Est. 1984

**ORIENTAL JOURNAL OF CHEMISTRY**
An International Open Access, Peer Reviewed Research Journal

www.orientjchem.org

ISSN: 0970-020 X
CODEN: OJCHEG
2022, Vol. 38, No.(5):
Pg. 1314-1319

# Synthesis of Biologically Potent α-aminophosphonates Derivatives by Nano-catalyst

**KAMALAKAR KAILASH WAVHAL[1]* and DEEPAK MANIK NAGRIK[2]**

[1]Department of Chemistry, Late Ku. Durga K. Banmeru Science College Lonar
Dist-Buldana 443302 (M.S), India.
[2]Department of Chemistry, G.S. Science, Arts and Commerce College Khamgaon
Dist-Buldana 443303 (M.S) India.
*Corresponding author E-mail: dmnagrik@gmail.com

http://dx.doi.org/10.13005/ojc/380532

(Received: July 23, 2022; Accepted: October 30, 2022)

**ABSTRACT**

α-Aminophosphonate and their derivatives are biologically potent and have received considerable attention in a recent research scenario. The main reason is that they show triguing biological activity. α-Aminophosphonate derivatives are gaining a lot of importance in medicinal chemistry due to their application as enzyme inhibitors, herbicides, antibiotics, pharmaceutical agents and inhibitors of Excitatory Post-Synaptic Potential(EPSP) synthesis, and HIV Protease. It is also important in ati-cancer, anti-HIV, antithrombotic and antibacterial, antioxidant activity. Unfortunately, these compounds have certain limitation such as extraction, purification, of bioactive molecule and their minimum yields. For this reason, many scientists have been orienting their research towards the synthesis of molecules as a new tool to overcome this problems he prime focus of this work is the combination of three reactant derivative of benzaldehyde derivative of aniline, and diethyl phosphonate to form α-aminophosphonates derivatives by multicomponent reaction(KFR). The novel nano-catalyst i.e. polyanilinedoped with manganese (PAni-Mn) was prepared. The catalyst shows excellent catalytic activity, high yields, short reaction times, easy synthesis. The PAni was fully characterized by X-ray diffraction, TEM, SEM, and FT-IR technique.

**Keyword:** α-Aminophosphonates, EPSP, (PAni-MN), TEM, SEM, FT-IR.

## INTRODUCTION

α-Aminophosphonate is a valuable part of organo-phosphorus compounds due to their similarity in structure and properties to α-amino acids[1]. it plays an important role in several field including organic synthesis and various potential applications[2]. Nowadays researchers have been attentively move towards pesticide, biochemistryand medicinal chemistry last few years because they show biological activity. Some α-aminophosphonate show activity against tumor[3], activity against microbes[4], they inhibits the enzyme[5], they act an antiviral agent[6], some of the α-aminophosphonates containing alkoxyethyl moieties shows antiviral bioactivity[7]. The Kabachnik-Field reaction and the Pudovic reaction are the two major routs to synthesizing the biologically

potent α-Aminophosphonates. In the first reaction (Phospha-Manich) it contains three component condensation including aldehyde or ketone, a mine and diethyl phosphate[8-9]. In the second, it contains imines with >P(O)H reagent[10]. The classical version of the "Phospha-Manich" reaction was discovered by independently Kabachnik and fields more than sixty years ago[11-12].

The researchers, while synthesizing of α-aminophosphonates used catalyst i.e. efficient Amberlight IRC-74813. An Extremely Efficient Three-Component (KFR) using oxidizing agent Magnesium Perchlorate[14], Zirconium(IV) compounds[15], The Efficient catalyst NbCl5[16], The efficient anthem sulphuric acid[17], Promiscuous Lipase catalyzed ($NiSO_4.6H_2O$) a new P-C bond formation in (MCR) [18]Tin(II) compound as catalyst for (KFR)[19].

