Cu(I)-CATALYZED SINGLE STEP ONE-POT SYNTHESIS OF 1,4-DISUBSTITUTED TRIAZOLES USING DEEP EUTECTIC SOLVENT (DES)

By:

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I dedicate this research work to my parents, and my wife “Sani.”

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Last but not the least; I'm always grateful to my parents and wife who have provided me constant support and encouragement in the course of this project.

ABSTRACT

The synthesis of different 1,4-disubstituted-1,2,3-triazoles were carried out in a eco-friendly, cheap and readily available deep eutectic solvent (DES) (1 : 2 molar mixture of choline chloride and glycerol) which involve reaction between alkyl halides or aryl halides, terminal alkynes and NaN_3 in presence of Cu(I) catalyst at an ambient temperature giving moderate to high yield. The transformations involving alkyl halides and aryl halides as azide precursors were found to be less effective in DES (1 : 2 molar mixture of choline chloride and glycerol) because of its polar protic nature which decreases the nucleophilicity of nucleophiles via solvation. Interestingly, the use of an organic azide instead of azide precursor was found to give an excellent yield of the triazole products in DES. Aryl halide especially, bromobenzene and its derivative as aryl azide precursors are not generally effective, however this limitation can be overcome using *N,N'*-dimethylethylenediamine as a ligand for the transformation. High recyclability of the reaction medium was observed during the study. In addition, a drastic reduction in reaction time was observed for the reaction involving benzyl azide and phenylacetylene in the presence of excess sodium azide.

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CHAPTER I

INTRODUCTION

Click Chemistry, introduced by K. B. Sharpless in 1999[1], represents a group of powerful, highly reliable, and selective transformations. These methods of joining together the individual units are modeled on reactions observed in natural product biosynthetic pathways. It does not only concern the production of new compounds but production of properties that mimic nature in generating substances by joining small units together with heterocyclic links.[2]

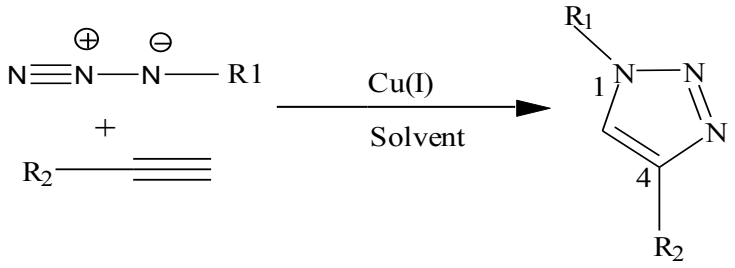
Sharpless and co-workers put forward some strict criteria about Click Chemistry: "the reaction must be modular, wide in scope, give very high yields, generate only inoffensive byproducts that can be removed by nonchromatographic methods, and be stereospecific (but not necessarily enantioselective). The required process characteristics include simple reaction conditions (ideally, the process should be insensitive to oxygen and water), readily available starting materials and reagents, the use of no solvent, or a solvent that is benign (such as water) or easily removed, and simple product isolation."[2] Simple purification methods such as crystallization or distillation must be employed if purification is needed. Click transformations are driven by a high thermodynamic force.[2] Its applications are rapidly increasing in the various aspects of life sciences and material science. It is also gaining special attention in the field of drug discovery. There are several classes of such reactions which meet the criteria of Click Reaction.

Classification of Click Reactions [1,2,3]

1. Cycloaddition reaction
    a. Huisgen 1,3-dipolar cycloaddition
        i. Thermal Huisgen reaction
        ii. Copper-catalyzed Huisgen reaction
    b. Diels-Alder reaction
2. Nucleophilic ring-opening reactions; includes openings of strained heterocyclic compounds, such as aziridines, epoxides, and cyclic sulphates.
3. Carbonyl chemistry of non-aldol type; includes formation of urea and thiourea, hydrazone, amides, and aromatic heterocycles.
4. Addition to carbon-carbon multiple bonds; includes epoxidations, dihydroxylations, nitrosyl halide additions, and certain Michael additions.

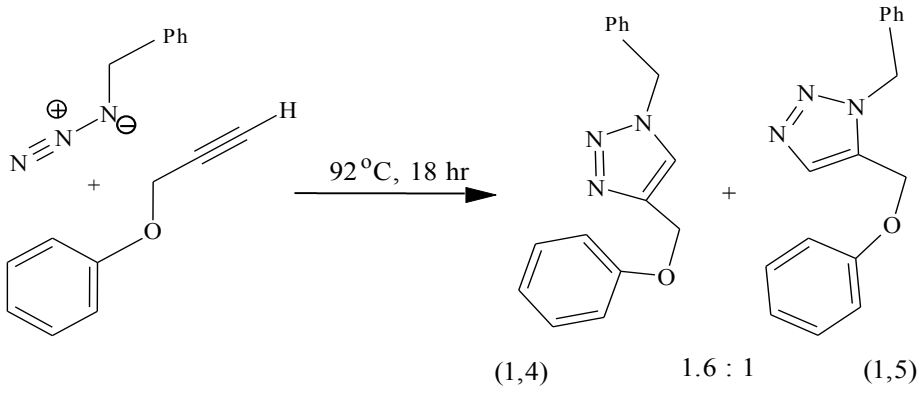
Copper-Catalyzed Huisgen Reaction (CuAAC)

Among the previously mentioned click transformations, Cu(I) catalyzed alkyne–azide cycloaddition (CuAAC), a copper catalyzed version of Huisgen dipolar cycloaddition that forms 1,2,3-triazoles, has appeared as the frontrunner. It is undoubtedly the premier Click Chemistry reaction in terms of applications[4] and has been referred to as "cream of the crop"[2] by Sharpless. This reaction involves treatment of an organic azide with a terminal alkyne in the presence of a Cu(I) catalyst and solvent, giving a 1,4-disubstituted 1,2,3-triazole (Scheme 1).



Scheme 1: Cu(I)-catalyzed alkyne-azide cycloaddition (CuAAC)

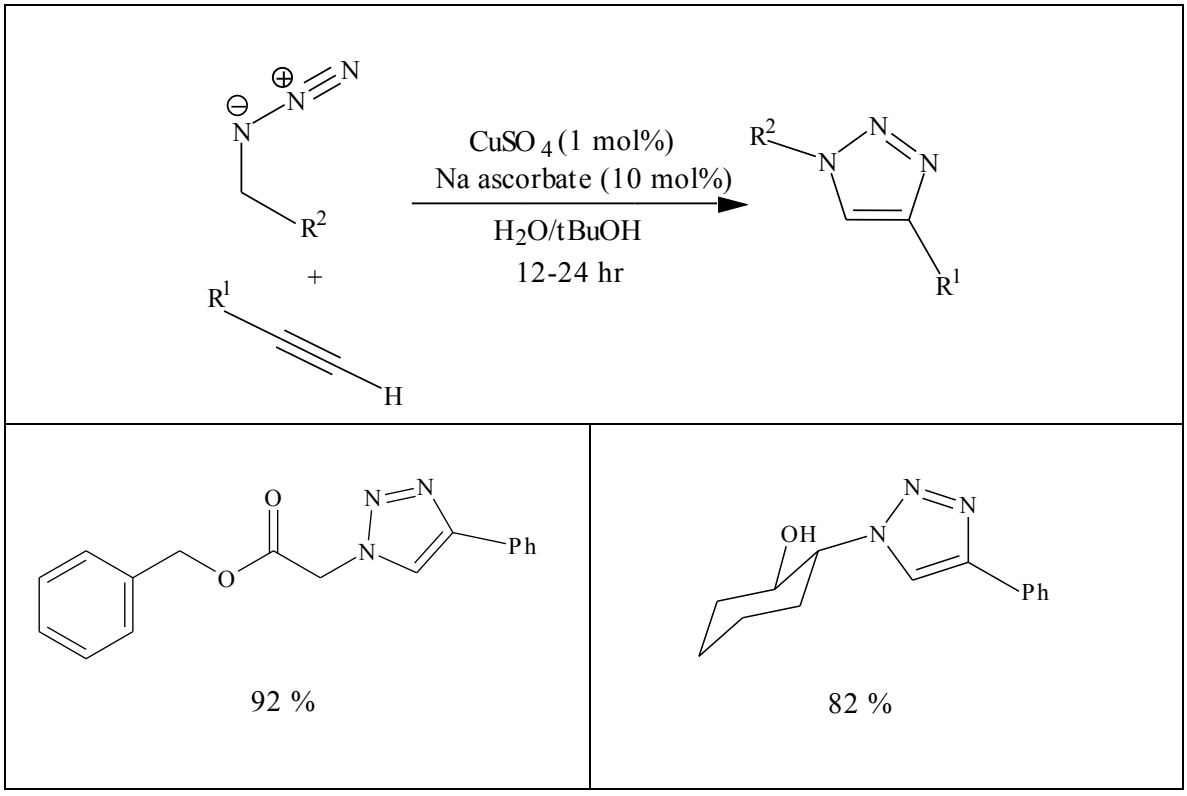
The relevancy of the Huisgen 1,3-dipolar cycloaddition reaction of azides and alkynes in the field of medicinal chemistry, biological and biomedical research,[5] and material science, gained popularity after the discovery that Cu(I) catalysis accelerated this transformation by up to 10^7 times.[6] Unlike the non-catalyzed thermal version (Scheme 2)[7], which gives very low regioselectivity between 1,4 and 1,5- disubstituted isomers, the special features such as exquisite selectivity and mild reaction conditions made it a powerful tool in multi-component reactions to prepare 1,2,3-triazoles with various functional groups.[8]

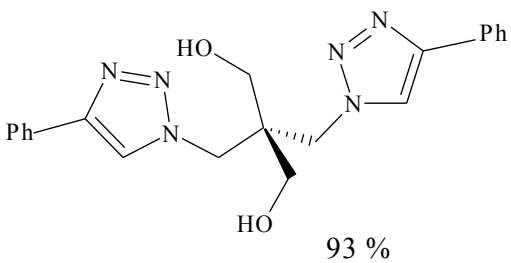
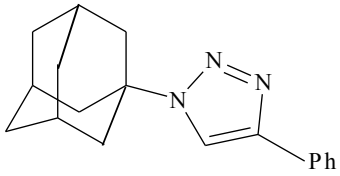
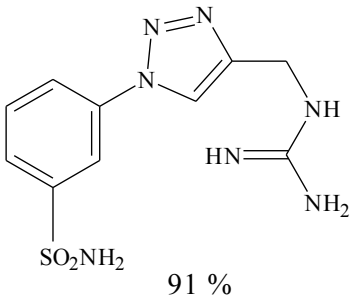
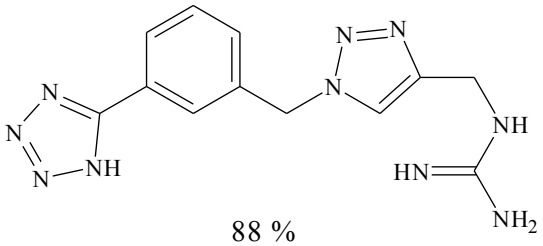
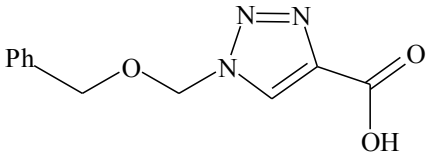
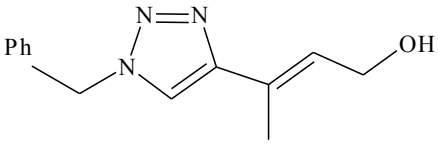
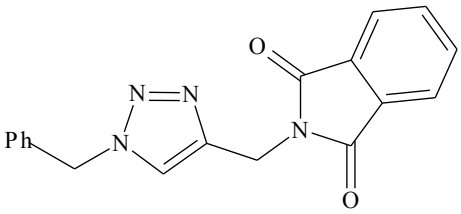
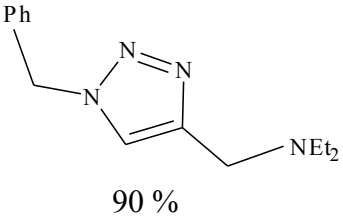


Scheme 2: Thermal Huisgen reaction

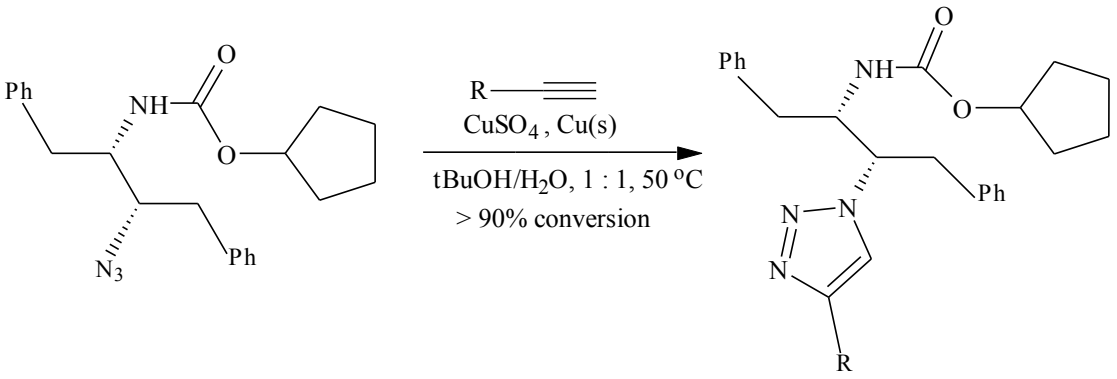
Because of the ease with which it proceeds in a variety of solvents and its tolerance for a wide range of pH and temperature,[9] as well as easy isolation of product, the Cu(I)-catalyzed Huisgen 1,3-dipolar cycloaddition is positioned apart from most other catalyzed processes. "Variously substituted primary, secondary, tertiary and aromatic azides readily participate in this transformation. Tolerance for variations in the acetylene component is also excellent."[7] This reaction is highly atom-economic (100%) and shows excellent functional group tolerance (Table 1).[7]

Table 1: Functional group tolerance



 93 %	 84 %
 91 %	 88 %
 88 %	 84 %
 88 %	 90 %

CuAAC chemistry has a great application in the field of peptide/protein modification, construction of fluorescent oligonucleotides for DNA sequencing, synthesis of biological inhibitors of HIV-1 protease (HIV-1PR) (Scheme 3)[10], combinatorial synthesis, polymer functionalization, and material/surface chemistry.[6]



Scheme 3: Synthesis of HIV Protease Inhibitors[10]

This efficient CuAAC reaction is especially useful for the construction of complex structures such as clusters (Figure 1)[11], dendrimers, macrocycles (Figure 2)[12] and polymers[6] (Figure 3). In all previously mentioned examples, various parts of these complex molecular constructions are fixed into position by the triazole ring.[13] Modification of DNA and nucleotides using CuAAC reaction has been widely utilized. It involves coupling of labels in DNA either at terminals or internally so that the intercellular distribution and binding properties of DNA, can be monitored as well as DNA-DNA interaction can be investigated. The reaction is compatible with completely deprotected DNA.[6]

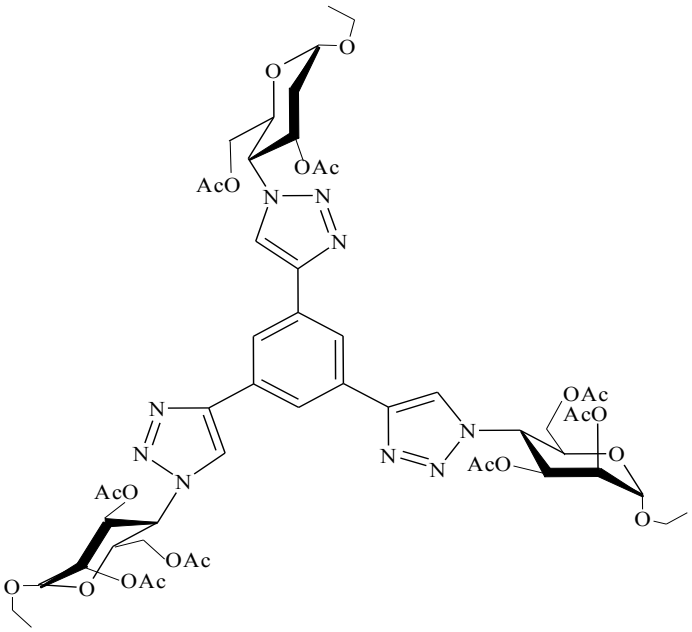


Figure 1: Carbohydrate cluster based on an aromatic core structure[11]

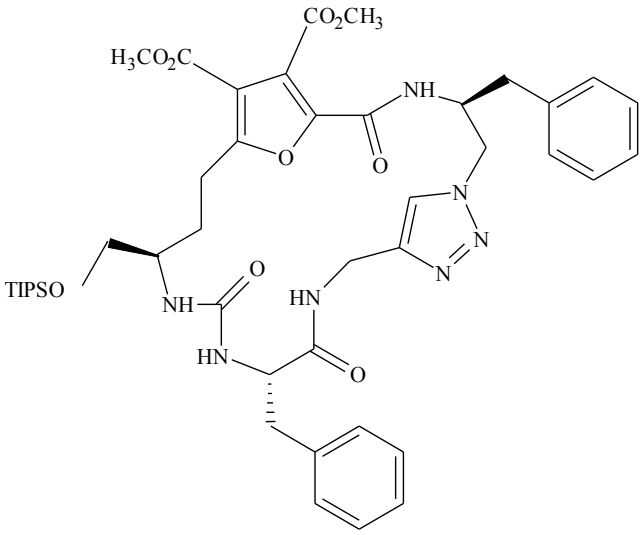


Figure 2: Peptide macrocycle[12] by CuAAC

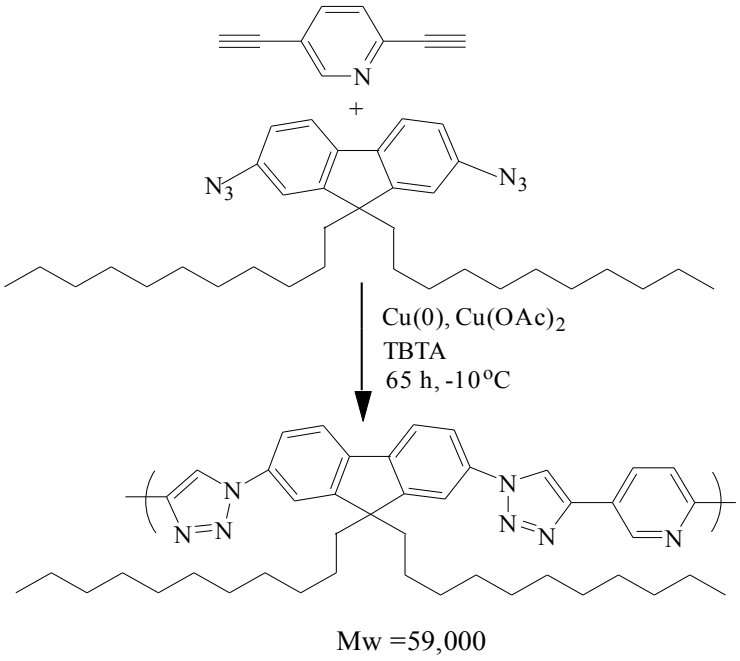
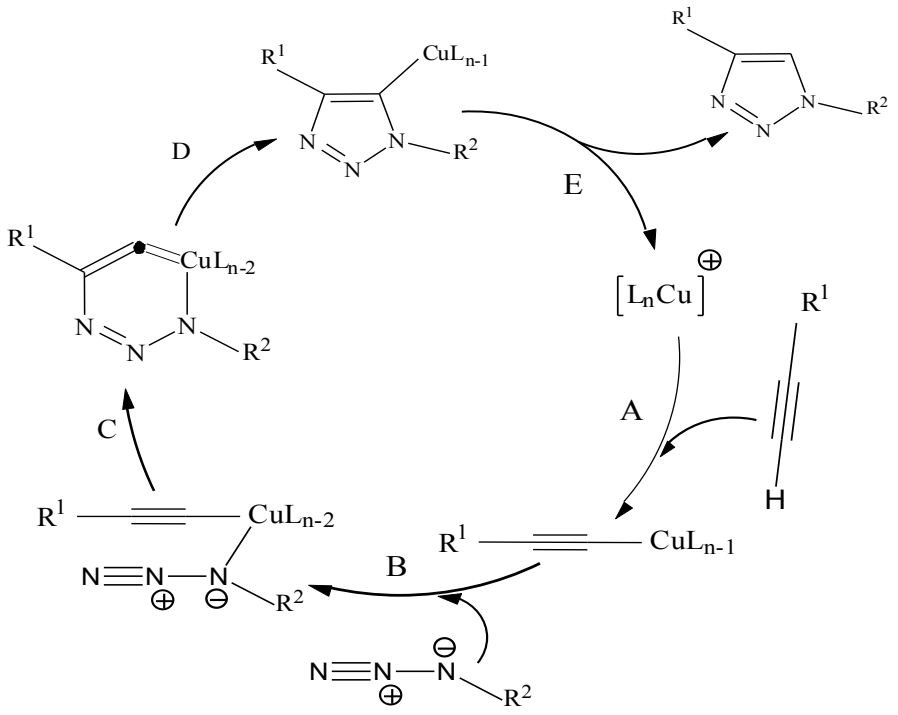


Figure 3: Conjugated polymers through CuAAC of bisazides with aromatic bisalkynes[6]

Proposed Mechanisms of CuAAC

Noodleman and co-workers in 2005, on the basis of Density Functional Theory (DFT) calculations, describe the Cu(I)-catalysis of the Huisgen 1,3-dipolar cycloaddition reaction of azides and alkynes and that it undergoes a stepwise reaction pathway (Scheme 4) instead of a concerted mechanism and is mediated by a single Cu atom in the +1 oxidation state. The Cu(I) species forms a pi-complex with the triple bond of a terminal alkyne *in situ*, followed by the formation of the acetylide. The Copper-acetylide complex coordinates the azide, which undergoes rearrangement into a six member metallocycle followed by ring contraction to a copper-metallated triazole, and finally releases the free triazole.[6,9]

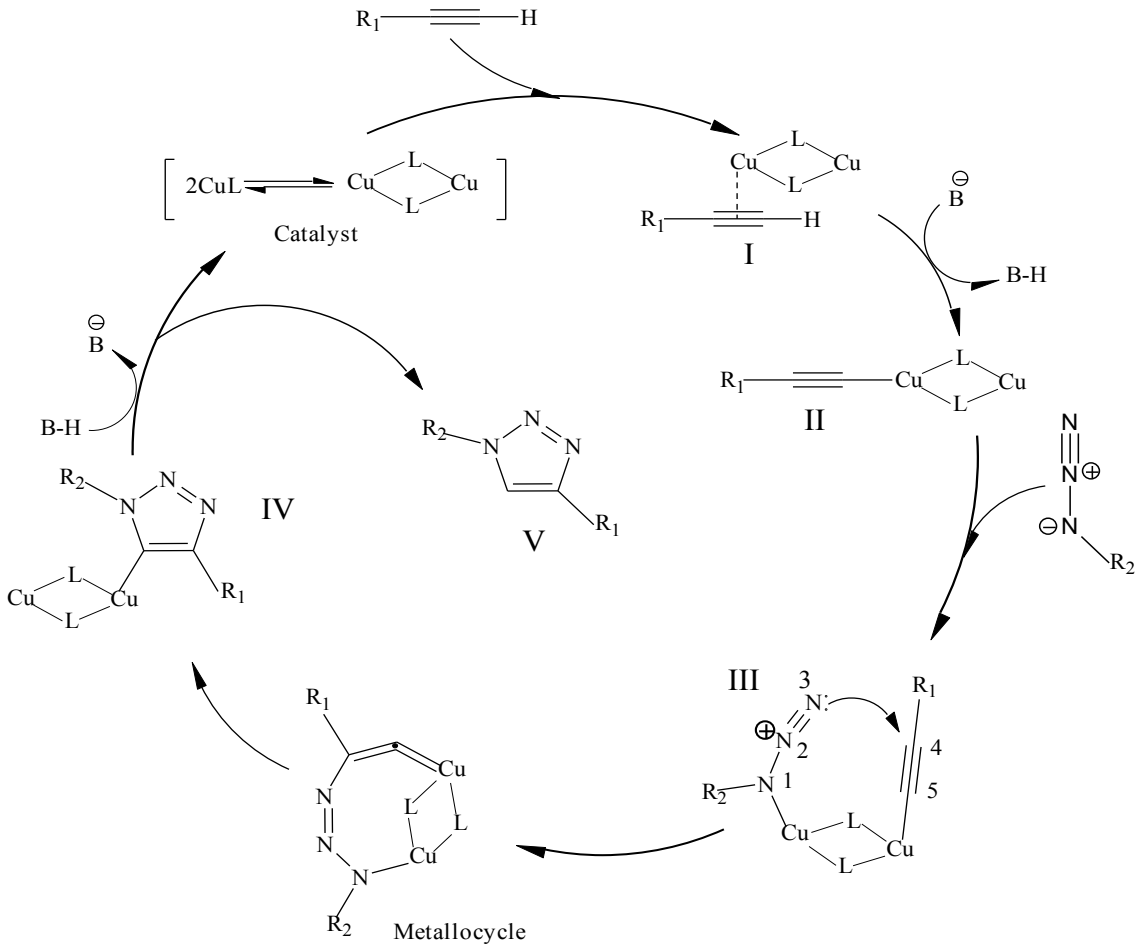


Scheme 4: Proposed mechanism[9] (mediated by a single Cu(I) species)

However, the observation of second order kinetics with respect to Cu(I)[14] suggested the transition state involves more than one Cu atom. The mechanism has been described to involve two copper atoms in the transition state in which one becomes attached to the terminal alkyne forming a Cu-acetylide whereas the other activates the organic azide.[6,14] It was further evidenced by the Straub's study, which explored the possibility of acetylide and azide being coordinated to different Cu atoms in the transition state (Scheme 5).[6,15]

During the reaction, π-complex (I) is formed, which dramatically lowers the p*K*a of the alkyne C-H and hence facilitates the removal of the terminal acidic hydrogen giving a Cu acetylide intermediate.[14,16] Formation of Intermediate (III) activates

nucleophilic attack by N(3) of azide on C(4) of alkyne undergoing cyclization that leads to the formation of a six-member metallocycle followed by ring contraction to give triazole (IV) (Scheme 5). Finally, the Cu(I) catalyst-ligand complex dissociates from the triazole (IV) after protonation giving 1,4-disubstituted triazole (V). The regenerated catalyst-ligand complex is utilized in further reaction cycles (Scheme 5).[1,14,16]



Scheme 5: Proposed mechanism[1,16] for the CuAAC reaction (Ligands are represented by "L")

Reactivity of Azides and Alkynes

The ease of this transformation depends on the reactivity of the substrate molecule. Low molecular weight organic azides are more reactive than the azide anion and at the same time they are prone to decomposition and are difficult to handle.[6] *In situ* generation of the organic azide is a good way to minimize these problems as the azide is consumed with copper acetylide during the course of reaction, finally giving 1,4-disubstituted triazoles. Different precursors such as alkyl or aryl halide, aniline or diazonium salts[17] can be used to generate organic azide in situ from inorganic azide (NaN_3). Solubility of the reactants throughout the process is an inevitable requirement for any reaction to go to completion.

