reducing benzil using sodium borohydride

reducing benzil using sodium borohydride is a fundamental chemical reaction widely employed in organic synthesis for converting diketones into diols. This process involves the selective reduction of benzil, a 1,2-diketone, using sodium borohydride (NaBH4), a mild and versatile reducing agent. The reaction typically yields hydrobenzoin, a vicinal diol with important applications in pharmaceuticals and as a chiral building block. Understanding the mechanism, reaction conditions, and practical applications of this reduction is essential for chemists working in synthetic organic chemistry. This article will explore the chemistry behind reducing benzil using sodium borohydride, detail the reaction procedure, discuss factors influencing the reaction, and highlight its significance in laboratory and industrial settings.

Chemistry of Benzil Reduction

Benzil, chemically known as 1,2-diphenylethane-1,2-dione, is a diketone characterized by two adjacent carbonyl groups attached to phenyl rings. The reduction of benzil involves the conversion of these carbonyl groups into hydroxyl groups, resulting in the formation of hydrobenzoin. This reaction is a classic example of the selective reduction of diketones to vicinal diols, which can exist as different stereoisomers.

Structure and Properties of Benzil

Benzil is a crystalline solid with a distinctive yellow color, insoluble in water but soluble in organic solvents such as ethanol and acetone. Its two ketone groups are electrophilic centers susceptible to nucleophilic attack, which makes it an ideal substrate for reduction reactions. The proximity of

the two carbonyl groups affects the stereochemistry of the product formed during reduction.

Significance of Vicinal Diols

Vicinal diols like hydrobenzoin are valuable intermediates in organic synthesis. They serve as chiral auxiliaries, ligands in asymmetric synthesis, and precursors for various pharmaceuticals. The ability to selectively reduce benzil to hydrobenzoin allows for controlled synthesis of these important compounds.

Role and Properties of Sodium Borohydride

Sodium borohydride (NaBH4) is a widely used reducing agent in organic chemistry due to its mildness, selectivity, and ease of handling. It effectively reduces ketones and aldehydes to their corresponding alcohols without affecting many other functional groups.

Chemical Nature of Sodium Borohydride

NaBH4 is an inorganic compound composed of sodium cations and borohydride anions. It acts as a hydride donor, transferring hydride ions (H–) to electrophilic centers such as carbonyl carbons. It is stable in basic and neutral aqueous solutions but reacts violently with water under acidic conditions.

Advantages of Using NaBH4 for Benzil Reduction

Compared to other reducing agents like lithium aluminum hydride (LiAlH4), sodium borohydride offers several benefits:

- Selective reduction of ketones without affecting esters or carboxylic acids.
- Safer and easier to handle due to its stability in protic solvents such as ethanol or water.
- Operates under mild reaction conditions, reducing the risk of side reactions.

Reaction Mechanism of Benzil Reduction

The reduction of benzil by sodium borohydride proceeds through a nucleophilic addition mechanism, where hydride ions attack the electrophilic carbonyl carbons, followed by protonation to yield the diol.

Stepwise Mechanism

The mechanism involves several key steps:

1. **Hydride Transfer:** The borohydride ion donates a hydride ion to one of the carbonyl carbons in benzil, forming an alkoxide intermediate.

2. **Protonation:** The alkoxide intermediate is protonated by solvent molecules (usually water or alcohol), forming a hydroxy group.

3. **Second Hydride Attack:** A second hydride ion attacks the adjacent carbonyl group, repeating the process and leading to the formation of a vicinal diol.

4. **Final Protonation:** The remaining alkoxide is protonated, completing the reduction to hydrobenzoin.

Stereochemical Outcomes

The reduction can produce different stereoisomers of hydrobenzoin, including meso and racemic forms. Reaction conditions and solvents influence the stereoselectivity and yield of these isomers.

Experimental Procedure and Conditions

Conducting the reduction of benzil using sodium borohydride requires careful control of reaction parameters to ensure high yield and purity of hydrobenzoin.

Typical Reaction Setup

The procedure generally involves dissolving benzil in an appropriate solvent, usually ethanol or methanol, followed by the gradual addition of sodium borohydride while stirring. The reaction is often performed at room temperature or under mild heating to accelerate the process.

Step-by-Step Protocol

- Dissolve a measured amount of benzil in ethanol under stirring.
- Slowly add sodium borohydride powder or solution to the benzil solution.
- Maintain stirring and monitor the reaction progress using thin-layer chromatography (TLC) or other analytical methods.
- After completion, quench the reaction by adding water or dilute acid to deactivate excess NaBH4.
- Isolate the hydrobenzoin product by filtration or extraction, followed by purification through recrystallization or chromatography.

Factors Affecting the Reduction Process

Several variables influence the efficiency and outcome of reducing benzil using sodium borohydride. Understanding these factors is critical for optimizing the reaction.

Solvent Effects

The choice of solvent plays a vital role in solubility, reaction rate, and selectivity. Protic solvents such as ethanol or methanol facilitate protonation steps and stabilize intermediates, enhancing reaction speed and yield.

Temperature

Elevated temperatures can accelerate the reduction but may also increase side reactions or decrease selectivity. Mild heating is often sufficient, while excessively high temperatures are typically avoided.

Stoichiometry of Reagents

Using stoichiometric or slight excess amounts of sodium borohydride ensures complete reduction of benzil. Insufficient hydride can lead to incomplete conversion, while excessive amounts may complicate purification.

Reaction Time

The duration of the reaction affects product formation. Prolonged reaction times may improve yield but also risk over-reduction or byproduct formation.

Purity of Starting Materials

Impurities in benzil or sodium borohydride can hinder the reaction or affect product quality. Using high-purity reagents is recommended for optimal results.

Applications of Hydrobenzoin

Hydrobenzoin, the product of benzil reduction, is a valuable compound with diverse applications in organic synthesis and industry.

Use in Chiral Synthesis

Hydrobenzoin is widely used as a chiral auxiliary and ligand in asymmetric synthesis. Its stereocenters enable enantioselective reactions, producing optically active compounds essential in pharmaceuticals.

