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## A B-Keto ester as a novel, efficient, and versatile ligand for copper (II)-catalyzed C-C coupling reactions and evaluation anti-bacterial activity

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### Abstract

Employing  $\alpha$ -acetyl- $\gamma$ -butyrolactone as a novel, efficient, and versatile ligand, the copper catalyzed Sonogashira and Suzuki coupling reactions with nucleophilic reagents with aryl halides and boronic acid could be successfully carried out under mild conditions. Synthesis, Present communication describes Synthesis, Characterization and IR spectrum, elemental analysis, mass spectrum, molar conductance, TGA and DTA analysis, catalytic activity, crystal structure with the help of single XRD and antimicrobial activity of Cu(II) complex.

**Keywords:**  $\alpha$ -acetyl- $\gamma$ -butyrolactone, copper acetate monohydrate, structural analysis, biological activity

### Introduction

The 1,3-dicarbonyl compounds are important class of organic compound used as intermediate for the synthesis of core heterocycles such as pyrazole [1-3], isoxazole [3-6] and triazole [7]. They find extensive applications in CVD (Chemical vapour deposition), processes which are used in wide range of industrial components and various items of chemical plant [8]. They are also used as chelating ligands for various lanthanide and transition metals in material chemistry [9-11]. Owing to such an enormous applications, the synthesis of 1, 3-diketones has gained considerable interest in recent years. The applications of 1,3-dicarbonyl compounds as ligand is well explored and are found to show great catalytic activities [12-17]. On the contrary the chemistry of 1,3-keto ester is not much explored and there is huge scope to explore the chemistry of 1, 3-ketoester. There are only few reports available on use of cyclic 1,3-keto ester as a ligand for organic transformation which utilizes *in situ* in the preparation of metal complex [18]. There is tremendous scope in exploration of premade metal 1,3-keto ester complexes. The premade 1,3-keto ester metal complex will be stable, less-sensitive to water, easy to handle and having ability to exhibit catalytic and show medicinal properties. Considering all the above facts, we have prepared metal complex of  $\alpha$ -acetyl- $\gamma$ -butyrolactone with copper (II), characterized and study its biological and catalytic activities discussed in current research.  $\alpha$ -Acetyl- $\gamma$ -butyrolactone is  $\beta$  ketoester, potentially reactive bis-electrophile, having ability to co-ordinate with metals due to presence of oxygen lone pair. The literature reports revealed that  $\alpha$ -acetyl- $\gamma$ -butyrolactone was used for the synthesis of various heterocyclic compounds having good biological activity.  $\gamma$ -Butyrolactone (GBL) is a hygroscopic colorless liquid with weak characteristic odour, soluble in water. GBL is a common solvent and reagent in chemistry as well as being used as a flavouring, as a cleaning solvent, as a superglue remover, and as a solvent in some wet aluminium electrolytic capacitors. In humans it acts as a pro-drug for  $\gamma$ -hydroxybutyric acid (GHBA) and it is used as recreational intoxicant with effects similar to alcohol. GBL is rapidly converted into GHB by paraoxonase (lactonase) enzymes, found in the blood animals which lack these enzymes exhibits no effect from GBL. GBL is more lipophilic (fat soluble) than GHB, and so absorbed faster and has higher bioavailability. Because of these pharmacokinetic differences, GBL tends to be more potent and faster acting than GHB, but has a shorter duration; where is the related compound 1, 4-butanediol (1,4-B) tends to be slightly less potent, slower to take effect but longer-acting than GHB.

The levels of lactonase enzyme ca[199n vary between individuals, meaning that first – time users can show unpredictable results, even from small doses. In many this manifests as slow onset of effects, followed by headaches, semi-consciousness which is distinct from GBL sleep in normal users. If the user decides to try again at a later date, they appear to be able to enjoy the effects normally. Keto Ester complexes of Copper(I) was also used as catalyzed for C-N, C-O, and C-S coupling reactions [19]. In literature variety in the coordination modes of  $\beta$ -dicarbonyl compounds in metal complexes [20].

### Material and methodology

All reagents were purchased commercially and were used directly without any further purification. The complex was characterized by IR, UV, HRMS, CHN analysis, single crystal XRD and physical constant. IR spectra were recorded as KBr pellets on a Shimadzu FTIR-408 instrument. UV-visible spectra were recorded on Shimadzu 2450 UV-visible spectrophotometer. Mass spectra were recorded on a Shimadzu LC-MS: EI QP 2010A mass spectrometer with an ionization potential of 70eV. Elemental analyses were performed on Quest flash 1112 Series EA Analyzer at SAIF, Punjab University, Chandigarh. Molar conductivity of complexes was recorded using  $1 \times 10^{-3}$  M solutions in DMSO on Toshniwal TSM 15 conductivity metre. Melting points were determined on a Gallenkamp melting point apparatus.

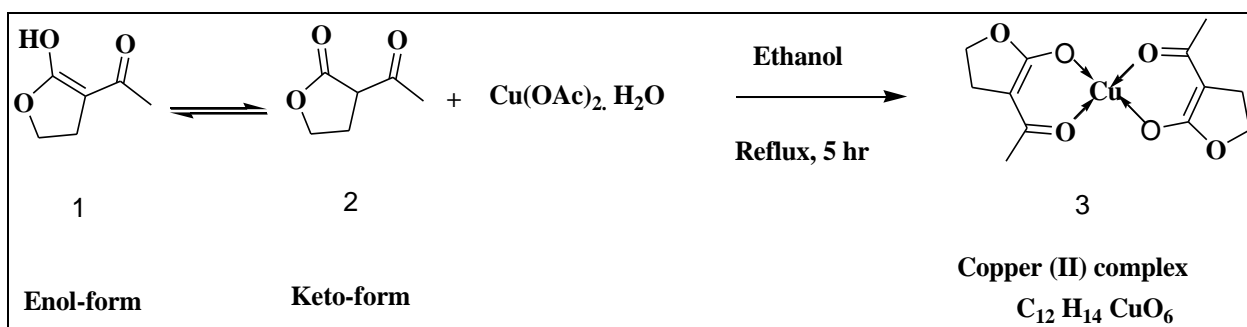
Reactions were monitored by thin layer chromatography (TLC), carried out on 0.2 mm silica gel 60 F254 Merck plates using UV light (254 and 366 nm) for detection.