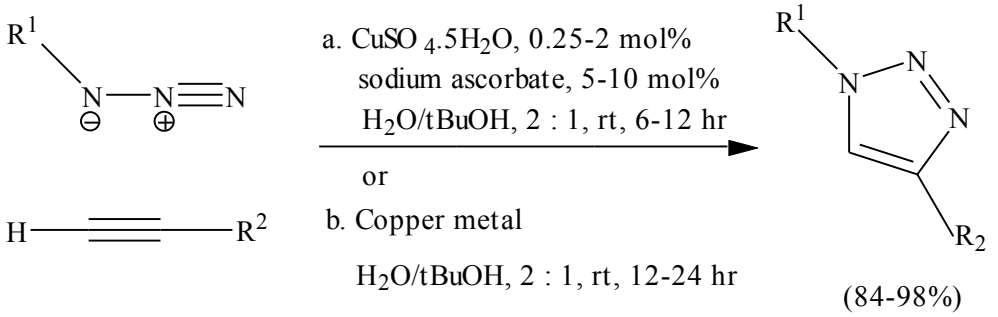
Different compounds have their own typical electronic environments that alter their reactivity. The reactivity of aromatic-alkynes is comparable or less than alkyl-alkynes whereas, α-carbonyl-alkynes are more reactive.[6,18] Allylic azides are prone to 1,3-sigmatropic rearrangement that competes with triazole formation. Among different substituted azides, tertiary azides show less preference for triazole formation over primary and secondary azides because of steric effects that lower the rate of reaction.[6] Reactivity of halides with halogen attached to sp^2 carbon such as, bromobenzene and chlorobenzene is relatively very low.

Sources of Cu(I) Catalyst and Solvents Employed

The Cu(I) catalyzed 1,3-dipolar reaction is an extraordinary reaction which can be performed under a wide range of conditions. The most common oxidation states of

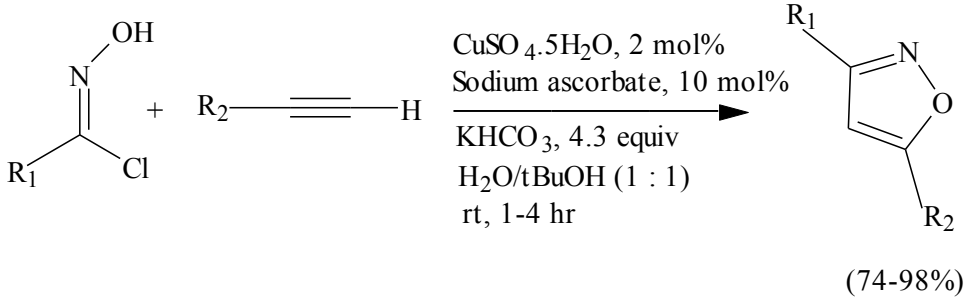
copper are 0, +1, and +2. Among these, +1 is the least stable. Different sources of active catalyst Cu(I) have been employed in the transformation to 1,2,3-triazoles in CuAAC reaction. The most common source is a Cu(II)/sodium ascorbate system[7,9,19-23] which was introduced by Fokin and co-workers (Scheme 6). Sodium ascorbate, a mild reducing agent, reduces readily available and stable Cu(II) salt such as $CuSO_4.5H_2O$ to the Cu(I) state (Scheme 6a). This method maintains a high concentration of Cu(I) at all times during the reaction which is very important for the reaction to go to completion effectively.[6,9]

In addition, the presence of ascorbate prevents formation of oxidative coupling products. These products are generally formed if the Cu(I) source is directly used in organic solvents.[9,23] There lies a possibility of reduction of Cu(I) to Cu(0), which can be prevented by using the proper ratio of catalyst to ascorbate or by adding tris-(hydroxypropyltriazolylmethyl)amine (THPTA) as a stabilizer.[16] The Cu(II)/Na ascorbate system is reported to be carried out in organic solvents such as CH_3CN/H_2O/ BuOH, *t*BuOH/ H_2O, DMF/H_2O, H_2O/THF, acetone/H_2O, and CH_2Cl_2/H_2O/MeOH.[6] Copper wire or shavings are also introduced in the reaction which generates Cu(I) *in situ* by comproportionation of Cu(II)/Cu(0) couple (Scheme 6b) as employed by the Sharpless group along with the Cu(II)/Na ascorbate system. Although it takes longer, this method provides pure triazole with very low copper contamination.[7,9,23] The reaction can be carried out in CH_3CN/H_2O, *t*BuOH/ H_2O, and DMF.[6]



Scheme 6: CuAAC reaction by using Cu(II)/ascorbate and Cu-metal systems

Also, they performed the reaction with nitrile oxide in the presence of Cu(I) catalyst which yielded 74-98% 3,5-disubstituted isoxazoles with exclusive regioselectivity within 1 hr at ambient temperature (Scheme 7). This outcome widened the scope of the reaction in the sense that it is not only limited to azide but works with other dipoles like nitrile oxide.[9]

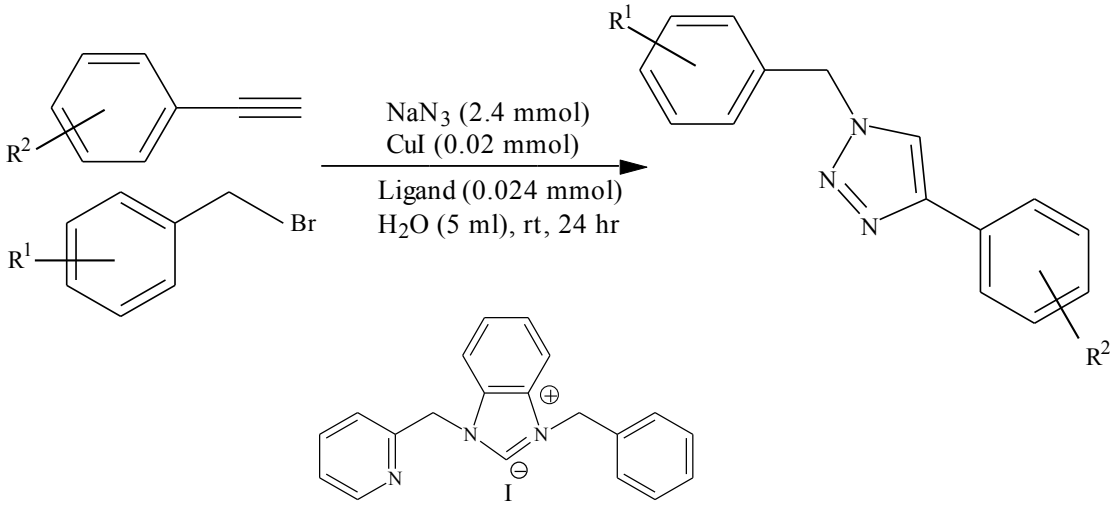


Scheme 7: Cu(I)-catalyzed synthesis of 3,5-disubstituted isoxazoles

Cu(I) salts (CuI and CuBr) are other frequent sources of Cu(I). These species are reported to be less active in forming Cu-acetylides in comparison to the Cu(II)/ascorbate system. According to the literature, CuI initially exists in stable clusters and before the

formation of a reactive complex, it requires a certain minimum concentration of acetylide anion. This can be achieved in the presence of an amine base or at high temperature.[6] CuAAC reaction in the presence of CuI, taking different alkynes and alkyl halides (azide precursors) in the medium of water[24] and ionic liquid/water system[8] have been reported to give good yield.

Kelei and co-workers performed the three component CuAAC reactions in the presence of CuI and benzimidozole ligands in water taking different alkyl halides and alkynes yielding 1,4-disubstituted triazoles in > 90% yield (Scheme 8).[25] The procedure involves low loading of copper.

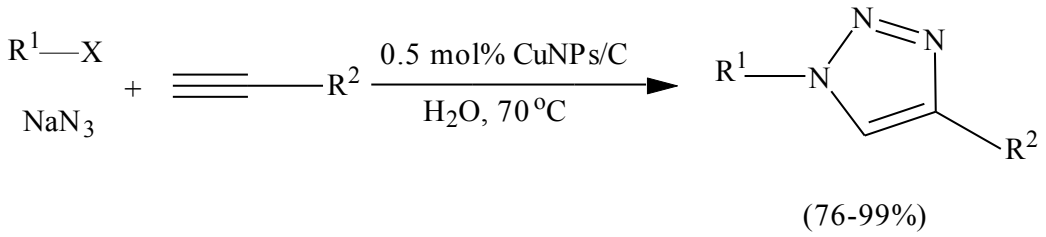


Ligand

Scheme 8: Synthesis of 1,4-disubstituted 1,2,3-triazole in water

$[Cu(CH_3CN)_4]PF_6$[7], $Cu(CH_3CN)_4OTf$[7], and $Cu(OAc)_2$[26] are also reported as sources of Cu(I) for some special cases. In 2007, Cu(I)-modified zeolites[27] which have

high concentration of active sites and are highly size selective, were reported as a catalyst in the Huisgen 1,3-dipolar reactions. Alonso and co-workers in 2011, introduced a catalyst consisting of oxidized copper nanoparticles on an activated carbon support (CuNPs)[17], which was readily prepared under mild conditions. In a three component CuAAC reaction catalysed by low copper loaded (0.5 mol%) CuNPs/C using different alkynes and alkyl halides (azide precursors), they obtained 76-99% yield of the triazole products (Scheme 9).[17]



Scheme 9: Three-component CuAAC reaction catalyzed by CuNPs/C

Common Ligands

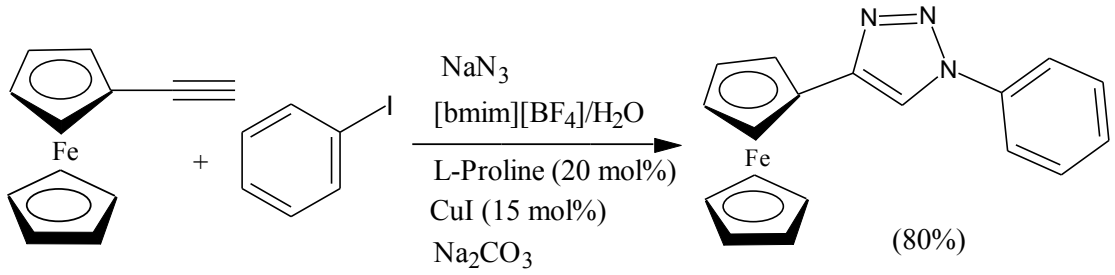
Although the ligand has no direct role in the reaction, it is effective for reaction outcome as it stabilizes the unstable Cu(I) catalyst. It protects the oxidation of Cu(I) to Cu(II), and also minimizes the formation of side product and functions as a proton acceptor.[28] Amine ligands have been employed in preventing the formation of unreactive polynuclear copper(I) acetylides. They also facilitate the ligand exchange step and help in maintaining the Cu(I) concentration in the solution by increasing the solubility of the copper complex and minimize the alkyne homocoupling problem.[23] Among various potential ligands, such as proline, *1S,2S*-bis(methylamino)hexane (BMAH), 2,6-lutidine,

pyridine, and bathophenanthrolinedisulphate (Batho), tris-(benzyltriazoylmethyl)amine (TBTA) is the one which has been widely employed in the CuAAC reaction but it is very expensive.[6]

One–Pot Cu(I)-Catalyzed Alkyne –Azide Cycloaddition

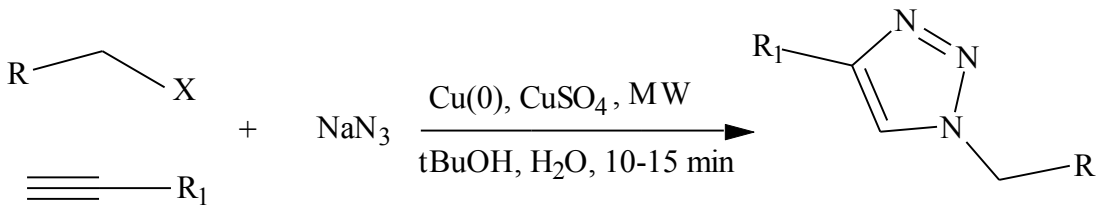
One of the most important limitations in organic synthesis is the number of steps. In general, more steps decrease the efficiency of the process. From a green chemistry point of view, the number of steps need to be reduced to a minimum and should be environmentally benign. One pot synthesis is one of the most appealing and effective alternatives. This method decreases the amount of waste by eliminating the intermediate recovery steps and generally, gives a higher yield than those obtained by a step-by-step procedure. The use of a green solvent and ambient temperature are also key characteristics to be considered.

In 2006, Liang's group explored the Huisgen reaction of ferrocenylacetylene which is interesting as ferrocene containing heterocyclic rings are reported to be useful in electrochemistry, biological sciences, and material science.[8] Reaction of iodobenzene (halide at sp^2 hybridized carbon) with ferrocenylacetylene and sodium azide catalyzed by Cu(I) in the presence of the ligand L-proline and in the medium of 1-butyl-3-methylimidazolium tetrafluoroborate [bimm][BF_4]/water system gave the desired product in 80% yield (Scheme 10). Nevertheless, the reaction was not successful with bromobenzene even at elevated temperature.[8]



Scheme 10: CuAAC reaction of ferocenylacetylene, halobenzene and sodium azide

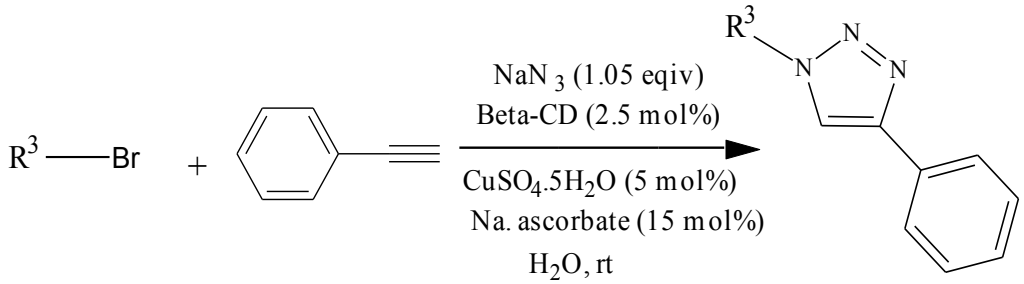
Fokin and co-workers in 2004, developed a microwave-assisted, three-component, one-pot procedure for the synthesis of 1,4- disubstituted 1, 2, 3-triazoles with 100% regioselectivity at 125 ^{o}C (Scheme 11) in which the Cu(I) catalyst was prepared *in situ* by comproportionation of a Cu(0)/Cu(II) couple.[29] Finally they found a drastic reduction in reaction time and easy isolation of products accompanied by better yield and exclusive regioselectivity although the reaction temperature was relatively high.



Scheme 11: Microwave-assisted one-pot synthesis of 1,4-disubstituted 1,2,3-triazoles

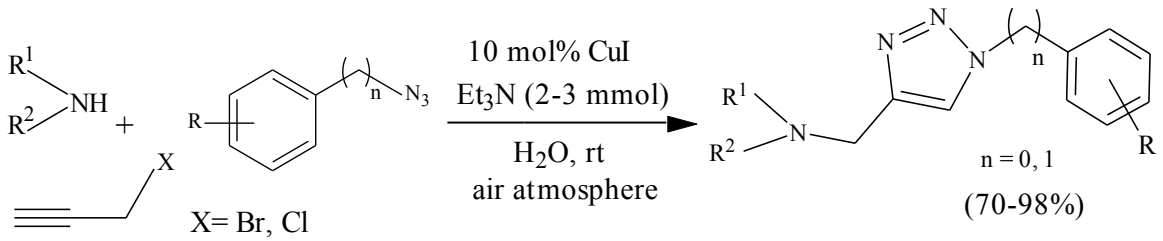
The use of water as a solvent offers hindrance in several reactions because of the limited solubility of organic compounds. A study by Lim and co-workers about the effect of phase transfer catalyst in the CuAAC reaction has been able to address this limitation of using water as a solvent. In the study, they found β-cyclodextrin (CD) works in

increasing the solubility of poorly soluble organic compounds simply by including water-insoluble organic molecules into its hydrophobic central cavity. On carrying out the reactions taking several bromides and phenylacetylene in the presence of $CuSO_4.5H_2O$/Na ascorbate and 2.5 mol% β-cyclodextrin (CD), excellent yields were obtained (up to 98%) at room temperature (Scheme 12).[30]



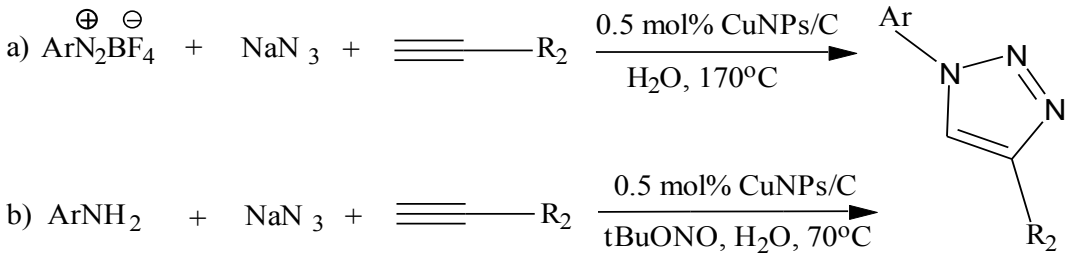
Scheme 12: One-pot synthesis of triazole from bromides

Synthesis of 5-aminomethyl-substituted 1,2,3-triazol-4-yl-*N,N*-dimethylmethaneamine hydrochloride analogues which are reported to be a human neurokinin-1 receptor, generally involved multiple steps.[31] Liang and co-workers in 2005 put forward a new protocol for the synthesis of (1-substituted-1*H*-1,2,3-triazol-4ylmethyl)-dialkylamines by a one-pot procedure from amines, propargyl halide and azides in the presence of CuI (10 mol%), excess Et_3N and water (Scheme 13). They also found that the two-step three-component reaction gave higher yield than the single step procedure because the formation of the propargylamines in the first step slowed down the oxidative coupling reaction.[31]



Scheme 13: Reaction of amines, propargyl halide and azides

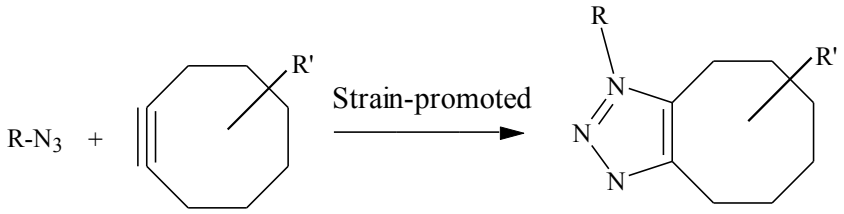
In 2011, Alonso and co-workers came up with two new methods that utilize diazonium salts or aniline as an aryl azide precursor.[17] They explored that the less reactive halides can be substituted by diazonium salts as azide precursors. Reaction between phenyldiazonium tetrafluoroborate and phenylacetylene in the presence of sodium azide and copper nanoparticles on activated carbon (CuNPs/C) as a catalyst was found to give 1,4-diphenyl-1,2,3-triazole in 85% yield. They obtained good yields for diazonium salts with the both electron withdrawing and donating substituents at the *para* position (Scheme 14a). Similarly, they used anilines as aromatic azide precursors and performed one-pot synthesis with tBuONO and NaN_3 in water which gave the desired products in 64-95% yield (Scheme 14b).[17]



Scheme 14: Protocols involving diazonium salts and aniline as an aryl azide precursors

Ju and co-workers in 2004 reported a catalyst-free protocol for the synthesis of 1,2,3-triazole from electron deficient internal or terminal alkynes. The reaction was found to proceed without catalyst at room temperature to afford the triazole products in 67-94% yield.[32] Because of the high reactivity of electron deficient alkynes, this transformation is prone to undesired side reactions.[1,33]

Bertozzi and co-workers in 2004 put forward an interesting scheme of incorporating an alkyne into an eight-member ring that results in a highly strained unstable cyclooctyne which can readily react with azide without catalyst giving triazole at room temperature (Scheme 15). Although the process is efficient energetically, it gives a racemic mixture.[1,33]



Scheme 15: Strain-promoted [3+2] cycloaddition of azides and cyclooctynes[33]

Deep Eutectic Solvent (DES)[34-40]

A deep eutectic solvent (DES) is a liquid composed of a mixture of two or three components that are cheap, safe, and also biodegradable, unlike traditional ionic liquids. There exists a self-association within the components through hydrogen bond interactions, forming an eutectic mixture which has a melting point much lower than either of the individual components. DESs and traditional ionic liquids share physico-

chemical properties. Generally, deep eutectic solvents are liquid at room temperature and are distinguished by a very large depression in melting point.[34]

Choline chloride (2-hydroxyethyl-trimethylammonium chloride) is the most common component of DES. It is a cheap and biodegradable quaternary ammonium salt which is mass produced as an important dietary additive in feed, especially for chickens. In most cases, DES is obtained by mixing a quaternary ammonium salt with a metal salt or a hydrogen bond donor (HDB) like urea, glycerol, and ethylene glycol and stirred at ~ 80^{o}C to obtain a homogeneous clear liquid.[34,35] Deep eutectic phenomenon was first explained by Abbott and coworkers in 2003 for a 1 : 2 molar mixture of Choline chloride (ChCl) and urea. Choline Chloride (mp 302 ^{o}C) and urea (mp 133 ^{o}C) form the eutectic mixture having a melting point of 12^{o}C which is significantly lower than the melting point of the individual components.[36] Similarly, a 1 : 2 molar mixture of choline chloride (ChCl) and glycerol is another DES that has melting point of -40 ^{o}C.[34] Many different combinations are possible which shows eutectic behavior. Choi and coworkers in 2011 reported more than 30 combinations of choline chloride, natural carboxylic acids, and sugars that form viscous liquids named “natural deep- eutectic solvents” (NADESs).[37]

This significant depression of the melting point is described to be a result of an interaction between the halide anion and the hydrogen bond donor component, urea or glycerol. The hydrogen bond strength of the different counterions of the choline salts influence the freezing points of Deep Eutectic Solvents.[36] The rapid decrease of the freezing point of the mixtures is also dependent on the molar ratio of the components.[38]

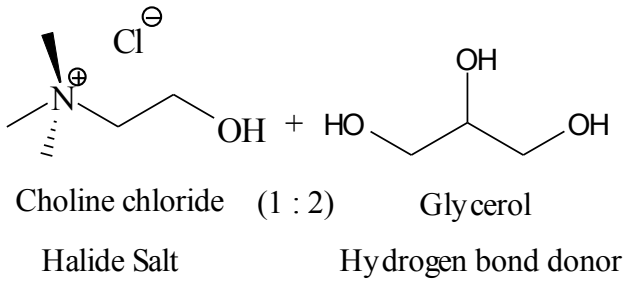
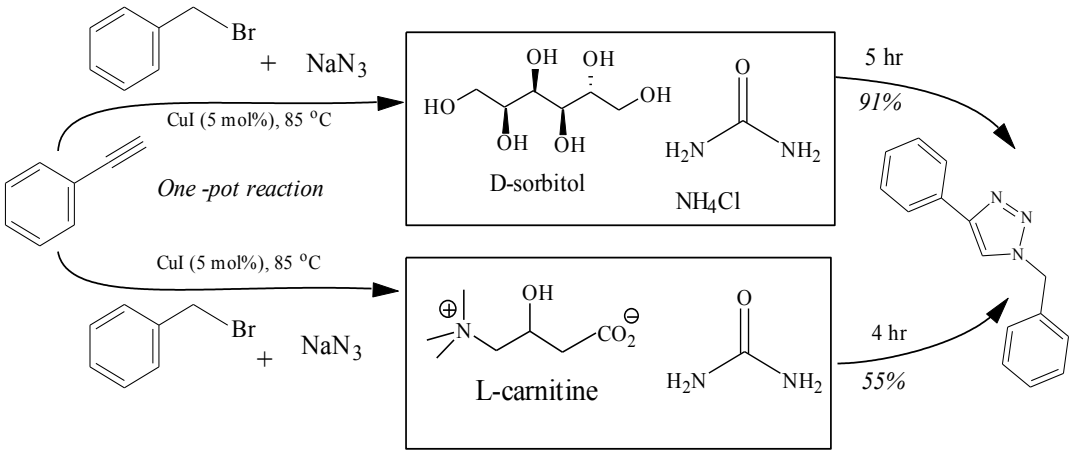


Figure 4: Deep Eutectic Solvent (DES)

Deep Eutectic mixtures have some genuine advantages over organic solvents and traditional ionic liquids particularly with respect to cost. The components of DES can be synthesized conveniently and economically in large scale, as a result of which they are readily available. Beside this, preparation of DES simply involves mixing of the components which cut off a tedious job of purification and waste disposal.[34] They can dissolve inorganic salts and also metal oxides.[39] They are chemically inert with water and have low vapor pressure and high boiling point. Many of their properties such as- being non-toxic, non-volatile, non-flammable, and biodegradable- illustrates their relevancy to Green Chemistry.[34]

There is little work reported using deep eutectic mixture as a solvent in CuAAC reaction. In 2009, Ilgen and Konig introduced a 7 : 2 : 1 mixture of D-sorbitol, urea and NH_4Cl respectively, as a solvent and 5 mol% CuI as a catalyst in a one-pot synthesis yielding 93% of 1,4-disubstituted 1,2,3-triazole in 5 hrs. This reaction gave about a 55% yield under the same conditions with another deep eutectic solvent (DES), L-Carnitine-urea (Scheme 16).[40]



Scheme 16: CuAAC reaction in D-sorbitol/urea/NH_4Cl or L-carnitine/urea melts

Current Project

The current project is concerned with the methodological development of the CuAAC reaction, a premier reaction in the field of triazole synthesis. Use of a cheap, readily available, recyclable, and non-toxic solvent is one of the genuine issues regarding the green synthesis of triazoles. In this project we are focused on the one-pot synthesis of 1,4-disubstituted 1,2,3-triazole using a mixture of choline chloride and glycerol (1 : 2 molar ratio), an eco- friendly Deep Eutectic Solvent. This method involves *in situ* generation of organic azides which ultimately reacts with terminal alkyne giving a desired triazole. Commonly, alkyl halides are employed as azide precursors. Except for iodobenzene, there is no literature on the use of aryl halides as an azide precursor to the best of our knowledge. In this study we have explored the possibility of use of the bromobenzene and its derivatives as an azide precursor in a single step one-pot CuAAC

reaction. This is remarkable in the sense that bromobenzene is less expansive, more stable, and less hazardous than iodobenzene.

