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Review Article

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HTIB and $PhICl_2$ Hypervalent Iodine Reagents: Versatile and Prominent Reagents in Synthetic Chemistry

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Abstract

Hypervalent iodine reagents are versatile, realistic, and ubiquitously used in organic and inorganic chemistry. Hypervalent iodine reagents have been used since the early twenty century by chemists and in this long time a large plethora of hypervalent iodine reagents have been designed by researchers. Well-known hypervalent reagents hydroxyl(tosyloxy)iodobenzene (HTIB) and iodobenzene dichloride ($PhICl_2$) have advantageous characteristics of innocuous, environmental-friendly, economical, readily available, high stability, and easy to handle, which make it highly applicable in synthesis chemistry. Iodine is present in a +3-oxidation state in these hypervalent iodine reagents, this oxidation state makes iodine a strong electrophile. Higher electrophilic nature combined with good leaving groups makes hypervalent iodine an epicenter of nucleophilic attacks and nucleophilic attacks are the pivotal step in the chemistry of these hypervalent iodine reagents. These hypervalent iodine reagents being highly pragmatic synthons play their role perfectly in general oxidation to selectively oxidation, halogenation, arylation, hetero-arylation, aminations, rearrangement, cyclization, carbon-carbon, carbon-hetero bond-forming, and alkylation. HTIB and $PhICl_2$ are easy to convert into other hypervalent iodine reagents.

Keywords

Organohypervalent iodine, Hydroxyl(tosyloxy)iodobenzene, Iodobenzene dichloride, Oxidations, Koser's reagent, Rearrangements

Introduction

Hypervalent iodine reagents have recently become industry standard for arylation of a wide range of nucleophiles in both metal-free and metal-catalyzed circumstances [1-4]. Because of the strong electrophilicity of iodine (III) and iodine (V) reagents, reactions can occur under moderate circumstances, and highly selective reaction results are frequently reported [5-9]. Hypervalent iodine reagents are not new to organic synthetic chemists but ubiquitously use of these reagents till present has good reasons. Hypervalent iodine has reactivity similar to transition or heavy metals but non-toxic, mild, readily available, higher stable, environmentally friendly, etc. characteristics that make the hypervalent iodine more preferred over the metallic catalysts [10-12]. Mostly hypervalent iodine reagents are found in solid states whether in amorphous or crystalline structures and have good stability in general conditions with some exceptions, which may be generated *in situ* [1]. The history of hypervalent goes centuries back, when 'Willgerodit Reagent' the first hypervalent iodine reagent, in 1886, was discovered [3, 5, 7, 13-16]. Hypervalent iodine throughout this span has a large plethora of reagents from Koser's reagent to most recently IBX or DMP, from cyclic Iodinanes to oxo-bridged iodanes reagents, having whether +3 or +5 oxidation states (Figure 1 and 2)[17].

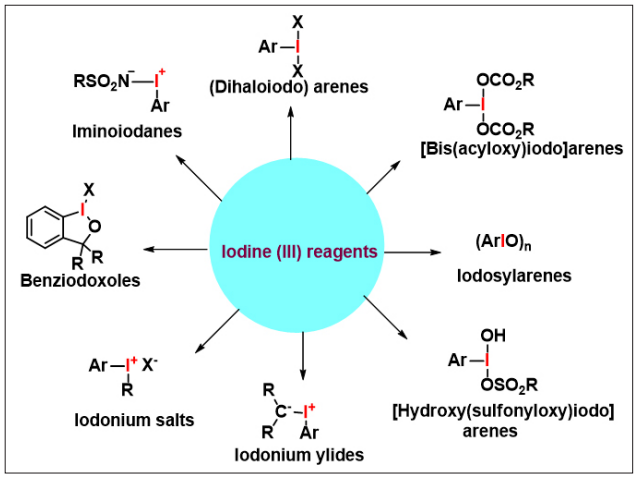


Figure 1: General classification of iodine (III) reagents.

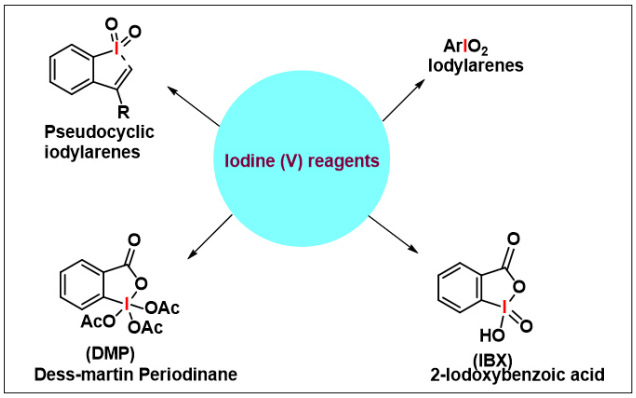


Figure 2: General classification of iodine (V) reagents.

