

APPLICATIONS OF Au & Ag NANOPARTICLES IN THE SYNTHESIS OF HETEROCYCLIC COMPOUNDS

Abstract

Role of Nano catalyst is between homogenous and heterogeneous catalyst. They are useful from the point of their activity, selectivity, efficiency and reusability, Noble metal nanoparticles such as Au, Ag and Pt with high surface area and more active sites gives faster reactions and increase yield of product. Some of the applications in the synthesis of heterocyclic scaffold using Au and Ag nanoparticles is discussed herewith.

Keywords: Nanoparticles, AgNPs, AuNPs, Quinoxalines, chemo-selective reduction.

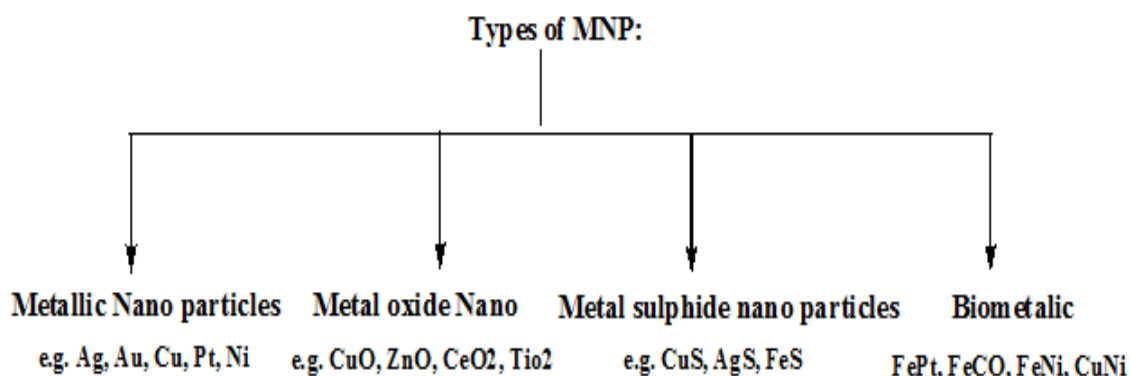
Author

Dr. R. A. Shastri
Post Graduate Department of Chemistry
S.B.E.S. College of Science
Aurangabad, Maharashtra, India
shastriranjana@yahoo.com

I. INTRODUCTION

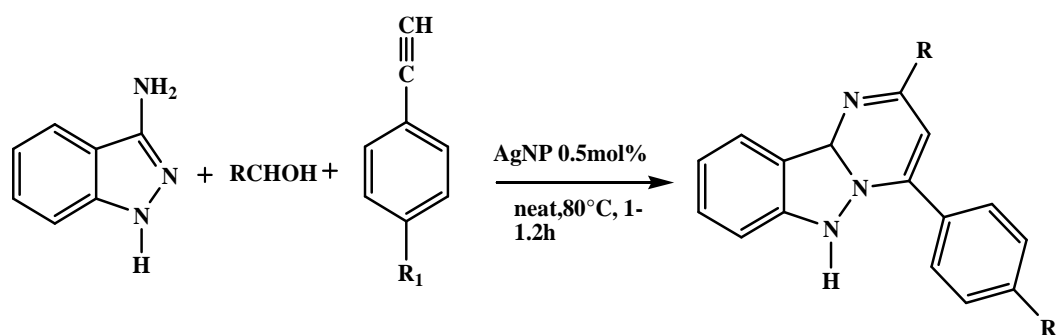
Heterocyclic compounds have wide range of applications they are used in the preparations pharmaceuticals, agrochemicals and veterinary products .They are important part of many drugs, agrochemicals and veterinary products.

Synthesis of new heterocycles is challenging for research's but due to wide range of applications of nanotechnology numerous metal nanoparticles were used for the synthesis of heterocyclic moieties .The metal nanoparticles used in the synthesis involves Ag, Au, Co, Cu, Fe, Ni, Pd, Pt, Rh, Ru, Si, Ti and Zn. Among this noble metallic nanoparticles are AuNPs, AgNPs PtNPs, which are commonly used in synthesis of heterocyclic scaffold ^{1,2} as it offers high stability. Metallic nanoparticles have metal core having inorganic metal or metal oxide which is covered with a shell made of inorganic or organic metal oxide.



