Earth Stewardship Science Research Institute

UFS·UV NATURAL AND AGRICULTURAL SCIENCES CHEMISTRY

Biomimetic Modelling of Catechol Oxidase Activity

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Ligand synthesis and characterization

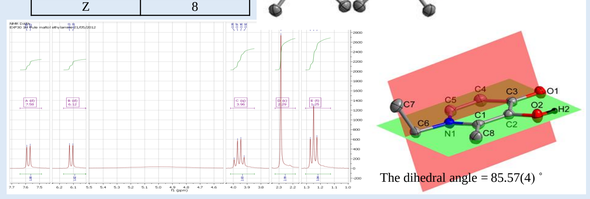
3-Hydroxy-1,2-dimethylpyrid-4(*H*)-one

	Value
Cell Parameters	a = 7.177(3) Å α= γ= β=90° b =12.915(6) Å c = 13.696(6) Å
Space Group	Orthorhombic
Crystal system	*Pbca*
Z	8

D-H…A	d(H…A) (Å)	d(D…A) (Å)	∟(D-H…A) (°)
O2-H2…O1	2.34	2.746(1)	112
O2-H2…O1$^{(i)}$	1.93	2.671(1)	151
C6-H6A…O1$^{(ii)}$	2.52	3.386(2)	150
C7-H7B…O2	2.39	2.832(2)	108
C7-H7C…O1$^{(iii)}$	2.51	3.457(2)	168

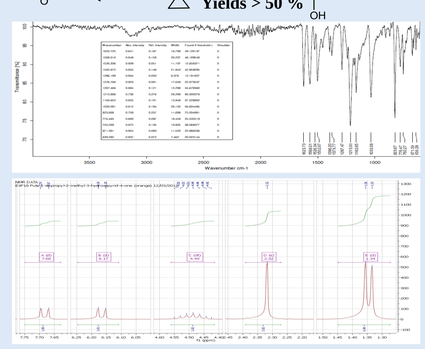
1-Ethyl-3-hydroxy-2-methylpyrid-4(*H*)-one

	Value
Cell Parameters	a = 11.517(5) Å α= γ= β=90° b =11.149(5) Å c = 12.323(5) Å
Space Group	Orthorhombic
Crystal system	*Pbca*
Z	8



The dihedral angle = 85.57(4) °

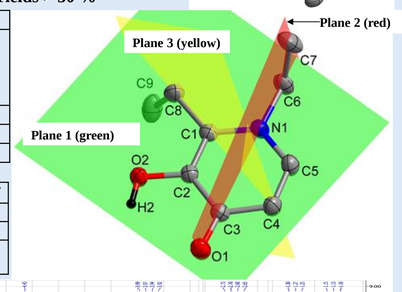
3-Hydroxy-2-methyl-1-isopropylpyrid-4(*H*)-one

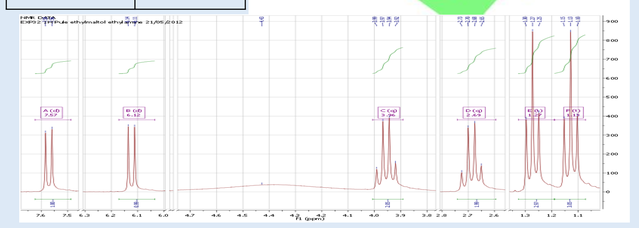


1,2-Diethyl-3-hydroxypyrid-4(*H*)-one

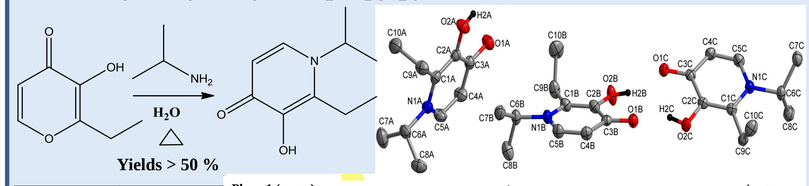
	Value
Cell Parameters	a = 7.092(2) Å α= γ= β=90° b =9.347(3) Å c = 13.431(4) Å
Space Group	Monoclinic
Crystal system	$P2_1/n$
Z	4

