QO‘QON DAVLAT PEDAGOGIKA INSTITUTI ILMIY XABARLARI
(2026-yil 4-son)

TABIIY FANLAR

NATURAL SCIENCES

https://doi.org/10.70728/a.series.tab.v08.i04.077

SYNTHESIS, CRYSTAL STRUCTURE, THERMAL BEHAVIOR, AND MESOPOROUS ADSORPTION PROPERTIES OF A Zn(II)-ISONICOTINATE COORDINATION POLYMER

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Annotatsiya. Ushbu tadqiqotda $[Zn(INA)_2(DMF)(H_2O)]_n$ formulali Zn(II)-asosidagi koordinatsion polimerning sintezi, kristall tuzilishi, termik barqarorligi hamda adsorbsiya xossalari bayon etilgan. Yakka kristalli rentgen difraksiyasi tahlili moddaning nosentrosimmetrik monoklinik *Ia* fazoviy guruhida kristallanishini ko‘rsatdi va natijada qutbli hamda strukturaviy jihatdan barqaror karkas hosil bo‘lishi aniqlandi. Tuzilma Zn(II) markazlarining izonikotinat ligandlari orqali karboksilat kislorod atomlari va piridin azot donor atomlari yordamida o‘zaro bog‘lanishi natijasida shakllanib, π–π stacking va vodorod bog‘lanishlari kabi supramolekulyar o‘zaro ta’sirlar bilan barqarorlashgan kengaytirilgan polimer tarmoq hosil qiladi. Batafsil poliedral tahlil deyarli ideal tetraedrik va buzilgan koordinatsion geometriyalarning birgalikda mavjudligini ko‘rsatdi, bu esa Zn(II) ionining strukturaviy moslashuvchanligini aks ettiradi. Termik tahlil (TGA/DTA) uch bosqichli parchalanish jarayonini ko‘rsatdi, bunda erituvchining yo‘qolishi, ligandning parchalanishi va yakunda ZnO qoldig‘ining hosil bo‘lishi kuzatildi, bu esa o‘rtacha termik barqarorlikni tasdiqlaydi. Azot adsorbsiya-desorbsiya tadqiqotlari gisterezisli IV-tip izotermani ko‘rsatdi, bu esa mezog‘ovakli materiallarga xosdir. Ushbu birikma 24.34 m^2/g solishtirma sirt maydoniga va 7.515×10^{-2} cm^3/g umumiy g‘ovak hajmiga ega bo‘lib, g‘ovak

o‘lchamlarining taqsimoti mezog‘ovak sohada (~3.6–3.8 nm) markazlashgan. Olingan natijalar Zn-asosidagi koordinatsion polimerlarda koordinatsion muhit, strukturaviy topologiya va adsorbsiya xatti-harakatlari o‘rtasidagi o‘zaro bog‘liqlikni yoritib beradi.

Аннотация.В данной работе представлены синтез, кристаллическая структура, термическая стабильность и адсорбционные свойства координационного полимера на основе Zn(II) с формулой $[Zn(INA)_2(DMF)(H_2O)]_n$. Анализ методом рентгеновской дифракции монокристалла показал, что соединение кристаллизуется в нецентросимметричной моноклинной пространственной группе *Ia*, формируя полярный и структурно устойчивый каркас. Структура образована центрами Zn(II), соединёнными лигандами изоникотината через карбоксилатные кислородные атомы и донорные атомы азота пиридинового кольца, что приводит к формированию протяжённой полимерной сети, стабилизированной супрамолекулярными взаимодействиями, такими как π–π стекинг и водородные связи. Детальный полиэдрический анализ показал сосуществование практически идеальной тетраэдрической и искажённой координационной геометрии, что отражает структурную гибкость иона Zn(II). Термический анализ (TGA/DTA) выявил трёхстадийный процесс разложения, включающий удаление растворителя, деградацию лиганда и конечное образование остатка ZnO, что подтверждает умеренную термическую стабильность соединения. Исследования адсорбции-десорбции азота показали изотерму IV типа с гистерезисом, характерную для мезопористых материалов. Соединение обладает удельной поверхностью 24.34 м²/г и общим объёмом пор 7.515×10^{-2} см³/г, при этом распределение размеров пор сосредоточено в мезопористой области (~3.6–3.8 нм). Полученные результаты подчёркивают взаимосвязь между координационной средой, структурной топологией и адсорбционным поведением в координационных полимерах на основе Zn.