MNP used in organic synthesis are safest as it keeps clean reaction and do not affect the environment .Number of organic transformations are brought by Nano particles but here we will discuss few synthesis of heterocycles by using nanoparticles.

- 1. AgNP-Catalyzed synthesis of heterocycles:** Synthesis of pyrimido [1,2-b]imidazole derivatives was carried by Balwea et al³.using silver nanoparticles (AgNPs) extracted from plant *Radix puerariae*.

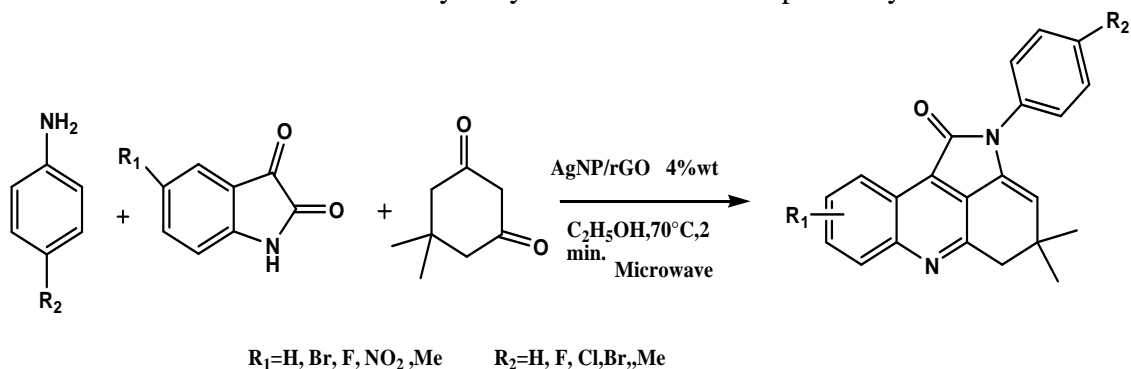


R=C₆H₄, 2-OMe-C₆H₄, 4-OMe-C₆H₄, 2-OET-C₆H₄, 4-Bu-C₆H₄, 2,5-(Me)₂, 2-CIFC₆H₃,
 4-Cl-C₆H₄, 4-F-C₆H₄, 3-Cl-C₆H₄, 4-BrC₆H₄, 3-F-C₆H₄, 2-F-C₆H₄, 2-Cl-C₆H₄, 3-BrC₆H₄,
 2-thienyl, 2-furanyl, 2-naphthyl, 2-cyclohexyl R₁=H, Me

Scheme 1: Synthesis of pyrimido [1,2-b]imidazole derivatives

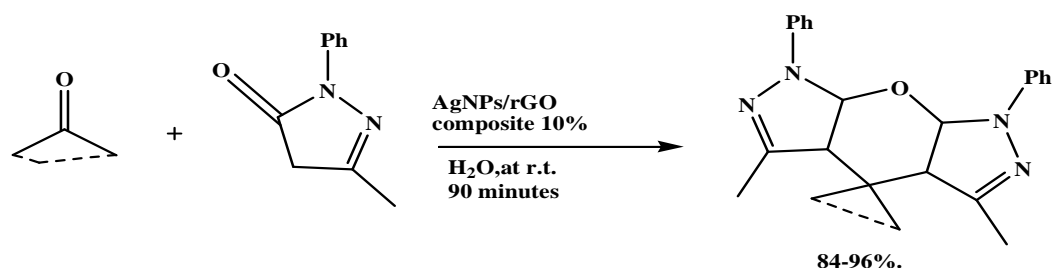
The synthesis of pyrimido [1,2-b]imidazole derivatives was carried using 3-aminoimidazole aldehyde which may be aryl, heteraryl, allylic and substituted phenyl acetate using AgNPs in 0.5mol%. The reaction was carried at 80°C for 1 hr. in solvent free condition. Yield of reaction is 90%. The catalyst is recovered after the reaction, washed with water and used for three consecutive reactions.

