

limiting and excess reactants pogil answer key pdf

limiting and excess reactants pogil answer key pdf is a topic that often comes up in chemistry education, and for good reason. Understanding how to identify limiting and excess reactants is fundamental to mastering stoichiometry and predicting the outcome of chemical reactions. This comprehensive guide aims to provide clarity on these concepts, offering insights into their significance and practical application. We will delve into the definitions, methods of identification, calculation strategies, and the importance of these concepts in various chemical contexts. Whether you are a student seeking to understand a POGIL activity or an educator looking for resources, this article will serve as a valuable reference for grasping the nuances of limiting and excess reactants, and how to effectively find and utilize a POGIL answer key PDF.

Understanding Limiting and Excess Reactants

What are Limiting and Excess Reactants?

In a chemical reaction, reactants are the substances that are consumed to form products. However, rarely are reactants present in the exact stoichiometric proportions required for all of them to be completely used up. This leads to the concept of limiting and excess reactants. The limiting reactant is the one that gets completely consumed first in a chemical reaction, thereby determining the maximum amount of product that can be formed. Conversely, the excess reactant is the one that is not completely used up; some of it will remain after the reaction has stopped because the limiting reactant has been depleted.

The Analogy of Making Sandwiches

A common and effective way to understand limiting and excess reactants is through an analogy. Imagine you are making ham and cheese sandwiches, and the recipe calls for 2 slices of bread and 1 slice of ham per sandwich. If you have 10 slices of bread and 4 slices of ham, you can only make 4 sandwiches because you will run out of ham first. In this scenario, the ham is the limiting reactant, and the bread is the excess reactant. You will have 2 slices of bread left over after making 4 sandwiches.

Stoichiometry and Reactant Ratios

The core of identifying limiting and excess reactants lies in stoichiometry, the study of the quantitative relationships between amounts of reactants and products in chemical reactions. Chemical equations, when balanced, provide the molar ratios in which reactants combine and products are formed. These ratios are crucial for determining which reactant will be exhausted first. For instance, in the reaction $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, two moles of hydrogen gas react with one mole of oxygen gas to produce two moles of water. If you have unequal molar amounts of hydrogen and oxygen, one will be limiting.

Identifying Limiting and Excess Reactants

The Importance of Balanced Chemical Equations

Before any calculations involving limiting and excess reactants can be performed, it is imperative to have a balanced chemical equation. A balanced equation ensures that the law of conservation of mass is upheld, meaning the number of atoms of each element is the same on both the reactant and product sides. Without a balanced equation, the stoichiometric ratios will be incorrect, leading to erroneous conclusions about which reactant is limiting and how much product can be formed. Therefore, always start by balancing the given chemical equation.

Methods for Determining the Limiting Reactant

There are several methods to determine the limiting reactant. One common approach involves calculating the amount of product that could be formed from each reactant individually, assuming the other reactant is in excess. The reactant that yields the smallest amount of product is the limiting reactant. Another method involves comparing the mole ratio of the reactants present to the mole ratio dictated by the balanced chemical equation. If the actual ratio of reactants is less than the stoichiometric ratio for a particular reactant, that reactant is limiting.

Calculating Moles and Molar Mass

To apply the methods for determining the limiting reactant, you often need to convert given masses of reactants into moles. This is achieved using the molar mass of each substance, typically found on the periodic table. The formula for converting mass to moles is: $\text{Moles} = \text{Mass (g)} / \text{Molar Mass (g/mol)}$. Once you have the moles of each reactant, you can use the stoichiometric coefficients from the balanced equation to compare their relative amounts and identify the limiting reactant.

Worked Example: Identifying the Limiting Reactant

Let's consider the reaction between nitrogen gas (N_2) and hydrogen gas (H_2) to form ammonia (NH_3): $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$. Suppose you have 28 grams of N_2 and 9 grams of H_2 . First, calculate the molar masses: Molar mass of N_2 is approximately 28 g/mol, and the molar mass of H_2 is approximately 2 g/mol. Convert the given masses to moles: Moles of $\text{N}_2 = 28 \text{ g} / 28 \text{ g/mol} = 1 \text{ mol}$. Moles of $\text{H}_2 = 9 \text{ g} / 2 \text{ g/mol} = 4.5 \text{ mol}$. According to the balanced equation, 1 mole of N_2 reacts with 3 moles of H_2 . To react completely with 1 mol of N_2 , you would need 3 mol of H_2 . Since you have 4.5 mol of H_2 , you have more than enough H_2 . Therefore, N_2 is the limiting reactant, and H_2 is the excess reactant.