Abstract. This study reports the synthesis, crystal structure, thermal stability, and adsorption properties of a Zn(II)-based coordination polymer formulated as $[Zn(INA)_2(DMF)(H_2O)]_n$. Single-crystal X-ray diffraction analysis revealed that the compound crystallizes in the non-centrosymmetric monoclinic space group *Ia*, forming a polar and structurally robust framework. The structure is constructed from Zn(II) centers interconnected by isonicotinate ligands through carboxylate oxygen atoms and pyridine nitrogen donors, generating an extended polymeric network stabilized by supramolecular interactions such as π-π stacking and hydrogen bonding. Detailed polyhedral analysis indicated the coexistence of nearly ideal tetrahedral and distorted coordination geometries, reflecting the structural flexibility of Zn(II). Thermal analysis (TGA/DTA) demonstrated a three-step decomposition process involving solvent loss, ligand degradation, and final formation of ZnO residue, confirming moderate thermal stability. Nitrogen adsorption-desorption studies revealed a type IV isotherm with hysteresis, characteristic of mesoporous materials. The compound exhibits a specific surface area of 24.34 m^2/g and a total pore

volume of 7.515×10^{-2} cm^3/g, with pore size distribution centered in the mesoporous region (~3.6-3.8 nm). The results highlight the relationship between coordination environment, structural topology, and adsorption behavior in Zn-based coordination polymers.

Keywords: Zn(II) coordination polymer; isonicotinate ligand; single-crystal X-ray diffraction; polyhedral distortion; thermal stability; TGA/DTA analysis; nitrogen adsorption; BET surface area; mesoporous materials; adsorption properties.

Introduction. Coordination polymers and metal-organic frameworks (MOFs) have emerged as an important class of crystalline materials due to their structural diversity and tunable physicochemical properties. These materials are constructed through the coordination-driven self-assembly of metal ions and multifunctional organic ligands, leading to the formation of one-, two-, or three-dimensional architectures with potential applications in catalysis, gas storage, sensing, and adsorption processes [1-3]. The design of such materials relies on the careful selection of metal centers and ligands, which directly influence the topology, porosity, and stability of the resulting frameworks. In particular, porous coordination materials have gained increasing attention due to their ability to selectively adsorb molecules based on size, shape, and chemical interactions [4-6].

Among various metal ions, Zn(II) has been widely used in the construction of coordination polymers because of its flexible coordination environment and diverse bonding modes. Zn(II) can adopt different coordination geometries, including tetrahedral, square pyramidal, and octahedral, which facilitates the formation of structurally diverse frameworks [7,8]. Furthermore, Zn-based coordination compounds often exhibit good thermal stability and chemical robustness, making them suitable candidates for functional materials. The coordination behavior of Zn(II) is also highly influenced by ligand design, particularly when using bifunctional ligands capable of bridging multiple metal centers [9,10].

Isonicotinic acid (INA) is a versatile ligand that contains both carboxylate and pyridine functional groups, allowing it to act as a bridging linker between metal centers. The presence of dual donor sites enables the formation of extended coordination networks with various dimensionalities and topologies. In addition, the aromatic nature of the ligand promotes supramolecular interactions such as π-π stacking and hydrogen bonding, which contribute to structural stabilization and packing efficiency [11-13]. Previous studies have shown that Zn-isonicotinate systems can exhibit interesting structural features and tunable porosity, making them attractive for adsorption-related applications. Moreover, understanding the relationship between coordination geometry, framework structure, and adsorption properties remains a key challenge in the field of coordination chemistry and materials science [14-16].

In this work, a Zn(II)-based coordination polymer constructed from isonicotinate ligands was synthesized and comprehensively characterized. Single-crystal X-ray diffraction analysis revealed the formation of a non-centrosymmetric monoclinic structure with a polar framework. The coordination environments of Zn(II) centers were investigated using polyhedral analysis, demonstrating the coexistence of nearly ideal tetrahedral and distorted

geometries. Thermal stability and decomposition behavior were evaluated by TGA/DTA, while nitrogen adsorption-desorption studies confirmed the mesoporous nature of the material with a type IV isotherm. The obtained results provide new insights into the structure-property relationships of Zn-based coordination polymers and highlight their potential for adsorption applications.