Another important focus of our study lies on the study of the recyclability of the reaction medium that involves a mixture of Deep Eutectic Solvent (1:2 mixture of choline chloride and glycerol), catalyst and ligand (*N,N'*-dimethylethylenediamine). Here, we are studying a possibility of the use of DES in the CuAAC reaction instead of traditional organic solvents and ionic liquids which are generally expensive and suffer from environmental issues.

CHAPTER II

EXPERIMENTAL

General - ^{1}H and ^{13}C NMR of all the compounds were recorded on JEOL AS 500 MHz NMR and chemical shifts were taken in ppm. $CDCl_3$ was used as a solvent. All the chemical shifts were recorded taking $CDCl_3$ as a standard reference.[41] Varian 8000 FT-IR was used to collect IR spectra. All the extracts were concentrated under reduced pressure using Buchi Rotary Evaporator. During purification and identification of compounds, Thin Layer Chromatography (TLC) was performed on silica coated TLC plates and it was monitored by short wavelength (254 nm) UV light and Flash Column Chromatography was performed using neutral alumina and silica gel. ACS grade reagents were employed during the experiments.

4-phenyl-1-(2-propen-1-yl)-1*H*-1,2,3-triazole[30] (Table 5, Entry 1)

To a reaction vessel, 0.102 g (1 mmol) phenyl acetylene, 0.121 g (1 mmol) allyl bromide, 0.072 g (1.1 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, and 2.0 mL solvent (1 : 2 molar mixture of choline chloride/glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The resulting mixture was extracted with EtOAc (100 mL) and concentrated *in vacuo*. The obtained residue was subjected to flash column chromatography, first eluting with 20% EtOAc in hexane (80 mL) and then with 50% EtOAc in hexane (50 mL) affording 56 mg (30%) of the desired product as a white solid having a melting point of 56-57 ^{o}C

(lit.[30] 56-58 ^{o}C). In presence of (0.2 mmol) ligand (N,N'-Dimethylethylenediamine), 71 mg (38%) of the desired product was obtained. ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.83 (d, *J* = 6.87 Hz, 2H), 7.76 (s, 1H), 7.42 (t, *J* = 7.45 Hz, 2H), 7.33 (t, *J* = 7.45 Hz, 1H), 6.11-6.03 (m, 1H), 5.39 (d, *J* = 10.31 Hz, 1H), 5.35 (d, *J* = 17.18 Hz, 1H), 5.03 (d, *J* = 6.30 Hz, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ 148.4, 131.6, 130.8, 129.2, 128.5, 126.1, 120.6, 119.7, 53.1. IR (neat) 3130, 2923, 1644, 1462, 1415, 1332, 1290, 1217, 1173, 1106, 1072, 1049, 988, 938, 827, 762, 692 cm^{-1}.

1-benzyl-4-phenyl-1*H*-1,2,3-triazole[42] (Table 5, Entry 2)

To a reaction vessel, 0.102 g (1 mmol) phenylacetylene, 0.171 g (1 mmol) benzyl bromide, 0.072 g (1.1 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred for 9 hrs. The resulting mixture was first extracted with EtOAc and concentrated *in vacuo*. The resulting white solid residue was purified by flash column chromatography using 20% EtOAc in hexane affording 120 mg (51%) of the desired product as an off- white solid with a melting point of 118-120 ^{o}C (lit.[42] 132.0-133.1 ^{o}C). In presence of (0.2 mmol) ligand (N,N'-Dimethylethylenediamine), 113 mg (48%) of the desired product was obtained. ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.80 (d, *J* = 6.87 MHz, 2H), 7.66 (s, 1H), 7.41-7.36 (m, 5H), 7.33-7.30 (m, 3H), 5.57 (s, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 148.8, 134.9, 130.8, 129.3, 129.0, 128.9, 128.3, 128.2, 125.8, 119.6, 54.4. IR (neat) 3142, 2929, 2837, 1606, 1555, 1492, 1449, 1359, 1246, 1174, 1105, 1044, 970, 923, 729 cm^{-1}.

1-methyl-4-phenyl-1*H*-1,2,3-triazole[24] (Table 5, Entry 3)

To a reaction vessel, 0.102 g (1 mmol) phenyl acetylene, 0.142 g (1 mmol) methyl iodide, 0.072 g (1.1 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred for 9 hr. The resulting mixture was first extracted with EtOAc (90 mL) and concentrated *in vacuo*. The resulting solid residue was purified by flash column chromatography with 20% EtOAc in hexane (80 mL) followed by 50% EtOAc in hexane (60 mL) affording 112 mg (70%) of the desired product as a white solid with a melting point of 100-103 ^{o}C (lit.[24] 126-127 ^{o}C). In presence of (0.2 mmol) ligand (N,N'-Dimethylethylenediamine), 116 mg (73%) of the desired product was obtained. ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.80 (d, J = 7.45 Hz, 2H), 7.72 (s, 1H), 7.40 (t, J = 7.45 Hz, 2H), 7.31 (t, J = 7.45 Hz, 1H), 4.10 (s, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 148.2, 130.9, 129.1, 128.4, 125.9, 120.9, 37.0. IR (neat) 3140, 2946, 1490, 1450, 1362, 1219, 1192, 1076, 1045, 972, 920, 838, 767, 723 cm^{-1}.

4-(1-cyclohexen-1-yl)-1-(phenylmethyl)-1*H*-1,2,3-triazole[43] (Table 5, Entry 4)

To a reaction vessel, 0.106 g (1 mmol) 1-ethynyl-1-cyclohexene, 0.171 g (1 mmol) benzyl bromide, 0.072 g (1.1 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath. The reaction mixture was heated for overnight at 65 ^{o}C over a magnetic hot plate with constant stirring. The resulting mixture was extracted with EtOAc (100 mL) and concentrated *in vacuo*. The resulting solid residue was purified by

flash column chromatography with 10% EtOAc in hexane (50 mL) followed by 30% EtOAc in hexane (90 mL) affording 120 mg (51%) of the desired product as a white solid with a melting point of 74-77 ^{o}C (lit.[43] 87-89 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.33-7.30 (m, 4H), 7.24-7.22 (m, 2H), 6.48-6.46 (m, 1H), 5.47 (s, 2H), 2.34-2.31 (m, 2H), 2.17-2.14 (m, 2H), 1.73-1.69 (m, 2H), 1.65-1.60 (m, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 150.1, 135.2, 129.2, 128.8, 128.1, 127.5, 125.2, 118.5, 54.2, 26.5, 25.5, 22.3, 22.4. IR (neat) 3101, 2926, 1550, 1494, 1451, 1362, 1332, 1216, 1173, 1137, 1068, 1045, 972, 919, 835, 767, 733, 707 cm^{-1}.

4-(1-cyclohexen-1-yl)-1-methyl-1*H*-1,2,3-triazole (Table 5, Entry 5)

To a reaction vessel, 0.106 g (1 mmol) 1-ethynyl-1-cyclohexene, 0.142 g (1 mmol) methyl iodide, 0.072 g (1.1 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted by EtOAc (80 mL) and concentrated *in vacuo*. The resulting solid residue was purified by flash column chromatography with 20% EtOAc in hexane (80 mL) followed by 50% EtOAc in hexane (90 mL) affording 110 mg (67%) of the desired product as a brown liquid. In presence of (0.2 mmol) ligand (N,N'-Dimethylethylenediamine), 108 mg (66%) of the desired product was obtained. ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.34 (s, 1H), 6.45-6.42 (m, 1H), 4.01 (s, 3H), 2.34-2.30 (m, 2H), 2.17-2.13 (m, 2H), 1.74-1.69 (m, 2H), 1.64-1.59 (m, 2H). ^{13}C NMR ($CDCl_3$, 125

MHz) δ = 149.9, 127.5, 125.1, 119.6, 36.8, 26.6, 25.4, 22.7, 22.4. IR (neat) 3140, 2928, 1658, 1541, 1446, 1222, 1170, 1054, 907, 800 cm^{-1}.

1-benzyl-4-butyl-1*H*-1,2,3-triazole[42] (Table 5, Entry 6)

To a reaction vessel, 0.083 g (1 mmol) 1-hexyne, 0.171 g (1 mmol) benzyl bromide, 0.072 g (1.1 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred 9 hrs. The reaction mixture was first extracted by EtOAc (70 mL) and concentrated *in vacuo*. The resulting solid residue was purified by flash column chromatography with 10% EtOAc in hexane (40 mL) followed by 30% EtOAc in hexane (100 mL) affording 135 mg (62%) of the desired product as a waxy solid having a melting point of 48-50 ^{o}C (lit.[42] 62.0-63.1 ^{o}C). In presence of (0.2 mmol) ligand (N,N'-Dimethylethylenediamine), 143 mg (66%) of the desired product was obtained. ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.38-7.31 (m, 3H), 7.25-7.23 (m, 2H), 7.17 (s, 1H), 5.47 (s, 2H), 2.67 (t, *J* = 7.45 Hz, 2H), 1.65-1.57 (m, 2H), 1.38-1.32 (m, 2H), 0.89 (t, *J* = 7.45 Hz, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 149.1, 135.2, 129.1, 128.6, 128.0, 120.7, 54.0, 31.6, 25.5, 22.4, 13.9. IR (neat) 3102, 2925, 1550, 1494, 1450, 1332, 1215, 1174, 1128, 1046, 972, 919, 835, 730, 705 cm^{-1}.

1,4-diphenyl-1*H*-1,2,3-triazole[22] (Table 3, Entry 1)

To a reaction vessel, 0.102 g (1 mmol) phenylacetylene, 0.157 g (1mmol) bromobenzene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2

mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The resulting mixture was extracted by EtOAc and concentrated in vacuo. The residue obtained was purified by flash column chromatography. It was eluted with 10% EtOAc in hexane (50 mL) followed by 50% EtOAc in hexane (110 mL) which gave 195 mg (88%) of the desired product as a white solid having a melting point of 160-164 ^{o}C (lit.[22] 165-171 ^{o}C). When the same reaction was carried out using iodobenzene instead of bromobenzene, 203 mg (92%) of the desired product (1,4-diphenyl-1*H*-1,2,3-triazole) was obtained. ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 8.20 (s, 1H), 7.91 (d, J = 6.87 Hz, 2H), 7.79 (d, J = 7.45 Hz, 2H), 7.55 (t, J = 7.45 Hz, 2H), 7.47-7.44 (m, 3H), 7.37 (t, J = 7.45 Hz, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 148.7, 137.4, 130.5, 130.1, 129.2, 129.1, 128.7, 126.2, 120.8, 117.9. IR (neat) 3053, 2160, 1597, 1501, 1465, 1414, 1227, 1073, 1040, 993, 909, 826, 754 cm^{-1}.

1-(4-methoxyphenyl)-4-phenyl-1*H*-1,2,3-triazole[44] (Table 3, Entry 2)

To a reaction vessel, 0.102 g (1 mmol) phenylacetylene, 0.187 g (1 mmol) 4-bromoanisole, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted by EtOAc and concentrated *in vacuo*. The resulting residue was

purified by flash column chromatography. It was eluted with 10% EtOAc in hexane (50 mL) followed by 50% EtOAc in hexane (110 mL) which gave 102 mg (40%) of the desired product as a white solid having melting point of 138-140 ^{o}C (lit.[44] 155-159 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 8.11 (s, 1H), 7.90 (d, J = 6.87 Hz, 2H), 7.67 (d, J = 9.16 Hz, 2H), 7.45 (t, J =7.45 Hz, 2H), 7.35 (t, J = 7.45, 1H), 7.02 (d, J = 9.16 Hz, 2H), 3.87 (s, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 160.1, 148.5, 130.8, 130.7, 129.2, 128.6, 126.1, 122.5, 118.2, 115.1, 55.9. IR (neat) 3122, 2922, 1609, 1552, 1516, 1479, 1458, 1248, 1229, 1172, 1108, 1071, 1028, 911, 826, 766 cm^{-1}.

4-phenyl-1-(2-thienyl)-1*H*-1,2,3-triazole[45] (Table 3, Entry 3)

To a reaction vessel, 0.102 g (1 mmol) phenylacetylene, 0.163 g (1 mmol) 2-bromthiophene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted with EtOAc (100 mL) and concentrated *in vacuo*. The resulting residue was purified by flash column chromatography. It was eluted with 10% EtOAc in hexane (80 mL) followed by 50% EtOAc in hexane (100 mL) which gave 105 mg (46%) of the desired product as an off-white solid having melting of 124-127 ^{o}C (lit.[45] 136-139 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 8.10 (s, 1H), 7.89 (d, J = 7.45 Hz, 2H), 7.45 (t, J = 7.45 Hz, 2H), 7.37 (t, J = 6.87 Hz, 1H), 7.29 (dd, J = 4.01, 1.15 Hz, 1H), 7.24 (d, J = 5.73 Hz, 1 H), 7.05 (dd, J = 5.15, 4.01 Hz, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 148.5,

138.7, 130.1, 129.3, 128.9, 126.6, 126.3, 123.2, 119.2, 118.5. IR (neat) 3102, 2921, 1608, 1554, 1517, 1467, 1404, 1229, 1070, 1026, 969, 946, 909, 815, 760 cm^{-1}.

4-phenyl-1-(3-thienyl)-1*H*-1,2,3-triazole[44] (Table 3, Entry 4)

To a reaction vessel, 0.102 g (1 mmol) phenylacetylene, 0.163 g (1 mmol) 3-bromthiophene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted with EtOAc (100 mL) and concentrated *in vacuo*. The resulting residue was purified by flash column chromatography. It was eluted with 10% EtOAc in hexane (70 mL) followed by 50% EtOAc in hexane (120 mL) which gave 130 mg (57%) of the desired product as an off-white solid having melting point of 146-148 ^{o}C (lit.[44] 164-166 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 8.11 (s, 1H), 7.90-7.88 (m, 2H), 7.61 (dd, J = 3.44, 1.72 Hz, 1H), 7.52 (dd, J = 5.15, 1.72 Hz, 1H), 7.48-7.43 (m, 3H), 7.38-7.35 (m, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 148.3, 136.2, 130.4, 129.3, 128.8, 127.6, 126.2, 121.2, 118.3, 114.5. IR (neat) 3102, 2922, 1657, 1557, 1471, 1446, 1230, 1074, 1041, 972, 916, 887, 853, 762, 690 cm^{-1}.

4-hydroxymethyl-1-phenyl-1*H*-1,2,3-triazole[46] (Table 3, Entry 5)

To a reaction vessel, 0.056 g (1 mmol) propargyl alcohol, 0.204 g (1 mmol) iodobenzene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture

of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The resulting mixture was extracted with EtOAc (100 mL) and concentrated *in vacuo.* The resulting residue was purified by flash column chromatography. It was eluted with 50% EtOAc in hexane (100 mL) followed by EtOAc (80 mL) to afford 133 mg (76%) of the desired product as an off-white solid (mp 93-95 ^{o}C, lit.[46] 110-112 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.80 (s, 1H), 7.71 (d, J = 8.02 Hz, 2H), 7.51 (t, J = 6.87 Hz, 2H), 7.43 (d, J = 7.45 Hz, 1H), 4.90 (s, 2H), 3.03 (s, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 148.9, 137.3, 130.1, 129.2, 120.9, 120.4, 56.8. IR (neat) 3371, 3188, 2921, 2852, 1594, 1499, 1465, 1349, 1237, 1173, 1004, 905, 814, 754, 684 cm^{-1}.

4-(1-cyclohexen-1-yl)-1-phenyl-1*H*-1,2,3-triazole[22] (Table 3, Entry 6)

To a reaction vessel, 0.106 g (1mmol) 1-ethynyl-1-cyclohexene, 0.157 g (1 mmol) bromobenzene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred for 9 hrs. The reaction mixture was extracted by EtOAc (60 mL) and concentrated *in vacuo*. The resulting residue obtained was purified by flash column chromatography. It was eluted with 10% EtOAc in hexane (30 mL) followed by 20% EtOAc in hexane (100 mL) to afford 110 mg (48%) of the desired product as a white solid (mp 86-89 ^{o}C, lit.[22] 90-91 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.81 (s, 1H), 7.70 (d, J = 7.45 Hz, 2H), 7.47 (t, J = 7.45 Hz, 2H),

7.37 (t, J = 7.45 Hz, 1H), 6.61-6.60 (m, 1H), 2.42-2.39 (m, 2H), 2.22-2.18 (m, 2H), 1.79-1.74 (m, 2H), 1.69-1.64 (m, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 150.3, 137.4, 129.9, 128.6, 127.1, 125.9, 120.5, 116.5, 26.6, 25.5, 22.7, 22.4. IR (neat) 3116, 3057, 2920, 1659, 1597, 1535, 1499, 1465, 1330, 1229, 1193, 1134, 1071, 1037, 992, 913, 813, 761, 690 cm^{-1}.

4-butyl-1-phenyl-1*H*-1,2,3-triazole[47] (Table 3, Entry 7)

To a reaction vessel, 0.082 g (1 mmol) 1-hexyne, 0.204 g (1 mmol) iodobenzene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted with EtOAc (60 mL) and concentrated *in vacuo.* The resulting residue was purified by flash column chromatography. It was eluted with hexane (30 mL) followed by 20% EtOAc in hexane (70 mL) to afford 196 mg (97%) of the desired product as a light yellow liquid (lit.[47] white solid, 44-46 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.71 (s, 1H), 7.69-7.67 (m, 2H), 7.45 (t, J = 7.45 Hz, 2H), 7.37 (t, J = 7.45 Hz, 1H), 2.76 (t, J = 7.45 Hz, 2H), 1.68 (quintet, J = 7.45 Hz, 2 H), 1.39 (sextet, J = 8.02 Hz, 2H), 0.92 (t, J = 7.16 Hz, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 149.0, 137.2, 129.6, 128.3, 120.2, 119.0, 31.5, 25.3, 22.3, 13.8. IR (neat) 3135, 3071, 2927, 2858, 1598, 1553, 1501, 1465, 1420, 1227, 1040, 987, 908, 754, 688 cm^{-1}.

4-(4-methoxyphenyl)-1-phenyl-1*H*-1,2,3-triazole[17] (Table 3, Entry 8)

To a reaction vessel, 0.133 g (1mmol) 4-ethynylanisole, 0.157 g (1 mmol) bromobenzene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred for 9 hrs. The reaction mixture was extracted with EtOAc (70 mL) and concentrated *in vacuo*. The resulting residue was purified by flash column chromatography. It was eluted with 20% EtOAc in hexane (70 mL) followed by 50% EtOAc in hexane (110 mL) to afford 126 mg (50%) of the desired product as an off-white solid (mp 140-142 ^{o}C, lit.[17] 152.5-154.5 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 8.11 (s, 1H), 7.83 (d, J = 8.59 Hz, 2H), 7.77 (dd, J = 8.59, 1.15 Hz, 2H), 7.53 (t, J = 7.45 Hz, 2H), 7.43 (t, J = 7.45 Hz, 1H), 6.98 (d, J = 8.59 Hz, 2H), 3.84 (s, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 160.1, 148.5, 137.3, 130.0, 128.9, 127.5, 123.2, 120.7, 117.1, 114.6, 55.6. IR (neat) 3106, 2928, 2836, 1559, 1492, 1463, 1409, 1350, 1303, 1239, 1175, 1105, 1075, 1033, 993, 912, 761, 689 cm^{-1}.

4-(1-hydroxycyclopentyl)-1-phenyl-1*H*-1,2,3-triazole (Table 3, Entry 9)

To a reaction vessel, 0.110 g (1 mmol) 1-ethynylcyclopentanol, 0.157 mL (1 mmol) bromobenzene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction

mixture was extracted by EtOAc (90 mL) and concentrated *in vacuo*. The resulting residue was purified by flash column chromatography. It was eluted with 20% EtOAc in hexane (50 mL) followed by 50% EtOAc in hexane (120 mL) to afford 130 mg (58%) of the desired product as a white solid (mp 120-123^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.92 (s, 1H), 7.73 (dd, *J* = 8.59, 1.15 Hz, 2H), 7.52 (t, *J* = 7.45 Hz, 2H), 7.44 (t, *J* = 7.45 Hz, 1H), 2.48-2.17 (m, 2H), 2.09-1.97 (m, 4H), 1.89-1.87 (m, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 155.2, 137.3, 130.0, 128.9, 120.8, 118.4, 79.4, 41.7, 23.9. IR (neat) 3332, 3144, 2944, 1599, 1502, 1441, 1217, 1179, 1063, 937, 751 cm^{-1}.

1-phenyl-4-propanol-1*H*-1,2,3-triazole[22] (Table 3, Entry 10)

To a reaction vessel, 0.084 g (1 mmol) 4-pentyn-1-ol, 0.157 g (1 mmol) bromobenzene, 0.079 g (1.2 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted by EtOAc (100 mL) and concentrated *in vacuo*. The resulting residue was purified by flash column chromatography. It was eluted with 20% EtOAc in hexane (70 mL) followed by 50% EtOAc in hexane (100 mL) to afford 143 mg (70%) of the desired product as a waxy solid (melting point 52-53 ^{o}C, lit.[22] 52 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 7.78 (s, 1H), 7.67 (d, *J* = 7.45 Hz, 2H), 7.45 (t, *J* = 7.45 Hz, 2H), 7.37 (t, *J* = 7.45 Hz, 1H), 3.72 (t, *J* = 5.73 Hz, 2H), 2.89 (t, *J* = 7.45 Hz, 2H), 2.00-1.95 (m, 2H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 148.5, 137.1, 129.8, 128.7, 120.4, 119.6, 61.4,

32.2, 22.1. IR (neat) 3249, 3128, 3085, 2927, 2863, 1598, 1552, 1502, 1466, 1451, 1378, 1346, 1276, 1225, 1038, 984, 910, 759 cm^{-1}.

2-(4-phenyl-1*H*-1,2,3-triazol-1-yl)benzonitrile (Table 3, Entry 11)

To a reaction vessel, 0.103 g (1mmol) phenylacetylene, 0.229 g (1 mmol) 2-iodobenzonitrile, 0.097 g (1.5 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL of solvent (1 : 2 molar mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 80 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted with EtOAc (70 mL) and concentrated *in vacuo*. The resulting residue was purified by flash column chromatography. First, it was eluted with 15% EtOAc in hexane (90 mL) and finally with 50% EtOAc in hexane (110 mL) to afford 137 mg (56%) of the desired product as a white crystalline solid (mp 148-150 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 8.47 (s, 1H), 7.98 (d, J = 7.45 Hz, 1H), 7.94-7.82 (m, 4H), 7.62 (t, J = 7.45 Hz, 1H), 7.48 (t, J = 7.45 Hz, 2H), 7.40 (t, J = 7.45 Hz, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 149.0, 138.9, 134.7, 134.6, 129.8, 129.3, 129.1, 128.9, 126.4, 125.6, 120.1, 116.6, 106.6. IR (neat) 3131, 2922, 2232, 1601, 1579, 1509, 1484, 1449, 1414, 1230, 1162, 1026, 993, 763, 688 cm^{-1}.

