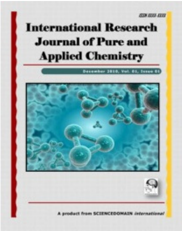

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Zinc(II) Complexes Based on *ortho*-Phthalic Acid and Ancillary N-Donor Ligands

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Review Article

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ABSTRACT

The versatile coordination abilities of *o*-phthalic acid, containing two carboxylic groups in *ortho*-position, allow for a variety of structures ranging from discrete complexes to 1D, 2D and 3D architectures. This review focuses on the synthesis and structural particularities of zinc(II) phthalates with ancillary N-containing ligands such as pyridine, imidazole and their derivatives [3-, 4-methylpyridine, and 1-, 2-methylimidazole], and 2,2′-, 4,4′-bipyridine. The coordination features manifested by this ligand are analyzed and discussed.

Keywords: o-Phthalic acid; zinc(II) complexes; carboxylates; coordination polymers; N-donor ligands.

1. INTRODUCTION

The design and synthesis of zinc(II) carboxylates are attracting large interest due to their fascinating architectures and remarkable physical and chemical properties such as photoluminescence and nonlinear optical (NLO) properties, catalysis, separation and sorption (see for example Erxleben, 2003; Allendorf et al., 2009; Redshaw et al., 2010; Perry et al., 2011; Wee et al., 2011). Being components of metalloproteins and executing important biochemical functions in living organisms these compounds are often used as artificial and biomimetic models to study biological processes in natural biosystems (Ryde, 1999; Sousa et al., 2007). In the past few years impressive developments have been made in the use of zinc carboxylates in the design of new metal-organic frameworks (MOFs),

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which exhibit high absorption properties and thermal stability (Li et al., 1999; Eddaoudi et al., 2000, 2001; Horike et al., 2011; Zhao et al., 2011). Involving in such systems polyfunctional ligands with two- and more carboxylic groups became an attractive alternative strategy for designing of hybrid materials with advantageous properties. Among these, *ortho*-phthalic acid (H_2Pht) is a versatile dicarboxylic ligand and has been widely used in the design of coordination compounds with different metals (Baca et al., 2004a and references therein). There are several reasons for the sustained interest in this ligand. Firstly, for many years, *o*-phthalic acid and its derivatives are of growing interest due to their significant usage in a large variety of substances from dyes, perfumes, and pharmaceuticals to synthetic fibers, plasticizers, gelling agent, lubricants, corrosion inhibitors and others (Ang et al., 2005). Their applications also include building materials, personal care products, detergents, glues and even food products, toys, textiles, and medical devices. Secondly, two carboxylic groups in *ortho*-position (ca. 60º) promote the variety of bonding of metal centers and resultin the formation of diverse topological structures ranging from discrete **mono**- and **polynuclear complexes** (Baca et al., 2005a, 2005b; Brechin et al., 1996, 2000; Canada-Vilalta et al., 2003; Chen et al., 2001; García-Zarracino et al., 2003; Gerbeleu et al., 1999;Johnston et al., 2008; Kato et al., 2006; Kobayashi et al., 2001; Lewinski et al., 1998; Li et al., 2000, 2007c; Ma et al., 2004; Matsumoto et al., 2007; Squire et al., 1995; Solari et al., 1996; Sundberg and Uggla, 1997; Tang et al., 2004; Tian et al., 2005, 2007b; Wang et al., 2008b;Wu et al., 1998; Xue et al., 1993; Yan et al., 2004;Yang et al., 2005) to **one-dimensional**(Baca et al., 2001,2003a,2004a, 2004b, 2005a, 2006; Bakalbassis and Paschalidis, 1998;Braverman et al., 2007; Burke et al., 2003;Burrows et al., 2000; Chen et al., 1998, 2004; Cheng et al., 2004; Cui et al., 2006; Escuer et al., 1997; Filippova et al., 2010; Fu et al., 2006; Gerbeleu et al., 1999; Gong et al., 2007; Hu et al., 2008; Huang et al., 2010b; Kumar et al., 2006; Liet al., 2006a, 2007a, 2007b; Liang et al., 2003; Liu et al., 2007a, 2007b, 2008; Lu et al., 2010; Ma et al., 2004; Padmanablan et al., 2007; Qi et al., 2008b; Simonov et al., 2001; Song and Yan, 2005a; Song et al., 2005b; Tian et al., 2007a; Thirumurugan and Natarajan, 2004a, 2005a; Thirumurugan and Rao, 2005b; Wan et al., 2003a, 2003b; Wang et al., 2007b, 2008c; Whitcomb and Rogers 1997; Yang et al., 2009a; Yao et al., 2002; Zhang et al., 2000; Zhang and Sun, 2006; Zhao et al., 2009; Zhou, 2007), **two-dimensional** (Askarinejad and Morsali, 2006; Bai et al., 2010; Charushnikova et al., 2007; Chen et al., 1998;Cheng et al., 2007a, 2007b, 2008;Du et al., 2007; Fan et al., 2006; Huang et al., 2010a, 2010b;Kan et al., 2011;Li et al., 2004, 2006b, 2009;Liu et al., 2004; Luo et al., 2010; Ma et al., 2003, 2004; Marandi et al., 2007; Meng et al., 2006; Qi et al., 2008a; Simonov et al., 2004; Song et al., 2010; Stein and Ruschewitz, 2005;Thirumurugan and Natarajan, 2004c; Suresh et al., 2001; Wan et al., 2003b; Wang et al., 2003, 2006, 2007a, 2008a, 2010; Xu et al., 2006; Yang et al., 2003a, 2003b, 2009b; Ye et al., 2005; Zeng et al., 2008; Zhang et al., 2001, 2008a, 2008b, 2008c, 2008d), and **three-dimensional** networks (Bai et al., 2010; Chen et al., 2010; Cheng et al., 2006, 2007a; Gu and Xue, 2006; Li et al., 2008b; Lightfoot and Snedden 1999; Luo et al., 2008; Qi et al., 2008a; Thirumurugan and Natarajan, 2004b; Wang et al., 2005, 2009, 2010). Thirdly, the phthalate ligand can participate in formation of hydrogen bonds as well as π-π stacking forces, all interactions playing an important role in the formation of extended architectures(Babb et al., 2003; Baca et al., 2003b, 2005a, 2005b; Braverman et al., 2007; Burke et al., 2003; Burrows et al., 2000, 2004; Chen et al., 1998; Filippova et al., 2010; Fondo et al., 2006; Kumar et al., 2006; Li et al., 2007a, 2008a;Ma et al., 2001; Raj et al., 2003; Sun et al., 2006; Wang et al., 2008a, 2008b, 2008c; Wu et al., 2009; Xuan et al., 2008; Yang et al., 2003c,2009a, 2009b; Ye et al., 2005; Zhang et al., 2005).

This review focuses on zinc(II) complexes constructed from phthalate and ancillary N-containing ligands and describes our efforts toward the preparation of such zinc(II) phthalates with pyridine (Py), imidazole (Im) and their derivatives [3-methylpyridine (β-Pic), 4-methylpyridine (γ-Pic), 1-methylimidazole (1-MeIm), and 2-methylimidazole (2-MeIm)],and 2,2′-bipyridine (bpy)and 4,4′-bipyridine (4,4′-bpy). Their synthesis and structural particularities are discussed.

2. COORDINATION MODES OF PHTHALATE LIGAND

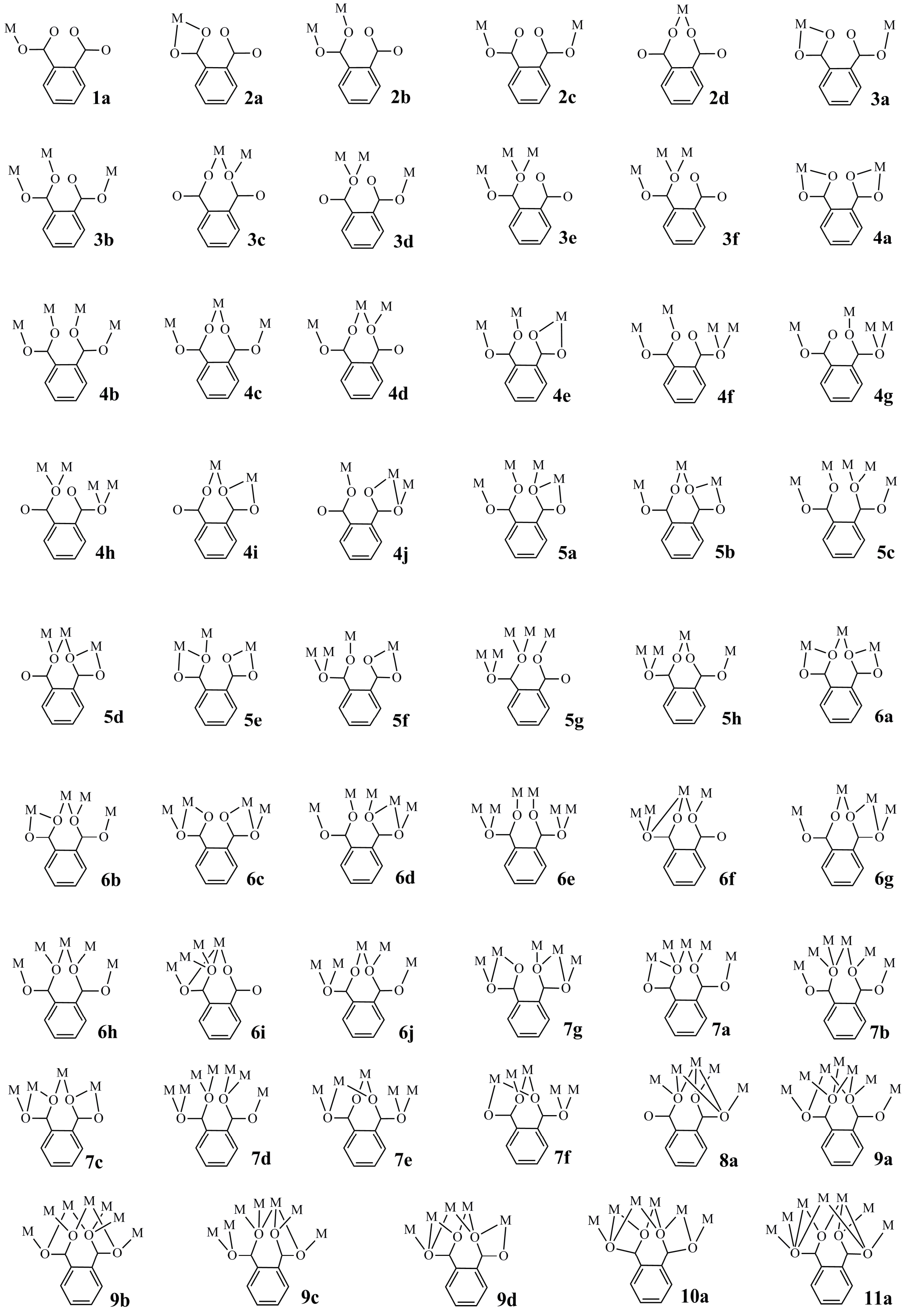
The huge number of metal carboxylates prepared to this day is the result of anextraordinary coordination ability of carboxylic COO^- group, which can dentate up to four metal centers and 19 modes (including *anti-anti*, *anti-syn* and *syn-syn* conformations) of metal binding to the carboxylate group were found to exist (Porai-Koshits, 1980). The presence of two carboxylic groups in *ortho*-phthalic acid opened up new opportunities for the preparation of both mononuclear complexes and polynuclear multidimensional systems with this ligand as the number of coordination modes of the metal to two carboxy groups in *ortho*-position is much larger. So far, twenty-six different coordination types, which are summarized on the base of the structural data retrieved from the Cambridge Structural Database (CSD) (Allen, 2002), have been observed in crystal structures of metal complexes containing this ligand and reported by Baca et al. (2004a).After this report, some additional coordination modes of *o*-phthalic acid have been found in structures extracted from CSD (2010 with updates). All coordination features of *o*-phthalic acid are shown in Scheme 1.

In metal complexes the phthalate ligand can coordinate up to seven metal centers at once showing the following connecting features: monodentate (**1a**), 1,3-chelating (**2a**), and 1,6-chelating (**2d**) linking modes, and various bridging modes with combinations of mono-, bi- and tridentate and chelating coordinations (Scheme 1). This coordination ability is influenced and controlled by a large number of different factors such as the nature of the metal ion and ancillary ligands used, the presence of outer sphere cations and anions, reaction conditions, etc. It is noteworthy that 1,6-bridging mode (**2c**), which promotes the formation of coordination polymers, is the most favored(Baca et al., 2004a). Other dominant mode of coordination for the carboxylate groups of the phthalate ligand appeared in its complexes is oftype**1a** in Scheme 1, where only one carboxylic group coordinated to a metal ion adopting a μ_1-η^1:η^0-monodentate mode, as well as bidentate chelating **2d** type with carboxylate groups adopting μ_1-η^1:η^2- chelating modes to connect one metal atom, and tridentate (**3a** in Scheme 1) type in which carboxylate groups adopting μ_1-η^1:η^0-monodentate and μ_1-η^1:η^1-chelating modes.