### Synthesis of $\alpha$ -acetyl- $\gamma$ -butyrolactone

$\alpha$ -Acetyl- $\gamma$ -butyrolactone is prepared by condensation of  $\gamma$ -butyrolactone with an acetic ester in presence of strongly base. Enolate obtained was subjected to protonation. All these three reactants are continuously fed into the reaction mixture, where the ratio of acetic acid ester is 1.0-6.0 parts by moles, 0.9-1.6 parts by moles of strongly basic substance per part by moles of  $\gamma$ -butyrolactone. The reaction mixture obtained was removed from reaction zone and then it was protonated.

### Synthesis of copper (II) complex with $\alpha$ -acetyl- $\gamma$ -butyrolactone

A solution of  $\alpha$ -acetyl- $\gamma$ -butyrolactone (2.15 mL; 20 mmol) 1 in 30 mL ethanol was stirred for 10 min, and then a solution of copper acetate monohydrate (1.99 gm; 10 mmol) 2 in ethanol was added slowly at room temperature. The reaction mixture was stirred at reflux temperature for 5 hrs. After cooling to room temperature, the pale green colored complex 3 compound was filtered off, washed thoroughly with ethanol, followed by diethyl ether. The compound obtained was recrystallized from methanol and was finally dried under vacuum. Scheme 1



Scheme 1: Synthesis of copper (II) complex of  $\alpha$ -acetyl- $\gamma$ -butyrolactone

### Results and Discussion

#### Elemental Analysis

The complex is hygroscopic having pale green and is stable in atmosphere. It is soluble in DMSO and methanol. The elemental analysis data for percentage of carbon and hydrogen was determined, was in agreement with the calculated based on proposed formula. The metal content in both complex measured and was in agreement with the calculated value. The elemental analysis data of the complex was calculated in Table No.1

Table 1: Analytical, physical data of lactone complexes

Complex	Colour % yield	Melting point °C	Elemental analysis found (Calculated %)			
			C	H	M	P
$\text{C}_{12}\text{H}_{14}\text{CuO}_6$	Pale green (80%)	220 °C	44.36 (45.35)	5.04 (4.38)	19.87 (20.00)	--

#### Infrared Spectra

Scan IR spectra of lactone and complex showed different stretching, and bending frequencies, indicates that complexation of lactone with metals. The IR spectra of the both complex was different when compared with that of

(lactone)  $\alpha$ -acetyl- $\gamma$  butyrolactone. The IR spectrum of the lactone is compared with that of Cu(II) complex to know the changes during complexation. The important IR spectra bands of lactone and metal complex along with their assignments are listed in Table No-2. Lactone,  $\alpha$ -acetyl- $\gamma$ -butyrolactone shows a band at  $1779\text{ cm}^{-1}$  indicates five member cyclic ester group in ligand. The stretching frequency at  $1726\text{ cm}^{-1}$  is attributed to carbonyl group. On complexing with copper ion these stretching is lowered to  $1626\text{ cm}^{-1}$  and  $1531\text{ cm}^{-1}$ . This indicated that coordination of ester oxygen and carbonyl oxygen with metal ions. A new M-O band stretching frequency at  $460\text{ cm}^{-1}$  in spectra of Cu(II) complex confirms the co-ordination between metal and oxygen. (Fig. 1, 2)

Table 2: IR spectra data of lactone and Cu(II) complex

Compound	$\nu\text{C=O ester cm}^{-1}$	$\nu\text{C=O carbonyl cm}^{-1}$	M - O $\text{cm}^{-1}$	PPh <sub>3</sub>
$\alpha$ -Acetyl- $\gamma$ -butyrolactone	1779	1726	--	--
$\text{C}_{12}\text{H}_{14}\text{CuO}_6$	1626	1531	460	