Experimental Methodology

All reagents and solvents were of analytical grade and used as received without further purification. The Zn(II)-based coordination polymer was synthesized via a solvothermal approach through the reaction of zinc nitrate and isonicotinic acid in a mixed DMF/H_2O solvent system. The homogeneous reaction mixture was sealed in a Teflon-lined stainless steel autoclave and subjected to controlled thermal treatment for a defined period, followed by slow cooling to ambient temperature to promote the formation of high-quality single crystals. The resulting crystalline product was isolated by filtration, thoroughly washed with fresh solvent to remove residual reactants, and dried under ambient conditions. The crystal structure was elucidated by single-crystal X-ray diffraction (SC-XRD) using Cu Kα radiation, and the structure was solved and refined by full-matrix least-squares methods on F^2, with all non-hydrogen atoms refined anisotropically and hydrogen atoms treated using a riding model.

Functional group identification and coordination mode analysis were performed using Fourier-transform infrared (FT-IR) spectroscopy, providing evidence for metal-ligand interactions through characteristic vibrational shifts. The thermal stability and decomposition pathway of the material were systematically investigated by thermogravimetric and differential thermal analysis (TGA/DTA) over a wide temperature range under an inert atmosphere. Textural properties were assessed via nitrogen adsorption-desorption measurements at 77 K after appropriate degassing under vacuum, and the specific surface area, pore size distribution, and pore volume were calculated using Brunauer-Emmett-Teller (BET), Barrett-Joyner-Halenda (BJH), and density functional theory (DFT) models. Furthermore, the morphological features and elemental composition of the synthesized material were examined by scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS), providing complementary insights into the microstructural characteristics and compositional homogeneity of the coordination polymer.

Single-crystal XRD analysis.

Single-crystal X-ray diffraction analysis shows that the title compound crystallizes in the monoclinic crystal system with the non-centrosymmetric space group *Ia* (No. 9), indicating a polar structural arrangement(Table 1). The unit cell parameters (a = 14.6022(2) Å, b = 18.8381(2) Å, c = 15.4293(2) Å, β = 98.950(1)°) define a relatively large unit cell volume of 4192.58(9) $Å^3$ with Z = 4, suggesting a complex packing of coordination units. The calculated density (1.500 $g \cdot cm^{-3}$) and absorption coefficient (μ = 2.587 mm^{-1}) are consistent with Zn-based coordination polymers. The data quality is high, as reflected by the low R(int) value (0.025) and the good agreement factors (R = 0.0276, wR2 = 0.0762), along with a goodness-of-fit value close to unity (S = 1.02). The Flack parameter of 0.08(3)

confirms the reliability of the absolute structure determination, while the low residual electron density (-0.30 to 0.26 $e \cdot Å^{-3}$) indicates the absence of significant disorder. The crystallographic results confirm that the structure is well-refined and suitable for detailed structural analysis.

Structure of complex $[Zn(INA)_2(DMF)(H_2O)]_n$.

The crystal structure consists of Zn(II) centers coordinated by isonicotinate (INA) ligands, forming an extended polymeric framework. The INA ligand acts as a bridging linker through its carboxylate oxygen atoms and pyridine nitrogen donors, connecting adjacent Zn(II) centers into a continuous coordination network. The structural formula indicates the presence of DMF and water molecules, which are most likely located in the lattice and contribute to the stabilization of the structure through hydrogen bonding and weak intermolecular interactions. The coordination connectivity leads to the formation of a multidimensional framework, where the metal centers are linked into polymeric chains that further extend into higher-dimensional architectures. The aromatic nature of the ligand enables additional supramolecular interactions, such as π-π stacking and weak C-H···O contacts, which enhance the overall stability and packing efficiency of the structure. Such organization is characteristic of Zn-isonicotinate systems, where the bifunctional ligand promotes framework propagation and structural robustness.

Table 1. Crystal data and structure refinement for $[Zn(INA)_2(DMF)(H_2O)]_n$.