3. ZINC(II) PHTHALATES WITH ANCILLARY N-DONOR LIGANDS

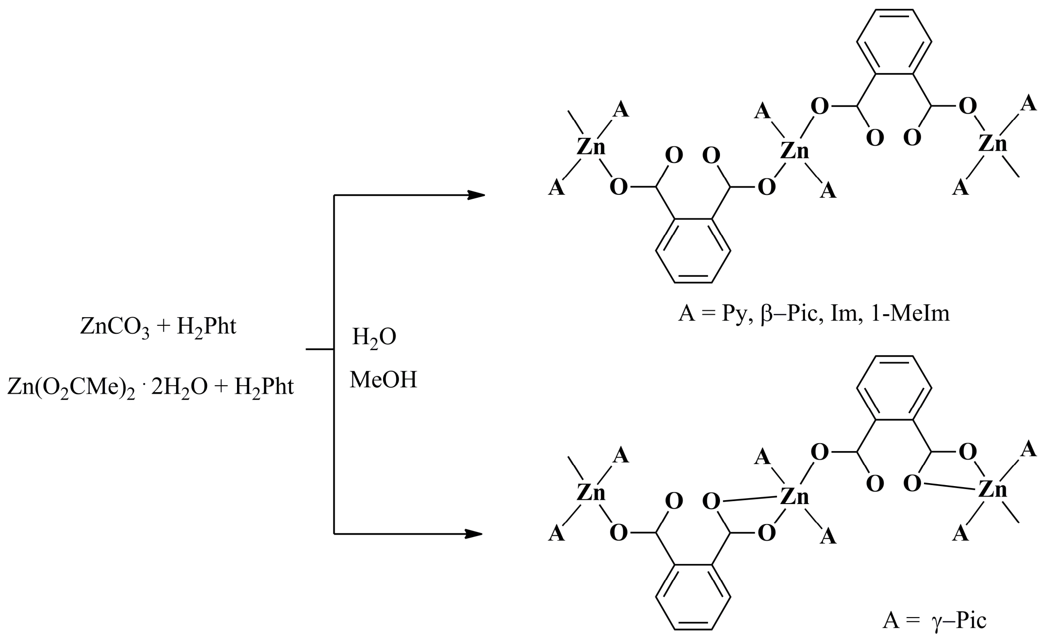
3.1 Synthesis of Zinc(II) Phthalates with N-donor Ligands

The design and construction of novel zinc(II) phthalates with an additional ancillary N-containing organic ligand is influenced by factors such as the structural characteristics of used N-donor ligands, the metal-acid-ligand ratio, the reaction conditions, the presence of groups able to form non-covalent interactions such as hydrogen bonds and π-πstacking and others. Zinc(II) phthalates with ancillary N-donor ligands such as pyridine or imidazole and their derivatives can be prepared by the addition of *o*-phthalic acid and the corresponding amines in an aqueous or methanolic solution to the aqueous solution of zinc carbonate or zinc acetate salt (Schemes 2-4).



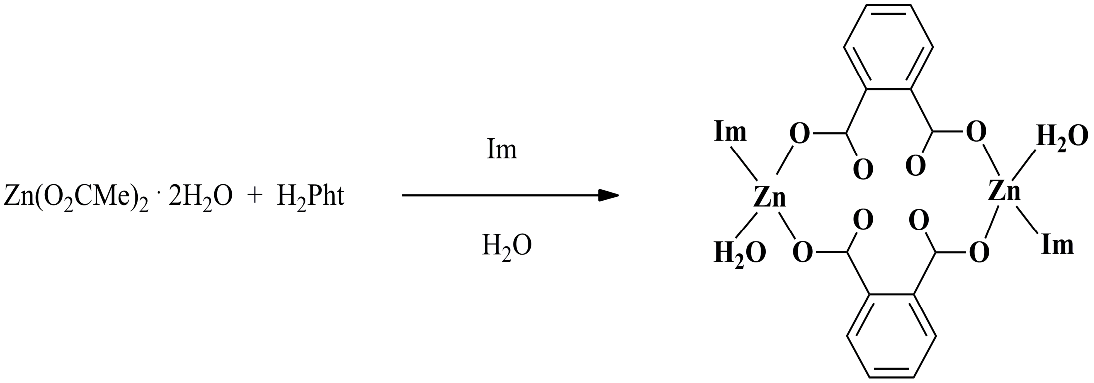
Scheme 1: Coordination modes of the phthalate ligand in metal complexes

Depending on the ratio between the starting materials, different products can be formed: $[Zn(Pht)A_2]_n$ (where A = Py, β-Pic, γ-Pic and 1-MeIm) and $[Zn(Pht)A]_n$ (where A = γ-Pic and 2-MeIm). The reaction of zinc(II) carbonate or zinc(II) acetate with pyridine, 3-, 4-methylpyridine and imidazole and *o*-phthalic acid in water in a 1:1:2 ratio under heating leads to crystalline products with the formulae $[Zn(Pht)A_2]_n$ (A = Py (**1**), β-Pic (**2**), γ-Pic (**3**), Im (**4**) (Baca et al., 2001, 2003a) having chain structures as shown in Scheme 2 due to the1,6-bridging function of the dicarboxylic ligand. In the coordination polymers **1**, **2** and **4** both carboxylate groups adopt a μ_1-η^1:η^0-monodentate coordination mode (**2c** type in Scheme 1), whereas in **3** one carboxylate group adopts a μ_1-η^1:η^0-monodentate coordination and otherμ_1-η^1:η^1-chelating mode (**3a** type in Scheme 1). The reaction of $Zn(O_2CMe)_2 \cdot 2H_2O$ with *o*-phthalic acid and an excess of 1-methylimidazole in methanol solution results in $[Zn(Pht)(1\text{-}MeIm)_2]_n$ (**5**) (Baca et al., 2004a) with the similar chains (Scheme 2).



Scheme 2: Schematic representation of the synthesis of 1-5 and the connectivity of Pht ligands

When in the reactions the ratio of initial components was 1:1:1 the following products were formed. In the reaction with imidazole two compounds, coordination polymer $[Zn(Pht)(Im)_2]_n$ (**4**) (Scheme 2) in ca. 40% yield and the14-membered cyclic dimer $[Zn(Pht)(Im)(H_2O)]_2$ (**6**, 20% yield) were isolated (Scheme 3). This cyclic dimer was the first example of the dinuclear associate in the family of polymeric Zn(II) complexes with *o*-phthalic acid and amines (Baca et al, 2003a). Two zinc atoms are linked by two phthalate ligands exhibiting a 1,6-bridging function (**2c** mode) with the formation of a metallocycle.



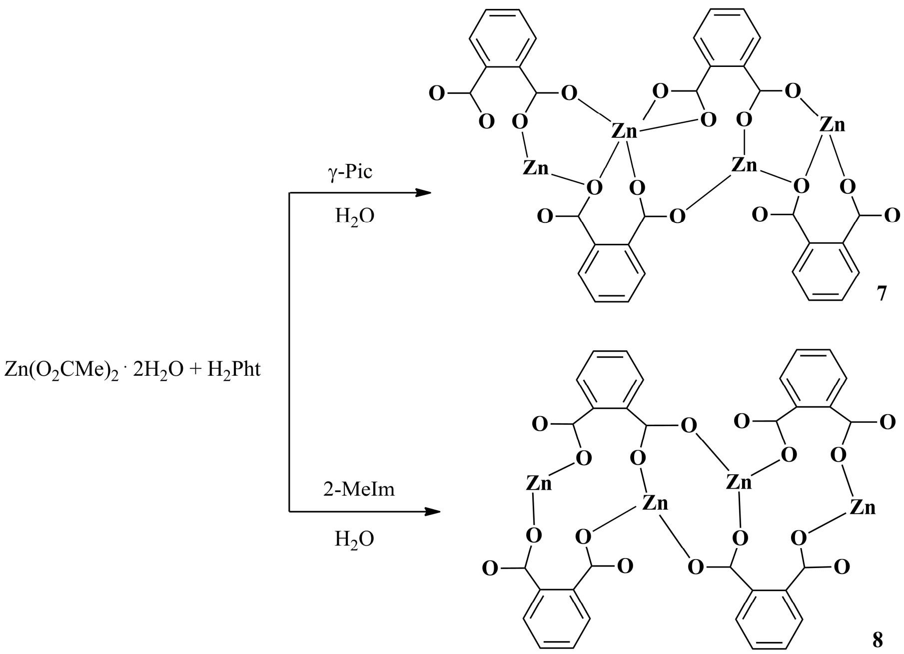
Scheme 3: Schematic representation of the synthesis of 6 and the connectivity of Pht ligands

The use of 4-methylpyridine (γ-Pic)and 2-methylimidazole (2-MeIm) in the reaction of Zn(II) salt with *o*-phthalic acid in the ratio of 1:1:1 leads to the one-dimensional double-stranded chain coordination polymers $[Zn(Pht)(\gamma\text{-Pic})]_n$ (**7**) (Baca et al., 2001) and $[Zn(Pht)(2\text{-MeIm})]_n$ (**8**) (Baca et al., 2003a) (Scheme 4), in which the *o*-phthalicanion behaves as a tetra- and tridentate ligand, respectively, adopting the different coordination modes. In the coordination polymer **7**, one phthalate ligand has carboxylate groups adopting a μ_1-η^1:η^1-chelating and a μ_2-η^1:η^1-bridging modes (**4e** type in Scheme 1), whereas other phthalate coordinates in the bridging μ_2-η^2:η^0andμ_2-η^1:η^1 binding modes (**4d** type in Scheme 1). In **8**, the phthalate ligand behaves as a tridentate ligand and adopts the**3b** coordination mode with one carboxylate group exhibiting aμ_1-η^1:η^0 coordination mode, while the other showsμ_2-η^1:η^1-bridging mode.

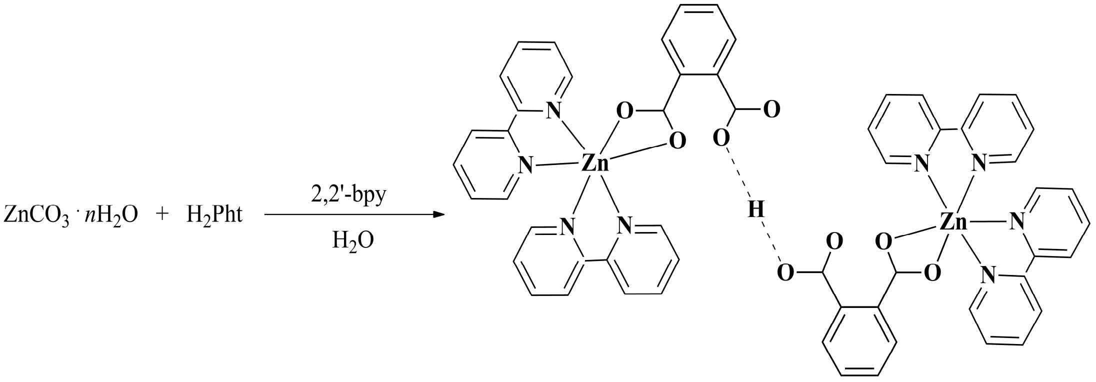
The reaction of *o*-phthalic acid and 2,2′-bipyridine with zinc(II) carbonate resulted in an unusual phthalate dimer $[(bpy)_2Zn(Pht)H(Pht)Zn(bpy)_2](HPht)(H_2Pht)] \cdot 2H_2O$ (**9**) in ca. 36% yield (Scheme 5) in which $[Zn(bpy)_2]$ units are held together via O...H...O interaction between carboxylate groups of two different coordinated phthalate ligands (Baca et al., 2003b). In **9**, the phthalate ligands adopt monodentate coordination mode (**1a**, Scheme 1). Using 4,4′-bipyridine in combination with zinc(II) acetate and hydrophthalate potassium in water solution afforded a coordination polymer $\{[Zn(Pht)(4,4'\text{-bpy})(H_2O)_2]\cdot 2H_2O\}_n$ (**10**) (Simonov et al., 2004) in ca. 68% yield (Scheme 6) consisting of two-dimensional sheets.