Pharmaceutical Intermediates

The vicinal diol functionality of hydrobenzoin facilitates the synthesis of various drugs and biologically active molecules. It serves as a precursor for compounds with antifungal, antibacterial, and anticancer properties.

Material Science and Catalysis

Hydrobenzoin derivatives find applications in the preparation of catalysts and materials with specialized properties. Its chemical versatility allows modification to tailor specific functionalities.

Frequently Asked Questions

What is the product of reducing benzil using sodium borohydride?

The reduction of benzil with sodium borohydride typically yields benzoin, which is an α-hydroxy ketone formed by the selective reduction of one of the

two ketone groups in benzil.

Why is sodium borohydride used for the reduction of benzil?

Sodium borohydride is used because it is a mild and selective reducing agent that can reduce ketones to alcohols without affecting other sensitive functional groups, making it suitable for selectively reducing benzil to benzoin.

What is the mechanism of benzil reduction by sodium borohydride?

Sodium borohydride delivers hydride ions (H-) to one of the carbonyl carbons in benzil, converting it to an alcohol group, resulting in benzoin. The reaction proceeds via nucleophilic attack of hydride on the electrophilic carbonyl carbon.

Can sodium borohydride reduce both carbonyl groups in benzil to diols?

Under typical conditions, sodium borohydride selectively reduces one carbonyl group in benzil to produce benzoin. However, with excess reagent and prolonged reaction time, both carbonyl groups can be reduced to give hydrobenzoin, a diol.

What solvents are commonly used for the reduction of benzil with sodium borohydride?

Common solvents include methanol, ethanol, or other protic solvents because they dissolve sodium borohydride and facilitate the hydride transfer to benzil.

How does the reaction temperature affect the reduction of benzil by sodium borohydride?

Lower temperatures help control the selectivity and rate of reduction, typically favoring the formation of benzoin. Higher temperatures can increase reaction rates but may lead to over-reduction to the diol.

Is the reduction of benzil by sodium borohydride stereoselective?

The reduction can produce a mixture of stereoisomers of benzoin or hydrobenzoin, as the hydride can attack from either face of the planar carbonyl group, leading to racemic mixtures.

What safety precautions should be taken when using sodium borohydride for benzil reduction?

Sodium borohydride should be handled with care as it reacts violently with water and acids, releasing hydrogen gas. Use appropriate protective equipment, work in a well-ventilated area, and avoid contact with moisture.

How can the progress of benzil reduction by sodium borohydride be monitored?

The reaction progress can be monitored by thin-layer chromatography (TLC), observing the disappearance of benzil and appearance of benzoin, or by spectroscopic methods such as NMR and IR spectroscopy.

What are common side reactions during the reduction of benzil with sodium borohydride?

Side reactions may include over-reduction to hydrobenzoin, decomposition of sodium borohydride in protic solvents, or formation of byproducts due to impurities or improper reaction conditions.

Additional Resources

1. *Selective Reduction of Benzil with Sodium Borohydride: Mechanisms and Applications*
This book offers an in-depth exploration of the chemical processes involved in the selective reduction of benzil using sodium borohydride. It covers the reaction mechanisms, conditions affecting selectivity, and practical applications in organic synthesis. Researchers and students will find detailed experimental procedures and case studies that highlight the nuances of this reduction.

2. *Organic Synthesis Techniques: Sodium Borohydride Reductions of α-Diketones*
Focusing on the broader category of α-diketones, this book details the use of sodium borohydride as a reducing agent, with benzil reduction as a key example. It discusses reaction kinetics, solvent effects, and product characterization. The text is ideal for chemists looking to optimize reduction protocols in laboratory settings.

3. *Practical Guide to Sodium Borohydride in Laboratory Reductions*
This practical manual emphasizes the safe and efficient use of sodium borohydride in various reductions, including benzil to hydrobenzoin. It provides step-by-step instructions, safety precautions, and troubleshooting tips. The book is particularly useful for undergraduate and graduate students performing organic reductions.

4. *Advanced Organic Chemistry: Reductions of Carbonyl Compounds*
A comprehensive textbook that covers the reduction of diverse carbonyl

compounds, with a dedicated chapter on benzil reduction using sodium borohydride. The book explains stereochemical outcomes and compares different reducing agents. It is a valuable resource for advanced students and professional chemists.

5. *Green Chemistry Approaches in Carbonyl Reductions: Sodium Borohydride Case Studies*
This book explores environmentally friendly methods for reducing carbonyl compounds, highlighting sodium borohydride's role in sustainable chemistry. It includes case studies on benzil reduction, emphasizing solvent choice and waste minimization. Ideal for researchers interested in green synthetic methodologies.

6. *Mechanistic Insights into Sodium Borohydride Reductions of α-Diketones*
Delving into the reaction pathways, this text offers detailed mechanistic analyses of sodium borohydride reducing benzil and related compounds. It integrates spectroscopic data and computational studies to explain product formation. The book is suited for chemists focused on reaction mechanism research.

7. *Laboratory Manual: Reduction of Benzil to Hydrobenzoin*
Designed as a hands-on guide, this manual provides detailed experimental protocols for reducing benzil to hydrobenzoin using sodium borohydride. It includes data sheets, expected results, and tips for optimizing yield and purity. Perfect for teaching laboratories and practical courses in organic chemistry.

8. *Sodium Borohydride in Industrial Organic Synthesis*
This book addresses the scale-up and industrial application of sodium borohydride reductions, featuring benzil as a model substrate. Topics include process optimization, cost analysis, and safety considerations. Industrial chemists and process engineers will find valuable insights into large-scale operations.

9. *Chiral Diol Synthesis via Sodium Borohydride Reduction of Benzil*
Focusing on the synthesis of chiral diols, this book discusses the stereoselective reduction of benzil using sodium borohydride and related catalysts. It covers asymmetric synthesis techniques and applications in pharmaceuticals. Researchers involved in chiral molecule synthesis will benefit from its detailed methodologies.