Crystal Data	
Formula	3(C12H8N2O4Zn),H2O
Formula Weight	946.74
Crystal System	monoclinic
Space group	Ia(No.9)
a, b, c [Å]	14.6022(2), 18.8381(2), 15.4293(2)
α, β, γ [º]	90, 98.950(1), 90
V [Å3]	4192.58(9)
Z	4
D(calc) [g/cm3]	1.500
Mu (CuKα) [mm-1]	2.587
F(000)	1912
Crystal Size [mm]	0.10x 0.12x 0.14
Data Collection	
Temperature (K)	293
Radiation [Å]	CuKα 1.54184

Theta Min-Max [º]	3.7, 67.7
Dataset	-17:17; -22:22; -13:18
Tot., Uniq. Data, R(int)	13318, 5550, 0.025
Observed Data [I > 0.0 sigma(I)]	5412
Refinement	
Nref, Npar	5550, 527
R, wR2, S	0.0276, 0.0762, 1.02
Max. and Av. Shift/Error	0.09, 0.00
Flackx	0.08(3)
Min. and Max. Resd. Dens. [e/Å3]	-0.30, 0.26

Coordination geometry and polyhedral distortion.

The coordination environments of the three crystallographically independent Zn(II) centers exhibit distinct geometrical features (Table 2). Zn(2) adopts a nearly ideal tetrahedral coordination geometry, as evidenced by its average bond length (1.9998 Å), low distortion index (0.02119), and quadratic elongation value close to unity (1.0146), indicating minimal deviation from an ideal tetrahedron. In contrast, Zn(1) and Zn(3) display more distorted coordination environments, where four shorter Zn-O and Zn-N bonds (1.94-2.07 Å) are accompanied by one significantly elongated Zn-O interaction (2.553(4) and 2.573(4) Å), suggesting a distorted five-coordinate geometry with weak axial coordination.

Table 2. Polyhedral parameters for $[Zn(INA)_2(DMF)(H_2O)]_n$.

Bond	**Distance (Å)**	**Bond**	**Distance (Å)**	**Bond**	**Distance (Å)**
Zn(1)-O(3)	1.940(3)	Zn(2)-O(5)	1.935(4)	Zn(3)-O(11)	1.957(4)
Zn(1)-O(1)	1.984(4)	Zn(2)-O(7)	1.980(3)	Zn(3)-O(9)	1.989(4)
Zn(1)-N(2)	2.017(3)	Zn(2)-N(3)	2.022(3)	Zn(3)-N(6)	2.050(4)
Zn(1)-N(1)	2.073(4)	Zn(2)-N(4)	2.063(4)	Zn(3)-N(5)	2.068(4)
Zn(1)-O(2)	2.553(4)			Zn(3)-O(10)	2.573(4)
Average bond length (Å)	2.1134		1.9998		2.1274
Polyhedral volume(Å3)	7.1676		4.0190		7.2700
Distortion index	0.08326		0.02119		0.08380
Quadratic elongation	-		1.0146		-
Bond angle variance (°2)	-		58.9210		-

Effective coordination number	3.9724		3.9094		3.9884

The higher distortion indices for Zn(1) and Zn(3) (0.08326 and 0.08380) and their larger polyhedral volumes (7.1676 and 7.2700 Å^3) compared to Zn(2) (4.0190 Å^3) indicate substantial deviation from ideal geometry. The effective coordination numbers (ECoN ≈