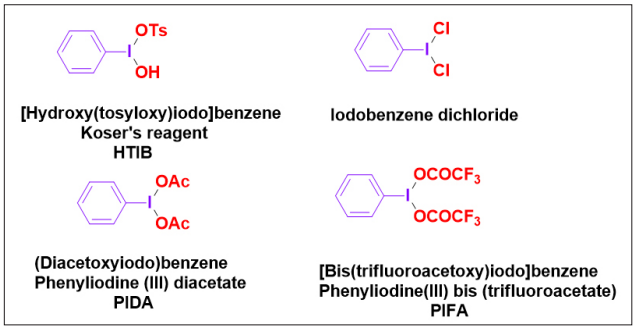


Figure 3: Iodine (III) reagents used in arylation having two heteroatom ligands.

Hypervalent iodine being a highly pragmatic synthon, plays its role perfectly in general oxidation to selectively oxidation, halogenation, arylation, hetero-arylation, aminations, rearrangement, cyclization, carbon-carbon, carbon-hetero bond-forming, and alkylation [18, 19]. Recently, prepared hypervalent iodine reagents are used in enantioselective synthesis, asymmetrical synthesis, regio selectively synthesis, and symmetric synthesis [20, 21]. The inclined reduction of iodine higher valency to more stable standard- valency *via* reductive-elimination is pivotal in the reactivity of the reagents [22]. Hypervalent iodine reagents react electrophilic, generally, its reaction proceeds in three major protocols (i) reductive elimination, (ii) ligand coupling, and (iii) ligand exchange as well as single electron transfer, homolytic cleavage giving a radical path [23]. The strong electrophilic nature of hypervalent iodine makes it prone to nucleophilic attack, the further tendency as a better leaving group of PhI enhances the reactivity of the reagents [24].

Hypervalent Iodine Compounds

Heterocycle building components may be found in an inclusive range of physiologically vigorous natural and synthetic compounds, and they are frequently used in the production of medicines, pesticides, dyes, and synthetic polymers [25-27]. In arylations, a variety of hypervalent iodine compounds can be used, the most common of which being iodine (III) reagents [28]. They are further categorized based on the iodine ligands. Reagents bearing two heteroatom ligands are mostly utilized as oxidants and are key umpolung reagents in the arylation of some heteroatom nucleophiles and the production of biaryls (Figure 3) [29]. Iodonium salts contain two carbon ligands, one of which is transferred to nucleophiles. The most frequent arylation salts are diaryliodonium salts (diaryl-λ^3-iodanes) [30-32]. By transferring the alkynyl or vinyl moiety to arenes, other iodonium salts can likewise be employed to obtain C-arylated compounds. Trivalent iodine compounds are known to as λ^3-iodanes, whereas pentavalent iodine compounds are known to as λ^5-iodanes[32, 33].

In X-ray structures, iodine (III) compounds have a T-shaped geometry, with the aryl group in an equatorial position and the other ligands sharing a 3c–4e hypervalent bond [34-36]. Because iodine atom in these reagents possesses more than eight electrons in its valence shell, therefore iodonium salts meet the requirements for being hypervalent. Organo hypervalent iodine compounds are widely used as oxidizing agents and electrophilic reagents in organic synthesis [4, 37, 38]. Hypervalent iodine reagents show radical type reactions, single-electron transfer reactions, and homolytic reactions under the appropriate circumstances (Figure 4) [39, 40].

Kamal et al. [41], designed a new synthesis strategy to prepare geminal β,β-ditosyloxy ketones **3** from HTIB **2** and α,β unsaturated ketone **1** in a polar aprotic solvent i.e., dichloromethane (CH_2Cl_2). The product may work as a precursor of β-keto aldehyde increasing the importance of methodology. Density functional theory and quantum-chemical calculation favors the geminal form over the vicinal forms of the ditosyloxy ketones according to the researchers. The methodology has a high tolerance of substituents on both aryl groups. An aprotic solvent is a must condition, and the best-proven solvent is CH_2Cl_2. The plausible reaction mechanism ascertains that reaction starts with an electrophilic attack by $Ph(OH)I^+$

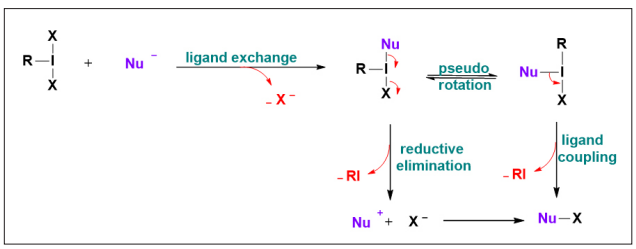


Figure 4: General mechanism for the organo-iodine (III) reagent.

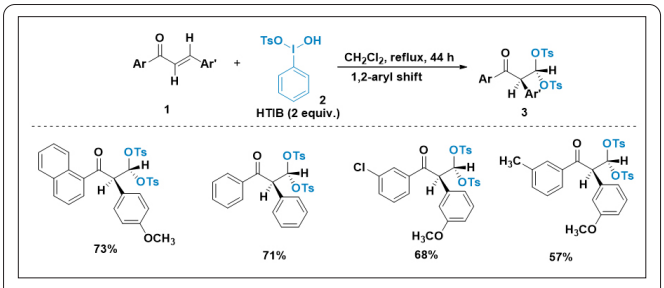
on the C=C bond of chalcone (substrate) followed by nucleophilic attack of OTs^- on β-carbon to the carbonyl. Lone pair on the oxygen of the -OTs group promotes the 1,2-migration of the aryl group, releasing OH^- and PhI group and making β-carbon prone to nucleophilic attack by OTs^-, in the last step nucleophilic attack of OTs^- on β-carbon to ketone give the desired product. The resulting geminal ditosyloxy ketone **3** acts as a precursor in the synthesis of trisubstituted pyrazoles and disubstituted isoxazole (Scheme 1).

