Preparation and Characterization of Copper(II) Complex with Maltol

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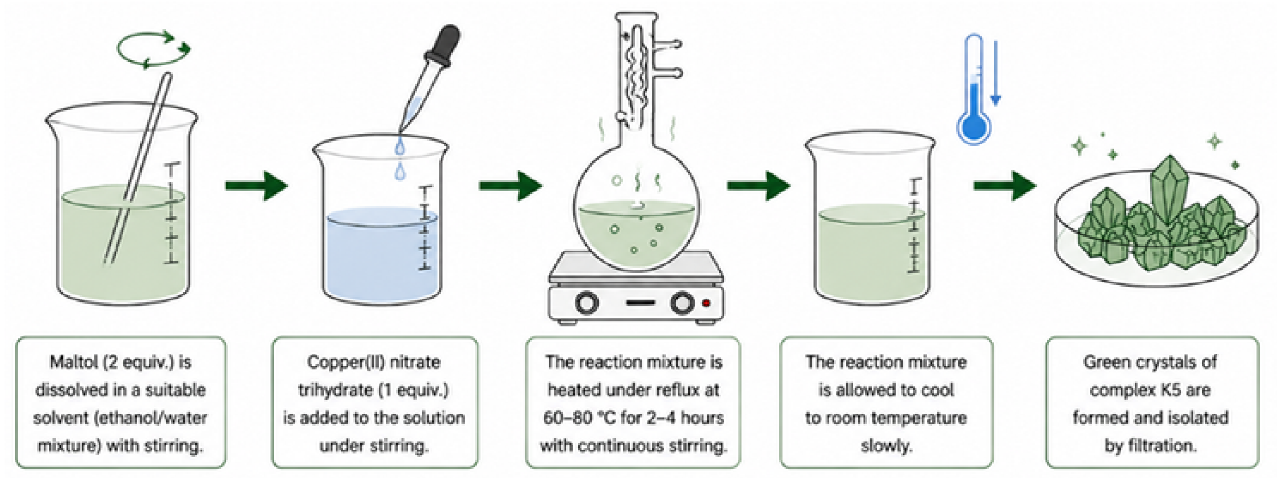
INTRODUCTION & AIM

Hydroxypyranones are heterocyclic compounds containing a pyranone ring with hydroxyl and carbonyl groups that can coordinate metal ions and form stable chelate complexes. Maltol (3-hydroxy-2-methyl-4H-pyran-4-one) is a widely studied ligand due to its biocompatibility, low toxicity, antioxidant properties, and strong metal-chelating ability. It is commonly used in the food industry and is important in medicinal chemistry because it enhances metal ion absorption and bioavailability.
Copper(II) complexes are of interest since copper is an essential biological element involved in enzymatic and redox processes, and Cu(II) compounds have shown potential antitumor activity with fewer side effects than platinum-based drugs. Therefore, the synthesis and characterization of novel Cu(II)–maltol complexes 1–4 is an important area of research.

METHOD

The Cu(II) complex was synthesized in solution at elevated temperature using a copper(II) salt and maltol as the ligand. The Cu(II) ion coordinated with two maltol molecules through the deprotonated hydroxyl and carbonyl oxygen atoms, forming stable five-membered chelate rings. Single crystals suitable for structural analysis were isolated after synthesis. The compound was characterized by FT-IR, TGA/DSC, PXRD, elemental analysis, and single-crystal X-ray diffraction to determine its coordination mode, thermal stability, crystallinity, and molecular structure.



RESULTS & DISCUSSION

FTIR Analysis

The FT-IR spectrum confirmed successful coordination of maltol to the Cu(II) center through the carbonyl oxygen and the deprotonated hydroxyl oxygen atom. The disappearance of O–H stretching vibrations and shifts in the ν(C=O) bands indicated formation of Cu–O bonds. The results also confirmed the absence of nitrate ions and solvent molecules, supporting the formation of a neutral copper(II)-maltol complex.

