

Dipyrrinate and Aminotroponimate Ligand Stabilized Ge(II) and Ge(IV) Compounds: Synthesis, Reactivity, and Biological Applications

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Abstract

The thesis entitled “*Dipyrrinate and Aminotroponimate Ligand Stabilized Ge(II) and Ge(IV) Compounds: Synthesis, Reactivity, and Biological Applications*” presents the details about the synthesis, and reactivity of air and water-stable dipyrrinato germylenes and germacarbonyl compounds, along with the oxidation products of aminotroponimate germylene metal complexes. This thesis is divided into six chapters. A brief description of each chapter is given below:

Chapter 1: This chapter describes *N*-heterocyclic germylenes by talking about their synthesis and reactivity (nucleophilic substitution and oxidation). The applications of germylenes and germacarbonyl compounds as ligands for the isolation of transition metal complexes are also briefed. Based on these discussions, the scope and objectives of the thesis are mentioned.

Chapter 2: This chapter presents the methods employed for cleaning and drying of glassware, purification and drying of solvents (used in synthesis and NMR spectroscopy), and drying of gases. Additionally, preparation and purification of starting materials and handling of air and moisture-sensitive compounds are discussed. The source of various commercially available chemicals are provided. Details regarding instruments used to characterize the synthesized compounds and software used for theoretical studies are also presented.

Chapter 3: The germylenes require an inert atmosphere for their stability. If they are made stable under ambient conditions, their applications in various fields can be explored. Accordingly, this chapter will describe the synthesis of air, water, and culture-medium stable germylene hydroxide DPMGeOH (**303**) and its biological applications. Compound **303** was synthesized under ambient conditions from germylene monochloride DPMGeCl (**302**) using an excess of cesium carbonate. The reactions of air and water stable germylene monochloride DPMGeCl (**302**) with alcohols, methylating agent (MeOTf), and fluorinating agent (CsF) offered germylene alkoxides DPMGeOR (R = Me (**304**), Et (**305**), ⁱPr (**306**)), cationic germanium(IV) compound DPMGeCl(Me)(OTf) (**307**), and germylene monofluoride DPMGeF (**308**), respectively. Interesting conversion of germylene alkoxides **304-306** to germylene hydroxide **303** is also discussed. The air stabilities of compounds **302-304** were monitored for up to 10 days and were stable. The compounds **302**, **303**, and **304** were stable in water for 36 h, 5 d, and 6 h, respectively. The antiproliferative effects of germylene **303** on human cancer lines (HeLa, MCF7, and Huh7) and normal epithelial cells (Vero) were studied using MTT, Trypan blue, and colony formation assays. Compound **303** exhibits comparable/better antiproliferative effects than that of cisplatin, depending on the cell studied. The cytotoxicity of compound **303** on normal epithelial cells is minimal, and this aspect is similar/marginally better to that of the currently used anticancer drugs.

Chapter 4: As the isolation of air and water stable germylenes and the demonstration of their biology applications were possible, the synthesis of hitherto unknown air and water stable germacarbonyl compounds with Ge=E bonds (E = S/Se) are attempted in this chapter. The starting materials used to synthesize these germacarbonyl compounds are dipyrromethene ligand stabilized hydroxygermylene **303**, ethoxygermylene **305**, phenylgermylene **401**, thienylgermylene **404**, and aminogermylene **411**. Germylenes **401**, **404**, and **411** were isolated using monochlorogermylene

302. The reactions of germynes **401**, **404**, **303**, **305**, and **411** with elemental sulfur and selenium powder in toluene at ambient conditions afforded the corresponding germacarbonyl compounds, i.e., germanones **402-403**, **405-406**, germacaroxylic acids **407-408**, germaesters **409-410**, and germaamides **412-413** with Ge=E bonds (E = S/Se), respectively. Interestingly, all these compounds are air and water stable. The attempted synthesis of germaaldehyde **A** through the reaction of germylene hydroxide **303** and alkoxides **304-305** independently with water borane adduct ($\text{H}_2\text{O}\cdot\text{B}(\text{C}_6\text{F}_5)_3$) afforded a germylene cation **414** with a weakly coordinating $[(\text{OH})\text{B}(\text{C}_6\text{F}_5)_3]^-$ anion. Preliminary reactivity studies of the first air and water stable germacarbonyl compounds **412-413** with copper(I) halides resulted in the first air and water stable germaamides stabilized monomeric (**415**, **416**) and dimeric copper(I) halides complexes (**417-420**).