3.2 Structural Diversity of Zinc(II) Phthalates with Ancillary N-donor Ligands

Zinc(II) complexes with *o*-phthalic acid and ancillary N-containing ligands have a variety of structural features ranging from discrete complexes (Baca et al., 2003a, 2003b; Li et al., 2007c; Wang et al., 2008b) to one-dimensional coordination polymers (Baca et al., 2001, 2003a, 2004a; Gong et al., 2007; Hu et al., 2008; Huang et al., 2010b; Li et al., 2006a,2007b; Liang et al., 2003; Liu et al., 2008; Lu et al., 2010; Padmanablan et al., 2007; Song et al., 2005b;Tang et al., 2004; Thirumurugan and Rao, 2005b;Wang et al.,2008c; Yao et al.,2002; Zhang et al., 2005; Zhang and Sun, 2006) and complex two- (Bai et al., 2010; Huang et al., 2010b; Li et al., 2004,2006b; Simonov et al., 2004; Zhang et al., 2008c;) and three-dimensional architectures (Bai et al., 2010; Chen et al., 2010).



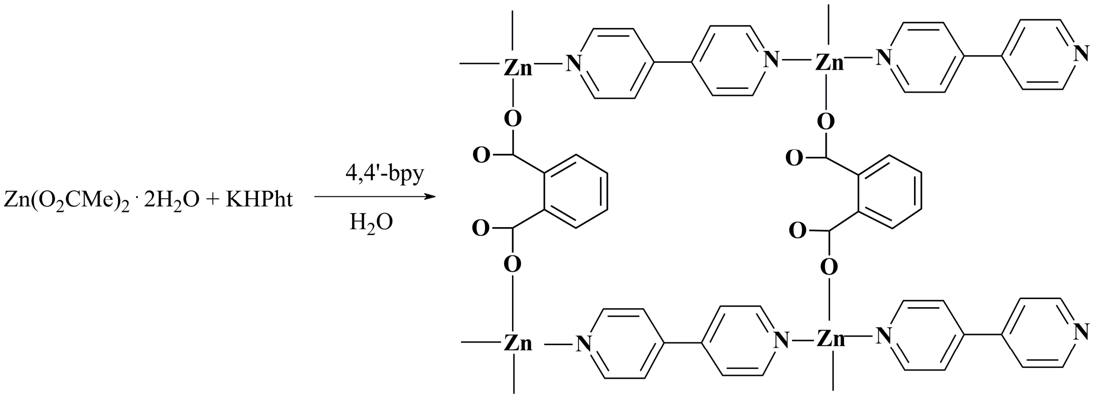
Scheme 4: Schematic representation of the synthesis of 7 and 8 and the connectivity of Pht ligands



Scheme 5: Schematic representation of the synthesis of 9 and the connectivity of Pht ligands

3.2.1 Discrete zero-dimensional (0D) structures

Although, the *o*-phthalate ligand has tendency to form extended polymeric structures adopting a1,6-bridging coordination mode, some discrete dinuclear complexes have also been obtained. As shown in figure 1, complex [Zn(Pht)(Im)(H_2O)]$_2$ (**6**) has a dinuclear structure, in which two phthalate ligands are bound to two Zn(II) centers in a 1,6-bridging coordination mode to form a 14-membered macrocycle (Baca et al., 2003a).



Scheme 6: Schematic representation of the synthesis of 10 and the connectivity of Pht ligands

The Zn(II) atoms in **6** are coordinated by two oxygen atoms of the Pht^{2-}carboxylate groups [Zn–O, 1.982(1) and 1.935(1) Å], the nitrogen atom of the imidazole molecule [Zn–N, 1.969(1) Å] and the oxygen atom of the water molecule [Zn–O, 1.995(1) Å] with formation of a tetrahedral NO_3 metal-binding site. The Zn…Zn distance in this dimer is 5.369(1) Å, which is slightly longer compared to 5.25 Å for adinuclear complex $[Zn(Pht)(L)(H_2O)]_2$ (where L = dipyrido[[3,2-d:2′,3′-f]quinoxaline]) reported by Wanget al. 2008b. The molecules of **6** form a 3D-network through N–H…O and O–H…O hydrogen bonds between carboxylate groups of Pht^{2-}, imidazole and water molecules.

Complex **9**, $[(bpy)_2Zn(Pht)H(Pht)Zn(bpy)_2](HPht)(H_2Pht) \cdot 2H_2O$ (Baca et al., 2003b), has a hydrogen-bonded dinuclear structure and consists of a dinuclear cation shown in figure 1, $HPht^-$ anion as well as H_2Pht and two water molecules. The Zn(II) atom in **9** has a six-coordinated distorted octahedral N_4O_2 geometry with four nitrogen atoms from two 2,2′-bpy (Zn–N, 2.104 – 2.151 Å), and two oxygen atoms from the chelating carboxylate group of the Pht ligand (Zn–O, 2.099 – 2.348 Å). The phthalate ligand coordinates to zinc(II) atom through only one of its two carboxylate groups ina μ_1-η^1:η^1-chelating fashion, while its second carboxylate group forms a very strong O–H...O hydrogen bond of 2.459Å with the carbonyl group of the phthalate ligand in neighboring cation to generate a hydrogen-bonded zinc(II) dimer. Such formation of hydrogen-bonded dinuclear unit is unprecedented in the metal phthalates and it was the first example of dinuclear associate with Pht...H...Phtbridge (Baca et al., 2003b).The hydrogen-bonded dimers are further assembled via hydrogen bonds involving $HPht^-$ anions, *o*-phthalic acid and lattice water molecules, into a 3D polymeric network.

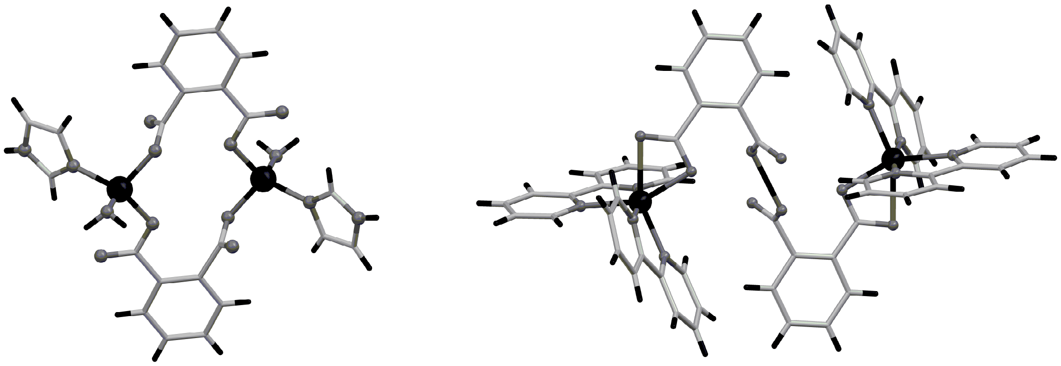


Figure 1: Molecular/cationic structures of complexes $[Zn(Pht)(Im)(H_2O)]_2$(left) and $[(bpy)_2Zn(Pht)H(Pht)Zn(bpy)_2]^+$(right)
Zn atoms, black balls; O and N atoms, dark grey balls;
C atoms, grey sticks; H atoms, black sticks

3.2.2 One-dimensional (1D) structures

Formation of one-dimensional motif is the most common type of structure formed from the interaction of zinc(II) salts with *o*-phthalic acid and N-containing ligands in a water/alcohol solution. Potentially polydentate phthalate ligand used both carboxyl groups to connect zinc(II) ions into one-dimensional chains with different topologies including zigzag, helical and double-stranded chains. Complexes **1**, **2**, **4** and **5** have similar structures consisting of $[ZnA_2]$ building blocks connected by 1,6-phthalate bridges to form infinite chains. However, the one-dimensional motif in complexes **1**, **2** and **4** is zigzag chains as shown in figures2 and 3, whereas in **5**helical chains are formed (Fig. 4).The Zn...Zn distances in the zigzag chains are at 6.645(1) (**1**), 6.896(2) (**2**) and 6.030(2)Å (**4**) (Fig. 3). Zn(II) ions coordinate to two nitrogen atoms of two pyridine (**1**), 3-methylpyridine (**2**), imidazole (**4**) or 1-methylimidazole (**5**) molecules [Zn–N, 1.985(4) – 2.073(5)Å] and two oxygen atoms of two Pht^{2-} ligands [Zn–O, 1.929(2) – 1.987(5)Å] adopting a tetrahedral N_2O_2environment.All these values agree well with those observed in other $[Zn(Pht)L_2]_n$ zigzag chains, where L = 1-vinylimidazole (Li et al., 2007b). The zigzag chains are further linked through C–H...O (**1** and **2**) and N–H...O (**4**) hydrogen bonds between aromatic and carboxylate groups into a 3D network.

Complex **5**, $[Zn(Pht)(1\text{-}MeIm)_2]_n$ (Baca et al., 2004a)**,** has helical chains as shown in figure4 with a pitch of 25.7 Å. One helical pitch includes five metal ions, which are separated by 6.943 and 6.985 Å (two independent metal atoms are present in the structure) and four phthalate bridges. Because left-handed and right-handed helical chains are coexisting in the structure, the whole crystal does not show any chirality. Two independent metal atoms are tetrahedrally N_2O_2 coordinated to a pair of Pht ligands and a pair of 1-MeIm molecules. The helical chains of complexes **5** are connected by C–H...O interactions between the methyl group of 1-MeIm and the carboxy oxygen atoms, leading to the formation of a supramolecular 3D structure.

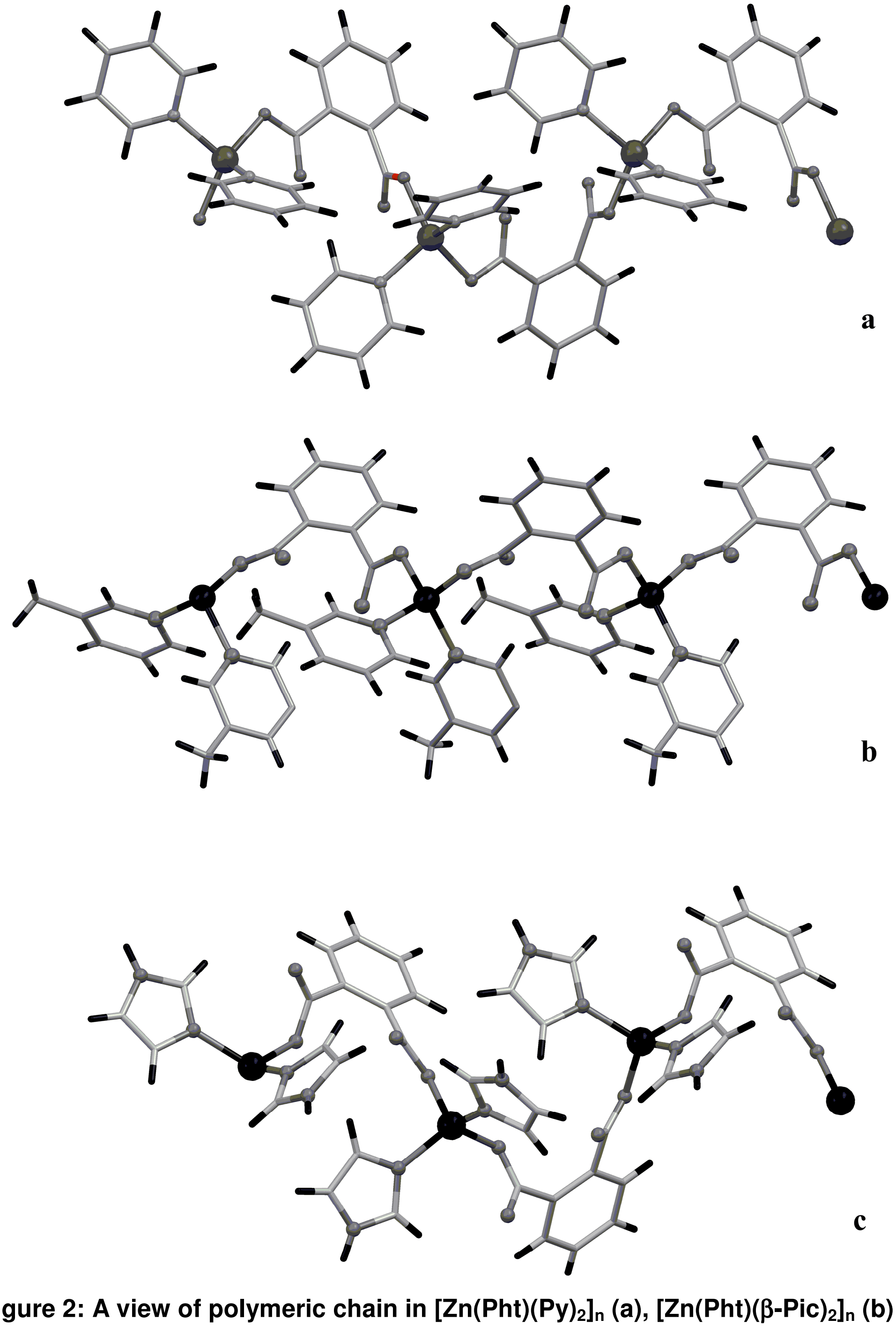


Figure 2: A view of polymeric chain in $[Zn(Pht)(Py)_2]_n$ (a), $[Zn(Pht)(\beta\text{-}Pic)_2]_n$ (b) and $[Zn(Pht)(Im)_2]_n$(c)