Planes	Dihedral Angles °
(Plane 1& Plane 2)	87.77(4)
(Plane 1 & Plane 3)	81.01(5)
(Plane 2 & Plane 3)	61.54(4)



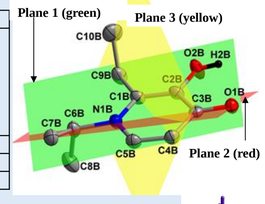


2-Ethyl-3-hydroxy-1-isopropylpyrid-4(*H*)-one

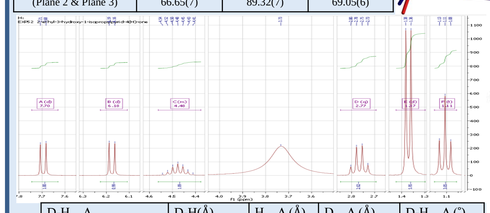


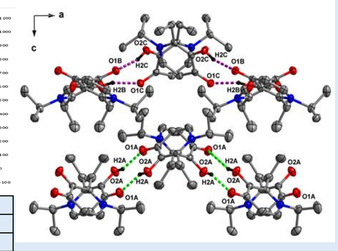
Yields > 50 %

	Value
Cell Parameters	a = 11.741(5) Å α= 90° b = 13.355(5) Å β=90° c = 37.552(5) Å γ=90°
Space Group	Orthorhombic
Crystal system	*Pbca*
Z	24



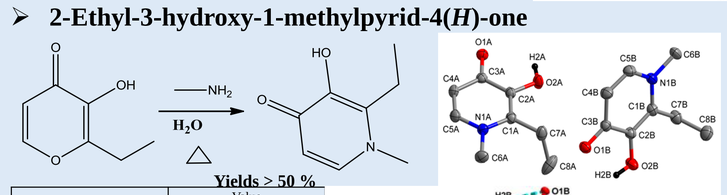
	Dihedral Angles °		
Planes	Molecule A	Molecule B	Molecule C
(Plane 1& Plane 2)	52.65(7)	30.32(7)	41.66(7)
(Plane 1 & Plane 3)	89.38(7)	75.54(7)	87.71(6)
(Plane 2 & Plane 3)	66.65(7)	89.32(7)	69.05(6)





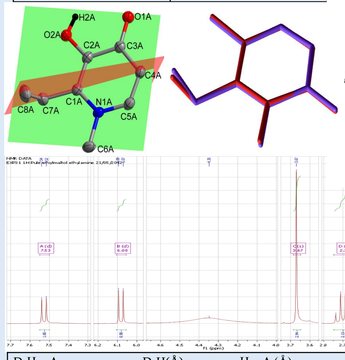
D-H…A	D-H(Å)	H…A (Å)	D…A (Å)	D-H…A (°)
O2B-H2B…O1B	0.88	2.34	2.7648	110
O2B-H2B…O1C$^{(i)}$	0.88	1.86	2.6506	149
O2A-H2A…O1A	0.87	2.34	2.7580	110
O2A-H2A…O1A$^{(ii)}$	0.87	1.87	2.6484	147
O2C-H2C…O1B$^{(iii)}$	0.86	1.80	2.5871	150
O2C-H2C…O1C	0.86	2.38	2.7820	109

2-Ethyl-3-hydroxy-1-methylpyrid-4(*H*)-one



Yields > 50 %

	Value
Cell Parameters	a = 8.301(5) Å α= 90.507(4)° b = 8.407(6) Å β=96.902(3)° c = 11.293(7) Å γ=95.241(4)°
Space Group	Triclinic
Crystal system	P-1
Z	4