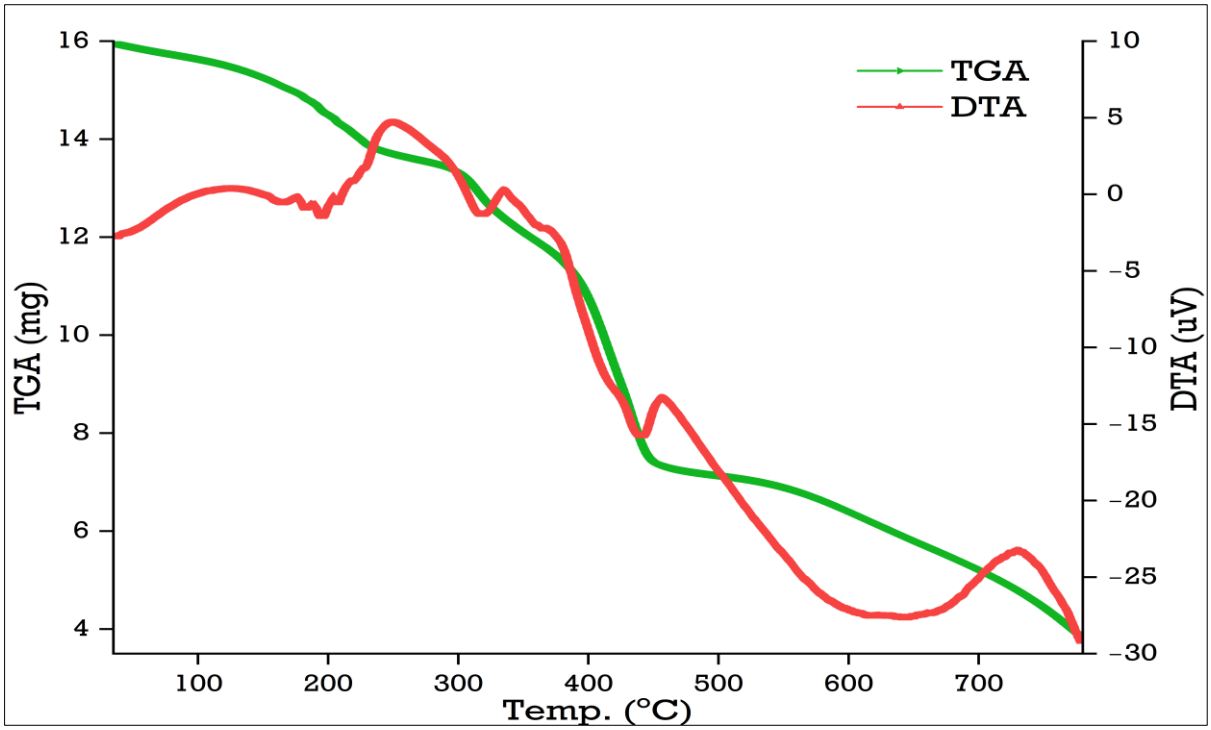


Fig. 1. TGA and DTA plots of $[Zn(INA)_2(DMF)(H_2O)]_n$

3.91-3.99) suggest that, despite the presence of additional weak interactions, the coordination environment is predominantly four-coordinate. These distortions arise from the asymmetric bridging mode of the isonicotinate ligand, which imposes geometrical constraints on the metal centers. The coexistence of nearly ideal tetrahedral and distorted coordination geometries plays a key role in defining the topology and stability of the polymeric framework, highlighting the structural flexibility of Zn(II) coordination chemistry and its influence on the formation of extended coordination networks.

Thermal Analysis.

The thermogravimetric analysis (TGA) and differential thermal analysis (DTA) of the synthesized Zn-isonicotinate coordination compound were carried out in the temperature range of 30-800 °C to evaluate its thermal stability and decomposition behavior. Based on the proposed structure, the compound contains coordinated Zn(II) centers linked by isonicotinate ligands, along with lattice or weakly coordinated DMF and H_2O molecules[17].

The first weight loss of about 18.51% observed in the temperature range of 37-313 °C can be attributed to the release of lattice and weakly coordinated solvent molecules, namely DMF and water. Considering the structure, these molecules are not strongly bound within the coordination sphere, which explains their removal over a relatively broad temperature

range. The corresponding weak endothermic peak at around 195 °C in the DTA curve further supports the desorption of these guest molecules.

The second major weight loss (34.60%) between 313-449 °C corresponds to the decomposition of the isonicotinate ligands bridging the Zn(II) centers. In this stage, both the Zn-O (carboxylate) and Zn-N (pyridine) coordination bonds begin to break, leading to the collapse of the coordination polymer framework. The pronounced DTA peak at approximately 318 °C is associated with this structural decomposition and organic ligand degradation.

The third weight loss of about 17.60% occurring in the range of 450-741 °C is attributed to the further decomposition and carbonization of residual organic fragments. This includes the breakdown of partially decomposed ligand residues and carbonaceous materials formed during earlier stages. The thermal event near 441 °C in the DTA curve corresponds to oxidation and structural collapse of these remaining organic components. At higher temperatures, the final residue is likely composed of thermally stable ZnO, indicating the complete removal of organic constituents and confirming the inorganic nature of the final decomposition product.

Adsorption properties.

The nitrogen adsorption-desorption isotherm of the synthesized coordination polymer $[Zn(INA)_2(DMF)(H_2O)]_n$ measured at 77 K is shown in Fig. 8. The obtained isotherm exhibits the characteristics of a type IV adsorption isotherm with a hysteresis loop, which is typically associated with mesoporous materials according to the IUPAC classification(Fig. 2). This behavior indicates the occurrence of capillary condensation within mesopores. The pore size distribution calculated using the BJH model shows that the majority of pores are concentrated in the mesoporous region. In addition, the DFT pore size distribution curve confirms the presence of relatively uniform mesopores within the framework. The cumulative pore volume versus pore width plot obtained from the DFT model further supports the porous nature of the synthesized material.