Zn atoms, black balls; O and N atoms, dark grey balls;
C atoms, grey sticks; H atoms, black sticks

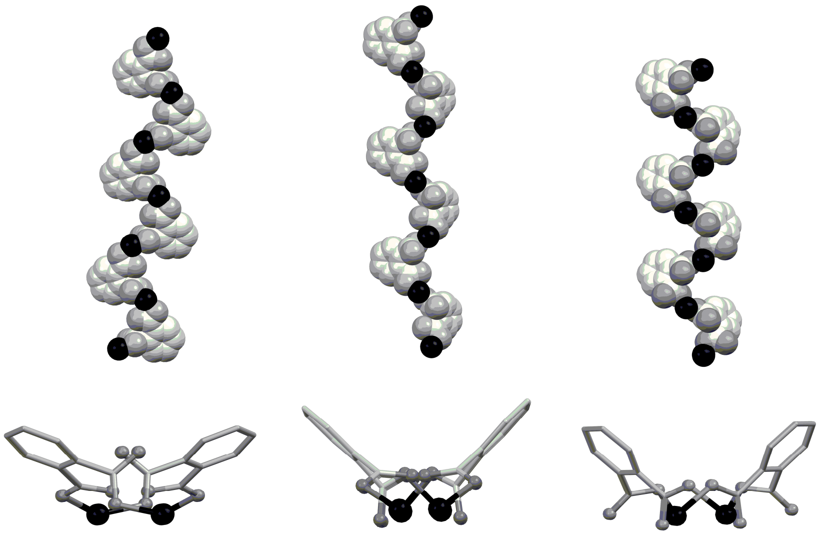


Figure 3: Side (space-filling representation) and top (bottom) view of polymeric chain in 1, 2, and 4

Hydrogen atoms and N-donor ligands are omitted for clarity.
Zn atoms, black balls; O atoms, dark grey balls; C atoms, grey sticks

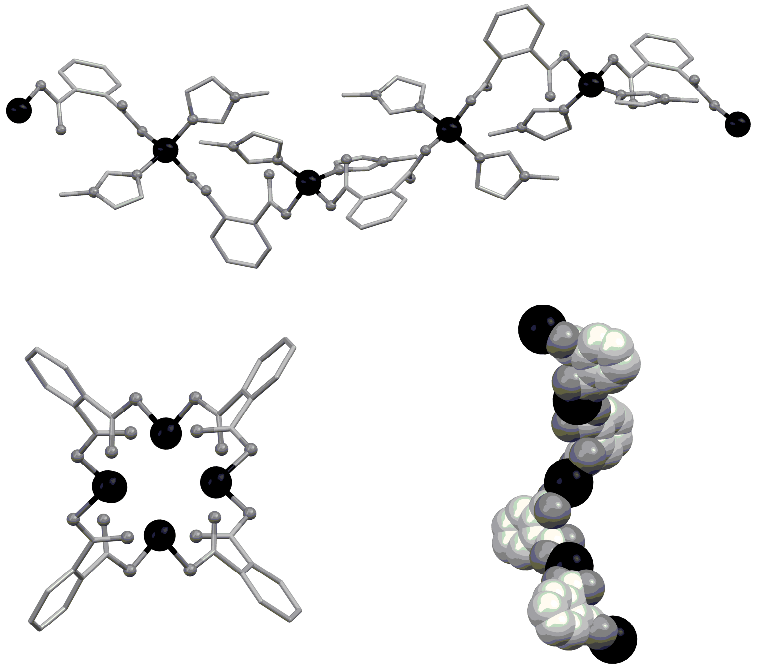


Figure 4: Helical chain in $[Zn(Pht)(1\text{-}MeIm)_2]_n$ (5) (up) and top and side (space-filling representation) view of the helix (bottom)

Hydrogen atoms and N-donor ligands (bottom) are omitted for clarity.
Zn atoms, black balls; O atoms, dark grey balls; C atoms, grey sticks

Complex **3**, $[Zn(Pht)(\gamma\text{-Pic})_2]_n$ (Baca et al., 2001), has a one-dimensional zigzag chain structure (Fig. 5) with $[Zn(\gamma\text{-Pic})_2]$ units connected by the phthalate ligands. One of the acid residues behaves as abidentate 1,6-bridge, while the other one acts as a tridentate (1,6-bridging and 1,3-chelating) ligand (**3a** type in Scheme 1). As a result, Zn(II) atoms in **3** have two different coordination geometries: tetrahedral N_2O_2 comprising two nitrogen atoms of two 4-methylpyridine molecules [Zn–N, 2.046(4) and 2.072(4)Å] and two oxygen atoms from different phthalate ligands [Zn–O, 1.921(3) and 1.990(3)Å], and distorted square-pyramidal N_2O_3 environment which is composed of two nitrogen atoms of γ-Pic [Zn–N, 2.044(4) and 2.075(4)Å] and three oxygen carboxylate atoms [Zn–O, 1.940(4), 2.047(4) and 2.405(4)Å]. The Zn...Zn intrachain distances are at 6.358 and 6.405 Å, which are shorter than those found in the coordination polymers **1** and **2,** but longer than in **4**. Similar to **1** and **2**, the three-dimensional network in **3** is assembled by C–H...O hydrogen bonds.

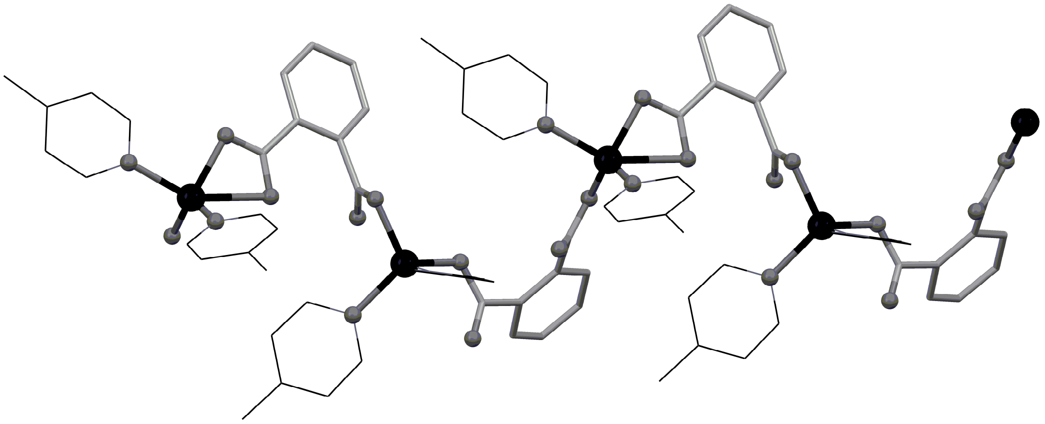


Figure 5: Zigzag chain in $[Zn(Pht)(\gamma\text{-Pic})_2]_n$ (3)
Zn atoms, black balls; O and N atoms, dark grey balls;
C atoms, grey sticks; C atoms of γ-Pic shown as grey lines

As the main feature of coordination polymers $[Zn(Pht)(\gamma\text{-Pic})]_n$ (**7**)(Baca et al., 2001)and $[Zn(Pht)(2\text{-MeIm})]_n$ (**8**) (Baca et al., 2003a) there is the formation of 1D double-stranded chains shown in figure 6, in which [Zn(A)] (A = γ-Pic, 2-MeIm) units are linked by a pair of Pht ligands to form infinite chains. In these double-stranded chains thePht^{2-}di anion acts as both a tetra- and tridentate ligand, respectively, and exhibits different coordination giving rise to the formation of 6-membered and 11-membered metallocycles in **7**, whereas8-membered and 14-memberedrings are formed in **8**. The double-stranded chain in **7**includes two independent Zn(II) atoms with the different coordination environments. One Zn(II) atom is coordinated by one nitrogen atom of γ-Pic [Zn–N, 2.002(4) Å] and three oxygen carboxylate atoms from three different Pht ligands [Zn–O, 1.945(3) – 2.031(3) Å] to form a NO_3 tetrahedron, while the coordination environment around the other Zn(II) atom corresponds to a distorted tetragonal bipyramid(NO_5) with one nitrogen atom from γ-Pic molecule [Zn–N, 2.072(4) Å] and five oxygen atoms from three different carboxylate ligands [Zn–O, 2.100(3) – 2.240(3) Å]. A pair of Phtdianions connects neighboring Zn(II) centers via a μ_2-η^1:η^1coordination mode with the formation of a 6-membered metallocycle with the Zn...Zn distance being 3.470(2) Å. Each metal ion is further connected through bridging Pht ligands (μ_2-η^1:η^1-bridging and μ_1-η^1:η^1-chelatingmodes) to form an 11-membered ring with Zn atoms being at 4.467(2) Å from each other. As a result, the 1D double-stranded chains with alternation of 6- and 11-membered metallocycles are formed in **7**. In complex **8**,[Zn(Pht)(2-

MeIm)]$_n$, the one-dimensional double-stranded chains are composed of two kinds of rings, the smaller 8-membered ring and the larger 14-membered ring. This double-stranded chains resemble those in $\{[Zn_2(Pht)_2(L)_2]\cdot H_2O\}_n$ (where L = dipyrido[3,2-d:2′,3′-f]quinoxaline) (Wang et al., 2008c). The phthalate ligand is coordinated to the zinc atoms with both bridging and monodentate binding modes: one of the zinc(II) pairs is linked by a 1,6-bridge of two Pht^{2-} to form a 14-membered ring with a Zn...Zn distance of 4.195(1) Å, while another zinc(II) pair is held together by 1,3-bridging mode from the same phthalates resulting in smaller 8-membered ring with a shorter Zn...Zn distance of 3.594(1) Å. Each Zn(II) atom in **8** is in a tetrahedral NO_3 environment being coordinated by one nitrogen atom from a 2-MeIm [Zn–N, 1.989(3) Å] and three oxygens from three phthalate ligands [Zn–O, 1.971(2) – 1.991(2) Å].The Zn–O distances are consistent with those for above-mentioned $\{[Zn_2(Pht)_2(L)_2]\cdot H_2O\}_n$ prepared by Wang et al., 2008c, whereas Zn–N distance is shorter than the corresponding values, 2.118(3) - 2.198(3) Å. The ancillary N-donor ligands, 4-methylpyridine in **7** and 2-methylimidazole in **8**, lie on one side of these chains in parallel fashion with strong aromatic π-π stacking interactions at a centroid-centroid distance of 3.583 Å between the γ-Pic pairs and 3.596 and 3.530 Å between 2-MeIm heterocycles. The double-stranded chains are further extended through C–H...O hydrogen bonds of 2.41–2.44 Å (**7**) and N–H...O hydrogen bonds of 2.72Å (**8**) between aromatic groups and carboxylate oxygen atoms into the final 3D and 2D architectures, respectively.

