Int.J.HIT.TRANSC:ECCN.Vol.7: Issue 2A (2021) Page 12-17 ISSN: 0973-6875

Available Online at www.hithaldia.in/locate/ECCN

ORIGINAL CONTRIBUTION

Synthesis of 1-Methoxyphenanthrene by Palladium-Catalyzed Heck Reaction

Rathin Jana

Department of Chemistry, ShahidMatanginiHazra Govt. General Degree College for Women, Nimtouri, West Bengal

ABSTRACT

A novel methodology for the synthesis of 1-methoxy phenanthrene has been developed via a palladium-assisted 6π electrocyclic reaction followed by formaldehyde elimination.

Keywords:1-methoxy phenanthrene, IntramolecularHeck, Phenanthrene, Palladium catalyzed **C-C** bond forming

1. INTRODUCTION

Palladium catalyzed **C-C** bond forming reaction is important for the synthesis of heterocyclic and carbocyclic compounds. Polycyclic aromatic hydrocarbons (PAHs), more simply known as polyarenes, constitute an extraordinary large and diverse class of organic molecules.[1,2]Within the chemical class of polycyclic aromatic compoundsphenanthrene is an important core structure. The phenanthrene moiety can not only be found in severalnatural products, of which many exhibit interesting biologicalactivity,[3] but more recently phenanthrenes have also been shown as interesting ligands for novel catalystsystems.[4]The discovery of the carcinogenic prosperities of polyarenes stimulated wide-ranging investigations of their structure activity relationships. Previously it was thought that PAHs are direct acting carcinogens, but this was proved to be wrong in latter stage. It is now recognized that PAHs require metabolic activation in order to express tumorogenic reactivity.[5,6]

Therefore, the development of new short syntheticmethods for this important class of organic compounds has regained importance.Several synthetic efforts for the preparation of PAH have been reported by different groups, of which most common procedure involves the classical oxidative photocyclization of stilbene derivatives.[7]Among other methods intramolecular Diels–Alder reaction,[8]flash vacuum pyrolysis,[9-12] olefin metathesis,[13]Friedel-Crafts type cyclization,[14]dimerisation or trimerisation of acetylenes and arynes,[15-16] transition metal catalyzed cycloisomerisation[17-18] etc.are used as the key stepfor construction of a benzene ring for the synthesis of PAH.We also contributed in this field by synthesizing tri-substituted benzene derivatives via base catalyzed condensation and aromatization of various bromoaldehydes with active methylene compound.[19]

Palladium catalyzed activation of aromatic C-H bond has been used extensively in many organic synthesis since this reaction gives a solution for the construction of carbo- and heterocycles from the corresponding halides and triflates.[20-26]Larock*et al* have developed a novel Palladium-catalyzed migration/C-H activation methodology for the synthesis of complex fused polycycles.[27, 28] The major sources of PAHs are crude oil, coal, oil shale. Methyl phenanthrene, belong to an important group alkyl-aromatic hydrocarbons which are present in natural environments.

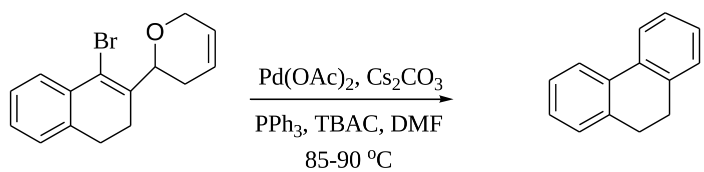
*Corresponding Address: rathin1983@hotmail.com

Methyl phenanthrene arises through the combustion of wood, coal; etc. There is a great variety of methods which are available for the synthesis of phenanthrene and its derivatives. Perhaps the most extensive method is the classical Haworth synthesis.

2. PRESENT WORK

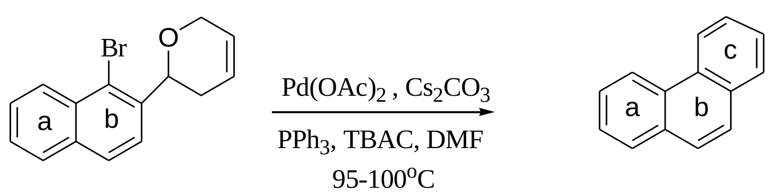
Being inspired by the importance of this polycyclic aromatic hydrocarbon and 9, 10dihydrophenanthrenewe attempted to synthesize PAH derivatives in our laboratory. Al though there are plenty of example of dihydrophenanthrene synthesis but these procedures suffer from some limitations such as drastic reaction conditions, toxic reagent and catalyst.

