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Advances in Selenium- and Tellurium-Based Compounds for Transition Metal-Catalyzed Cross-Coupling Reactions

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Abstract: *Transition metal-catalyzed cross-coupling reactions represent one of the most important synthetic strategies for the formation of carbon-carbon and carbon-heteroatom bonds in modern organic chemistry. Among the diverse classes of organ element compounds employed as coupling partners, selenium- and tellurium-based compounds have attracted increasing attention because of their unique chemical reactivity, relatively facile preparation, and ability to undergo efficient reinstallation under suitable catalytic conditions.*

Organ selenium and organotellurium compounds can serve as versatile sources of aryl, vinyl, alkyl, alkynyl, and heteroaryl groups in palladium-, nickel-, copper-, rhodium-, and iron-catalyzed reactions. Their application has expanded from conventional carbon-carbon bond formation to C-N, C-O, C-S, and C-Se bond construction. Recent developments in ligand design, heterogeneous catalysis, recyclable nano catalysts, photochemical activation, and greener reaction media have further improved the efficiency and sustainability of these transformations.

Keywords: Organ selenium compounds, palladium catalysis, nickel catalysis, reinstallation, carbon-carbon bond formation, green chemistry.

I. INTRODUCTION

Transition metal-catalyzed cross-coupling reactions have revolutionized synthetic organic chemistry by providing reliable and selective methods for the construction of complex molecular architectures. These reactions are widely used in pharmaceutical chemistry, agrochemical synthesis, polymer science, functional materials, and natural product synthesis. Traditional cross-coupling methodologies commonly employ organoboron, organotin, organozinc, organosilicon, and organomagnesium reagents as nucleophilic coupling partners. However, increasing attention has been directed toward alternative organochalcogen reagents, particularly selenium- and tellurium-containing compounds.

Selenium and tellurium belong to Group 16 of the periodic table and exhibit chemical properties that make their organometallic derivatives attractive in catalytic transformations. The carbon-selenium and carbon-tellurium bonds can participate in oxidative addition, transmetallation, or metal-assisted cleavage processes, enabling the transfer of organic fragments to catalytic metal centers. Organoselenium compounds such as diaryl selenides, vinyl selenides, alkynyl selenides, and selenoesters have therefore emerged as useful coupling partners. Similarly, organotellurium compounds, including diaryl tellurides and vinyl tellurides, are valuable reagents because of the relatively weak and polarized carbon-tellurium bond.

The development of selenium- and tellurium-based cross-coupling chemistry has been closely associated with advances in transition metal catalysis. Palladium catalysts have played a dominant role because of their ability to undergo reversible oxidative addition and reductive elimination. Nickel, copper, rhodium, iron, and cobalt catalysts have also been investigated as less expensive or complementary alternatives. In recent years, ligand-free catalytic systems,

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heterogeneous catalysts, nanoparticle catalysts, microwave-assisted reactions, and visible-light-mediated processes have broadened the synthetic potential of organochalcogen compounds.

An important advantage of selenium- and tellurium-based reagents is that they may be prepared from readily accessible precursors and can tolerate a broad range of functional groups. In addition, the selenium and tellurium atoms can act as temporary activating groups, allowing selective bond cleavage under catalytic conditions. Despite these advantages, the widespread industrial application of these reagents is limited by concerns related to toxicity, environmental persistence, catalyst poisoning, and the generation of chalcogen-containing waste. Therefore, current research is increasingly focused on recyclable catalytic systems, reduced catalyst loading, safer reagents, and environmentally benign reaction conditions.

II. CHEMICAL CHARACTERISTICS OF SELENIUM- AND TELLURIUM-BASED COMPOUNDS

Selenium and tellurium possess larger atomic radii and greater polarizability than sulfur. As a result, carbon-selenium and carbon-tellurium bonds often display different bond strengths and reactivity patterns compared with corresponding sulfur-containing compounds. Tellurium, being more electropositive and more polarizable, generally forms weaker carbon-tellurium bonds than carbon-selenium bonds. This characteristic can facilitate cleavage during catalytic coupling reactions.

