Jun-Xia Li* and Zhong-Xiang Du

The crystal structure of catena-poly[(μ₂-4,4′-dipyridine-κ²N,N′)-bis(3,5,6-trichloropyridine-2-oxyacetato-κO)-bis(ethanol-κO)nickel(II)], C_{28}H_{26}Cl_{6}N_{4}NiO_{8}

https://doi.org/10.1515/ncrs-2020-0083
Received February 11, 2020; accepted March 18, 2020; available online April 24, 2020

Abstract

C_{28}H_{26}Cl_{6}N_{4}NiO_{8}, monoclinic, I_2/a (no. 15), a = 15.7577(10) Å, b = 12.6176(7) Å, c = 16.7333(10) Å, β = 99.609(6) Å, V = 3280.3(3) Å³, Z = 4, R_{gt}(F) = 0.0674, wR_{ref}(F²) = 0.1665, T = 291.2(3) K.

Crystal: Green block
Size: 0.29 × 0.25 × 0.22 mm
Wavelength: Mo Kα radiation (0.71073 Å)
µ: 1.14 mm⁻¹
Diffactometer, scan mode: SuperNova, ω
θ_{max}, completeness: 28.4°, >99%
N(hkl)_{measured}, N(hkl)_{unique}, R_{int}: 7139, 3421, 0.051
Criterion for I_{obs}, N(hkl)_{gt}, I_{obs} > 2 σ(I_{obs}), 2154
N(param)_{refined}: 217
Programs: CrysAlisPRO [1], Olex2 [2], SHELX [3, 4]

Apart of the molecular structure is shown in the figure. Table 1 contains crystallographic data and Table 2 contains the list of the atoms including atomic coordinates and displacement parameters.

Table 1: Data collection and handling.

| Crystal: | Green block |
| Size: | 0.29 × 0.25 × 0.22 mm |
| Wavelength: | Mo Kα radiation (0.71073 Å) |
| µ: | 1.14 mm⁻¹ |
| Diffactometer, scan mode: | SuperNova, ω |
| θ_{max}, completeness: | 28.4°, >99% |
| N(hkl)_{measured}, N(hkl)_{unique}, R_{int}: | 7139, 3421, 0.051 |
| Criterion for I_{obs}, N(hkl)_{gt}, I_{obs} > 2 σ(I_{obs}), 2154 |
| N(param)_{refined}: | 217 |

Experimental details

CrysAlisPro 1.171.39.46 (Rigaku Oxford Diffraction, 2018) [1] was used for empirical absorption correction using spherical harmonics, implemented in SCALE3 ABSPACK scaling algorithm. Using Olex2 [2], the structure was solved with the ShelXT [3] structure solution program using Intrinsic Phasing and refined with the ShelXL [4] refinement package. The H atoms bonded to C atoms were fixed, with C—H distance of 0.93 Å; and/or positioned geometrically in the riding-model approximation, with C—H distance of 0.97 Å; U_{iso}(H) = 1.2U_{eq}(C).

At the beginning stage of the coordination chemistry, aromatic carboxylate ligands have been frequently selected to construct metal-organic frameworks due to their rich structural features and valuable potential applications [5–9]. Subsequently, modification of these carboxylate ligands by various electron donating and withdrawing substituents groups such as Me- [10, 11], ‘Bu- [12, 13], MeO- [10, 14, 15],
including co-crystal Zn$^{II}$ [41] and Ni$^{II}$ complexes [42], binuclear Cd$^{II}$ cluster [43], 1D Ni$^{II}$ [44], Co$^{II}$ [45] and Mn$^{II}$ [46] polymers containing this ligand, have been reported by us recently.

Single-crystal X-ray diffraction analysis shows that the asymmetric unit of I includes one half of a Ni$^{II}$ ion, one 3,5,6-tcpa ligands, one half of a 4,4′-dipy together with one ethanol molecule.

The six-coordinated Ni$^{II}$ ion is bonded to two carboxy oxygen of two unidentate 3,5,6-tcpa anions [Ni-Ni1-O1 = 2.109(3) Å], two pyridyl nitrogen atoms of two 4,4′-dip $\mu_2$-O solvent for that of 4,4′-dipy is 11.452 Å. The adjacent Ni...Ni distance parallel to the a axis is 15.758 Å. The 3D crystal packing is constructed by O—H···O hydrogen bonding and weak Cl—Cl halogen bonding.