Khan and team [42] developed the ring expansion strategy to synthesize seven-membered heterocycles **5** and heterocyclic fused rings applying hypervalent iodine (HTIB) **2**. The methodology proceeds in mild condition, without any metal-catalyst and is environmentally friendly; this methodology was highly successful in the aqueous-acetonitrile reaction medium, having high functional group tolerance, giving high yield. The plausible reaction mechanism explains that a nucleophilic attack by H_2O on carbocation, the carbocation is originated by the electrophilic attack of HTIB on vinyl carbon, gives the aliphatic HTIB intermediate. The aryl bond migration and elimination of the H_2O and PhI from the intermediate give the targeted product (Scheme 2).

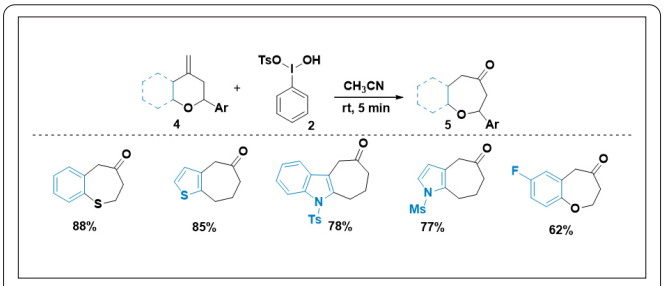
Ravindra D. Jadhav et al. [43], developed a one-pot simplified method to prepare 3,5-disubstituted isoxazole **8** using hypervalent iodine (HTIB) reagent **2**. The methodology was simple, straightforward, and results in a highly pure product with a simplified purification process. The yields were negligible on having electron-donating substitute on aryl aldoxime, contrary to it electron-withdrawing substitutes give good yields. The detection of products may be done with titration without any chromatography. The reaction proceeds with aromatic nitrile oxides intermediate **7** originated from aryl aldoxime **6**; followed by cycloaddition between intermediate **7** and alkyne (Scheme 3).

Vitor H. Menezes and his team [44] evolved a new technique for the synthesis of trans-1,3-disubstituted indane **11** *via* the ring contraction of 1,2-dihydronapthalenes **10** using hypervalent iodine (HTIB) **2** in a metal-free condition. The methodology was highly important due to its deep investigation on the role of solvent (here CH_3OH) torsional effects on stereoselectivity (here *trans* preferred over *cis*) and on energy potential barrier, using the density functional theory and continuum-micro solvation model system. According to computational studies, [45] investigators described that three major steps happen in this reaction i.e., electrophilic addition of HTIB **2** to unsaturated bond of alkene, nucleophilic attack by methanol solvent on carbocation, which is generated by the electrophilic attack on olefinic, in third step migration of aryl group making oxidative rearrangement, results in the desired products **11** (Scheme 4).

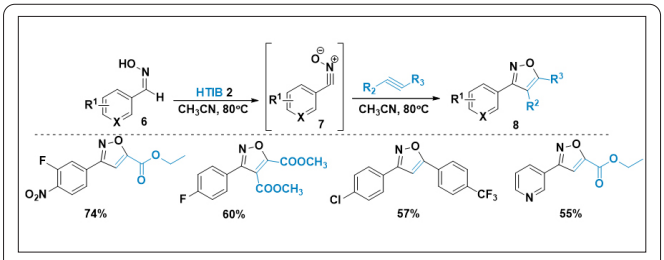
Dhananjay Bhattacherjee et al. [46], designed a unique and effective path to the synthesis of cabazolones and imidazo [1, 2-a] pyridines **13** through intramolecular annulation of exocyclic β-enanminones **12** promoted by a collaborative combination of two reagents hypervalent iodine (HTIB) **2** and $AgSbF_6$. The methodology investigated by deuterium labeling experiment and spectroscopic data describes those two rival



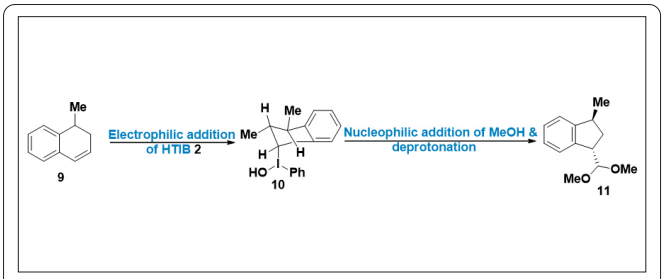
Scheme 1: Synthetic protocol for geminal ditosyloxy ketone **3**.



