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PİRİDİNKARBOKSİLİK ASİT TÜREVLERİ İLE BİPİRİDİN TÜREVLERİNİN METAL KOMPLEKSLERİ

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ÖZ

Bu çalışmada, literatürde yapılan piridindikarboksilik asit türevleri {2,3-piridindikarboksilik asit, 2,3-piridindikarboksilik asit *n*-oksid, 3,4-piridindikarboksilik asit, 3,5-piridindikarboksilik asit, 5-etil-2,3-piridindikarboksilik asitin, 2,4-piridindikarboksilik asit, 6-metil-2,4-piridindikarboksilik asit *N*-oksid, 2,5-piridindikarboksilik asit, 2,6-piridindikarboksilik asit, 4-hidroksi-2,6-piridindikarboksilik asit, 2,6-piridindikarboksilik asit *N*-oksid, 2,3,5-piridinrikarboksilik asit, 6-metil-2,3,5-piridinrikarboksilik asit, 2,4,6-piridinrikarboksilik asit, 2,3,5,6-piridintetrakarboksilik asit, 2,2'-bipiridin-3,3',6,6'-piridintetrakarboksilik asit, 4,4'-bipiridin-2,2',6,6'-piridintetrakarboksilik asit} ile bipiridin türevlerinin {2,2'-ditiyodipiridin, 4,4'-bipiridin, 4,4'-ditiyodipiridin, 1,2-bis(4-piridil)etan, 1,2-bis(piridin-4-il)eten, 1,2-bis(4-piridil)etilen, 1,3-di(4-piridil)propan, 1,2-bis(2,4-piridil)etan, 1,2,3,4-tetrakis(4-piridil)bütan, 4,4'-bipiridin *N,N*-dioksid, bis{2-(piridin-4-il)etenil}benzene, 4,4'-dipiridil-*N,N'*-dioksid, 1,2,4,5-tetrakis(4-piridil)benzene ve bis(4-piridil)amin} bazı metallerle {La(III), Mn(II), Co(II), Ni(II), Cu(I), Cu(II), Zn(II), Cd(II), Ag(I), Ru(II), In(III), Sn(II), Ga(III), La(III), Ce(III), Sm(III), Tb(III), Dy(III), Ho(III)} karışık ligandlı kompleksleri ve biyolojik aktiviteleri incelenmiştir. Literatürde piridindikarboksilik asit ve bipiridin türevlerinin anti oksidan, anti fungal, anti mikrobiyal, anti tümör, anti kanser, anti inflamatuvar, anti ülser, anti diyabetik, analjezik ve radyoprotektif aktivite gibi biyolojik aktiviteleri vardır. Bu iki aktif grubun gösterdiği biyolojik özellikler, bunlardan elde edilecek olan proton transfer tuzu ve metal kompleksleri de benzer özellikler göstereceği aşikardır. Ancak metal komplekslerin aktivite çalışmaları oldukça azdır. Metal komplekslerinin biyolojik özelliklerin daha ayrıntılı bir şekilde çalışılması literature önemli bir katkı olacaktır.

Anahtar kelimeler: Piridindikarboksilik asit, Bipiridin, Metal kompleksi.

METAL COMPLEXES OF PYRIDINECARBOXYLIC ACID DERIVATIVES AND BIPYRIDINE DERIVATIVES

ABSTRACT

In this study, complexes and biological activities of pyridinecarboxylic acid derivatives {2,3-pyridinecarboxylic acid, 2,3-pyridinecarboxylic acid n-oxide, 3,4-pyridinecarboxylic acid, 3,5-pyridinecarboxylic acid, 5-ethyl-2,3-pyridinecarboxylic acid, 2,4-pyridinecarboxylic acid, 6-methyl-2,4-pyridinecarboxylic acid N-oxide, 2,5-pyridinecarboxylic acid, 2,6-pyridinecarboxylic acid, 4-hydroxy-2,6-pyridinecarboxylic acid, 2,6-pyridinecarboxylic acid N-oxide, 2, 3,5-pyridinetricarboxylic acid, 6-methyl-2,3,5-pyridinetricarboxylic acid, 2,4,6-pyridinetricarboxylic acid, 2,3,5,6-pyridinetetracarboxylic acid, 2,2'-bipyridine-3,3', 6,6'-pyridinetetracarboxylic acid, 4,4'-bipyridine-2,2', 6,6'-pyridinetetracarboxylic acid} and bipyridine derivatives {2,2'-ditiyodipiridin, 4,4'-bipiridin, 4,4'-ditiyodipiridin, 1,2-bis(4-piridil)etan, 1,2-bis(piridin-4-il)eten, 1,2-bis(4-piridil)etilen, 1,3-di(4-piridil)propan, 1,2-bis(2,4-piridil)etan, 1,2,3,4-tetrakis(4-piridil)bütan, 4,4'-bipiridin *N,N*-dioksit, bis{2-(piridin-4-il)etenil}benzene, 4,4'-dipiridil-*N,N*-dioksit, 1,2,4,5-tetrakis(4-piridil)benzene ve bis(4-piridil)amin} with mixed ligands with some metals {La(III), Mn(II), Co(II), Ni(II), Cu(I), Cu(II), Zn(II), Cd(II), Ag(I), Ru(II), In(III), Sn(II), Ga(III), La(III), Ce(III), Sm(III), Tb(III), Dy(III), Ho(III)} were investigated. In the literature, pyridinecarboxylic acid and bipyridine derivatives have biological activities such as anti oxidant, anti fungal, anti microbial, anti tumor, anti cancer, anti inflammatory, anti ulcer, anti diabetic, analgesic and radioprotective activity. It is obvious that the biological properties of these two active groups, the proton transfer salt and metal complexes obtained from them will also show similar properties. However, activity studies of metal complexes are very few. A more detailed study of the biological properties of metal complexes will be an important contribution to the literature.

Keywords: *Pyridinecarboxylic acid, Bipyridine, Metal complex.*

1. GİRİŞ

Organik asitlerden olan piridindikarboksilik asitler, yapısında iki -COOH grubundaki dört oksijen ve piridin halkasında bulunan elektron verici azot atomu içermektedir. 2,3-Piridindikarboksilik asit, 3,4-piridindikarboksilik asit, 3,5-piridindikarboksilik asit, 2,4-piridindikarboksilik asit, 2,5-piridindikarboksilik asit ve 2,6-piridindikarboksilik asit olmak üzere piridindikarboksilik asitlerin altı farklı izomeri vardır. Yapılan çalışmalarda piridindikarboksilik asitler metal iyonlarına ya metal merkezlerine karboksilat köprüsü ile bağlanarak dimerik veya polimerik kompleks oluşturdıkları veya O, N, O' uçlarından bir metal atomu ile şelat oluşturdıkları gözlenmiştir. Piridinkarboksilik asit türevleri (H_2pka) ve proton vermiş formları ($Hpka$, pka^2) ile birçok çalışma yapılmaktadır. Bu bileşikler antioksidan, antifungal, antimikrobiyal, antitümör, antikanser, antiinflamatuvar, antiülser, antidiyabetik, antimütajen, süperoksit giderici ve radyoprotektif aktiviteye gibi biyolojik özelliklere sahiptir [1-6].

Bipiridiller, bipiridinler veya dipiridinler olarak adlandırılan bipiridin türevleri, iki piridin halkasının birbirini bağlanmasıyla oluşurlar. İki azot atomunun halkalara 2,2'-, 2,3'-, 2,4'-, 3,3'-, 4,4'- ve 3,4'- konumlarına bağlanmasıyla altı izomeri vardır [7,8]. Bipiridin türevlerinin anti hipertansif, antibakteriyel, anti psikotik, kas gevşetici, analjezik, antioksidan, anti diyabetik, antiinflamatuvar, anti

kanser, anti sıtma, enzim inhibisyonu, anti depresan, antikolinerjik gibi biyolojik aktiviteleri mevcuttur [9,10].

2. SENTEZLENEN METAL KOMPLEKSLERİ

2,3-Piridindikarboksilik asit (H_223pka) ile 4,4'-bipiridin'in proton transfer tuzu $\{(H_2bpy)(H_23pka)_2\}$ [11,12] ve $Mn(III) \{ \{(H_2bpy)[Mn(23pka)_2] \cdot (bpy) \cdot 6H_2O \}_n \}$ [13], $Cu(II) \{ [Cu(H_23pka)_2] \cdot 2(bpy) \cdot 6H_2O \}_n$ [14], $[Cu(bipy)_{0.5}(23pka)] \cdot 3H_2O$, $[Cu(bipy)_{0.5}(23pka)] \cdot 0.5bipy \cdot 3H_2O$ [15], $Zn(II) \{ [Zn_2(2,3pka)_3] \cdot (H_2bpy) \cdot 3H_2O \}_n$ [16], $\{ [Zn(23pka)(2,2'-bpy)(H_2O)] \cdot 2H_2O \}_n$ ve $Cd(II) \{ [Cd_2(23pka)(bpy)_2(NO_3)(H_2O)_2] \cdot (NO_3) \cdot 3H_2O \}_n$ [17], 1,2-bis(4-piridil)etan'ın (bpa) ile $Cu(II) \{ \{ H_2bpa[Cu(\mu-23pka)_2] \}_n \}$, $Cd(II) \{ [Cd(\mu-23pka)(\mu-bpa)_{0.5}(H_2O)_2]_n \}$ [18] ve 2,3-piridindikarboksilik asit *N*-oksit ($H_223pkao$) ile 4,4'-bipiridin'in $Mn(II) \{ [Mn(23pkao)(bpy)(H_2O)_2] \}$, $Co(II) \{ [Co_2(23pkao)_2(bpy)(H_2O)_2] \cdot H_2O \}$, $Cu(II) \{ [Cu(23pkao)(bpy) \cdot H_2O] \}$ ve $Zn(II) \{ [Zn_2(23pkao)_2(bpy)(H_2O)_2] \}$ [19] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik çalışmalar ile aydınlatılmıştır.