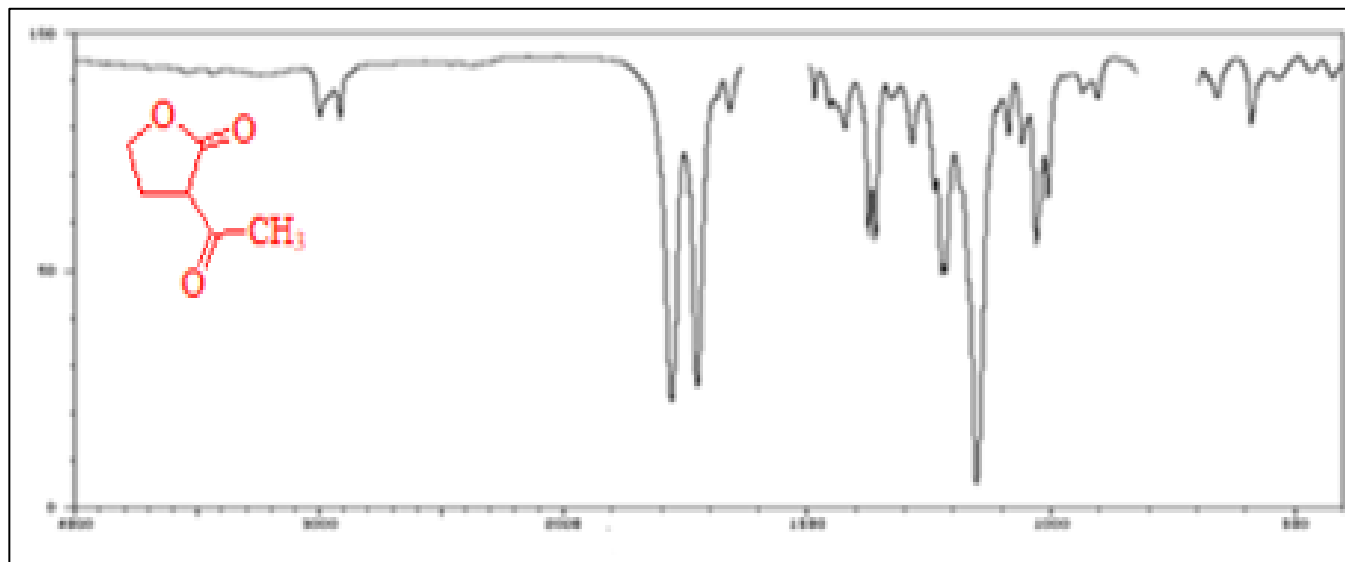


Fig 1: IR Spectrum of  $\alpha$ -acetyl- $\gamma$ -butyrolactone

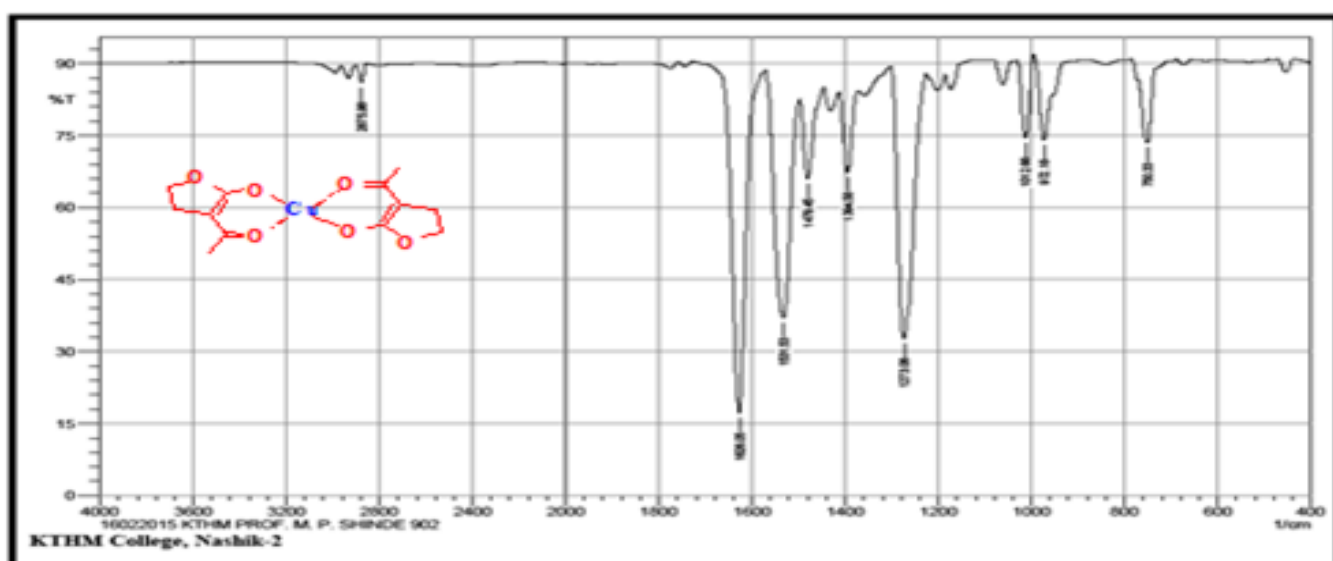


Fig 2: IR spectrum of Cu (II) complex of  $\alpha$ -acetyl- $\gamma$ -butyrolactone

### Mass Spectra

The mass spectrum of the Cu(II) complex were recorded showed molecular ion peak at MS(  $m/z$  – 339.99)  $M^+$  Na for

Cu(II) complex  $C_{12}H_{14}CuO_6$ , which agrees with molecular weight of the Cu(II) complex 317. (Fig.3)

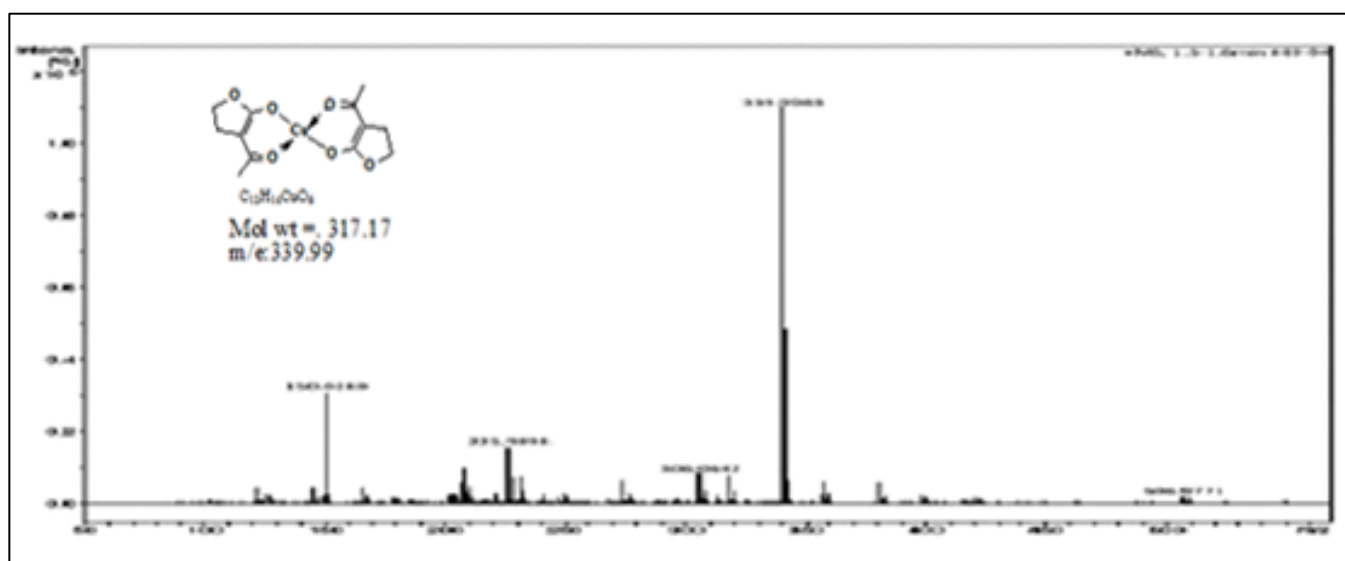


Fig 3: Mass spectrum of complex  $C_{12}H_{14}CuO_6$

### Molar conductance Measurements

The conductance value of complex  $C_{12}H_{14}CuO_6$  when dissolved in DMSO was  $28.7 \cdot 2^{-1} \text{cm}^2$  which indicates the non-

electrolyte nature of the complex.

