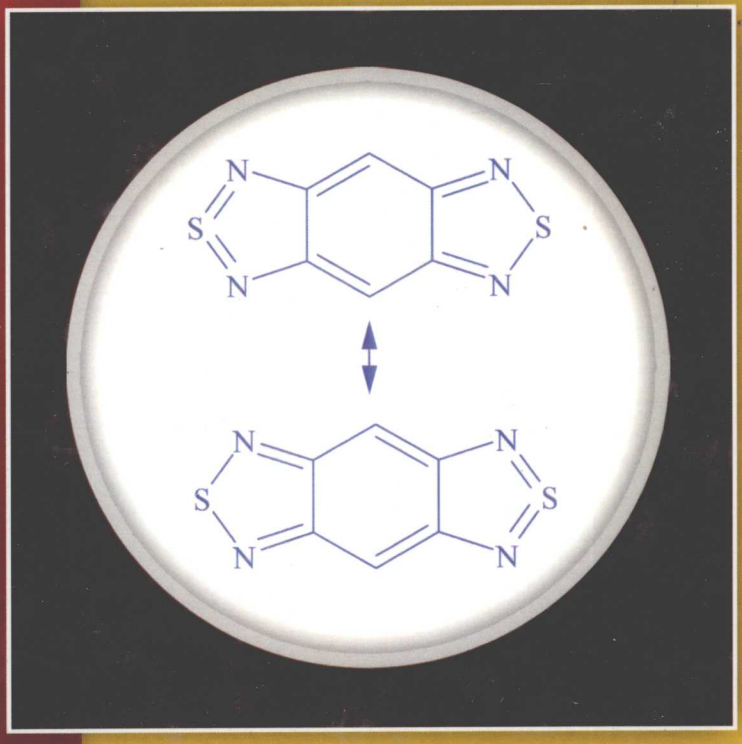
Chalcogenadiazoles

Chemistry and Applications



Zory Vlad Todres

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About the Book

This book offers a timely and authoritative treatise on the chemistry and diverse applications of chalcogenadiazoles—five-membered rings containing two carbons, two nitrogens, and one chalcogen (an atom of oxygen, sulfur, selenium, or tellurium). Chalcogenadiazole oxides and species fused with other cyclic fragments are also considered. The book compares the effects of the chalcogen nature and the alternation manner of all atomic constituents on properties of these heterocyclic compounds. Chemical, physicochemical, and physical aspects as well as biomedical and technical applications are equally considered. Many of the already-available findings deserve to be widened in their usage and need to be advanced, but remain unknown to those working in boundary fields. As a whole, this book covers an important and rapidly developing branch of heterocyclic chemistry and can serve as an essential supplement to the corresponding textbooks for students, especially for those who are about to enter the job market.

Preface

This book considers the chemical, biomedical, and technical importance of chalcogenadiazoles. These compounds contain five-membered cycles composed of two carbons, two nitrogens, and one chalcogen—the latter as the key heteroatom. Chalcogens are chemical elements of VIA group of the periodic system, namely, oxygen (O), sulfur (S), selenium (Se), tellurium (Te), and polonium (Po). At present, all chalcogenadiazoles are known naturally except for the polonium species.

The external shells of the O, S, Se, and Te atoms have s^2p^4 configuration. These elements are isovalent. As the atomic number increases, covalent and ionic radii increase, and ionization energies decrease. At first glance, some similarities between analogously constructed chalcogenadiazoles might be expected. At a narrower glance, the fundamental properties of the key atoms in chalcogenadiazoles vary significantly, and these differences can lead to disparities between the molecules under consideration.

The number of different chalcogenadiazoles and their structural diversity make it difficult to gain a good understanding of the subject by studying an individual class of these hetrocycles. The book tries to identify and emphasize general features of this family of heterocycles. The combined presence of the mentioned atoms endows heterocyclic systems with some specific properties. The book concentrates on properties of each class of chalcogenadiazoles and their cycle-fused derivatives, considering chemical reactions of functional groups only in cases when these properties permit to characterize the heterocycles as substituents or in respect of their aromaticity. Nitrogen-oxides and chalcogen-oxides of these heterocycles are equally discussed.

The properties of chalcogenadiazoles are in many respects defined with electron affinity and electronegativity. For future consideration, it is useful to compare magnitudes of these characteristics. According to handbooks, the electron affinity (in eV) changes as follows: O—1.46, S—2.07, Se—2.02, and Te—1.96. The first ionization potential (eV) drops in the following order: O—13.62, S—10.36, Se—9.75, Te—9.01. Pauling's electronegativities are as follows: N—3.04, O—3.50, S—2.50, Se—2.40, and Te—2.10. From these values and keeping in mind the equal alternation of the atoms in heterocycles, it is possible to predict that the chemical behavior should be more or less similar for thia, selena, and tellura analogs and should differ for oxadiazoles. Namely, the N–O bond should be polarized with a partial negative charge on oxygen, whereas the N–S, N–Se, and N–Te bonds might be polarized in the opposite direction. For chalcogen atoms, oxidation states are variable. Thus, oxygen can bear from –2 to +2 charges, whereas sulfur can change its charge from –2 to +6. Consequently, in chalcogenadiazoles, oxygen must form two ordinary bonds with adjacent atoms, and sulfur can be bivalent or tetravalent. For selenium and tellurium, tetravalent states are possible but less stable.

The size of VIA group elements increases down in the series O < S < Se < Te. The covalent radii are 0.073, 0.103, 0.117, and 0.135 nm, respectively. The size difference can be crucial for crystal packing and for technical applications.

Technically, chalcogenadiazoles are used as dyestuffs, lubricating additives, corrosion inhibitors, and as components of microelectronic devices or solar cells. The heterocyclic compounds under consideration also find their applications in industrial monitoring (analytical) procedures. The material of the corresponding chapters will be analyzed from these points of view too.