The hydroxy atom (O4) of ethanol as donor involves in intra-molecular hydrogen bond with uncomplexed carboxy oxygen (O2) of 3,5,6-tcpa as acceptor.

The halogen...halogen interactions are seen between C6-C12 and C7G-C13G (symmetry code for G: x, 3/2−y, 1/2+z), as well as C12...C13G separation of 3.444 Å. In I, the geometries of these halogen bonds is characterized by angles of C6-C12...C13G (119.20°) and C12...C13G-C7G (93.02°), nearly corresponding to halogen bond of Type II [47, 48].

Comparing I with [Ni(3,5,6-tcpa)$_2$(4,4′-dipy)]$_{1/2}$, both of which prepared from the same starting reagents, some important similarities and differences can be found as follows: (i) The structure. They are both 1D polymer. The title structure is a zigzag chain, while II is a linear structure. (ii) The $\mu_2$-function of 4,4′-dipy. Both 4,4′-dipy join Ni$^{II}$ centers to form the corresponding polymer. (iii) The composition. There are complexed ethanal molecules in I, but absence in II. This is because of the use of the mixed H$_2$O-ethanol solvent for synthesis of I, while pure H$_2$O solvent for that of II. (iv) The coordination mode of 3,5,6-tcpa. It is monodentate in I, but bidentate in II. (v) The coordination geometry of Ni$^{II}$ ion. It is in octahedron for I, while in tetragonal pyramid for II.

From the above careful discussion, it was confirmed again that the different synthesis conditions, such as by changing the solvent, greatly affected the composition and structure of complexes.

Now, many further attempts on developing new complexes with 3,5,6-Htcpa as the first ligand, for instance

### Table 2: Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å$^2$).

| Atom | x   | y   | z   | U(eq)/*U(eq) |
|------|-----|-----|-----|-------------|
| C1   | 0.7488(3) | 0.4078(4) | 0.3258(3) | 0.0379(12) |
| C2   | 0.7127(4) | 0.3887(4) | 0.2373(3) | 0.0414(13) |
| H2A  | 0.7416 | 0.3282 | 0.2182 | 0.050* |
| H2B  | 0.6520 | 0.3717 | 0.2321 | 0.050* |
| C3   | 0.6715(3) | 0.5633(4) | 0.1934(3) | 0.0408(13) |
| C4   | 0.6951(4) | 0.6599(4) | 0.1646(5) | 0.0517(15) |
| C5   | 0.6454(4) | 0.7480(5) | 0.1724(4) | 0.0599(17) |
| H5   | 0.608 | 0.8144 | 0.1554 | 0.072* |
| C6   | 0.5715(4) | 0.7347(4) | 0.2068(4) | 0.0543(16) |
| C7   | 0.5525(3) | 0.6362(5) | 0.2317(3) | 0.0466(14) |
| C8   | 0.5276(3) | 0.2057(4) | 0.5409(3) | 0.0442(13) |
| H8   | 0.5999 | 0.2613 | 0.5858 | 0.053* |
| C9   | 0.5386(3) | 0.1276(4) | 0.5332(3) | 0.0435(13) |
| H9   | 0.5032 | 0.1307 | 0.5924 | 0.052* |
| C10  | 0.5312(3) | 0.0435(4) | 0.4989(3) | 0.0325(11) |
| C11  | 0.5867(4) | 0.0459(4) | 0.4435(3) | 0.0547(16) |
| H11  | 0.5848 | −0.0081 | 0.4055 | 0.066* |
| C12  | 0.6432(4) | 0.1277(5) | 0.4439(4) | 0.0557(16) |
| H12  | 0.6816 | 0.1266 | 0.4056 | 0.067* |
| C13  | 0.8826(5) | 0.5237(6) | 0.5548(4) | 0.097(3) |
| H13A | 0.9334 | 0.4930 | 0.5872 | 0.117* |
| H13B | 0.8415 | 0.5370 | 0.5908 | 0.117* |
| C14  | 0.9061(6) | 0.6224(6) | 0.5252(5) | 0.120(3) |
| H14A | 0.8573 | 0.6531 | 0.4910 | 0.181* |
| H14B | 0.9518 | 0.6121 | 0.4945 | 0.181* |
| C14C | 0.9253 | 0.6690 | 0.5699 | 0.181* |
| C11  | 0.7852(12) | 0.6702(15) | 0.1187(13) | 0.0864(7) |
| C12  | 0.5057(14) | 0.8462(14) | 0.2182(14) | 0.0975(7) |
| C13  | 0.4600(10) | 0.6149(13) | 0.2718(10) | 0.0668(5) |
| N1   | 0.6018(3) | 0.5516(3) | 0.2259(2) | 0.0412(11) |
| N2   | 0.6521(2) | 0.2079(3) | 0.4962(2) | 0.0343(9) |
| N1   | 0.7500 | 0.3293(6) | 0.5000 | 0.0262(2) |
| O1   | 0.7342(2) | 0.3337(2) | 0.3724(2) | 0.0397(8) |
| O2   | 0.7901(3) | 0.4905(3) | 0.3453(2) | 0.0568(11) |
| O3   | 0.7292(2) | 0.4792(2) | 0.1871(2) | 0.0499(10) |
| O4   | 0.8467(3) | 0.4474(3) | 0.4975(2) | 0.0553(11) |
| H4   | 0.846(3) | 0.477(3) | 0.4507(8) | 0.083* |