Thederivatives of α-Aminophosphonates synthesized by Multicomponent condensation through Kabachnik-Field Reaction[12], are widely explained with a variety of catalysts. Now we have recently reporte the nano (PAni-Mn) catalyst as a novel catalyst used to form α-Aminophosphonates. The (PAni-Mn) Nano catalyst was used for the first time in Kabachnik-Field Reaction for α-Aminophosphonates synthesis. During the last decade, Polyaniline had great importance in the catalytic field[20-21]. The doping of the polyanilinewith metal increases the catalytical activity[22]. The Fe-polyaniline composite Nano-fiber catalystfor chemo selective hydrolysis ofoxime[23]. In proposed work first prepares polyaniline, doping should be done with the help of $MnCl_2$. The synthesized Nano material i.e the nano catalyst (PAni-Mn) is utilized for preparation of α-aminophosphonates derivatives.KFR involes condensation of primary or secondary amines, carbonyl compounds i.e. aldehyde or ketonesand dialkyl phosphite[24]. The Nano catalyst gives a high yield, short reaction time, it provides high surface area, increased catalytical activity. The synthesized Nano–catalyst was fully characterized by X-ray Diffraction, HR-TEM, FEG-SEM, FTIR.

## MATERIALS AND METHODS

### Materials

All chemicals are used in these experiments, which are supplied by Sigma Aldrich with high purity.

### Synthesis of polyaniline

The chemical oxidation methods were used for PANI-ES synthesis lower than (5ºC ). mL, Aniline (mL) was dissolved in Hydrochloric acid (70 mL, 1.5 M) his mixture is kept in an ice bath to maintain the temperature below 4-5 ºC. The 10 g Oxidizing agent Ammonium Per Sulfate (APS) was dissolved in deionized water. The solution of APS was added drop by drop into monomer solution. This mixture was stirred with a magnetic stirrer up to 4-5 hours[25]. The polymerization process is carried out, at the end of the polymerization reaction, the green color Polyaniline was formed, washed 2-3 times with D.W. and methanol. Finally, the dark-green composite powder is dried at 70ºC in a hot air oven, for 10-12 hours. The final product was grounded to form a green powder (Figure 1 ).

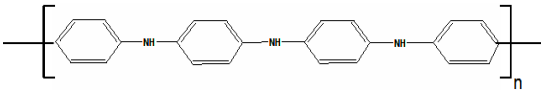



**Fig. 1. Structure of Polyaniline**

### Preparation of Polyaniline Nano-catalyst

After formation of polyaniline Emeraldine salt (ES), the accurate amount of solution of manganese chloride $MnCl_2$ slowly and carefully dissolved in polyaniline. The polyaniline manganese chloride solution was kept for stirring with the help of a round bottom flask and Magnetic stirrer (700 RPM) for about 5 hours. After filtration, the product washed 3 times with deionized water and three times with ethanol. The prepared nano catalyst was kept in a hot air oven for 6 h at 70-80$^0$C. In this method the nano particles of Mn was uniformly distributed in polyaniline[26-27]. There is formation of a nano catalyst having a dark green color (Figure 2).

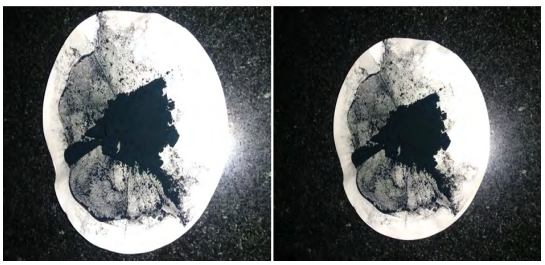


**Fig. 2. Freshly PAni-Mn Nano catalyst prepared**

## RESULT AND DISCUSSION

### Polyaniline (X-RD) Analysis

The X-RD technique is used to determine the crystalline nature of polyaniline. ThePANi-ES

gives three different peaks at room temperature i.e. 20.1, 25.3, 26.7$^0$C, respectively as shown in Fig. 2. Polymer is semi-crystalline in nature as the pattern shows sharp peaks due to the presence of Benzenoid and qunonoid groups in the polyaniline28. The sharp peak is observed in the XRD spectrum 2θ=25.2550 Thei nterplanar distance value obtained is 3.35A0. Hence the average crystallite size is calculated on the basis of the Debye Scherer Equation. (D=kλ/βcosθ) in this equation 1) D=average size of crystallite 2) k=0.89 (Shape of factor), λ=(1.54A0), β=full width at half maximum; θ=angle of diffraction[29].