3,4-Piridindikarboksilik asit (H_234pka) ile 1,2-bis(4-piridil)etilen'in (bpe) $Co(II) \{ [Co_2(\mu_4-34pka)_2(\mu-bpe)(H_2O)_2] \cdot H_2O \}_n$ [18] ve 3,5-piridindikarboksilik asit ile 4,4'-bipiridin'in $Sn \{ [(n-Bu_3Sn)_2(\mu-35pka)(\mu-bpy)]_n \}$ [20] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik metotlar ile açıklanmıştır.

5-Etil-2,3-piridindikarboksilik asitin ($H_2Et23pka$) ile 4,4'-bipiridin'in $Co(II) \{ [Co_2(Et23pka)_2(bpy)(H_2O)_2] \cdot 3H_2O \}_n$, 1,2-di(4-piridil)etilen'nin (bpe) $Co(II) \{ [Co_2(Et23pka)_2(bpe)(H_2O)_2] \cdot 3H_2O \}_n$ [21] ve $Zn(II) \{ [Zn_3(Et23pka)_2(HEt23pka)_2(bpe)]_n \}$ [22], 1,2-bis(4-piridil)etan'ın (bpa) $Co(II) \{ [Co_2(Et23pka)_2(bpa)(H_2O)_2] \cdot 3H_2O \}$ [23] ve $Zn(II) \{ [Zn_3(Et23pka)_2(HEt23pka)_2(bpa)]_n \}$ [22] ve 1,3-di(4-piridil)propan'ın (bpp) $Zn(II) \{ [Zn_2(Et23pka)_2(bpp)_2] \cdot H_2O \}_n$ kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik çalışmalar ile karakterize etmişlerdir.

2,4-Piridindikarboksilik asit (H_224pka) ile 4,4'-bipiridin'in $Co(II) \{ [(2,4pka)Co(bpy)Co(2,4pka)] \cdot 2H_2O \}$ [24], $Cu(I)/Cu(II) \{ [CuI_2CuII(bpy)_2(24pka)_2] \cdot 4H_2O \}$ [25], $Zn(II) \{ [Zn_2(24pka)_2(bpy)(H_2O)_4] \cdot 2H_2O \}$ [26], $[Zn_2(24pka)_2(bpy)(H_2O)_6] \cdot 2H_2O$ [27], 1,2-bis(4-piridil)etan $Mn(II) \{ [Mn_2(24pka)_2(bpe)(H_2O)_6] \cdot 2H_2O \}$ [28], 1,2-bis(2,4-piridil)etan (bpa) $Co(II) \{ [Co_2(24pka)_2(bpa)(H_2O)_6] \cdot (H_2O)_2 \}$ [29], 2,2'-ditiyodipiridin'in (ald) $Cu(II) \{ [Cu_2(24pka)_2(ald)_2(H_2O)_2] \cdot 8H_2O \}$ [30] ve 2,4-piridindikarboksilik asit *N*-oksit ($H_224pkao$) ile 4,4'-bipiridin'in $Co(II) \{ [Co(24pkao)(bpy)(H_2O)(H_2O)]_n \}$, $Ni(II) \{ [Ni(24pkao)(bpy)(H_2O)(H_2O)]_n \}$, 6-metil-2,4-Piridindikarboksilik asit *N*-oksit ($H_2M24pkao$) ile 1,2,3,4-tetrakis(4-piridil)bütan'ın (tpb) $Co(II) \{ [Co(M24pkao)(tpb)_{0.5}(H_2O)(H_2O)_x]_n \}$, $Ni(II) \{ [Ni(M24pkao)(tpb)_{0.5}(H_2O)(H_2O)_x]_n \}$, $Zn(II) \{ [Zn(M24pkao)(tpb)_{0.5}(H_2O)(H_2O)_x]_n \}$, $Cd(II) \{ [Cd(M24pkao)(tpb)_{0.5}(H_2O)(H_2O)_x]_n \}$ [31] ve $Zn(II) \{ [Zn(M24pkao)(tpb)(H_2O)(H_2O)]_n \}$ [32] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik metotlar ile aydınlatılmıştır.

2,5-Piridindikarboksilik asit (H_225pka) ile 4,4'-bipiridin'in $Fe(II) \{ [Fe(25pka)(bpy)] \cdot H_2O \}$ [33], $[Fe(25pka)(bpy)] \cdot H_2O$ [34], $Co(II) \{ [Co(25pka)_2(H_2O)_2] \cdot (H_2bpy) \}$ [35], $\{ [Co_2(25pka)(25Hpka)_2(bpy)(H_2O)_3] \cdot 6H_2O \}_\infty$ [36], $[Co_2(bpy)(25pka)_2(H_2O)_6]_n$ [37], $Ni(II) \{ [Ni_2(bipy)_{1.5}(25pka)_2(H_2O)_2] \cdot 3.5H_2O \}$ [38], $Zn(II) \{ (H_2bpy)[Zn(25pka)_2(H_2O)_2] \}$ [39], $[Zn_2(25pka)_2(bpy)(H_2O)_8]$ [40], $Sn \{ [(n-Bu_3Sn)_2(\mu-26pka)(\mu-bpy)]_n \}$ [20], $In(III)$

{[Hbpy][In(H25pka)(H2O)Cl₃].2H₂O]_n, {[H₂bpy]₄[In₂(25pka)₇(H₂O)].7H₂O]_n, {[H₂bipy]₃[In₂(25pka)₆(H₂O)].6H₂O]_n} [41], 4,4'-bipiridin *N,N*-dioksit'in (bpyo) In(III) {[In₂(25pka)₂(bpyo)(H₂O)₂Cl₂].2H₂O]_n} [42], Co(II) {[Co(2,5-pydc)(bipyo)_{0.5}(H₂O)₃.3H₂O]_n} [43] ve 1,2-di(4-piridil)etan Cu(II) {[Cu₂(25pka)₂(bpa)(H₂O)₂].3H₂O.DMF, [Cu₂(25pka)₂(bpa)(H₂O)₂].7H₂O} [44], 4,4'-ditiyodipiridin'in (ald-4) Cu(II) {[Cu₂(25pka)₂(ald-4)(H₂O)₂].3H₂O.MeOH]_n} [45] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik çalışmalar ile açıklanmıştır.