Scheme 2: HTIB-facilitated ring expansion reaction.



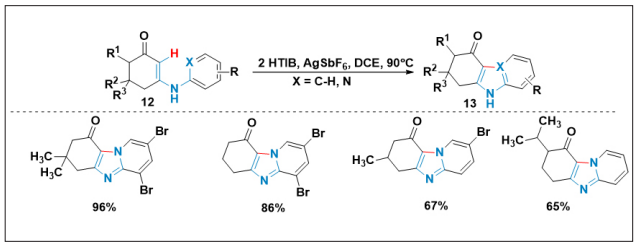
Scheme 3: Synthesis of disubstituted isoxazole **8** and representative examples.



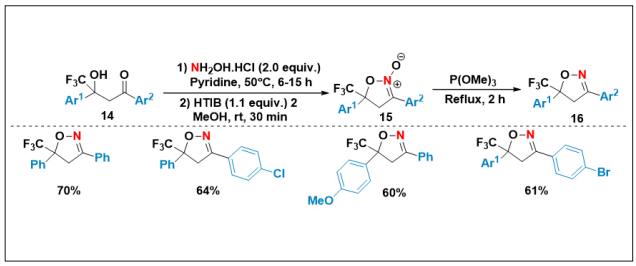
Scheme 4: HTIB mediated formation of indanes **11**.

reactions go parallel to each other, but $AgSbF_6$ plays crucial role *via* metathesis step steering off the reaction in the desired direction. Iodonium salts combined with SbF_6^- start free radical reaction, which makes intramolecular annulation feasible *via* creating C-N and C-C bonds and leading toward targeted products. The methodology has good functional group tolerance and EDG or EWG substituents do not have any significant effects on yields and any single reagent is unable to give even a trace amount of targeted product (Scheme 5).

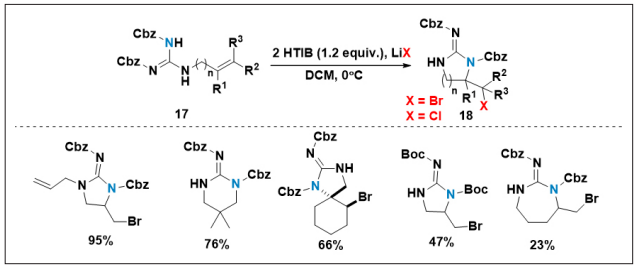
Hiroyuki Kawai and his fellows [47] designed a highly effective protocol for the synthesis of 5-trifluoro-methyl-2-isoxazoline *N*-oxide **16**, which may be readily enantio selectively reduced to anti-parasitic 5-triflouro-methyl-2-isoxazoline (A). The research team synthesized the 5-triflouro methyl-2-isoxazoline through oxidative N-O coupling between



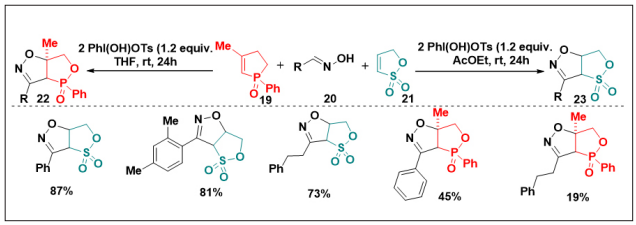
Scheme 5: Intramolecular annulation of exocyclic β-enanminones **12** and selected examples.



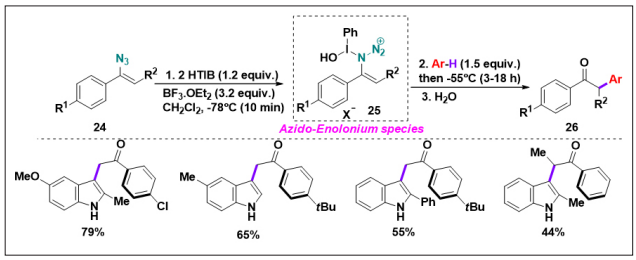
Scheme 6: Synthesis of isooxazoline **16** and selected examples.



Scheme 7: Cyclization reaction of unsaturated guanidines **18**.



Scheme 8: Oxidative Heterocyclization of aldoximes **20** and selected examples.



Scheme 9: Azido-Enolonium **25** based reaction and selected examples.

β-hydroxy ketoximes which is originated from trifluoromethyl β-keto alcohol and NH_2OH reaction promoted by hypervalent iodine (HTIB) known as Koser's reagent **2**. The methodology is highly potent in enantioselective synthesis of targeted product and the antiparasitic drugs (A). The methodology has high functional tolerance and equally effective on presence of EDG and EWG substituents on aryl moiety of (X). The reaction proceeds in very mild and simple condition, in two simple steps, first (X) reacting with NH_2OH results in aldoxime derivatives and in second step aldoxime derivatives reacts with HTIB **2** and gives the desired product **16** (Scheme 6).