**Table 1: Polyaniline data of XRD**

| Pos[$^0$2Th] | Heightt [cts] | FWHM[$^0$2Th] | d-Spacing[A$^0$] | Rel.Int[%] |
|---|---|---|---|---|
| 25.255 | 17.32 | 1 | 3.53544 | 100.00 |

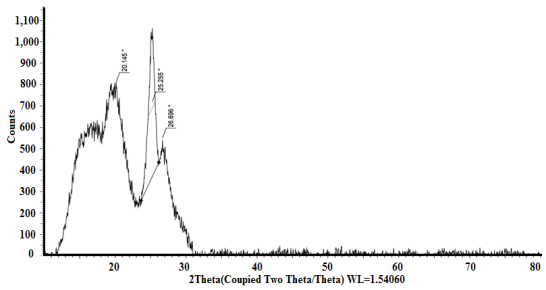



**Fig. 3. XRD Analysis of Polyaniline (ES)**

The average crystallite size value obtained is 1.387 nm on the basis of XRD data given in Table 1.

## SEM Characterization

The main objective of scanning electron microscopy is to determine morphological features and surface characteristics of the compounds. The instruments used JEOL JSM-7600F FEG-SEM. Morphology of polyaniline (ES) shows fibrous in nature particle size is around 1μm,100μm.This shows that the material is in good shape having high surface area, nano fibre which is used for further application. at high temperature polyaniline (ES), tends to formnano-rod like structure. The factors such as polymerization process, polymerization rate, growth of polymers and solvent interfacial tension are also involved in the formation of nano rods[30].

## TEM (300kV) Characterization

The TEM300kV.can be used to study electron beams to image a Nano particle and generate highly magnified images. The Nano structure of the polyaniline is shown in the following micrographs on the basis of TEM analysis, the particle size of Polyaniline is very small, i.e.1um, 200nm, 50nm. It is spherical in shapes, having the rough surface.

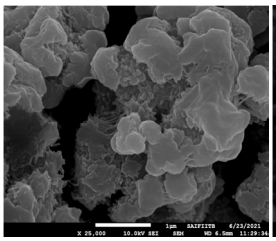


**Fig. 4a. SEM-Polyaniline (ES) 1μm**

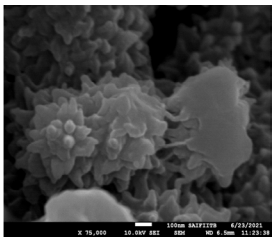


**Fig. 5b. SEM-PANI (ES) 100μm**

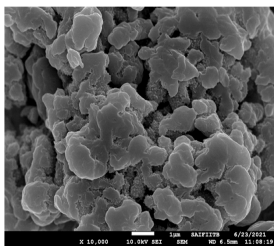


**Fig. 6c. SEM-Pani(Es) 1μm**

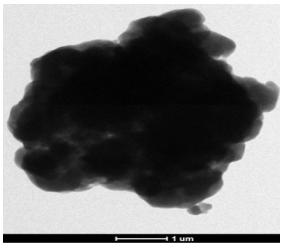


**Fig. 7. TEM Images of PAni (1μm)**

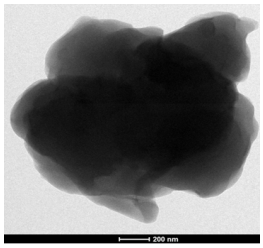


**Fig. 8. TEM Images of PAni (200nm)**

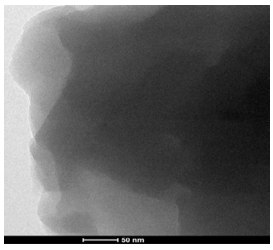


**Fig. 9. TEM Images of PAni 50nm**

## Fourier- transforms infrared spectroscopy (FTIR)

The prepared polyaniline was identified by FT-IR spectroscopy. The main characteristics peaks observed as 377, 3464, 3232, 2923, 2852, 1663, 1558, 1469, 1299, 1240, 1113, 1006, 878, 797, 679, 562, and 504 cm$^{-1}$ sample was run in the wavelength 4000-900 cm$^{-1}$. The FT-IR spectra of synthesized pure polyaniline (ES) is presented in

Fig. 9. In a spectrum, the characteristic band observed at 3464-3727 $cm^{-1}$ as a result of nitrogen-hydrogen stretching. The polymers peak observed on 3232, 2923, 2852 $cm^{-1}$ as a result of asymmetric, symmetric carbon-hydrogen vibration. The C=C of aromatic ring Absorption spectra observed on 1663 $cm^{-1}$ [31]. absorption spectra observed on sharp 1557 $cm^{-1}$ is the result of C-H stretching in an aromatic compound. The IR spectrum band observed at 1468.59 $cm^{-1}$ corresponds to C=N stretching in ring aromatic compound. 1240-1299 $cm^{-1}$. The polymer absorption band of C-N stretching On the basis of this, it confirm the presence of amine group[32].