2,6-Piridindikarboksilik asit (H₂26pka) ile 4,4'-bipiridin'in Sr {(H₂bpy)[Sr(26pka)₂(H₂O)₃].3H₂O} [46], V(V) {[H₂bpy]_{0.5}[VO₂(26pka)].2H₂O} [47], V(VI) {[H₂bpy]_{0.5}[VO₂(26pka)].4H₂O} [48], Cr(III) {(H₂bpy)[Cr(26pka)₂].4H₂O} [49], Mn(II) {[Mn(bpy)₂(H₂O)₄](26pka).4H₂O} [50], Mn(III) {(H₂bpy)[Mn(26pka)₂].4H₂O} [51], Fe(II) {[Fe(bpy)₂(H₂O)₄](26pka).4H₂O} [52], Fe(III) {(Hbpy)[Fe(26pka)₂].4H₂O} [53,54], Co(II) {[Co₂(26pka)₂(μ-bpy)(H₂O)₄].4H₂O} [54], [Co(bpy)₂(H₂O)₄](26pka).4H₂O [55], {[Co(26pka)(bpy)]·(MeOH)]_n [56], [(26pka)Co(μ-bpy)Co(26pka)].8H₂O [57], [Co(26pka)(bpy)].0,5MeOH [58], [Co(26pka)(bpy)].0,5MeOH [55], {[Co(μ-26pka)](μ-bpy)].3H₂O]_∞, {[Co(μ-26pka)](μ-bpy)].H₂O.MeOH]_∞, {[Co(μ-26pka)](μ-bpy)].2H₂O.0,5Me₂SO]_∞, {[Co(26pka)(OH₂)₂](μ-bpy)].3H₂O]_∞, {[Co(26pka)(OH₂)₂](μ-bpy)].4H₂O]_∞} [59], {[Co₃(O26pka)₂(bipy)₂(H₂O)₄].16/3H₂O]_n, {[Co(HO26pka)(bipy)].19/6H₂O]_n, {[Co(bipy)(H₂O)₄][Co(HO26pka)₂].1/2(bipy).4H₂O]_n, ve [Co₂(HO26pka)₂(bipy)(H₂O)₄].2H₂O} [60], {(H₂bpy)[Co(26pka)₂].6H₂O, (Hbpy)(H₂bpy)_{0.5}[Co(26pka)₂].3(23dhn)_{0.3}(H₂O)₂, (H₂bpy)[Co(26pka)₂].3(27dhn)_{0.6}(H₂O), (Hbpy)₂[Co(26pka)₂](phgl)_{0.5}(H₂O) 2,3- or 2,7-dihidroksinaftalin ve florogüsinol} [61], Ni(II) {[Ni(26pka)(bpy)(μ-bpy)]₄.8H₂O} [54], [Ni₂(26pka)₂(μ-bpy)(H₂O)₄].4H₂O} [62], [Ni₂(26pka)₂(bpy)(H₂O)₄].4H₂O} [63], {[Ni(26pka)(μ-bpy)]_{1.5}.H₂O.Me₂SO]_∞} [59], Cu(II) {[Cu(26pka)(H₂O)₂](μ-bpy)].2H₂O} [64], {Cu₂(26pka)₂(bpy)(H₂O).3H₂O]₂} [65], {Cu₂(26pka)₂(bpy).4H₂O]_n} [66], {[Cu₃(26pka)₃(bpy)_{1.5}(H₂O)_{2.25}].2,5(H₂O)]_n} [67], 2Cu₂(H₂O)₂(bpy)(26pka)₂Cu₂(H₂O)(bpy)(26pka)₂.6H₂O, {[Cu(26pka)₂](μ-bpy)].2H₂O.CH₂Cl₂]_∞} [68], [Cu₂(26pka)₂(bipy)].4H₂O, [Cu(26pka)(OH₂)](μ-bpy)_{0.5}[Cu(26pka)(OH₂)_{0.75}(OHMe)_{0.25}](μ-bpy)[Cu(26pka)(OH₂)₂].2,25H₂O.0,5MeOH, [69], Zn(II) {[Zn₂(HO26pka)₂(bipy)(H₂O)₂].2H₂O]_n} [60], {[Zn₂(26pka)₂(bpy)(H₂O)₂].5H₂O]_n} [70], [H₂bpy][Zn(26pka)₂].6H₂O, [H₂bpy][Zn(26pka)₂].3,5(4np).2H₂O (4np = 4-nitrofenol), [H₂bpy][Zn(26pka)₂].2(2,7dhn).5H₂O, [H₂bpy][Zn(26pka)₂].2(pyrogl).6H₂O (pyrogl = pirogallol) [71], Ga(III) {(H₂bpy)_{1/2}(H₂26pka)_{1/2}[Ga(26pka)₂].4H₂O} [72] (H₂bpy)[Ga(26pka)₂].(H₂26pka).4H₂O} [73], Sn {[Sn-Bu₃Sn]₂(μ-25pka)(μ-bpy)]_n} [10], La(III) {(H₂bpy)_{1.5}[La(26pka)₃].2(cat).4H₂O, (H₂bpy)₃[La(26pka)₃].3(23dhn).19H₂O, (H₂bpy)_{1.5}[La(26pka)₃].3(27dhn).10H₂O [cat = 1,2-dihidroksibenzen, 23dhn = 2,3-dihidroksinaftalin, 27dhn = 2,7-dihidroksinaftalin]} [74], Ru(II) {[{(26pka)(COD)Ru]₂(μ-bipy)] (COD = 1,5-siklooktadien)} [75], In(III) {[In₂Cl₄(26pka)(bpy)₂]} [76], Ce(III) {[{(H₂bpy)[Ce₂(26pka)₄(H₂O)₄].5H₂O]} [77], Ce(IV) {(H₂bpy)[Ce(26pka)₃].4H₂O} [78], Sn(II) {[Sn₂(H26pka)₂(H₂O)₂O]_n}, Pb(II) {(H₂bpy)_{0.5}[Pb(26pka)₂(Hbpy)].bpy.4H₂O} [79], Pr(III), Nd(III), Sm(III), Eu(III), Gd(III), Tb(III), Er(III), Yb(III) {[Ln(26pka)₃Cu₃(bipy)₃.m(H₂O)]_n (Ln = Pr, Nd, m = 5; Ln = Sm, Eu, Gd, Tb, Er, Yb, m = 4)} [80], Hg(II) {[H₂bpy]₂[Hg(26pka)₂].Hg(H₂O)₂(H26pka)₂.12H₂O} [81], Sm(II), Eu(II), Gd(II), Tb(II), Dy(II) {[Ln₂(SO₄)₂(H₂O)₂(26pka)₂Cu₂(bpy)₂.2(H₂O)]_n (Ln = Sm, Eu, Gd, Tb, Dy)} [82], Sb(III) {(Hbpy)₂[Sb(26pka)(OH)₂(μ-OH)]₂.8H₂O} [83], UO₂ {(UO₂)₂(μ₂-OH)(26pka)₂Zn(bpy)(OAc)₂(H₂O)₉} [84] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik metotlar ile karakterize etmiştir.

2,6-Piridindikarboksilik asit (H_226pka) ile 1,2-bis(piridin-4-il)eten'in (bpe) Cu(II) $\{[Cu(26pka)(OH_2)](\mu-bpe)[Cu(26pka)]\} \cdot 3H_2O$, $[Cu_2(26pka)_2(bpe)] \cdot 2H_2O$, 1,4-bis{2-(piridin-4-il)etenil}benzen'in (bpeb) Cu(II) $\{[Cu_2(26pka)_2(bpeb)] \cdot 4H_2O$, $\{[Cu(26pka)(OHMe)]_2(\mu-bpeb)\}$ [69], 4,4'-dipiridil-N,N'-dioksit'in (dpyo) Cu(II) $\{[Cu_2(26pka)_2(dpyo)(H_2O)_2]_n\}$, 1,3-bis(4-piridil)propan'ın (bpp) Cu(II) $\{[Cu_2(26pka)_2(bpp)(H_2O)_2] \cdot 2H_2O\}_n$, 1,2,4,5-tetrakis(4-piridil)benzen'in (bztpy) Ag(I) $\{[Ag_3(26pka)(\mu-26pka)_{0.5}(bztpy)_2] \cdot 3EtOH \cdot 6H_2O\}$ [85], bis(4-piridil)amin'in Ce(IV) $\{(H_2bpa)[Ce(26pka)_3] \cdot 3,5H_2O\}$ [78] ve 1,3-bis(4-piridin)propan'ın (bpp) Zn(II) $\{[H_2bpp][Zn(26pka)_2] \cdot 5H_2O$, $[H_2bpp][Zn(26pka)_2] \cdot 4(2,7dhn) \cdot 3H_2O$ (2,7dhn = 2,7-dihidroksinaftalin), $[H_2bpp][Zn(26pka)_2] \cdot 2(2,6dhn) \cdot 8H_2O$ (2,6dhn = 2,6-dihidroksinaftalin) [71] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik çalışmalar ile aydınlatılmıştır.

4-Hidroksi-2,6-piridindikarboksilik asit ($H_3O26pka$) ile 4,4'-bipiridin'in Mn(II) $\{[Mn_2(HO26pka)_3(H_2bpy)] \cdot 5H_2O\}_n$ [86], $[Mn_3(HO26pka)_3(H_2O)_7] \cdot bpy \cdot 3H_2O$, $[Mn_2(HO26pka)_2(bpy)(H_2O)_2] \cdot 4H_2O$ [87], Co(II) $\{[Co_3(HO26pka)_3(H_2O)_7] \cdot bipy \cdot 3H_2O\}$ [88], Cu(II) $\{[Cu_2(HO26pka)_2(bpy)(H_2O)_2] \cdot 4H_2O$, $[Cu_2(HO26pka)_2(bpy)(H_2O)_2]$ [39], $(H_2O)(O26pka)Cu(bpy)Cu(O26pka)(H_2O)$ [89], $\{[Cu(HO2,6pka)(bpy)_{0.5}(H_2O)] \cdot 2H_2O\}_n$ [90], Zn(II) $\{[Zn(HO26pka)(H_2O26pka)_2] \cdot bpy \cdot 3,5H_2O\}_n$ [39], $[Zn(HO26pka)(bpy)_{0.5}] \cdot H_2O\}_n$ [91], $[Zn_2(HO26pka)_2(bpy)] \cdot 2H_2O$ [92], $Zn_2(bpy)(O26pka)_2(H_2O)_2 \cdot 4H_2O$ [93], Ga(III) $\{(H_2bpy)[Ga(HO26pka)_2] \cdot 7H_2O\}$ [73], Sb(III) $\{(H_2bpy)[Sb_2(O26pka)_2(OH)_2(H_2O)_2] \cdot 2H_2O\}$ [94], Y(III) $\{(bpy)[Y(HO26pka)(H_2O26pka)(H_2O)_2] \cdot 3H_2O\}$, Er(III) $\{(bpy)[Er(HO26pka)(H_2O26pka)(H_2O)_2] \cdot 3H_2O\}$, La(III) $\{(bpy)[La(HO26pka)(H_2O26pka)(H_2O)_2] \cdot 4,5H_2O\}$, Sm(III) $\{(bpy)[Sm(HO26pka)(H_2O26pka)(H_2O)_2] \cdot 4,75H_2O\}$, Pr(III) $\{(bpy)[Pr(HO26pka)(H_2O26pka)(H_2O)_2] \cdot 4,75H_2O\}$ [95], 1,2-bis(4-piridil)etan'ın Cu(II) $\{[Cu(HO26pka)(L)_{0.5}(H_2O)] \cdot 2H_2O\}_n$, 1,2-bis(4-piridil)eten'in Cu(II) $\{[Cu(HO26pka)(L)_{0.5}(H_2O)] \cdot 2H_2O\}_n$ ve 1,3-bis(4-piridil)propan'ın Ni(II) ve Cu(II) $\{[M(HO26pka)(L)(H_2O)] \cdot 2H_2O\}_n$ [90] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik metotlar ile açıklanmıştır.