Calculating Product Yield and Excess Reactant

Remaining

Theoretical Yield Calculation

Once the limiting reactant has been identified, it can be used to calculate the theoretical yield of the product. The theoretical yield is the maximum amount of product that can be produced from the given amounts of reactants, assuming the reaction goes to completion and there are no losses. This calculation is based on the stoichiometry of the balanced equation and the moles of the limiting reactant. You use the mole ratio between the limiting reactant and the product to determine the moles of product formed, and then convert this to mass using the product's molar mass.

Percent Yield and Its Significance

In a real-world laboratory setting, the actual amount of product obtained is often less than the theoretical yield. This is due to various factors such as incomplete reactions, side reactions, and loss of product during purification. The percent yield is a measure of how efficient a reaction is and is calculated using the formula: $\text{Percent Yield} = (\text{Actual Yield} / \text{Theoretical Yield}) \times 100\%$. A high percent yield indicates that the reaction was successful in producing a large proportion of the theoretical maximum. Understanding percent yield is critical for optimizing chemical processes.

Calculating the Amount of Excess Reactant Remaining

After the limiting reactant is completely consumed, a certain amount of the excess reactant will be left over. To calculate this remaining amount, you first determine how much of the excess reactant was used up in the reaction. This is done by using the moles of the limiting reactant and the stoichiometric ratio between the limiting reactant and the excess reactant. Subtract the amount of excess reactant used from the initial amount of excess reactant to find the amount remaining. This calculation is often expressed in moles or grams.

The Role of Limiting and Excess Reactants in Chemistry

Industrial Applications of Stoichiometry

The concepts of limiting and excess reactants are not just academic exercises; they have profound implications in industrial chemistry. Many chemical manufacturing processes involve large-scale reactions where precise control over reactant amounts is crucial for efficiency and cost-effectiveness. For example, in the Haber-Bosch process for ammonia synthesis, carefully managing the ratio of nitrogen and hydrogen is vital to maximize ammonia production and minimize waste. Industries use these principles to optimize yields and reduce raw material costs.

Experimental Design and Analysis

In chemistry laboratories, experimental design often involves deliberately using one reactant in excess to ensure that the other reactant, usually a more expensive or reactive one, is completely consumed. This allows for the complete analysis of the limiting reactant or the product formed. For instance, in titrations, one solution is often in excess to ensure complete reaction with the analyte. Understanding limiting and excess reactants helps chemists interpret experimental results accurately and design more effective experiments.

Troubleshooting and Optimization in Chemical Reactions

When a chemical reaction does not proceed as expected, identifying the limiting and excess reactants can be a key step in troubleshooting. If the yield is lower than anticipated, it might indicate an issue with the initial reactant quantities or an unforeseen side reaction consuming the limiting reactant. Conversely, if a significant amount of a reactant remains, it might suggest that the reaction did not reach completion. This understanding allows chemists to optimize reaction conditions, adjust reactant ratios, or modify experimental procedures to improve efficiency and outcomes.

Frequently Asked Questions

What is the primary purpose of a limiting and excess reactants POGIL activity?

The primary purpose of a POGIL (Process Oriented Guided Inquiry Learning) activity on limiting and excess reactants is to help students understand the concept of how reactants are consumed in a chemical reaction and how to identify which reactant will be completely used up first, thereby limiting the amount of product formed.

How does a POGIL activity typically guide students to identify the limiting reactant?

A POGIL activity typically guides students through a series of questions and data analysis that involve calculating the amount of product that could be formed from each reactant, assuming the other is in excess. The reactant that yields the least amount of product is then identified as the limiting reactant.

What is the definition of a limiting reactant provided in most POGIL answer keys for this topic?

The definition of a limiting reactant in a POGIL answer key is usually: 'The reactant that is completely consumed in a chemical reaction. It determines the maximum amount of product that can be formed.'