An FT-IR spectrum valued at 1113 $cm^{-1}$ reveals the C-H bending vibrations. The absorption band lies below 504, 562, 679, 798, 878, 1006, 1044 $cm^{-1}$ show these spectral values showing the benzene ring being substituted by another group Consequently it shows polymerization[33]. The coupling of the phenyl nuclei within the amine group is mainly attached to Para position. On the basis of above FT-IR analysis data confirm that the prepared compound is polyaniline.

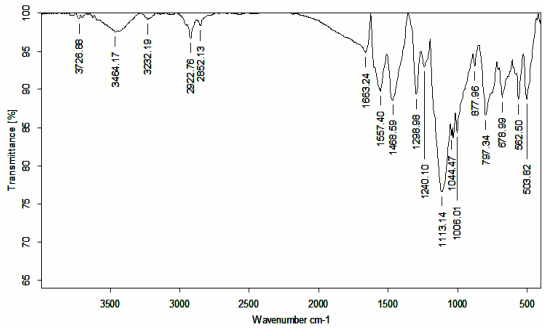



**Fig. 10. FT-IR spectrum of polyaniline(ES)**

## Preparation of α-Aminophosphonates using Nano-Catalyst

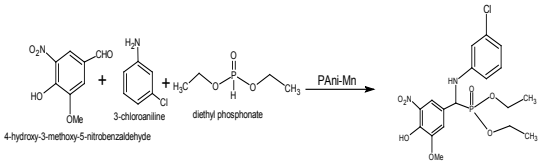
α-Aminophosphonate derivates are synthesized through Kabachnik-Fields reaction. Equimolar quantity of aldehyde (10 mmol), different aromatic amine (10mmol), diethyl phosphate (10mmol). Using a catalytic quantity of (PAni-Mn) nano catalyst. In a solvent free environment, they were agitated at room temperature[34]. The completion of reaction as indicated by TLC[35-36]. The reaction mixture was extracted with ethyl acetate and quenched with water (10 mL). The formation of pure α-aminophosphonate follows the purification of the compound in silica gel.

## RESULT AND DISCUSSION

Following α-Aminophosphonate derivatives were prepared.

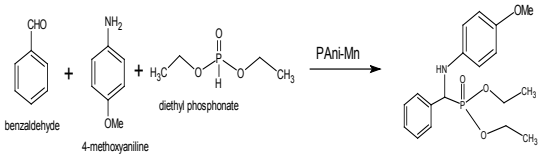
### Diethyl-3-chlorophenylamino-4-hydroxy-3-methoxy-5-nitrophenyl methylphosphonates.

M.F. $C_{18}H_{22}ClN_2O_7P$ M.W= 444, dark brown color m. p. = 177-179°C, yield=88% $^1$HNMR(300MHz, DMSO-$d_6$)$\delta_H$; 10.3 (s, 1H,-OH), 8.90-6.58 (m, 6H, Ar-H), 5.02-xx (m, 1H,N-H), 4.05-xx (m, 1H,P-CH), 3.81 (q ,4H, P-OCH2), 3.15 (s, 3H, -$OCH_3$), and 1.12 (s, 3H, -$OCH_3$) (t, H, -$OCCH_3$)./1162 MHz, 32 M/Z=444 and 446 with a 3:1 ratio for 31P-NMR37.



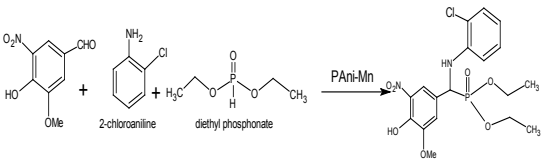

### Diethyl (4-methoxyphenyl)-N -(Phenyl amino) methylphosphonate

M.F. $C_{18}H_{24}NO_4P$ M.W=349, dark yellow color m.p. = 57-59°C, yield=92% $^1$HNMR(300MHz, CDCl3)$\delta_H$; 1.01-1.07(m,3H), 1.17-1.21(m, 3H), 3.71 (s,3H) 3.62-3.64, 3.84-3.88, 4.04-xx(m, 4H), 4.57-4.68 (m, 2H), 6.51-6.62(m, 3H), 6.76-6.80(m, 2H) and 7.0-xx(m,2H), 7.30-7.32(m, 2H). 31P-NMR (16.9 MHz, DMSO-$d_6$) With a 3:1 ratio, 30.6 M/Z equals 444 and 44638.