Reducing Benzil Using Sodium Borohydride

Reducing Benzil Using Sodium Borohydride

Author: Dr. Eleanor Vance, PhD (Organic Chemistry)

Ebook Chapter Outline:

Introduction: The significance of reduction reactions in organic chemistry, introducing benzil and its reduction products. Brief overview of sodium borohydride as a reducing agent.
Mechanism of Benzil Reduction: A detailed step-by-step explanation of the reaction mechanism, including relevant electron movements and intermediate formation. Discussion of stereochemistry.
Experimental Procedure: A comprehensive guide to performing the reduction, including detailed instructions on reagent preparation, reaction setup, workup, and purification techniques (recrystallization). Safety precautions are emphasized.
Characterization of the Product: Techniques for confirming the identity and purity of the reduced product (benzoin). Discussion of melting point determination, IR spectroscopy, and NMR spectroscopy.
Yield Calculation and Analysis: Explanation of yield calculation, potential sources of error, and methods for improving the reaction yield.
Applications of Benzil Reduction: Exploring the applications of benzoin and its derivatives in various fields, including organic synthesis and material science.
Conclusion: Summary of the key findings, highlighting the importance of the reaction and its practical applications.

Reducing Benzil Using Sodium Borohydride: A Comprehensive Guide

Introduction: The Power of Reduction in Organic Synthesis

Reduction reactions are fundamental transformations in organic chemistry, enabling the conversion of functional groups with higher oxidation states to those with lower oxidation states. These reactions are crucial for the synthesis of a vast array of organic molecules, including pharmaceuticals, polymers, and natural products. One such reaction involves the reduction of benzil, a diketone, to benzoin, an α-hydroxyketone. This transformation is a classic example of a nucleophilic addition reaction, frequently used in undergraduate organic chemistry laboratories to illustrate the reducing power of sodium borohydride ($NaBH_4$). Benzil's reduction to benzoin is particularly significant because benzoin itself serves as a valuable intermediate in the synthesis of many other compounds. Understanding this reaction offers a practical understanding of reaction mechanisms, purification techniques, and spectroscopic characterization methods vital to organic chemistry.

Mechanism of Benzil Reduction: A Step-by-Step Analysis

Sodium borohydride ($NaBH_4$) is a mild reducing agent commonly used to reduce ketones and aldehydes. Its selectivity makes it a valuable tool in organic synthesis, as it avoids reducing other functional groups that might be present in a molecule. The reduction of benzil to benzoin proceeds via a nucleophilic addition mechanism.

1. Hydride Attack: The hydride ion (H^-), a powerful nucleophile, from $NaBH_4$ attacks the electrophilic carbonyl carbon of benzil. This attack leads to the formation of an alkoxide intermediate. The reaction is often carried out in a protic solvent like methanol or ethanol, which helps to stabilize the alkoxide.

2. Protonation: The alkoxide intermediate is then protonated by the solvent (methanol or ethanol) or water, resulting in the formation of a hydroxyl group (-OH).

3. Second Hydride Attack (Less Common): While a single hydride attack from NaBH4 is sufficient for the majority of benzil reduction, under certain conditions a second hydride attack can occur on the other carbonyl group, followed by a second protonation step leading to a diol. However, this side reaction is usually minimized by controlling the stoichiometry and reaction conditions.

4. Stereochemistry: The reduction of benzil can produce both diastereomers (threo and erythro benzoin), depending on the reaction conditions. However, the stereochemical outcome is often not highly controlled using sodium borohydride reduction alone.

Experimental Procedure: A Detailed Guide to Benzil Reduction

Materials:

Benzil (precisely weighed amount)
Sodium borohydride ($NaBH_4$)
Methanol (or ethanol)
Ice bath
Erlenmeyer flask
Filter paper
Buchner funnel
Recrystallization solvent (e.g., ethanol/water)

Procedure:

1. Dissolution: Dissolve the weighed benzil in a suitable amount of methanol in an Erlenmeyer flask. An ice bath helps to control the exothermic nature of the reaction.
2. Addition of $NaBH_4$: Slowly add the $NaBH_4$ to the benzil solution, ensuring that the temperature remains below 25°C. Stir the mixture continuously. The reaction is exothermic and may cause foaming.
3. Reaction Completion: Allow the reaction to proceed for a specific time (generally 30-60 minutes)

with constant stirring. Monitor the reaction using TLC (thin-layer chromatography) if possible.
4. Work-up: Carefully add dilute hydrochloric acid or acetic acid to quench any excess $NaBH_4$. The solution will become slightly acidic.
5. Filtration: Filter the resulting mixture using vacuum filtration to remove any insoluble impurities.
6. Recrystallization: Recrystallize the crude benzoin from a suitable solvent mixture (e.g., ethanol/water) to obtain pure crystals.
7. Drying: Dry the purified crystals and weigh them to determine the yield.

Safety Precautions: Sodium borohydride reacts vigorously with water, so careful addition and quenching are crucial. Always wear appropriate safety glasses and gloves. Dispose of waste materials properly according to the safety guidelines.

Characterization of the Product: Confirming Benzoin Identity and Purity

The identity and purity of the synthesized benzoin can be confirmed through various techniques:

Melting Point Determination: The melting point of the recrystallized benzoin can be compared to the literature value (137°C) to assess its purity.
Infrared (IR) Spectroscopy: IR spectroscopy provides information about the functional groups present in the molecule. The presence of a broad hydroxyl (O-H) stretch and a carbonyl (C=O) stretch confirms the formation of benzoin.
Nuclear Magnetic Resonance (NMR) Spectroscopy: ^{1}H NMR and ^{13}C NMR spectroscopy provide detailed information about the structure of the molecule. The chemical shifts and coupling patterns in the NMR spectra help confirm the identity and purity of benzoin.