Synthesis of Pyrrolo[2,3,4-*kl*]acridin-1-ones was reported by Dandia et al⁴. using silver nanoparticles decorated reduced graphene oxide (AgNP/rGO) involves simultaneous reduction of graphene oxide (GO). The structure of these nanoparticles were confirmed by using TEM, XRD, SEM, XPS, EDX, UV-VIS spectroscopy, cyclic voltammetry, Raman and FTIR spectroscopy. Synthesis of Pyrrolo[2,3,4-*kl*]acridin-1-ones was carried by treating substituted isatin, anilines and dimedones in ethanol under microwave reduction at 70°C for 2 minutes in 89-93% yield. Ethanol is suitable solvent among all due to higher dispersion of catalyst and reactants. The catalyst recovered from reaction was used for seven catalytic cycles without loss of product yield.



Scheme 2: Synthesis of Pyrrolo[2,3,4-*kl*]acridin-1-ones

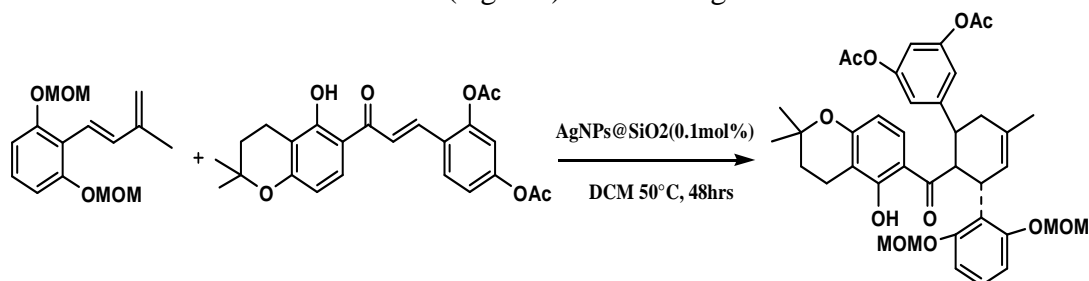
Synthesis of Pyrano [2,3-*c6,5c*]dipyrazol-2-ones was reported by Dandia et al⁵ by using AgNP decorated GO (graphene oxide) as catalyst on water in excellent yield. Here AgNPs role is as Lewis acid which is able to proceed through Knoevenagel than Michael addition and further cyclization. The catalyst recovered from reaction was found to be as effective for seven catalytic cycles.



Aldehyde C_6H_5 , 4-Me- C_6H_4 , 4-OMe- C_6H_4 , 3,4,5-(OMe)₃ C_6H_2 , 3-OPh- C_6H_4 , 4- FeC_6H_4 , 4-Cl C_6H_4 , 4-NO₂ C_6H_4 , Indole -3-yl, thiophene-2-yl, Ketones 1,2-Acenaphthoquinones, isatin

Scheme 3: Synthesis of Pyrano [2,3-*c6,5c*]dipyrazol -2-ones

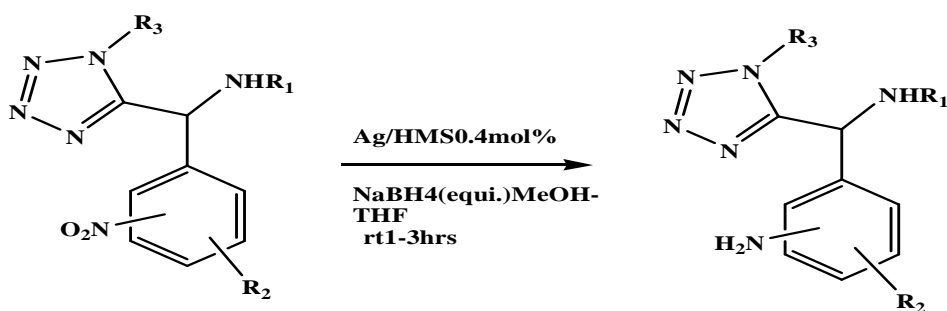
Diels-Alder [4+2] cycloaddition reaction by using AgNPs was reported by Porco et al⁶. The reaction was carried by using chalcone and diene to give cycloadduct which gives endo and exo diastereoisomers in 2:1 ratio. The AgNPs were prepared via the reduction of silver tetrafluoroborate (AgFB4) with silica gel in dichloromethane.