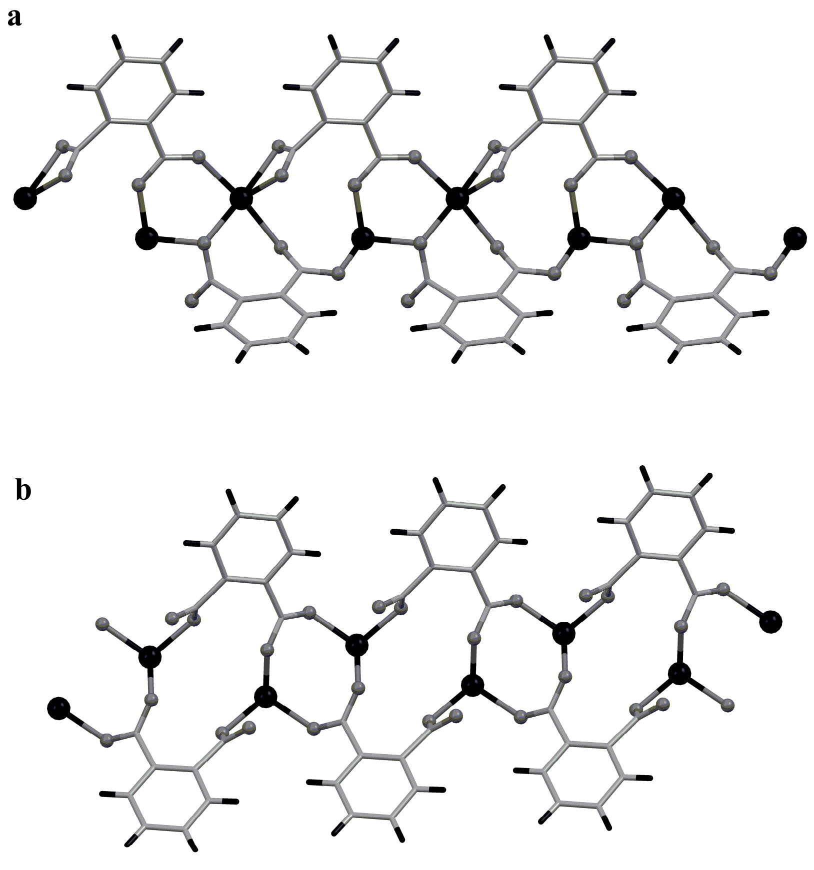


Figure 6: Double-stranded chain in [Zn(Pht)(γ-Pic)]$_n$ (a) and [Zn(Pht)(2-MeIm)]$_n$ (b)

N-donor ligands are omitted for clarity. Zn atoms, black balls; O atoms, dark grey balls; C atoms, grey sticks; H atoms, black sticks

3.2.3 Two-dimensional (2D) structures

By using additional bridging linkers, in particular 4,4′-bpy, two-dimensional structures can be generated. In coordination polymer $\{[Zn(Pht)(4,4'\text{-bpy})(H_2O)_2]\cdot 2H_2O\}_n$ (**10**) (Simonov et al., 2004),both ligands, *o*-phthalate and 4,4′-bpy, execute bridging functions. The phthalates act as a 1,6-bridging ligand and connect Zn(II) atoms into1D chains that are further interlinked through 4,4′-bpy ligands into rectangular grids shown in figure 7. The Zn…Zn distances across the phthalate and 4,4′-bpy linkers are 7.627(2) and 11.302(2) Å, respectively. Each Zn(II) atom is coordinated by two N atoms of different 4,4′-bipyridine molecules [Zn–N, 2.117(3) and 2.131(3) Å], two O atoms of two *o*-phthalic residues [Zn–O, 2.171(2) Å], and two O atoms from two water molecules [Zn–O, 2.129(2) Å] in a distorted octahedral geometry. The complex **10** is isostructural to other reported 2D coordination polymers $[M(Pht)(4,4'\text{-bpy})(H_2O)_2]\cdot 2H_2O\}_n$(where M = Co, Cd (Suresh et al., 2001); M = Mn (Ma et al., 2003). Note, theπ–πstacking interactions between the phthalic acid residues and the pyridine rings with the centroid-centroid distance being3.929 Å are observed in the grid layers. The adjacent layers are linked through hydrogen-bonding interactions involving coordinated and lattice water molecules [O–H…O, 2.694(2) – 2.818(3) Å] into a 3D network.

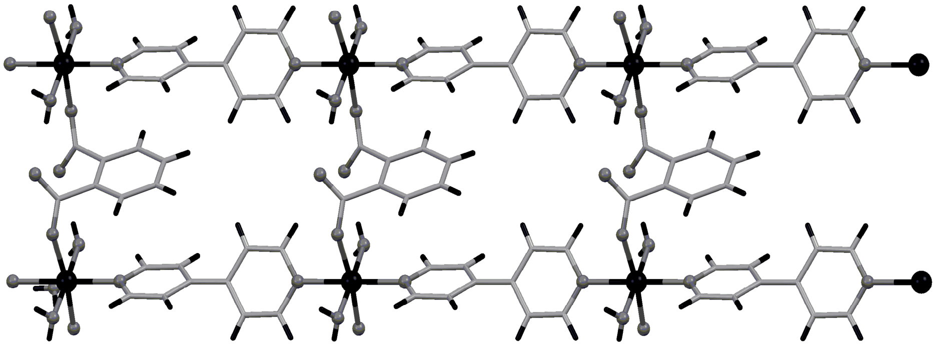


Figure 7: Two-dimensional layer in $\{[Zn(Pht)(4,4'\text{-bpy})(H_2O)_2]\cdot 2H_2O\}_n$ (10)
Zn atoms, black balls; O and N atoms, dark grey balls;
C atoms, grey sticks; H atoms, black sticks

4. CONCLUSION

Simple synthetic approach to a series of discrete complexes and coordination polymers with chain and layer structures by using Zn(II) ions, *o*-phthalate bridging ligand and the different co-ligands like pyridine, imidazole and its derivatives, and 2,2′-, 4,4′-bipyridine was developed. The strategy is to use multi-bridging ligand and $[Zn(amine)_n]^{2+}$(n = 1, 2) blocks as the key elements. These studies revealed that using of the different N-donor ligands leads to the formation of dinuclear complexes and one-, two-dimensional coordination polymers with different topologies including zigzag, helical and double-stranded chains, and rectangular grid-like layers. The chains and two-dimensional sheets are held together by strong or weak hydrogen bonds and/or aromatic-aromatic interactions, to generate 2D or 3D networks.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

Allen, F.H. (2002). The Cambridge structure database: A quarter of a million structures and rising. Acta Cryst., B58, 380-388.

Allendorf, M.D., Bauer, C.A., Bhakta, R.K., Houk, R.J.T. (2009). Luminescent metal-organic frameworks. Chem. Soc. Rev., 38, 1330-1352.

Ang, W.H., Pilet, S., Scopelliti, R., Bussy, F., Juillerat-Jeanneret, L., Dyson, P.J. (2005). Synthesis and characterization of platinum(IV) anticancer drugs with functionalized aromatic carboxylate ligands: influence of the ligands on drug efficacies and uptake. J. Med. Chem., 48, 8060-8069.

Askarinejad, A., Morsali, A. (2006). Synthesis and structural characterization of a new two-dimensional polymeric thallium(I) compound, $\{Tl[(H)phthalate)]\}_n$. J. Coord. Chem., 59, 997-1005.

Babb, J.E.V., Burrows, A.D., Harrington, R.W., Mahon, M.F. (2003). Zinc thiosemicarbazide dicarboxylates: the influence of the anion shape on supramolecular structure. Polyhedron, 22, 673-686.

Baca, S.G., Simonov, Yu.A., Gerbeleu, N.V., Gdaniec, M., Bourosh, P.N., Timco, G.A. (2001). Synthesis and X-ray diffraction study of Zn(II) complexes with *o*-phthalic acid and aromatic amines. Polyhedron, 20, 831-839.

Baca, S.G., Filippova, I.G., Gerbeleu, N.V., Simonov, Yu.A., Gdaniec, M., Timco, G.A., Gherco, O.A., Malaestean, Yu.L. (2003a). Zinc(II) carboxylates with imidazole and 2-methylimidazole: unprecedented cyclic dimer and polynuclear coordination polymers based on bridging phthalate ions. Inorg. Chim. Acta, 344, 109-116.

Baca, S.G., Simonov, Yu.A., Gdaniec, M., Gerbeleu, N., Filippova, I.G., Timco, G.A. (2003b). Synthesis and structural characterization of unprecedented dinuclearzinc(II) complex with H-bonded bridging phthalate ions. Inorg. Chem. Commun., 6, 685-689.

Baca, S.G., Filippova, I.G., Gherco, O.A., Gdaniec, M., Simonov, Yu.A., Gerbeleu, N.V., Franz, P., Basler, R., Decurtins, S. (2004a). Nickel(II)-, cobalt(II)-, copper(II)-, and zinc(II)-phthalate and 1-methylimidazole coordination compounds: synthesis, crystal structures and magnetic properties. Inorg. Chim. Acta, 357, 3419-3429.

Baca, S.G., Malinovskii, S.T., Franz, P., Ambrus, C., Stoeckli-Evans, H., Gerbeleu, N., Decurtins, S. (2004b). Synthesis, structure and magnetic properties of cobalt(II) and copper(II) coordination polymers assembled by phthalate and 4-methylimidazole. J. Solid State Chem., 117, 8, 2841-2849.

Baca, S.G., Filippova, I.G., Ambrus, C., Gdaniec, M., Simonov, Yu.A., Gerbeleu, N., Gherco, O.A., Decurtins, S. (2005a). From mono- and dinuclear to polynuclear cobalt(II) and cobalt(III) coordination compounds based on *o*-phthalic acid and 2,2′-bipyridine: synthesis, crystal structures and properties. Eur. J. Inorg. Chem., 3118-3130.

Baca, S.G., Filippova, I.G., Franz, P., Ambrus, C., Gdaniec, M., Stoeckli-Evans, H., Simonov, Yu.A., Gherco, O.A., Bejan, T., Gerbeleu, N., Decurtins, S. (2005b). Ni(II) coordination compounds based on mixed phthalate and aromatic amine ligands: synthesis, crystal structures and magnetic properties. Inorg. Chim. Acta, 358, 1762-1770.

Baca, S.G., Reetz, M.T., Goddard, R., Filippova, I.G., Simonov, Yu.A., Gdaniec, M., Gerbeleu. N. (2006). Coordination polymers constructed from *o*-phthalic acid and diamines: Syntheses and crystal structures of the phthalate- imidazole complexes $\{[Cu(Pht)(Im)_2]\cdot 1.5H_2O\}_n$ and $[Co(Pht)(Im)_2]_n$ and their application in oxidation catalysis. Polyhedron, 25, 1215-1222.

Bai, H.-Y., Ma, J.-F., Yang, J., Zhang, L.-P., Ma, J.-C., Liu, Y.-Y. (2010). Eight two-dimensional metal-organic frameworks based on a flexible tetrakis(imidazole) ligand: synthesis, topological structures, and photoluminescent properties. Cryst. Growth Des., 10, 1946-1959.

Bakalbassis, E.G., Paschalidis, D.G. (1998). Synthesis, crystal structure, and magnetic properties of a one-dimensional polymeric copper(II) complex, containing unicoordinatedphthalato bridges. Inorg. Chem., 37, 4735-4737.

Braverman, M.A., Supkowski, R.M., LaDuca, R.L. (2007). One-dimensional nickel and cobalt phthalate coordination polymers incorporating the kinked dipodalorganodiimine 4,4′-dipyridylamine. Hydrothermal synthesis, structural characterization and thermal properties. Inorg. Chim. Acta, 360, 7, 2353-2362.

Brechin, E.K., Gould, R.O., Harris, S.G., Parsons, S., Winpenny, R.E.P. (1996). Four cubes and an octahedron: a nickel-sodium supracage assembly. J. Am. Chem. Soc., 118, 11293-11294.

Brechin, E.K., Graham, A., Parkin, A., Parsons, S., Seddon, A.M., Winpenny, R.E.P. (2000). Structural studies of heptanuclear cobalt complexes and larger oligomers based on heptanuclear fragments. J. Chem. Soc., Dalton Trans., 3242-3252.

Burke, N.J., Burrows, A.D., Donovan, A.S., Harrigton, R.W., Mahon, M.F., Price, C.E. (2003). Zinc dicarboxylate polymers and dimers: thiourea substitution as a tool in supramolecular synthesis. Dalton Trans., 3840-3849.

Burrows, A.D., Harrington, R.W., Mahon, M.F., Price, C.E. (2000).The influence of hydrogen bonding on the structure of zinc co-ordination polymers. J. Chem. Soc., Dalton Trans., 3845-3854.

Burrows, A.D., Harrington, R.W., Mahon, M.F., Teat, S.J. (2004). Manipulation of molecular and supramolecular structure in nickel(II) complexes through the orientation of dicarboxylate hydrogen bonding faces. Cryst. Growth Des., 4, 813-822.

Canada-Vilalta, C., Pink, M., Christou, G. (2003). Preparation and properties of $[NH_2Et_2]Mn_{10}(OH)_3(phth)_9(bpy)_6]$, a new decanuclear Mn(II) compound with a variety of phthalate binding modes. Dalton Trans., 1121-1125.

Charushnikova, I.A., Krot, N.N., Polyakova, I.N., Starikova, Z.A. (2007). Synthesis and crystal structure of new Np(VI) and Pu(VI) phthalates, $Na_4\{AnO_2[(OOC)_2C_6H_4]_3\} \cdot nH_2O$. Radiochemistry, 49, 117-122.

Chen, C., Zhu, H., Huang, D., Wen, T., Liu, Q., Liao, D., Cui, J. (2001). Synthesis, structure and magnetic properties of mono- and di-manganese inclusion compounds. Inorg. Chim. Acta, 320, 159-166.