1- [2-(4-phenyl-1*H*-1,2,3-triazol-1-yl)phenyl)ethan-1-one (Table 3, Entry 12)

To a reaction vessel, 0.102 g (1mmol) phenylacetylene, 0.200 g (1 mmol) 2'-bromoacetopheenone, 0.097 g (1.5 mmol) sodium azide, 0.019 g (0.1 mmol) CuI, 0.018 g (0.2 mmol) ligand (*N,N'*-Dimethylethylenediamine), and 2.0 mL of solvent (1 : 2 molar

mixture of choline chloride and glycerol) was added and placed in a sand bath heated at 80 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. The reaction mixture was extracted with EtOAc (70 mL) and concentrated *in vacuo*. The resulting residue was purified by flash column chromatography. First, it was eluted with 10% EtOAc in hexane (50 mL) and finally with 30% EtOAc in hexane (120 mL) to afford 140 mg (53%) of the desired product as a white solid (mp 96-98 ^{o}C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ = 8.10 (s, 1H), 7.92-7.90 (m, 2H), 7.73 (dd, J = 7.45, 1.72 Hz, 1H), 7.67-7.58 (m, 2H), 7.54-7.52 (m, 1H), 7.46 (t, J = 7.45 Hz, 2H), 7.36 (t, J = 7.45 Hz, 1H), 5.29 (s, 3H). ^{13}C NMR ($CDCl_3$, 125 MHz) δ = 200.0, 148.6, 136.6, 134.6, 132.2, 130.2, 129.3, 129.2, 128.8, 126.1, 125.7, 121.3, 29.6. IR (neat) 3132, 2922, 1680, 1598, 1498, 1480, 1449, 1359, 1278, 1232, 1044, 991, 827cm^{-1}.

Recyclability of the Reaction Medium

In order to study the recyclability of the reaction medium, two reactions were employed (Scheme 20 and 21). General method involved addition of phenylacetylene (1 mmol), bromobenzene (1 mmol), sodium azide (1.2 mmol), CuI (0.1 mmol), ligand (0.2 mmol) (*N,N'*-Dimethylethylenediamine), and 2.0 mL of solvent (1 : 2 molar mixture of choline chloride and glycerol) into a reaction vessel and placed in a sand bath heated at 65 ^{o}C over a magnetic hot plate. The reaction mixture was stirred overnight. After the completion of reaction, the reaction mixture was extracted with EtOAc. Once the extraction process was completed, additional reactant species i.e. bromobenzene, phenyl acetylene, and sodium azide were added to the same reaction vessel and reaction was

conducted under the same conditions. In this way, after the complete extraction of the desired product in each cycle, a new cycle was carried out in the same vessel using the same reaction medium. Unless specified, no additional ligand (*N,N'*-Dimethylethylenediamine) and catalyst were added. The yield of the product in each trial or cycle was calculated (Table 6 and 7).

CHAPTER III

RESULTS AND DISCUSSIONS

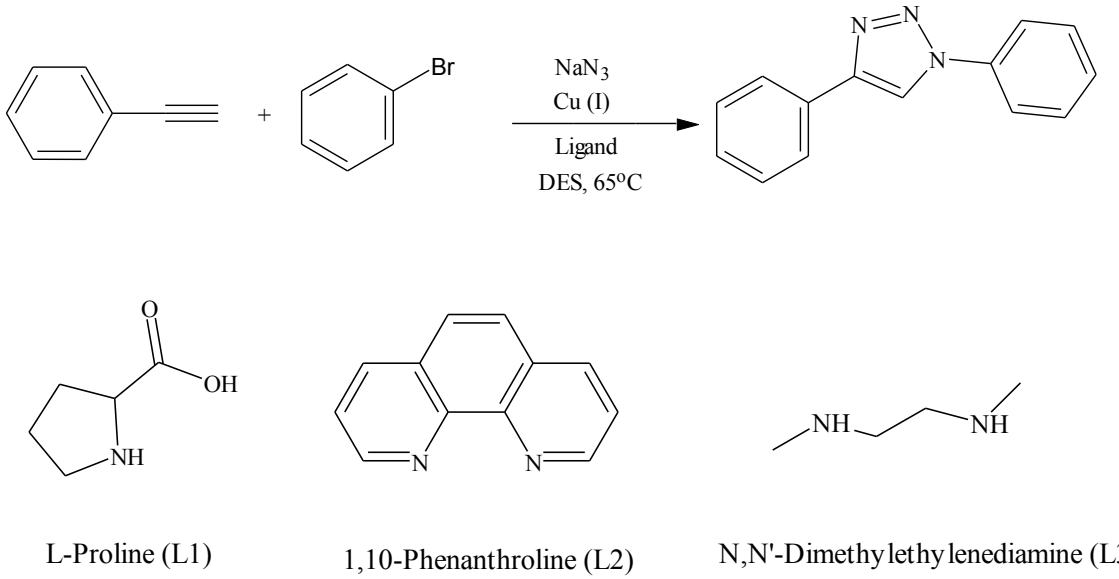
The Cu (I) catalyzed CuAAC reaction has been employed widely in the field of triazole synthesis. It involves the reaction of an organic azide with a terminal alkyne. In the majority of research articles two step synthesis have been reported. In carrying out these steps the organic azide is prepared first and is then allowed to react with the alkyne in the next step. This two step process suffers from being longer and requiring the handling of azides. Although, high molecular weight organic azides are fairly stable in the reaction conditions such as water and presence of oxygen, low molecular weight azides can be unstable and toxic which make them hazardous to handle.[48] One-pot synthesis is one of the best methods to avoid these concerns. In this research we are studying a possibility of the use of an eco-friendly deep eutectic 1 : 2 molar mixture of choline chloride and glycerol instead of organic solvents and expensive ionic liquids, as a solvent for one-pot synthesis of 1,4-disubstituted 1,2,3- triazole.

In case of alkyl halide as an azide precursor, reactions proceed via nucleophilic substitution (S_N2) of halide by an azide ion giving alkyl azide which simultaneously undergoes cycloaddition with the terminal alkyne in the presence of Cu(I) catalyst giving 1,4-disubstituted-1,2,3-triazole. Since alkyl halide participates with ease in S_N2 reaction, formation of the organic azide is facile. But unlike alkyl halide, aryl halide (halide at sp^2

hybridized carbon) as an azide precursor suffers greatly from a lack of an efficient synthetic route.

Among aryl halides, aryl iodides are more reactive than the corresponding bromides.[22] Liang's group reported the reaction of iodobenzene with ferrocenylacetylene in the presence of ligand L-proline giving 80% yield but reaction failed in case of bromobenzene even at elevated temperature.[8] Although employing aryl iodide as an azide precursor has been reported several times, the use of bromobenzene and its derivative in the single step one-pot synthesis of 1,4-disubstituted triazole has not been reported. In this research an approach has been developed that utilizes bromobenzene and its derivatives as azide precursors along with iodobenzene. Use of a suitable ligand can drastically change the fate of a reaction although it has no direct role in the chemical transformation. Keeping this in a mind, a reaction involving bromobenzene, phenylacetylene and sodium azide was used to screen the effectiveness of three different ligands (L1, L2, and L3) as shown in Table 2.

The reaction was carried out employing bromobenzene (1 mmol), phenylacetylene (1 mmol), sodium azide (1.2 mmol), in the presence of a Cu (I) catalyst (0.1 mmol) and ligand (0.2 mmol) in 2 mL of solvent (1 : 2 molar mixture of choline chloride and glycerol) at 65 ^{o}C for 9 hr (Scheme 17). The completion of the reaction was monitored by TLC.



L-Proline (L1) 1,10-Phenanthroline (L2) N,N'-Dimethylethylenediamine (L3)

Scheme 17: Evaluation of ligands for the reaction

Table 2: Screening of ligands for azide-alkyne cycloaddition

Entry	Ligand	Yield (%)
1	L1	---
2	L2	---
3	L3	88

In the presence of L3, bromobenzene reacted with phenylacetylene giving an 88% yield of the triazole product. This was an exciting result which enables the use of bromobenzene as an azide precursor. Using this methodology, iodobenzene, bromobenzene and their derivatives were reacted with alkynes (Table 3).

Table 3: One-pot synthesis of 1,2,3-triazole from aryl halides, NaN_3, and alkynes

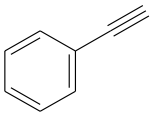
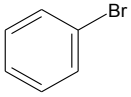
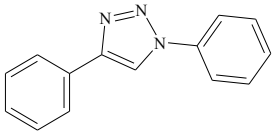
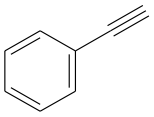
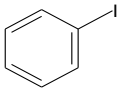
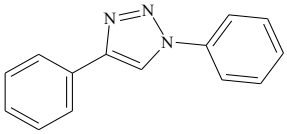
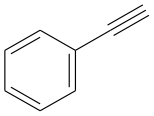
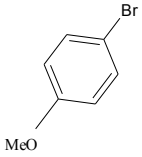
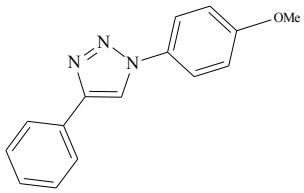
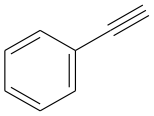
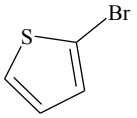
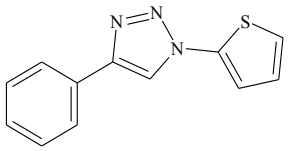
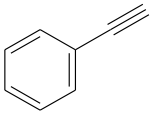
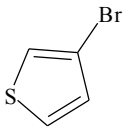
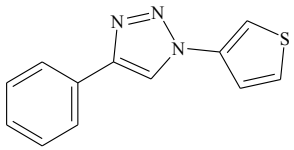
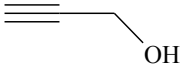
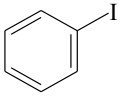
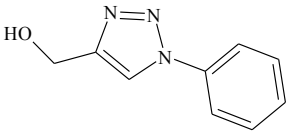
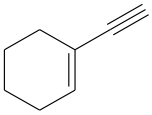
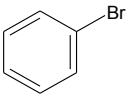
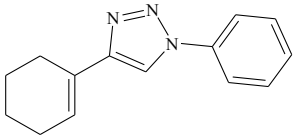
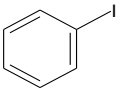
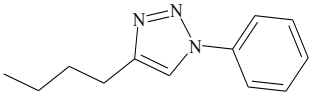
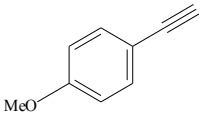
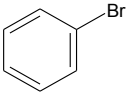
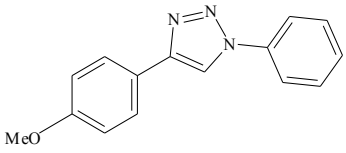
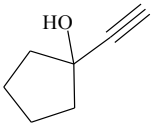
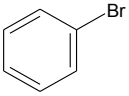
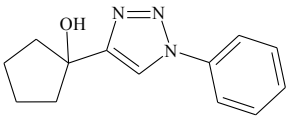
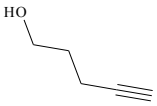
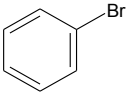
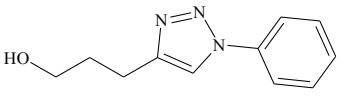
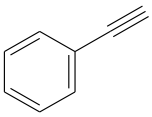
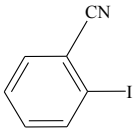
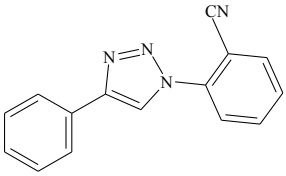
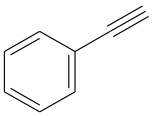
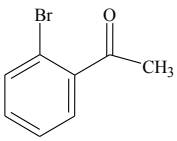
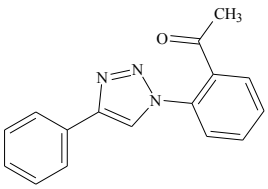
Entry	Alkyne	Alkyl Halide	Product	Yield (%)
1a				88
1b				92
2				40
3				46
4				57
5				76

Table 3 (cont.): One-pot synthesis of 1,2,3-triazole from aryl halides, NaN_3, and alkynes

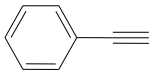
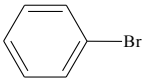
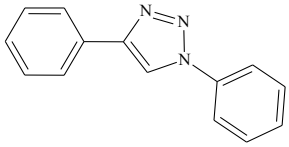
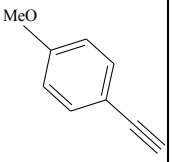
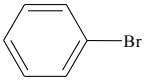
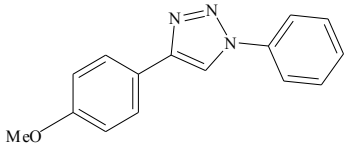
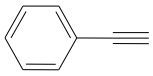
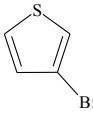
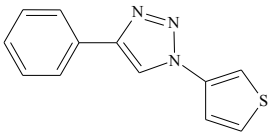
Entry	Alkyne	Alkyl Halide	Product	Yield (%)
6				48
7	1-hexyne			97
8				50
9				58
10				70
11				56
12				53

Aryl halides are highly inert towards nucleophilic substitution reactions. In the above transformations (Table 3) it is not clear how reaction proceeds i.e. whether it undergoes nucleophilic substitution to give aryl azide followed by cycloaddition to a terminal alkyne in presence of Cu(I) catalyst giving the desired triazole or goes through some other mechanism. If first option is considered, aryl halides may undergo nucleophilic substitution via an S_NAr mechanism since an S_N2 pathway is not possible on the grounds of geometry. The presence of an electron withdrawing group in the aryl halide enhances the reactivity towards nucleophilic substitution by stabilizing the negative charge in the intermediate species which ultimately activates the halide towards alkyne-azide cycloaddition. But, in case of 2-iodobenzonitrile and 2'-bromoacetophenone (Table 3, entries 11 and 12) the yield was not obtained as expected. Steric hindrance can be one of the factors affecting the yield of the reaction. Except entries 1a, 1b, and 7 (Table 3), a moderate yield was obtained.

The nucleophilic substitution reaction is greatly affected by the nature of the solvent whether the mechanism is S_N2 or S_NAr. Polar protic solvent decreases the rate of S_N2 displacement. Similarly, in case of aryl halide the rate of an S_NAr reaction proceeds very slowly in a polar protic solvent in compared to the rate in polar aprotic solvents.[49] A QM/MM simulation study of solvent effects and mechanism for S_NAr by Orland and William in 2004 suggested the lower reaction rate in the presence of a polar protic solvent is because of greater stabilization of the azide ion than the transition structure.[50] These explanations possibly address the lower yield of the reactions studied although there may be possibilities of some other reaction pathways . For these reasons three

different sets of reactions were performed to evaluate the effect of polar protic and polar aprotic solvents on the overall yield. All three reactions were carried out under similar conditions in polar protic DES and polar aprotic DMSO solvent, and the isolated yields were compared (Table 4). The overall result shows consistency with the above discussed idea.

Table 4: Evaluation of solvent for azide-alkyne cycloaddition reaction.

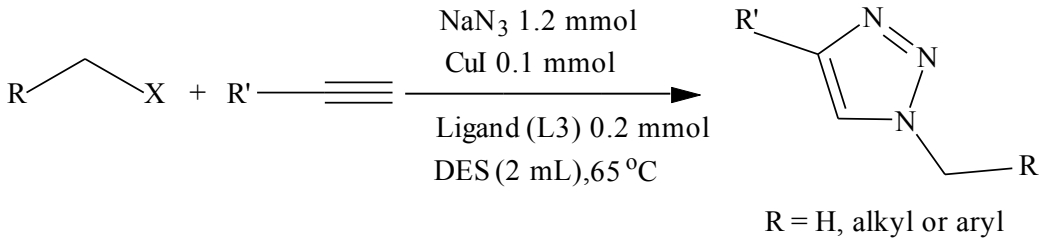
Entry	Alkyne	Halide	Product	Solvent	Yield (%)
1.				DES	89%
				DMSO	90%
2.				DES	40%
				DMSO	72%
3.				DES	57%
				DMSO	88%

All reactions were carried out using aryl halide (1.0 mmol), alkyne (1.0 mmol), sodium azide (1.2 mmol), CuI (0.1 mmol), ligand (0.2 mmol) (L3), and 2 mL solvent kept in a reaction vessel and stirred overnight at 65 ^{o}C.

Six more reactions were performed taking alkyl halides (halide at sp^3 carbon), alkynes, and sodium azide in the presence of CuI as catalyst (Scheme 18). In this one-pot

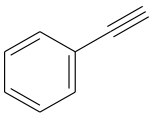
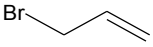
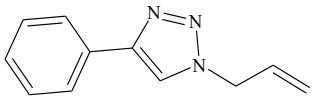
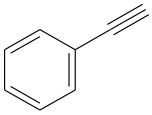
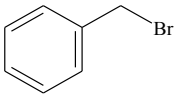
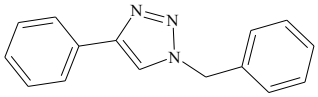
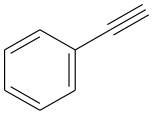
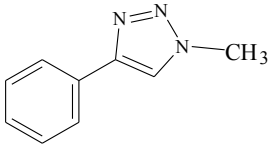
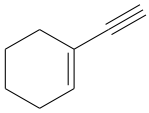
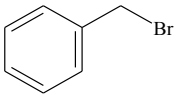
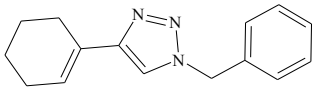
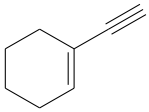
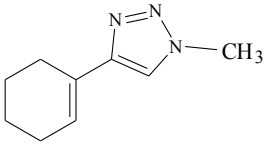
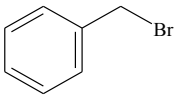
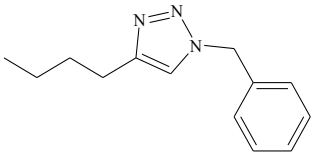
synthesis first, alkyl azide is formed from the corresponding halide through nucleophilic substitution (S_N2) of halide by an azide. Especially, in the case of activated halides such as allylic, propargylic, and benzylic, the substitution is easy.[22] It has been further reported that with allylic azide there is a chance of 1,3-sigmatropic rearrangement which competes with the triazole formation.[51] This can be one possible reason for the low yield observed (entry 1, Table 5). On the other hand, activated benzyl bromide gave moderate (entries 2, 4 and 6) (Table 5). Since the reactivity of alkyl iodide is expected to be higher than the alkyl bromide, the yield of the reactions (entries 3 and 5, Table 5) using methyl iodide was around 70%.

Reactivity of an alkyne is also another crucial factor that affects the efficiency of overall conversion. Electron-deficient alkynes are highly reactive towards azide-alkyne cycloaddition.[6] All the reactions involving alkyl halide (halide at sp3 hybridized carbon atom), were carried out of both in absence and presence of the ligand (L3) (Table 5, entry 1-6).



Scheme 18: CuAAC reaction involving alkyl halide as an azide precursor

Table 5: One-pot synthesis of 1,2,3-triazole from alkyl halides, NaN_3, and alkynes.

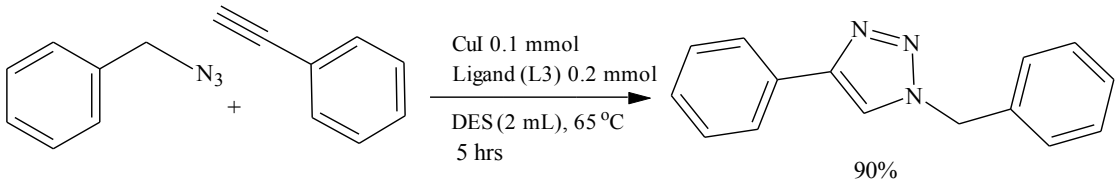
Entry	Alkyne	Alkyl Halide	Product	Yield (%)	
				a	b
1				30	38
2				51	48
3		MeI		70	73
4				50	56
5		MeI		67	66
6	1-hexyne			62	66

a = Isolated yield for the reaction performed without addition of ligand (L3)

b = Isolated yield for the reaction performed in presence of ligand (L3)

No significant differences were observed for the reactions performed in the presence or absence of a ligand (L3). Formation of the organic azide is essential for the formation of 1,4-disubstituted triazole. So, any factors that affect this step obviously influence the overall yield of a reaction. One of the genuine reasons behind the moderate yield can be the nature of the solvent. In the cases of above mentioned transformations (entries 1-6, table 5), which involve S_N2 displacement of halides by azide ions; the presence of polar protic solvent decreases the nucleophilic character of the nucleophile by solvating the anion. This decreases the rate of S_N2 displacement since the nucleophile must desolvate in order to displace the leaving group from the substrate molecule. Since DES is a polar protic solvent, its effect as explained above can be one of the prominent factors responsible for the moderate yields (entries 1-6, table 5).

In order to confirm the above explanation a reaction was screened using an organic azide and a terminal alkyne. For this purpose, benzyl azide was prepared by Alvarez and Alvarez's method.[52] The resulting benzyl azide (1 mmol) was reacted with phenyl acetylene (1 mmol) in presence of Cu(I) (0.1 mmol) catalyst and ligand (L3) (0.2 mmol) at 65 ^{o}C (Scheme 19).



Scheme 19: CuAAC reaction between benzyl azide and phenyl acetylene

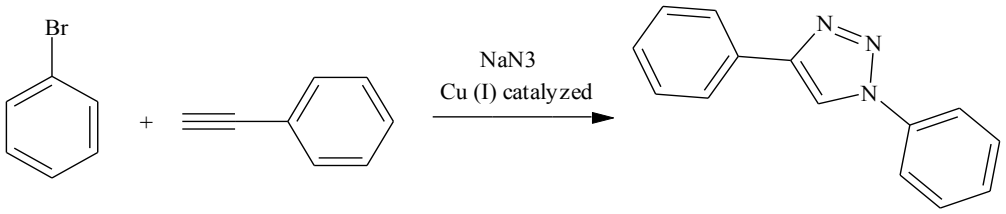
Employing of benzyl azide instead of benzyl bromide resulted in 90% of the desired product in 5 hour in comparison to the reaction that uses benzyl bromide as an azide precursor (yield- 51%)(entry 2, Table 5). This result clearly indicates that the reaction suffers greatly during the organic azide formation step because of the presence of the polar protic solvent i.e. (DES).

Another interesting result was observed for the same reaction (Scheme 19) when it was carried out adding excess of sodium azide (1.5 mmol). The reaction completed in 30 minutes giving 92% yield. This unusual reduction of the reaction time is remarkable. It might be because of the formation of a new and highly active catalytic species, copper azide which itself is explosive in nature.

Use of inexpensive, environmentally benign solvent, maximum atom economy, low catalyst loading, recyclability of the reaction medium (solvent, catalyst and ligand), and low energy consumption are some of the major elements of "green synthesis."[53] The described methodology employs a deep eutectic solvent, a 1 : 2 molar mixture of choline chloride and glycerol which is greener than traditional organic solvents and expensive ionic liquids in the sense that it is inexpensive, environmentally innocuous and can be easily prepared.

One of the interesting properties of this solvent was found to be its recyclability. The reaction medium which incorporates catalyst and ligand, can be successfully recycled. For the study, the following two reactions were employed (Scheme 20 and 21). All reactions were carried out using 1.0 mmol aryl halide , 1.0 mmol alkyne, 1.2 mmol sodium azide, 0.1 mmol CuI, 0.2 mmol ligand (L3), and 2 mL solvent kept in a reaction

vessel and stirred at 65 ^{o}C overnight. Each cycle represents a subsequent uses of the recycled reaction medium which includes catalyst and ligand.



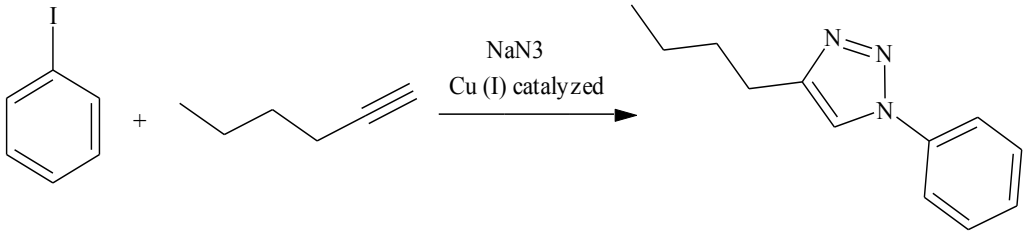
Scheme 20: Reaction monitored for evaluation of solvent recycling (bromobenzene-azide precursor).

Table 6: Recycle of DES reaction medium (Scheme 20)

Cycle	Time (hr)	Yield (%)
0	9	86
1	9	83
2	10	56
3	12	18
Ligand added (0.2 mmol)		
4	9	83

For scheme 20, during the extraction process, a kind of suspension was formed which raises the possibility of catalyst leaching. In the presence of copper catalyst, the addition of ligand gives a bluish green color to the mixture. But, after the second cycle the reaction mixture turned reddish. This may be presumed to be the result of a significant decrease in the ligand concentration during the previous successive extraction process. In the fourth cycle (Table 6), addition of 0.2 mmol of ligand (L3) restored activity, giving

83% yield. This suggest that a small amount of catalyst is also sufficient to drive the reaction if there is certain minimum amount of ligand (L3) present in the reaction medium.



Scheme 21: Reaction monitored for evaluation of solvent recycling (iodobenzene- azide precursor).

Table 7: Recycle of DES reaction medium (Scheme 21)

Cycle	Time (hr)	Yield (%)
0	12	98
1	12	97
2	10	81

In case of Scheme 21, very good yield was obtained even after second cycle (Table 7, cycle 2). This can be attributed to the easy and complete extraction of the product because of its high solubility in EtOAc. Most probably, the leaching of both the catalyst and ligand decreased greatly allowing more efficient recycling of reaction medium and catalyst.

These results show the efficient nature of the reaction medium in terms of recyclability. During the course of this study, using this reaction medium, four different 1,4-disubstituted 1,2,3-triazoles (Table 3 entry 9, 11, and 12, Table 5 entry 5) have been synthesized which are not reported in literature.

CHAPTER IV

CONCLUSION

The Cu(I) catalyzed azide-alkyne cycloaddition reaction is a powerful tool to prepare 1,2,3-triazoles with various functional groups. As mentioned in the earlier chapters, this reaction has application in the medical field for protein/peptide modification, inhibitor synthesis and many other purposes. It has gained equal attention in the field of material science. It is also one of the prominent reactions used for constructing complex molecular architectures like clusters, polymers and dendrimers. Since it is simple to perform and affords 100% regioselectivity in the product, its relevancy and importance in the field of organic synthesis is very high.