Yield Calculation and Analysis: Optimizing the Reaction

The percentage yield of the reaction is calculated using the following formula:

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

The actual yield is the weight of the purified benzoin obtained, while the theoretical yield is calculated based on the stoichiometry of the reaction and the initial amount of benzil used. Low yields can result from incomplete reaction, loss of product during work-up, or inefficient purification. Careful attention to experimental details and optimization of reaction conditions (solvent, temperature, reaction time) are crucial for maximizing the yield.

Applications of Benzil Reduction: Beyond the Laboratory

Benzoin, the product of benzil reduction, has various applications in:

Organic Synthesis: Benzoin serves as a crucial building block in the synthesis of other organic compounds, including pharmaceuticals and natural products.
Material Science: Benzoin and its derivatives find use in the preparation of polymeric materials and advanced materials.

Conclusion: A Valuable Synthetic Transformation

The reduction of benzil using sodium borohydride is a simple yet powerful reaction with significant pedagogical and practical value. It allows for a detailed exploration of reaction mechanisms, purification techniques, and spectroscopic characterization methods in organic chemistry. Understanding this reaction provides a strong foundation for further exploration of reduction reactions and their importance in the synthesis of a wide range of organic compounds. The applications of benzoin, the product of this reaction, further highlight its importance in various scientific and industrial fields.

FAQs

1. What are the safety precautions when handling sodium borohydride? Sodium borohydride reacts exothermically with water and acids. Always wear appropriate personal protective equipment (PPE), including gloves and safety glasses. Add the reagent slowly and carefully.

2. What is the role of the solvent in the benzil reduction? The solvent, usually methanol or ethanol, acts as both a solvent for the reactants and a proton source for the alkoxide intermediate.

3. Why is recrystallization necessary? Recrystallization is a purification technique used to remove impurities from the crude benzoin, resulting in a higher purity product with a sharper melting point.

4. What spectroscopic techniques are used to characterize the product? IR, ^{1}H NMR, and ^{13}C NMR spectroscopy are commonly used to confirm the structure and purity of the benzoin.

5. What factors can affect the yield of the reaction? Incomplete reaction, loss of product during work-up, and inefficient purification can all affect the yield.

6. Can other reducing agents be used to reduce benzil? Yes, other reducing agents, such as lithium aluminum hydride ($LiAlH_4$), can reduce benzil. However, $LiAlH_4$ is a more powerful reducing agent and may reduce other functional groups as well.

7. What are the differences between threo and erythro benzoin? Threo and erythro benzoin are diastereomers, differing in the stereochemistry of the hydroxyl and ketone groups.

8. How can I monitor the progress of the reaction? Thin-layer chromatography (TLC) can be used to monitor the reaction progress and determine when the reaction is complete.

9. What are some common errors to avoid during the experiment? Common errors include adding $NaBH_4$ too quickly, insufficient stirring, and using impure starting materials.

Related Articles:

1. Sodium Borohydride Reductions: A Comprehensive Overview: An extensive review of the uses and applications of sodium borohydride in organic synthesis.

2. Stereochemistry of Reduction Reactions: A detailed explanation of stereochemical aspects of reduction reactions and how to control stereoselectivity.

3. Purification Techniques in Organic Chemistry: A guide to common purification techniques used in organic chemistry laboratories, including recrystallization, distillation, and chromatography.

4. Spectroscopic Characterization of Organic Compounds: A detailed discussion of various spectroscopic techniques used to characterize organic molecules, including IR, NMR, and mass spectrometry.

5. Mechanism of Nucleophilic Addition Reactions: A comprehensive explanation of nucleophilic addition mechanisms and their importance in organic chemistry.

6. The Chemistry of Diketones: An overview of the properties and reactivity of diketones, including their reduction reactions.

7. The Chemistry of α-Hydroxy Ketones: An explanation of the properties and reactivity of α-hydroxy ketones like benzoin.

8. Green Chemistry Approaches to Benzil Reduction: Exploration of environmentally friendly methods for reducing benzil.

9. Applications of Benzoin Derivatives in Material Science: A detailed look at how benzoin and its derivatives are used in the creation of advanced materials.

reducing benzil using sodium borohydride: Microscale and Miniscale Organic Chemistry Laboratory Experiments Allen M. Schoffstall, Barbara A. Gaddis, Melvin L. Druelinger, 2000 This work offers a comprehensive introductory treatment of the organic laboratory techniques for handling glassware and equipment, safeety in the laboratory, micro- and mini-scale experimental procedures, theory of reactions and techniques, applications and spectroscopy.

reducing benzil using sodium borohydride: Comprehensive Organic Chemistry Experiments for the Laboratory Classroom Carlos A. M. Afonso, Nuno R. Candeias, Dulce Pereira Simão,

Alexandre F. Trindade, Jaime A. S. Coelho, Bin Tan, Robert Franzén, 2016-12-16 This expansive and practical textbook contains organic chemistry experiments for teaching in the laboratory at the undergraduate level covering a range of functional group transformations and key organic reactions.The editorial team have collected contributions from around the world and standardized them for publication. Each experiment will explore a modern chemistry scenario, such as: sustainable chemistry; application in the pharmaceutical industry; catalysis and material sciences, to name a few. All the experiments will be complemented with a set of questions to challenge the students and a section for the instructors, concerning the results obtained and advice on getting the best outcome from the experiment. A section covering practical aspects with tips and advice for the instructors, together with the results obtained in the laboratory by students, has been compiled for each experiment. Targeted at professors and lecturers in chemistry, this useful text will provide up to date experiments putting the science into context for the students.