Chen, S.-S., Fan, J., Okamura, T., Chen, M.-S., Su, Z., Sun, W.-Y., Ueyama, N. (2010). Synthesis, crystal structures, and photoluminescence of a series of zinc(II) coordination polymers with 1,4-di(1*H*-imidazol-4-yl)benzene and varied carboxylate ligands. Cryst. Growth Des., 10, 812-822.

Chen, Y., Zhang, J., Cheng, J.-K., Kang, Y., Li, Z.-J., Yao, Y.-G. (2004). 1D chain structure, NLO and luminescence properties of $^{1}_{\infty}[Zn_2(bpp)(pht)_2]$. Inorg. Chem. Commun., 7, 1139-1141.

Chen, Z.-N., Zhang, H.-X., Yu, K.-B., Kang, B.-S., Cai, H., Su, C.-Y., Wang, T.-W., Lu, Z.-L. (1998). 3D extended supramolecular structures via H-bonded linkages of 2D sheet like or 1D zigzag coordination polymers. Inorg. Chem., 37, 4775-4781.

Cheng, J.-W., Zhang, J., Zheng, Sh.-T., Zhang, M.-B., Yang, G.-Z. (2006). Lanthanide-transition-metal sandwich framework comprising $\{Cu_3\}$ cluster pillars and layered networks of $\{Er_{36}\}$ wheels. Angew. Chem. Int. Ed., 45, 73-77.

Cheng, J.-W., Zheng, S.-T., Yang, G.-Y. (2007a). A series of lanthanide-transition metal frameworks based on 1-, 2-, and 3D metal-organic motifs linked by different 1D copper(I) halide motifs. Inorg.Chem., 46, 10261-10267.

Cheng, J.-W., Zheng, S.-T., Ma, E., Yang, G.-Y. (2007b). $\{Ln^{III}[\mu_5\text{-}\kappa^2,\kappa^1,\kappa^1,\kappa^1,\kappa^1\text{-}1,2\text{-}(CO_2)_2C_6H_4][\text{isonicotine}][H_2O]\}_2Cu^{I} \cdot X$ (Ln = Eu, Sm, Nd; X = ClO_4^-, Cl^-): a new pillared-layer approach to heterobimetallic 3d-4f 3D-network solids. Inorg. Chem., 46, 10534-10538.

Cheng, P., Yan, S.-P., Xie, C.-Z., Zhao, B., Chen, X.-Y., Liu, X.-W., Li, C.-H., Liao, D.-Z., Jiang, Z.-H., Wang, G.-L. (2004). Ferromagnetic and antiferromagnetic polymeric complexes with the macrocyclic ligand 1,4,7-triazacyclononane. Eur. J. Inorg. Chem., 2369-2378.

Cheng, X.-N., Xue, W., Zhang, W.-X., Chen, X.-M. (2008). Weak ferromagnetism and dynamic magnetic behavior of two 2D compounds with hydroxyl/carboxylate-bridged Co(II) chains. Chem. Mater., 20, 5345-5350.

Cui, Y.-C., Wang, J.-J., Che, G.-B., Li, C.-B. (2006). Catena-poly[[tris (benzimidazole)cadmium(II)]-*l*-benzene-1,2-dicarboxylato]. Acta Cryst., E62, m2761–m2763.

Du, M., Jiang, X.-J., Zhao, X.-J. (2007). Molecular tectonics of mixed-ligand metal-organic frameworks: positional isomeric effect, metal-directed assembly, and structural diversification. Inorg. Chem., 46, 10, 3984 -3995.

Eddaoudi, M., Li, H., Yaghi, O.M. (2000). Highly porous and stable metal-organic frameworks: structure, design and sorption properties. J. Am. Chem. Soc., 122, 1391-1397.

Eddaoudi, M., Moler, D.B., Li, H., Chen, B., Reineke, T.M., O'Keeffe, M., Yaghi, O.M. (2001). Modular chemistry: secondary building units as a basis for the design of highly porous and robust metal-organic carboxylate frameworks. Acc. Chem. Res., 34, 319-330.

Erxleben, A. (2003). Structures and properties of Zn(II) coordination polymers. Coord. Chem. Rev., 246, 203-228.

Escuer, A., Vicente, R., Mautner, F.A., Goher, M.A.S. (1997). Structure and magnetic behavior of a new 1-D compound with simultaneous end-on azido and carboxylate bridges. Unexpected strong ferromagnetic coupling for a Cu-N-Cu bond angle of 111.9° as a consequence of ligand HOMOs countercomplementarity. Inorg. Chem., 36, 1233-1236.

Fan, L., Qin, C., Li, Y., Wang, E., Wang, X., Xiao, D., An, H., Xu, L. (2006). A three-dimensional supramolecular framework built from two-dimensional wave-shaped layers. J. Coord. Chem., 59(8), 883 – 890.

Filippova, I.G., Gherco, O.A., Simonov, Yu.A., Deseatnic-Ciloci, A.A., Clapco, S.F., Tiurina, J.P., Baca, S.G. (2010). Synthesis, structures and biological properties of nickel(II) phthalates with imidazole and its derivatives. Polyhedron, 29(3), 1102-1108.

Fondo, M., Garcia-Deibe, A.M., Ocampo, N., Sanmartin, J., Bermejo, M.R., Llamas-Saiz, A.L. (2006). Dinuclear nickel complexes with a Ni_2O_2 core: a structural and magnetic study. Dalton Trans., 4260-4270.

Fu, X.-C., Wang, X.-Y., Li, M.-T., Wang C.-G., Deng. X.-T. (2006). Poly[[aquatetra-imidazoledi-μ-phthalato-dicopper(II)]monohydrate]. Acta Cryst., C62, m343-m345.

García-Zarracino, R., Ramos-Quiñones, J., Höpfl, H. (2003). Macrocyclic structure in the solid state and a mixture of fast interchanging cyclooligomeric structures in solution. Inorg. Chem., 42, 3835-3845.

Gerbeleu, N., Simonov, Yu., Timco, G., Bourosh, P., Lipkowskii, J., Baka, S., Saburov, D., Mazus, M. (1999). Synthesis and structure of Cu(II) complexes with *o*-phthalic acid. Russian Journal of Inorganic Chemistry, 44(8), 1191-1204.

Gong, Y., Wang, R., Yuan, D., Su, W., Huang, Y., Yue, C., Jiang, F., Hong, M. (2007). Chains, ladders and sheets of d^{10} metal–organic polymers generated from the flexible bipyridyl ligands. Polyhedron, 26, 5309-5316.

Gu, X., Xue D. (2006). Selected controlled synthesis of three-dimensional 4d–4f heterometallic coordination frameworks by lanthanide carboxylate subunits and silver centers. Cryst. Growth Des., 6, 2551-2557.

Horike, S., Kitagawa, S. (2011). Design of porous coordination polymers/metal-organic frameworks: Past, present and future, in: Farrusseng, D. (Ed.), Metal-Organic Frameworks: Application from Catalysis to Gas Storage. Willey-VCH, Weinheim, Germany, pp. 1-21.

Hu, T.-L., Zou, R.-Q., Li, J.-R., Bu, X.-H. (2008). d^{10} Metal complexes assembled from isomeric benzenedicarboxylates and 3-(2-pyridyl)pyrazole showing 1D chain structures: syntheses, structures and luminescent properties. Dalton Trans., 1302-1311.

Huang, F.-P., Tian, J.-L., Gu, W., Liu, X., Yan, S.-P., Liao, D.-Z., Cheng, P. (2010a). Co(II) coordination polymers: positional isomeric effect, structural and magnetic diversification. Cryst. Growth Des., 10,1145-1154.

Huang, F.-P., Tian, J.-L., Chen, G.-J., Li, D.-D., Gu, W., Liu, X., Yan, S.-P., Liao, D.-Z., Cheng, P. (2010b). A case study of the Zn^{II}-BDC/bpt mixed-ligand system:positional isomeric effect, structural diversification and luminescent properties. Cryst Eng Comm., 12, 1269-1279.

Johnston, L.L., Martin, D.P., Supkowski, R.M., LaDuca, R.L. (2008). One- and two-dimensional copper benzene dicarboxylate coordination polymers incorporating the flexible tethering diimine*N*,*N*′-bis(3-pyridylmethyl)piperazine: Synthesis, structure, and thermal properties. Inorg.Chim. Acta, 361, 2887-2894.

Kan, W.-Q., Yang, J., Liu, Y.-Y., Ma, J.-F. (2011). A series of metal-organic frameworks based on 9,10-bis(imidazol-1-ylmethyl)anthracene and structurally aromatic dicarboxylates: syntheses, structures, and photoluminescence. Polyhedron, 30, 2106-2113.

Kato, M., Sah, A.K., Tanase, T., Mikuriya, M. (2006). Tetranuclearcopper(II) complexes bridged by α-d-glucose-1-phosphate and incorporation of sugar acids through the Cu_4 core structural changes. Inorg. Chem., 45, 6646-6660.

Kobayashi, K., Izawa, H., Yamaguchi, K., Horn, E., Furukawa, N. (2001). Macrocyclic multi-telluranes with hypervalentTe-O apical linkages. Chem. Commun., 1428-1429.

Kumar, D.K. Das, A., Dastidar, P. (2006). Exploring hydrogen-bond capable backbone and ligating topologies: Co(II) coordination polymers derived from mixed ligand systems. J. Mol. Struct., 796, 1-3, 139-145.

Lewinski, J., Zachara, J., Justyniak, I. (1998). Structural aspects of the aluminium-carboxylate interaction. Molecular structure of the tetranuclear $[(AlMe_2)_2(\mu\text{-}O_2C)_2\text{-}1,2\text{-}C_6H_4]_2$ adduct. Inorg. Chem., 37, 2575-2577.

Li, B., Li, B., Zhu, X., Lu, X., Zhang, Y. (2004). Two novel zinc coordination polymers based on bis(1,2,4-triazole-1-yl)ethane and benzenedicarboxyl. J. Coord. Chem., 57, 16, 1361-1367.

Li, C.-B., Li, Y.-W., Fang, W., Liu, B. (2006a). catena-Poly[[[2-(2-furyl)-*1H*-imidazo[4,5-*f*][1,10]phenanthroline]zinc(II)]-μ-benzene-1,2-dicarboxylato]. Acta Cryst., E62, m3541-m3543.

Li, H., Eddaoudi, M., O'Keeffe, M., Yaghi, O.M. (1999).Design and synthesis of an exceptionally stable and highly porous metal-organic framework. Nature, 402, 276-279.

Li, L., Liao, D., Jiang, Z., Yan, S. (2000). Synthesis, structure and magnetic properties of di-carboxylato-bridged complex $[Cu_2(phen)_2(Hpht)_2(NO_3)(H_2O)]NO_3 \cdot 2H_2O$. Polyhedron, 2529-2532.

Li, P., Qiu, Y., Liu, J., Ling, Y., Cai, Y., Yue, S. (2007a). Puckered-boat conformation $(H_2O)_{14}$ cluster on the self-assembly of an inorganic-metal-architecture. Inorg. Chem. Commun., 10, 705-708.

Li, R.-X., Li, S.-X., Wu, Q.-Y., Liu, G.-Y., Liu, F.-Q. (2007b). *catena*-Poly[[bis(1-vinylimidazole-κN^3)zinc(II)]-μ-phthalato-$\kappa^2 O^1$:O^2]. ActaCryst., E63, m2874.

Li, W.-H., Liu, F.-Q., Pang, X.-H., Hou, B.-R. (2007c). Triaqua(benzene-1,2-dicarboxylato-*kO*)(1,10-phenanthroline-$k^2 N,N'$)zinc(II) monohydrate. Acta Cryst., E63, m1114-m1115.

Li, X.-F., An, Y., Yin, Y.-S. (2008a). *catena*-Poly[[bis[(2-carboxybenzoato-κO)silver(I)](Ag-Ag)]bis(μ-isonicotinic acid-$\kappa^2 N$:O)]. Acta Cryst., E64, m779.

Li, X.-M., Wang, Q.-W., Cui, Y.-C., Li, C.-B., Wang, R.-Z., Liu, B. (2006b). Hydrothermal synthesis, crystal structure and photoluminescent property of a zinc(II) coordination polymer assembled by phthalate and 4,4′-bipyridine. Chinese J. Struct. Chem., 25, 5, 621-625.

Li, X., Zha, M.-Q., Wang, X.-W., Cao, R. (2009). Novel topological nets of lanthanide metal-organic frameworks based on dicarboxylate ligands. Inorg. Chim. Acta, 362, 3357-3363.