There are several different methods developed to improve the CuAAC reaction but still there is a room for the improvement of its greener aspects which has been highly considered in this study. The research has been able to explore the possibility of the use of a greener solvent, DES, in the CuAAC reaction. During our research work, one new method has been developed for the single step one-pot azide-alkyne cycloaddition involving bromobenzene as the aryl azide precursor which employs *N,N'*-Dimethylethylenediamine as a ligand. Since bromobenzene is more beneficial in terms of its lower cost, greater stability, and less hazardous nature compared to iodobenzene, this finding is remarkable.

Through a one-pot multi-component reaction, the tedious job of isolating and handling organc azides has been eliminated by *in situ* generation of azide which ultimately helps to reduce reaction waste. The methodology described herein highly incorporates the essential characteristics of green synthesis: atom economy is 100% as it incorporate all the starting atoms into the product, the reaction is carried out at ambient temperature, all the processes are safe and the solvent used i.e., DES (1 : 2 molar mixture of choline chloride and glycerol) is highly eco-friendly, inexpensive and readily available.

Interestingly, a drastic reduction in the reaction time of 30 min was observed for a reaction involving benzyl azide and phenyl acetylene as a substrate species in the presence of Cu(I) and ligand (L3) when an excess (1.5 mmol) of sodium azide was added.

The recyclability of the reaction medium has also been noted. Although there always remains the possibility of catalyst and ligand leaching during the extraction process, the study shows it is less pronounced here.

Finally, the use of DES (1 : 2 molar mixture of choline chloride/glycerol) was found to be more effective for the single step one-pot synthesis of 1,4-disubstituted-1,2,3-triazole employing organic azide instead of the azide precursor (alkyl and/or aryl halide).

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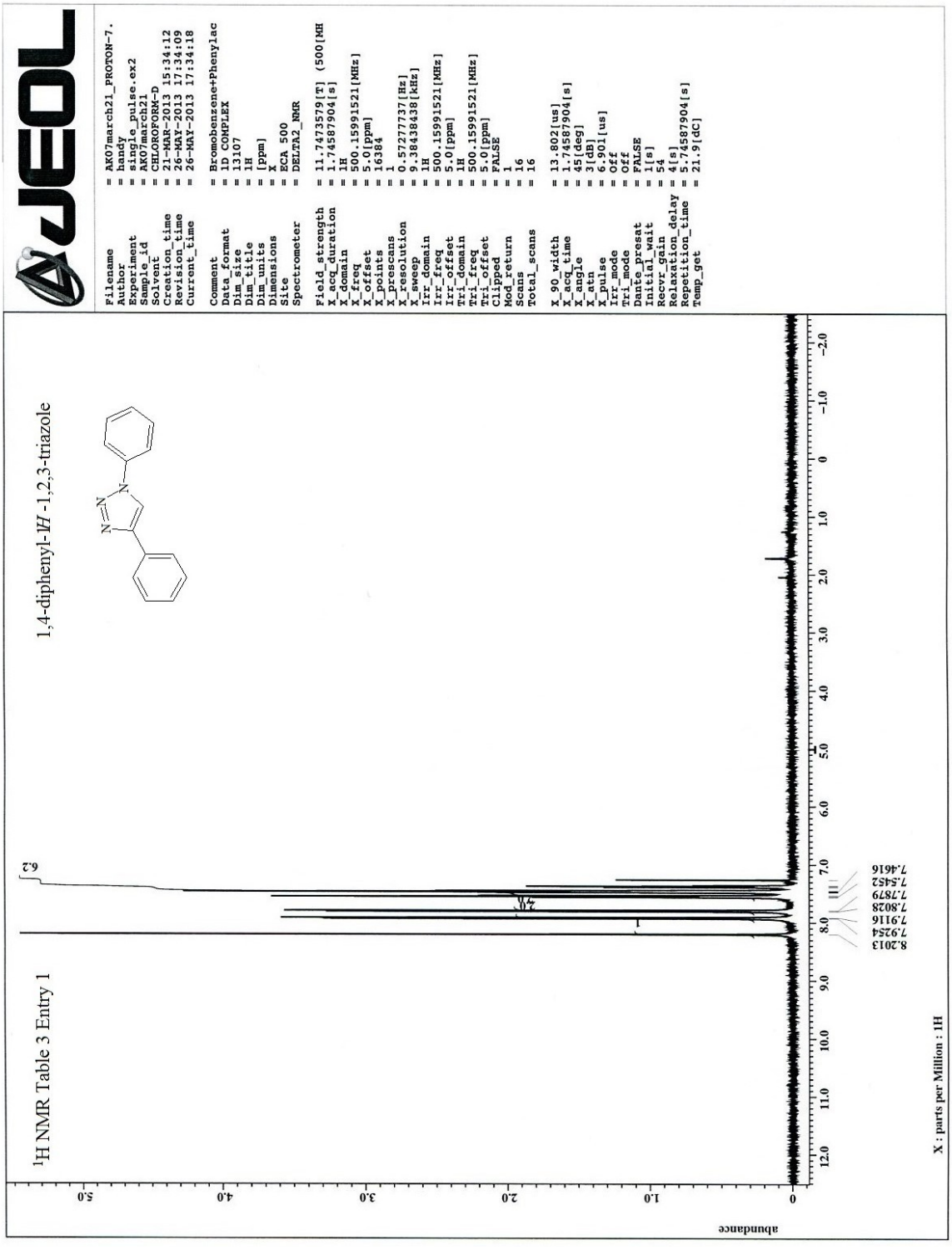
APPENDIX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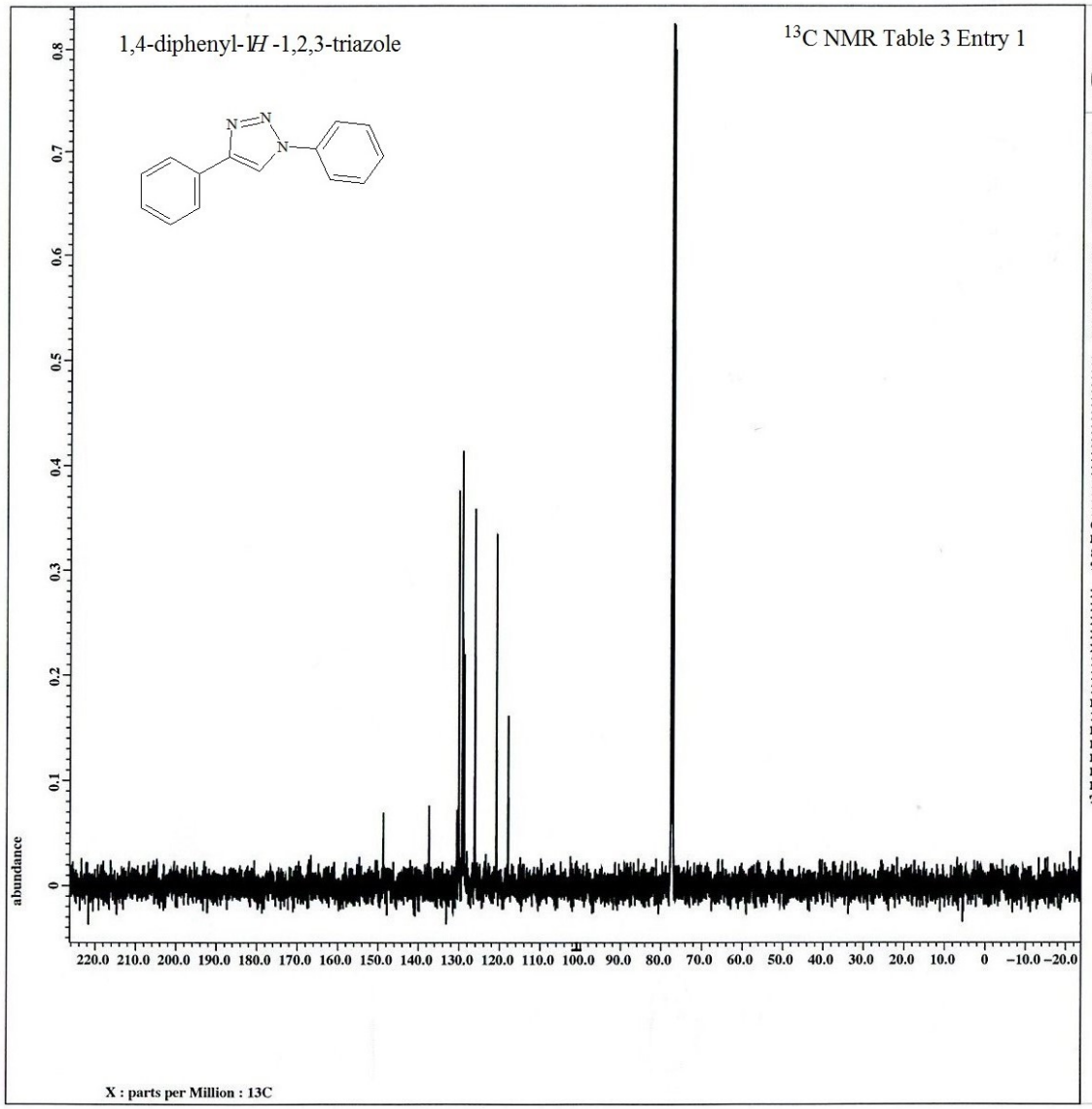


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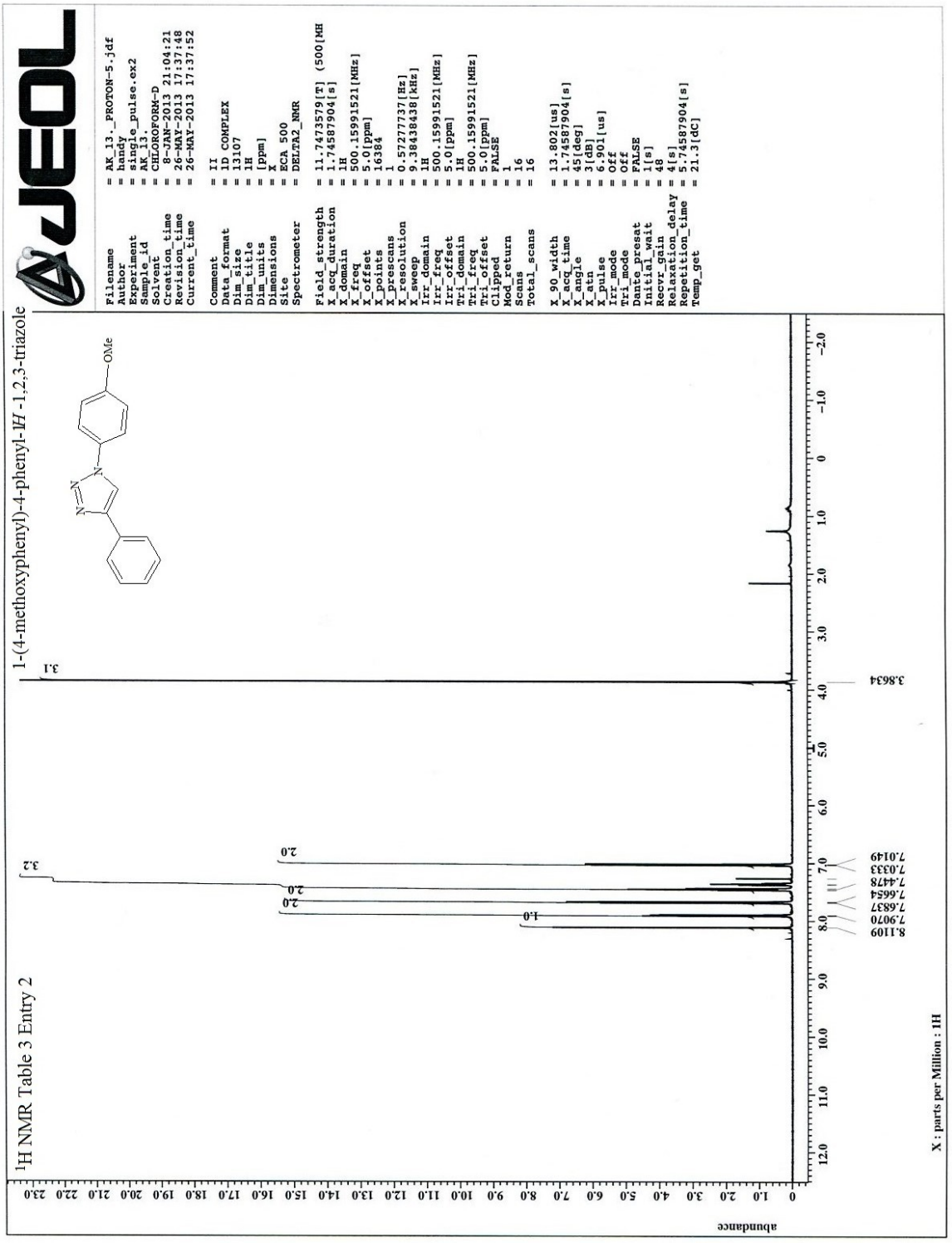
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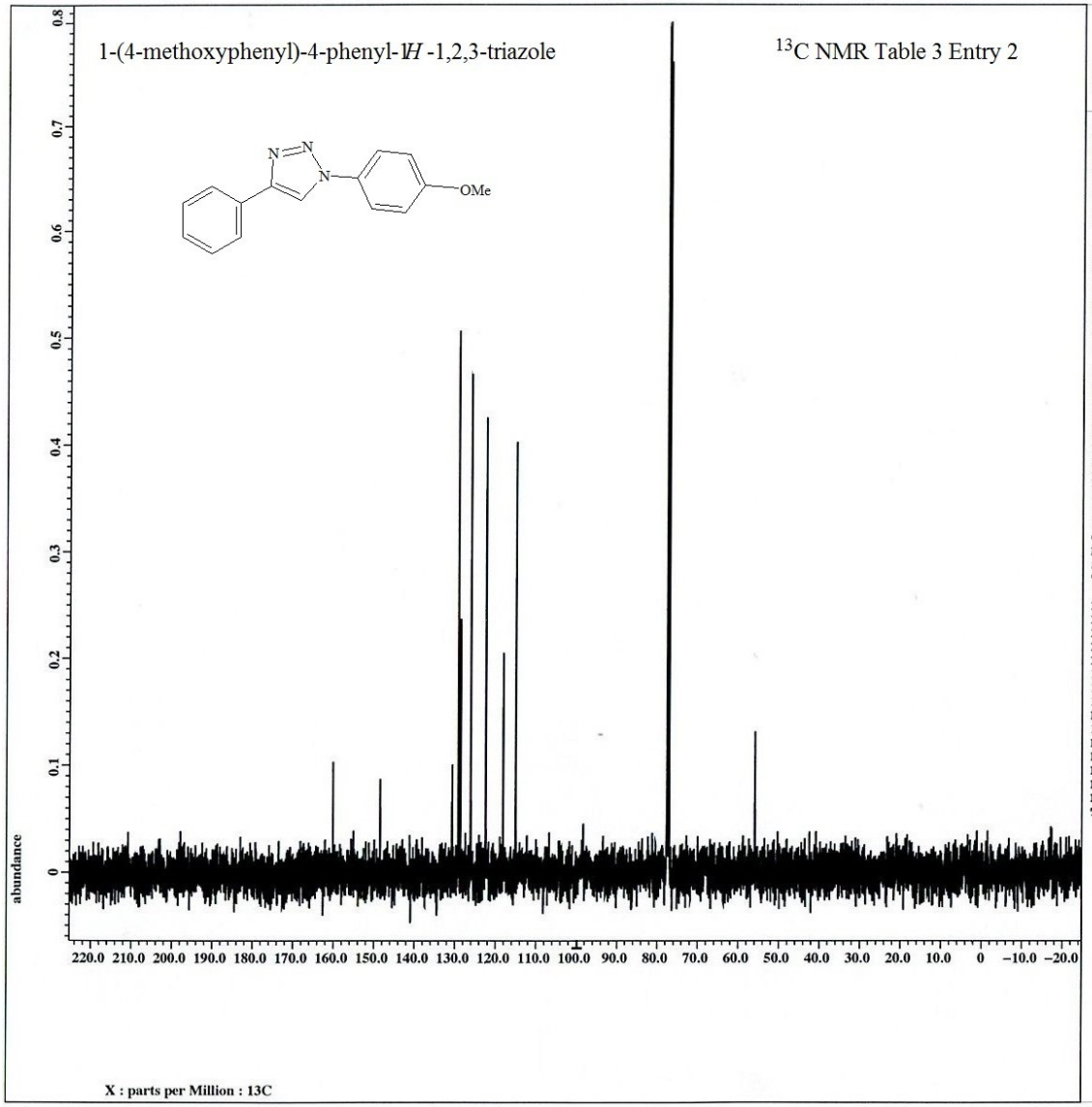
Recvr_gain = 4[s]
Relaxation_delay = 5.74587904[s]
Repetition_time = 21.3[dC]
Temp_get
1-(4-methoxyphenyl)-4-phenyl-1H -1,2,3-triazole
OMe
N
N
N
1H NMR Table 3 Entry 2
3.1
3.2
2.0
2.0
2.0
1.0
3.8634
8.1109
7.9070
7.6837
7.6654
7.4478
7.0333
7.0149
abundance
X : parts per Million : 1H



JEOL

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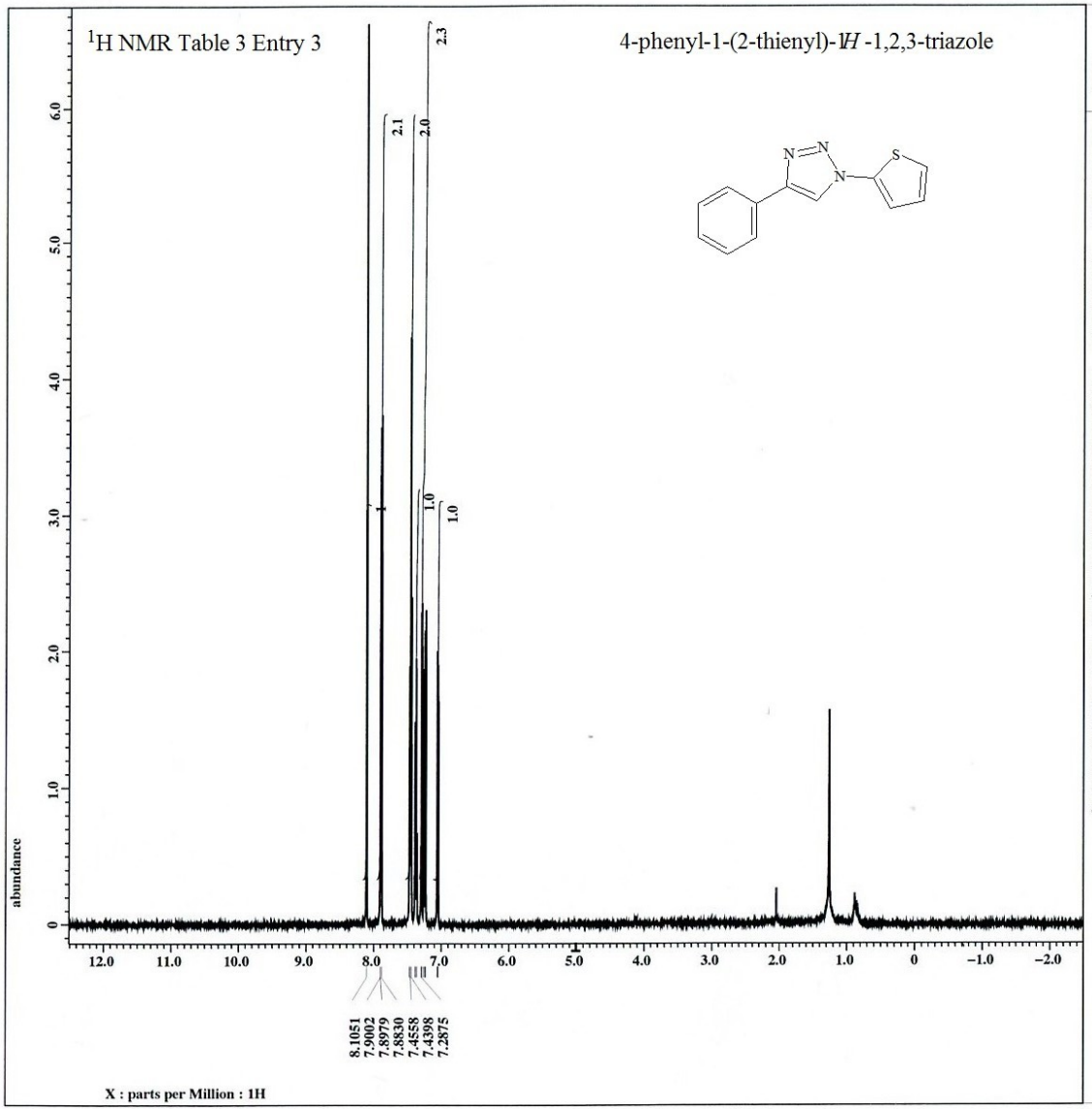
Filename          = AK_13._CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_13.
Solvent           = CHLOROFORM-D
Creation_time     =  8-JAN-2013 21:07:18
Revision_time     = 16-MAY-2013 18:41:21
Current_time      = 16-MAY-2013 18:41:56

Comment           = II
Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 14
Total_scans       = 14