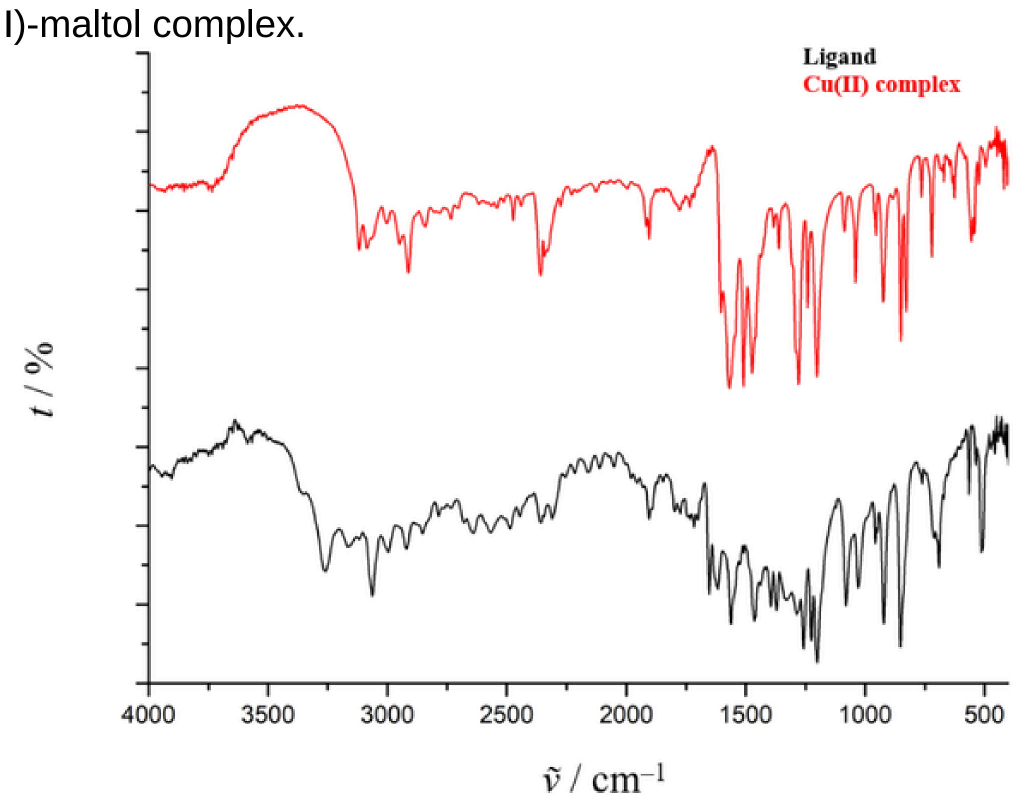


Figure 1. Comparative FT-IR spectra of maltol (black) and complex (red).

Thermal Analysis

Thermogravimetric analysis showed that the complex does not contain coordinated or crystallization solvent molecules. Its decomposition was accompanied by a sharp exothermic DSC peak at approximately 220 °C, with CuO formed as the final decomposition product. The experimentally determined copper content from the residual mass was 19.2%, in excellent agreement with the theoretical value of 20.2%, confirming the proposed molecular composition and thermal stability of the complex.