—OH and —SO$_2$H [16–18], —SH [19, 20], —NH$_2$ [21, 22], —NO$_2$ [23, 24], —CF$_3$ [25], —CN [26], —F [27–30], —Cl [31–33], —Br [34–37], —I [38–40], has been employed. Because of the steric and/or electronic effects of the substituent groups, these decorated ligands may afford new supramolecular assemblies owing to their special linking types and ligand-metal interactions. Among them, the halogen containing carboxylate ligands are attractive as they may form halogen bonds, which played an important role in the fields of molecular recognition and supramolecular assemblies.

Lately, a trichloro substituent aromatic carboxylate ligand, namely, 3,5,6-trichloropyridine-2-oxacetic acid (3,5,6-Htcpa) has aroused our interests. A series of compounds,
by the use of other solvents, introducing other N/O-donor bridging or chelate auxiliary ligands will be gradually implemented.

Acknowledgements: This work was supported by the Key scientific research projects in Colleges and Universities of Henan province (No. 17A150040).

References

1. Oxford Diffraction Ltd: CrysalisPRO®. Rigaku Oxford Diffraction, Version 1.171.39.6a, England (2018).
2. Dolomanov, O. V.; Bourhis, L. J.; Gildea, R. J.; Howard, J. A. K.; Puschmann, H.: OLEX2 : a complete structure solution, refinement and analysis program. J. Appl. Crystallogr. 42 (2009) 339–341.
3. Sheldrick, G. M.: SHELXT – integrated space-group and crystal-structure determination. Acta Crystallogr. A71 (2015) 3–8.
4. Sheldrick, G. M.: Crystal structure refinement with SHELXL. Acta Crystallogr. C71 (2015) 3–8.
5. Mehrotra, R. C.; Bohra, R.: Metal carboxylates. Academic Press, London (1983).
6. Li, J.-X.; Du, Z.-X.: Crystal structure of catena-poly[(μ₂-4,4’-bipyridine-κ²N,N):tetraaquamanganese(II)](3-(carboxylatomethyl) benzoic acid)-water (1/2/2). C28H34MnN2O14. Z. Kristallogr. NCS 230 (2015) 339–340.
7. Du, Z.-X.; Li, J.-X.: Crystal structure of catena-poly[(μ₂-4,4’-bipyridine-κ²N,N):tetraqua-cobalt(II)](3-(carboxylatomethyl) benzoic acid)-water (1/2/2), C28H34CoN2O14. Z. Kristallogr. NCS 230 (2015) 321–322.
8. Li, J.-X.; Du, Z.-X.: Syntheses, structures and magnetic properties of two mononuclear nickel(II) complexes based on bicarboxylate ligands. Z. Naturforsch. 70b (2015) 505–511.
9. Li, J.-X.; Du, Z.-X.: Zinc and cobalt complexes with (2-carboxyphenoxy) acetic acid ligand: syntheses, structures, fluorescent and magnetic properties. J. Coord. Chem. 69 (2016) 2563–2572.
10. Han, M.-L.; Wang, J.-G.; Ma, L.-F.; Guo, H.; Wang, L.-Y.: Construction of Cd(II) coordination polymers based on R-isophthalate (R = -CH3 or -OCH3) and flexible N-donor co-ligands: syntheses, structures and photoluminescence. CrystEngComm 14 (2012) 2691–2701.
11. Alturk, S.; Avci, D.; Basoglu, A.; Tamer, O.; Atalay, Y.; Dege, N.: Copper(II) complex with 6-methylpyridine-2-carboxylic acid: experimental and computational study on the XRD, FT-IR and UV-Vis spectra, refractive index, band gap and NLO parameters. Spectrochim. Acta, Part A 190 (2018) 220–230.
12. Wang, J.-G.; Chai, N.; Wang, S.-C.; Ma, L.-F.; Wang, L.-Y.: Two new 3-D coordination polymers with 6-tert-butyl isophthalic acid and flexible N-donor co-ligands bearing linear trinuclear secondary building blocks. Inorg. Chem. Commun. 30 (2013) 143–146.
13. Chang, X.-H.: Crystal structure of poly[(μ₂-5,5-tertbutylisophthalato-κ²O,O,O’O’):N-(1,3-dimethyl-2-imidazolidinone-κO)Zn]. Z. Kristallogr. NCS 233 (2018) 1043–1045.