D-H…A	D-H(Å)	H…A (Å)	D…A (Å)	D-H…A (°)
O2A-H2A…O1A	0.84	2.29	2.738(1)	113
O2A-H2A…O1A$^{(i)}$	0.84	1.94	2.637(1)	140
O2B-H2B…O1B	0.84	2.31	2.748(1)	113
O2B-H2B…O1B$^{(ii)}$	0.84	1.91	2.651(1)	146
C6A-H6AB…O1B$^{(iii)}$	0.98	2.34	3.290(2)	163
C6B-H6BA…O2A$^{(iv)}$	0.98	2.36	3.194(2)	143
C5B-H5B-O1A$^{(i)}$	0.95	2.29	3.237(1)	173
C7A-H7AB-O2A	0.99	2.39	2.782(1)	103
C8B-H8BB-O1A$^{(v)}$	0.98	2.57	3.513(2)	161
C8B-H8AB-O1B$^{(vi)}$	0.98	2.54	3.336(2)	138

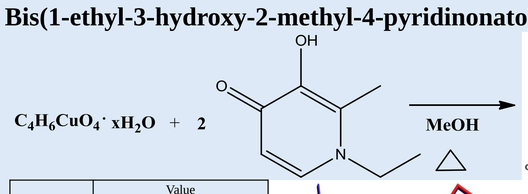
Insights from structural comparisons of synthesized ligands