### Thermogravimetric Analysis; Complex $C_{12}H_{14}CuO_6$

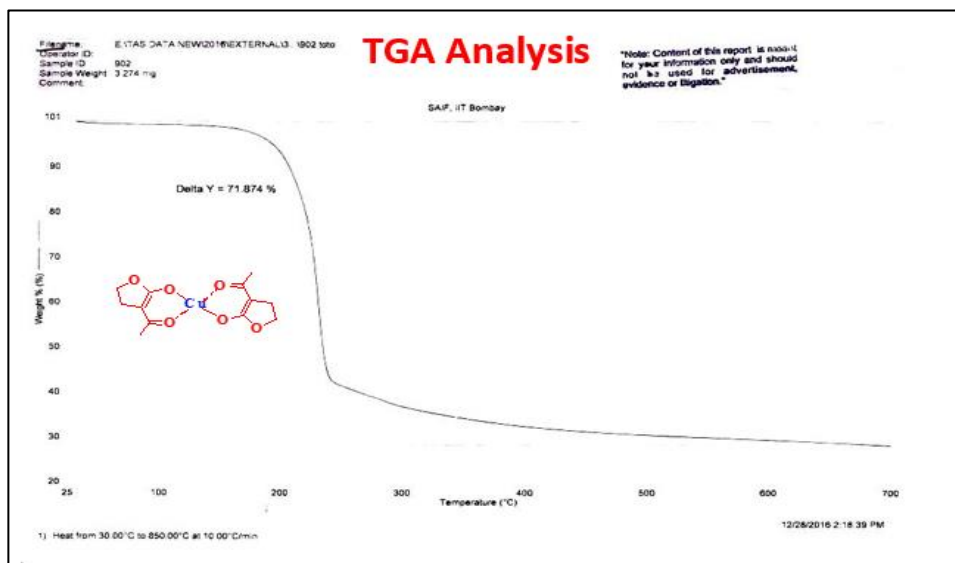


Fig 5: TGA curve for complex  $C_{12}H_{14}CuO_6$

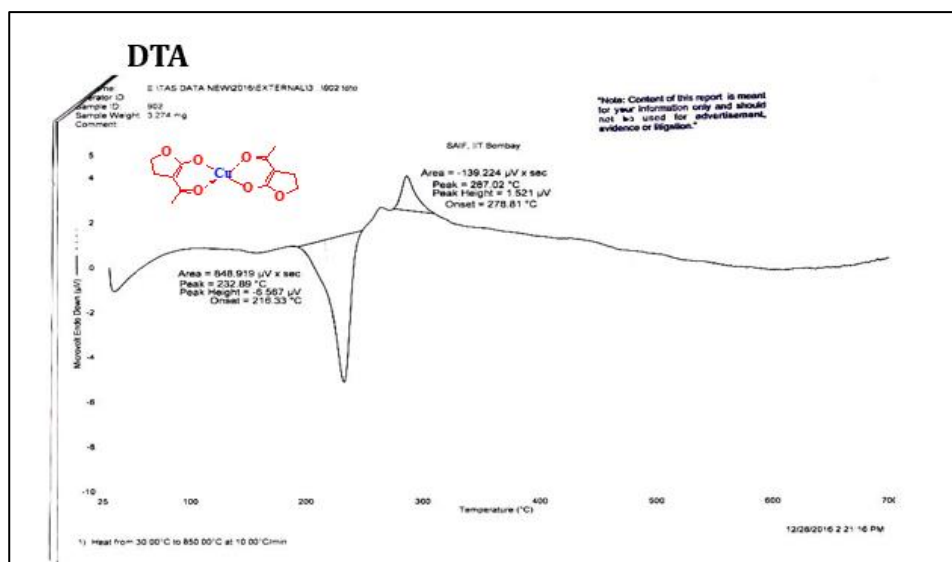


Fig 6: DTA curve for complex  $C_{12}H_{14}CuO_6$

Thermoanalytical measurement was performed in range the  $25^\circ\text{C} - 700^\circ\text{C}$  temperature. Thermal decomposition takes place in one step. The complex is stable below  $180^\circ\text{C}$ . Gradual decomposition from  $170^\circ\text{C}$  to  $250^\circ\text{C}$  is related to loss of the organic moiety by a 71.874 % weight loss (theoretical 79.454%). The weight of the residue is consistent with metal oxide  $\text{CuO}$  from the 34.31% residual weight (calcd=35.11%). (Fig. 5 & 6)

### X-ray diffractogram of Cu (II) complex

The x-ray diffractogram of Cu (II) complex was scanned in the range  $0-60^\circ$  at wavelength  $1.543\text{\AA}$ . The diffractogram and associated data depict the  $2\theta$  value for each peak, relative intensity and interplanar spacing (d-values). The diffractogram of Cu (II) complex of L had twelve reflections with maxima at  $2\theta = 11.945^\circ$  corresponding to d value  $7.0403\text{\AA}$ . The x-ray diffraction pattern of these complexes with respect to major peaks of relative intensity greater than 10 % has been indexed by using computer programme. The above indexing method also yields Miller indices (hkl), unit cell

parameters and unit cell volume. The unit cell of Cu (II) complex of L yielded values of lattice constants,  $a=8.9840\text{\AA}$ ,  $b=11.9837$

$\text{\AA}$ ,  $c = 10.4635\text{\AA}$  and unit cell volume  $V=19383.98\text{\AA}^3$ . In concurrence with these cell parameters, the condition such as  $a=b=c$  and  $\alpha=\beta=\gamma=90^\circ$  required for sample to be orthorhombic were tested and found to be satisfactory. Hence it can be concluded that Cu(II) complex has orthorhombic crystal system. (Fig.6)

Table 3: The x-ray diffractogram data of Cu (II) Complex

2Theta	Relative Intensity	d spacing	hkl
11.945	100	7.0403	100
16.027	3.41675551	5.5256	111
24.336	7.067044315	3.6545	101
25.843	11.87224759	3.4448	110
26.523	12.37177182	3.3579	201
27.349	7.440973824	3.2584	222
28.467	10.06616278	3.1329	200
34.541	4.687262312	2.5946	202