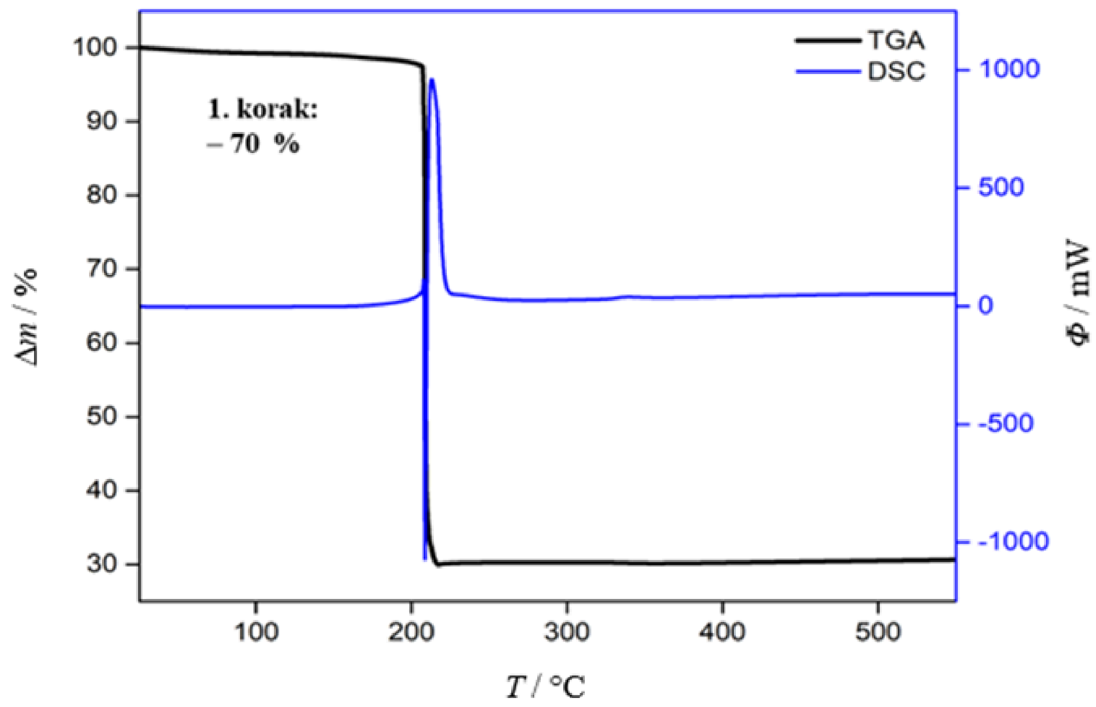


Figure 2. TGA/DSC diagram of complex.

XRD Analysis

Powder X-ray diffraction confirmed the formation of a new crystalline phase. Comparison with crystallographic database patterns showed no traces of the starting Cu(II) salt or impurities. The PXRD results thus confirmed the successful synthesis of a new coordination compound with a 2:1 ligand-to-metal ratio.

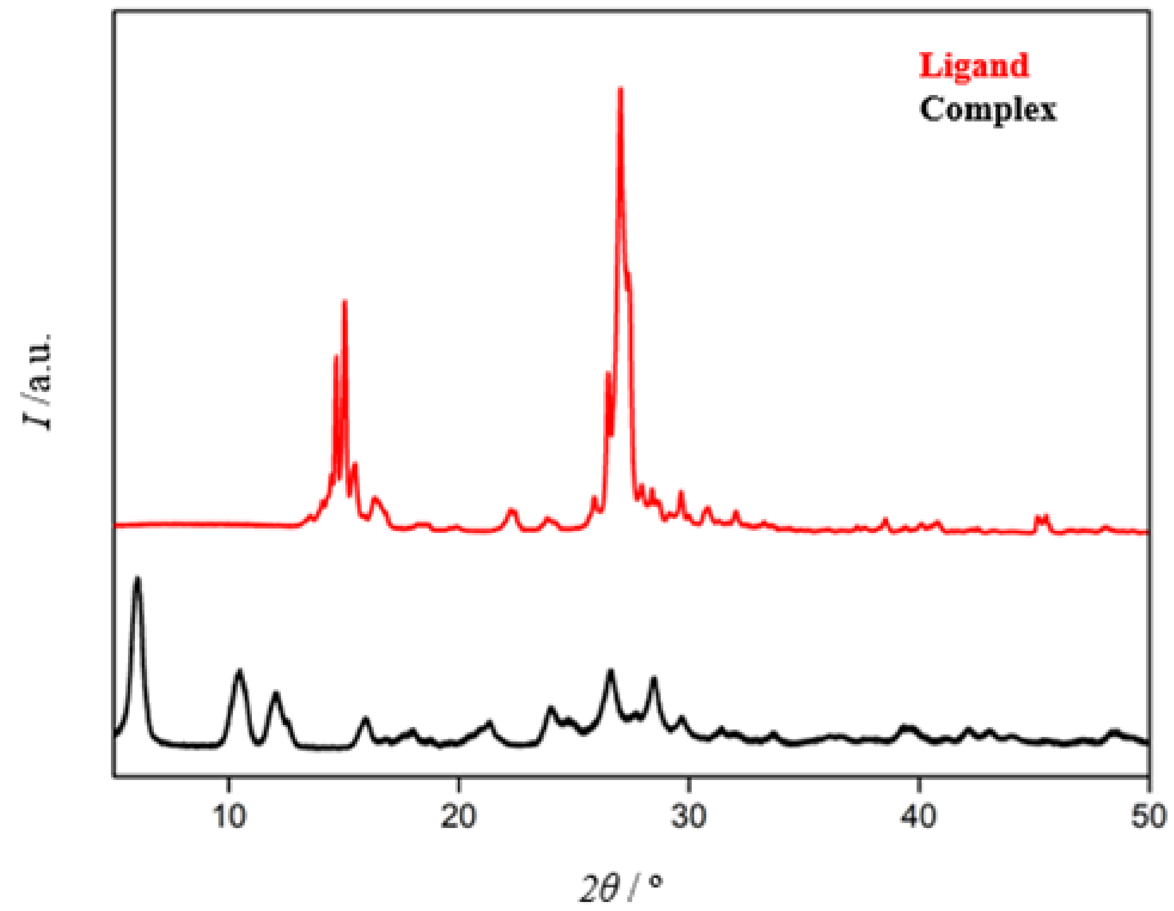


Figure 3. Comparative PXRD diffractograms of complex and the free ligand.