4,4'-bipiridin'in 2,6-piridindikarboksilik asit N-oksit ($H_226pkao$) ile Ni(II) $\{(Ni(26pkao)(bpy)_{0.5}(H_2O)] \cdot 2H_2O\}$ [96], Zn(II) $\{[Zn_2(26pkao)_2(bpy)_2(H_2O)_2] \cdot 3H_2O\}_n$ [97], 1,2-bis(4-piridil)etan'ın Ni(II) $\{[Ni_2(pdco)_2(bpe)(H_2O)_2] \cdot 4H_2O\}_n$ [98], 2,3,5-piridintri-karboksilik asit ($H_3235ptc$) ile Cd(II) $\{[Cd_3(235ptc)_2(bpy)(H_2O)_4]\}$ [99] ve 6-metil-2,3,5-piridintri-karboksilik asit ($H_3M235ptc$) ile Ag(I) $\{[Ag_4(HM235ptc)_2(bpy)_3] \cdot 4,5H_2O\}$ [100], 2,4,6-Piridintri-karboksilik asit (H_3ptc) ile Fe(III) $\{(Hbpy)_2[Fe(ptc)(Hptc)] \cdot 3H_2O\}$ [101], Co(II) $\{[Co(bpy)(H_2O)_4][Co(ptc)(H_2O)]_2\}_n$ [102], $[Co(ptc)(Hbpy)(H_2O)_2] \cdot 2H_2O$ [103] ve $[Co_2(Hptc)_2(bpy)(H_2O)_4] \cdot 2H_2O$ [104], Ni(II) $\{[Ni(ptc)(bipy) \cdot 4,5H_2O]\}$ [105], Cu(I)/Cu(II) $\{[Cu_2(ptc)(bpy)] \cdot H_2O\}_n$ [106] ve Zn(II) $\{[Zn(bpy)(Hptc) \cdot bul.H_2O]_n\}$ [107], $[Zn_2(ptc)_2(pby)(H_2O)_4] \cdot 2H_2O$ [108], 2,3,5,6-piridintetrakarboksilik asit (H_4ptka) ile Ag(I) $\{[Ag_2(H_2ptka)(bpy)_2] \cdot 3H_2O\}_n$ [109], Cu(II) $\{[Cu_2(ptka)(bpy)(H_2O)_2] \cdot 3H_2O\}_n$, $\{[Cu_2(ptka)(bpy)(H_2O)_2] \cdot 2H_2O\}_n$ [110], $[Cu_3(H_2O)_4(Hptka)_2(bpy)_2] \cdot 3H_2O$, Zn(II) $\{[Zn_4(H_2O)_6(ptka)_2(bpy)] \cdot 5H_2O\}$ [111] ve 1,2-bis(4-piridil)etilen (bpe) ile Zn(II) $\{[Zn_2(Hptka)_2(Hbpe)_2] \cdot 5H_2O$, $[Zn_2(ptka)(bpe)_{1.5}]_n$ [110] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik metotlar ile karakterize etmişlerdir.

2,2'-bipiridin-3,3',6,6'-piridintetrakarboksilik asit (H_4bptc) ile 1,2-bis(4-piridil)etilen'in Co(II) $\{[Co_2(H_2bptc)_2(H_2O)_4] \cdot bpe \cdot 9H_2O\}$, Ni(II) $\{[Ni_2(H_2bptc)_2(H_2O)_4] \cdot bpe \cdot 9H_2O\}$ ve 1,4-di(4-piridil)etan ile Ni(II) $\{[Ni_2(H_2bptc)_2(H_2O)_4] \cdot 0,5bpp \cdot 7H_2O\}$ [112], 4,4'-bipiridin-2,2',6,6'-piridintetrakarboksilik

asitin (H_4bptca) $Co(II)$ $\{[Co(H_2O)_6][Co_3(bptca)_2(H_2O)_2].10H_2O\}_n$, $Ni(II)$ $\{[Cu_2(bptca)(H_2O)_4]_n\}$ [113], $La(III)$, $Ce(III)$, $Sm(III)$, $Tb(III)$, $Dy(III)$, $Ho(III)$ $\{[Ln(Hbptca)(H_2O)]_n.3H_2O\}_n$ [$Ln = La, Ce, Sm$], $[Ln_4(bptca)_3(H_2O)_4]_n$ [$Ln = Tb, Dy, Ho$]] [114] ve 1,3,5-tris(imidazol-1-yilmetil)-2,4,6-trimetilbenzen ($titmb$) ile $Mn(II)$ $\{[Mn_4(bptca)_2(titmb)(H_2O)_7].DMF.4H_2O\}$, $Co(II)$ $\{[Co_2(bptca)(titmb)_2].13H_2O\}$ ve $Ni(II)$ $\{[Ni_2(bptca)(titmb)_2].13H_2O\}$ [115] kompleksleri sentezlenmiş ve yapıları çeşitli spektroskopik çalışmalar ile karakterize etmişlerdir.

3. SONUÇLAR

Piridinkarboksilik asit ve proton vermiş formları ile birçok çalışma yapılmaktadır. Bu bileşiklerin antioksidan, antifungal, antimikrobiyal, antitümör, antikanser, antiinflamatuvar, antiülser, antidiyabetik, antimütajen, süperoksit giderici ve radyoprotektif aktiviteye gibi biyolojik özelliklere sahiptir. Bipiridin türevlerinin antihipertansif, antibakteriyel, anti psikotik, kas gevşetici, analjezik, antioksidan, antidiyabetik, antiinflamatuvar, antikanser, antisıtma, enzim inhibisyonu, antidepresan, antikolinergik gibi biyolojik aktiviteleri mevcuttur. Piridinkarboksilik asit ve bipiridin türevlerinden elde edilecek proton transfer tuzları ve metal kompleksleri de benzer özellikler göstereceği aşıkardır. Literatürde yapılan incelemeler sonucunda bu iki grubun bir arada bulunduğu metal komplekslerinin çok, ancak biyolojik özelliklerinin daha az çalışıldığı gözlenmiştir. Bu iki gruptan elde edilecek metal komplekslerinin biyolojik özelliklerin daha ayrıntılı bir şekilde çalışılması literature önemli bir katkı olacaktır. Bu çalışma bu açıklığı belirtmek için yapılmıştır.

KAYNAKÇA

- [1] Paula, M.M.S., Pich, C.T., Petronilho, F. Drei, L.B., Rudnicki, M., de Oliveira, M.R., Moreira, J.C.F., Henriques, J.A.P., Franco, C.V. and Pizzol, F.D., (2005). Antioxidant activity of new ruthenium compounds. Redox Report, 10:3, 139-143.
- [2] Salvadores, V., (2000). Synthesis, characterization and catalytic and biological activity of new manganase(II) carboxylate complexes. Doctoral thesis. Technological University Dublin. doi:10.21427/ D78K6T.
- [3] Singh, N.K. and Singh, D.K., (2002). Synthesis, spectroscopic characterization, and biological activity of n-isonicotinoyl- N' - thiobenzoylhydrazine complexes of $Co(II)$, $Ni(II)$, $Cu(II)$, and $Zn(II)$. Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry, 32:2, 203-218.
- [4] Xu, D., Xu, Y., Cheng, N., Zhou, X., Shi, Y. and He, Q., (2010). Synthesis, characterization, and biological studies of lanthanide complexes with 2,6-pyridine dicarboxylic acid and α -picolinic acid. Journal of Coordination Chemistry, 63:13, 2360-2369
- [5] Chitra, V. and Singh, D.R., (2018). Anti-bacterial activity, anti-cancer activity and nanofiber formation of certain poly (ester amides) from 2, 5-pyridine dicarboxylic acid. Journal of Drug Delivery and Therapeutics, 8(6-s):166-173
- [6] Celestine, Michael J.; Bullock, Jimmie L.; Boodram, Shivani; Rambaran, Varma H.; Holder, Alvin A. Interesting properties of p-, d-, and f-block elements when coordinated with dipicolinic

acid and its derivatives as ligands: their use as inorganic pharmaceuticals. *Reviews in Inorganic Chemistry* (2015), 35(2), 57-67