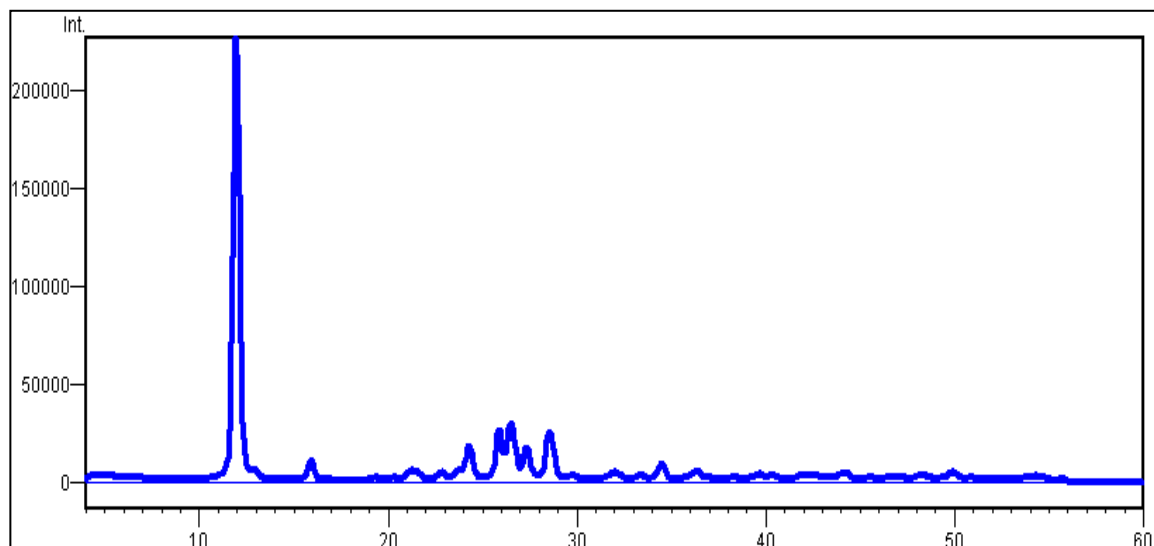


Fig 6: X-ray diffractogram of Cu (II) complex

### Crystal structure analysis

Crystal structure of Cu (II) complex of  $\alpha$ -acetyl- $\gamma$ -butyrolactone:- For XRD the suitable single crystal were obtained by the slow evaporation of methanolic solution of the complex. The geometry of the complex is found to be square planar. The compound crystallises in monoclinic crystal system with the space group P21/C. The central Cu

atom is four co-ordinated with four oxygen atoms of two bidentate ligands. A summary of crystallographic data and refinement parameters are given in Table No.4.

The molecular structure of the compound was solved at 200(2) k. (Figure 7) gives the ORTEP diagram of the complex with atomic labelling scheme.

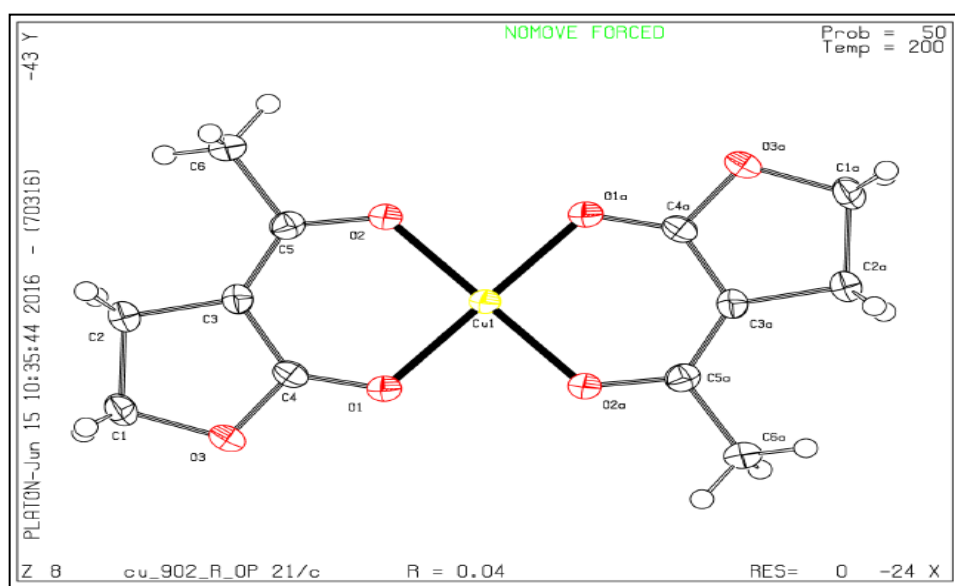


Fig 7: ORTEP drawing of the complex a) with atomic labeling b) Crystal Packing of Cu II complex

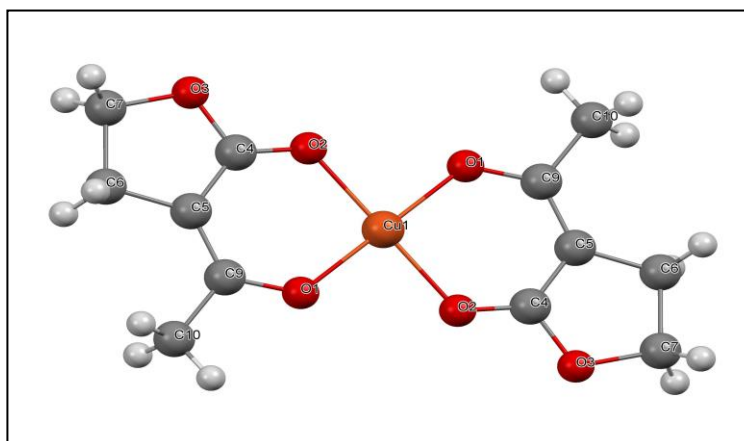
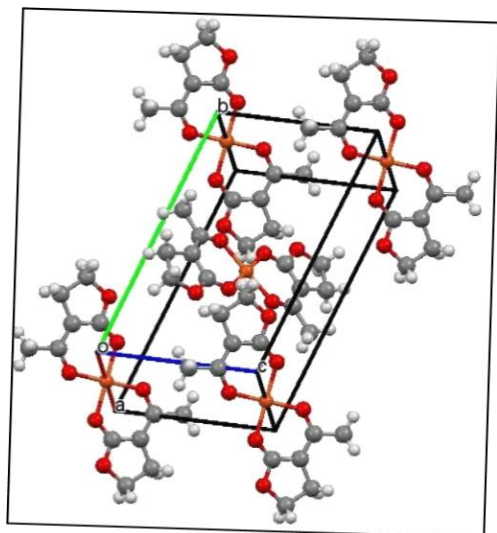


Fig 8: Single crystal XRD of Cu (II) complex





**Fig 9:** Single crystal XRD of Cu (II) complex

The important inter atomic distances and angles are listed in Table 7. The complex geometry can be explained by a structure resulting in O(2)-Cu -O (2)a and O2-Cu (1) - O (1) bond angles which is 180.00. In the co-ordination sphere, the Cu-O bond lengths are 1.9052(19) and 1.946(2) Å. The O-Cu-O bond angles are 85.77<sup>o</sup> and 94.28<sup>o</sup> and the sum of them indicating a square planar configuration of complex which is also evident from UV analysis.