Endo :Exo=2:1 90%

Scheme 4: Diels-Alder reaction

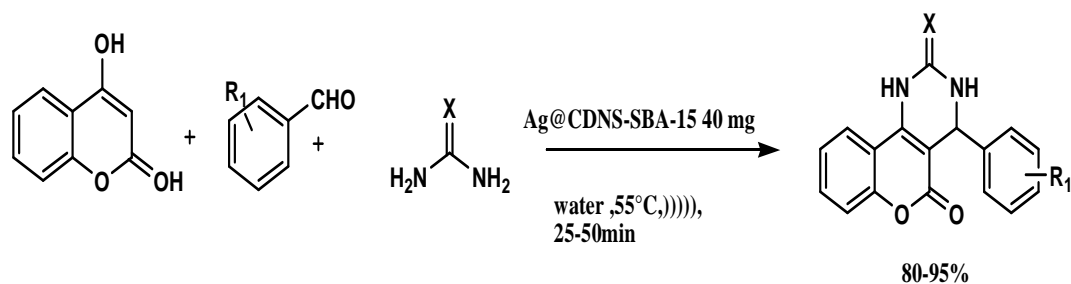
Chemo selective reduction of tetrazoles containing nitroarenes was reported by Lykakis⁷ by using AgNP-supported mesoporous silica (Ag/HMS).



R₁=iPr, cyclopentyl, cyclohexyl, C(Me)-2-COOMe, CH₂CH₂COOMe, CHMeCOOMe
 CH(CH₂iPr)COOMe, CH(iPr)COOMe, 4-OMeC₆H₄-CH₂, 4-MeC₆H₄
 R₂=H, 2-Me, 4-Cl, R₃ = t-Bu, CH(Me)₂, CH₂ t-Bu, OMe

Scheme 5: Chemo-selective reduction of tetrazole

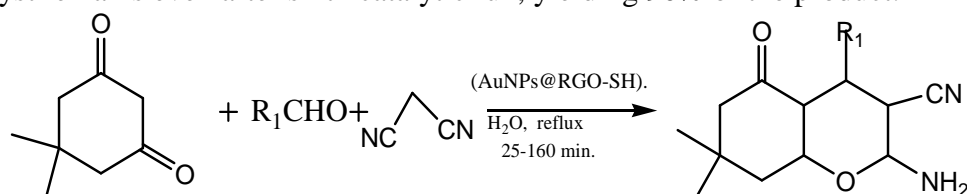
Catalytic use of bio-assisted AgNPs supported on an SBA-15/cyclodextrin nanosponge adduct was reported by Heravi et. al⁸. The reaction was carried under ultrasonication. Here benzopyranopyrimidine was synthesized from 4-hydroxycoumarins, substituted benzaldehydes and urea or thiourea. Here cyclodextrin plays important key role it brings reagents in close proximity of AgNPs. The catalyst was used again four times with the same catalytic activity



X= O, S; R₁=H, 2-OH, 4-OMe, 4-NMe₂, 2-Cl, 4-Cl, 3-NO₂

Scheme 6: Synthesis of benzopyranopyrimidine

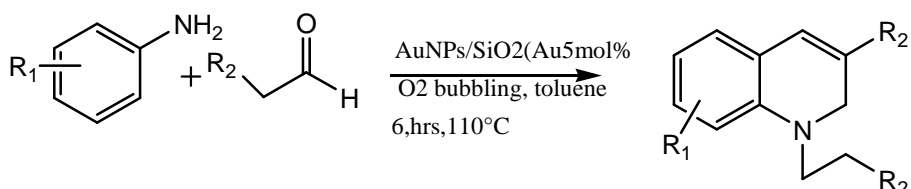
2. **AuNPs catalyzed synthesis of heterocycles:** Naeimi et al⁹ reported the synthesis of tetrahydro-4H-chromones by using gold nanoparticles supported on thiol functionalized reduced graphene oxide (**AuNPs@RGO-SH**). These nanoparticles are treated to benzaldehyde, malono nitrile in aqueous medium under reflux. The catalytic activity of catalyst remains even after sixth catalytic run, yielding 90% of the product.