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 56
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.5[dC]
```

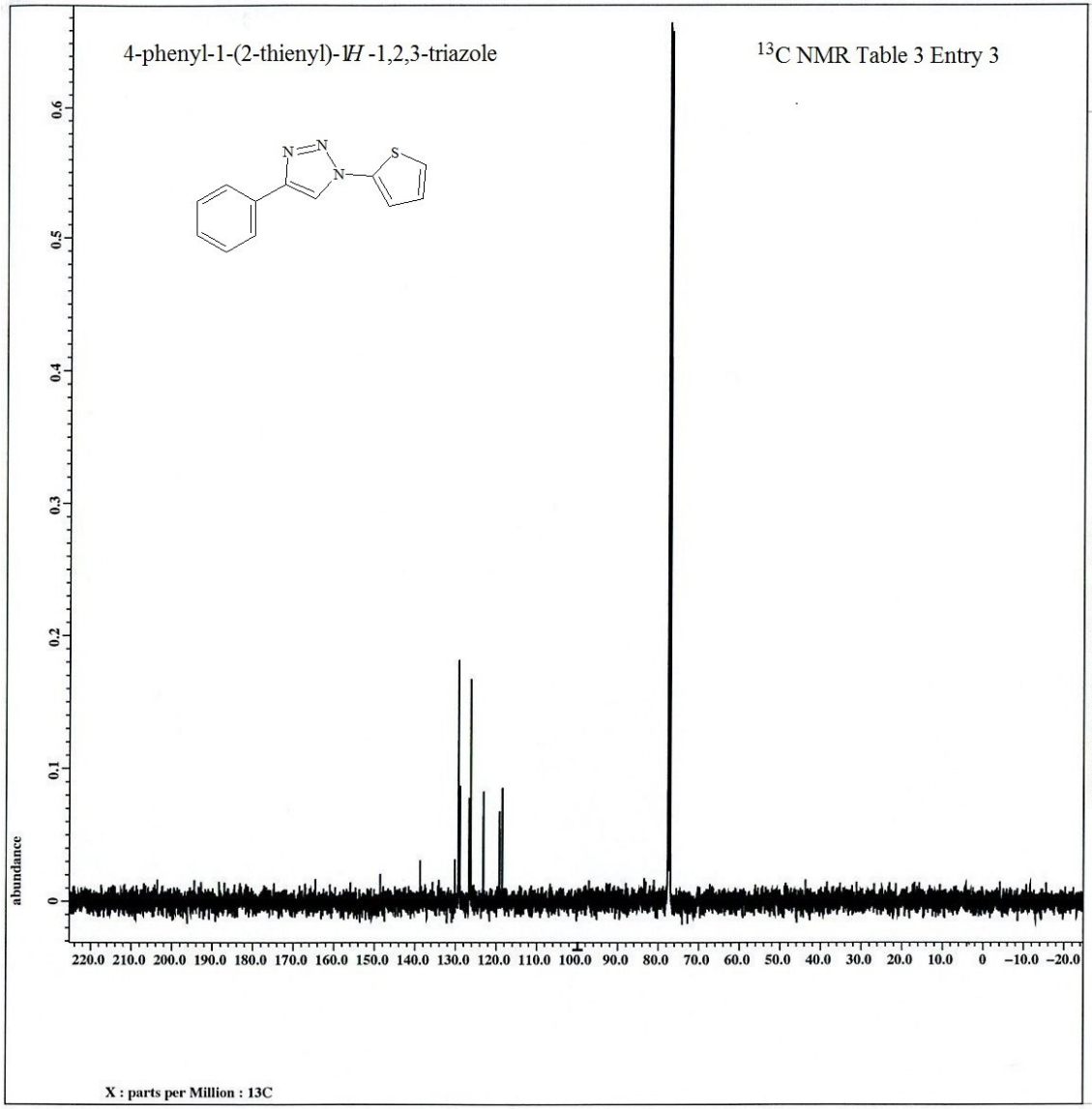


JEOL

Filename	= AK09march21_PROTON-5.
Author	= handy
Experiment	= single_pulse.ex2
Sample_id	= AK09march21
Solvent	= CHLOROFORM-D
Creation_time	= 21-MAR-2013 15:48:50
Revision_time	= 26-MAY-2013 17:42:51
Current_time	= 26-MAY-2013 17:42:55
Comment	= 2-Bromothiophene+Phen
Data_format	= 1D COMPLEX
Dim_size	= 13107
Dim_title	= 1H
Dim_units	= [ppm]
Dimensions	= X
Site	= ECA 500
Spectrometer	= DELTA2_NMR
Field_strength	= 11.7473579[T] (500[MH
X_acq_duration	= 1.74587904[s]
X_domain	= 1H
X_freq	= 500.15991521[MHz]
X_offset	= 5.0[ppm]
X_points	= 16384
X_prescans	= 1
X_resolution	= 0.57277737[Hz]
X_sweep	= 9.38438438[kHz]
Irr_domain	= 1H
Irr_freq	= 500.15991521[MHz]
Irr_offset	= 5.0[ppm]
Tri_domain	= 1H
Tri_freq	= 500.15991521[MHz]
Tri_offset	= 5.0[ppm]
Clipped	= FALSE
Mod_return	= 1
Scans	= 16
Total_scans	= 16
X_90_width	= 13.802[us]
X_acq_time	= 1.74587904[s]
X_angle	= 45[deg]
X_atn	= 3[dB]
X_pulse	= 6.901[us]
Irr_mode	= Off
Tri_mode	= Off
Dante_presat	= FALSE
Initial_wait	= 1[s]
Recvr_gain	= 54
Relaxation_delay	= 4[s]
Repetition_time	= 5.74587904[s]
Temp_get	= 21.9[dC]

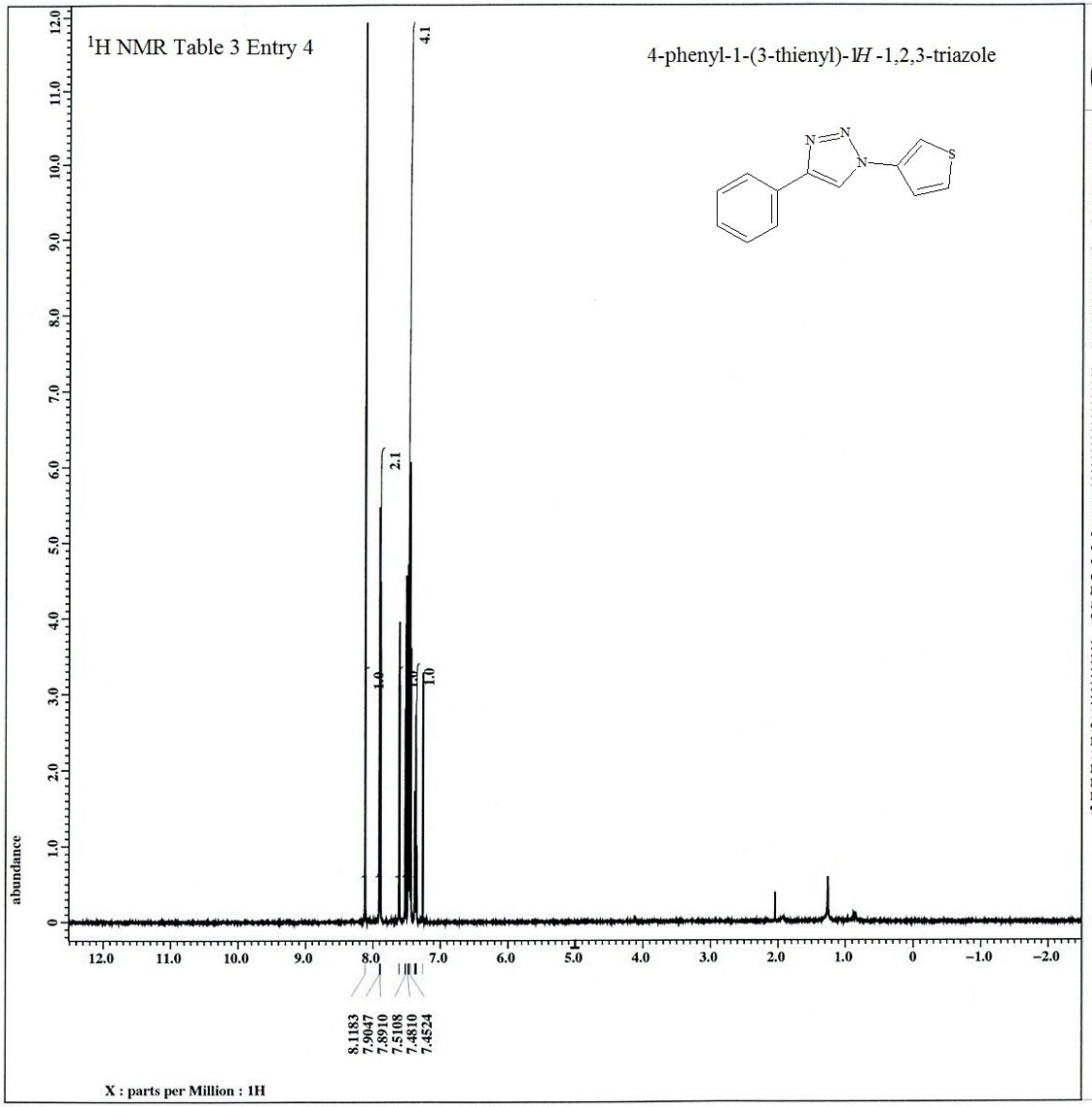
4-phenyl-1-(2-thienyl)-1*H*-1,2,3-triazole

^{13}C NMR Table 3 Entry 3



JEOL

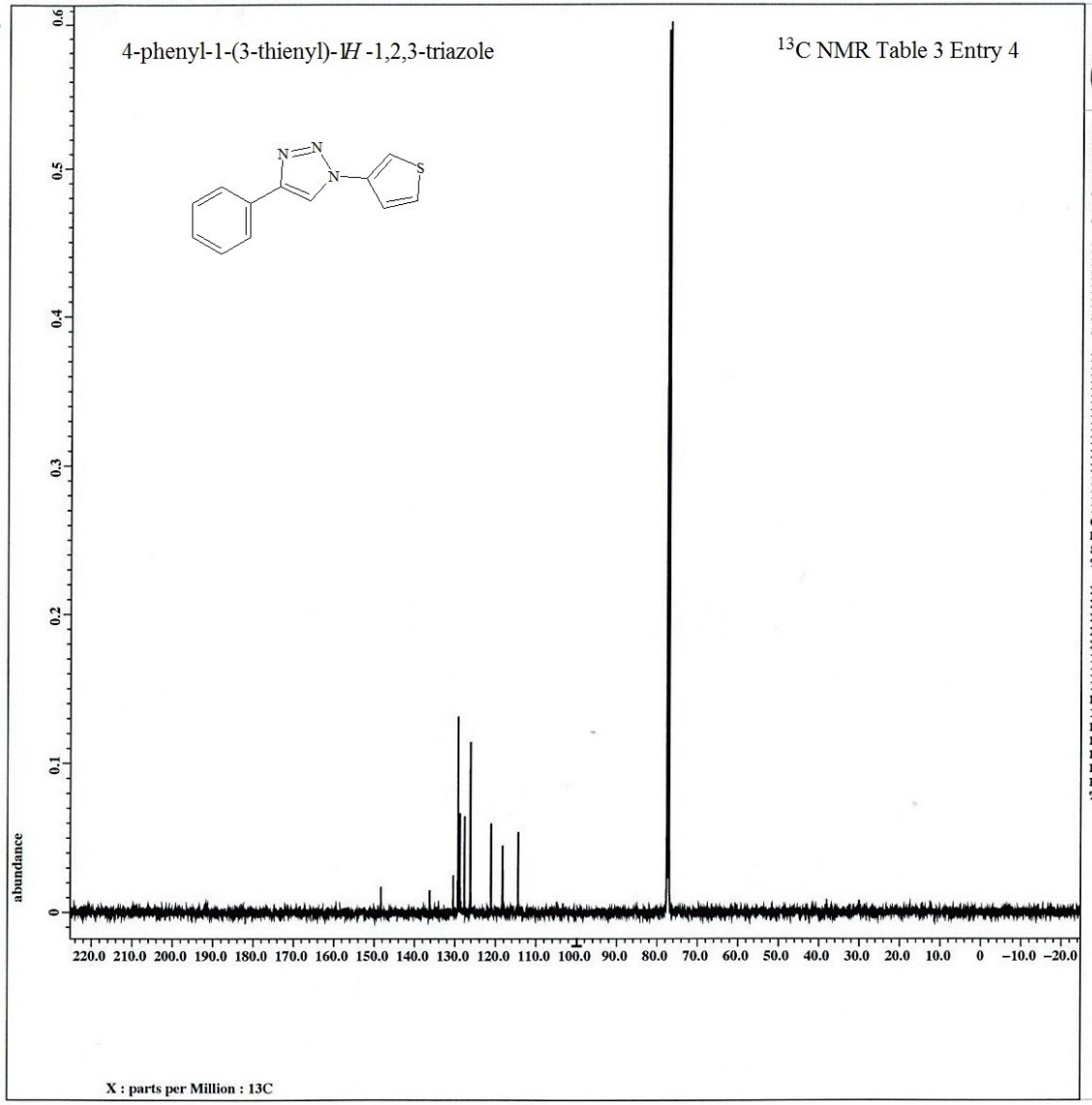
Filename	= AK_14.._CARBON-4.jdf
Author	= handy
Experiment	= single_pulse_dec
Sample_id	= AK_14..
Solvent	= CHLOROFORM-D
Creation_time	= 9-JAN-2013 00:01:19
Revision_time	= 16-MAY-2013 18:51:59
Current_time	= 16-MAY-2013 18:52:06
Data_format	= 1D COMPLEX
Dim_size	= 26214
Dim_title	= 13C
Dim_units	= [ppm]
Dimensions	= X
Site	= ECA 500
Spectrometer	= DELTA2_NMR
Field_strength	= 11.7473579[T] (500[MH
X_acq_duration	= 0.83361792[s]
X_domain	= 13C
X_freq	= 125.76529768[MHz]
X_offset	= 100[ppm]
X_points	= 32768
X_prescans	= 4
X_resolution	= 1.19959034[Hz]
X_sweep	= 39.3081761[kHz]
Irr_domain	= 1H
Irr_freq	= 500.15991521[MHz]
Irr_offset	= 5.0[ppm]
Clipped	= FALSE
Mod_return	= 1
Scans	= 85
Total_scans	= 85
X_90_width	= 12[us]
X_acq_time	= 0.83361792[s]
X_angle	= 30[deg]
X_atn	= 3[dB]
X_pulse	= 4[us]
Irr_atn_dec	= 21[dB]
Irr_atn_noe	= 21[dB]
Irr_noise	= WALTZ
Decoupling	= TRUE
Initial_wait	= 1[s]
Noe	= TRUE
Noe_time	= 2[s]
Recvr_gain	= 56
Relaxation_delay	= 2[s]
Repetition_time	= 2.83361792[s]
Temp_get	= 21.6[dC]



Filename	= AK10march21_PROTON-5.
Author	= handy
Experiment	= single_pulse.ex2
Sample_id	= AK10march21
Solvent	= CHLOROFORM-D
Creation_time	= 21-MAR-2013 16:12:10
Revision_time	= 26-MAY-2013 17:52:38
Current_time	= 26-MAY-2013 17:52:45
Comment	= 3-Bromothiophene+Phen
Data_format	= 1D COMPLEX
Dim_size	= 13107
Dim_title	= 1H
Dim_units	= [ppm]
Dimensions	= X
Site	= ECA 500
Spectrometer	= DELTA2_NMR
Field_strength	= 11.7473579[T] (500[MH
X_acq_duration	= 1.74587904[s]
X_domain	= 1H
X_freq	= 500.15991521[MHz]
X_offset	= 5.0[ppm]
X_points	= 16384
X_prescans	= 1
X_resolution	= 0.57277737[Hz]
X_sweep	= 9.38438438[kHz]
Irr_domain	= 1H
Irr_freq	= 500.15991521[MHz]
Irr_offset	= 5.0[ppm]
Tri_domain	= 1H
Tri_freq	= 500.15991521[MHz]
Tri_offset	= 5.0[ppm]
Clipped	= FALSE
Mod_return	= 1
Scans	= 16
Total_scans	= 16
X_90_width	= 13.802[us]
X_acq_time	= 1.74587904[s]
X_angle	= 45[deg]
X_atn	= 3[dB]
X_pulse	= 6.901[us]
Irr_mode	= Off
Tri_mode	= Off
Dante_presat	= FALSE
Initial_wait	= 1[s]
Recvr_gain	= 54
Relaxation_delay	= 4[s]
Repetition_time	= 5.74587904[s]
Temp_get	= 21.9[dC]

4-phenyl-1-(3-thienyl)-1*H*-1,2,3-triazole

^{13}C NMR Table 3 Entry 4

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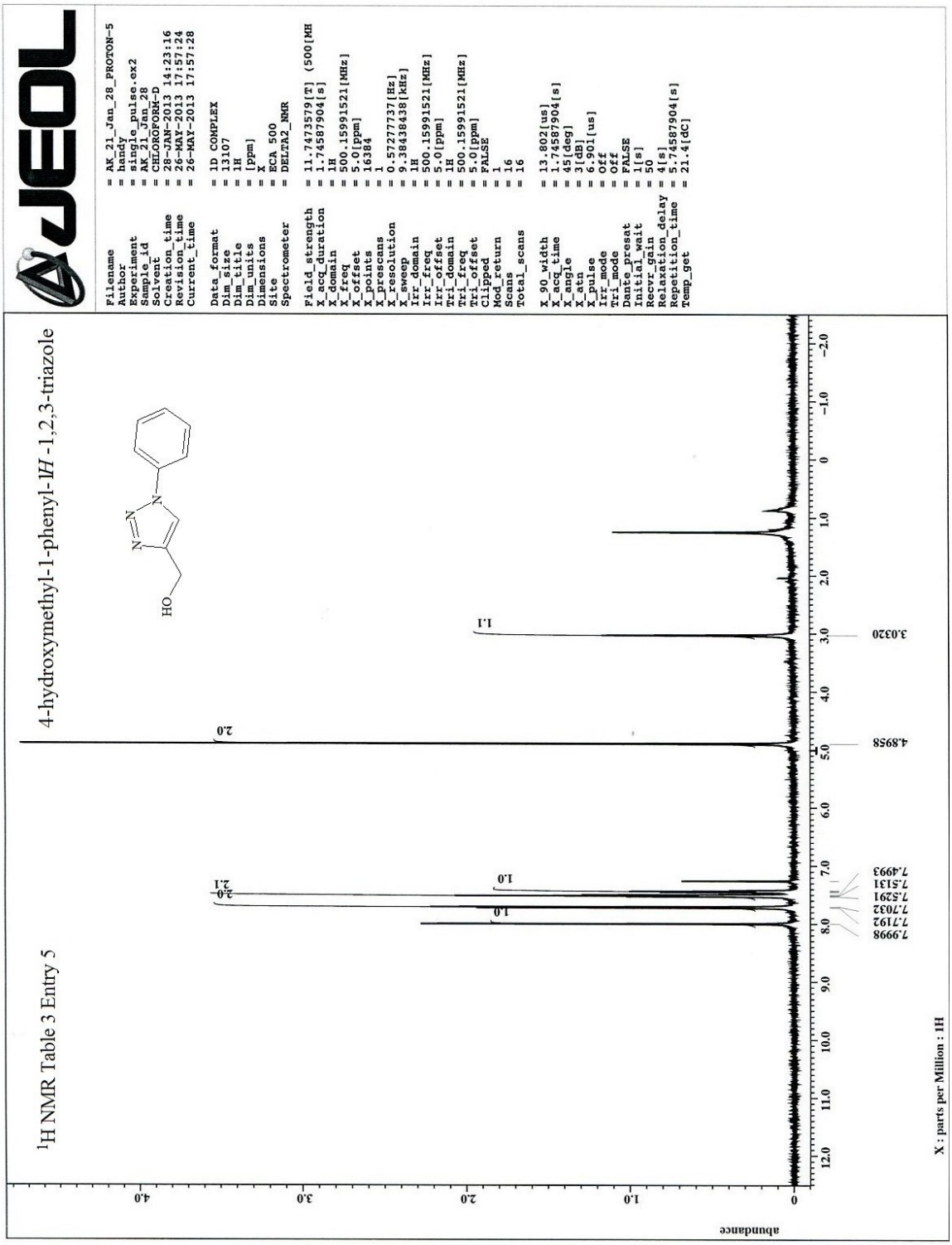
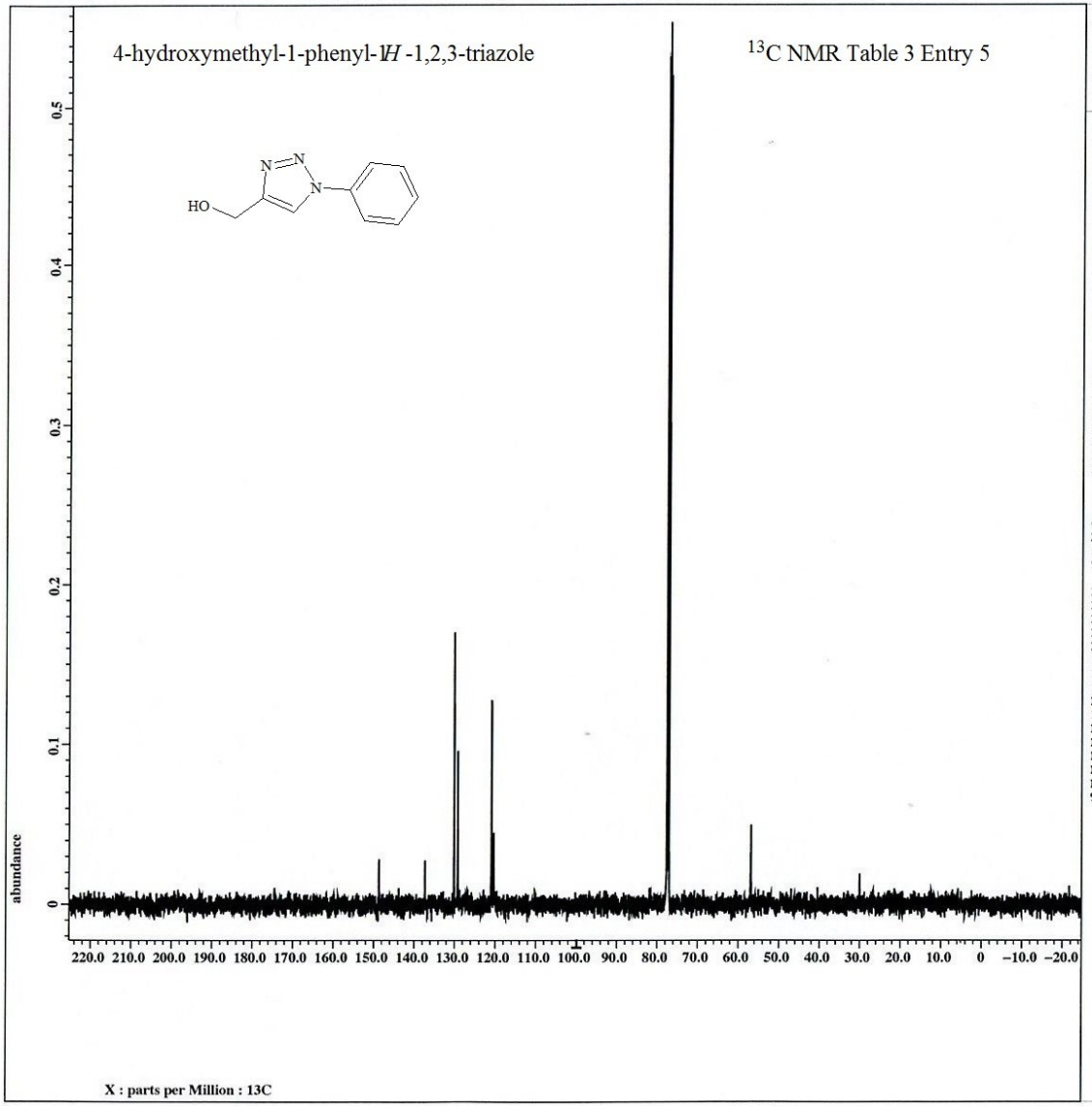
Filename          = AK_15_CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_15
Solvent           = CHLOROFORM-D
Creation_time     =  9-JAN-2013 17:16:21
Revision_time     = 16-MAY-2013 19:01:07
Current_time      = 16-MAY-2013 19:01:47

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 987.0
Total_scans       = 987.0

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 56
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.8[dC]
```


JEOL
Filename = AK_21_Jan_28_PROTON-5
Author = handy_
Experiment = single_pulse.ex2
Sample_id = AK_21_Jan_28
Solvent = CHLOROFORM-D
Creation_time = 28-JAN-2013 14:23:16
Revision_time = 26-MAY-2013 17:57:24
Current_time = 26-MAY-2013 17:57:28
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735791[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Irr_mode = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 50
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.4[dC]
4-hydroxymethyl-1-phenyl-1H-1,2,3-triazole
HO
^{1}H NMR Table 3 Entry 5
2.0
1.1
2.0
2.1
1.0
1.0
3.0320
4.8958
7.9998
7.7192
7.7032
7.5291
7.5131
7.4993
abundance
X : parts per Million : 1H



JEOL

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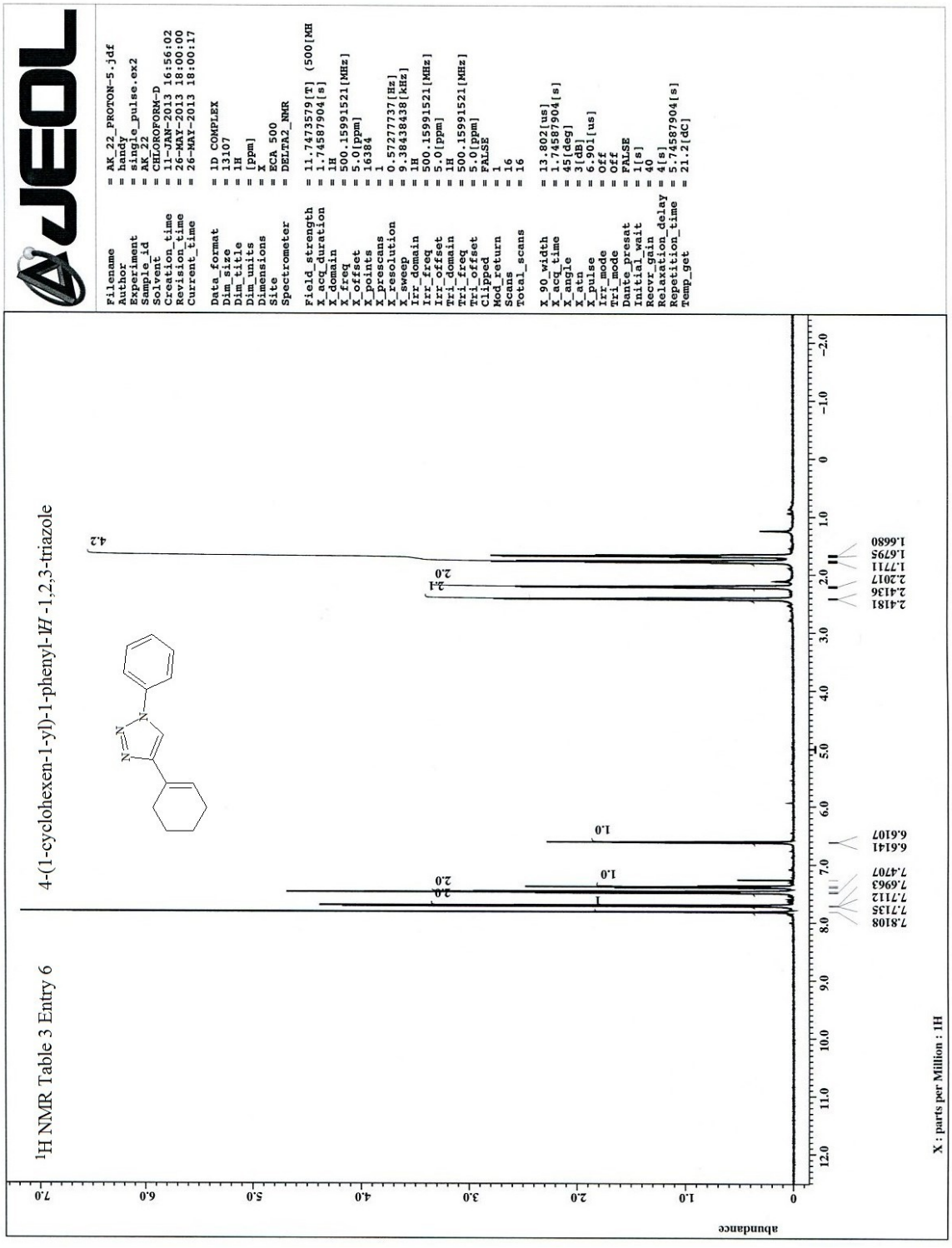
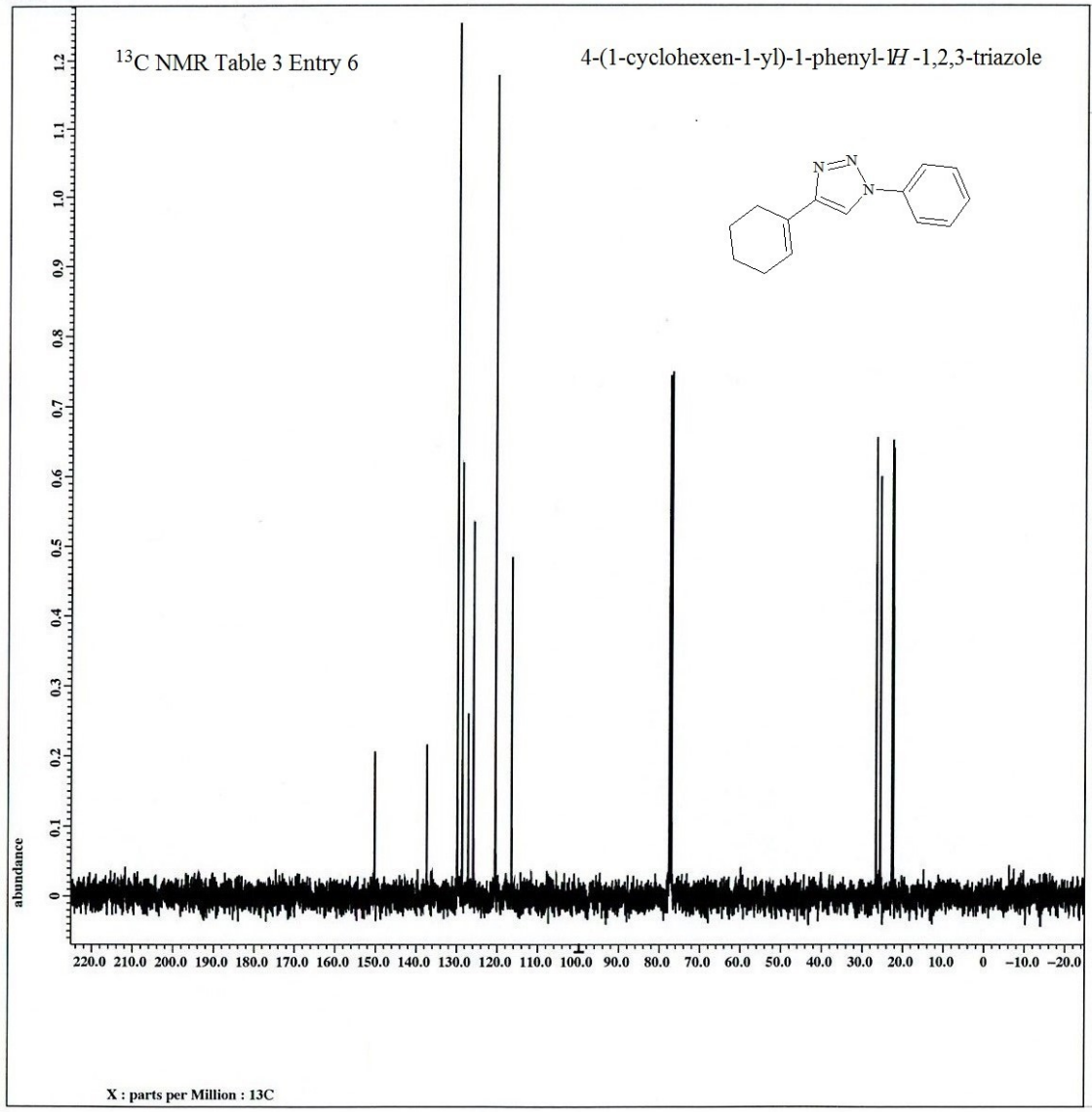
Filename          = AK_21_CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_21
Solvent           = CHLOROFORM-D
Creation_time     = 10-JAN-2013 17:23:25
Revision_time     = 16-MAY-2013 19:09:55
Current_time      = 16-MAY-2013 19:09:59