The quantitative textural parameters derived from the nitrogen adsorption analysis are summarized in Table 3. The specific surface area calculated using the multi-point BET method was found to be 24.34 m^2/g, indicating the presence of accessible adsorption sites within the coordination framework. Comparable surface area values were obtained using other theoretical models, including 17.65 m^2/g from the BJH adsorption method and 18.04 m^2/g from the DH adsorption method, whereas the BJH and DH desorption calculations yielded lower values of 7.58 m^2/g and 7.89 m^2/g, respectively. The t-method external surface area was identical to the BET surface area (24.34 m^2/g), while the DFT cumulative surface area was estimated to be 6.48 m^2/g, indicating that micropores contribute only slightly to the overall surface area.

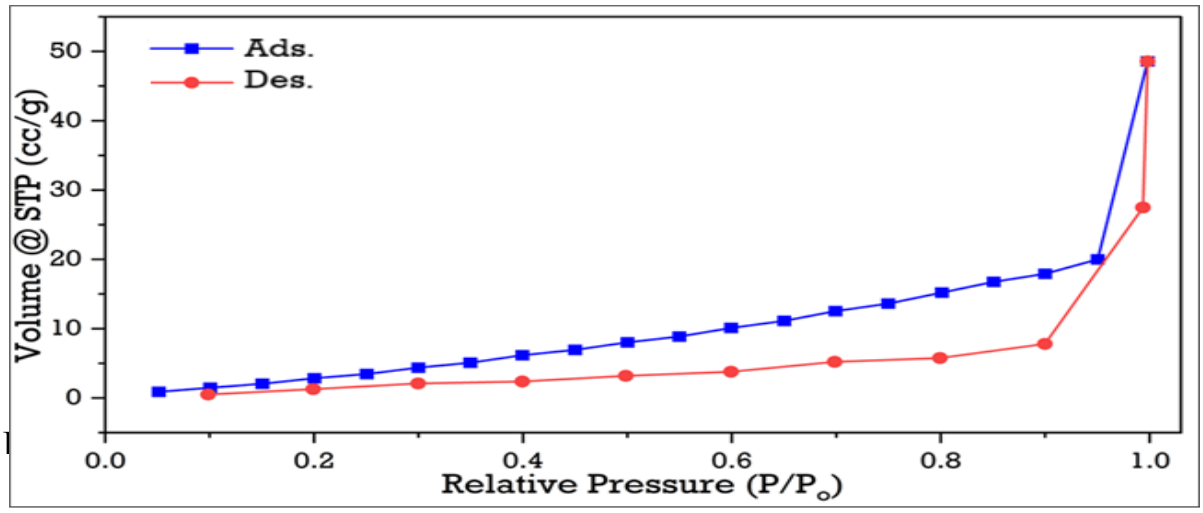


Table 3. Textural characteristics of $[Zn(INA)_2(DMF)(H_2O)]_n$ based on nitrogen adsorption.

Surface Area Data	
Multi Point BET	2.434e+01m2/g
BJH method cumulative adsorption surface area	1.765e+01m2/g
BJH method cumulative desorption surface area	7.578e+00m2/g
DH method cumulative adsorption surface area	1.804e+01m2/g
DH method cumulative desorption surface area	7.886e+00m2/g
t-method external surface area	2.434e+01m2/g
DFT cumulative surface area	6.483e+00m2/g
Pore Volume Data	
Total pore volume for pores with Radius	
lessthan5093.33EatP/Po=0.998121	7.515e-02cc/g
BJH method cumulative adsorption pore volume	7.460e-02cc/g
BJH method cumulative desorption pore volume	7.536e-02cc/g
DH method cumulative adsorption pore volume	7.251e-02cc/g
DH method cumulative desorption pore volume	7.326e-02cc/g
HK method micro pore volume	3.243e-03cc/g
SF method micro pore volume	8.432e-04cc/g
DFT method cumulative pore volume	3.246e-02cc/g
Pore Size Data	
Average pore Radius	6.174e+01E