R₁= nPr, n-Bu, C₆H₅, 4-N(Me)₂-C₆H₄, 2Cl-C₆H₄, 4-Cl-C₆H₄, 2,4-(Cl) C₆H₃, 3-Br-C₆H₄, 4-Br-C₆H₄, 4-F-C₆H₄, 4-(OMe)-C₆H₄, 3-(OMe)-C₆H₄, 2-OH-5-Br-C₆H₃, thiophenel-2-yl

Scheme 7: Synthesis of tetrahydro-4H-chromens

Polysubstituted Quinolines were synthesized by Che et al¹⁰ from substituted anilines and aryl/alkyl aldehydes by using SiO₂ supported AuNPs under oxygenated environment. The structure of synthesized nanoparticles were characterized by XRD, XPS, TEM, SAED analysis EDX And ICPMS

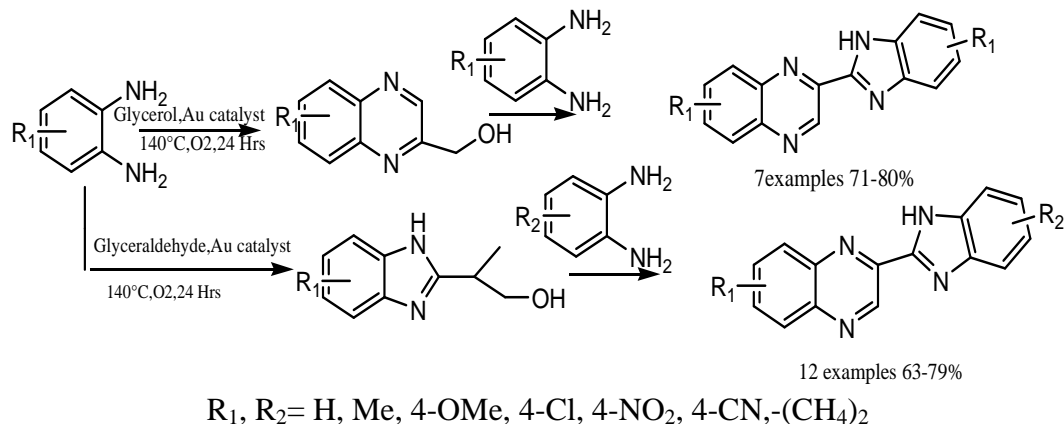


R₁= H, 2-Me, 3-Me, 4-Me, 2,3-(Me)₂, 2,4-(Me)₂, 2,5-(Me)₂, 4-*ipr*, 3-OMe, 4-OMe, 3,4,5-trimethoxy, 4-Cl-2Ph R₂=ethyl, n-butyl, n-decoyl

Scheme 8: Synthesis of polysubstituted Quinolines

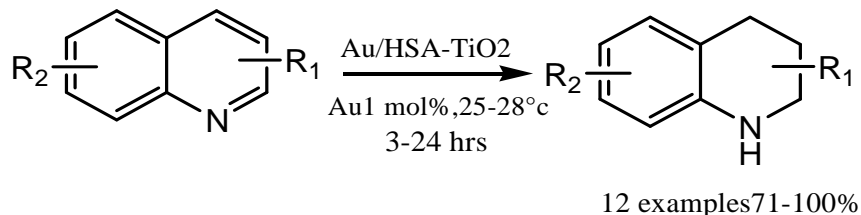
Synthesis of poly substituted benzimidazolyl quinolines from o-phenylene diamine, glycerol and glycealdehyde was carried by Climent et al¹¹ by using gold

nanoparticles immobilized on Nano particulate CeO₂ in catalytic amount in the presence of air.



Scheme 9: Synthesis of poly substituted benzimidazolyl quinolines

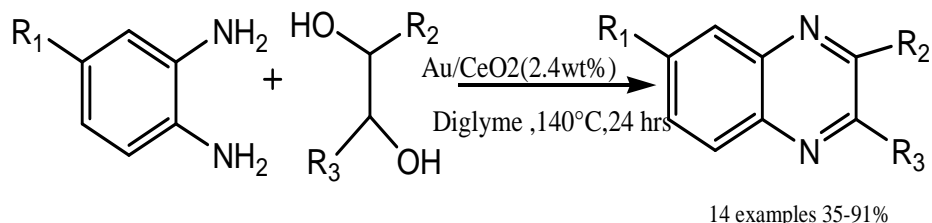
Renet al¹² carried chemoselective reductions of substituted quinolines by using AuNPs supported on high surface area of TiO₂ (Au/HSA-TiO₂) at 25-28°C synthesized nanoparticles were characterized by XPS, DRIFTS, XANES, yield of reactions was 100%