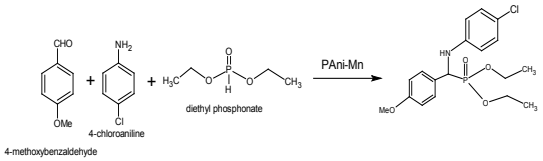

### Diethyl (2-chloro phenyl amino) nitrophenyl methyl (4-hydroxy-3-methoxy) phosphonate

M.F. $C_{18}H_{22}ClN_2O7P$ M.W=408, brown color m.p. = 174-177°C, yield=87% $^1$HNMR(300MHz, DMSO-$d_6$)$\delta_H$: 8.20(s, 1H, ArH), 7.28(d, 1H, *J*=6.5 Hz, ArH), 6.989d, 1 h, *J*=6.5 Hz, ArH), 6.92 (d, 2H, *J*=6.5Hz, ArH) 6.70(s, 1H, ArH), 4.80 (d, 1H, JCHPO=23.7 Hz, CHP) 4.02-4.12(m, 2H, $OCH_2CH_3$), 3.95-3.98(m, 1H, $OCH_2CH_3$), 3.90 (s, 3H, $OCH_3$) 3.70-3.75(m, 1H, $OCH_2CH_3$), 1.26 (t, 3H, *J*=6.4 Hz, $CH_3$), 1.15(t, 3h, *J*=6.4 Hz, $CH_3$) 31P–NMR (16.5 MHz, DMSO-$d_6$, at 30.4M/Z=440 and 44239.



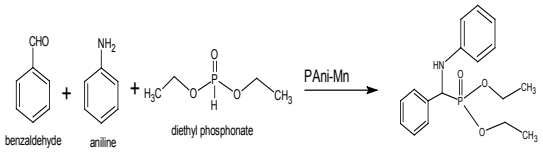
**Diethyl(4-methoxy phenyl)-N- (4-chlorophenyl amino) methylphosphonates**

M.F. $C_{18}H_{23}ClNO_4P$ M.W= 366, yellow color m.p. = 161-163°C, yield=91% $^1$HNMR(300MHz, DMSO-$d_6$)$\delta_H$; 7.41(d, 2H, *J*=7.4Hz, Ar-H), 7.14 ((t, 2H, *J*=7.4 Hz, ArH,), 6.91(d, 2H, *J*=8.4 Hz, Ar H), 6.71(d, 2H, *J*=8.4 Hz, Ar-H), 6.71(t, 1H, *J*=7.24, Hz, Ar-H), 6.62(d, 2H, *J*=8.1 Hz, Ar-H), 4.76 (s, 1H, NH), 4.75(d, 1H, *J*CHPO=40.0. Hz, CHP), 4.12-4.18(m, 2H, $OCH_2CH_3$), 3.94-4.0 (m, 1H, $OCH_2CH_3$), 3.78(s, 3H$OCH_3$), 3.70-3.76 (m, 1H, $OCH_2CH_3$), 1.30(t, 3H, *J*=7.2Hz, $CH_3$), 1.18 (t, 3H, *J*=7.2 Hz, $CH_3$).$^{31}$P-NMR (16.1 MHz, DMSO-$d_6$) 30.1M/Z=448 and 447 with 3:1 ratio[40].




**Diethyl phenyl (phenyl amino) methyl phosphonate**

M.F. $C_{17}H_{22}NO_3P$ M.W=318, white color m.p. =93-95°C, yield=89% $^1$HNMR(300MHz, $CDCl_3$) $\delta_H$; 1.1(3H, JHH= 7.1Hz, t, $OCH_2CH_3$); 1.3 (3H, JHH=7.1Hz, t, $OCH_2CH_3$); 3.74-4.4 (m, 4H, $OCH_2CH_3$); 5.1(s, 1H, NH); 4.8(1H, JHP=24.6 Hz, d, CHP); 5.1(m, 10H, Ar-H), 31P –NMR (16.3 MHz DMSO-$d_6$) with 3:1 ratio.[41]




## CONCLUSION

Using the one-pot, three-component Kabachnik-field reaction, it was possible to synthesize novel derivatives of α-amino-phosphonates. The use of different types of aldehyde, substituted aniline and dialkyl phosphate under solvent free condition using a novel nano-catalyst (PAni-Mn). The nano catalyst doped polyaniline with manganese (PAni-Mn) has greater efficiency, simple reaction condition, easy to handle and efficient. The Nano-catalyst was characterized by X-ray diffraction, HR-TEM, FEG-SEM, FTIR technique. All the prepared compounds were analyzed. It is worth mentioning that this catalyst is first used in the synthesis of α-aminophosphonates.