We first report a novel and rapid convenient approach to the synthesis of substituted 9, 10-dihydrophenanthrene along with its analogues by a palladium-catalyzed 6πelectrocyclic reaction.[29]Recently, we described the palladium-catalyzed intramolecular Heck reaction by β-H elimination or C-H activation to afford a polycyclic pyran moiety.[30,31] We were planning to apply this reaction for the synthesis of a bicyclicpyran ring, but surprisingly we obtained 9, 10-dihydrophenanthrene in good yield (Scheme 1).



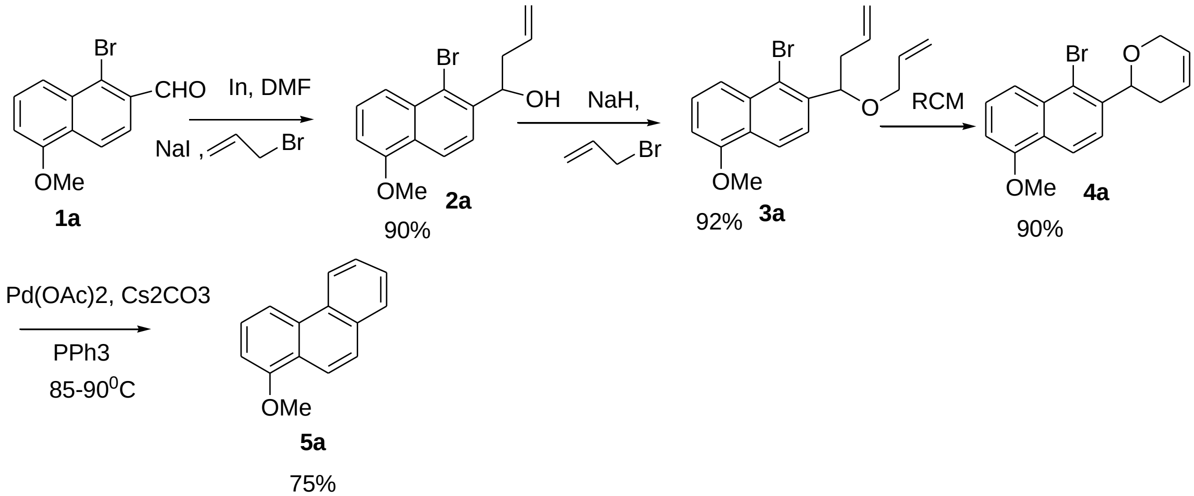
(Scheme 1)

Then we have employed our methodology to the aromatic bromoaldehydes system, we got successful result to synthesize phenanthrene and alkyl phenanthrene in good yield.[32, 33] Importance of this methodology is that we can introduce alkyl group in any one or two position of newly formed benzene ring**(c)** of phenanthrene (Scheme 2). Here using this methodology we have synthesized 1-methoxy phenanthrene by palladium catalyzed Heck reaction.



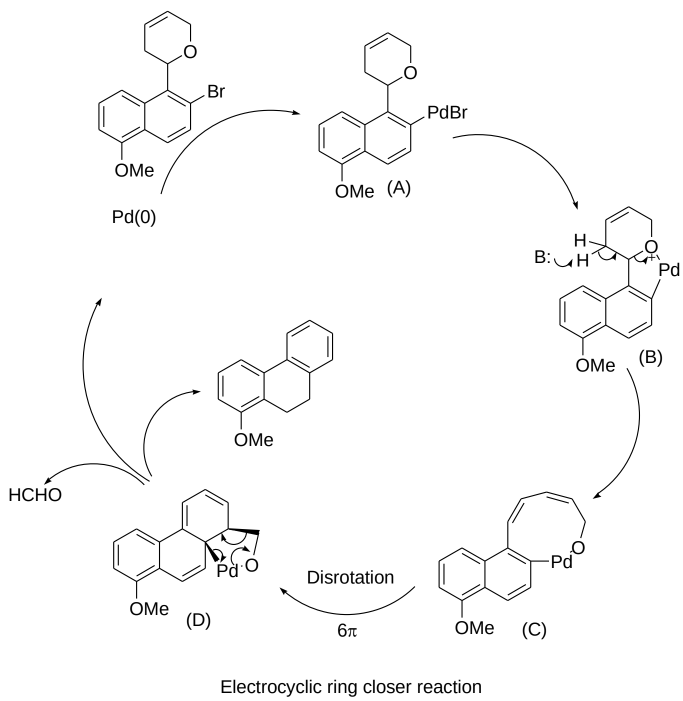
(Scheme 2)

