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

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Abstract

The thesis entitled “Dipyrrinate and Aminotroponiminate 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 germynes and germa-carbonyl compounds, along with the oxidation products of aminotroponiminate 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 germynes by talking about their synthesis and reactivity (nucleophilic substitution and oxidation). The applications of germynes and germa-carbonyl 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 dipyrrromethene ligand stabilized hydroxygermylene 303, ethoxygermylene 305, phenylgermylene 401, thienylgermylene 404, and aminogermylene 411. Germylenes 401, 404, and 411 were isolated using monochlorogermylene
The reactions of germylenes 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, germacarboxylic 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 (H₂O·B(C₆F₅)₃) afforded a germylene cation 414 with a weakly coordinating [(OH)B(C₆F₅)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 germylenes stabilized zinc complexes. The reactions of monochlorogermylene [(tBu₂ATIGeCl] (101q), germylene pyrrole [(tBu₂ATIGeNC₄H₄] (101r), and aminogermylene [(tBu₂ATIGeN(TMS)] (101v) with ZnI₂ in tetrahydrofuran resulted in the germylene stabilized zinc iodide complexes [(tBu₂ATIGeCl→ZnI₂(THF)] (501), [(tBu₂ATIGeNC₄H₄→ZnI₂(THF)] (502), and [(tBu₂ATIGeN(TMS)₂→ZnI₂(THF)] (503), respectively. The synthesis of germylene stabilized dimeric zinc complexes with Zn₂I₄ core [(tBu₂ATIGeN(TMS)₂→(ZnI₂)]₂ (504) and [(tBu₂ATIGePr→(ZnI₂)]₂ (505) are also reported. Further, the catalytic application of germylene stabilized zinc complex [(tBu₂ATIGePr→(ZnI₂)]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 germyle 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 germa carbonyl compounds. Here, the synthesis of germa acid chloride [(iBu)$_2$ATIGe(E)Cl→ZnI$_2$(THF)] (E = S (601), Se (602)) and the germa amides [(iBu)$_2$ATIGe(E)N(TMS)$_2$→ZnI$_2$(THF)] (E = O (604), S (607), Se (608)) are reported as their zinc iodide complexes. The synthesis of bisgerma carbonyl compounds, i.e., bisgerma amide [(iBu)$_2$ATIGe(O)N(TMS)$_2$→(ZnI$_2$)]$_2$ (605) and bisgermanones [(iBu)$_2$ATIGe(E)iPr→(ZnI$_2$)]$_2$ (E = O (609), S (610), Se (611)) as their dimeric zinc iodide complexes are also discussed. Further, attempted reactions of germyle ne pyrrole stabilized zinc complex 502 with N$_2$O and S/Se leading to the formation of a cationic cyclo triger moxane 603 with capping $\mu_3$-oxo ligand and an unidentified mixture of products are discussed, respectively.