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 196
Total_scans       = 196

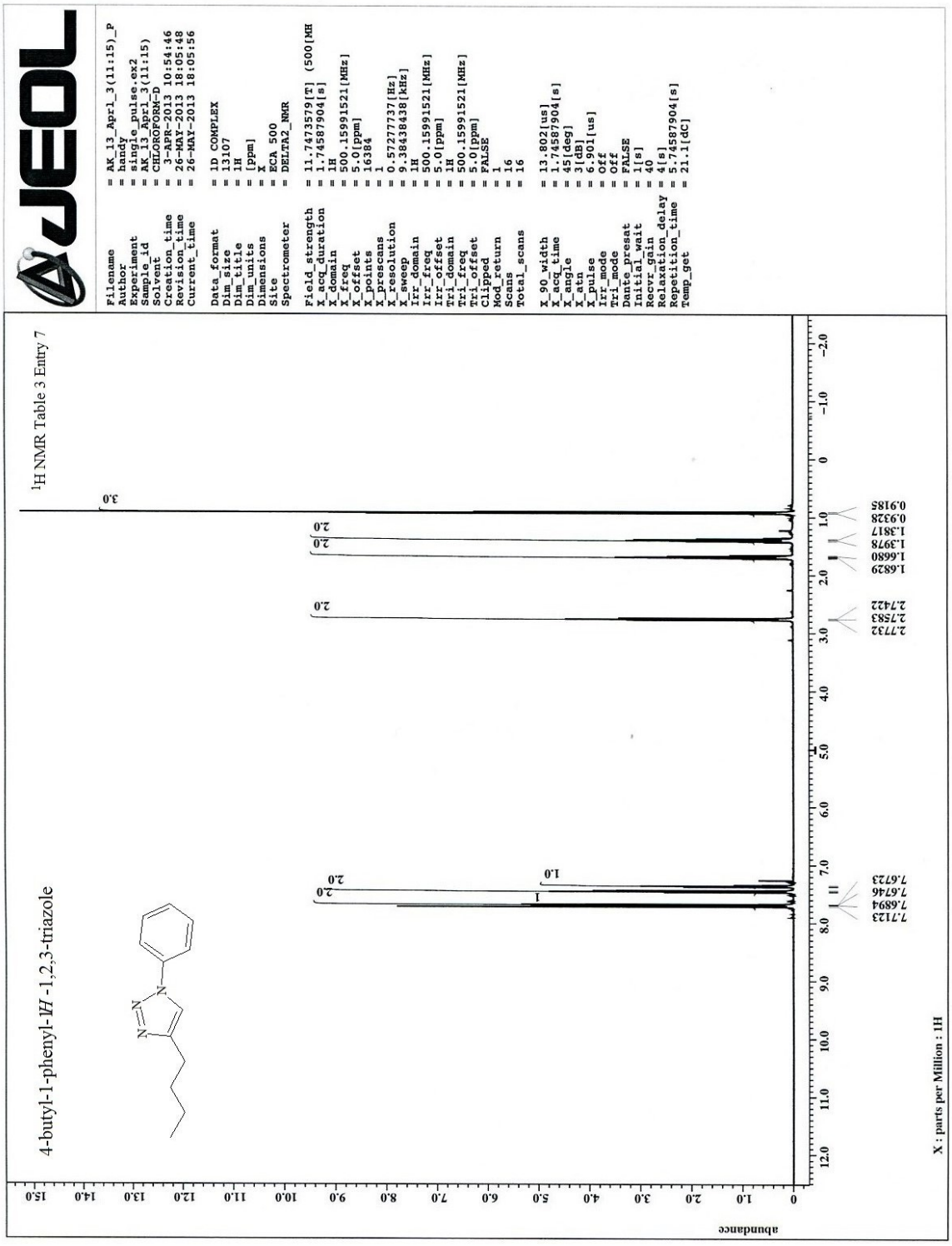
X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 56
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.6[dC]
```

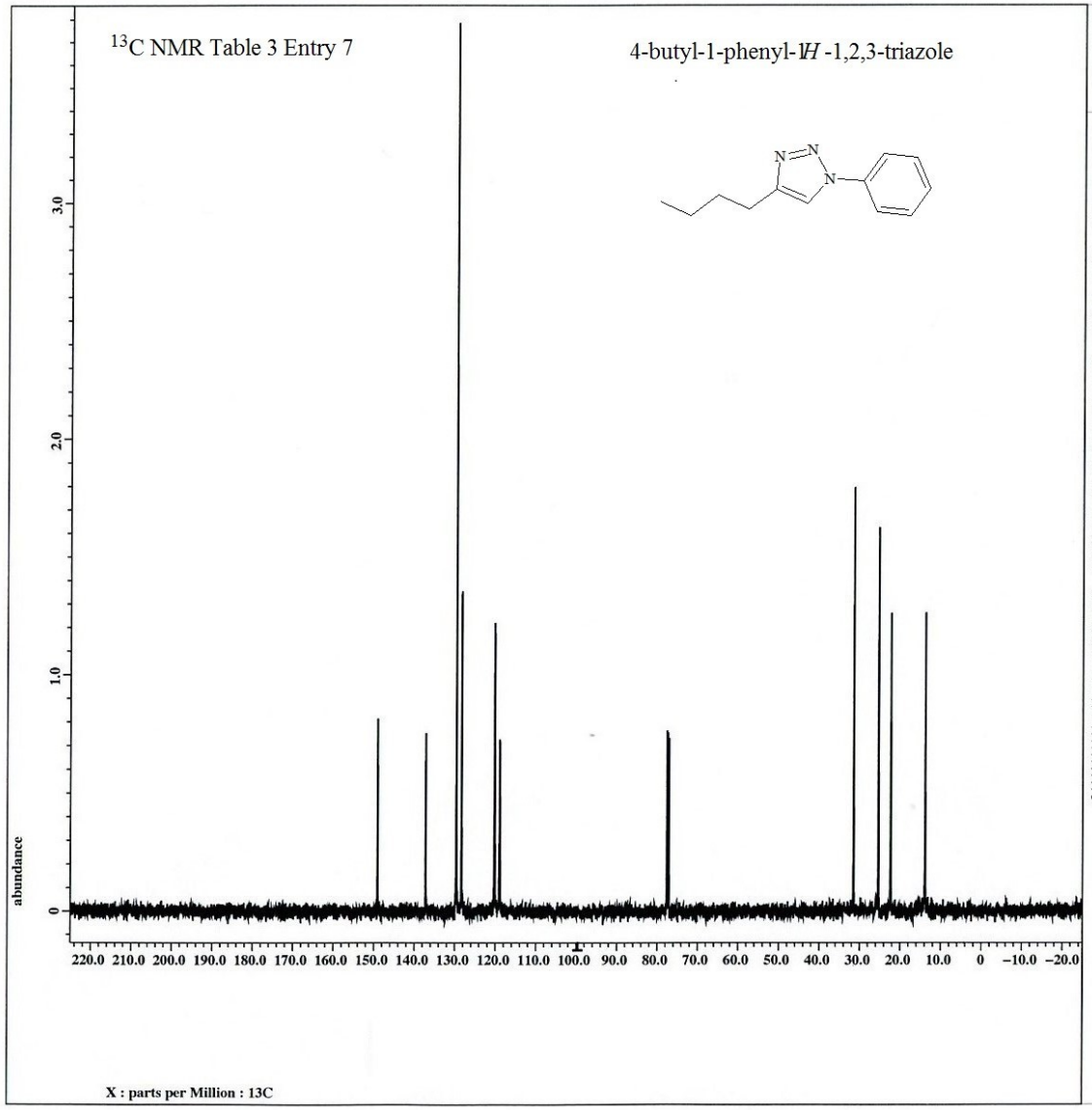

JEOL
Filename = AK_22_PROTON-5.jdf
Author = handy_
Experiment = single_pulse.ex2
Sample_id = AK_22
Solvent = CHLOROFORM-D
Creation_time = 11-JAN-2013 16:56:02
Revision_time = 26-MAY-2013 18:00:00
Current_time = 26-MAY-2013 18:00:17
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735579[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.159915 21[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.159915 21[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.159915 21[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scan_s = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_delay = 6.901[us]
X_pulse = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 40
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.2[dC]
1H NMR Table 3 Entry 6
4-(1-cyclohexen-1-yl)-1-phenyl-1H-1,2,3-triazole
4.2
2.0
2.1
2.0
1.0
2.0
1.0
1
7.8108
7.7135
7.7112
7.6963
7.4707
6.6141
6.6107
2.4181
2.4136
2.2017
1.7711
1.6795
1.6680
abundance
X : parts per Million : 1H



JEOL

Filename	= AK_22_CARBON-4.jdf
Author	= handy
Experiment	= single_pulse_dec
Sample_id	= AK_22
Solvent	= CHLOROFORM-D
Creation_time	= 11-JAN-2013 16:58:07
Revision_time	= 16-MAY-2013 19:12:49
Current_time	= 16-MAY-2013 19:13:22
Data_format	= 1D COMPLEX
Dim_size	= 26214
Dim_title	= 13C
Dim_units	= [ppm]
Dimensions	= X
Site	= ECA 500
Spectrometer	= DELTA2_NMR
Field_strength	= 11.7473579[T] (500[MH
X_acq_duration	= 0.83361792[s]
X_domain	= 13C
X_freq	= 125.76529768[MHz]
X_offset	= 100[ppm]
X_points	= 32768
X_prescans	= 4
X_resolution	= 1.19959034[Hz]
X_sweep	= 39.3081761[kHz]
Irr_domain	= 1H
Irr_freq	= 500.15991521[MHz]
Irr_offset	= 5.0[ppm]
Clipped	= FALSE
Mod_return	= 1
Scans	= 14
Total_scans	= 14
X_90_width	= 12[us]
X_acq_time	= 0.83361792[s]
X_angle	= 30[deg]
X_atn	= 3[dB]
X_pulse	= 4[us]
Irr_atn_dec	= 21[dB]
Irr_atn_noe	= 21[dB]
Irr_noise	= WALTZ
Decoupling	= TRUE
Initial_wait	= 1[s]
Noe	= TRUE
Noe_time	= 2[s]
Recvr_gain	= 56
Relaxation_delay	= 2[s]
Repetition_time	= 2.83361792[s]
Temp_get	= 21.3[dC]


JEOL
Filename = AK_13_Apr1_3(11:15)_P
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_13_Apr1_3(11:15)
Solvent = CHLOROFORM-D
Creation_time = 3-APR-2013 10:54:46
Revision_time = 26-MAY-2013 18:05:48
Current_time = 26-MAY-2013 18:05:56
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735579[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Ir_domain = 1H
Ir_freq = 500.15991521[MHz]
Ir_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 40
Relaxation_delay = 5[s]
Repetition_time = 21.1[dC]
Temp_get
4-butyl-1-phenyl-1H -1,2,3-triazole
1H NMR Table 3 Entry 7
abundance
X : parts per Million : 1H
7.7123
7.6894
7.6746
7.6723
2.7732
2.7583
2.7422
1.6829
1.6680
1.3978
1.3817
0.9328
0.9185



JEOL

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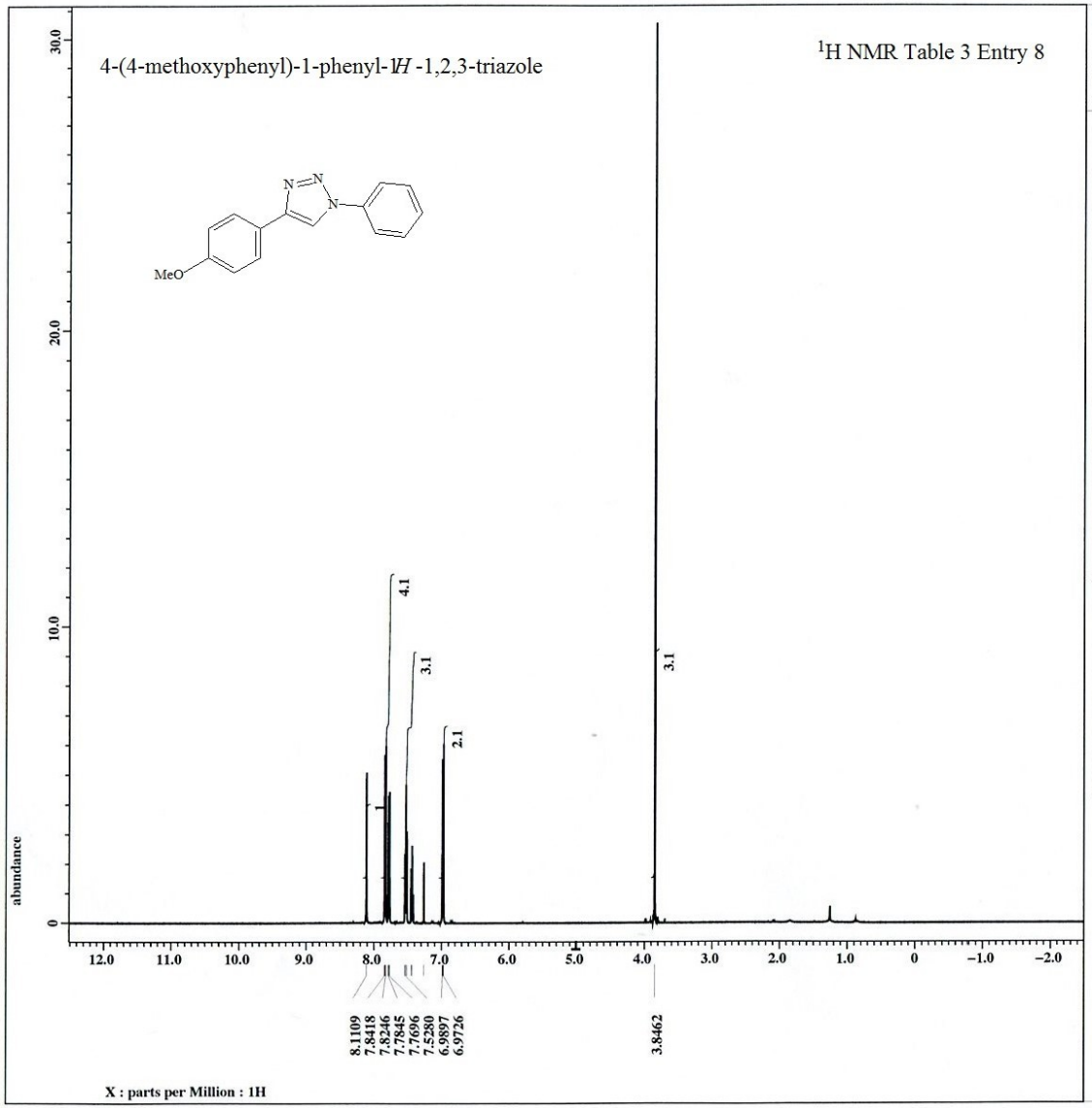
Filename          = AK_27_CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_27
Solvent           = CHLOROFORM-D
Creation_time     = 10-JAN-2013 19:08:57
Revision_time     = 16-MAY-2013 19:20:17
Current_time      = 16-MAY-2013 19:22:13

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 14
Total_scans       = 14

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 58
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.5[dC]
```

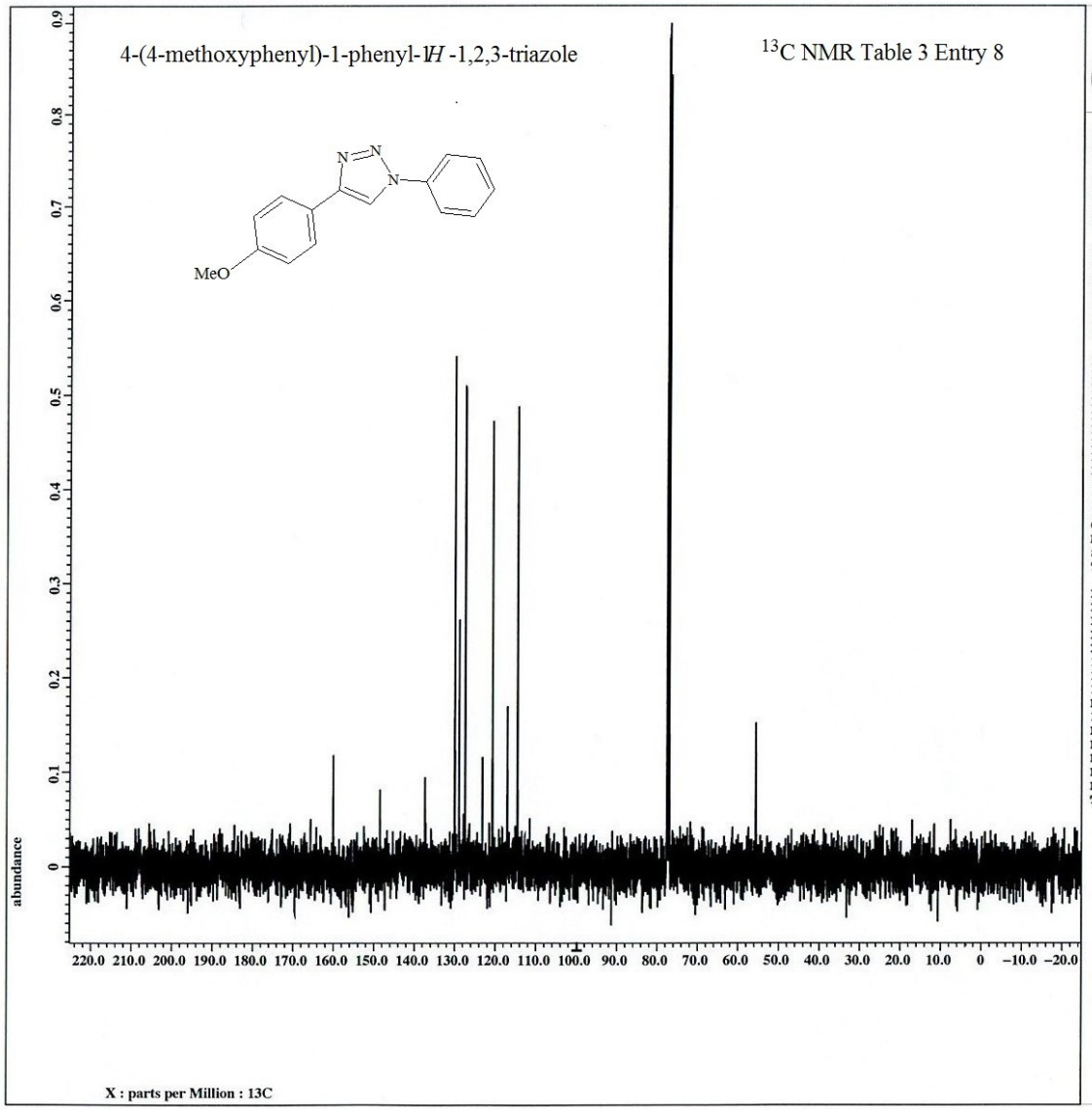



```
Filename          = AK_30._PROTON-8.jdf
Author            = handy
Experiment        = single_pulse.ex2
Sample_id         = AK_30.
Solvent           = CHLOROFORM-D
Creation_time     = 18-JAN-2013 14:40:54
Revision_time     = 26-MAY-2013 18:12:46
Current_time      = 26-MAY-2013 18:13:12

Data_format       = 1D COMPLEX
Dim_size          = 13107
Dim_title         = 1H
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 1.74587904[s]
X_domain          = 1H
X_freq            = 500.15991521[MHz]
X_offset          = 5.0[ppm]
X_points          = 16384
X_prescans        = 1
X_resolution      = 0.57277737[Hz]
X_sweep           = 9.38438438[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Tri_domain        = 1H
Tri_freq          = 500.15991521[MHz]
Tri_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 16
Total_scans       = 16

X_90_width        = 13.802[us]
X_acq_time        = 1.74587904[s]
X_angle           = 45[deg]
X_atn             = 3[dB]
X_pulse           = 6.901[us]
Irr_mode          = Off
Tri_mode          = Off
Dante_presat      = FALSE
Initial_wait      = 1[s]
Recvr_gain        = 48
Relaxation_delay  = 4[s]
Repetition_time   = 5.74587904[s]
Temp_get          = 21.7[dC]
```