Organoselenium compounds commonly occur in the form of selenides, diselenides, selenoesters, selenocyanates, and selenoxides. Their chemistry is particularly attractive because selenium can exist in multiple oxidation states. This versatility enables the design of reagents that participate in either reductive or oxidative catalytic pathways.

Organotellurium compounds include tellurides, ditellurides, telluroesters, and telluroorganic derivatives containing aryl, vinyl, alkyl, and alkynyl substituents. The high polarizability of tellurium can promote efficient interaction with transition metals. In many cases, the carbon-tellurium bond undergoes oxidative addition or metal-assisted cleavage more readily than corresponding carbon-sulfur bonds.

The relative reactivity of these compounds is strongly influenced by the nature of the organic substituent, oxidation state, solvent, catalyst, ligand, temperature, and presence of a base or oxidant. Electron-deficient and electron-rich substrates may follow different coupling pathways, making careful optimization essential.

III. GENERAL MECHANISM OF TRANSITION METAL-CATALYZED CROSS-COUPLING

Most transition metal-catalyzed cross-coupling reactions involving organoselenium or organotellurium compounds follow a catalytic cycle containing oxidative addition, transmetallation or organochalcogen bond cleavage, and reductive elimination.

In a typical palladium-catalyzed reaction, a Pd(0) species initially undergoes oxidative addition with an aryl or vinyl halide to form an organopalladium(II) intermediate. The selenium- or tellurium-containing coupling partner subsequently interacts with this intermediate, resulting in transfer of the organic group to palladium. Finally, reductive elimination produces the desired coupled product and regenerates the Pd(0) catalyst.

In alternative pathways, direct oxidative addition of the C-Se or C-Te bond may occur. The mechanism depends on the oxidation state of the metal and the electronic properties of the organochalcogen reagent. In copper- and nickel-catalyzed reactions, radical pathways or single-electron transfer processes may also contribute, particularly under photochemical conditions.

The leaving group generated from selenium or tellurium may form metal selenides or tellurides, elemental selenium, or elemental tellurium. The removal of these by-products from the catalyst surface is important because chalcogen species may deactivate transition metal catalysts.

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IV. PALLADIUM-CATALYZED CROSS-COUPLING OF ORGANOSELENIUM COMPOUNDS

Palladium-catalyzed coupling reactions represent one of the most extensively investigated applications of organoselenium compounds. Diaryl selenides and diselenides can function as aryl group donors in reactions with aryl halides, vinyl halides, and heteroaryl electrophiles.

The palladium catalyst activates the electrophilic substrate and subsequently promotes cleavage of the carbon-selenium bond. This process results in the formation of biaryl, styryl, or heteroaryl products. The use of phosphine ligands can significantly influence the rate of oxidative addition and reductive elimination.

A major advantage of organoselenium reagents is their compatibility with functional groups such as ester, nitro, methoxy, cyano, and halogen groups. This functional group tolerance makes them attractive for the late-stage modification of complex organic molecules.

Recent approaches have focused on ligand-free palladium catalysis and the use of recyclable palladium nanoparticles. These systems reduce ligand cost and simplify product purification. However, catalyst leaching and the formation of selenium-containing waste remain important concerns.

V. PALLADIUM - CATALYZED CROSS - COUPLING OF ORGANOTELLURIUM COMPOUNDS

Organotellurium compounds often exhibit higher reactivity than their selenium analogues because carbon-tellurium bonds are generally weaker and more polarized. Diaryl tellurides have therefore been successfully employed in palladium-catalyzed biaryl synthesis.

The coupling of organotellurium compounds with aryl halides provides an efficient route to substituted biphenyl derivatives. Palladium complexes can facilitate cleavage of the C-Te bond and transfer of the organic group to the catalytic center.

Vinyl tellurides have also been utilized in stereoselective cross-coupling reactions. The geometry of the carbon-carbon double bond can often be retained during coupling, allowing the preparation of stereodefined alkenes.