$R_1 = 2\text{-Me, 4-Me, } R_2 = 6\text{-OMe, 8-NH}_2, 8\text{-OH, 5-Cl-8-OH, 6-F, 6-Cl, 6-COMe, 7-CH=CH}_2$

Scheme 10: Hydrogenation of Quinolines catalyzed by AuNPs

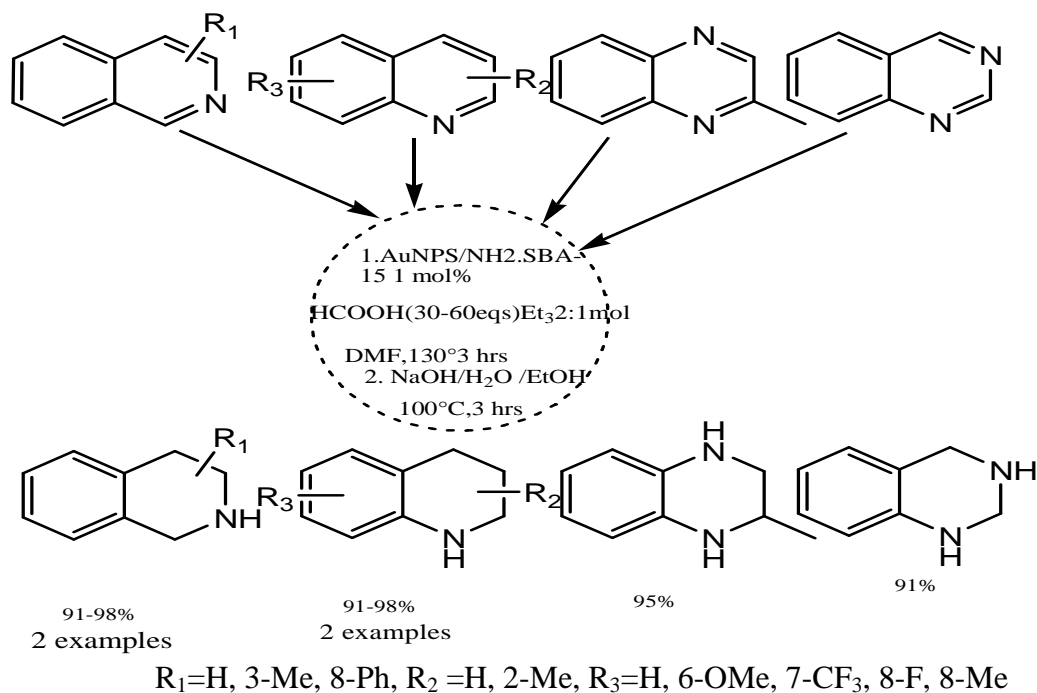
Synthesis of Quinoxalines was reported by Iborra et al¹³. These authors condensed a phelyene diamide with biomass derived substituted glycol or Vicinol diols using AuNPs supported on CeO₂ catalyst and dimethyl glyoxmie as solvent at 140 °C without base. The catalytic activity of catalyst remains same upto 4th cycle.



$R_1 = \text{H, Me, OMe, Cl, CN, NO}_2, \quad R_2 = \text{H, Me, Ph} \quad R_3 = \text{H, Me, Et, nPr, n-Bu}$

Scheme 11 Synthesis of Quinoxalines

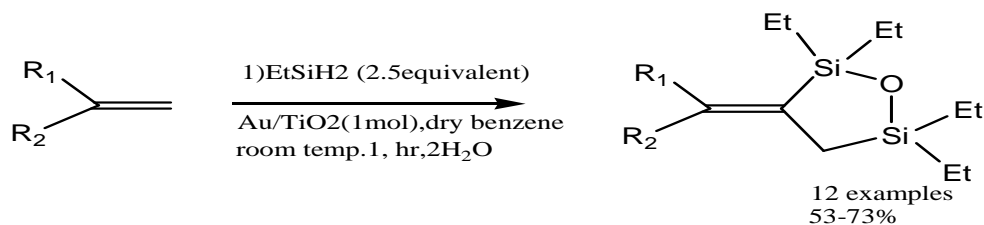
Silver nano particles AuNPs supported on 3-amino propyl functionalized silica (AuNPs/NH₂/3-SBA- s) as catalyst in anhydrous DMF in formic acid¹⁴ was shown to be effective for hydrogenation of N- heterocyclic compounds such as isoquinolines, quinolines quinoxalines and quinazoline.



