DESTRUCTION OF HAZARDOUS CHEMICALS IN THE LABORATORY

Third Edition

GEORGE LUNN
ERIC B. SANSONE

WILEY

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Preface

This is the third edition of *Destruction of Hazardous Chemicals in the Laboratory*, originally published in 1990 with a second edition in 1994. Many of the monographs from the second edition that deals with specific chemicals have been modified to a greater or lesser extent to take into account recent developments in the literature. Methods for the destruction of pharmaceuticals have been similarly modified and greatly expanded and moved to a separate section. Entirely new monographs have been included, particularly for toxins derived from biological agents.

We have also added a section that deals with non-specific methods for the destruction of hazardous organic chemicals. The methods in this section include potassium permanganate oxidation and the so-called advanced oxidation processes, for example the Fenton reaction and photolysis. They may be of use when no procedures for destroying a particular compound have been reported. In such cases it is particularly important to take stringent safety precautions when dealing with previously untried procedures. These procedures are illustrated with many examples drawn from the literature.

Procedures for the destruction of specific compounds are detailed in the individual monographs, as before. The format for the individual monographs is essentially the same as that used in earlier editions.

As before, this book is a collection of detailed procedures that can be used to degrade and dispose of a wide variety of hazardous materials. The procedures are applicable to the amounts of material typically found in the chemical laboratory. Exotic reagents and special apparatus are not required.

The procedures may readily be carried out, often by technicians, in the laboratory where the hazardous materials are used.

Specific funding for research on methods for degrading hazardous chemicals in the laboratory essentially ended in 1993. However, work continues on procedures for the large-scale destruction of hazardous chemicals in connection with the prevention or remediation of environmental pollution. This type of research is frequently carried out on a laboratory scale and on occasion these laboratory scale experiments provide useful information for researchers wishing to dispose of hazardous chemicals in their laboratory.

We have selected reported procedures that appear to us to be adaptable for laboratory use. The procedures described were selected because it appeared that they could be carried out in the laboratory with readily available reagents and equipment. A number of excellent procedures were omitted because they appeared to require specialized equipment or biological cultures. Procedures in which a critical reagent must be synthesized were also generally avoided. Because the research we cite is generally aimed at developing a process that could be used on an industrial scale, not all aspects of the process may have been thoroughly explored. Complete destruction of the target compound has not always been demonstrated and the extent of degradation has frequently been estimated by us, often from a graph. Additionally the final reaction mixtures were seldom tested for toxicity although major degradation products have been identified in some cases.

Any method that is developed from the research cited should be thoroughly tested before being used on a routine basis. Small changes, for example, reactor geometry or dissolved oxygen, can lead to large changes in the efficiency of the reaction. In some cases reactions may fail to go to completion because of the accumulation of light-absorbing products.

The safe handling and disposal of hazardous chemicals is an essential requirement for working with these substances. We hope that this book will contribute to and encourage the use of tested and sound practices.

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INTRODUCTION

Most biological agents can be inactivated by treating them with formaldehyde, ethylene oxide, or moist heat, and radioactive materials will decay with the passage of sufficient time, but there are no destruction techniques that are universally applicable to chemical agents. The availability of destruction techniques for specific hazardous chemical agents would be particularly helpful because of the dangers associated with their handling and disposal. In addition, being able to destroy or inactivate the hazardous materials where they are used is advantageous because the user should be familiar with the hazards of these materials and the precautions required in their handling.

Here, we present summaries of destruction procedures for a variety of hazardous chemicals. Many of the procedures have been validated, some by international collaborative testing. We have drawn on information available in the literature[1–13] through the end of 2010 with some later publications and on our own published and unpublished work. It is a cause of regret that technological changes have essentially resulted in the closing of many scientific libraries to the general public. It is unfortunate that a work such as this can no longer be written without the access provided by an institutional affiliation.

Destruction of Hazardous Chemicals in the Laboratory, Third Edition. George Lunn and Eric B. Sansone.

About This Book

This book is a collection of techniques for destroying a variety of hazardous chemicals. It is intended for those whose knowledge of the chemistry of the compounds covered is rather sophisticated; that is, for those who are aware not only of the obvious dangers, such as the toxic effects of the compounds themselves and of some of the reagents and other materials used in the methods but also of the potential hazards represented, for example, by the possible formation of diazoalkanes when *N*-nitrosamides are treated with base. If you are not thoroughly familiar with the potential hazards and the chemistry of the materials to be destroyed and the reagents to be used, do not proceed.

In this edition of the book, we have expanded the number of monographs that deal with the destruction of hazardous compounds that are derived from biological sources, for example, ricin, tetrodotoxin, but we do not deal with the destruction of biological organisms themselves. However, it should be noted that guidelines for handling biological materials in the laboratory have been described and specific procedures for their destruction have been published. A survey of the existing literature on this subject is beyond our scope, but overviews of biological safety are available from the Centers for Disease Control and Prevention,[14] the World Health Organization,[15] the National Research Council,[16] and the American Society for Microbiology.[17] Each of these publications deals to a greater or lesser extent with the destruction of biological materials. For a more encyclopedic approach, see McDonnell.[18] Note that steam sterilization, a method of choice for the treatment of much biological waste in laboratories, hospitals, and commercial establishments, does not eliminate all the potential hazards from antineoplastic drug residues.[19]