## ACKNOWLEDGEMENT

The SAIF IIT Bombay, SAIF COCCHI, and KERAL are gratefully acknowledged by the authors for providing analytical assessment facilities. The Research Center, Department of Chemistry, G.S. College Khamgaon, Dist-Buldana (MS) India, and Late Ku.Durga K. Banmeru Science College Lonar-Dist-Buldana-443302 (MS) India has both provided assistance to the authors.

## REFERENCES

1. Weigang, F.; Charlie, V.; Lianjie, W.; Mohammed, A.; Jia-Neng, T.; *Recent trends in Carbohydrate Chemistry*., **2020**, *1*, 73-100 https://doi.org/10.1016/B978-0-12-817467-8.00002-5
2. Alcha, A.; Zeneb A.; Hacene K.; Yasmine C.; Racha, G.; Rachida, Z.; Nour-Eddine, A.; *European Chemical Societies Publishing*., **2015**, https://doi.org/10.1002/slct.202101360
3. Du, S. C.; Faiger, H.; Belakhov.; Timor B. T.; *Journal of Bioorganic Medicianal Chemistry*., **2018**, *7*, 2671-2682. doi:10.1016/S0968-0896(99)00233-3.
4. Zomova, A. M.; Molodykh, Z. H.; Kudryavtseva, L.A.; Teplyakova, L.V.; Fedorov S.B.; Lvanov, B. E. *Pharmaceutical Chemistry Journal*., **1986**, *20*, 774-777.
5. Jin, L. H.; Song, B. A.; Zhang, G. P.; Xu, R. Q.; Zhang, S. M.; Gao X. W.; Hu, D. Y.; Song, Y. S.; *Bioorganic & Medicinal Chemistry Letters*., **2006**, *16*, 1537–1543.
6. Kukhar, V. P.; Hudson H. R.; *Chemistry*., **2000**. Corpus ID 94692114.
7. Yingshuxu.; Kai, V. B.; Gangfang, Xu.; Song, Y.; Wei, X.; Devu, H.; Ping, L.; Guiping, O.; Linhong, J.; Zhuo C.; *Molecules*., **2006**, doi:10.3390/11090666.
8. Fields, E. K.; *J. of American Chemi. Society*., **1952**, *74*, 1528. doi:10.1021/ja011 26a054.
9. Cherkasov, R. A.; Galkin, V. I.; *Russian Chemical Rewiev*., **1998**, *67*, 857–882. doi:10.1070/RC1998v067n10ABEH000421.
10. Sobanov,A.A.; ZolotukhinA.V.; GalkinV.I.; Cherkasov, R.A.; PudovikA.N.; *Rassian Journal of General Chemistry*, **2002**, *72*, 1067-1070.