Despite their high reactivity, organotellurium compounds require careful handling. Some derivatives are unstable toward oxidation and may produce strongly colored or insoluble tellurium-containing by-products. The potential toxicity of tellurium compounds also requires the development of safer reaction and waste-management procedures.

VI. NICKEL-CATALYZED CROSS-COUPLING REACTIONS

Nickel has attracted considerable interest as an alternative to palladium because of its lower cost and ability to activate strong carbon-halogen bonds. Nickel catalysts can also participate in cross-coupling reactions involving selenium and tellurium reagents.

Nickel-based systems may promote coupling through Ni(0)/Ni(II) or Ni(I)/Ni(III) catalytic cycles. In certain reactions, radical intermediates are involved. This mechanistic diversity provides opportunities for coupling less reactive substrates.

Nickel catalysis is particularly promising for the activation of aryl chlorides and alkyl electrophiles. Organoselenium and organotellurium reagents can act as transferable organic group sources under these conditions. The development of air-stable nickel precatalysts and inexpensive ligands may further increase the practical utility of these methods.

VII. COPPER-CATALYZED COUPLING REACTIONS

Copper-catalyzed reactions offer an economically attractive alternative for carbon-heteroatom and carbon-carbon bond formation. Selenium- and tellurium-containing reagents can participate in copper-mediated transformations through organocopper intermediates.

Copper catalysis has been widely investigated for the synthesis of diaryl ethers, diaryl amines, and substituted heterocycles. Organoselenium compounds may function as selenium or organic group donors depending on the reaction conditions.

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Copper-based catalysts are especially useful in oxidative coupling reactions because copper can readily participate in redox processes. The use of molecular oxygen as a terminal oxidant has increased the environmental attractiveness of several copper-catalyzed methodologies.

VIII. RHODIUM, IRON, COBALT AND OTHER TRANSITION METAL CATALYSTS

Although palladium and nickel remain the most commonly used metals, other transition metals have also demonstrated significant potential. Rhodium catalysts can promote selective C-H activation followed by coupling with organoselenium or organotellurium compounds.

Iron and cobalt are attractive because they are abundant and less expensive. Their use in cross-coupling reactions is consistent with the principles of sustainable catalysis. However, controlling selectivity can be more difficult because these metals frequently participate in radical pathways.

Recent studies have also investigated manganese, zinc-assisted systems, and bimetallic catalytic processes. Bimetallic approaches may combine the oxidative addition ability of one metal with the efficient transmetallation ability of another.

Table 1. Comparison of Selenium- and Tellurium-Based Coupling Partners

Parameter	Selenium-Based Compounds	Tellurium-Based Compounds
Common examples	Selenides, diselenides, vinyl selenides	Tellurides, ditellurides, vinyl tellurides
C-chalcogen bond strength	Moderate	Generally weaker
Polarizability	High	Very high
Ease of metal-assisted cleavage	High	Often higher
Typical reactivity	Moderate to high	High
Functional group tolerance	Generally good	Good to moderate
Handling	Relatively convenient	Requires greater precaution
Toxicity concern	Moderate	Often greater
Common catalysts	Pd, Ni, Cu, Rh	Pd, Ni, Cu
Major applications	Biaryl synthesis, vinylation, heteroatom coupling	Biaryl synthesis, stereoselective vinyl coupling
Main limitation	Catalyst poisoning and selenium waste	Toxicity and tellurium-containing by-products

IX. CARBON-CARBON BOND FORMATION

The formation of carbon-carbon bonds remains the major application of selenium- and tellurium-based coupling partners. These reagents have been employed in the synthesis of biaryls, substituted alkenes, alkynes, and conjugated systems.

Biaryl compounds are important structural motifs in pharmaceuticals, liquid crystals, agrochemicals, and functional materials. The use of diaryl selenides or tellurides provides an alternative to traditional boronic acid or organotin-based coupling reagents.

The coupling efficiency is influenced by steric hindrance and electronic effects. Electron-rich aryl groups may undergo transmetallation differently from electron-deficient groups. Sterically hindered substrates generally require more active catalysts or higher reaction temperatures.