reducing benzil using sodium borohydride: Cobalt Catalysis in Organic Synthesis Marko Hapke, Gerhard Hilt, 2019-12-17 Provides a much-needed account of the formidable cobalt rush in organic synthesis and catalysis Over the past few decades, cobalt has turned into one of the most promising metals for use in catalytic reactions, with important applications in the efficient and selective synthesis of natural products, pharmaceuticals, and new materials. Cobalt Catalysis in Organic Synthesis: Methods and Reactions provides a unique overview of cobalt-catalysed and -mediated reactions applied in modern organic synthesis. It covers a broad range of homogeneous reactions, like cobalt-catalysed hydrogenation, hydrofunctionalization, cycloaddition reactions, C-H functionalization, as well as radical and biomimetic reactions. First comprehensive book on this rapidly evolving research area Covers a broad range of homogeneous reactions, such as C-H activation, cross-coupling, synthesis of heterocyclic compounds (Pauson-Khand), and more Chapters on low-valent cobalt complexes as catalysts in coupling reactions, and enantioselective cobalt-catalyzed transformations are also included Can be used as a supplementary reader in courses of advanced organic synthesis and organometallic chemistry Cobalt Catalysis in Organic Synthesis is an ideal book for graduates and researchers in academia and industry working in the field of synthetic organic chemistry, catalysis, organometallic chemistry, and natural product synthesis.

reducing benzil using sodium borohydride: Organic Experiments Louis Frederick Fieser, Kenneth L. Williamson, 1992

reducing benzil using sodium borohydride: Irradiation of Polymers Roger Lee Clough, Shalaby W. Shalaby, 1996 Discusses structural and physiochemical effects of irradiation and presents techniques to model and monitor radiation events. Describes the use of radiation as a sterilization method in the biomedical, pharmaceutical, and food industries. Examines current topics in the stability and stabilization of polymers exposed to ionizing radiation. Reviews advances in the use of radiation with photosensitive metathesis polymers, chemical amplification, and dry-develop resist technology.

reducing benzil using sodium borohydride: *Organic Chemistry* David R. Klein, 2022 Organic Chemistry, 4th Edition provides a comprehensive, yet accessible treatment of all the essential organic chemistry concepts covered in a two-semester course. Presented with a skills-based approach that bridges the gap between organic chemistry theory and real-world practice, the book places special emphasis on developing their problem-solving skills through applied exercises and activities. It incorporates Klein's acclaimed SkillBuilder program which contains a solved problem that demonstrates a skill and several practice problems of varying difficulty levels—including conceptual and cumulative problems that challenge students to apply the skill in a slightly different environment. An up-to-date collection of literature-based problems exposes students to the dynamic and evolving nature of organic chemistry and its active role in addressing global challenges. The text is also enriched with numerous hands-on activities and real-world examples that help students understand both the why and the how behind organic chemistry.

reducing benzil using sodium borohydride: Biomaterials and Bionanotechnology ,

2019-05-29 Biomaterials and Bionanotechnology examines the current state of the field within pharmaceutical sciences and concisely explains the history of biomaterials including key developments. Written by experts in the field, this volume within the Advances in Pharmaceutical Product Development and Research series deepens understanding of biomaterials and bionanotechnology within drug discovery and drug development. Each chapter delves into a particular aspect of this fast-moving field to cover the fundamental principles, advanced methodologies and technologies employed by pharmaceutical scientists, researchers and pharmaceutical industries to transform a drug candidate or new chemical entity into a final administrable dosage form, with particular focus on biomaterials and bionanomaterials. This book provides a comprehensive examination suitable for researchers working in the pharmaceutical, cosmetics, biotechnology, food and related industries as well as advanced students in these fields. - Examines the most recent developments in biomaterials and nanomaterials for pharmaceutical sciences - Covers important topics, such as the fundamentals of polymers science, transportation and bio interaction of properties in nanomaterials across biological systems, and nanotechnology in tissue engineering as they pertain specifically to pharmaceutical sciences - Contains extensive references for further discovery on the role of biomaterials and nanomaterials in the drug discovery process

reducing benzil using sodium borohydride: Advances in Magnetic Materials Sam Zhang, Dongliang Zhao, 2017-02-24 Advances in Magnetic Materials: Processing, Properties, and Performance discusses recent developments of magnetic materials, including fabrication, characterization and applications in the aerospace, biomedical, and semiconductors industries. With contributions by international professionals who possess broad and varied expertise, this volume encompasses both bulk materials and thin films and coatings for magnetic applications. A timely reference book that describes such things as ferromagnetism, nanomaterials, and Fe, ZnO, and Co-based materials, Advances in Magnetic Materials is an ideal text for students, researchers, and professionals working in materials science. Describes recent developments of magnetic materials, including fabrication, characterization, and applications Addresses a variety of industrial applications, such as aerospace, biomedical, and semiconductors Discusses bulk materials and thin films and coatings Covers ferromagnetism, nanomaterials, Fe, ZnO, and Co-based materials Contains the contributions of international professionals with broad and varied expertise Covers a holistic range of magnetic materials in various aspects of process, properties, and performance

reducing benzil using sodium borohydride: Green Chemistry V.K. Ahluwalia, 2021-07-02 This book presents a large number of organic reactions performed under green conditions, which were earlier performed using anhydrous conditions and various volatile organic solvents. The conditions used involve green solvents like water, super critical carbon dioxide, ionic liquids, polymer-supported reagents, polyethylene glycol and perfluorous liquids. A number of reactions have been conducted in solid state without using any solvent. Most of the reactions have been conducted under microwave irradiations and sonication. In large number of reactions, catalysts like phase transfer catalysts, crown ethers and biocatalysts have been used. Providing the protocols that every laboratory should adopt, this book elaborates the principles of green chemistry and discusses the planning and preparations required to convert to green laboratory techniques. It includes applications relevant to practicing researchers, students and environmental chemists. This book is useful for students (graduate and postgraduate), researchers and industry professionals in the area of chemical engineering, chemistry and allied fields.