Scheme 12: Hydrogenation of N-heterocyclic compounds

The same reaction was also showed for the reduction of acridine, 1,10-phenanthroline, phenanthridine and benzo quinoline. The reaction proceeds via protonation using formic acid which underwent 1,2 addition followed by dis propitiation to give the hydrogenated product.

Synthesis of 3-alkylidene 1,2,5-oxadisilolanes was reported by Stratakis et.al¹⁵ from AuNPs supported TiO₂(Au/TiO₂) catalyzed regioselective dehydrogenative 1,2-desilylation from allenesand diethyl dihydrosilane.



R₁=H, Me, Bn, R₂=Me, OMe, cyclohexyl, Ph, 4-Me-C₆H₄, 4-Cl-C₆H₄, Bn, 2-naphthyl

Scheme 13 Synthesis of 3-alkylidene 1,2,5-oxadisilolanes

II. CONCLUSION

Synthesis of heterocyclic compounds with nitrogen and oxygen using metal Nano catalyst plays a vital role by increasing the surface area of catalyst, bringing the electrophiles and nucleophiles in vicinity, reducing the energy gap between reactant and product. Metal nano particles have been used for the synthesis of five, six or seven membered monocyclic, bicyclic tricyclic and tetracyclic heteroaromatic scaffolds. AuNPs are generally used for the synthesis of substituted Quinolines, and Quinoxalines. AgNPs are generally used for the synthesis of imidazole derivatives, Pyrrolo[2,3,4-k]acridin-1ones, Chemo selective reduction of tetrazole and various reactions. The use of metal nanoparticles such as Au and Ag led to significant advancement in the synthesis of heterocyclic moieties.

REFERENCES

- [1] R. Kaur , J. Bariwal , L. G. Voskressensky and E. V. Van Der Eycken , *Chem. Heterocycl. Compd.*, 2018, **54**, 241 —248.
- [2] N. Tarannum , Divya and Y. K. Gautam , *RSC Adv.*, 2019, **9** , 34926 —34948.
- [3] S. G. Balwe, V. V. Shinde , A. A. Rokade , S. S. Park and Y. T. Jeong , *Catal. Commun.*, 2017, **99** , 121-126.
- [4] Dandia , A. Sharma , V. Parewa , B. Kumawat , K. S. Rathore and A. Sharma , *RSC Adv.*, 2015, **5** , 91888-91902.
- [5] Dandia , S. L. Gupta , A. Indora , P. Saini , V. Parewa and K. S. Rathore , *Tetrahedron Lett.*, 2017, **58** , 1170-1175.
- [6] H. Cong and J. A. Porco , *Org. Lett.*, 2012, **14** , 2516-2519.
- [7] D. Iordanidou , T. Zarganes-Tzitzikas , C. G. Neochoritis , A. Dömling and I. N. Lykakis , *ACS Omega*, 2018, **3** , 16005 —16013.
- [8] S. Sadjadi , M. M. Heravi and M. Malmir , *Appl. Organomet. Chem.*, 2018, **32**.
- [9] H. Naeimi and M. Farahnak Zarabi , *Appl. Organomet. Chem.*, 2018, **32**, e4225.
- [10] M. H. So , Y. Liu , C. M. Ho , K. Y. Lam and C. M. Che , *ChemCat Chem*, 2011, **3** , 386-393.
- [11] M. J. Climent , A. Corma , S. Iborra and S. Martínez-silvestre , *ChemCatChem*, 2013, **5** , 3866-3874.
- [12] D. Ren, L. He , L. Yu , R. Ding , Y. Liu , Y. Cao , H. He and K. Fan, *J. Am. Chem. Soc.*, 2012, **134**, 17592 —17598.
- [13] M. J. Climent , A. Corma , J. C. Hernández , A. B. Hungría , S. Iborra and S. Martínez-Silvestre , *J. Catal.*, 2012, **292** , 118-129.
- [14] Vilhanová, J. A. van Bokhoven and M. Ranocchiari , *Adv. Synth. Catal.*, 2017, **359** , 677-686.
- [15] M. Kidonakis , V. Kotzabasaki , E. Vasilikogiannaki and M. Stratakis , *Chem.–Eur. J.*, 2019, **25** , 9170-9173.