The destruction methods are organized in what we believe to be rational categories. These categories are listed in the Table of Contents. It is quite likely, however, that others would have categorized these methods differently, so we have provided five indexes. We have assembled many synonyms of the compounds covered into a Name Index. In each case, the page number given is the first page of the monograph in which the destruction of that compound is discussed. In some cases, the compound itself may not have been studied; it may have been referred to in the Related Compounds section. Since it is not possible to cite every synonym and every variation in spelling, we have also provided a CAS Registry Number Index and a Molecular Formula Index. With these aids one should be able to find

the appropriate destruction method for the compound in question. Pharmaceuticals are referred to in the monographs and in the Name Index mostly by their United States Adopted Name (USAN). However, we recognize that many people may be more familiar with these pharmaceuticals by their Trade Names or by their International Nonproprietary Name (INN) or by some other name, so we have provided a Cross-Index of Pharmaceutical Names, which you should consult if you cannot find the name you are looking for in the Name Index. In a similar fashion, many dyes and biological stains have multiple names so in the monograph we have used a common name for each dye and provided a Cross-Index for the various other names that are used.

One of the difficulties in preparing a book such as this is deciding what should be included and what should be excluded from the text. We have tried to make the method descriptions and the supporting references complete, but at the same time not include unnecessary details. We also tried to eliminate ambiguity wherever possible, going so far as to repeat almost verbatim certain procedures for some compounds rather than noting a minor change and referring to another section and so risking a wrong page number or a misinterpretation. Some general safety precautions are given below. These are not repeated for each group of compounds; in some cases, unusual hazards are noted. For many of the destruction procedures we use the word "discard" in connection with the final reaction mixture. This *always* means "discard in compliance with all applicable regulations".

Although we have included all the validated destruction procedures known to us, we realize that there may be other procedures in the literature or in development. Thus, we would be pleased to hear from readers who have any information or suggestions.

Properties of a Destruction Technique

We have already indicated the advantages of destroying hazardous chemicals at the place where they were generated. It is also useful to consider the desirable properties of a destruction technique for hazardous chemicals.

- Destruction of the hazardous chemical should be complete.
- A substantially complete material accountance should be available, with the detectable products being innocuous materials. (This accountance is often difficult to accomplish. In the absence of a complete material accountance, an assessment of the mutagenic activity of the

reaction mixture may provide useful information concerning the potential biological hazards associated with the decomposition products.)

- The effectiveness of the technique should be easy to verify analytically.
- The equipment and reagents required should be readily available, inexpensive, and easy and safe to use. The reagents should have no shelf-life limitations.
- The destruction technique should require no elaborate operations (such as distillation or extraction) that might be difficult to contain; it must be easy to perform reliably and should require little time.
- The method should be applicable to the real world; that is, it should be capable of destroying the compound itself, solutions in various solvents, and spills.

These properties characterize an ideal destruction technique. Most techniques cannot meet all of these criteria, but they represent a goal toward which one should strive.

Contents of a Monograph

Each monograph usually contains the following information:

- An introduction describes the various properties of the compound or class of compounds being considered.
- The principles of destruction section details, in general terms, the chemistry of the destruction procedures, the products, and the efficiency of destruction.
- The destruction procedures section may be subdivided into procedures for bulk quantities, solutions in water, organic solvents, and so on.
- The analytical procedures section describes one or more procedures that may be used to test the final reaction mixtures to ensure that the compound has been completely degraded. The techniques usually involve packed column gas chromatography (GC) or reverse phase high-performance liquid chromatography (HPLC), but colorimetric procedures and thin-layer chromatography (TLC) are also used in some cases.
- The mutagenicity assays section describes the data available on the mutagenic activity of the starting materials, possible degradation products, and final reaction mixtures. The data were generally

obtained from the plate incorporation technique of the *Salmonella*/mammalian microsome mutagenicity assay (see below).

- The related compounds section describes other compounds to which the destruction procedures should be applicable. The destruction procedures have not usually been validated for these materials, however; they should be fully investigated before adopting them.
- References identify the sources of the information given in the monograph.

For pharmaceuticals and nonspecific methods of destruction, however, the nature of the material has led us to take a different approach, and the organization of these monographs is based on the type of reaction under consideration, for example, potassium permanganate oxidation, photolysis.

Mutagenicity Assays

In many cases the residues produced by the destruction methods were tested for mutagenicity. Unless otherwise specified, the reaction mixtures from the destruction procedures and some of the starting materials and products were tested for mutagenicity using the plate incorporation technique of the *Salmonella*/mammalian microsome assay essentially as recommended by Ames et al.[20] with the modifications of Andrews et al.[21] Some or all of the tester strains TA98, TA100, TA1530, TA1535, TA1537, and TA1538 of *Salmonella typhimurium* were used with and without S9 rat liver microsomal activation. The reaction mixtures were neutralized before testing. In general, basic reaction mixtures were neutralized by adding acetic acid. Acidic reaction mixtures were neutralized by adding solid sodium bicarbonate. Reaction mixtures containing potassium permanganate were decolorized with sodium ascorbate before neutralization. A 100 μL aliquot of the solution (corresponding to varying amounts of undegraded material) was used per plate. Pure compounds were generally tested at a level of 1 mg per plate in either dimethyl sulfoxide (DMSO) or aqueous solution. To each plate were added 100 μL of these solutions. The criterion for significant mutagenicity was set at more than twice the level of the control value. The control value was the average of the cells only and cells plus solvent runs. Unless otherwise specified, residues did not exhibit mutagenic activity. The absence of mutagenic activity in the residual solutions, however, does not necessarily imply that they are nontoxic or have no other adverse biological or environmental effects.