**Table 4:** Crystal data and structure refinement for cu\_902\_r\_0m

Identification code	cu_902_R_0m	
Empirical formula	C12 H14 Cu O6	
Formula weight	317.77	
Temperature	200(2) K	
Wavelength	1.54178 Å	
Crystal system	Monoclinic	
Space group	P 21/c	
Unit cell dimensions	a = 4.6948(3) Å	$\alpha$ (°) = 90°.
	b = 14.8343(8) Å	$\beta$ (°) = 99.346(2)°.
	c = 8.7072(5) Å	$\gamma$ (°) = 90°.
Volume	598.36(6) Å <sup>3</sup>	
Z	2	
Density (calculated)	1.764 Mg/m <sup>3</sup>	
Absorption coefficient	2.802 mm <sup>-1</sup>	
F(000)	326	
Crystal size	0.320 x 0.149 x 0.055 mm <sup>3</sup>	
Theta range for data collection	5.952 to 68.198°	
Index ranges	-5 ≤ h ≤ 5, -17 ≤ k ≤ 17, -10 ≤ l ≤ 10	
Reflections collected	8462	
Independent reflections	1093 [R(int) = 0.0498]	
Completeness to theta = 67.679°	99.3 %	
Refinement method	Full-matrix least-squares on F <sup>2</sup>	
Data / restraints / parameters	1093 / 0 / 89	
Goodness-of-fit on F <sup>2</sup>	1.256	
Final R indices [I > 2σ(I)]	R1 = 0.0394, wR2 = 0.1097	
R indices (all data)	R1 = 0.0418, wR2 = 0.1112	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.708 and -0.435 e.Å <sup>-3</sup>	

**Table 5:** Atomic coordinates (x 104) and equivalent isotropic displacement parameters (Å<sup>2</sup>x 10<sup>3</sup>) for cu\_902\_r\_0m. U(eq) is defined as one third of the trace of the orthogonalized U<sub>ij</sub> tensor

	X	Y	Z	U(eq)
Cu(1)	15000	5000	5000	21(1)
O(1)	13176(4)	3821(1)	4991(2)	25(1)
O(1)	12225(4)	5462(1)	3347(2)	24(1)
O(3)	9957(5)	2785(1)	4067(3)	29(1)
C(1)	7365(7)	2688(2)	2893(4)	31(1)
C(2)	6955(6)	3579(2)	1992(3)	25(1)
C(3)	9304(6)	4164(2)	2884(3)	21(1)
C(4)	10961(6)	3631(2)	4042(3)	21(1)
C(5)	10007(7)	5044(2)	2611(3)	21(1)
C(6)	8130(7)	5584(2)	1385(4)	28(1)

**Table 6:** Bond lengths [Å] and angles [°] for cu\_902\_r\_0m

Bond lengths [Å]		Bond angles [°]	
Cu(1)-O(2)	1.9052(19)	O(2)-Cu(1)-O(2)#1	180.00(10)
Cu(1)-O(2)#1	1.9052(19)	O(2)-Cu(1)-O(1)#1	85.77(8)
Cu(1)-O(1)#1	1.946(2)	O(2)#1-Cu(1)-O(1)#1	94.23(8)
Cu(1)-O(1)	1.946(2)	O(2)-Cu(1)-O(1)	94.23(8)
O(1)-C(4)	1.251(4)	O(2)#1-Cu(1)-O(1)	85.77(8)
O(2)-C(5)	1.290(4)	O(1)#1-Cu(1)-O(1)	180.0
O(3)-C(4)	1.342(3)	C(4)-O(1)-Cu(1)	121.57(18)
O(3)-C(1)	1.464(4)	C(5)-O(2)-Cu(1)	126.89(18)
C(1)-C(2)	1.534(4)	C(4)-O(3)-C(1)	109.6(2)
C(2)-C(3)	1.514(4)	O(3)-C(1)-C(2)	107.1(2)
C(3)-C(5)	1.377(4)	C(3)-C(2)-C(1)	102.2(2)
C(3)-C(4)	1.411(4)	C(5)-C(3)-C(4)	122.3(3)
C(5)-C(6)	1.501(4)	C(5)-C(3)-C(2)	129.0(3)
		C(4)-C(3)-C(2)	108.5(2)
		O(1)-C(4)-O(3)	117.2(2)
		O(1)-C(4)-C(3)	130.4(3)
		O(3)-C(4)-C(3)	112.4(3)
		O(2)-C(5)-C(3)	124.5(3)
		O(2)-C(5)-C(6)	115.5(2)
		C(3)-C(5)-C(6)	120.0(3)

Symmetry transformations used to generate equivalent atoms:

#1 -x+3,-y+1,-z+1

**Table 7:** Anisotropic displacement parameters (Å<sup>2</sup>x 10<sup>3</sup>) for cu\_902\_r\_0m. The anisotropic displacement factor exponent takes the form: -2□[h2a\*2U11 + ... + 2 h k a\* b\* U12 ]

	U11	U22	U33	U23	U13	U12
Cu(1)	24(1)	16(1)	20(1)	1(1)	-2(1)	-1(1)
O(1)	27(1)	19(1)	26(1)	2(1)	-3(1)	0(1)
O(2)	25(1)	19(1)	26(1)	3(1)	-3(1)	-2(1)
O(3)	32(1)	16(1)	36(1)	2(1)	-2(1)	-4(1)
C(1)	28(2)	20(2)	43(2)	-5(1)	-5(1)	-4(1)
C(2)	25(2)	23(2)	27(2)	-3(1)	-1(1)	-4(1)
C(3)	20(1)	22(1)	21(1)	-3(1)	2(1)	-2(1)
C(4)	24(1)	16(1)	23(1)	-2(1)	5(1)	-1(1)
C(5)	24(1)	22(2)	17(1)	-2(1)	3(1)	-2(1)
C(6)	30(2)	23(2)	28(2)	6(1)	-2(1)	-1(1)

### Electronic Spectra

The spectra of complex shows shifting in wavelength. The complex shows stretching at 266, 330, 410 and d-d broad and weak band between 525 to 690 nm. This indicates  $\pi \rightarrow \pi^*$ ,  $\pi-\pi^*$ ,  $n-\pi^*$  (LMCT) and d-d  $2B_{1g} \rightarrow 2E_g$  and  $2B_{1g} \rightarrow 2A_{1g}$  transition in metal complex. The broadness of band may be due to John Teller distortion, indicating square planar geometry of complex.