What is the definition of an excess reactant provided in most POGIL answer keys for this topic?

The definition of an excess reactant in a POGIL answer key is usually: 'The reactant that is not completely consumed in a chemical reaction. Some of this reactant will be left over after the reaction is complete.'

What is the role of stoichiometry in determining limiting and excess reactants within a POGIL context?

Stoichiometry is fundamental to POGIL activities on this topic. Students use mole ratios from balanced chemical equations to calculate how much product can be formed from a given amount of each reactant, which is the key to identifying the limiting reactant.

How do POGIL activities address the concept of 'percent yield' in relation to limiting reactants?

While not always the primary focus, POGIL answer keys for limiting reactants will often include follow-up questions or examples that introduce percent yield, explaining that the theoretical yield (calculated using the limiting reactant) is the maximum possible product, and actual yield is what is experimentally obtained.

What common misconceptions do POGIL activities aim to correct regarding limiting reactants?

POGIL activities aim to correct misconceptions such as assuming reactants are present in stoichiometric amounts, confusing mass with moles, or failing to use the correct mole ratios from a balanced equation when determining the limiting reactant.

How might a POGIL activity use a real-world analogy to explain limiting and excess reactants?

A common analogy used in POGIL activities is making sandwiches. If you have 10 slices of bread and 5 slices of cheese, and each sandwich requires 2 slices of bread and 1 slice of cheese, the bread is the limiting reactant because you can only make 5 sandwiches (using all the bread) even though you have enough cheese for 5 sandwiches. The cheese would be in excess.

What are the key steps to solving a limiting reactant problem, as outlined in a typical POGIL answer key?

The key steps usually outlined are: 1. Write and balance the chemical equation. 2. Convert the given amounts of each reactant to moles. 3. Use the mole ratios from the balanced equation to calculate the moles of product that can be formed from each reactant. 4. The reactant that produces the smallest amount of product is the limiting reactant. 5. The smallest amount of product calculated is the theoretical yield.

Additional Resources

Here are 9 book titles related to limiting and excess reactants, with descriptions, keeping in mind the context of a "POGIL answer key PDF." This implies a focus on pedagogical resources for understanding these concepts in chemistry.

1. Exploring Limiting and Excess Reactants: A POGIL Approach

This book would serve as a direct companion to the POGIL activities on limiting and excess reactants. It would likely offer detailed explanations of each step within the POGIL model, clarifying the reasoning behind questions and providing alternative perspectives for students who are struggling. The focus would be on conceptual understanding, guiding students through the problem-solving process rather than just presenting answers.

2. Mastering Stoichiometry: Limiting Reactants and Beyond

This title suggests a comprehensive guide that delves deeply into stoichiometry, with a significant portion dedicated to the nuances of limiting and excess reactants. It would likely include a wealth of worked examples, ranging from basic to complex, and explain common pitfalls and misconceptions. The "Beyond" implies it would also connect these concepts to subsequent stoichiometry topics.

3. The POGIL Chemistry Toolkit: Reactants, Reactions, and Yields

Framed as a broader toolkit, this book would integrate the POGIL methodology with fundamental chemistry concepts. The sections on reactants, reactions, and yields would naturally encompass limiting and excess reactants. It would likely offer pedagogical strategies and best practices for instructors using POGIL, alongside student-facing explanations and practice problems.

4. Unlocking Limiting Reactant Problems: A Step-by-Step Workbook

This workbook format emphasizes practical application and skill-building. It would provide a structured series of problems designed to build confidence and proficiency in identifying and calculating limiting and excess reactants. Each problem would likely be accompanied by clear, detailed solutions, mirroring the functionality of an answer key.

5. Visualizing Chemical Reactions: Limiting Reactants in Focus

This book would leverage visual aids such as diagrams, molecular models, and animations to explain the abstract concepts of limiting and excess reactants. By providing a visual representation of the reaction process, it aims to make the idea of one reactant running out first more intuitive. The POGIL context suggests these visualizations would be tied to specific guided inquiry activities.

6. Conceptual Chemistry: Understanding Limiting Reactants Through Inquiry

This title highlights a focus on the underlying principles rather than rote memorization. It would guide students through understanding why limiting reactants are important and how they affect reaction outcomes. The "Inquiry" aspect suggests a strong connection to POGIL's active learning philosophy, emphasizing discovery and critical thinking.