First aromatic bromoaldehydes**1a** is treated with allyl bromide, sodium iodide in presence of indium metal to obtained corresponding alcohol **2a.** This alcohol isallylated in presence of sodium hydride in THF medium at 0 ^oC to obtained diallylated compound **3a**which is subjected to 2[nd] generation Grubbs catalyst to Obtained desired cyclic precursor **4a**. Then this cyclic precursor is finally treated with $Pd(OAc)_2$, PPh_3, Cs_2CO_3 in DMF solvent at 85-90 ^oC to afforded 1-methoxy phenanthrenes**5a** in good yield which is shown in Scheme 3.



Scheme 3

The reaction mechanismpresumely involves a 6π electrocyclic ring closer reaction followed by formaldehyde elimination. The catalytic cycle involves initial oxidation of the Pd(0) to generate alkenyl palladium (II) intermediate (A) via oxidative addition of the Pd (0) to the substrate, which then co-ordinates with oxygen to generate the intermediate (B),

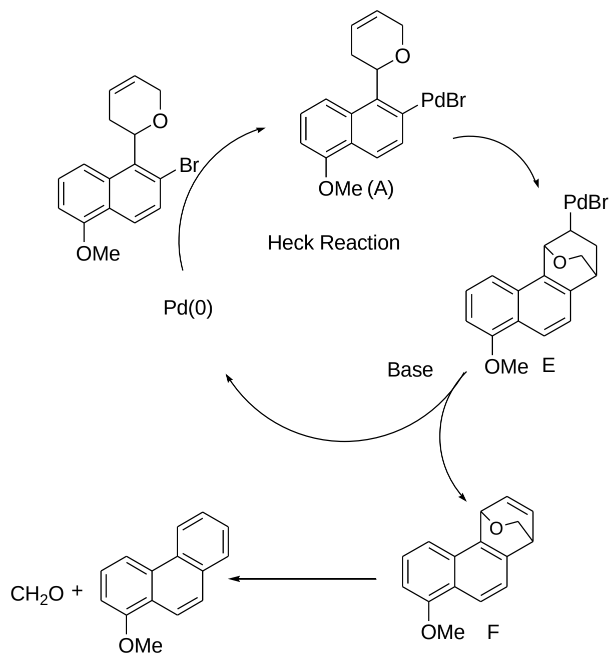


Scheme-4

ISSN: 0973-6875 DOI: 10.5281/zenodo.5893120

This undergoes proton abstraction followed by rearrangement to afford a nine membered cyclic Pd-O complex (C). This complex undergoes 6π electrocyclic ring closer reaction forming complex (D), followed by formaldehyde elimination to afford 1-methoxy phenanthrene.

Lan at el.proposed analternative mechanism that occurs through an intramolecularHeck[34] reaction. Using theoretical calculations they investigated both, mechanisms and find that the intramolecular Heck mechanism (Scheme 5) is lower in energy than the electrocyclic pathway (Scheme 4).



Scheme-5

3. CONCLUSION

We have developed a new method for synthesis of 1-methoxy phenanthrene derivatives. This method also useful for the synthesis of higher homologous of polynuclear aromatic hydrocarbons provided the efficient route to synthesis of suitable starting material.

Spectral data of compound5a:Solid,^{1}H NMR ($CDCl_3$, 400 MHz) δ: 4.04 (s, 3H), 7.03 (d, 1H, J = 7.8Hz), 7.51-7.71(m, 3H) 7.80 (d, 1H, *J* = 9.1Hz), 7.95(d, 1H, *J* = 7.7Hz), 8.31 (t, 2H, J = 8.9), 8.70 (d, 1H, *J* = 7.6 Hz).^{13}C NMR ($CDCl_3$, 100 MHz) δ:55.7, 105.8, 115, 120.3, 123, 123.3, 126, 126.5, 126.6, 126.7, 128.5, 130, 131.4, 132.3, 160.