Marion Daniel et al. [48], developed a highly effective and versatile protocol for the synthesis of halogenated cyclic guanidine **18** of various sizes by employing hypervalent iodine (HTIB) **2** promoted umpolung for lithium halide salts. The cyclization occurs mostly in *exo* mode with highly regio and stereoselectivity. This methodology has a large scope of guanidine substrate tolerance and gives a broad scope of various substituents on olefinic to prepare rings having different kinds of functional groups. This transformation gives moderate to good yields for five and six-membered rings but a little lower for seven membered rings. Both bromo- and chloro cyclization of guanidine can be achieved easily but bromo substituted five-membered cyclo-guanidine provides a huge scope of synthesis of various bio-active products (Scheme 7).

Akira Yoshimura and his fellows [49], invented a potent strategy for the synthesis of isoxazoline fused heterobicyclic compounds of sultones **23** and phospholines **22** *via* oxidative intermolecular cyclization, promoted by hypervalent iodine (Koser's reagent) **2**. The methodology was equally effective in the synthesis of isoxazolin-fused bicyclic phospholine **22** and isoxazoline-fused bicyclic sultone **23**. The transformation has a broad scope of aldoxime substrates and gives good to moderate yields with high regioselectivity. The plausible reaction mechanism explains that nitrile oxide intermediate was originated through oxidation of aldoxime by Koser's reagent **2**. Further, nitrile oxide undergoes intermolecular 1,3-dipolar cycloaddition with heterocyclic alkenes resulting in the desired products (Scheme 8).

Atul A. More and co-workers [50] evolved a new methodology for the synthesis of azido-enolonium species **25** by making a reaction between Koser's reagents (HTIB) **2** provoked by $BF_3.OEt_2$ and vinyl azides **24** in mild and metal-free conditions. This transformation has a broad scope in synthesis chemistry because prepared azido-enolonium species readily react with aryl-groups, benzene derivates, azoles, allyl trimethylsilanes, and triazoles, and forms C-N, C-C bonds which may be further hydrolyzed to give α-functionalized ketones **26**. The reaction mechanism and intermediates in this methodology were deeply studied by spectroscopic techniques. The methodology has a large functional group tolerance both on vinyl azides **24** and at reacting species of azide-enoloniums **25** (Scheme 9).

Bowen Xu et al. [51], developed a productive reaction method, promoted by hypervalent iodine (Koser's reagent) **2** for tosylation on 3-position of 4-hydroxycoumarine **27** in a metal-free, mild condition. This transformation is highly applicable in synthesis of various pharmacophores like warfarin. The stratagem affords large diversity of substituents on the aryl motif of HTIB **2**, as well as this scheme has a high tolerance for various functional groups on substrate 4-hydroxycoumarine. The feasible reactions mechanism details that a

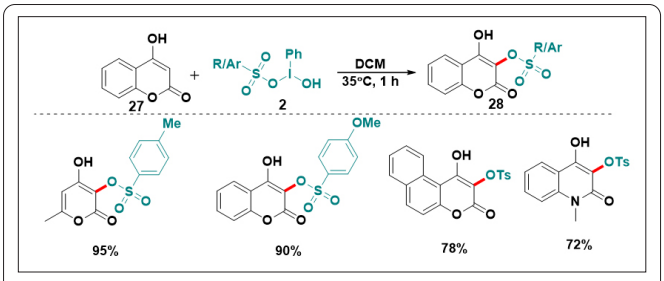
nucleophilic attack occurs on electrophilic iodine of HTIB by 4-hydroxycoumarine **27** in enol-keto tautomerism form, producing iodine ylide by elimination of TsOH. The nucleophilic attack by TsOH, extrudes the iodine aryl ion in the PhI form to produce the desired product **28** (Scheme 10).

Shimon Maksymenko et al. [52], evaluated an alternative path for highly regioselective α-arylation of enolonium species, which is generated from readily available TMS-enolate **29** and Koser's reagent **2** actives by $BF_3.Et_2O$. The transformation has huge importance since it precludes the necessity of transition-metal catalysts and pre-functionalized aryl halides substrate and proceeds in mild conditions. The methodology bypasses the conventional hindrance of dimerization of aryl groups, diaryliodonium, polymerization and other side reactions of aryl groups in acid mediums. The methodology affords a large diversity of functional groups and substituents on both enolonium species **30** and aromatic substituents. The possible reactions mechanism elaborates that an electrophilic substitution attack occurs by nucleophilic aromatic substrates on α-carbon of enolonium species; the attack expels the PhI and OH^- and results in the desired products (Scheme 11).