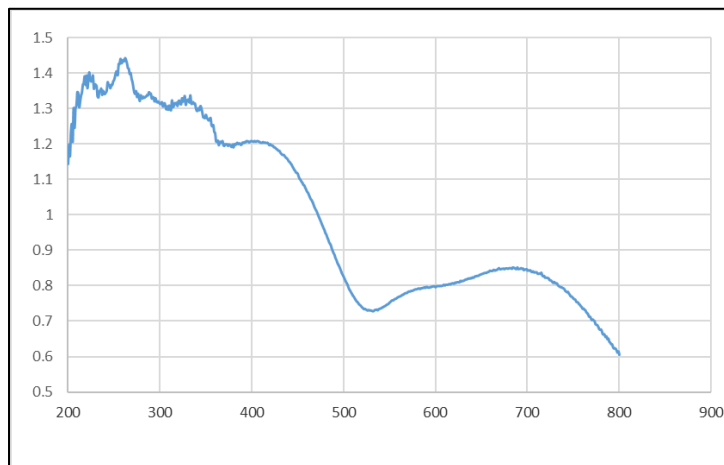


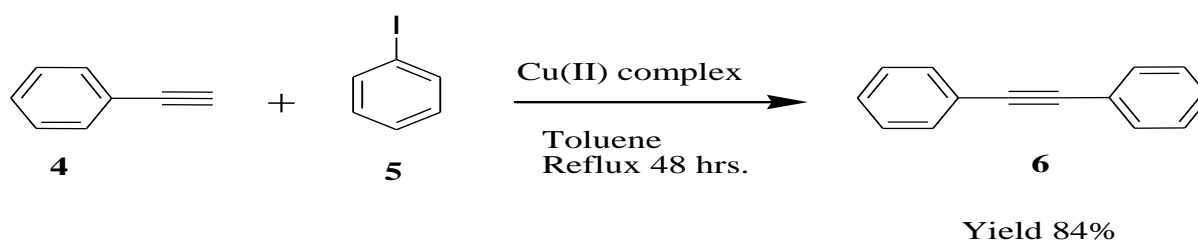
Fig 10: Electronics Spectra of complex  $C_{12}H_{14}CuO_6$

### Catalytic activity

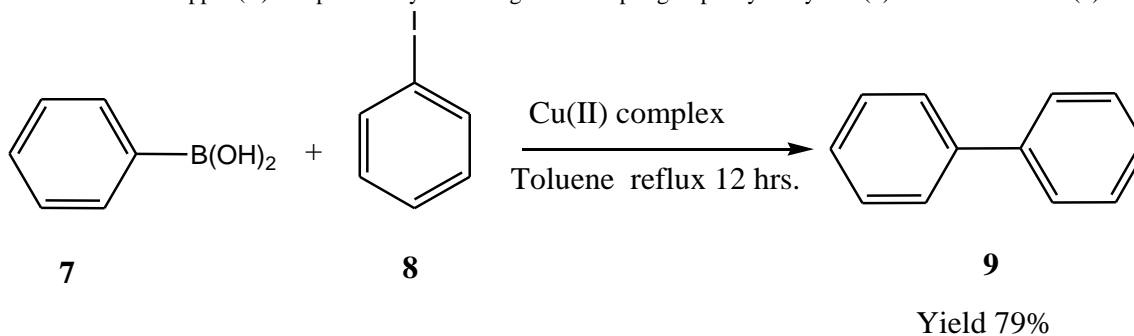
Inspired by the biological studies, we decided to explore the synthesized and well characterized copper (II) complex as a catalyst for coupling reactions. In order to test its applicability as catalyst, we used the complex for Sonogashira and Suzuki coupling reactions. The complex found to yield the desired products 4 and 5 for mentioned reaction in excellent yield of 84% and 79 % respectively. The yield and structure of

coupling products were confirmed by GC-MS analysis. The reaction conditions used to test catalytic behaviour of copper (II) complex for Sonogashira and Suzuki coupling reactions are mentioned in following scheme.

**Reaction conditions: 1 (2.0 mmol), 2 (1 mmol), Cu(II) Complex (10 mol %),  $K_3PO_4$  (2.0 mmol), toluene (3 ml),  $135^\circ C$ , Time: 48 h.**



Scheme 2: Copper (II) complex catalyzed Sonogashira coupling of phenylacetylene (1) with iodobenzene (2).



**Reaction conditions: 4 (1.2 mmol), 5 (1 equiv), Cu(II) Complex (10 mol %),  $K_2CO_3$  (2 mmol), toluene (5 ml),  $130^\circ C$ , Time: 12 h.**

Scheme 3: Copper (II) complex catalyzed Suzuki coupling of phenylboronic acid with iodo benzene.

### Biological Activity

The synthesized copper (II) complex was tested *in vitro* against representative Gram-positive/negative bacteria species *E. Coli* and *Staphylococcus aureus*, and two fungal species *Aspergillus niger* and *Candida albicans* by agar well diffusion method. All the bacterial strains were incubated at  $37^\circ C$  for 48hrs by inoculation into nutrient broth and the fungal strains were incubated for 72hrs by inoculation in to potato dextrose broth. The molten media were inoculated with  $100\mu L$  of the inoculums and poured into the Petri plate. After medium was solidified, a well was made in the plates with the help of cup-borer (0.85cm). Then the test compounds were introduced into the well and Petri plates were incubated. Compound was

dissolved in DMSO to prepare stock solution. Commercially available bactericide Gentamicin and antifungal Flucanazole were used as standard ( $100\mu g$  per  $100\mu L$  of sterilized distilled water) concurrently with the test samples. The diameter of inhibition zones (in mm) was determined and data was statistically evaluated by Turkey's pair-wise comparison test. All the experiments were repeated for three times and the results were confirmed.