Bond no.	Atoms	MM(naltol)H (1)	ME(naltol)H (2)	M(altol)H (3)^{a}	EM(naltol)H (4)		EE(naltol)H (5)	EP(naltol)H (6)			E(altol)H (7)^{b}
					Mol A	Mol B		Mol A	Mol B	Mol C	
		Bond distances (Å)									
(1)	O1-C3	1.272(2)	1.267(1)	1.246(3)	1.269(1)	1.265(1)	1.265(1)	1.261(2)	1.264(2)	1.269(2)	1.235(3)
(2)	O2-C2	1.360(1)	1.356(1)	1.353(2)	1.354(1)	1.355(1)	1.355(1)	1.353(2)	1.359(1)	1.354(1)	1.348(3)
(3)	N1-C6	1.471(2)	1.482(1)	-	1.473(1)	1.473(1)	1.484(1)	1.498(2)	1.496(2)	1.498(2)	-
(4)	C1-C9	1.497(2)	1.499(2)	1.482(4)	1.503(2)	1.510(2)	1.505(1)	1.500(2)	1.507(2)	1.503(2)	1.471(2)
(5)	C1-C2	1.376(2)	1.373(2)	1.358(2)	1.374(1)	1.376(1)	1.375(1)	1.370(2)	1.373(2)	1.377(2)	1.343(3)
(6)	C4-C5	1.366(2)	1.364(2)	1.342(3)	1.366(2)	1.366(2)	1.363(1)	1.360(2)	1.358(2)	1.362(2)	1.319(3)
(7)	O/N1-C1	1.378(2)	1.381(1)	1.365(4)	1.377(2)	1.380(1)	1.379(1)	1.383(2)	1.385(2)	1.382(2)	1.354(3)
(8)	O/N1-C5	1.350(2)	1.355(1)	1.344(4)	1.354(2)	1.355(2)	1.352(1)	1.355(2)	1.352(2)	1.354(2)	1.335(3)
(9)	C2-C3	1.423(2)	1.442(2)	1.445(3)	1.437(2)	1.442(2)	1.438(1)	1.438(2)	1.438(2)	1.436(2)	1.434(2)
(10)	C3-C4	1.439(2)	1.419(2)	1.438(3)	1.423(2)	1.419(2)	1.423(1)	1.422(2)	1.373(2)	1.420(2)	1.428(4)
Angle no.		Bond angles (°)									
(1)	C2-C3-C4	115.0(1)	114.81(9)	115.1(2)	114.68(9)	114.6(1)	114.42(8)	114.0(1)	114.0(1)	114.3(1)	113.9(2)
(2)	C1-N1/O-C5	120.8(1)	120.46(9)	119.4(2)	120.47(9)	120.62(9)	120.09(8)	119.5(1)	119.7(1)	119.7(1)	119.3(2)
(3)	C2-C1-C9	122.4(1)	121.71(9)	126.3(2)	120.8(1)	121.0(1)	119.92(8)	119.5(1)	119.5(1)	119.8(1)	126.9(2)
(4)	C1-N1-C6	120.1(1)	121.91(9)	-	121.76(9)	121.12(9)	121.74(7)	122.5(1)	121.2(1)	121.2(1)	-
(5)	O2-C2-C1	118.7(1)	118.79(9)	119.6(2)	118.09(9)	118.49(9)	117.89(8)	118.2(1)	118.0(1)	117.5(1)	118.5(2)
(6)	O1-C3-C4	124.3(1)	124.2(1)	124.0(3)	120.8(1)	124.6(1)	124.68(8)	124.4(1)	124.1(1)	123.9(1)	124.7(2)
(7)	O/N1-C1-C9	118.7(1)	119.22(9)	112.8(2)	120.5(1)	120.2(1)	121.18(8)	120.8(1)	121.5(1)	120.6(1)	112.0(2)
(8)	N1-C6-C7	-	111.38(9)	-	-	-	111.32(8)	109.8(1)	109.2(1)	109.3(1)	-
(9)	C1-C9-C10	-	-	-	112.4(1)	114.23(9)	111.92(8)	111.3(1)	112.9(1)	112.0(1)	112.4 (2)
Torsion no.		Torsion angles (°)									
(1)	O2-C2-C3-O1	0.6(2)	-0.4(2)	-1.27(4)	-0.3(2)	1.8(2)	-1.5(1)	0.4(2)	-2.9(2)	0.4(2)	1.1(3)
(2)	C6-N1-C1-C9	2.3(2)	3.5(1)	-	0.3(2)	-5.0(2)	4.9(1)	-0.6(2)	4.2(2)	2.4(2)	-
(3)	C9-C1-C2-O2	-0.3(2)	-0.6(2)	-1.2(4)	-2.1(2)	4.3(2)	-0.9(1)	1.3(2)	-1.8(2)	0.1(2)	0.7(3)
(4)	C1-N1-C6-C7	-	89.8(1)	-	-	-	-82.9(1)	126.7(1)	150.6(1)	138.8(1)	-
(5)	O1/N1-C1-C9-C10	-	-	-	82.9(1)	93.0(1)	98.0(1)	-87.9(1)	102.9(1)	86.5(1)	-70.4(2)
(6)	C1-N1-C6-C8	-	-	-	-	-	-	-109.2(1)	85.0(1)	95.6(1)	-

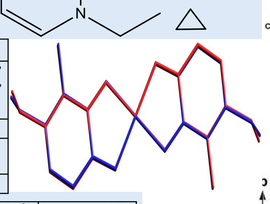
General comments

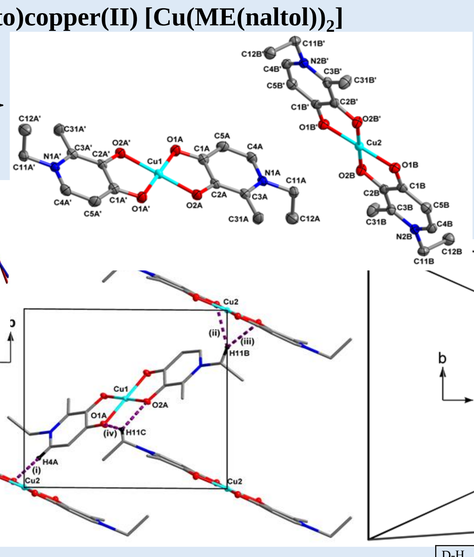
- All the ligands are in the ketone-enol tautomeric form in the solid state
- C=O bond length increase with increase in electron donating capacity of substituent
- dimers form *via* weak O—H…O hydrogen interaction (≈ 1.9 Å with bond angles ≈ 150 ˚) which primarily stabilized the structure
- Carbon atoms sp^2 or sp^3 hybridised in all the structures