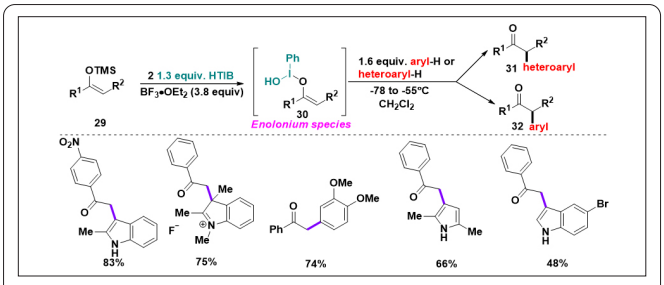
Atul More et al. [53], extended the technique of α-functionalization (the previous was arylation/alkylation) of enolonium species **29** to α-amination and α-azidation. The enolonium species stemmed from umpolung ketone enolates and hypervalent iodine (HTIB) **2** mediated by $BF_3.Et_2O$ undergoes α-amination/azidation in a metal-free, mild condition in a very lesser time than classical methods and gives good yields. This methodology tolerates a huge diversification of functional groups and substituents on phenyl moiety of enoloniums and equally affords various azole substrates. The feasible reaction mechanism was equal to previous α-arylation methods, this starts with a nucleophilic attack by *N*-atom of azides on α-carbon of enoloniums, expelling PhI and OH^- gives desired product **34** and **35** (Scheme 12).

Myriam S. Carle and co-workers [54] invented an effective approach to chlorination of carboxylic acids **36** and benzyl alcohols providing carboxylic chlorides **38** and benzyl chlorides by *in situ* generated dichlorotriphenylphosphorane (Ph_3PCl_2). The chlorinating agent phosphorane (Ph_3PCl_2) is *in situ* engendered from easily available PPh_3 and iodobenzene dichloride ($PhICl_2$) **37**, which instantly converts carboxylic acids and benzyl alcohols into carboxylic chlorides and benzyl chlorides approved by a time-lapse ^{31}P NMR test. The methodology tolerates a large number of substrates of carboxylic acids bearing various types of functional groups and is equally compatible with saturated and unsaturated carboxylic acids or alcohols. The reaction proceeds in moisture less conditions, giving excellent yields. The approach provides a worthwhile path to prepare esters, diazoketones, and amides from carboxylic chlorides by mixing alcohols, phenols, CH_2N_2 or amines during reactions (scheme 13).

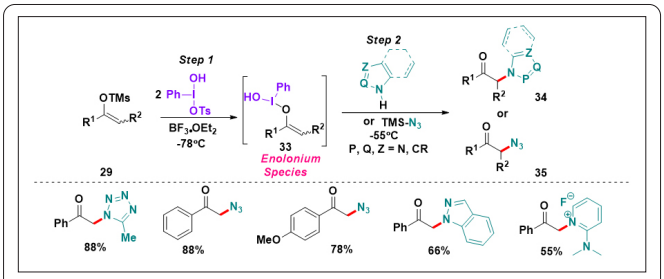
Yunfei du and co-workers [55] developed an effective protocol for synthesis of *N*-alkoxyindole 3-carbonitrile **42** in a mild state, one-pot fashion method. The reagents used in this transformation 3-alkyoxyimino-2-arylalkylnitriles **40** as a substrate activated by hypervalent Iodine ($PhICl_2$) **37** and



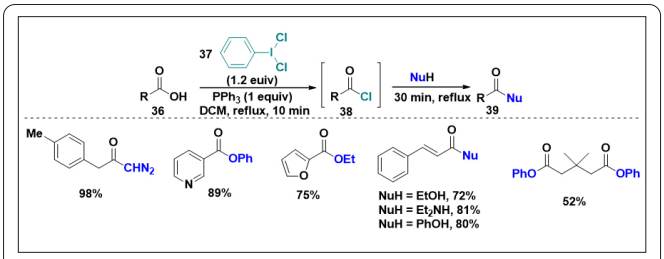
Scheme 10: HTIB mediated tosyloxylation of hydroxycoumarins **27**.



Scheme 11: Arylation of ketone and selected examples.



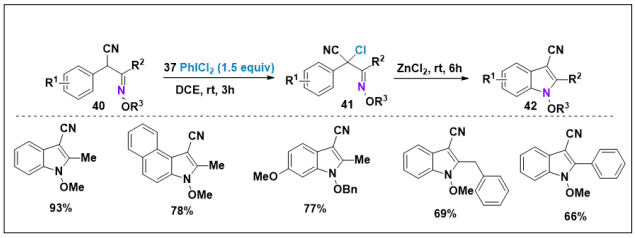
Scheme 12: Amination and azidation by enolonium species.



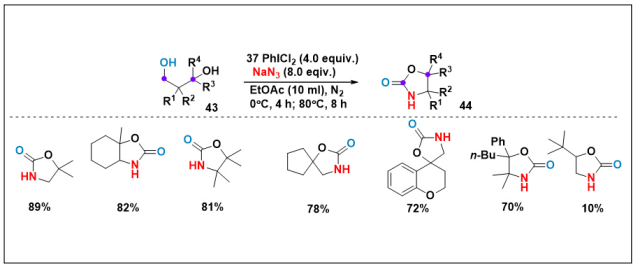
Scheme 13: Amidation and esterification of carboxylic acid and representative examples.

$ZnCl_2$ are inexpensive and readily available. The transformation proceeds *via* a vital intermediate nitrenium ion, which is engendered by chlorination-dechlorination of the substrate by $PhICl_2$ **37**. The plausible reaction mechanism believes that reaction starts with a nucleophilic attack on iodine atom of $PhICl_2$ **37** by *N*-atom of the substrate, at the last step intramolecular heterocyclization occurs by nitrenium ion resulting in the desired product. This method has high potential in the synthesis sector since the product *N*-alkoxyindole carbonitrile facilitates an easy path for synthesis of various natural and pharmaceutical compounds (Scheme 14).