reducing benzil using sodium borohydride: Reductions by the Alumino- and Borohydrides in Organic Synthesis Jacqueline Seyden-Penne, 1997-09-01 A complete guide to selection and use of the best reagents for a wide range of transformations This book is the updated and expanded Second Edition of Jacqueline Seyden-Penne's practical guide to selection of reducing reagents in organic synthesis. It is an indispensable working resource for organic synthetic chemists-the only reference focusing exclusively on aluminohydrides and borohydrides and their derivatives. Simple to use, it is organized according to specific reductions so that chemists can more

easily match the best reagent to a given transformation. Throughout, Dr. Seyden-Penne emphasizes four crucial categories: compatibility, possibilities for partial reduction, the regio- and stereoselectivity of reductions that are altered or controlled by neighboring groups, and asymmetric reductions. Extremely well-referenced, Reductions by the Alumino- and Borohydrides in Organic Synthesis provides the most up-to-date, detailed coverage of: * Successful techniques for performing highly selective reductions * Chemo-, regio-, stereo-, and enantioselective reductions of both simple and complex compounds * Best methods for obtaining the main functional groups by hydridereduction, provided in quick-reference tabular form * New and more selective reagents developed within the last five years * Experimental conditions, including solvent and temperature, and yields for most cases described.

reducing benzil using sodium borohydride: Cyclodextrin Technology J. Szejtli, 2013-04-17

reducing benzil using sodium borohydride: *Macroscale and Microscale Organic Experiments* Kenneth L. Williamson, 1999

reducing benzil using sodium borohydride: *Organic Experiments* Kenneth L. Williamson, 2004 This text for the two-semester introductory organic chemistry lab offers a series of clear and concise experiments that encourage accurate observation and deductive reasoning. A focus on biochemical and biomedical applications renders the narrative ideal for the mainstream organic chemistry laboratory. Emphasis is also placed on safety and the disposal of hazardous waste. Pre-lab exercises, marginal notes, clear line drawings, and questions help retain student interest and comprehension from lesson to lesson. The Ninth Edition includes In This Experiment objectives that clarify the goals of procedures. Optional, additional For Further Investigation features offer an in-depth exploration of the chemical principles presented.

reducing benzil using sodium borohydride: Organic Experiments Kenneth L. Williamson, Katherine M. Masters, 2010-07-11 The market leader for the full-year organic laboratory, this manual derives many experiments and procedures from the classic Feiser lab text, giving it an unsurpassed reputation for solid, authoritative content. The Sixth Edition includes new experiments that stress greener chemistry, as well as updated NMR spectra and a Premium Website that includes glassware-specific videos with pre-lab, gradable exercises. Offering a flexible mix of macroscale and microscale options for most experiments, this proven manual emphasizes safety and allows instructors to save on the purchase and disposal of expensive, sometimes hazardous, organic chemicals. Macroscale versions can be used for less costly experiments, allowing students to get experience working with conventionally-sized glassware.

reducing benzil using sodium borohydride: Semimicro Experiments in Organic Chemistry Bruce Nelson Campbell, Ernest Ray Kline, 1964

reducing benzil using sodium borohydride: Handbook of Asymmetric Heterogeneous Catalysis Kuiling Ding, Yasuhiro Uozumi, 2008-10-20 In this most up-to-date handbook each chapter contains a general introduction, followed by the principles of the immobilization and, finally, applications. In this way, it covers the most important approaches currently employed for the heterogenization of chiral catalysts, including data tables, applications, reaction types and literature citations. For chemists in both academia and industry as well as those working in the fine chemical and pharmaceutical industry.

reducing benzil using sodium borohydride: *Purification of Laboratory Chemicals* W.L.F. Armarego, 2003-03-07 Now in its fifth edition, the book has been updated to include more detailed descriptions of new or more commonly used techniques since the last edition as well as remove those that are no longer used, procedures which have been developed recently, ionization constants (pKa values) and also more detail about the trivial names of compounds.In addition to having two general chapters on purification procedures, this book provides details of the physical properties and purification procedures, taken from literature, of a very extensive number of organic, inorganic and biochemical compounds which are commercially available. This is the only complete source that covers the purification of laboratory chemicals that are commercially available in this manner and format.* Complete update of this valuable, well-known reference* Provides purification procedures

of commercially available chemicals and biochemicals* Includes an extremely useful compilation of ionisation constants

reducing benzil using sodium borohydride: Organic Reaction Mechanisms V. K. Ahluwalia, Rakesh Kumar Parashar, 2005 This book, written explicitly for graduate and postgraduate students of chemistry, provides an extensive coverage of various organic reaction and rearrangements with emphasis on there application in synthesis. A summary of oxidation and reduction of organic compounds is given in tabular form (correlation tables) for the convenience of students. The most commonly encountered reaction intermediates are dealt with. Applications of organic reagents illustrated with examples and problems at the end of each chapter will enable students to evaluate their understanding of the topic.

reducing benzil using sodium borohydride: *Second Conference on Catalytic Hydrogenation and Analogous Pressure Reactions* , 1969

reducing benzil using sodium borohydride: Novel Trends in Electroorganic Synthesis Sigeru Torii, 2013-03-09 Among the topics of interest to organic chemists today are the versatility and uniqueness of electrolysis procedures in organic synthesis, as well as the latest advances in methodology, including basic concepts for the design of electrolysis conditions and apparatus. The International Symposium on Electroorganic Synthesis met in Kurashiki, Japan, in September 1997 for lectures on all aspects of current research in the field. This volume comprising the papers from the symposium consists of two parts. Part I, Electrooxidation, includes papers on alcohols and phenols, olefins and aromatics, halogenation, polymers, and electrodes, among others. Included in Part II, Electroreduction, are papers on carbonyl compounds, halogen-containing compounds, reaction with EG bases, and metal complexes. The novel trends presented here will be of special interest to researchers and graduate students in electroorganic chemistry and are a valuable resource for all organic chemists.

reducing benzil using sodium borohydride: Annals of the New York Academy of Sciences New York Academy of Sciences, 1969 Records of meetings 1808-1916 in v. 11-27.