7. The Limiting Reactant Detective: Solving Chemical Mysteries

This more engaging title suggests a problem-solving approach that frames limiting and excess reactant calculations as investigative tasks. It would likely present scenarios where students need to deduce which reactant is limiting based on given information. The POGIL influence would mean the "mysteries" are broken down into manageable, inquiry-based steps.

8. POGIL Chemistry Solutions Manual: Limiting and Excess Reactants Edition

This is the most direct interpretation of the request, implying a manual specifically dedicated to

providing answers and explanations for POGIL activities related to limiting and excess reactants. It would be an indispensable resource for students to check their work and understand the rationale behind correct solutions. The emphasis would be on clarity and accuracy.

9. Applied Stoichiometry: From Limiting Reactants to Real-World Chemistry

This book would bridge the gap between theoretical concepts and practical applications. It would demonstrate how limiting and excess reactants are crucial in various chemical processes, from industrial synthesis to biological reactions. The POGIL connection would suggest the foundational understanding derived from inquiry-based learning is applied to these real-world examples.

Limiting And Excess Reactants Pogil Answer Key Pdf

Limiting and Excess Reactants POGIL Answer Key PDF

Name: Mastering Limiting and Excess Reactants: A Comprehensive Guide with POGIL Activities and Solutions

Outline:

Introduction: What are limiting and excess reactants? Why are they important? Brief overview of stoichiometry.

Chapter 1: Understanding Stoichiometry: Moles, molar mass, balanced chemical equations, mole ratios.

Chapter 2: Identifying Limiting and Excess Reactants: Step-by-step methods for identifying the limiting reactant. Practice problems with varying complexities.

Chapter 3: Calculating Theoretical Yield: Determining the maximum amount of product that can be formed. Addressing potential sources of error.

Chapter 4: Calculating Percent Yield: Understanding actual yield versus theoretical yield. Analyzing factors affecting percent yield.

Chapter 5: Advanced Applications: Real-world examples and applications of limiting and excess reactants.

Chapter 6: POGIL Activities and Answer Key: Detailed solutions and explanations for each POGIL activity.

Conclusion: Recap of key concepts and problem-solving strategies. Encouragement for further learning.

Mastering Limiting and Excess Reactants: A Comprehensive Guide with POGIL Activities and Solutions

Introduction: Unveiling the Secrets of Limiting and Excess Reactants

Stoichiometry, the cornerstone of quantitative chemistry, deals with the relative amounts of reactants and products in chemical reactions. A crucial aspect of stoichiometry involves understanding limiting and excess reactants. In any chemical reaction where two or more reactants are involved, one reactant will inevitably be consumed completely before the others. This reactant, the one that runs out first, is known as the limiting reactant, because it limits the amount of product that can be formed. The other reactants, which are present in greater amounts than needed for complete reaction with the limiting reactant, are called excess reactants.

Understanding limiting and excess reactants is paramount for several reasons. Firstly, it allows chemists to predict the maximum amount of product that can be obtained from a given reaction, a value known as the theoretical yield. Secondly, it enables efficient resource allocation in industrial processes, minimizing waste and maximizing product yield. Finally, it provides a framework for understanding reaction efficiency and optimizing reaction conditions. This comprehensive guide will equip you with the necessary tools and knowledge to confidently tackle problems involving limiting and excess reactants.

Chapter 1: Laying the Foundation - Understanding Stoichiometry

Before diving into the intricacies of limiting reactants, a solid grasp of basic stoichiometry is essential. This includes:

Moles: The fundamental unit of measurement in chemistry, representing Avogadro's number (6.022×10^{23}) of particles. Understanding mole calculations is critical for converting between mass, moles, and number of particles.

Molar Mass: The mass of one mole of a substance, expressed in grams per mole (g/mol). Calculating molar mass involves summing the atomic masses of all atoms in a chemical formula.

Balanced Chemical Equations: These equations represent chemical reactions, showing the reactants and products with their stoichiometric coefficients. These coefficients are crucial for determining the mole ratios between reactants and products.