Bis(1-ethyl-3-hydroxy-2-methyl-4-pyridinonato)copper(II) [Cu(ME(naltol))$_2$]



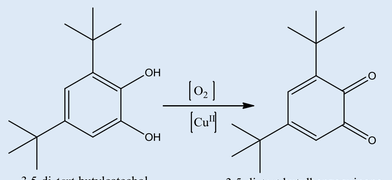
	Value
Cell Parameters	a = 7.225(2) Å α=89.658(8)° b = 10.146(2) Å β=104.98(1)° c = 11.316(8) Å γ=89.72(1)°
Space Group	P-1
Crystal system	Triclinic
Z	2

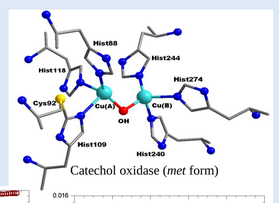




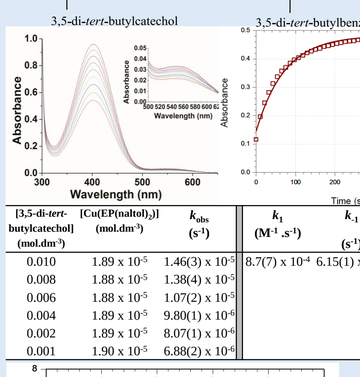
D-H…A	d(H…A) (Å)	d(D…A) (Å)	∟(D-H…A) (°)
C4A-H4A…O1B$^{(i)}$	2.39	3.201(3)	146
C11A-H11B…O1B$^{(ii)}$	2.50	3.355(3)	146
C11A-H11B…O2B$^{(iii)}$	2.54	3.302(3)	136
C11B-H11C…O2A	2.44	3.250(3)	140
C11B-H11C…O2A$^{(iv)}$	2.42	3.234(3)	142

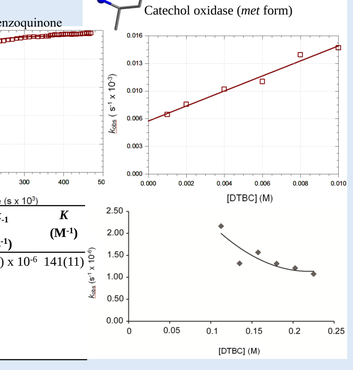
Cu(II) nano-particles and solution studies



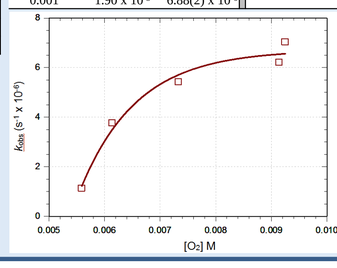


Cell Parameters	a = 11.115(2) Å α=89.66(0)° b = 7.556(2) Å β=109.749 (2)° c = 15.012(2) Å γ=89.72(0)°
Space Group	$P2_1/c$
Crystal system	Monoclinic
Z	2





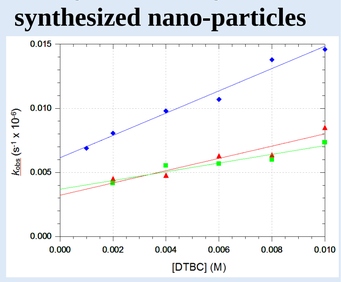
[3,5-di-*tert*-butylcatechol] (mol.dm^{-3})	[Cu(EP(naltol)$_2$)] (mol.dm^{-3})	k_{obs} (s^{-1})	k_1 ($M^{-1}.s^{-1}$)	k_{-1} (s^{-1})	K (M^{-1})
0.010	1.89 x 10^{-5}	1.46(3) x 10^{-5}	8.7(7) x 10^{-4}	6.15(1) x 10^{-6}	141(11)
0.008	1.88 x 10^{-5}	1.38(4) x 10^{-5}			
0.006	1.88 x 10^{-5}	1.07(2) x 10^{-5}			
0.004	1.89 x 10^{-5}	9.80(1) x 10^{-6}			
0.002	1.89 x 10^{-5}	8.07(1) x 10^{-6}			
0.001	1.90 x 10^{-5}	6.88(2) x 10^{-6}			



