedness and competence in science, family background, and governmental and institutional policies that affect STEM educational pathways. Because many students do not take the traditional 4-year path to a STEM undergraduate degree, Barriers and Opportunities describes several other common pathways and also reviews what happens to those who do not complete the journey to a degree. This book describes the major changes in student demographics; how students, view, value, and utilize programs of higher education; and how institutions can adapt to support successful student outcomes. In doing so, Barriers and Opportunities questions whether definitions and characteristics of what constitutes success in STEM should change. As this book explores these issues, it identifies where further research is needed to build a system that works for all students who aspire to STEM degrees. The conclusions of this report lay out the steps that faculty, STEM departments, colleges and universities, professional societies, and others can take to improve STEM education for all students interested in a STEM degree.

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