Crystal and Molecular Structure of Cu(II) complex

Single-crystal X-ray diffraction revealed a neutral Cu(II) complex with two maltol ligands in a trans arrangement. The ligands coordinate bidentately through hydroxyl and carbonyl oxygen atoms, forming five-membered chelate rings. The complex crystallizes in the monoclinic system (C2/c) with a predominantly square-planar Cu(II) geometry slightly distorted by the Jahn–Teller effect. Crystal packing is stabilized by π⋯π interactions (Cg9⋯Cg12 = 3.643 Å), which contribute to lattice stability.

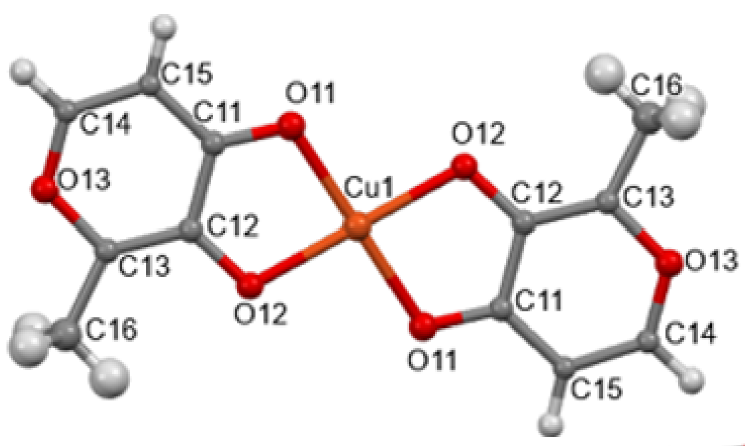


Figure 4. Crystals structure of Cu(II) complex.

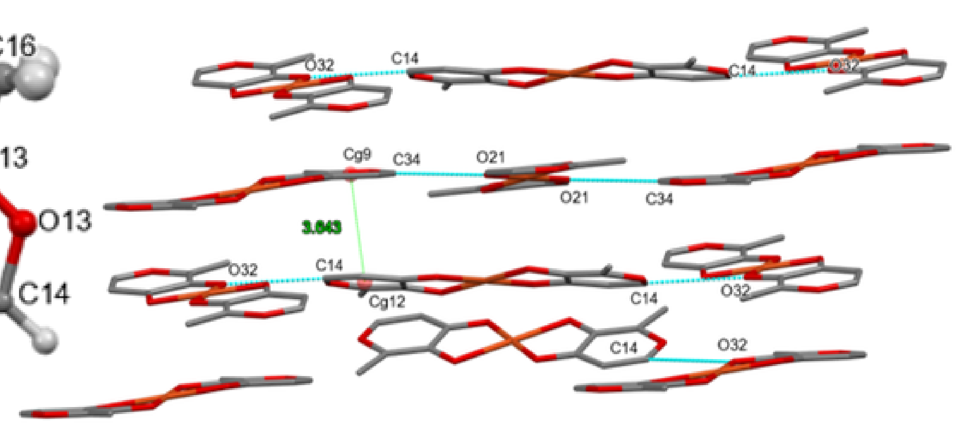


Figure 5. Representation of intermolecular interactions and π⋯π interactions in the molecular structure of complex.

CONCLUSIONS

The copper(II)-maltol complex was synthesized and characterized using spectroscopic, thermal, diffraction, and crystallographic methods. The results confirm a neutral bis(maltolato)Cu(II) complex with maltol acting as a bidentate O,O-donor ligand. The structure is solvent-free and shows a mainly square-planar geometry around Cu(II) with Jahn–Teller distortion. Good stability and crystallinity suggest potential for further biological and pharmacological studies.

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

1. S. Karthikeyan, M. Grishina, S. Kandasamy, R. Mangaiyarkarasi, A. Ramamoorthi, S. Chinnathambi, G.N. Pandian, L. John Kennedy, J. Biomol. Struct. Dyn. 21 (2023) 1–21.
2. T. Qadir, A. Amin, P.K. Sharma, I. Jeelani, H. Abe, Open Med. Chem. 16 (2022) 1–34.f
3. S. Tahlan, S. Kumar, B. Narasimhan, BMC Chemistry. 13 (2019) 1–27.
4. A.P. Taylor, R.P. Robinson, Y.M. Fobian, D.C. Blakemore, L.H. Jones, O. Fadeyi, Org. Biomol. Chem. 14 (2016) 6611–6637.

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