14. Qin, J.-H.; Ma, L.-F.; Hu, Y.; Wang, L.-Y.: Syntheses, structures and photoluminescence of five zinc(II) coordination polymers based on 5-methoxyisophthalate and flexible N-donor ancillary ligands. CrystEngComm 14 (2012) 2891–2898.
15. Ma, L.-F.; Zhao, J.-W.; Han, M.-L.; Wang, L.-Y.; Du, M.: Two novel 3-D coordination polymers with 5-methoxyisophthalate and flexible N-donor co-ligands showing pentanuclear or alternate mono/binuclear Cu(II) units. Dalton Trans. 41 (2012) 2078–2083.
16. Du, Z.-X.; Li, J.-X.; Han, R.-Q.: Syntheses, characterizations and crystal structures of two copper coordination polymers both having Cu₂Cl₂ bridging subunit [Cu₂(bipy)1/2Cl]₂⁺ (1) and [[Cu⁺³](phen),[SSA][C₂H₄(NO₂)₂(DMF)]½], (2). J. Chem. Crystallogr. 41 (2011) 34–38.
17. Li, J.-X.; Du, Z.-X.: Syntheses, structures and fluorescent properties of copper(II) and manganese(II) helical complexes bridged by 4,4′-dipyridylsulfide. Chin. J. Struct. Chem. 31 (2012) 877–883.
18. Xu, T.-Y.; Wang, H.; Li, J.-M.; Zhao, Y.-L.; Han, Y.-H.; Wang, X.-L.; He, K.-H.; Wang, A.-R.; Shi, Z.-F.: A water-stable luminescent Zn(II) coordination polymer based on 5-sulfosalicylic acid and 1,4-bis(4H-imidazol-1-yl)benzene for highly sensitive and selective sensing of Fe³⁺ ion. Inorg. Chim. Acta 493 (2019) 72–80.
19. Li, J.-X.; Du, Z.-X.: Crystal structure of catena-5-sulfosalicylato-κ²O,O'-bis(μ₂-4-thiophenopyridinium-κ²S) cadmium(II) hydrate, Cd(C₇H₇O₆S)(C₇H₇NS)·2.5 H₂O. Z. Kristallogr. NCS 226 (2011) 331–332.
20. Du, Z.-X.; Li, J.-X.: The synthesis, structure and magnetic properties of a mononuclear cobalt compound with dipyrimidine sulfane ligand derived from 2-thiobarbituric acid. Inorg. Chim. Acta 436 (2015) 159–162.
21. Chang, X.-H.; Zhai, Z.-M.; Lu, X.-M.: Crystal structure of tetraqua-bis(μ₂-5-aminoisophthalato-κ²O,O'-)bis(4,4′-dipipyridylsulfide-κ²S) dizinc(II), C₁₆H₁₅N₂O₂S₂Zn₂. Z. Kristallogr. NCS 235 (2020) 73–75.
22. Shao, Z.-C.; Meng, X.-R.; Hou, H.-W.: Two new Cd(II) and Zn(II) coordination polymers incorporating 1-amino-benzenesulfonic acid and zinc(II); characterization. Acta Crystallogr. C75 (2019) 1065–1072.
23. Han, M.-L.; Xing, L.-X.: Crystal structure of diaqua-bis(5- nitrobenzene-3-carboxy-1,2-dicarboxylato)-bis(1,3-(4H-benzimidazol-1-yl)propyl)-benzimidazole)manganese(II), [Mn(H₂O)₂(O₂N₃C₆H₅O₂)(C₁₃H₁₃N₂O₃)]₂C₁₂H₁₆MnN₂O₂O₁₈. Z. Kristallogr. NCS 227 (2012) 574–576.
24. Li, G.-L.; Liu, G.-Z.; Ma, L.-F.; Xing, L.-Y.; Li, X.-L.; Wang, L.-Y.: Crystallographic determination of solid-state structural transformations in a dynamic metal-organic framework. Chem. Commun. 50 (2014) 2615–2617.
25. Chai, J.; Liu, Y.; Liu, B.; Yang, B.: Effect of substituent groups R = -CH₃, -Br and -CF₃ on the structure, stability and redox property of [Cr(R-picolinate)(H₂O)]NO₃·H₂O complexes. J. Mol. Struct. 1550 (2017) 307–315.
26. Li, J.-X.; Du, Z.-X.; Wang, J.-G.; Wang, T.; Lv, J.-N.: Zinc and manganese coordination polymers constructed by a new coordination mode of 4,5-dicyanoimidazolate ligand: syntheses, crystal structures, fluorescent and magnetic properties. Inorg. Chem. Commun. 15 (2012) 243–247.
27. Feng, X.; Sun, Y. L.; Li, R.-F.; Zhang, T.; Guo, N.; Wang, L. Y.: Two novel europium coordination polymers based on fluoride...
substituted and similar carboxylate ligands: syntheses, structures and luminescence. Inorg. Chem. Commun. 73 (2016) 190–195.