reducing benzil using sodium borohydride: Electronic Aspects of Biochemistry , 1969

reducing benzil using sodium borohydride: 1987 Abstracts , 1987

reducing benzil using sodium borohydride: *Microwave Assisted Organic Synthesis* Jason Tierney, Pelle Lidström, 2009-02-12 The first reports on the application of microwaves in organicsynthesis date back to 1986, but it was not until the recentintroduction of specifically designed and constructed equipment,which countered the safety and reproducibility concerns, thatsynthetic application of microwaves has become established as alaboratory technique. Microwave assisted synthesis is now beingadopted in many industrial and academic laboratories to takeadvantage of the novel chemistry that can be carried out using avariety of organic reaction types. This book demonstrates the underlying principles of microwavedielectric heating and, by reference to a range of organic reactiontypes, it's effective use in synthetic organic chemistry. Toillustrate the impact microwave assisted organic synthesis can haveon chemical research, case studies drawn mainly from thepharmaceutical industry are presented.

reducing benzil using sodium borohydride: Handbook of Composites from Renewable Materials, Nanocomposites Vijay Kumar Thakur, Manju Kumari Thakur, Michael R. Kessler, 2017-04-06 This unique multidisciplinary 8-volume set focuses on the emerging issues concerning synthesis, characterization, design, manufacturing and various other aspects of composite materials from renewable materials and provides a shared platform for both researcher and industry. The Handbook of Composites from Renewable Materials comprises a set of 8 individual volumes that brings an interdisciplinary perspective to accomplish a more detailed understanding of the interplay between the synthesis, structure, characterization, processing, applications and performance of these advanced materials. The Handbook comprises 169 chapters from world renowned experts covering a multitude of natural polymers/ reinforcement/ fillers and biodegradable materials. Volume 7 is solely focused on the Nanocomposites: Science and Fundamentals of renewable materials. Some of the important topics include but not limited to: Preparation, characterization, and

applications of nanomaterials from renewable resources; hydrogels and its nanocomposites from renewable resources: preparation of chitin-based nanocomposite materials through gelation with ionic liquid; starch-based bionanocomposites; biorenewable nanofiber and nanocrystal; investigation of wear characteristics of dental composite reinforced with rice husk-derived nanosilica filler particles; performance of regenerated cellulose/vermiculite nanocomposites fabricated via ionic liquid; preparation, structure, properties, and interactions of the PVA/cellulose composites; green composites with cellulose nanoreinforcements; biomass composites from bamboo-based micro/nanofibers; synthesis and medicinal properties of polycarbonates and resins from renewable sources; nanostructured polymer composites with modified carbon nanotubes; organic–inorganic nanocomposites derived from polysaccharides; natural polymer-based nanocomposites; cellulose whisker-based green polymer composites; poly (lactic acid) nanocomposites reinforced with different additives; nanocrystalline cellulose; halloysite-based bionanocomposites; nanostructurated composites based on biodegradable polymers and silver nanoparticles; starch-based biomaterials and nanocomposites; green nanocomposites based on PLA and natural organic fillers; and chitin and chitosan-based nanocomposites.

reducing benzil using sodium borohydride: Journal of the Chemical Society Chemical Society (Great Britain), 1954 Titles of chemical papers in British and foreign journals included in Quarterly journal, v. 1-12.

reducing benzil using sodium borohydride: Encyclopedia of Reagents for Organic Synthesis Leo A. Paquette, 1995

reducing benzil using sodium borohydride: Quarterly Journal of the Chemical Society of London Chemical Society (Great Britain), 1954-11

reducing benzil using sodium borohydride: Detection and Identification of Organic Compounds Miroslov Vecera, 2012-12-06 The American edition of our monograph is not a mere translation of the Czech edition, which appeared some five years ago. We have had to respect the fact that even such a short period has sufficed for progress in this field, and that the field of application of methods of organic analysis has widened. We have therefore revised a number of chapters in Part 1, the general part of the monograph-mainly those devoted to chromatographic methods, which have been extended and complemented by methods of thin-layer chromatography and electrophoresis. The chapters on the theory of color reactions and on analytical literature have also been extended; the chapter on spectral methods has been extended by including the use of proton magnetic resonance in organic analysis, and the list of references has been enlarged by adding books of importance for organic analysis. In Part 2, the part dealing specifically with various elements and chemical groups, we have extended the chapters on solubility and on acids and bases. The methods for the detection and identification of given classes of compounds have also been supplemented by references to recent papers.

reducing benzil using sodium borohydride: Chemistry of Plant Natural Products Sunil Kumar Talapatra, Bani Talapatra, 2015-03-05 Aimed at advanced undergraduate and graduate students and researchers working with natural products, Professors Sunil and Bani Talapatra provide a highly accessible compilation describing all aspects of plant natural products. Beginning with a general introduction to set the context, the authors then go on to carefully detail nomenclature, occurrence, isolation, detection, structure elucidation (by both degradation and spectroscopic techniques) stereochemistry, conformation, synthesis, biosynthesis, biological activity and commercial applications of the most important natural products of plant origin. Each chapter also includes detailed references (with titles) and a list of recommended books for additional study making this outstanding treatise a useful resource for teachers of chemistry and researchers working in universities, research institutes and industry.

reducing benzil using sodium borohydride: Synthesis of Essential Drugs Ruben Vardanyan, Victor Hruby, 2006-03-10 Synthesis of Essential Drugs describes methods of synthesis, activity and implementation of diversity of all drug types and classes. With over 2300 references, mainly patent, for the methods of synthesis for over 700 drugs, along with the most widespread synonyms for these