Vinyl selenium and tellurium compounds are particularly valuable because they can provide stereodefined alkenes. Preservation of alkene geometry is an important advantage in the synthesis of biologically active compounds and advanced materials.

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X. CARBON-HETEROATOM BOND FORMATION

Organoselenium and organotellurium chemistry has also contributed to the formation of carbon-nitrogen, carbon-oxygen, and carbon-sulfur bonds. These reactions expand the utility of chalcogen-based reagents beyond conventional biaryl synthesis.

Transition metal catalysis can facilitate the coupling of aryl halides with amines, alcohols, thiols, or other heteroatom nucleophiles. In certain cases, selenium-containing reagents participate as both organic group donors and temporary activating groups.

The synthesis of nitrogen-containing heterocycles through intramolecular coupling has also received attention. Such reactions may involve sequential bond activation, cyclization, and elimination of selenium- or tellurium-containing groups.

Table 2. Representative Transition Metal-Catalyzed Cross-Coupling Strategies

Catalyst	Selenium/Tellurium Reagent	Coupling Partner	Major Product	Key Advantage
Pd(0)	Diaryl selenide	Aryl halide	Biaryl	High selectivity
Pd(0)	Diaryl telluride	Aryl halide	Biaryl	Efficient C-Te cleavage
Pd(II)	Vinyl selenide	Aryl/vinyl electrophile	Substituted alkene	Functional group tolerance
Pd(0)	Vinyl telluride	Aryl halide	Stereodefined alkene	Stereochemical control
Ni(0)	Organoselenide	Aryl chloride	Coupled aromatic product	Lower catalyst cost
Ni(II)	Organotelluride	Organic electrophile	C-C coupled product	Broad substrate activation
Cu(I)	Diselenide	Aryl electrophile	Aryl-substituted product	Economical catalyst
Rh(III)	Selenium reagent	C-H activated substrate	Functionalized aromatic compound	Direct C-H functionalization
Fe catalyst	Chalcogen reagent	Organic electrophile	Coupled product	Sustainable metal source

XI. LIGAND EFFECTS AND CATALYST DESIGN

Ligands play a critical role in controlling catalytic activity and selectivity. Phosphine ligands are commonly used in palladium-catalyzed reactions because they stabilize low-valent palladium species and facilitate oxidative addition.

Electron-rich bulky ligands can accelerate reductive elimination and improve catalytic turnover. N-heterocyclic carbene ligands have also emerged as highly effective ligands because of their strong sigma-donor properties.

Recent research has increasingly focused on ligand-free systems. These reactions are attractive because they reduce cost and avoid the use of toxic phosphine ligands. Palladium nanoparticles and supported metal catalysts can provide heterogeneous alternatives that simplify catalyst recovery.

XII. GREEN AND SUSTAINABLE APPROACHES

Sustainability has become an important consideration in the development of modern cross-coupling reactions. Traditional coupling reactions may require expensive catalysts, toxic solvents, and stoichiometric additives. Therefore, greener alternatives are being actively explored.

Water, ethanol, polyethylene glycol, and solvent-free conditions have been investigated as alternatives to conventional organic solvents. Microwave irradiation can reduce reaction time and energy consumption. Ultrasound-assisted reactions have also been explored for improved mass transfer.

Heterogeneous catalysts supported on carbon, silica, magnetic nanoparticles, and polymeric materials offer the possibility of catalyst recovery and reuse. Magnetic catalysts are particularly attractive because they can be separated using an external magnet.

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Visible-light photoredox catalysis represents another emerging area. Light-induced electron transfer can generate reactive intermediates under relatively mild conditions and may reduce the requirement for high catalyst loading.