- [7] Li, S., Crooks, P., Wei, X. and Leon, J., (2004), Toxicity of Dipyridyl Compounds and Related Compounds. *Critical Reviews in Toxicology*, 34(5), 447-460
- [8] Kaes, C., Katz, A. and Hosseini, M.W., (2000), Bipyridine: The Most Widely Used Ligand. A Review of Molecules Comprising at Least Two 2,2'-Bipyridine Units. *Chemical Reviews*, 100, 3553-3590.
- [9] Altaf, A.A., Shahzad, A., Gul, Z., Rasool, N., Badshah, A., Lal, B. and Khan, E., (2015), A Review on the Medicinal Importance of Pyridine Derivatives. *Journal of Drug Design and Medicinal Chemistry*, 1(1), 1-11.
- [10] Patil, P., Sethy, S.P., Sameena, T. and Shailaja, K., (2013), Pyridine and Its Biological Activity: A Review. *Asian Journal of Research in Chemistry*, 6 (10) 888-999
- [11] Soleimannejad, J., Aghabozorg, H., Morsali, A., Hemmati, F. and Manteghi, F., (2009), 4,4'-Bipyridinium bis(2-carboxypyridine-3-carboxylate). *Acta Crystallographica, Section E: Structure Reports Online*, 65(1), o153, o153/1-o153/9.
- [12] Kumaresan, S., Seethalakshmi, P.G., Kumaradhas, P. and Devipriya, B., (2013). Synthesis and structural characterization of organic co-crystals 4,4'-bipyridine-bis(*N*-phenylanthranilic acid) and 4,4'-bipyridinium bis(3-carboxypyridine-2-carboxylate). *Journal of Molecular Structure*, 1032, 169-175.
- [13] Soleimannejad, J. and Nazarnia, E., (2013), A coordination polymer of Mn(III) with pyridine-2,3-dicarboxylic acid and 4,4'-bipyridine. *Majallah-i Bulurshinasi va Kanishinasi-i Iran*, 21(3), 596Persian, 59English-68English.
- [14] Yin, H. and Liu, S.X., (2009), Copper and zinc complexes with 2,3-pyridinedicarboxylic acid or 2,3-pyrazinedicarboxylic acid: Polymer structures and magnetic properties. *Journal of Molecular Structure*, 918(1-3), 165-173.
- [15] Kanoo, P., Matsuda, R., Kitaura, R., Kitagawa, S. and Maji, T.K., (2012), Topological difference in 2D layers steers the formation of rigid and flexible 3D supramolecular isomers: Impact on the adsorption properties. *Inorganic Chemistry*, 51(17), 9141-9143.
- [16] Baruah, A.M., Karmakar, A. and Baruah, J.B., (2007), Hydrolytic ring opening reactions of anhydrides for first row transition metal dicarboxylate complexes. *Polyhedron*, 26(15), 4518-4524.
- [17] Yin, W.X., Liu, Y.T., Ding, Y.J., Lin, Q., Lin, X.M., Wu, C.L., Yao, X.D. and Cai, Y.P., (2015), Construction of variable dimensional cadmium(II) coordination polymers from pyridine-2,3-dicarboxylic acid. *CrystEngComm*, 17(19), 3619-3626.

- [18] Semerci, F., Yesilel, O.Z., Yuksel, F. and Sahin, O., (2016), Synthesis and characterization of new coordination polymers based on 2,3-/3,4-pyridinedicarboxylates and bispyridine ligands with structural diversity. *Polyhedron*, 111, 1-10.
- [19] Wen, L.L., Lu, Z.D., Ren, X.M., Duan, C.Y., Meng, Q.J. and Gao, S., (2009), Metal-organic coordination polymers containing pyridine-2,3-dicarboxylic acid *N*-oxide (2,3-PDCO). *Crystal Growth & Design*, 9(1), 227-238.
- [20] Chandrasekhar, V., Mohapatra, C. and Butcher, R.J., (2012), Synthesis of one- and two-dimensional coordination polymers containing organotin macrocycles. reactions of (n-Bu₃Sn)₂O with pyridine dicarboxylic acids. structure-directing role of the ancillary 4,4'-bipyridine ligand. *Crystal Growth & Design*, 12(6), 3285-3295.
- [21] Li, X.L., Liu, G.Z. and Xin, L.Y., (2013), Two pillared-layer Co(II) metalorganic frameworks displaying pore modulation by rodlike ligands. *Chinese Journal of Structural Chemistry*, 32(6), 871-876.
- [22] Li, X.L., Liu, G.Z., Xin, L.Y. and Wang, L.Y., (2012), Three Zn(II) metal-organic frameworks assembled from a versatile tecton 5-ethyl-pyridine-2,3-dicarboxylate and dipyrindyl-type co ligand. *CrystEngComm*, 14(5), 1729-1736.
- [23] Li, X.L., Liu, G.Z., Xin, L.Y. and Wang, L.Y., (2012), A novel metal-organic framework displaying reversibly shrinking and expanding pore modulation. *CrystEngComm*, 14(18), 5757-5760.
- [24] Zhang, X.M., (2005), m-4,4'-Bipyridine-κ²N:N'-bis[triaqua(pyridine-2,4-dicarboxylato-κ²N,O)cobalt(II)] dihydrate. *Acta Crystallographica, Section E: Structure Reports Online*, 61(7), m1332-m1333.
- [25] Zhang, X.M. and Chen, X.M., (2003), A new porous 3-D framework constructed from fivefold parallel interpenetration of 2-D (6,3) Nets: A mixedvalence copper(I,II) coordination polymer [Cu_{1.2}CuII(4,4'-bpy)₂(pydc)₂].4H₂O. *European Journal of Inorganic Chemistry*, (3), 413-417.
- [26] Jeon, Y., Lee, M., Kim, H. and Park, K.M., (2015), Crystal structure of tetraaquabis(4-carboxypyridine-2,6-dicarboxylato-κ³N,O,O')(m2-4,4'-bipyridine-κ²N:N')dizinc(II)dihydrate, [Zn₂(C₈H₃NO₆)₂(C₁₀H₈N₂)(H₂O)₄].2H₂O, C₂₆H₂₆N₄O₁₈Zn₂. *Zeitschrift fuer Kristallographie - New Crystal Structures*, 230(3), 213-214.
- [27] Li, X.M., Niu, Y.L., W., Qing W. and Liu, B., (2007), μ-4,4'-Bipyridine-κ²N:N'-bis[triaqua(pyridine-2,4-dicarboxylato-κ²N,O²)zinc(II)] dihydrate. *Acta Crystallographica, Section E: Structure Reports Online*, 63(2), m487-m488.
- [28] Mohapatra, S., Roy, S., Ghoshal, D. and Maji, T.K., (2014), Two 3D supramolecular frameworks assembled from the dinuclear building block: A crystallographic evidence of carboxylate(O)...p interaction. *Journal of Chemical Sciences (Bangalore, India)*, 126(4), 1153-1161.

- [29] Piromchom, J., Wannarit, N., Boonmak, J., Pakawatchai, C. and Youngme, S., (2014), Synthesis, crystal structure and water-induced reversible crystal-to-amorphous transformation property of $[\text{Co}_2(2,4\text{-pydc})_2(\text{bpa})(\text{H}_2\text{O})_6](\text{H}_2\text{O})_2$. *Inorganic Chemistry Communications*, 40, 59-61.
- [30] Sarkar, D., Chandra Rao, P., Aiyappa, H.B., Kurungot, S., Mandal, S., Ramanujam, K. and Mandal, S., (2016), Multifunctional copper dimer: structure, band gap energy, catalysis, magnetism, oxygen reduction reaction and proton conductivity. *RSC Advances*, 6(44), 37515-37521.
- [31] Lin, J.G., Su, Y., Tian, Z.F., Qiu, L., Wen, L.L., Lu, Z.D., Li, Y.Z. and Meng, Q.J., (2007), Organic-inorganic hybrid coordination polymers based on 6-methylpyridine-2,4-dicarboxylic acid *N*-oxide (MPDCO) ligand: Preparations, interpenetrating structures, and magnetic and luminescent properties. *Crystal Growth & Design*, 7(12), 2526-2534.
- [32] Qiu, L., Lin, J. and Xu, Y., (2009), Synthesis, characterization and luminescent property of a novel zinc(II) 1,2,3,4-tetra(4-pyridyl)thiophene metal-organic framework. *Inorganic Chemistry Communications*, 12(10), 986-989.
- [33] Xu, R., Lin, M., Li, X. and Zeng, M., (2006), Study on guest molecules in micropore of porous coordination polymer by using TG/IR. *Zhongshan Daxue Xuebao, Ziran Kexueban*, 45(1), 125-126.
- [34] Zeng, M.H., Feng, X.L. and Chen, X.M., (2004), Crystal-to-crystal transformations of a microporous metal-organic laminated framework triggered by guest exchange, dehydration and readsorption. *Dalton Transactions*, (15), 2217-2223.
- [35] Fang, M.J., Li, M.X., He, X., Shao, M., Pang, W. and Zhu, S.R., (2009), Synthesis, structure and thermal stability of ternary metal complexes based on polycarboxylate and Nheterocyclic ligands. *Journal of Molecular Structure*, 921(1-3), 137-143.
- [36] Chuang, S.T., Shen, F.M., Kuo, T.S. and Shiu, K.B., (2007), Versatile 2,5-pyridinedicarboxylate in linking transition-metal atoms into 1D and 2D coordination polymers and concomitant polymorphs. *Journal of the Chinese Chemical Society (Taipei, Taiwan)*, 54(4), 893-902.
- [37] Liu, Z., Wang, H., Han, J., Li, Q. and Zhang, S., (2018), Synthesis and application of cobalt complex metal organic framework compound constructed based on pyridine-2,5-dicarboxylic acid and 4,4'-bipyridine. *Faming Zhuanli Shenqing*, CN 107739442 A 20180227,
- [38] Chandrasekhar, V., Mohapatra, C. and Butcher, R.J., (2012), Synthesis of one- and two-dimensional coordination polymers containing organotin macrocycles. Reactions of $(n\text{-Bu}_3\text{Sn})_2\text{O}$ with pyridine dicarboxylic acids. Structure-directing role of the ancillary 4,4'-bipyridine ligand. *Crystal Growth & Design*, 12(6), 3285-3295.
- [39] Wang, H., Li, M.X., Shao, M. and He, X., (2006), 4,4'-Bipyridinium diaquabis(pyridine-2,5-dicarboxylato- $\kappa^2\text{N},\text{O}^2$)zincate(II). *Acta Crystallographica, Section E: Structure Reports Online*, 62(12), m3309-m3311.