Mole Ratios: Derived from the balanced chemical equation, mole ratios represent the relative amounts of reactants and products involved in a reaction. These ratios are essential for performing stoichiometric calculations.

Example: Consider the reaction: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. The mole ratio of H_2 to O_2 is 2:1, meaning that two moles of H_2 react with one mole of O_2 .

Chapter 2: Identifying the Limiting Reactant - The Decisive Factor

Identifying the limiting reactant is a crucial step in stoichiometric calculations. Several approaches can be used:

Method 1: Comparing Mole Ratios: Determine the moles of each reactant present. Using the balanced chemical equation, compare the mole ratio of the reactants to the actual mole ratio present. The reactant that produces the least amount of product is the limiting reactant.

Method 2: Converting to Moles of Product: Convert the moles of each reactant to moles of a chosen product using the mole ratios from the balanced equation. The reactant that produces the smaller amount of product is the limiting reactant.

Example: If 4 moles of H_2 and 2 moles of O_2 react according to the equation $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, H_2 is the limiting reactant because it would produce only 4 moles of water, while O_2 could potentially produce 4 moles of water.

Chapter 3: Calculating Theoretical Yield - Predicting the Maximum Output

Once the limiting reactant is identified, the theoretical yield can be calculated. The theoretical yield is the maximum amount of product that can be formed if the reaction goes to completion, assuming 100% efficiency. It's calculated by using the moles of the limiting reactant and the appropriate mole ratio from the balanced equation to determine the moles of product formed, then converting moles of product to grams using its molar mass.

Chapter 4: Calculating Percent Yield - Assessing Reaction Efficiency

The actual yield is the amount of product obtained experimentally. It's always less than or equal to the theoretical yield due to various factors such as incomplete reactions, side reactions, and loss during purification. The percent yield provides a measure of the reaction's efficiency:

$$\text{Percent Yield} = (\text{Actual Yield} / \text{Theoretical Yield}) \times 100\%$$

A high percent yield indicates a more efficient reaction. Understanding factors that affect percent yield, such as reaction conditions (temperature, pressure, catalysts), purity of reactants, and experimental errors, is essential for optimizing reactions.

Chapter 5: Advanced Applications - Real-world Implications

Limiting and excess reactant concepts extend far beyond textbook problems. They have significant applications in various fields, including:

Industrial Chemistry: Optimizing production processes, minimizing waste, and maximizing profitability.

Environmental Science: Understanding reaction pathways and predicting the fate of pollutants in the environment.

Biochemistry: Analyzing metabolic pathways and determining rate-limiting steps in biological processes.

Chapter 6: POGIL Activities and Answer Key - Hands-on Practice

This section contains a series of POGIL (Process Oriented Guided Inquiry Learning) activities designed to reinforce the concepts covered. Each activity presents a problem or scenario, guiding you through the problem-solving process, followed by a detailed answer key and explanations to ensure complete understanding.

Conclusion: Mastering the Art of Stoichiometry

Understanding limiting and excess reactants is fundamental to mastering stoichiometry. By employing the techniques and strategies outlined in this guide, you can confidently tackle complex stoichiometric problems and apply these concepts to real-world applications. Continue practicing and exploring further resources to solidify your understanding.

FAQs

1. What is the difference between a limiting reactant and an excess reactant? The limiting reactant is completely consumed in a reaction, limiting the amount of product formed. The excess reactant is present in a greater amount than needed and some remains unreacted after the limiting reactant is consumed.
2. How do I identify the limiting reactant? Compare the mole ratios of reactants to the actual mole ratios present, or convert moles of each reactant to moles of product. The reactant yielding the least product is limiting.

3. What is theoretical yield? The maximum amount of product that can be formed if the reaction proceeds to completion with 100% efficiency.
4. What is percent yield? The ratio of actual yield to theoretical yield, expressed as a percentage, reflecting reaction efficiency.
5. Why is percent yield usually less than 100%? Due to factors such as incomplete reactions, side reactions, loss during purification, and experimental errors.
6. How do I calculate theoretical yield? Use the moles of the limiting reactant and the mole ratio from the balanced equation to determine the moles of product, then convert moles to grams using molar mass.
7. What are some real-world applications of limiting and excess reactants? Industrial chemical processes, environmental chemistry, and biochemistry.
8. What are POGIL activities? Process-Oriented Guided Inquiry Learning activities designed to promote active learning and problem-solving skills.
9. Where can I find more resources on stoichiometry? Textbooks, online tutorials, and educational websites.