BJH method adsorption pore Radius	1.912e+01E
BJH method desorption pore Radius	1.812e+01E
DH method adsorption pore Radius	1.912e+01E
DH method desorption pore Radius	1.812e+01E
HK method pore Radius	9.687e+00E
SF method pore Radius	1.938e+01E
DFT pore Radius	3.535e+01E

The total pore volume, determined at $P/P_o \approx 0.998$, was 7.515×10^{-2} cc/g, confirming the formation of a porous framework. Similar pore volume values were obtained using BJH and DH methods, including 7.460×10^{-2} cc/g (BJH adsorption), 7.536×10^{-2} cc/g (BJH desorption), 7.251×10^{-2} cc/g (DH adsorption), and 7.326×10^{-2} cc/g (DH desorption). The micropore volume calculated by the HK method was relatively small (3.243×10^{-3} cc/g), suggesting that microporosity contributes minimally to the overall pore structure. Furthermore, the pore size distribution analysis revealed an average pore radius of 61.74 Å, while the BJH model indicated dominant pore radii of 19.12 Å (adsorption) and 18.12 Å (desorption), corresponding to pore diameters of approximately 3.6-3.8 nm. These values confirm that the synthesized material predominantly contains mesoporous channels.

Conclusion

In summary, a Zn(II)-based coordination polymer incorporating isonicotinate ligands was successfully synthesized and structurally characterized. The crystallographic analysis confirmed the formation of a non-centrosymmetric, polar framework with mixed coordination geometries, where both ideal tetrahedral and distorted environments coexist due to ligand bridging effects. Thermal studies demonstrated that the compound possesses moderate stability, undergoing sequential decomposition with the final formation of ZnO. Adsorption analysis revealed a type IV isotherm with a well-defined hysteresis loop, confirming the mesoporous nature of the material. Despite its relatively low surface area, the material exhibits a significant pore volume and uniform pore size distribution, indicating accessible adsorption sites within the framework. These findings emphasize that structural features such as ligand connectivity, coordination geometry, and supramolecular interactions play a crucial role in determining the physicochemical and adsorption properties of coordination polymers. The obtained results provide valuable insights for the rational design of Zn-based porous materials for potential adsorption-related applications.

References

1. A.A. Khabibjonovich, Y.Y. Yusupboevich, A.B. Zamirovich, R.A. Khamidjanovich, N.A. Sadullayevich, M.D. Behzodjon, K.P. Kodamboevich, I.I. Abdullaev, C. Balakrishnan, I.B. Tulaganovich, A.J. Mengnorovich, Two-dimensional coordination polymer of Pb(II) complex with m-sulfanilic acid: synthesis, characterization, electrical conductivity, adsorption properties, and Hirshfeld surface analysis. *Adsorption* 31 (2025) 32.

2. K. Konstas, T. Osl, Y. Yang, M. Batten, N. Burke, A.J. Hill, M.R. Hill, Methane storage in metal organic frameworks. *J. Mater. Chem.* 22 (2012) 16698-16708. https://doi.org/10.1039/C2JM32719H

3. S.G. Dunning, A.J. Nuñez, M.D. Moore, A. Steiner, V.M. Lynch, J.L. Sessler, B.J. Holliday, S.M. Humphrey, A sensor for trace H_2O detection in D_2O. *Chem* 2 (2017) 579-589. https://doi.org/10.1016/j.saa.2025.126740

4. C.S. Liu, J. Li, H. Pang, Metal-organic framework-based materials as an emerging platform for advanced electrochemical sensing. *Coord. Chem. Rev.* 410 (2020) 213222. https://doi.org/10.1016/j.ccr.2020.213222

a. Karmakar, A.J. Pombeiro, Recent advances in amide functionalized metal organic frameworks for heterogeneous catalytic applications. *Coord. Chem. Rev.* 395 (2019) 86-129. https://doi.org/10.1016/j.ccr.2019.05.022

1. D.S. Yuldashboyevna, B.G. Bakhtiyarovna, Z.B. Yakubzhanova, A. Kumar, Y.Y. Yusupboevich, T.K. Suleimanovich, A.B. Ibragimov, Synthesis, structure and multifunctional adsorptive properties of a Cu(II) 4-acetamidobenzoate MOF, Adsorption 32 (2026) 1-12, https://doi.org/10.1007/s10450-025-00665-w.