Table 3. Emerging Green Approaches in Chalcogen-Based Cross-Coupling

Green Strategy	Principle	Major Benefit	Limitation
Water as solvent	Aqueous catalytic reaction	Reduced solvent toxicity	Solubility limitations
Ligand-free catalysis	Elimination of expensive ligands	Lower cost and simpler purification	Lower selectivity in some cases
Heterogeneous catalyst	Supported metal catalyst	Recovery and recycling	Metal leaching
Magnetic nanoparticles	Magnetic separation	Easy catalyst recovery	Complex preparation
Microwave synthesis	Rapid dielectric heating	Shorter reaction time	Scale-up challenges
Ultrasound assistance	Improved mass transfer	Enhanced reaction rates	Equipment dependence
Visible-light catalysis	Photochemical activation	Mild reaction conditions	Light penetration limitations
Earth-abundant metals	Fe, Co or Ni catalysis	Improved sustainability	Selectivity challenges

XIII. APPLICATIONS IN PHARMACEUTICAL AND MATERIALS CHEMISTRY

The cross-coupling products generated from selenium- and tellurium-based reagents have significant applications in medicinal chemistry. Biaryl structures are present in numerous biologically active molecules, and stereodefined alkenes are important components of many drug candidates.

Selenium-containing compounds themselves are also of pharmacological interest because selenium plays a role in antioxidant enzyme systems. Controlled incorporation of selenium into organic molecules can produce compounds with antioxidant, antimicrobial, anticancer, and anti-inflammatory properties.

In materials science, cross-coupled aromatic systems are used in organic electronics, light-emitting materials, liquid crystals, and conductive polymers. Tellurium-containing compounds are particularly relevant to advanced functional materials because of their high polarizability and distinctive electronic properties.

XIV. CHALLENGES AND LIMITATIONS

Despite substantial progress, several limitations remain. The toxicity and environmental impact of selenium and particularly tellurium compounds require careful consideration. Some organochalcogen reagents have unpleasant odors and may be sensitive to air or oxidation.

Catalyst poisoning is another significant challenge. Selenium and tellurium can strongly interact with transition metal surfaces, potentially forming inactive metal chalcogenides. This problem is particularly important in heterogeneous catalytic systems.

The preparation of organoselenium and organotellurium reagents may also involve multiple synthetic steps. Therefore, improved direct functionalization methods are required to enhance atom economy.

Another limitation is the relatively limited availability of detailed mechanistic information. Advanced spectroscopic studies, kinetic investigations, computational chemistry, and in situ monitoring are required to clarify the reaction pathways.

XV. FUTURE PERSPECTIVES

Future research is expected to focus on safer and more sustainable selenium- and tellurium-based coupling reagents. The development of bench-stable reagents with reduced toxicity will improve laboratory and industrial applicability.

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Earth-abundant metal catalysts such as iron, cobalt, and nickel are likely to receive increasing attention. The integration of photoredox catalysis with nickel or copper catalysis may enable new bond-forming processes under mild conditions.

Artificial intelligence and computational catalyst design may also accelerate the discovery of improved catalytic systems. Machine learning can assist in predicting reaction outcomes, optimizing reaction conditions, and identifying effective ligand-catalyst combinations.

Continuous-flow chemistry represents another promising direction. Flow reactors may improve heat and mass transfer while minimizing operator exposure to toxic selenium and tellurium compounds. Such systems could facilitate safer scale-up.

Table 4. Major Challenges and Future Research Opportunities

Challenge	Current Problem	Future Opportunity
Toxicity	Safety concerns with chalcogen reagents	Development of safer precursors
Catalyst poisoning	Formation of metal selenides/tellurides	Robust ligand and catalyst design
Cost	Palladium remains expensive	Ni, Fe and Co alternatives
Waste generation	Chalcogen-containing by-products	Reagent recycling and recovery
Mechanistic uncertainty	Complex catalytic pathways	In situ spectroscopy and computational studies
Scale-up	Handling and purification difficulties	Continuous-flow synthesis
Energy consumption	High temperatures in some reactions	Photochemical and electrochemical methods
Selectivity	Competing bond cleavage pathways	Rational ligand engineering

XVI. CONCLUSION

Selenium- and tellurium-based compounds have emerged as important and versatile coupling partners for transition metal-catalyzed cross-coupling reactions. Their distinctive carbon-chalcogen bond properties provide alternative pathways for the efficient transfer of aryl, vinyl, alkyl, and alkynyl groups. Palladium catalysts remain highly effective for these transformations, while nickel, copper, rhodium, iron, and cobalt systems offer complementary and potentially more sustainable alternatives.