REFERENCES

[1] Harvey, R. G. Polycyclic Aromatic Hydrocarbons; Wiley-VCH: New York, 1997.

[2] Harvey, R. G. Polycyclic Aromatic Hydrocarbons: Chemistry and Carcinogenicity,

[3] CambridgeUniversity Press: Cambridge, 1991.

[4] 3.deKoning, C. B.; Michael, J. P.; Rousseau, A. L.A novel method for the synthesis of phenanthrenes and benzo[a]carbazoles. Tetrahedron Lett. 1998, 39, 8725.

[5] Pathak, R.; Vandayar, K.; van Otterlo, W. A. L.; Michael, J.P.; Fernandes, M. A.; de Koning, C. B.The synthesis of angularly fused polyaromatic compounds by using a light-assisted, base-mediated cyclization reaction. Org. Biomol. Chem.2004, 2, 3504.

[6] Harvey, R. G. Activated metabolites of carcinogenic hydrocarbons.Acc. Chem. Res.1981, 14, 218.

[7] Harvey, R. G.; Geacintov. N. E.Intercalation and binding of carcinogenic hydrocarbon metabolites to nucleic acids. Acc. Chem. Res. 1988, 21, 66.

[8] Liu, L.; Yang, B.; Katz, T. J.; Poindexter, M. K.Improved methodology for photocyclization reactions.J. Org. Chem.1991, 56, 3769.

[9] Levy, L.A.; Sashikumar, V. P.Synthesis of chrysene, 5-substituted chrysenes, and chrysene derivatives via intramolecularcycloaddition reactions.J.Org.Chem.1985, 50, 1760.

[10] Scott, L. T.; Hashemi, M. M.; Meyer, D. T.; Warren, H. B.Corannulene. A convenient new synthesisJ. Am. Chem. Soc. 1991, 113, 7082.

[11] 10.Plater, M. J. Cyclisation of Stilbenes to Phenanthrenes by Flash Vacuum pyrolysis.TetrahedronLett. 1995, 35, 801.

[12] 11. Mehta, G.; Rao, H. S. P.Synthetic studies directed towards bucky-balls and bucky-bowls. Tetrahedron1998,54, 13325.

[13] 12.Sonoda, M.; Itahashi, K.; Tobe, Y. Flash vacuum pyrolysis of 1,6-diphenyl-1,5-hexadien-3-ynes: tandem diaryldienynecyclizations to form chrysene. Tetrahedron Lett. 2002, 43, 5269.

[14] 13. Bonifacio, M. C.; Robertson, C. R.; Jung, J. Y.; King, B. T. Polycyclic Aromatic Hydrocarbons by Ring-Closing Metathesis.J. Org. Chem. 2005, 70, 8522.

[15] 14. Ichikawa, J.; Yokota, M.; Kudo, T.; Umezaki, S.Efficient Helicene Synthesis: Friedel-Crafts-type Cyclization of 1,1-Difluoro-1-alkenes.Angew. Chem. Int. Ed. 2008, 47, 4870.

[16] 15. Pena, D.; Perez, D.; Guitian, E.; Castedo, L.Synthesis of Hexabenzotriphenylene and Other Strained Polycyclic Aromatic Hydrocarbons by Palladium-Catalyzed Cyclotrimerization of Arynes Org. Lett. 1999, 1, 1555.

[17] 16. Lu, J.; Zhang, J.; Shen, X.; Ho, D. M.; Pascal, R. A.Octaphenylbiphenylene and Dodecaphenyltriptycene. J. Am. Chem. Soc.2002, 124, 8035.

[18] 17.Furstner, A.; Mamane, A.Flexible Synthesis of Phenanthrenes by a $PtCl_2$-Catalyzed Cycloisomerization Reaction.J. Org. Chem. 2002, 67, 6264.

[19] 18. Storch, J.; Cermak, J.; Karban, J.Synthesis of 1-(2-ethynyl-6-methylphenyl)- and 1-(2-ethynyl-6-methoxyphenyl)-naphthalene and their cyclization .Tetrahedron Lett. 2007,48, 6814.

[20] 19. Ray, D.; Ray, J. K.Base-catalyzed condensation of β-bromovinylaldehydes with β-ketoesters followed by water-mediated cyclization and aromatization: one-pot access to substituted benzene derivatives .Tetrahedron Lett. 2007, 48, 673.