The newly synthesized complex was found to reveal considerable antibacterial activity almost equal to the activity of Gentamicin. The complex was also screened for its antifungal activity against *Aspergillus niger* and *Candida albicans* by agar disc diffusion method. The results of the

antifungal testing of the complex was compared with the typical broad spectrum of the potent antifungal drug Fluconazole. The antifungal activity data shows that Cu (II) complex had comparable activity for *A. Niger* and had showed excellent activity against *Candida albicans*, which is found to be better than the standard Fluconazole. The antimicrobial assay evaluation

of the synthesized of Cu (II) complex was done using agar well plate method. The antibacterial and antifungal assays were performed in Muller-Hintonbroth and CrazeK Dox broth. The standard strains used for the antimicrobial assay was procured from Microbial Culture Collection, Pune, India. Antimicrobial evaluation was performed using the bacteria reseeded in Muller-Hinton broth for 24 hr at 37 °C and fungi reseeded in CrazeK Dox broth for 48 hr at 25 °C. The

antibacterial activity of tested sample was studied intriplicate against gram positive bacteria *Staphylococcus aureus* (ATCC 29737) and gram negative bacteria *Escherichia coli* (ATCC 25922). The same sample was tested for antifungal activity in triplicate against *Candida albicans* (MTCC 277) and *Aspergillus niger* (MCIM 545). The compound was dissolved in DMSO at desired concentrations of 40, 20, 10 µg/ mL. DMSO was loaded as negative control. Gentamicin (10 µg/ mL) and Fluconazole (20 µg/ mL) was used as standards for evaluating the antibacterial and antifungal activity. The zone of inhibition (mm) was determined from the diameter of the zone of inhibition using caliper as per National Committee for Chemical Laboratory Standards (NCCLS, M7-A5, January 2000). Both metal complex shows good antibacterial as well as good antifungal activity.

**Table 9:** Antimicrobial screening of compounds 1-12: Inhibition Zone Diameter (mm)

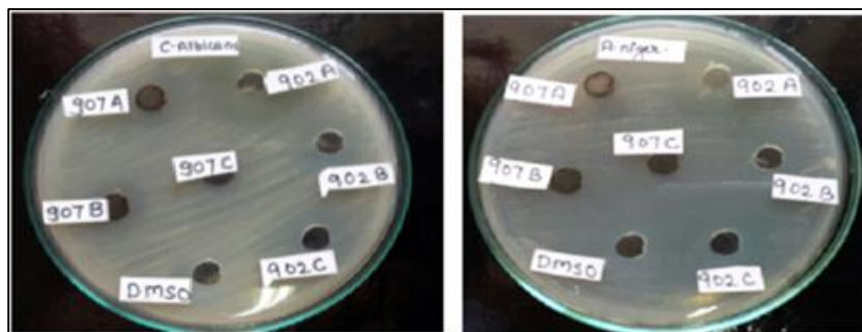
Complex	<i>E. coli</i> (ATCC25922)	<i>S. aureus</i> (ATCC 29737)	<i>A. niger</i> (MCIM 545)	<i>C. albicans</i> (MTCC 277)
C <sub>12</sub> H <sub>14</sub> CuO <sub>6</sub>	20 +/- 0.8	21 +/- 0.4	22 +/- 0.7	26 +/- 0.7
DMSO	11 ± 0.7	12 ± 0.9	12 ± 0.6	13 ± 0.3
Gentamicin	22 ± 0.4	23 ± 0.7	-	-
Fluconazole	-	-	23 ± 0.8	24 ± 0.5

Gentamicin (10 µg/ mL) and fluconazole (20 µg/ mL) Inhibition Zone= 9-14 mm: slight activity, 15-19 mm: moderate activity, 20 -24 mm : high activity, >25 mm: excellent activity NT: Not Tested

**Table 10:** Antimicrobial screening of complexes: MIC in µg / mL values

Complex	<i>Escherichia coli</i> (ATCC25922)	<i>Staphylococcus aureus</i> (ATCC 29737)	<i>Aspergillus niger</i> (MCIM 545)	<i>Candida albicans</i> (MTCC 277)
C <sub>12</sub> H <sub>14</sub> CuO <sub>6</sub>	10	10	10	10
Gentamicin	10	10	-	-
Fluconazole	-	-	20	20

Gentamicin (10 µg/ mL) and Fluconazole (20 µg/ mL), (MIC in µg / mL)=10 µg / mL: excellent activity, 20 µg / mL: moderate activity, 40 µg / mL: slight activity

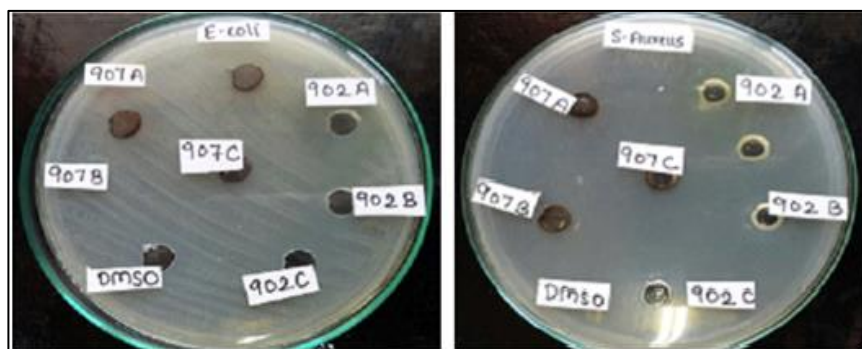


*C. albicans*

*A. niger*

The complex C<sub>12</sub>H<sub>14</sub>CuO<sub>6</sub> showed excellent antibacterial activity against *Escherichia coli* (ATCC25922) with MIC 20 µg/mL when compared with standard antibacterial drug Gentamicin (10 µg/mL). Similarly it also showed excellent anti fungal activities against

*Aspergillus niger* (MCIM 545), *Candida albicans* (MTCC 277) with MIC 10 µg/mL when compared with standard antifungal drug Fluconazole (20 µg/mL).<sup>[45]</sup>



*E. coli*

*S. aureus*

**Fig 11:** Biological Activity of 902 (C<sub>12</sub>H<sub>14</sub>CuO<sub>6</sub>)



## Conclusion

The novel copper (II) complex of  $\alpha$ -acetyl- $\gamma$  butyrolactone was synthesized as a ligand and were well characterized using various analytical tools viz. IR, UV, HRMS, elemental analysis, single crystal XRD, conductometer, physical constant etc. The Cu (II) complex was tested for antibacterial and antifungal activities by agar disc diffusion method and showed truly biological activities. The Cu (II) complex showed excellent catalytic activity towards Sonogashira and Suzuki coupling reactions.

## Supporting Information

CCDC reference number 1520126 contains the supplementary crystallographic data for this paper. This data can be obtained free of charge via [www.ccdc.cam.ac.uk](http://www.ccdc.cam.ac.uk) or from the crystallographic data centre, 12 union road, Cambridge CB2 1EZ UK.

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