28. Zhang, J.; Liu, Y.-Y.; Ying, K.: Crystal structure of 2,2′-bipyridino-tetrafluorophthalato-copper(II) [Cu(C₂H₅F₄O)₂(C₂H₅H₂N₃)₂][Cu(C₂H₅F₄O)₃], C₄₂H₃₀CuF₁₂N₂O₁₂. Z. Kristallogr. NCS 227 (2012) 410–412.

29. Zhang, J.; Liu, Y.-Y.; Ying, K.: Crystal structure of [(1,10-phenanthroline)(tetrafluorophthalato)copper(II), [Cu(C₂F₆O)₂(C₂H₂N₂)]₂(C₂H₅F₄O)₃, C₄₀H₃₂CuF₈N₈O₈]. Z. Kristallogr. NCS 227 (2012) 568–570.

30. Li, J.-X.; Du, Z.-X.; Feng, X.: A new binuclear Ni⁸ complex with tetrafluorophthalate and 2,2′-bipyridine ligands: synthesis, crystal structure and magnetic properties. Z. Naturforsch. 74b (2019) 833–838.

31. Zhang, J.; Li, J.-X.: Synthesis, structure and magnetic properties of a binuclear copper(II) complex constructed by a new coordination mode of the tetrachlorophthalaligand. Z. Naturforsch. 71b (2016) 45–49.

32. Sharma, R.-P.; Saini, A.; Kumar, J.; Kumar, S.; Venugopalan, P.; Ferretti, V.: Coordination complexes of copper(II) with herbicide-trichlorophenoxyacetate: syntheses, characterization, single crystal X-ray structure and packing analyses of monomeric [Cu(pic)(2,4,5-trichlorophenoxyacetate)]_3·2H₂O and dimeric [Cu₂(H₂tea)(2,4,5-trichlorophenoxyacetate)]_2·2H₂O. Inorg. Chim. Acta 457 (2017) 59–68.

33. Xu, X.; Hu, F.; Ma, Y.; Gao, J.; Shuai, Q.: Facile microwave synthesis, structural diversity and herbigal activity of six novel alkaline-earth metal complexes (AECs) based on skeletal isomerization chlorophenoxyacetic acids. New J. Chem. 42 (2018) 4155–4166.

34. Li, J.-X.; Du, Z.-X.; Bai, R.-F.: Crystal structure of aqua-bis(5-bromo-6-methylpicolinato-κ²N,O) zinc(II) dihydrate, C₁₈H₁₆BrN₂O₂Zn. Z. Kristallogr. NCS 235 (2020) 63–65.

35. Li, S.-H.; Wang, J.-G.: Crystal structure of (μ₂-5-bromoisophthalate-κ⁴O⁴O⁴′O⁴′′O⁴″)bis(2-methyl-4H-imidazole-κN)cobalt(I), C₁₈H₁₈BrCoN₄O₂. Z. Kristallogr. NCS 229 (2014) 421–422.

36. Chang, X.-H.: The crystal structure of poly[(μ₅-4,4′-bromoisophthalate-κ⁴O⁴″O⁴″O⁴″O⁴″)zinc(II)], C₂₅H₁₉BrO₄Zn. Z. Kristallogr. NCS 235 (2020) 3–4.