11. Kabachnik M.I.; Medved T.Y.; dokladya kademiinauk SSSR., **1952**, *83*, 689-692.
12. Fields E.K. "The Synthesis of Esters of Substituted Amino Phosphonic Acids". *Jounal of American Chemical Society*., **1952**, *74,* 1528–1531. doi: 10.1021/ja01126a054.
13. Nellisara, D. S.; *Journal of Chemistry*., **2013**, https://doi.org/10.1155/2013/240381.
14. Shrikant,B.;Chakraborati,A.K.*Journal of Organic Chemistry.,* **2007**, *72*(4), 1263-1270 https://doi.org/10.1021/jo062140i.
15. Shrikant, B.; Asit K. C.; *Journal of Organic Chemistry*., **2008**, *73*(15), 6029-6032. https://doi.org/10.1021/jo8009006.
16. Jun-Tao, H.; Jian-Wu, G.; Zhan-hui, Z.; Applied Organometallic Chemistry., **2010**; https://doi.org/10.1002/aoc.1687.
17. Guo-Ying, S.; Jun-Tao H.; Jing Jie, D.; Jun, L.; Yong-Jie H.; TuoXue.; Zhan-Hui, Z.; *Journal of the Chinese Chemical Society*., **2013**; https://doi.org/10.1002/jccs.201000194.
18. Samia, G.L.; Martial, L.; Aribi-Zouioueche.; *Heteroatom Chemistry*., **2017**, *28*, 21408. https://doi.org/10.1002/hc.21408.
19. Ricardo, G.M.; Kensaku, N.; **2010**, *1*, 57-62, DOI: 10.1055/s-0029-1217091.
20. Mandal, P.; Chengchem, G.; Jeffery L. Y.; *Arebian Journal of Chemistry*., **2019**, https://doi.org/10.1016/j.arabjc.2019.05.004.
21. Harish, K.; Anurag, Boora.; Ankita,Y.; Rajni, R.; *Results in Chemistry*., **2020**, *2*, 100046, https://doi.org/10.1016/j.rechem.2020.100046.
22. Grzegorz, K.; Jan P.; Miroslaw, G.; The Scientific *World Journal*., **2014**, *15*, 1234-1239https://doi.org/10.1155/2014/648949.
23. Sanjit, K. M.; Madhumita, B.; Arun, M.; Abhijit D.; Debabrata, A. M.; *Journal of Colloid and Interface Science*., **2018**, *523*, 592-601. https://doi.org/10.1016/j.jcis.2017.11.059.
24. Gyorgy, K.; Erika, B.; *Molecule*, **2012**, *17(*11), 12821-12835: https://doi.org/10.3390/molecules171112821.
25. Nicolae, O.; Ioanasisu.; Mircea, P.; Victor L. P.; Ludovic, K.; *Farmacia*., **2010**, *58*, 5.
26. Alam, J.; Riaz, U.; Sharif A.; *Journal of Composite Materials*., **2010**, *31*, 32.
27. Gupta, A.; Mahendra K.; *Journal of Material Science and Engineering*., **2017**,*10*, 4172.
28. Vadiraj K.T,; Belagali, S. L.*Journal of Applied Chemistry*., **2015**, *8*, 53-56. DOI: 10.9790/5736-08125356.
29. Petra R.; Varga, Gyorgy, K; *Molecules*., **2021**, 26092511.
30. Ajeel, K.I.; Kareem, Q.S.; J. Phys.: *Conf. Ser*., **2019**, *12*(34), 012020,
31. Hou, J.; Gao, J.; Zhang H.; *Applied Organometallic Chemistry*., **2011**, *25*(1), 47-53.
32. Bavio, M.A.; Acosta G.G.; *Journal of Power Sources*., **2014**, *245*, 475-481.
33. Francisco, R.; Rangel-Olivares.; *Coating*., **2021**,*11*, 653.
34. Nicolae, O.; Ioanasisu.;Mircea, P.; Victor L.P.; Ludovic, K.; *Farmacia*., **2010**, *58*(5).
35. Du-Lin K.; Ming-Shu W.; Chang-R H.; Jin-Ya M.; De-Hui W.; *Asian Journal of Chemistry*., **2011**, *23*(7), 2871-2873.
36. Erika, B.; AnnaTripolszky.; Adam, T.; **2018**; https://doi.org/10.1515/9783110535839-006.
37. Kuhelika D.; Nasruddeen Y.A.; Shivkumar, B.; Sankar, V.; Arthanareeawari, M.; Kamaraj,A.; *International Journal of Advanced Chemical Science and Application*., **2015**, *3*, 2.
38. Sobhani, S.;Zarifi,F.; Barani, F.; Skibsted, F.; *Organic Chemistry Research*., **2019**, *5*(2), 117-127.
39. Boutaina A.; Bouchra E.K.; Papa Daouda M.; Najoie, F.; Ansari.; Abdelhakim el makssoudi.; Abdelazizsoukri.; *ACTA Scientific Pharmaceutical Sciences*., **2018**, *2*(11), 63-72.
40. Subramanyam, S. K.; Thaslim B.; Madhava, G.; Sk.Nayab, Rasool.; Sk.Adam.; Durga Shrinivas M.; **2017**, 192,3, https://doi.org/10.1080/10426507.2016.1225056.
41. Sravya, G.; Balkrishna, A.; Grigory V.; Zyryanov, G.; Mohan, C.; Suresh Reddy.; Bakthavachala N. R.; Phosphorous, Sulfur and Silicon, **2021**, *196*, 4. https://doi.org/10.1080/10426507.2020.1854258