Due to the increasing importance of chalcogenadiazoles as medication, their biomedical properties are described in reasonable detail. The focus is on trends in search of compounds with established bioactivity. The traditional drugs of this class can be found in the existing handbooks. Where relevant, new chalcogenadiazoles as agrochemicals or reagents for environmental and biochemical analysis are also considered.

In this book, different classes of chalcogenadiazoles are compared with respect to their degree of aromaticity. Aromaticity is unique in providing a comparison of oxygen, sulfur, selenium, and tellurium systems, with an approach intended to emphasize general concepts that will be helpful to the nonspecialist.

Each chapter is designed to be self contained, and there are extensive cross-references between chapters. The book is divided into four chapters devoted to compounds with oxygen, sulfur, selenium, and tellurium key heteroatoms. Chapters 1 through 3 contains four sections considering 1,2,3, 1,2,4, 1,2,5, and 1,3,4 isomers of the corresponding chalcogenadiazole. At the end of these chapters, a brief comparison of structure–property relationships is given. Telluradiazoles are an exception to this total correlation because the contemporary literature contains only data on 1,2,3 and 1,2,5 isomers. The concluding Chapter 5 compares chalcogenadiazoles from the standpoint of isosterism in chemical, technical, and biomedical aspects.

Each chapter can be read separately from the others. Nevertheless, the materials of different chapters are compared by means of a general outlook and by formulating problems for their future solution. The book is not loaded with mathematical considerations and contains as minimal quantum-chemical thoughtfulness as possible. Its main intent is to serve as a reference tool for future research.

The multidisciplinary approach (that combines data from organic, biological, medicinal, material science, and supramolecular practioners) presents the book as an important source of information not only for chemists in the field of organic, inorganic, organometallic chemistry but also for physicists, biochemists, pharmachemists, agrochemists, and other professionals, who in some way deal with chalcogenadiazoles. The treatise proposed can also serve as a supplement to a textbook on heterocyclic chemistry for senior and doctoral students. This may not be a book for faint-hearted undergraduates, but it can be a guide for students who are about to enter the job market.

We hope that this book will induce some curiosity and attract readers toward this branch of heterocyclic chemistry. On a personal note, I have been involved in some way or the other with various fields of organic, physical organic chemistry, and organic mechanochemistry. However, chalcogenadiazoles were what first attracted

me to the field of chemistry, and this has now lasted a lifetime. I am deeply indebted to my student-years mentor, and whole-life esteemed friend, Professor Lev S. Efros, who made me interested in this elegant and practically important field of chemistry. This interest provided me the incentive for my PhD and ScD (habilitat) theses, although these works were not directly related to this field. This obviously testifies to the fruitful cross-pollination between heterocyclic chemistry and other branches of organic chemistry.

Author

Zory Vlad Todres holds an MSc and a PhD in heterocyclic chemistry as well as a doctor habilitatus in physical organic chemistry. He has authored several books for CRC Press, and his books have been well received by the chemical community. Through his books, he aspires to engraft new and practically important branches to the great tree of organic chemistry. Such titles are *Organic Ion-Radicals* (2003), *Organic Mechanochemistry* (2006), and *Ion-Radical Organic Chemistry* (2009). Presently, he is working on a book entitled *Organic Chemistry in Confinement.*

He is listed in the *Who's Who* of the United States and the United Kingdom sources.

E-mail: zorytodres@yahoo.com

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1 Oxadiazoles

1.1 1,2,3-OXADIAZOLES

1,2,3-Oxadiazole systems hold a distinctive position in the oxadiazole series. There are few compounds really containing the 1,2,3-oxadiazole ring. Most of them exist in the open diazoketone tautomeric form. Sydnones and sydnone imines (that are at present considered as 1,2,3-oxadiazole derivatives) are stable and their chemistry and medical applications are very reach.

1.1.1 Formation

1,2,3-Oxadiazoles were first postulated as intermediates in the 1,3-dipolar cycloaddition of dinitrogen oxide (N_2O) to alkynes (Buckley and Levy 1951). Nevertheless, the unsubstituted 1,2,3-oxadiazole is still unknown and ab initio calculations predict that this compound cannot be isolated as a discrete species even in an inert matrix at low temperatures (Nguen et al. 1985). However, 1,2,3-oxadiazole-3-oxides and aryl-annulated oxadiazoles are stable products. Methods of their preparation are listed below.

1.1.1.1 From Alkynes, or Benzyl Cyanide, or Potassium Malonate

The substrates mentioned form 1,2,3-oxadiazole 3-oxides upon reaction with mononitrogen monoxide in THF at –78°C. Scheme 1.1 exemplifies the reaction with alkyne lithium (Sugihara et al. 2004). A computational study (Wu et al. 2005) explains features of the reaction. Mononitrogen monoxide is a free radical and it reacts with the triple bond as a dimer to form an adduct containing lithium. Water treatment of the adduct leads to the final product.

Scheme 1.2 illustrates formations of the corresponding oxides from benzyl cyanide (Bohle and Perepichka 2009) or from potassium malonate (Arulsamy and Bohle 2002). Both reactions were performed in methanol solution of potassium methylate.

The product of the reaction between potassium malonate and nitrogen oxide of Scheme 1.2 is remarkably stable in acidic or basic medium (Arulsamy et al. 2007).

1.1.1.2 From Nitrosated Mannich Bases

Condensation of aldehydes, hydroxylamine, and cyanide results in the formation of Mannich bases. Being treated with nitrous acid, the Mannich bases form 5-amino-1,2,3-oxadiazole-3-oxides (Scheme 1.3) (Gotz and Grozinger 1971).