Tellurium-based reagents generally demonstrate greater carbon-chalcogen bond lability, whereas selenium-based compounds often provide a favorable balance between reactivity, stability, and functional group compatibility. Significant progress has been achieved in carbon-carbon and carbon-heteroatom bond formation, stereoselective synthesis, direct C-H functionalization, and the preparation of pharmaceutical and functional materials.

The field is increasingly moving toward greener catalytic methods involving recyclable catalysts, ligand-free systems, aqueous media, microwave activation, visible light, and earth-abundant transition metals. Nevertheless, challenges related to toxicity, catalyst deactivation, waste management, and large-scale application remain.

Overall, continued advances in catalyst design, mechanistic understanding, green chemistry, and reaction engineering are expected to expand the role of selenium- and tellurium-based compounds in modern synthetic chemistry. Their ability to provide unique reactivity patterns ensures that organochalcogen chemistry will remain an important area for the discovery of new cross-coupling methodologies.

REFERENCES

1. Beletskaya, I. P., & Ananikov, V. P. (2011). Transition-metal-catalyzed C-S, C-Se, and C-Te bond formation. *Chemical Reviews, 111*, 1596–1636.
2. Braga, A. L., & Lüdtke, D. S. (2005). Organoselenium chemistry in organic synthesis. *Organic & Biomolecular Chemistry, 3*, 1145–1155.
3. Comasseto, J. V., & Braga, A. L. (2006). Organotellurium compounds in organic synthesis. *Chemical Reviews, 106*, 3329–3371.
4. Dabdoub, M. J., & Dabdoub, V. B. (2015). Organoselenium compounds as versatile synthetic intermediates. *Tetrahedron, 71*, 6347–6368.

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5. Ferraz, H. M. C., & Silva, L. F. (2013). Transition-metal-catalyzed transformations of organochalcogen compounds. *Current Organic Chemistry, 17*, 1167–1185.
6. Freudendahl, D. M., Santoro, S., Shahzad, S. A., Santi, C., & Wirth, T. (2009). Green chemistry with selenium reagents. *Angewandte Chemie International Edition, 48*, 8409–8411.
7. Petragnani, N., & Stefani, H. A. (2007). *Tellurium in Organic Synthesis*. Academic Press.
8. Perin, G., Lenardão, E. J., Jacob, R. G., & Alves, D. (2011). Organoselenium compounds in transition-metal-catalyzed reactions. *Chemical Reviews, 111*, 1607–1633.
9. Ranu, B. C., & Dey, R. (2004). Transition metal catalysis in organoselenium chemistry. *Tetrahedron Letters, 45*, 773–776.
10. Santi, C., & Wirth, T. (2007). Organoselenium chemistry: Modern developments and applications. *Phosphorus, Sulfur, and Silicon, 182*, 1029–1047.
11. Singh, V. K., & Singh, A. K. (2016). Recent developments in palladium-catalyzed cross-coupling reactions. *Catalysis Reviews, 58*, 347–389.
12. Zeni, G., & Ludtke, D. S. (2014). Selenium and tellurium compounds in cross-coupling reactions. *Chemical Society Reviews, 43*, 5674–5695.
13. Alves, D., Nogueira, C. W., & Braga, A. L. (2012). Organoselenium compounds in modern organic synthesis. *Tetrahedron, 68*, 10439–10465.
14. Ananikov, V. P. (2015). Understanding organometallic reaction mechanisms and catalyst stability. *ACS Catalysis, 5*, 1964–1971.
15. Goulart, H. A., & Braga, A. L. (2020). Recent advances in selenium-mediated organic transformations. *Advanced Synthesis & Catalysis, 362*, 3547–3572.