Related Articles

1. Stoichiometry Calculations: A Step-by-Step Guide: A comprehensive tutorial covering basic stoichiometric calculations, including mole conversions and mass-to-mass conversions.
2. Understanding Mole Ratios in Chemical Reactions: A detailed explanation of mole ratios and their use in solving stoichiometric problems.
3. Calculating Theoretical and Percent Yield: A focused guide on calculating these key parameters in chemical reactions.
4. Advanced Stoichiometry Problems and Solutions: A collection of challenging problems and their step-by-step solutions.
5. Limiting Reactants in Real-World Applications: Case studies showcasing the importance of limiting reactants in various industries.
6. Error Analysis in Stoichiometric Experiments: A discussion on common sources of error and techniques for minimizing them.
7. Introduction to Chemical Reactions and Equations: A foundational article explaining chemical reactions and how to balance equations.
8. Moles and Molar Mass: A Comprehensive Overview: A detailed explanation of these crucial concepts in chemistry.

9. POGIL Activities for Chemistry: Benefits and Examples: A discussion on the benefits of POGIL activities and examples of their application in chemistry education.

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limiting and excess reactants pogil answer key pdf: *Biophysical Chemistry* James P. Allen, 2009-01-26 Biophysical Chemistry is an outstanding book that delivers both fundamental and complex biophysical principles, along with an excellent overview of the current biophysical research areas, in a manner that makes it accessible for mathematically and non-mathematically inclined readers. (Journal of Chemical Biology, February 2009) This text presents physical chemistry through the use of biological and biochemical topics, examples and applications to biochemistry. It lays out the necessary calculus in a step by step fashion for students who are less mathematically inclined, leading them through fundamental concepts, such as a quantum mechanical description of the hydrogen atom rather than simply stating outcomes. Techniques are presented with an emphasis on learning by analyzing real data. Presents physical chemistry through the use of biological and biochemical topics, examples and applications to biochemistry Lays out the necessary calculus in a step by step fashion for students who are less mathematically inclined Presents techniques with an emphasis on learning by analyzing real data Features qualitative and quantitative problems at the end of each chapter All art available for download online and on CD-ROM

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limiting and excess reactants pogil answer key pdf: *Overcoming Students' Misconceptions in Science* Mageswary Karpudewan, Ahmad Nurulazam Md Zain, A.L. Chandrasegaran, 2017-03-07 This book discusses the importance of identifying and addressing misconceptions for the successful teaching and learning of science across all levels of science education from elementary school to high school. It suggests teaching approaches based on research data to address students' common misconceptions. Detailed descriptions of how these instructional approaches can be incorporated into teaching and learning science are also included. The science education literature extensively documents the findings of studies about students' misconceptions or alternative conceptions about various science concepts. Furthermore, some of the studies involve systematic approaches to not only creating but also implementing instructional programs to reduce the incidence of these misconceptions among high school science students. These studies, however, are largely unavailable to classroom practitioners, partly because they are usually found in various science education journals that teachers have no time to refer to or are not readily available to them. In response, this book offers an essential and easily accessible guide.

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limiting and excess reactants pogil answer key pdf: *Introduction to Materials Science and Engineering* Elliot Douglas, 2014 This unique book is designed to serve as an active learning tool that uses carefully selected information and guided inquiry questions. Guided inquiry helps readers reach true understanding of concepts as they develop greater ownership over the material presented. First, background information or data is presented. Then, concept invention questions lead the students to construct their own understanding of the fundamental concepts represented. Finally, application questions provide the reader with practice in solving problems using the concepts that they have derived from their own valid conclusions. KEY TOPICS: What is Guided Inquiry?; What is Materials Science and Engineering?; Bonding; Atomic Arrangements in Solids; The Structure of Polymers; Microstructure: Phase Diagrams; Diffusion; Microstructure: Kinetics; Mechanical Behavior; Materials in the Environment; Electronic Behavior; Thermal Behavior; Materials Selection and Design. MasteringEngineering, the most technologically advanced online

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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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