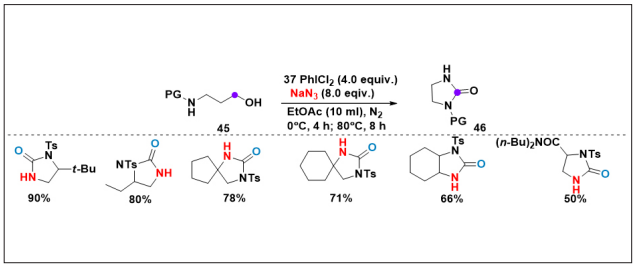
Tian He et al. [56], evolved a simple but highly effective strategy for the synthesis of oxazolidin-2-ones **44** (Scheme 15) and imidazolidin-2-ones **46** (Scheme 16) employing a mixture of reagents sodium azide (NaN_3) and iodobenzene di-



Scheme 14: Iodobenzene dichloride **37** mediated synthesis of alkoxyindole carbonitrile **42**.



Scheme 15: Synthesis of 2-oxazolidone **44** and selected examples.



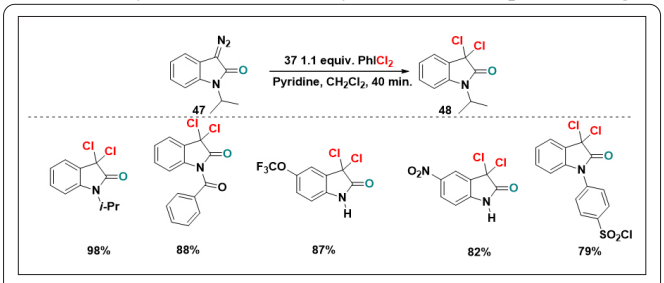
Scheme 16: Synthesis of imidazolidinone **46** and selected examples.

chloride ($PhICl_2$) **37** with substrates 1,3-diols **43** and 3-amino alcohols **45**, respectively. The methodology affords a large diversity of both substrates bearing various functional groups or substituents. The methodology also gives excellent yields in both kinds of products. The feasible reaction mechanism explains that aryl-azide is produced by the reaction of substrates with $PhICl_2$-NaN_3 reagents combination, which undergoes Curtius rearrangement to give isocyanate functionality. The nucleophilic attack by hydroxyl or amino groups on isocyanate moiety makes intramolecular cyclization which results in targeted products.

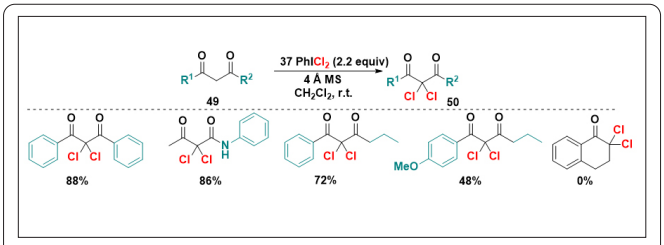
Graham K. Murphy and co-workers [57] designed a broadly applicable scheme for α-carbonyl dichlorination of 2-oxindoles **47** generating the product 3,3–dichloro-2-oxindoles **48**, by using iodobenzene dichloride ($PhICl_2$) **37** reagent activated by Lewis base, pyridine. The methodology has good tolerance of various substituents on substrate 3-diazo-2-oxindoles. The reaction proceeds rapidly, through high chemoselective chlorination, in a mild, metal-free state, giving excellent yields. Activation of $PhICl_2$ **37** by pyridine, produce $[PhIClPy]^+C^{l-}$ ion, which reacts with 3-diazo-2-oxindoles *via* nucleophilic substitution, geminal dichlorination, and expulsion of N_2, and PhI resulting in the targeted product. The substrate 3-diazo-2-oxindoles is synthesized from readily available and inexpensive isatin and NH_2NHTs (Scheme 17).

Xiyan Duan and co-workers [58] invented a cogent scheme for α,α-dichlorination of 1,3-diketones **49**, β-ketoesters, and β-oxo amides applying benign reagent iodobenzene dichloride ($PhICl_2$) **37** in a simple and mild state of reaction. CH_2Cl_2 works as the best solvent in the company of 4Å molecular sieves at normal temperature and gives good to excellent yields. The substrates *β*-keto esters, 1,3-diketones **49** and *β*-oxoamides bearing various substituents are highly tolerated in this transformation. The reaction proceeds *via* nucleophilic attack by keto-enol tautomerized substrates at $PhICl_2$ **37** making α- monochlorination of substrates through intramolecular oxidative addition of Cl and reductive elimination of PhI the same phenomenon occurs a second time by α-chlorinated substrates for α,α -geminal dichlorination of substrates and to give the targeted product (Scheme 18).