37. Miroslaw, B.; Mahmoudi, G.; Ferenc, W.; Cristovao, B.; Osypiuk, D.; Sarzynski, J.; Gluchowska, H.; Franconetti, A.; Frontera, A.: Halogen interactions in dinuclear copper(II) 2,4-dibromophenoxyacetate – crystal structure and quantum chemical calculations. J. Mol. Struct. 1202 (2020) 127227.

38. Ridenour, J. A.; Carter, K. P.; Cahill, C. L.: RE-p-halobenzoic acid–terpyridine complexes, part III: structural and supramolecular trends in a series of p-iodobenzoic acid rare-earth hybrid materials. CrystEngComm 19 (2017) 1190–1203.

39. Carter, K. P.; Kalaj, M.; Cahill, C. L.: Harnessing uranyl oxo atoms via halogen bonding interactions in molecular uranyl materials featuring 2,5-diiodobenzoic acid and N-donor capping ligands. Inorg. Chem. Front. 4 (2017) 65–78.

40. Li, B.; Dong, M.-M.; Fan, H.-T.; Feng, C.-Q.; Zang, S.-Q.; Wang, L.-Y.: Halogen···halogen interactions in the assembly of high-dimensional supramolecular coordination polymers based on 3,5-diiodobenzoic acid. Cryst. Growth Des. 14 (2014) 6325–6336.

41. Li, J.-X.; Du, Z.-X.; Wang, J.; Feng, X.: Two mononuclear zinc(II) complexes constructed by two types of phenoxycetic acid ligands: syntheses, crystal structures and fluorescence properties. Z. Naturforsch. 74b (2019) 839–845.

42. Du, Z.-X.; Li, J.-X.; Bai, R.-F.: The crystal structure of catena-poly(μ₂-4,4′-bipyridine-κ²N₂N₂′′)-tetrakis(μ₂-2-(3,5,6-trichlorophenol-2-yl)oxy)acetato-κ²O⁴O⁴′ acetato-nickel(II), C₂₈H₂₄Cl₂N₂NiCl₂O₈. Z. Kristallogr. NCS 235 (2020) 881–883.

43. Li, J.-X.; Du, Z.-X.: A binuclear cadmium(II) cluster based on n···n stacking and halogen···halogen interactions: synthesis, crystal analysis and fluorescent properties. J. Cluster Sci. 31 (2020) 507–511.

44. Du, Z.-X.; Li, J.-X.; Bai, R.-F.: The crystal structure of catena-poly(μ₂-4,4′-bipyridine-κ²N₂N₂′′)-tetrakis(μ₂-2-(3,5,6-trichlorophenol-2-yl)oxy)acetato-κ²O⁴O⁴′ dicobalt(II)], C₃₀H₂₀Cl₂Ni₂O₄. Z. Kristallogr. NCS 235 (2020) 55–56.

45. Du, Z.-X.; Li, J.-X.; Bai, R.-F.: Crystal structure of catena-poly(μ₂-4,4′-bipyridine-κ²N₂N₂′′)-tetrakis(μ₂-2-(3,5,6-trichlorophenol-2-yl)oxy)acetato-κ²O⁴O⁴′ dicobalt(II)], C₃₀H₂₀Cl₂Co₂O₄. Z. Kristallogr. NCS 235 (2020) 15–17.

46. Li, J.-X.; Du, Z.-X.; Pan, Q.-Y.; Zhang, L.-L.; Liu, D.-L.: The first 3,5,6-trichlorophenol-2-oxyacetate bridged manganese coordination polymer with features of n···n stacking and halogen···halogen interactions: synthesis, crystal analysis and magnetic properties. (2020) https://doi.org/10.1016/j.jica.2020.119677.

47. Biju, S.; Gopakumar, N.; Bunzli, J.-C. G.; Scopelliti, R.; Kim, H. K.; Reddy, M. L. P.: Brilliant photoluminescence and triboluminescence from ternary complexes of Dy³⁺ and Tb³⁺ with 3-phenyl-4-propanoyl-5-isoxazolonate and a bidentate phosphine oxide coligand. Inorg. Chem. 52 (2013) 8750–8758.

48. Cavallo, G.; Metrangolo, P.; Milani, R.; Pilati, T.; Primagi, A.; Resnati, G.; Terraneo, G.: The halogen bond. Chem. Rev. 116 (2016) 2478–2601.