Li, Y.-W., Wang, Y.-H., Li, Y.-G., Wang, E.-B. (2008b). New anion-templated 3D heterobimetallic open frameworks based on lanthanide-carboxylate layers and copper pillars. J. Solid State Chem., 181, 6, 1485-1491.

Liang, X., Weishaupl, M., Parkinson, J.A., Parsons, S., McGregor, P.A., Sadler, P.J. (2003). Selective recognition of configurational substates of zinc cyclam by carboxylates: implications for the design and mechanism of action of anti-HIV agents. Chem.-Eur. J., 9, 4709-4717.

Lightfoot, P., Snedden, A. (1999). Metal-organic co-ordination frameworks based on mixed N- and O-donor ligands: crystal structures of $[Co(phth)_2(bipy)]$ and $[Co_2(mal)_2(bipy)(H_2O)_2]$ (phth = phthalate, mal = malonate, bipy = 4,4′-bipyridine). J. Chem. Soc., Dalton Trans., 3549-3551.

Liu, F.-Q., Li, R.-X., Li, S.-X., Sun, L.-S., Liu, G.-Y. (2007a). *catena*-Poly[[bis(1-vinyl-1*H*-imidazole-κN^3)copper(II)]-μ-phthalato-$\kappa^2 O$:O']. ActaCryst., E63, m2441.

Liu, H.-L., Mao, H.-Y., Zhang, H.-Y., Xu, C., Wu, Q.-A., Li, G., Zhu, Y., Hou, H.-W. (2004). Two novel heterometallacrowns: syntheses and crystal structures of two copper(II) complexes with malonate and *o*-phthalate. Polyhedron, 23, 943-948.

Liu, C.-Q., Yang, X.-T., An, L.-L., Li, R., Shi, J.-M. (2007b).*catena*-Poly[[diaquabis(methanol)cobalt(II)]-μ-phthalato]. Acta Cryst., E63, m2311.

Liu, Y.-Y., Ma, J.-F., Yang, J., Ma, J.-C., Ping, G.-J. (2008). Structures of metal-organic networks based on flexible 1,1-(1,4-butanediyl)bis(imidazole-2-phenyl) ligand. CrystEngComm., 10, 565 – 572.

Lu, X., Chen, Y.-Y., Li, P.-Z., Bi, Y.-G., Yu, C., Shi, X.-D., Chi, Z.-X. (2010). Self-assembly of three 1-D zinc-benzenedicarboxylate coordination polymers with 1,10-phenanthroline. J. Coord. Chem., 63, 3923-3932.

Luo, F., Che, Y., Zheng, J. (2008). Employing La_2- (La = Eu, Tb, Pr) or Co_3-based molecule building blocks to construct 3,8-connected nets: hydrothermal synthesis, structure, luminescence, and magnetic properties. Cryst. Growth Des., 8, 2006-2010.

Luo, F., Luo, M.-B., Tong, X.-L. (2010). The Ln-Cu(II)-Hpic-H_2BDC system showing interesting production variety upon different reaction conditions: hydrothermal synthesis, structures, thermostability, and magnetism. J. Coord. Chem., 63, 1147-1156.

Ma, C., Wang, W., Zhu, H., Chen, C., Liu, Q. (2001). Phenanthroline-manganese inclusion complexes of dicarboxylic acid containing extensive hydrogen-bonding interactions. Inorg. Chem. Commun., 4, 730-733.

Ma, C., Chen, C., Liu, Q., Liao, D., Li, L., Sun, L. (2003). Structural transformation mediated by *o*-, *m*-, and *p*-phthalates from two to three dimensions for manganese/phthalate/4,4′-bpy complexes (4,4′-bpy = 4,4′-bipyridine). New J. Chem., 27, 890-894.

Ma, C., Wang, W., Zhang, X., Chen, C., Liu, Q., Zhu, H., Liao, D., Li, L. (2004). Molecular, one- and two-dimensional systems built from manganese(II) and phthalate/diimine ligands: syntheses, crystal structures and magnetic properties. Eur. J. Inorg. Chem., 3522-3532.

Marandi, F., Ghorbanloo, M., Soudi, A.A. (2007). Lead(III) complexes of *o*-phthalate including a crystal structure of a novel 2D coordination polymer, $[Pb(pht)(H_2O)]_n$. J. Coord. Chem., 60, 1557-1565.

Matsumoto, Z., Aridomi, T., Igashira-Kamiyama, A., Kawamoto, T., Konno, T. (2007). Proton-induced cis–trans conversion of a platinum(II) center coordinated by L-cysteinatocobalt(III) metalloligands. Inorg. Chem., 46, 2968–2970.

Meng, Z.-R., Zhang, Q.-Z., Wu, X.-Y., Chen, L.-J., Lu, C.-Z. (2006). Poly[aquabis(μ_4-benzene-1,2-dicarboxylato)(μ_3-benzene-1,2-dicarboxylato)digadolinium(III)]. Acta Cryst., E62, m1033-m1035.

Padmanabhan, M., Joseph, K.C., Puranik, V.G., Huang, X., Li, J. (2007). An unprecedented two-dimensional polymeric $[Zn(OOC–C_6H_4–COO)_2]_n^{2-}[^+H_3N–(CH_2)_3–NH_3^+]_n$ system bearing one-dimensional chain of zinc(II) bis(phthalate) dianions held by propane-1,3-diammonium cations: Crystal structure, thermal and fluorescent properties. Solid State Sciences, 9, 6, 491-495.

Perry, J.J., Bauer, C.A., Allendorf, M.D. (2011).Luminescent metal-organic frameworks, in: Farrusseng, D. (Ed.), Metal-Organic Frameworks: Application from Catalysis to Gas Storage. Willey-VCH, Weinheim, Germany, pp. 267-308.

Porai-Koshits, M.A. (1980). Crystallochemistry and stereochemistry of monobasic carboxylates of transition metals. Russian Journal of Structural Chemistry, 21, 146-180.

Qi, Y., Luo, F., Che, Y., Zheng, J. (2008a). Hydrothermal synthesis of metal–organic frameworks based on aromatic polycarboxylate and flexible bis(imidazole) ligands. Cryst. Growth Des., 8, 606-611.

Qi, Y., Che, Y., Luo, F., Batten, S.R., Liu Y., Zheng, J. (2008b). A variety of 1D to 3D metal–organic coordination architectures assembled with 1,1′-(2,2′-oxybis(ethane-2,1-diyl))bis(1*H*-imidazole). Cryst. Growth Des., 8, 1654-1662.

Raj, S.B., Muthiah, P.T., Bocelli, G., Cantoni, A. (2003). Interplay of coordination and hydrogen bonding modes in the self-assembly of the supramolecular network in copper(II) phthalate-trimethoprim complex (0.5:1:1). Inorg. Chem. Commun., 6, 748-751.

Redshaw, C., Jana, S., Shang, C.X., Elsegood, M.R.J., Lu, X.S., Guo, Z.X. (2010). Multinuclear zinc pentafluorobenzene carboxylates: Synthesis, characterization, and hydrogen storage capability. Ogranometallics, 29, 6129-6132.

Ryde, U. (1999). Carboxylate binding modes in zinc proteins: A theoretical study. Biophysical Journal, 77, 2777-2787.

Simonov, Yu.A., Gdaniec, M., Filippova, I.G., Baca, S.G., Timco, G.A., Gerbeleu, N.V. (2001). Synthesis and structure of *catena*-[(2-methylimidazole)(μ-phthalato)cobalt(II)]. Russian Journal of Coordination Chemistry, 27, 5, 353-356.

Simonov, Yu.A., Baca, S.G., Filippova, I.G., Gdaniec, M., Gherco, O.A., Gerbeleu, N.V.(2004). Two-dimensional coordination polymer $\{[Zn(Pht)(4,4'\text{-}Bipy)(H_2O)_2] \cdot 2H_2O\}_n$: synthesis and structure. Russian Journal of Coordination Chemistry, 30, 10, 727-732.

Squire, R.C., Aubin, S.M.J., Folting, K., Streib, W.E., Christou, G., Hendrickson, D.N. (1995).Octadecanuclearity in manganese carboxylate chemistry: preparation and properties of $K_4[Mn_{18}O_{16}(O_2CPh)_{22}(phth)_2(H_2O)_4] \cdot 10MeCN$. Inorg. Chem., 34, 6463-6471.

Solari, E.S., Latronico, M., Blech, P., Floriani, C. (1996). An organometallic methodology affording dinuclearcopper(I) complexes. Inorg. Chem., 35, 4526-4528.

Song, W.-D., Yan, J.-B., Wang, H., Ji, L.-L., Ma, D.-Y., Ng, S.W. (2010). Hydro(solvo)thermal synthesis and structural characterization of three lanthanide-carboxylate coordination polymers based on BDC and/or EDTA. J. Coord. Chem., 63, 625-633.

Song, Y.-S., Yan, B. (2005a). A novel unexpected luminescent quarternary coordination polymer $\{Sm_3(C_8H_4O_4)_4(C_{12}N_2H_8)_2(NO_3)\}_n$ with three high asymmetrical central Sm fragments by hydrothermal assembly. Inorg. Chim. Acta, 358, 191-195.

Song Y.-S., Yan, B., Chen, Z.-X. (2005b). Synthesis of two luminescent coordination polymers based on self-assembly of Zn(II) with polycarboxylic acids ligands and heteroaromatic N-donor. Applied Organometallic Chemistry, 20, 1, 44 – 50.

Sousa, S.F., Fernandes, P.A., Ramos, J. (2007). The carboxylate shift in zinc enzymes: A computational study. J. Am. Chem. Soc., 129, 1378-1385.

Stein, I., Ruschewitz, U. (2005). Polymeric diaquatetrakis(μ-1,2-benzenedicarboxylato)di-μ-nitrato-pentastrontium(II). Acta Cryst., E61, m141-m143.

Sun, L.-P., Niu, S.-Y., Jin, J., Yang, G.-D., Ye, L. (2006). Crystal structure and surface photovoltage of a series of Ni(II) coordination supramolecular polymer. Inorg. Chem. Commun., 9, 679-682.

Sundberg, M.R., Uggla, R. (1997). Conformational flexibility of the di(1,3-diaminopropane)copper(II) cation Part 3[1]. Structure determination for *trans*-diaquabis(1,3-diaminopropane-*N*,*N'*)copper(II) *trans*-di(*ortho*-phthalato-*O*)bis(1,3-diaminopropane-*N*,*N'*)cuprate(II) monohydrate and DFT calculations for the *trans*-diaquabis(1,3-diaminopropane- *N*,*N'*)copper(II) cation[2]. Inorg. Chim. Acta, 254, 259-265.

Suresh, E., Boopalan, K., Jasra, V.R., Bhadbhade, M.M. (2001). Synthesis and single crystal investigation of two-dimensional rectangular network $[M(4,4'\text{-}bpy)(Phth)(H_2O)]_n \cdot 2H_2O$ with small neutral cavities. Inorg. Chem., 40, 4078-4080.

Tang, E., Dai, Y-M., Lin, S. (2004). Bis(4,4'-bipyridine-κN)bis(hydrogen phthalato)-$\kappa^2 O,O';\kappa O$-zinc(II). Acta Cryst., C60, m433.

Tian, L.-J., Sun, Y.-X., Yang, M., Ng, S.W. (2005). Phthalato-bis[tris(2-methyl-2-phenylpropyl)tin(IV)]. ActaCryst.,E61, m74-m75.

Tian, L., Chen, L., Shen, S.-H., Wen, C.-L., Liu, S.-L. (2007a). Synthesis, crystal structure and magnetic properties of a 1D coordination polymer $[Ni(phth)(phen)(H_2O)]_n \bullet nH_2O$. J. Coord. Chem., 60, 6, 683–689.

Tian, L., Yu, L.-C., Chen, L., Xia, W.-G. (2007b). Synthesis, crystal structure, and luminescence of a quaternary binuclear europium complex $[Eu_2(phth)_2(Hphth)_2(phen)_2(H_2O)_4]$. J. Coord. Chem., 60, 17, 1847–1854.

Thirumurugan, A., Natarajan, S. (2004a). Synthesis, structure and luminescent properties of yttrium benzene dicarboxylates with one- and three-dimensional structure. Dalton Trans., 2923-2928.

Thirumurugan, A., Natarajan, S. (2004b). Inorganic-organic hybrid compounds: Synthesis and structures of new metal organic polymers synthesized in the presence of mixed dicarboxylates. Eur. J. Inorg. Chem., 762-770.

Thirumurugan, A., Natarajan, S. (2004c). Yttrium coordination polymers with layered structures. Solid State Sciences, 6, 599-604.