- [40] Zhang, P., Song, Y.J., Ma, Y. and Han, Z.B., (2009), A new complex constructed by Zn(II) with Pydc and Bipy ligands (H_2Pydc = 2,5-Pyridinedicarboxylic Acid, Bipy = 4,4'-bipyridine). Russian Journal of Coordination Chemistry, 35(6), 445-448.
- [41] Gao, Q., Jiang, F.L., Wu, M.Y., Huang, Y.G., Yuan, D.Q., Wei, W. and Hong, M.C., (2009), Indium(III)-2,5-pyridinedicarboxylate complexes with mononuclear, 1D chain, 2D layer and 3D chiral frameworks. CrystEngComm, 11(5), 918-926.
- [42] Gao, Q., Jiang, F.L., Wu, M.Y., Huang, Y.G., Yuan, D.Q., Wei, W. and Hong, M.C., (2009), Indium(III)-2,5-pyridinedicarboxylate complexes with mononuclear, 1D chain, 2D layer and 3D chiral frameworks. CrystEngComm, 11(5), 918-926.
- [43] Wang, D.E., Tian, Z.F., Wang, F., Wen, L.L. and Li, D.F., (2009), Syntheses and crystal structures of two inorganic-organic hybrid frameworks constructed from pyridine-2,5-dicarboxylic acid. Journal of Inorganic and Organometallic Polymers and Materials, 19(2), 196-201.
- [44] Llano-Tome, F., Bazan, B., Urtiaga, M.K., Barandika, G., Antonia Senaris-Rodriguez, M., Sanchez-Andujar, M. and Arriortua, M.I., (2015), Cu-PDC-bpa solid coordination frameworks (PDC=2,5-pyridinedicarboxylate; bpa=1,2-DI(4-pyridyl)ethane): 2D and 3D structural flexibility producing a 3-c herringbone array next to ideal. Journal of Solid State Chemistry, 230, 191-198.
- [45] Singha, S., Saha, A., Goswami, S., Dey, S.K., Payra, S., Banerjee, S., Kumar, S. and Saha, R., (2018), A Metal-organic framework to CuO nanospheres of uniform morphology for the synthesis of α -aminonitriles under solvent-free condition along with crystal structure of the framework. Crystal Growth & Design, 18(1), 189-199.
- [46] Soleimannejad, J., Aghabozorg, H., Hooshmand, S. and Adams, H., (2007), 4,4'-Bipyridinediium triaquabis(pyridine-2,6-dicarboxylato)strontium(II) trihydrate. Acta Crystallographica, Section E: Structure Reports Online, 63(12), m3089-m3090, m3089/1-m3089/14.
- [47] Chen, C., Bai, F.Y., Zhang, R., Song, G., Shan, H., Xing, N. and Xing, Y.H., (2013), Synthesis, structure, and catalytic bromination of supramolecular oxovanadium complexes containing oxalate. Journal of Coordination Chemistry, 66(4), 671-688.
- [48] Zhu, L., Duan, C., Wang, Y., Yang, X., You, X. and Huang, J., (1994), Synthesis and crystal structure of pyridine-2,6-dicarboxylate vanadium complex: [(pyridine-2,6-dicarboxylate) VO_2] $_2$ [4,4'-bipyridine]. $4H_2O$. Jiegou Huaxue, 13(2), 83-6.
- [49] Soleimannejad, J., Aghabozorg, H. and Hooshmand, S., (2008), 4-(4-Pyridyl)pyridinium bis(pyridine-2,6-dicarboxylato)chromium(III) tetrahydrate. Acta Crystallographica, Section E: Structure Reports Online, 64(4), m564-m565, m564/1-m564/12.
- [50] Gao, Y.X., Wang, L.B. and Niu, Y.L., (2007), Tetraaquabis(4,4'-bipyridine)manganese(II) pyridine-2,6-dicarboxylate tetrahydrate. Acta Crystallographica, Section E: Structure Reports Online, 63(9), m2283.

- [51] Uhrecky, R., Svoboda, I., Ruzickova, Z., Koman, M., Dlhan, L., Pavlik, J., Moncol, J. and Boca, R., (2015), Synthesis, structure and magnetism of manganese and iron dipicolinates with *N,N'*-donor ligands. *Inorganica Chimica Acta*, 425, 134-144.
- [52] Gao, Y.X., Wang, L.B. and Niu, Y.L., (2007), Tetraaquabis(4,4'-bipyridine)iron(II) pyridine-2,6-dicarboxylate tetrahydrate. *Acta Crystallographica, Section E: Structure Reports Online*, 63(7), m1845-m1846.
- [53] Soleimannejad, J., Aghabozorg, H. and Sheshmani, S., (2010), 4-(4-Pyridyl)pyridinium bis(pyridine-2,6-dicarboxylato)ferrate(III) tetrahydrate. *Acta Crystallographica, Section E: Structure Reports Online*, 66(4), m411.
- [54] Soleimannejad, J., Aghabozorg, H., Mohammadzadeh, Y., Nasibipour, M., Sheshmani, S., Shokrollahi, A., Karami, E. and Shamsipur, M., (2011), Different complexation behavior of Fe(III), Co(II) and Ni(II) with pyridine-2,6-dicarboxylic acid and 4,4'-bipyridine adduct: syntheses, crystal structures and solution studies. *Journal of the Iranian Chemical Society*, 8(1), 247-264.
- [55] Guan, G., Gao, Y., Wang, L. and Wang, T., (2007), Tetraaquabis(4,4'-bipyridine)cobalt(II) pyridine-2,6-dicarboxylate tetrahydrate. *Acta Crystallographica, Section E: Structure Reports Online*, 63(10), m2601, Sm2601/1-Sm2601/10.
- [56] Xie, C., Zhang, B., Liu, X., Wang, X., Kou, H., Shen, G. and Shen, D., (2004), Synthesis, crystal structure, and magnetic property of a novel 2D polymer [Co(PDC)(4,4'-bpy)](CH₃OH). *Inorganic Chemistry Communications*, 7(9), 1037-1040.
- [57] Zhu, L., Wang, Y., Duan, C., Yang, X., You, X. and Huang, J., (1992), Synthesis and crystal structure of pyridine-2,6-dicarboxylate cobalt complexes. *Huaxue Xuebao*, 50(6), 583-8.
- [58] Ghosh, S.K., Ribas, J. and Bharadwaj, P.K., (2005), Characterization of 3-D metal-organic frameworks formed through hydrogen bonding interactions of 2-D networks with rectangular voids by CoII- and NiII-pyridine-2,6-dicarboxylate and 4,4'-bipyridine or 1,2-di(pyridyl)ethylene. *Crystal Growth & Design*, 5(2), 623-629.
- [59] Felloni, M., Blake, A.J., Hubberstey, P., Teat, S.J., Wilson, C. and Schroder, M., (2010), Transition metal dipicolinates as designer T-shaped building blocks. *CrystEngComm*, 12(5), 1576-1589.
- [60] Wu, S.L., Zou, J.P., Chen, M.H., Yang, H.B., Li, M.J., Luo, X.B., Luo, F., Wu, M.F. and Guo, G.C., (2012), Effect of synthetic conditions on the structures and properties of metal complexes with chelidamic acid and 4,4'-bipyridyl. *Polyhedron*, 48(1), 58-67.
- [61] Shankar, K., Singh, M.P. and Baruah, J.B., (2018), Extent of protonation of 4,4'-bipyridinium cations and nature of host influences the amount of guest intake by cobalt(II) 2,6-pyridinedicarboxylate. *Inorganica Chimica Acta*, 469, 440-446.