drugs, this book fills the gap that exists in the literature of drug synthesis. It provides the kind of information that will be of interest to those who work, or plan to begin work, in the areas of biologically active compounds and the synthesis of medicinal drugs. This book presents the synthesis of various groups of drugs in an order similar to that traditionally presented in a pharmacology curriculum. This was done with a very specific goal in mind – to harmonize the chemical aspects with the pharmacology curriculum in a manner useful to chemists. Practically every chapter begins with an accepted brief definition and description of a particular group of drugs, proposes their classification, and briefly explains the present model of their action. This is followed by a detailed discussion of methods for their synthesis. Of the thousands of drugs existing on the pharmaceutical market, the book mainly covers generic drugs that are included in the WHO's Essential List of Drugs. For practically all of the 700+ drugs described in the book, references (around 2350) to the methods of their synthesis are given along with the most widespread synonyms. Synthesis of Essential Drugs is an excellent handbook for chemists, biochemists, medicinal chemists, pharmacists, pharmacologists, scientists, professionals, students, university libraries, researchers, medical doctors and students, and professionals working in medicinal chemistry. * Provides a brief description of methods of synthesis, activity and implementation of all drug types* Includes synonyms* Includes over 2300 references

reducing benzil using sodium borohydride: Protective Groups in Organic Chemistry J. McOmie, 2012-12-06 During the past decade there has been a great increase in the use of protective groups, especially in the synthesis of large and complex organic molecules. Perhaps the greatest activity has been in the peptide field where such triumphs as the total synthesis of insulin and of bovine ribonuclease (molecular weight 13,700) have been achieved. Correspondingly, more protective groups have been devised for the protection of amino and imino groups than for any other functional group. There are many reviews and books on the synthesis of pep tides but there has been no general survey of protective groups since my 1 own review in 1963. At that time the five main methods for the removal of protective groups involved acid or base hydroly sis, reduction, oxidation, or thermal elimination reactions. Recent advances include the use of photo-sensitive and metal ion sensitive protective groups, and the attachment of functional groups to reactive polymers as a method of protec tion during the solid-phase synthesis of peptides and poly nucleotides. Another interesting development is the design and use of protective groups with a built-in 'safety-catch', which can be 'released' by a specific chemical reaction, so that an otherwise stable bond is made labile at the appropriate moment thereby allowing the protective group to be removed under very 2 mild conditions. My own interest in protective groups dates from 1944 when, as a student, I gave two lectures on the subject and produced an 11 page review including 70 references.

reducing benzil using sodium borohydride: Practical Synthetic Organic Chemistry Stéphane Caron, 2020-02-05 This book is a hands-on guide for the organic chemist. Focusing on the most reliable and useful reactions, the chapter authors provide the information necessary for a chemist to strategically plan a synthesis, as well as repeat the procedures in the laboratory. Consolidates all the key advances/concepts in one book, covering the most important reactions in organic chemistry, including substitutions, additions, eliminations, rearrangements, oxidations, reductions Highlights the most important reactions, addressing basic principles, advantages/disadvantages of the methodology, mechanism, and techniques for achieving laboratory success Features new content on recent advances in CH activation, photoredox and electrochemistry, continuous chemistry, and application of biocatalysis in synthesis Revamps chapters to include new and additional examples of chemistry that have been demonstrated at a practical scale

reducing benzil using sodium borohydride: Synthesis of Cyclic Dendroasymmetric Compounds George Gordon Lowry, 1951

reducing benzil using sodium borohydride: *The Organic Chemistry of Drug Synthesis, Volume 7* Daniel Lednicer, 2007-12-14 The classic reference on the synthesis of medicinal agents -- now completely updated The seventh volume in the definitive series that provides a quick yet

thorough overview of the synthetic routes used to access specific classesof therapeutic agents, this volume covers approximately 220 new non-proprietary drug entities introduced since the publication of Volume 6. Many of these compounds represent novel structural types firstidentified by sophisticated new cell-based assays. Specifically, a significant number of new antineoplastic and antiviral agents are covered. As in the previous volumes, materials are organized by chemical class and syntheses originate with available starting materials. Organized to make the information accessible, this resource covers disease state, rationale for method of drug therapy, and the biological activities of each compound and preparation. The Organic Chemistry of Drug Synthesis, Volume 7 is a hands-on reference for medicinal and organic chemists, and a great resource for graduate and advanced undergraduate students in organic and medicinal chemistry.

reducing benzil using sodium borohydride: Fundamentals of Ionic Liquids Douglas R. MacFarlane, Mega Kar, Jennifer M. Pringle, 2017-12-04 Written by experts who have been part of this field since its beginnings in both research and academia, this textbook introduces readers to this evolving topic and the broad range of applications that are being explored. The book begins by examining what it is that defines ionic liquids and what sets them apart from other materials. Chapters describe the various types of ionic liquids and the different techniques used to synthesize them, as well as their properties and some of the methods used in their measurement. Further chapters delve into synthetic and electrochemical applications and their broad use as Green solvents. Final chapters examine important applications in a wide variety of contexts, including such devices as solar cells and batteries, electrochemistry, and biotechnology. The result is a must-have resource for any researcher beginning to work in this growing field, including senior undergraduates and postgraduates.

reducing benzil using sodium borohydride: Journal Chemical Society (Great Britain), 1954

reducing benzil using sodium borohydride: *Journal of the American Chemical Society* American Chemical Society, 1966 Proceedings of the Society are included in v. 1-59, 1879-1937.

reducing benzil using sodium borohydride: Comprehensive Dissertation Index, 1861-1972: Chemistry Xerox University Microfilms, 1973

reducing benzil using sodium borohydride: C-X Bond Formation Arkadi Vigalok, 2010-06-30 Contents: Kilian Muñiz: Transition Metal Catalyzed Electrophilic Halogenation of C-H bonds in alpha-Position to Carbonyl Groups; Arkadi Vigalok * and Ariela W Kaspi: Late Transition Metal-Mediated Formation of Carbon-Halogen Bonds; Paul Bichler and Jennifer A. Love*: Organometallic Approaches to Carbon-Sulfur Bond Formation; David S. Glueck: Recent Advances in Metal-Catalyzed C-P Bond Formation; Andrei N. Vedernikov: C-O Reductive Elimination from High Valent Pt and Pd Centers; Lukas Hintermann: Recent Developments in Metal-Catalyzed Additions of Oxygen Nucleophiles to Alkenes and Alkynes; Moris S. Eisen: Catalytic C-N, C-O and C-S bond formation promoted by organoactinide complexes.