Thirumurugan, A., Natarajan, S. (2005a). Hydrothermal synthesis, structure and luminescent properties of one-dimensional lanthanide benzenedicarboxylates, $[M(NO_3)M_2(C_{12}H_8N_2)][(C_8H_4O_4)_4] \cdot H_2O$, (M = La, Pr), possessing infinite M-O-M linkages. J. Mater. Chem., 15, 4588-4594.

Thirumurugan, A., Rao, C.N.R. (2005b). 1,2-, 1,3- and 1,4-Benzenedicarboxylates of Cd and Zn of different dimensionalities: process of formation of the three-dimensional structure. J. Mater. Chem., 25, 3852-3858.

Wan, Y.-H., Jin, L.-P Wang, K.-Z. (2003a). Hydrothermal synthesis and structural characterization of two novel lanthanide supramolecular coordination polymers with nano-chains. J. Mol. Struct., 649, 85-93.

Wan, Y., Zhang, L., Jin, L., Gao, S., Lu, S. (2003b). High-dimensional architectures from the self-assembly of lanthanide ions with benzenedicarboxylates and 1,10-phenanthroline. Inorg. Chem., 42, 4985-4994.

Wang, G.-M., Li Z.-X., Xue S.-Y., Liu, H.-L. (2009). Poly[tetraaqua-μ_3-benzene-1,2-dicarboxylato-μ_3-bromido-penta-μ_2-bromido-octa-μ_3-isonicotinato-heptacopper(I)trilanthanum(III)]. (2009). ActaCryst., E65, m550-m551.

Wang, L.-Y., Yang, Y., Liu, K., Li, B.-L., Zhang, Y. (2008a). A new “opened-cube” $(H_2O)_{10}$ cluster and undulated water chain in porous metal-organic frameworks. Cryst. Growth Des., 8, 3902-3904.

Wang, S., Hou, Y., Wang, E., Li, Y., Xu, L., Peng, J., Liu, S., Hu, C. (2003). A novel organic-inorganic hybrid material with fluorescent emission: $[Cd(PT)(H_2O)]_n$ (PT = phthalate). New J. Chem., 27, 1144-1147.

Wang, X., Qin, C., Wang, E., Xu, L. (2005) A homochiral 3D covalent framework assembled from vertical chiral layers with achiral bridging ligands. J. Mol. Struct., 737, 49-54.

Wang, X.-L., Bi, Y.-F., Lin, H.-Y., Liu, G.-Ch. (2007a). Three novel Cd(II) metal-organic frameworks constructed from mixed ligands of dipyrido[3,2-*d*:2′,3′-*f*]quinoxaline and benzene-dicarboxylate: From a 1-D ribbon, 2-D layered network, to a 3-D architecture. Cryst. Growth Des., 6, 1086-1091.

Wang, X.-L., Chen, B.-K., Lin, H.-Y., Bi, Y.-F., Liu, G.-C. (2008b). Two isostructural complexes constructed from mixed ligands of dipyrido[3,2-d:2′,3′-f]quinoxaline and phthalate with novel oxygen clusters. J. Chem. Cryst., 38, 339-343.

Wang, X.-L., Bi, Y.-F., Liu, G.-C., Lin, H.-Y., Hu, T.-L., Bu,X.-H. (2008c). Zn(II) coordination architectures with mixed ligands of dipyrido[3,2-d:2′,3′-f]quinoxaline/2,3-di-2-pyridylquinoxaline and benzenedicarboxylate: syntheses, crystal structures, and photoluminescence properties.CrystEngComm.,10, 349-356.

Wang, X.-Y., Dong, C.-C., Deng, X.-T., Wang, C.-G., Hu, B. (2007b).*catena*-Poly[[diaqua(2,2'-bipyridine-$\kappa^2 N,N'$)cadmium(II)]-μ-phthalato-$\kappa^2 O:O'$]. Acta Cryst., E63, m2079.

Wang, Y.-L., Liu, Q.-Y., Zhong, S.-L. (2006). Poly[aqua(μ_3-benzene-1,2-dicarboxylato)(μ_2-hydroxo)indium(III)]. Acta Cryst., C62, m395-m397.

Wang, Z., Xing, Y.-H., Wang, C.-G., Sun, L.-X., Zhang, J., Ge, M.-F., Niu, S.-Y. (2010). Synthesis, structure and luminescent properties of coordination polymers with 1,2-

benzenedicarboxylic acid and a series of flexible dicarboxylate ligands. Cryst Eng Comm., 12, 762-773.

Wee, L.H., Alaerts, L., Martens, J.A., De Vos, D. (2011). Metal-organic frameworks as catalysts for organic reactions, in: Farrusseng, D. (Ed.), Metal-Organic Frameworks: Application from Catalysis to Gas Storage. Willey-VCH, Weinheim, Germany, pp. 191-212.

Whitcomb, D.R., Rogers, R.D. (1997). The molecular structure of catena-[(μ-phthalato)-di-(μ-phthalazine)-di-silver(I)hydrate] $(Ag_2(\mu\text{-}(O_2C)_2C_6H_4)(\mu\text{-}PHZ)_2(H_2O))]_n$: carboxylate control of side-on versus stacked coordination polymerization. Inorg.Chim.Acta, 263-267.

Wu, L., Xia, J., Chen, C., Huang, X., Yao, Y., Lu, J. (1998). X-ray crystal structures of $Mo_3S_4(DTP)_3(salicylate)(CH_3CN)$ and $[Mo_3S_4(DTP)_3(phthalate)(Py)]_2\cdot EtOH\cdot CH_2Cl_2$: intramolecular H-bonds and S-S interactions in trinuclear molybdenum cluster compounds. Polyhedron, 17, 4203-4212.

Wu, W., Xie, J.-M., Xuan, Y.-W. (2009). Synthesis and structure of a hybrid metal phthalate compound and its magnetic property. Z. Anorg. Allg. Chem., 635, 2, 351–354.

Xu, H., Sun, R., Li, Y.-Z., Bai, J.-F. (2006). Poly[[diaqua-μ-1,2-benzene-1,2-dicarboxylato-μ-4,4'-bipyridine-copper(II)]dihydrate]: a two-dimensional copper(II) polymer. Acta Cryst., E62, m1156-m1158.

Xuan, Y.-W., Wu, W., Xie, D.-P., Yuan, N.-X. (2008). Diaquabis(2-carboxybenzoato-κO)nickel(II). Acta Cryst., E64, m101.

Xue, F.-C., Jiang, Z.-H., Liao, D.-Z., Ma, S.-L., Yan, S.-P., Wang, G.-L. (1993). Novel structure of nickel(II) complex $Ni(phth)(bpy)(H_2O)_3$ ($phth^{2-}$ = the dianion of phthalic acid; bpy = 2,2′-bipyridine). Polyhedron, 12, 2787-2789.

Yan, B., Song, Y.-S., Chen, Z.-X. (2004). A novel quaternary dinuclear luminescent terbium complex $Tb_2(phth)_2(Hphth)_2(phen)_2(H_2O)_4$: hydrothermal synthesis, crystal structure and photophysics. J. Mol. Struct., 694, 1-3, 115-120.

Yang, J.-M., Zhou, Z.-H., Zhang, H., Wan, H.-L., Lu, S.-J. (2005). Temperature effect on the conversions of phthalato and maleato manganese(II) complexes with diamine ligands. Inorg. Chim. Acta, 358, 1841-1849.

Yang, J., Ma, J.-F., Liu, Y.-Y., Ma, J.-C., Batten, S.R. (2009a). A series of lead(II) complexes with π-π stackings: structural diversities by varying the ligands. Cryst. Growth Des., 9, 1894-1911.

Yang, Q.-F., Yu, Y., Song, T.-Y., Yu, J.-H., Zhang, X., Xu, J.-Q., Wang, T.-G. (2009b). 2D and 3D networks of lanthanide with mixed dicarboxylate ligands: syntheses, crystal structures and photoluminescent properties. Cryst. Eng. Comm., 11, 1642-1149.

Yang, S.-Y., Long, L.-S., Huang, R.-B., Zheng, L.-S., Ng, S.W. (2003a). Polymeric dihydroxydiphthalato-tricobalt(II). Acta Cryst., C59, m456-m458.

Yang, S.-Y., Long, L.-S., Huang, R.-B., Zheng, L.-S., Ng, S.W. (2003b). Aqua(4,4-bipyridine)phthalatonickel(II) trihydrate. Acta Cryst., E59, m507-m509.

Yang, S.-Y., Long, L.-S., Huang, R.-B., Zheng, L.-S., Ng, S.W.(2003c).*catena*-Poly[tetraaquacobalt(II)]-μ-pyrazine]phthalate]. Acta Cryst., E59, m961-m963.

Yao, J., Huang, W., Li, B., Gou, S., Xu, Y. (2002). A novel one-dimensional single helix derived from 2,2′-bipyridine based Zn(II) species directed self-assembly with 1,2-benzenedicarboxylate. Inorg. Chem. Commun., 5, 711-714.

Ye, B.-H., Ding, B.-B., Weng, Y.-Q.,Chen, X.-M. (2005). Multidimensional networks constructed with isomeric benzenedicarboxylates and 2,2'-biimidazole based on mono-, bi-, and trinuclear units. Cryst. Growth Des., 5, 801-806.

Zeng, Y.-F., Hu, X., Zhao, J.-P., Hu, B.-W., Sanudo, E.C., Liu, F.-C., Bu, X.-H. (2008). Partial substitution of hydroxyl by azide: an unprecedented 2D azido-copper-hydroxyl compound with a [Cu_{24}] macrocycle in the presence of [$Cu(H_2O)_6]^{2+}$. Chem. Eur. J., 14, 7127-7130.

Zhang, J., Li, Z.-J., Cao, X.-Y., Yao, Y.-G. (2005). A new polar supramolecular 3D framework [$Zn(pyz)(H_2O)_4$]pht. J. Mol. Struct., 750, 39-43.

Zhang, H.-X., Kang, B.-S., Xu, A.-W., Chen, Z.-N., Zhou, Z.-Y., Chan, A.S.C., Yu, K.-B., Ren, C. (2001). Supramolecular architectures from the self-assembly of trans-oxamido-bridged dicopper(II) building blocks and phenyldicarboxylates. J. Chem. Soc., Dalton Trans., 2559-2566.

Zhang, L., Ling, Y., Li, J., Gao, H. (2008a). Supramolecular self-assembly of two Cu(II) complexes with 1,2,4-triazole derivatives: syntheses, crystal structures and magnetic properties. Struct. Chem., 19, 911-916.

Zhang, L.-P., Yang, J., Ma, J.-F., Jia, Z.-F., Xie, Y.-P., Wie, G.-H., (2008b). A series of 2D and 3D metal-organic frameworks based on different polycarboxylate anions and flexible 2,2′-bis(1*H*-imidazolyl)ether ligand. Cryst. Eng. Comm., 10, 1410-1420.

Zhang, S.-C., Sun, J. (2006). Poly[(dipyrido[3,2-a:2′,3′-c]phenazine)zinc(II)]-μ_3-benzene-1,2-dicarboxylato]. Acta Cryst., E62, m3107–m3109.

Zhang, W.-L., Liu, Y.-Y. Ma, J.-F., Jiang, H., Yang, J. (2008c). Syntheses and characterizations of nine coordination polymers of transition metals with carboxylate anions and bis(imidazole) ligands. Polyhedron, 27, 16, 3351-3358.

Zhang, X., Yi, Z.H., Xia, W., Yang, C., Li, B. (2008d). Poly[[diaqua-μ_2-4,4'-bipyridyl-μ_2-*o*-phthalato-nickel(II)] dihydrate]. Acta Cryst., E64, m345-m346.

Zhang, Y., Li, J., Su, Q., Wang, Q., Wu, X. (2000). Synthesis, structure and spectroscopic properties of an *o*-phthalate-bridged copper(II) chain complex. J. Mol. Struct., 516, 231-236.

Zhao, H.-X., Zhuang, G.-L., Wu, S.-T., Long, L.-S., Guo, H.-Y., Ye, Z.-G., Huang, R.-B., Zheng, L.-S. (2009). Experimental and theoretical demonstration of ferroelectric anisotropy in a one-dimensional copper(II)-based coordination polymer. Chem. Commun., 1644-1646.

Zhao, Y., Wu, H., Emge, T.J., Gong, Q., Nijem, N., Chabal, Y.J., Kong, L., Langreth, D.C., Liu, H., Zeng, H., Li, J. (2011). Enhancing gas adsorption and separation capacity through ligand functionalization of microporous metal-organic framework structures. Chem. Eur. J., 17, 5101-5109.

Zhou, X.-G. (2007). Poly[[bis(isonicotinamide)copper(II)]-μ-benzene-1,2-dicarboxylato] monohydrate]. Acta Cryst., E63, m3166.