- [62] Gangu, K.K., Maddila, S., Mukkamala, S.B. and Jonnalagadda, S.B., (2019), Catalytic activity of supra molecular self-assembled Nickel(II) coordination complex in synthesis of indenopyrimidine derivatives. *Polyhedron*, 158, 464-470.
- [63] Wang, X., Qin, C., Wang, E., Hu, C. and Xu, L., (2004), A novel three-dimensional supramolecular network containing one-dimensional trapezoid channels based on nickel and mixed organic ligands assembly. *Journal of Molecular Structure*, 692(1-3), 187-193.
- [64] Kumaresan, S. and Ramadevi, P., (2005), Molecular ribbons: Hydrothermal synthesis and structural characterization of $[\{Cu(dipic)(H_2O)\}_2(\mu-4,4'-bipy)] \cdot 2H_2O$ (dipic = pyridine-2,6-dicarboxylato; 4,4'-bipy = 4,4'-bipyridine). *Indian Journal of Chemistry, Section A: Inorganic, Bio-inorganic, Physical, Theoretical & Analytical Chemistry*, 44A(2), 299-302.
- [65] Wen, Y.H., Zhang, J., Qin, Y.Y., Li, Z.J., Kang, Y., Chen, Y.B., Cheng, J.K. and Yao, Y.G., (2004), Synthesis and crystal structure of $\{Cu_2(pdc)_2(4,4'-bipy)(H_2O) \cdot 3H_2O\}_2$. *Jiegou Huaxue*, 23(9), 1001-1004.
- [66] Ghosh, S.K., Ribas, J. and Bharadwaj, P.K., (2004), Metal-organic framework structures of Cu(II) with pyridine-2,6-dicarboxylate and different spacers: identification of a metal bound acyclic water tetramer. *CrystEngComm*, 6, 250-256.
- [67] Manna, S.C., Ribas, J., Zangrando, E. and Chaudhuri, N.R., (2007), Supramolecular networks of dinuclear copper(II): Synthesis, crystal structure and magnetic study. *Inorganica Chimica Acta*, 360(8), 2589-2597.
- [68] Wen, Y.H. and He, Y.H., (2006), Crystal structure of bis(diaqua- μ -(4,4'-bipyridine- κN)bis(pyridine-2,6-dicarboxylato- $\kappa^3 O, N, O$)dicopper(II)) mono-aqua- μ -(4,4'-bipyridine- κN)bis(pyridine-2,6-dicarboxylato- $\kappa^3 O, N, O$)dicopper(II) hexahydrate, $2Cu_2(H_2O)_2(C_{10}H_8N_2)(C_7H_3NO_4)_2 \cdot Cu_2(H_2O)(C_{10}H_8N_2)(C_7H_3NO_4)_2 \cdot 6H_2O$. *Zeitschrift fuer Kristallographie - New Crystal Structures*, 221(2), 142-144.
- [69] Felloni, M., Blake, A.J., Hubberstey, P., Wilson, C. and Schroder, M., (2009), Solvent control of supramolecular architectures derived from 4,4'-bipyridyl-bridged copper(II) dipicolinate complexes. *Crystal Growth & Design*, 9(11), 4685-4699.
- [70] Deng, D., Liu, P., Fu, W., Li, L., Yang, F. and Ji, B., (2010), Metal-organic open frameworks with one-dimension channels assembled with pyridine 2,6-dicarboxylic acid and *N*-containing auxiliary ligands: Syntheses, crystal structures, and physical characterization. *Inorganica Chimica Acta*, 363(5), 891-898.
- [71] Shankar, K., Kirillov, A.M. and Baruah, J.B., (2015), A modular approach for molecular recognition by zinc dipicolinate complexes. *Dalton Transactions*, 44(32), 14411-14423.
- [72] Soleimannejad, J., Sheshmani, S., Solimannejad, M., Nazarnia, E. and Hosseinabadi, F., (2014), Two supramolecular complexes of gallium(III) with different adduct ion pairs containing pyridine-2,6-dicarboxylic acid: Syntheses, characterization, crystal structures and computational study. *Journal of Structural Chemistry*, 55(2), 342-352.

- [73] Soleimannejad, J. and Nazarnia, E., (2016), The effect of ligand substituent on crystal packing: Structural and theoretical studies of two Ga(III) supramolecular compounds. *Journal of Molecular Structure*, 1116, 207-217.
- [74] Shankar, K. and Baruah, J.B., (2017), Inclusion of dihydroxyaromatics by a lanthanum(III) 2,6-dipicolinate complex. *Polyhedron*, 126, 262-267.
- [75] Xie, Y.F., Jia, A.Q., Zhu, H., Shi, H.T. and Zhang, Q.F., (2015), Synthesis and reactivity of ruthenium(II) complexes with 1,5-cyclooctadiene and pyridine-2,6-dicarboxylato ligands. *Inorganica Chimica Acta*, 438, 31-36.
- [76] Yang, L., Xu, J., Xia, J., Liu, Y., Wang, L. and Fan, Y., (2014), Two novel indium coordination polymers derived from 2,6-pyridinedicarboxylate ligand: Syntheses, structures and photoluminescent properties. *Journal of Molecular Structure*, 1075, 279-285.
- [77] Aghabozorg, H., Omidvar, S., Mirzaei, M. and Notash, B., (2011), catena-Poly[4,4'-bipyridinium [[tetraaqua(pyridine-2,6-dicarboxylato- $\kappa^3 O^2, N, O^6$)cerate(III)]- μ -pyridine-2,6-dicarboxylato- $\kappa^4 O^2: O^2, N, O^6$ -(pyridine-2,6-dicarboxylato- $\kappa^3 O^2, N, O^6$)cerate(III)]- μ -pyridine-2,6-dicarboxylato- $\kappa^4 O^2, N, O^6: O^6$] pentahydrate]. *Acta Crystallographica, Section E: Structure Reports Online*, 67(3), m335-m336, Sm335/1-Sm335/17.
- [78] Zeng, X.Z., Zhang, A.Y.; He, C. and Li, Y.W., (2013), Synthesis, structure and thermal properties of two cerium(IV) complexes with 2,6-pyridinedicarboxylic acid. *Wuji Huaxue Xuebao*, 29(7), 1557-1562.
- [79] Soleimannejad, J., Aghabozorg, H., Hooshmand, S., Ghanbari, M., Manteghi, F. and Shamsipur, M. Two novel metal organic frameworks of Sn(II) and Pb(II) with pyridine-2,6-dicarboxylic acid and 4,4'-bipyridine: syntheses, crystal structures and solution studies., (2010), *Journal of the Iranian Chemical Society*, 7(2), 405-418.
- [80] Bo, Q.B., Sun, G.X. and Geng, D.L., (2010), Novel Three-Dimensional Pillared-Layer Ln(III)-Cu(I) Coordination Polymers Featuring Spindle-Shaped Heterometallic Building Units. *Inorganic Chemistry*, 49(2), 561-571.
- [81] Aghabozorg, H., Omidvar, S., Mirzaei, M. and Notash, B., (2011), Crystal structure of 4,4'-bipyridinium bis(pyridine-2,6-dicarboxylato)mercurate(II)-diaquabis(6-carboxypyridine-2-carboxylato)mercury(II)-water (2:1:12) $[C_{10}H_{10}N_2]_2[Hg(C_7H_3NO_4)_2]_2 Hg(H_2O)_2(C_7H_4NO_4)_2 \cdot 12H_2O$. *Zeitschrift fuer Kristallographie - New Crystal Structures*, 226(1), 123-125.
- [82] Bo, Q.B., Sun, Z.X. and Forsling, W., (2008), A new family of 3D 3d-4f heterometallic frameworks comprising 1D inorganic lanthanide ladders and organic CuI-bipyridine chains. *CrystEngComm*, 10(2), 232-238.
- [83] ¹ Soleimannejad, J., Aghabozorg, H., Golenji, Y.M.A., Attar Gharamaleki, J. and Adams, H., (2008), Bis(4,4'-bipyridinium) di- μ -hydroxido-bis[dihydroxido(pyridine-2,6-dicarboxylato)

- antimonate(III,V)] octahydrate. Acta Crystallographica, Section E: Structure Reports Online, 64(2), m387-m388, m387/1-m387/13.
- [84] Jiang, Y.S., Li, G.H., Tian, Y., Liao, Z.L. and Chen, J.S., (2006), Uranyl pyridine-dicarboxylate compounds with clustered water molecules. Inorganic Chemistry Communications, 9(6), 595-598.
- [85] Liu, W., Chen, C., Zhou, J., Ni, C., Zhang, J., Niu, Z., Dong, Z., Gan, Z. and Li, T., (2019), Coordination polymer crystal material with good green fluorescence emission performance, and its preparation method and fluorescent application. Faming Zhuanli Shenqing, CN 110078933 A 20190802.
- [86] Sun, Y.G., Rong, S.T., Wu, Y.L., Yu, W., Wang, C.S., Zhang, W.Z. and Gao, E.J., (2009), Synthesis and crystal structure of a 1-D chain coordination complex $\{[\text{Mn}_2(\text{HCAM})_3(\text{H}_2\text{bipy})].5\text{H}_2\text{O}\}_n$. Chinese Journal of Structural Chemistry, 28(9), 1131-1135.
- [87] Zou, J.P., Dai, S.C., Guan, W.T., Yang, H.B., Feng, Y.F. and Luo, X.B., (2012), Syntheses, crystal structures, and optical properties of a series of transition metal coordination polymers with chelidamic acid and 4,4'-bipyridine. Journal of Coordination Chemistry, 65(16), 2877-2892.
- [88] Wang, Y.F., Li, Y.Y., Zhao, J.S. and Wang, L.Y., (2012), Syntheses, crystal structures, and magnetic properties of manganese(II) and cobalt(II) complexes with 4-hydroxypyridine-2,6-dicarboxylic acid. Zeitschrift fuer Anorganische und Allgemeine Chemie, 638(3-4), 658-663.
- [89] Chen, X.L., Qiao, Y.L., Gao, L.J., Cui, H.L. and Zhang, M.L., (2012), μ -4,4'-Bipyridinebis[aqua(4-hydroxypyridine-2,6-dicarboxylato)copper(II)]. Acta Crystallographica, Section E: Structure Reports Online, 68(3), m326-m327.
- [90] Liu, J.Q., Wu, W.P., Wang, Y.Y. Huang, W.H., Zhang, W.H., Shi, Q.Z. and Miller, J.S., (2009), New examples of low-dimensional metal-pydc complexes: Syntheses, structures and magnetic properties. Inorganica Chimica Acta, 362(4), 1295-1302.
- [91] He, C. J. and Chen, J. Q., (2014), Synthesis, characterization, and crystal structure of one zinc(II) complex with 4-hydroxypyridine-2,6-dicarboxylic acid and 4,4'-bipyridine. Russian Journal of Coordination Chemistry, 40(9), 659-663.
- [92] Zou, J., Ma, J., Zhang, L., Xiao, X., Yan, X. and Cai, J., (2011), Metal zinc organic coordination polymer and its preparation. Faming Zhuanli Shenqing, CN 102180895 A 20110914.
- [93] Cui, H.L., Chen, X.L., Qiao, Y.L., Zhang, M.L. and Lv, J.F., (2012), Crystal structure of aqua(4,4'-bipyridine)(4-hydroxypyridine-2,6-dicarboxylato)zinc(II) hydrate, $[\text{Zn}_2(\text{C}_{10}\text{H}_8\text{N}_2)(\text{C}_7\text{H}_3\text{NO}_5)_2(\text{H}_2\text{O})_2].4\text{H}_2\text{O}$, $\text{C}_{24}\text{H}_{26}\text{N}_4\text{O}_{16}\text{Zn}_2$. Zeitschrift fuer Kristallographie - New Crystal Structures, 227(4), 517-518.
- [94] Soleimannejad, J., Gharamaleki, J.A., Aghabozorg, H. and Golenji, Y.M.A., (2010), 4,4'-Bipyridiniumbis(μ -4-oxo-1,4-dihydropyridine-2,6