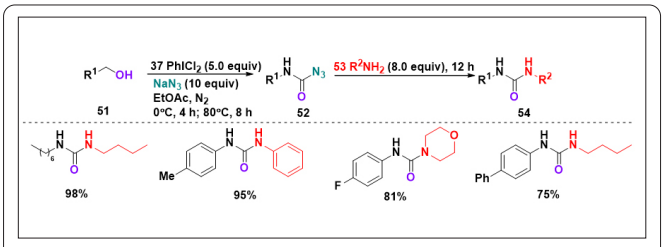
Chai Zhang and associates [59] evolved a pragmatic stratagem for the synthesis of substituted urea **54** in a one-pot fashion from inexpensive and readily accessible primary alcohols **51** and amines **53** mediated by combining reagents of $PhICl_2$ **37** and NaN_3 The scheme is highly competent to afford wide diversities of aliphatic and aromatic primary alcohols and amines substrates bearing various functional groups on it. Ethyl acetate as a solvent plays a vital role in increasing the yields that are good to excellent in this methodology. This transformation proceeds in four steps *via* oxidation of alcohol, formation of acyl azide and Curtius rearrangement, the formation of acyl azide from aldehyde is a vital step according to



Scheme 17: Dichlorination of oxindole **47** and representative examples.



Scheme 18: α, α-Dichlorination of dicarbonyl compound **49** and selected examples.

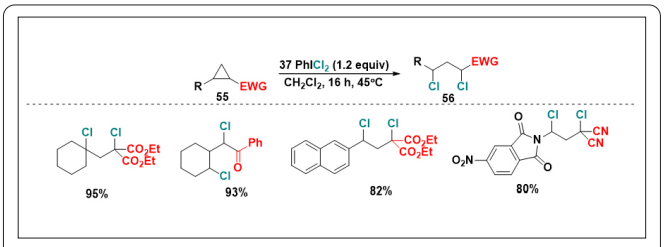


Scheme 19: One pot synthesis of substituted urea **54** and representative examples.

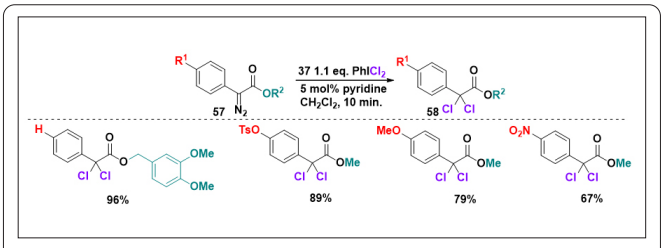
chemical kinetic studies (Scheme 19).

Lennert KB Garre and associates [60] invented a novel approach for a ring-opening 1,3-dichlorination **56** adjoining to acceptor-donor groups attached on cyclopropane **55**. The substrates can afford aromatic, aliphatic, O, and N derivates as donor groups, along with providing a broad scope of diesters, dinitriles, and other carbonyl derivatives as acceptor groups on cyclopropane substrates. Readily accessible hypervalent iodine ($PhICl_2$) **37** reagent reacting with diversely substituted cyclopropane **55** in one-pot fashion, requiring mild condition, providing good to excellent yields like features make the transformation pragmatic and highly applicable. The homolytic cleavage of the I-Cl bond of $PhICl_2$ **37** produces Cl· free-radicals which attack at the strained cyclopropane, cleavage of the C-C bond in homolytic manner and expulsion of PhI results in the desired product (Scheme 20).

Jason Tao and co-workers [61] divulged a novel scheme of geminal dichlorination **58** or difluorination at α-position to carbonyl derivates **57** by deploying hypervalent iodine reagents **37**. The methodology proceeds rapidly in a one-pot fashion, metal-free condition, being highly chemoselective. The substrates diazoacetate derivates having diversified functional groups are well-tolerated in this transformation and give both kinds of dihalogenation in good to excellent yields. The chlorinating agent iodobenzene dichloride ($PhICl_2$) **37** is activated by Lewis base pyridine in CH_2Cl_2 solvent and fluorinating agent iodotoluene difluoride ($TolIF_2$) is activated by stronger Lewis acid $BF_3{\cdot}Et_2O$ in PhCl solvent. The halogenating agents and substrates are readily prepared from readily accessible and inexpensive regents making reaction more practical (Scheme 21).



Scheme 20: Ring opening reaction of cyclopropanes **55** and representative examples.



Scheme 21: Chlorination by iodobenzene dichloride **37** and representative examples.

Conclusion

This review has summarized an overview of hypervalent iodine reagents, HTIB also known as Koser's reagent, and $PhICl_2$. Both reagents are ubiquitously used in organic-inorganic chemistry. This summary focused on stability, availability, effective alternatives to metal-catalyzed reaction paths, application in synthetic chemistry, and reaction aptitude of the central atom I (in +3 oxidation state), which will benefit the chemists working in synthetic and catalystic chemistry. We hope that this overview covering these two hypervalent reagents will catch the attention of researchers working in hypervalent iodine-promoted synthetic chemistry, and will help in understanding the reactivities of iodine, as well as comparing the reactivities of these reagents with other hypervalent reagents. This review will help in modifying these reagents into other hypervalent iodine reagents to expand the use of these greener reagents in various branches of chemistry.

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