[21] 20. Ritleng, V.; Sirlin, C.; Pfeffer, M.Ru-, Rh-, and Pd-Catalyzed C−C Bond Formation Involving C−H Activation and Addition on Unsaturated Substrates: Reactions and Mechanistic Aspects. Chem. Rev.2002, 102, 1731.

[22] 21.Li, C.-J.Quasi-Nature Catalysis: Developing C−C Bond Formations Catalyzed by Late Transition Metals in Air and Water.Acc. Chem. Res. 2002, 35, 533.

[23] 22.Catellani, M.; Chiusoli, G. P. The terminations step in palladium-catalyzed insertion reactions. J. Organomet. Chem. 1983, 250, 509.

[24] 23.Jia, C.; Piao, D.; Kitamura, T.; Fujiwara, Y.New Method for Preparation of Coumarins and Quinolinones via Pd-Catalyzed IntramolecularHydroarylation of C−C Triple Bonds.J. Org. Chem. 2000, 65, 7516.

[25] 24. Deshpande, P. P.; Martin, O. R. A concise total synthesis of the aglycone of the gilvocarcins.Tetrahedron Lett. 1990, 31, 6313.

[26] 25. Gonzalez, J. J.; Garcia, N.; Gomez-Lor, B.; Echavarren, A. M. Synthesis of Spiro Polycyclic Aromatic Hydrocarbons by Intramolecular Palladium-Catalyzed Arylation. J. Org. Chem. 1997, 62, 1286.

[27] 26. Martin-Matute, B.; Mateo, C.; Cardenas, D. J.; Echavarren, A. M. Intramolecular C-H Activation by Alkylpalladium(II) Complexes: Insights into the Mechanism of the Palladium-Catalyzed Arylation Reaction Chem. Eur. J.2001, 7, 2341.

[28] 27. Campo, M. A.; Huang, Q.; Yao, T.; Tian, Q.; Larock, R.1,4-Palladium Migration via C−H Activation, Followed by Arylation: Synthesis of Fused Polycycles.J. Am. Chem. Soc.2003,125, 11506.

[29] 28. Huang, Q.; Fazio, A.; Dai, G.; Campo, M. A.; Larock, R.Pd-Catalyzed Alkyl to Aryl Migration and Cyclization: An Efficient Synthesis of Fused Polycycles via Multiple C−H Activation.J. Am. Chem. Soc.2004, 126, 7460.

[30] 29. Jana, R.;Chaterjee, I.;Samanta, S.; Ray,k.J,Novel and Rapid Palladium-Assisted 6π

[31] Electrocyclic Reaction Affording9, 10-Dihydrophenanthrene and Its

[32] Analogue.Organic Lettere, 2008Vol. 10, No. 21, 4795-4797

[33] 30. Jana, R.; Samanta, S.; Ray,K.J, Substrate dependent intramolecular palladium-catalysed cyclisation and subsequentb-H elimination or C–H activation: a genera method for the synthesis of fused pyran rings. Tetrahedron Letters 49 (2008) 851–854

[34] 31. Jana, R.;Dewan, M.; Roymahapatra,G. Synthesis of fused pyran and tetracyclicpyran rings by intramolecular palladium-catalyzed β-H elimination and C-H bond Functionalization.ES Materials & Manufacturing2021, 13, 40-52

[35] 32. Jana, R.;Dewan, M.; Roymahapatra,G. Synthesis of 9,10 –Dihydrophenanthrine, phenanthrine, mono and DialkylPhenanthrine and Octa-hydro Phenanthrine by Palladium catalyzed Heck reaction. ES Materials & Manufacturing2021, 14, 51-58

[36] 33. Jana, R.; Biswas, A.; Samanta, A.; Ray, J. K. Synthesis of Phenanthrene and alkyl Phenanthrene by Pd(0) catalyzed electrocyclic reaction. Synthesis (10), 1463-1468, 2010

[37] 34. Lan, Y.; Wang, C.; Sowa, J. R.; Wu, Y.-D.A Theoretical Investigation on the Mechanism of aPalladium-Mediated Formal 6π Electrocyclic Synthesis of 9, 10-Dihydrophenanthrenes. J. Org. Chem. 2010, 75, 951.