The effect of varied oxygen conc. on oxidative catalysis

[3,5-di-*tert*-butylcatechol] (mol.dm^{-3})	[Cu(MP(naltol)$_2$)] (mol.dm^{-3})	[O_2] (mol.dm^{-3})	k_{obs} (s^{-1})
0.0101	1.89 x 10^{-5}	5.59 x 10^{-3}	1.1(1) x 10^{-6}
0.0100	1.88 x 10^{-5}	6.14 x 10^{-3}	3.76(5) x 10^{-6}
0.0102	1.87 x 10^{-5}	7.33 x 10^{-3}	5.42(4) x 10^{-6}
0.0104	1.86 x 10^{-5}	9.14 x 10^{-3}	6.21(5) x 10^{-6}
0.0103	1.88 x 10^{-5}	9.25 x 10^{-3}	7.03(1) x 10^{-6}

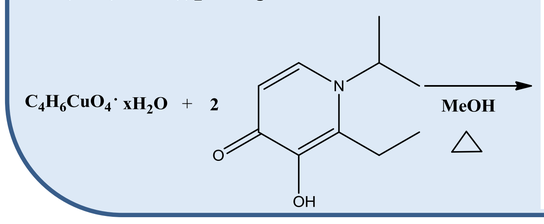
Catalytic efficiency of the synthesized nano-particles

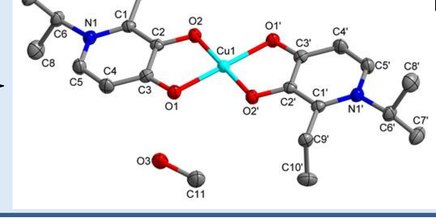


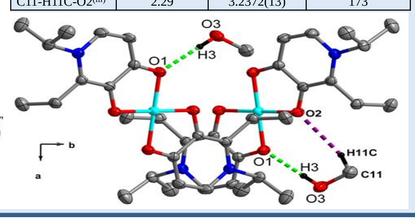
Conclusive remarks

- In total 12 nano-particles were synthesized and characterized from this study
- The copper(II) nano-particles were planar with the copper centers lying on inversion centers
- The least electron donating/ the most steric compound/ the compound with the strongest hydrogen interactions was the most effective
- Further studies have to be done to determine which parameter is the most influential in this regard

Bis(2-ethyl-3-hydroxy-1-isopropyl-4-pyridinonato)copper(II) methanol solvate [Cu(EP(naltol))$_2$].CH_3OH







D-H…A	d(H…A)(Å)	d(D…A) (Å)	D-H…A (°)
O3-H3…O1$^{(i)}$	2.29	2.7379(11)	113
C5-H5…O3$^{(ii)}$	2.34	3.2903(15)	163
C9-H9…O2	2.36	3.1943(15)	143
C11-H11C-O2$^{(iii)}$	2.29	3.2372(13)	173

The effect of varied oxygen conc. on oxidative catalysis

Acknowledgements: The author would like to thank Inkaba yeAfrica, DST, THRIP, the UFS Research Fund, SASOL, NRF (The opinions, findings and conclusions and/or recommendations expressed in this poster are that of the author, and the different enterprises/stakeholders mentioned here accept no liability whatsoever in this regard) as well as his supervisors; *Gideon Steyl and Andreas Roodt.*