Chapter 5: The catalytic utility of germylene stabilized zinc complexes is rare, and there is no report on their use as hydroboration catalysts. This chapter addresses this issue by studying the aminotroponimate germynes stabilized zinc complexes. The reactions of monochlorogermylene $[(^i\text{Bu})_2\text{ATIGeCl}]$ (**101q**), germylene pyrrole $[(^i\text{Bu})_2\text{ATIGeNC}_4\text{H}_4]$ (**101r**), and aminogermylene $[(^i\text{Bu})_2\text{ATIGeN}(\text{TMS})_2]$ (**101v**) with ZnI_2 in tetrahydrofuran resulted in the germylene stabilized zinc iodide complexes $[(^i\text{Bu})_2\text{ATIGeCl}\rightarrow\text{ZnI}_2(\text{THF})]$ (**501**), $[(^i\text{Bu})_2\text{ATIGeNC}_4\text{H}_4\rightarrow\text{ZnI}_2(\text{THF})]$ (**502**), and $[(^i\text{Bu})_2\text{ATIGeN}(\text{TMS})_2\rightarrow\text{ZnI}_2(\text{THF})]$ (**503**), respectively. The synthesis of germylene stabilized dimeric zinc complexes with Zn_2I_4 core $[(^i\text{Bu})_2\text{ATIGeN}(\text{TMS})_2\rightarrow(\text{ZnI}_2)]_2$ (**504**) and $[(^i\text{Bu})_2\text{ATIGe}^i\text{Pr}\rightarrow(\text{ZnI}_2)]_2$ (**505**) are also reported. Further, the catalytic application of germylene stabilized zinc complex $[(^i\text{Bu})_2\text{ATIGe}^i\text{Pr}\rightarrow(\text{ZnI}_2)]_2$ (**505**) for the hydroboration of aldehydes and ketones is shown. Compounds **501-505** were

characterized through multinuclear NMR spectroscopy, and single-crystal X-ray diffraction studies were performed on compounds **502-505**.

Chapter 6: As the reactivity of germylene stabilized zinc complexes are hardly known, this chapter is devoted to the study of their reaction with chalcogens with an objective to isolate Lewis acid (ZnI_2) stabilized germacarbonyl compounds. Here, the synthesis of germaacid chloride $[(i\text{Bu})_2\text{ATIGe}(\text{E})\text{Cl} \rightarrow \text{ZnI}_2(\text{THF})]$ ($\text{E} = \text{S}$ (**601**), Se (**602**)) and the germaamides $[(i\text{Bu})_2\text{ATIGe}(\text{E})\text{N}(\text{TMS})_2 \rightarrow \text{ZnI}_2(\text{THF})]$ ($\text{E} = \text{O}$ (**604**), S (**607**), Se (**608**)) are reported as their zinc iodide complexes. The synthesis of bisgermacarbonyl compounds, i.e., bisgermaamide $[(i\text{Bu})_2\text{ATIGe}(\text{O})\text{N}(\text{TMS})_2 \rightarrow (\text{ZnI}_2)]_2$ (**605**) and bisgermanones $[(i\text{Bu})_2\text{ATIGe}(\text{E})^i\text{Pr} \rightarrow (\text{ZnI}_2)]_2$ ($\text{E} = \text{O}$ (**609**), S (**610**), Se (**611**)) as their dimeric zinc iodide complexes are also discussed. Further, attempted reactions of germylene pyrrole stabilized zinc complex **502** with N_2O and S/Se leading to the formation of a cationic cyclotrigermoxane **603** with capping μ_3 -oxo ligand and an unidentified mixture of products are discussed, respectively.