2. M.C. Sardaru, N.L. Marangoci, S. Shova, D. Bejan, Novel Lanthanide(III) Complexes Derived from an Imidazole-Biphenyl-Carboxylate Ligand: Synthesis, Structure and Luminescence Properties. *Molecules* 26 (2021) 6942. https://doi.org/10.3390/molecules26226942

3. A.O. Surov, A.G. Ramazanova, A.P. Voronin, K.V. Drozd, A.V. Churakov, G.L. Perlovich, Virtual screening, structural analysis, and formation thermodynamics of carbamazepine cocrystals. *Pharmaceutics* 15 (2023) 836 https://doi.org/10.3390/pharmaceutics15030836

4. Z.H. Wang, J. Fan, W.G. Zhang, Studies of radii-dependent lanthanide coordination behavior with 4-acetamidobenzoate and 1,10-phenanthroline. *Z. Anorg. Allg. Chem.* 635 (2009) 2333-2339. https://doi.org/10.1002/zaac.200801412Digital Object Identifier (DOI)

5. A.A. Garcia-Valdivia, E. Echenique-Errandonea, G.B. Ramirez-Rodriguez, J.M. Delgado-Lopez, B. Fernandez, S. Rojas, J. Cepeda, A. Rodriguez-Dieguez, Photoluminescent coordination polymers based on Group 12 metals and 1H-indazole-6-carboxylic acid. *Inorganics* 9 (2021) 20.https://doi.org/10.3390/inorganics9030020

6. Loubalová, P. Kopel, Coordination compounds of Cu, Zn, and Ni with dicarboxylic acids and N donor ligands, and their biological activity: a review. *Molecules* 28 (2023) 1445.https://doi.org/10.3390/molecules28031445

7. D.K. Dutta, P. Chutia, B.J. Sarmah, B.J. Borah, B. Deb, J.D. Woollins, Rhodium carbonyl complexes containing pyridine carboxylic acid ligands: Reactivity towards various electrophiles and catalytic activity. *J. Mol. Catal. A Chem.* 300 (2009) 29-35. https://doi.org/10.1016/j.molcata.2008.09.024

8. Singh, H. D., Nandi, S., Chakraborty, D., Singh, K., Vinod, C. P., & Vaidhyanathan, R. (2022). Coordination Flexibility Aided CO2-specific Gating in an Iron Isonicotinate MOF. *Chemistry-An Asian Journal*, *17*(4), e202101305. https://doi.org/10.1002/asia.202101305Digital Object Identifier

9. Armaya’u, U., Zango, M. U., Ariffin, M. M., Khalik, W. M. A. W. M., Yusoff, H. M., Zango, Z. U., ... & Keshta, B. E. (2024). Copper (II) isonicotinate metal-organic framework for reusable adsorption of salmeterol from wastewater. *Sustainable Chemistry One World*, *4*, 100030. https://doi.org/10.1016/j.scowo.2024.100030

10. D.K. Saidov, K.K. Turaev, S.A. Kasimov, A. Kumar, B.Z. Adizov, Y.Y., Yakubov, B.T., Ibragimov, A., Lakshmanan, A.S., Normamatov, B.D. Mamatkodirov, J. Gao, Cd(II)-based 2D coordination polymer with hydroxynaphthoate: Synthesis, DFT insights and surface analysis, J. Mol. Struct. (2025) 145225. https://doi.org/10.1016/j.molstruc.2025.145225.

11. Collings, I. E., Tucker, M. G., Keen, D. A., & Goodwin, A. L. (2011). Static disorder and local structure in zinc (II) isonicotinate, a quartzlike metal-organic framework. *arXiv preprint arXiv:1112.5680*. https://doi.org/10.48550/arXiv.1112.5680

12. Gao, C., Wang, T., & Wang, X. (2022). A NH3 Gas Sensor Based on Flexible Copper (II) isonicotinate MOF/Reduced Graphene Oxide Composite Modified Interdigital Electrode. *International Journal of Electrochemical Science*, *17*(7), 220763. https://doi.org/10.20964/2022.07.65

13. A.R. Safarov, H. Ferjani, YG.Abou El-Reash, A.B. Ibragimov, Y.R. Takhirov, Kh.Kh. Turaev, D Kh. Saidov, T.A. Yousef, B.Z. Adizov ,Ch. Balakrishnan. Structural, spectroscopic, and Hirshfeld surface analysis of novel zinc(II) complexes with aminobenzoate and thiadiazole units. Polyhedron 15 February 2026 https://doi.org/10.1016/j.poly.2026.118038