- dicarboxylato)bis[aquahydroxidoantimonate(III)] dihydrate. Acta Crystallographica, Section E: Structure Reports Online, 66(4), m467-m468.
- [95] Zou, J.P., Chen, M.H., Zhang, L.Z., Xing, Q.J. and Xiong, Z.Q., (2011), Syntheses, Structures and Optical Properties of a Series of Lanthanide Complexes with Chelidamic Acid and 4,4'-Bipyridyl. Journal of Chemical Crystallography, 41(12), 1820-1833.
- [96] Zhou, C.S. and Zhang, G.C., (2008), Crystal structure of poly-aqua[(pyridine-2,6-dicarboxylic acid *N*-oxide) (4,4'-bipyridine)nickel(II)] dihydrate, (Ni(C₇H₃NO₅)(C₁₀N₂H₈)_{0.5}(H₂O)).2H₂O. Zeitschrift fuer Kristallographie - New Crystal Structures, 223(2), 175-176
- [97] Wen, L.L., Dang, D.B., Duan, C.Y., Li, Y.Z., Tian, Z.F. and Meng, Q.J., (2005), 1D Helix, 2D brick-wall and herringbone, and 3d interpenetration d¹⁰ metal-organic framework structures assembled from pyridine-2,6-dicarboxylic acid *N*-oxide. Inorganic Chemistry, 44(20), 7161-7170.
- [98] Yang, M.H., (2008), catena-Poly[[[bis[aquanickel(II)]bis(μ-pyridine-2,6-dicarboxylato-*N*-oxide)]-μ-1,2-di-4-pyridylethane]tetrahydrate]. Acta Crystallographica, Section E: Structure Reports Online, 64(11), m1358, m1358/1-m1358/7.
- [99] Qiu, L., Lin, J.G. and Meng, Q.J., (2010), Synthesis and characterization of a novel cadmium(II) photoluminescent coordination polymer based on pyridine-2,3,5-tricarboxylic acid. Journal of Molecular Structure, 980(1-3), 257-260.
- [100] Gao, H.L., Zhang, Q.Q., Cheung, C.W., Yi, Y.L., Li, F.F., Qu, J., Jiang, S.X., Shi, X.Y. and Cui, J.Z., (2014), Syntheses, structures and properties of silver(I) complexes constructed from nitrogenous aromatic heterocyclic carboxylic acids and *N*-donor ligands. Inorganic Chemistry Communications, 46, 194-197.
- [101] Zhao, L., Dong, Y.R. and Xie, H.Z., (2009), Bis[4-(4-pyridyl)pyridinium] (4-carboxypyridine-2,6-dicarboxylato-κ³O²,N,O⁶)(pyridine-2,4,6-tricarboxylato-κ³O²,N,O⁶)ferrate(III) trihydrate. Acta Crystallographica, Section E: Structure Reports Online, 65(4), m450-m451.
- [102] Zheng, Y.Q., Xu, W., Zhu, H.L., Lin, J.L., Zhao, L. and Dong, Y.R., (2011), New pyridine-2,4,6-tricarboxylato coordination polymers: synthesis, crystal structures and properties. CrystEngComm, 13(7), 2699-2708.
- [103] Xie, C.Z., Qin, J.H., Wang, J.G., Li, C.B. and Li, Y.F., (2007), Diaqua(pyridine-2,4,6-tricarboxylato-κ³N,O²,O⁶)[4-(4-pyridyl)pyridinium-κN¹]cobalt(II) dihydrate. Acta Crystallographica, Section E: Structure Reports Online, 63(2), m498-m500.
- [104] Ghosh, S.K. and Bharadwaj, P.K., (2005), Self-assembly of a Co(II) dimer through H-bonding of water molecules to a 3D open-framework structure. Journal of Chemical Sciences (Bangalore, India), 117(1), 23-26.

- [105] Yu, W., Wu, Y.L.; Rong, S.T. and Sun, Y.G., (2009), Study on synthesis and crystal structure of a mixed-ligands complex [Ni(ptc)(bipy).4.5H₂O]. Shenyang Huagong Xueyuan Xuebao, 23(4), 305-308.
- [106] Dong, Y.R., Wang, X.W. and Zheng, Y.Q., (2007), A novel mixed-valence copper complex, poly[[μ_2 -4,4'-bipyridine- μ^3 -pyridine-2,4,6-tricarboxylato-dicopper(I,II)] monohydrate]. Acta Crystallographica, Section C: Crystal Structure Communications, 63(1), m19-m21.
- [107] Lin, J., Wen, L., Zang, S., Su, Y., Lu, Z., Zhu, H. and Meng, Q., (2007), A novel 2D herringbone-like zinc coordination polymer built from helical motif: Hydrothermal synthesis, structure and properties. Inorganic Chemistry Communications, 10(1), 74-76.
- [108] Jeon, Y., Lee, M., Kim, H. and Park, K.M., (2015), Crystal structure of tetraaquabis(4-carboxypyridine-2,6-dicarboxylato- κ^3 N,O,O')(μ_2 -4,4'-bipyridine- κ^2 N:N')dizinc(II)dihydrate, [Zn₂(C₈H₃NO₆)₂(C₁₀H₈N₂)(H₂O)₄].2H₂O, C₂₆H₂₆N₄O₁₈Zn₂. Zeitschrift fuer Kristallographie - New Crystal Structures, 230(3), 213-214.
- [109] Qu, J., Yi, Y.L., Hu, Y.M., Chen, W.T., Gao, H.L., Cui, J.Z. and Zhai, B., (2012), Syntheses, structures, and photo-luminescence of three silver complexes with N-heterocyclic multicarboxylic acids and 4,4'-bipyridine. Journal of Coordination Chemistry, 65(21), 3740-3751.
- [110] Li, F.F., Zhang, Q.Q., Zhao, Y.Y., Jiang, S.X., Shi, X.Y., Cui, J.Z. and Gao, H., (2014), Syntheses, structures, and properties of six new coordination polymers constructed from N-heterocyclic multicarboxylic acids. RSC Advances, 4(21), 10424-10433.
- [111] Yan, S.T., Shi, L.X., Sun, F.F. and Wu, C.D., (2010), The roles of the coordination modes of bridging ligands for the formation of two 3D metal-organic coordination networks. CrystEngComm, 12(11), 3437-3440.
- [112] Bing, Y.Y.; Wu, Z.T. and Hu, M., (2015), Syntheses, crystal structures and properties of three transition metal coordination compounds based on 2,2'-bipyridine-3,3',6,6'-tetracarboxylic acid. Wujia Huaxue Xuebao, 31(10), 2059-2064.
- [113] Zhao, Z., He, X., Zhao, Y., Shao, M. and Zhu, S., (2009), Coordination polymer based on Cu(II), Co(II) and 4,4'-bipyridine-2,6,2',6'-tetracarboxylate: synthesis, structure and adsorption properties. Dalton Transactions, (15), 2802-2811.
- [114] Bai, Z.S., Xu, J., Okamura, T.A., Chen, M.S., Sun, W.Y. and Ueyama, N., (2009), Novel dense organic-lanthanide hybrid architectures: syntheses, structures and magnetic properties. Dalton Transactions, (14), 2528-2539.
- [115] Chen, M., Bai, Z.S., Liu, Q., Okamura, T.A., Lu, Y. and Sun, W.Y., (2012), Coordination polymers with mixed 4,4'-bipyridine-2,2',6,6'-tetracarboxylate and imidazole-containing ligands: synthesis, structure and properties. CrystEngComm, 14(24), 8642-8648.