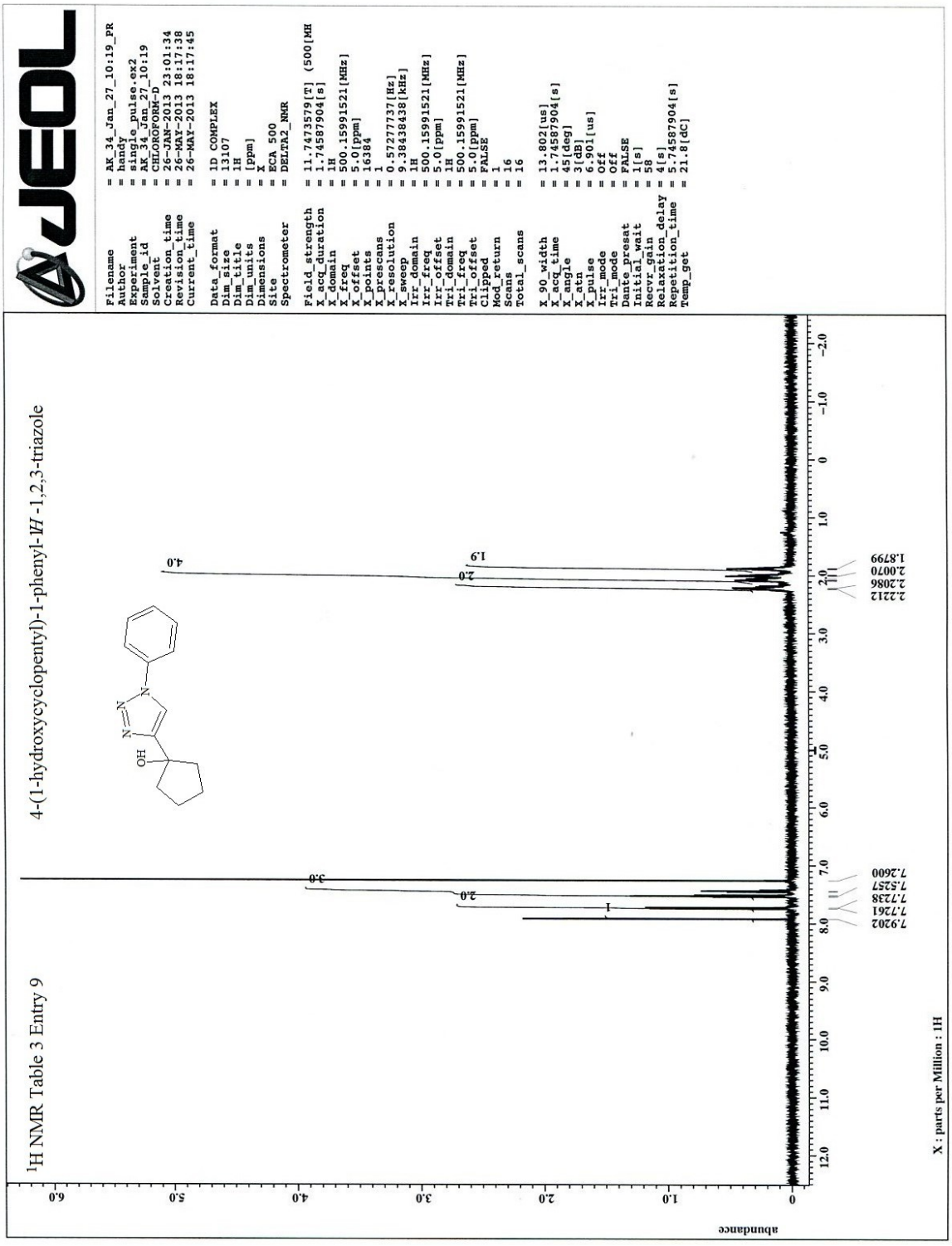
JEOL

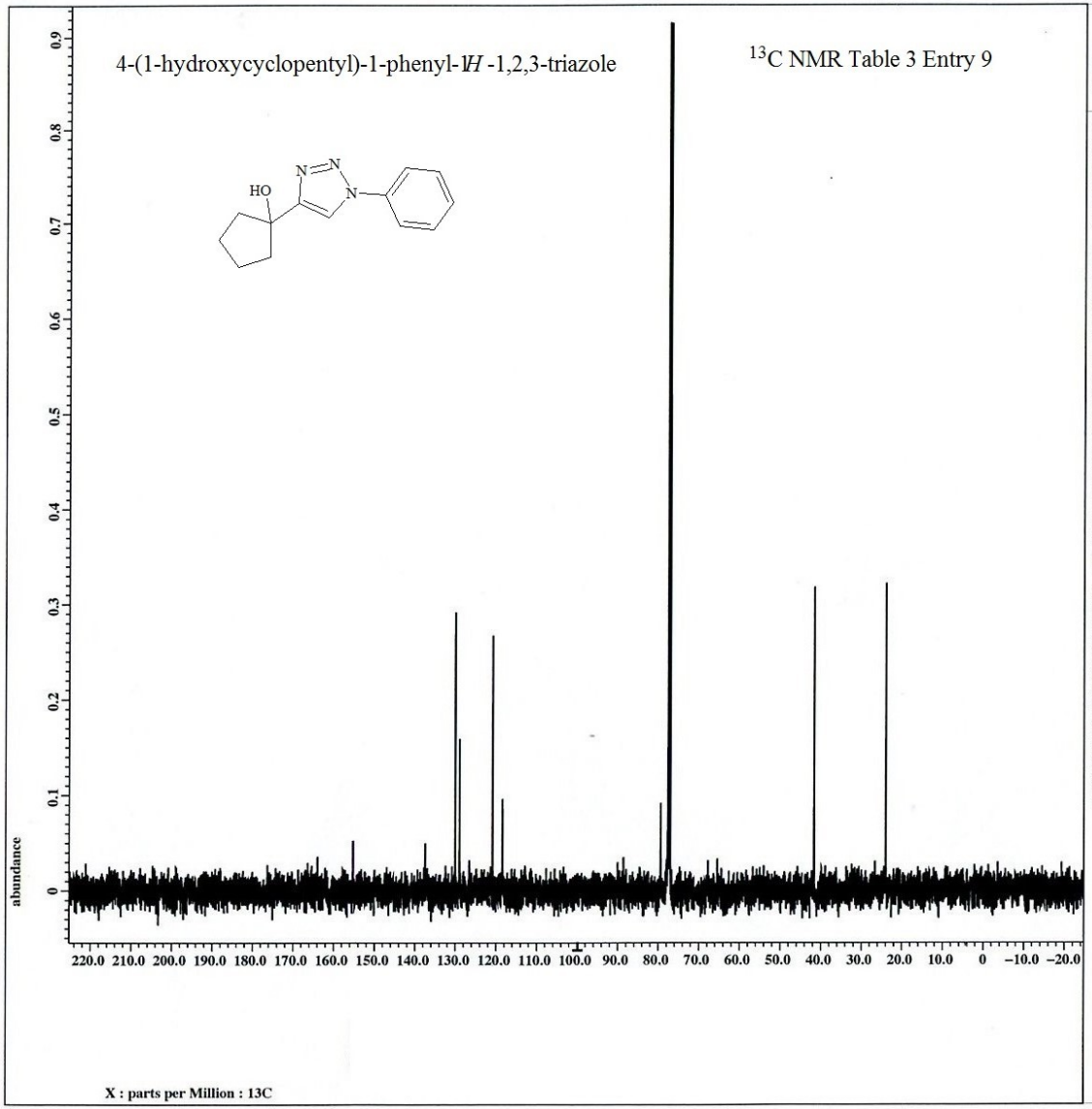
```
Filename          = AK_30._CARBON-11.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_30..
Solvent           = CHLOROFORM-D
Creation_time     = 18-JAN-2013 14:54:11
Revision_time     = 16-MAY-2013 19:28:00
Current_time      = 16-MAY-2013 19:28:02

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 14
Total_scans       = 14

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 58
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.9[dC]
```


JEOL
Filename = AK_34_Jan_27_10:19_PR
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_34_Jan_27_10:19
Solvent = CHLOROFORM-D
Creation_time = 26-JAN-2013 23:01:34
Revision_time = 26-MAY-2013 18:17:38
Current_time = 26-MAY-2013 18:17:45
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.159991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.159991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.159991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Irr_mode = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recyc_gain = 58
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.8[dC]
1H NMR Table 3 Entry 9
4-(1-hydroxycyclopentyl)-1-phenyl-1H-1,2,3-triazole
OH
N
N
N
7.9202
7.7261
7.7238
7.5257
7.2600
2.2212
2.2086
2.0070
1.8799
4.0
3.0
2.0
2.0
1.9
I
abundance
X : parts per Million : 1H



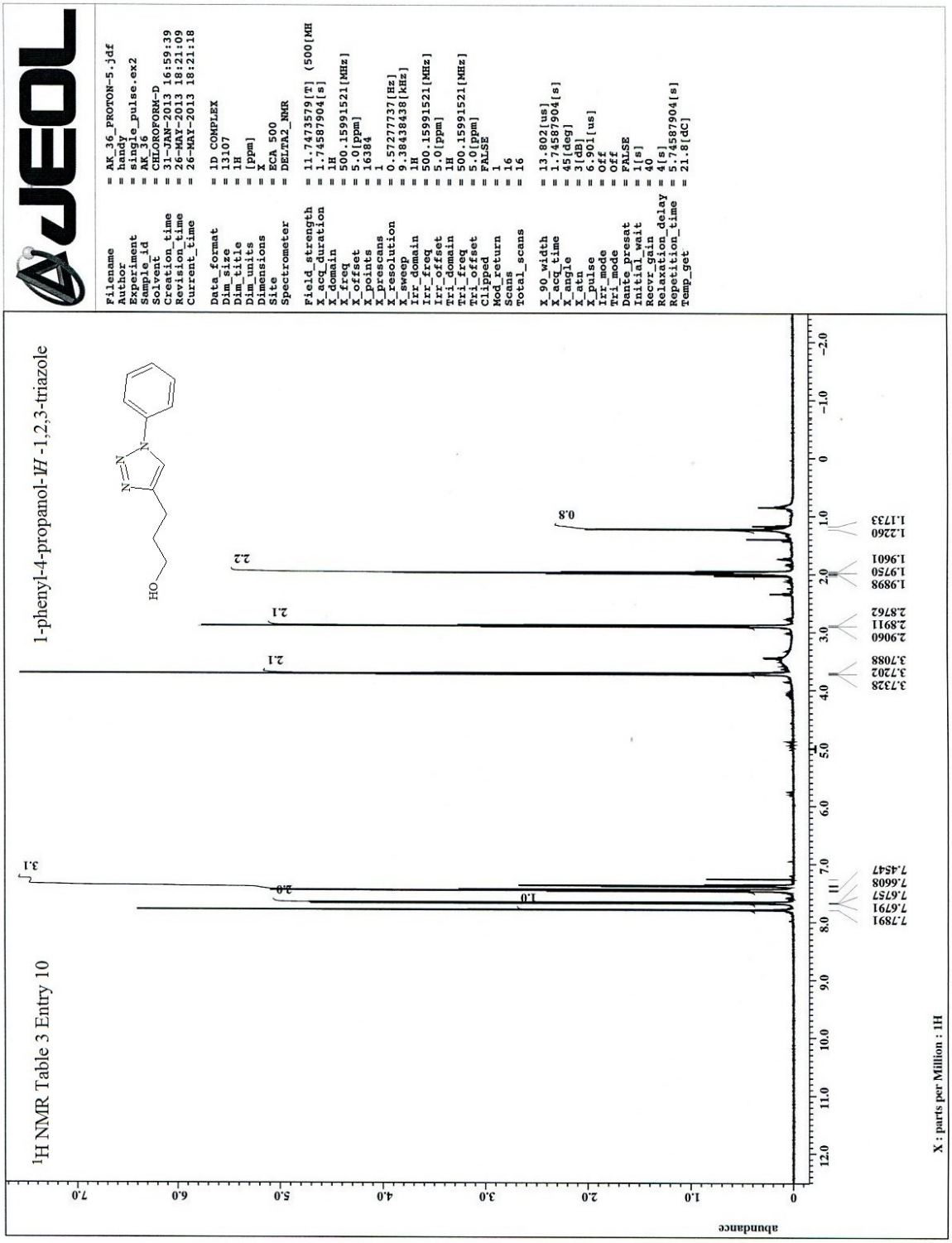
JEOL

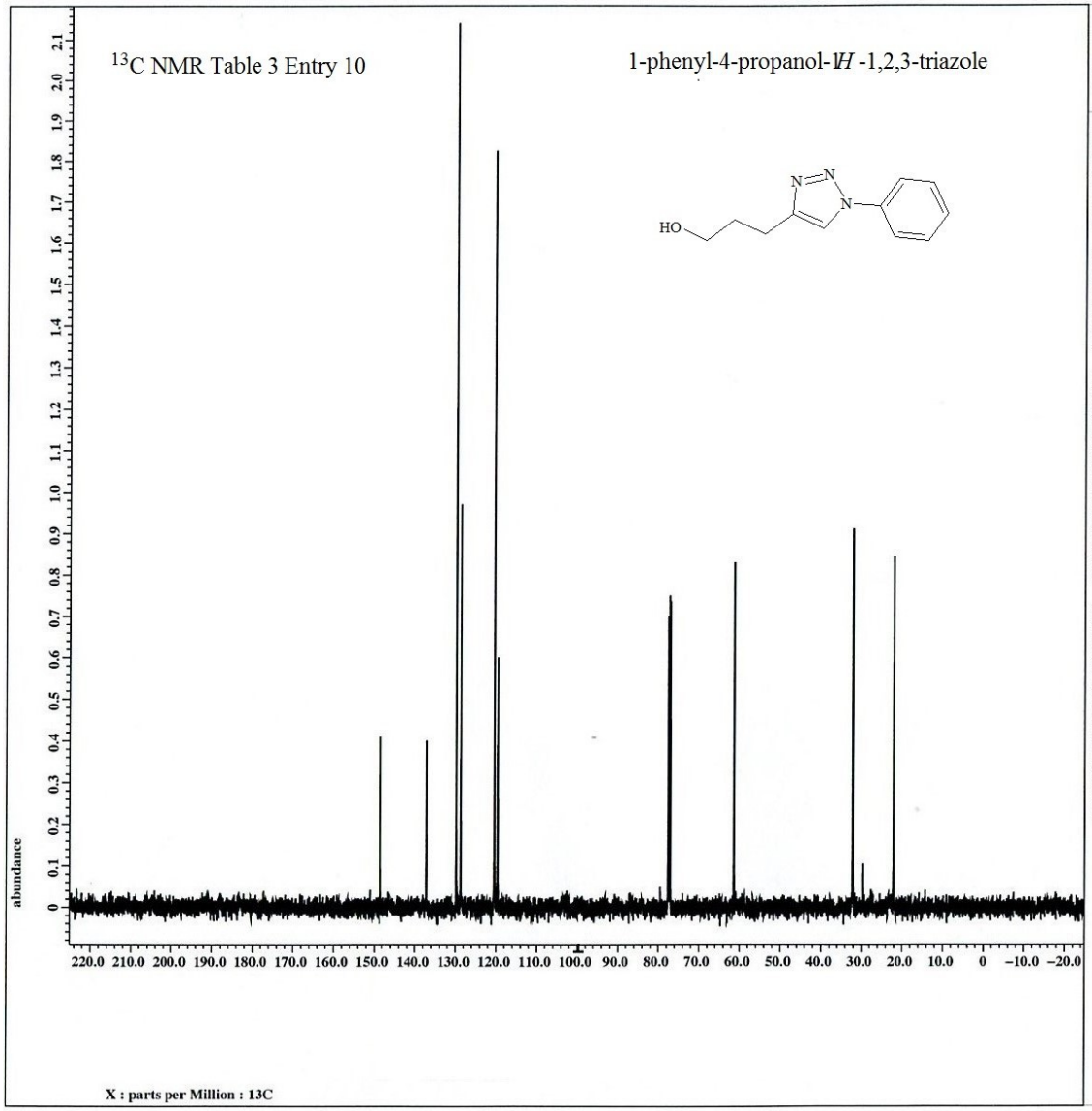
```
Filename          = AK_34_Jan_27_10:30_CA
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_34_Jan_27_10:30
Solvent           = CHLOROFORM-D
Creation_time     = 26-JAN-2013 23:13:51
Revision_time     = 16-MAY-2013 19:35:15
Current_time      = 16-MAY-2013 19:35:19

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 35
Total_scans       = 35

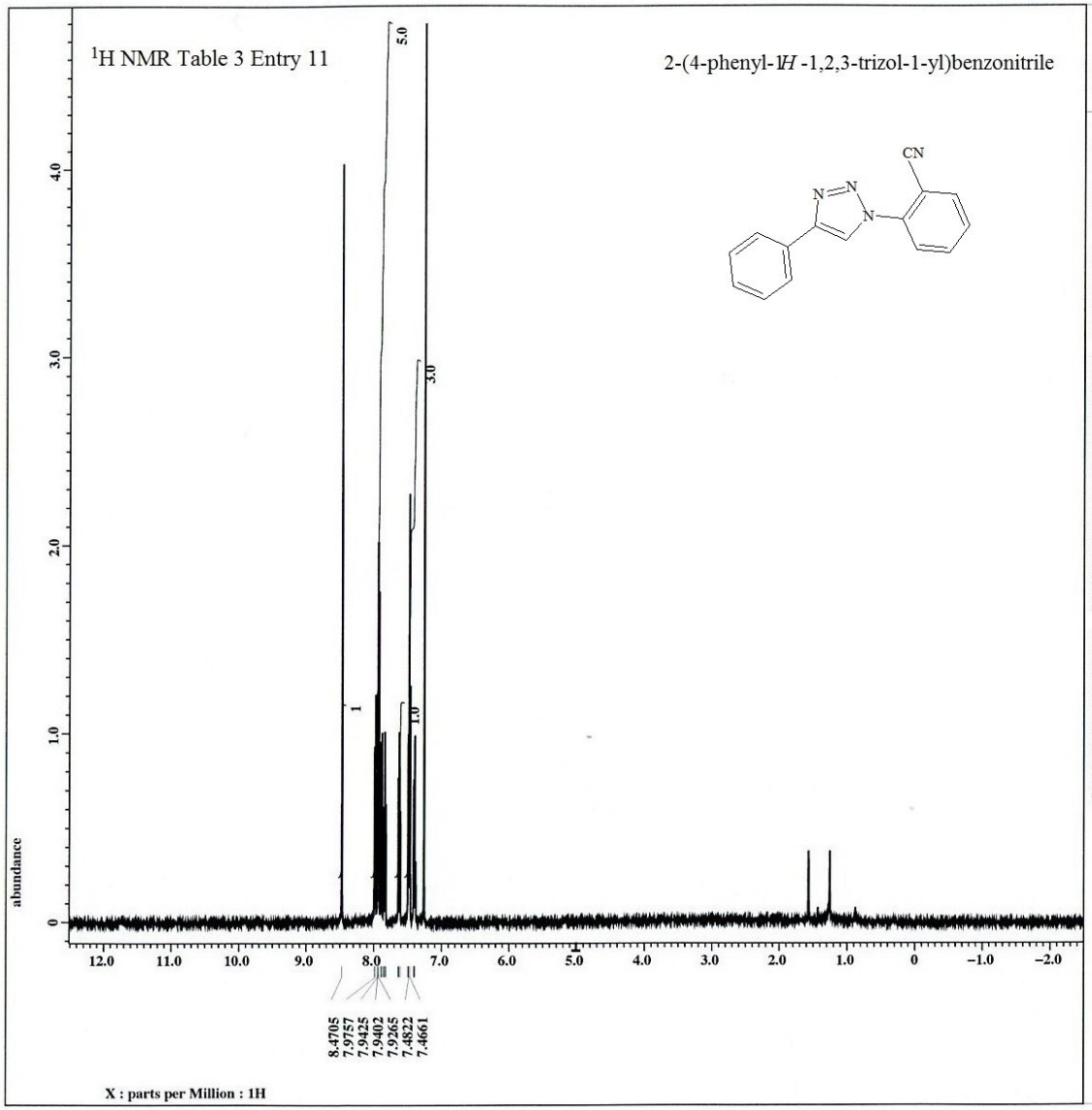
X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 58
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.9[dC]
```


JEOL
Filename = AK_36_PROTON-5.jdf
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_36
Solvent = CHLOROFORM-D
Creation_time = 31-JAN-2013 16:59:39
Revision_time = 26-MAY-2013 18:21:09
Current_time = 26-MAY-2013 18:21:18
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 1[dB]
X_pulse = 6.901[us]
Irr_mode = off
Tri_mode = off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 40
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.8[dC]
1H NMR Table 3 Entry 10
1-phenyl-4-propanol-1H -1,2,3-triazole
HO
N
N
N
3.1
2.0
1.0
2.1
2.2
2.1
0.8
7.7891
7.6791
7.6757
7.6608
7.4547
3.7328
3.7202
3.7088
2.9060
2.8911
2.8762
1.9898
1.9750
1.9601
1.2260
1.1733
abundance
X : parts per Million : 1H



JEOL

Filename	= AK16March21_CARBON-4.
Author	= handy
Experiment	= single_pulse_dec
Sample_id	= AK16March21
Solvent	= CHLOROFORM-D
Creation_time	= 21-MAR-2013 22:40:09
Revision_time	= 16-MAY-2013 19:42:06
Current_time	= 16-MAY-2013 19:42:50
Comment	= Pent-4-yn-1-ol + Benz
Data_format	= 1D COMPLEX
Dim_size	= 26214
Dim_title	= 13C
Dim_units	= [ppm]
Dimensions	= X
Site	= ECA 500
Spectrometer	= DELTA2_NMR
Field_strength	= 11.7473579[T] (500[MH
X_acq_duration	= 0.83361792[s]
X_domain	= 13C
X_freq	= 125.76529768[MHz]
X_offset	= 100[ppm]
X_points	= 32768
X_prescans	= 4
X_resolution	= 1.19959034[Hz]
X_sweep	= 39.3081761[kHz]
Irr_domain	= 1H
Irr_freq	= 500.15991521[MHz]
Irr_offset	= 5.0[ppm]
Clipped	= FALSE
Mod_return	= 1
Scans	= 14
Total_scans	= 14
X_90_width	= 12[us]
X_acq_time	= 0.83361792[s]
X_angle	= 30[deg]
X_atn	= 3[dB]
X_pulse	= 4[us]
Irr_atn_dec	= 21[dB]
Irr_atn_noe	= 21[dB]
Irr_noise	= WALTZ
Decoupling	= TRUE
Initial_wait	= 1[s]
Noe	= TRUE
Noe_time	= 2[s]
Recvr_gain	= 56
Relaxation_delay	= 2[s]
Repetition_time	= 2.83361792[s]
Temp_get	= 22[dC]



JEOL

```
Filename          = AK_018__PROTON-5.jdf
Author            = handy
Experiment        = single_pulse.ex2
Sample_id         = AK_018_
Solvent           = CHLOROFORM-D
Creation_time     =  5-APR-2013 22:45:32
Revision_time     = 26-MAY-2013 18:24:09
Current_time      = 26-MAY-2013 18:24:18

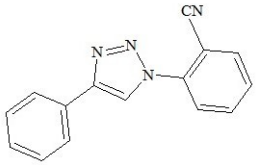
Data_format       = 1D COMPLEX
Dim_size          = 13107
Dim_title         = 1H
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 1.74587904[s]
X_domain          = 1H
X_freq            = 500.15991521[MHz]
X_offset          = 5.0[ppm]
X_points          = 16384
X_prescans        = 1
X_resolution      = 0.57277737[Hz]
X_sweep           = 9.38438438[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Tri_domain        = 1H
Tri_freq          = 500.15991521[MHz]
Tri_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 16
Total_scans       = 16

X_90_width        = 13.802[us]
X_acq_time        = 1.74587904[s]
X_angle           = 45[deg]
X_atn             = 3[dB]
X_pulse           = 6.901[us]
Irr_mode          = Off
Tri_mode          = Off
Dante_presat      = FALSE
Initial_wait      = 1[s]
Recvr_gain        = 60
Relaxation_delay  = 4[s]
Repetition_time   = 5.74587904[s]
Temp_get          = 21.1[dC]
```

2-(4-phenyl-1*H*-1,2,3-triazol-1-yl)benzonitrile

^{13}C NMR Table 3 Entry 11




```
Filename          = AK_018__CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_018_
Solvent           = CHLOROFORM-D
Creation_time     =  5-APR-2013 23:34:37
Revision_time     = 16-MAY-2013 19:46:30
Current_time      = 16-MAY-2013 19:47:28

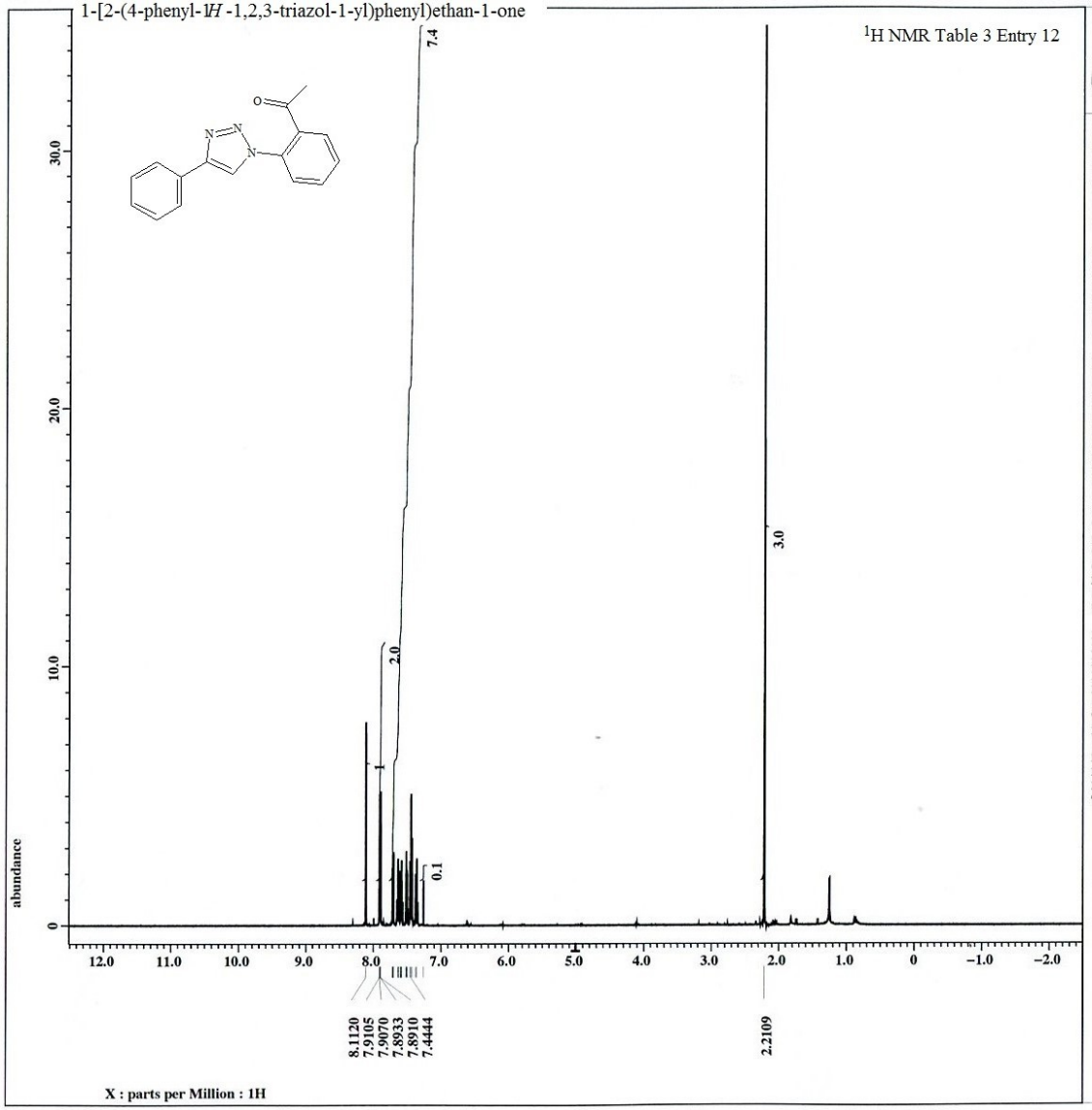
Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = TRUE
Mod_return        = 1
Scans             = 1024
Total_scans       = 1024

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 56
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.5[dC]
```

1-[2-(4-phenyl-1*H*-1,2,3-triazol-1-yl)phenyl)ethan-1-one

^{1}H NMR Table 3 Entry 12

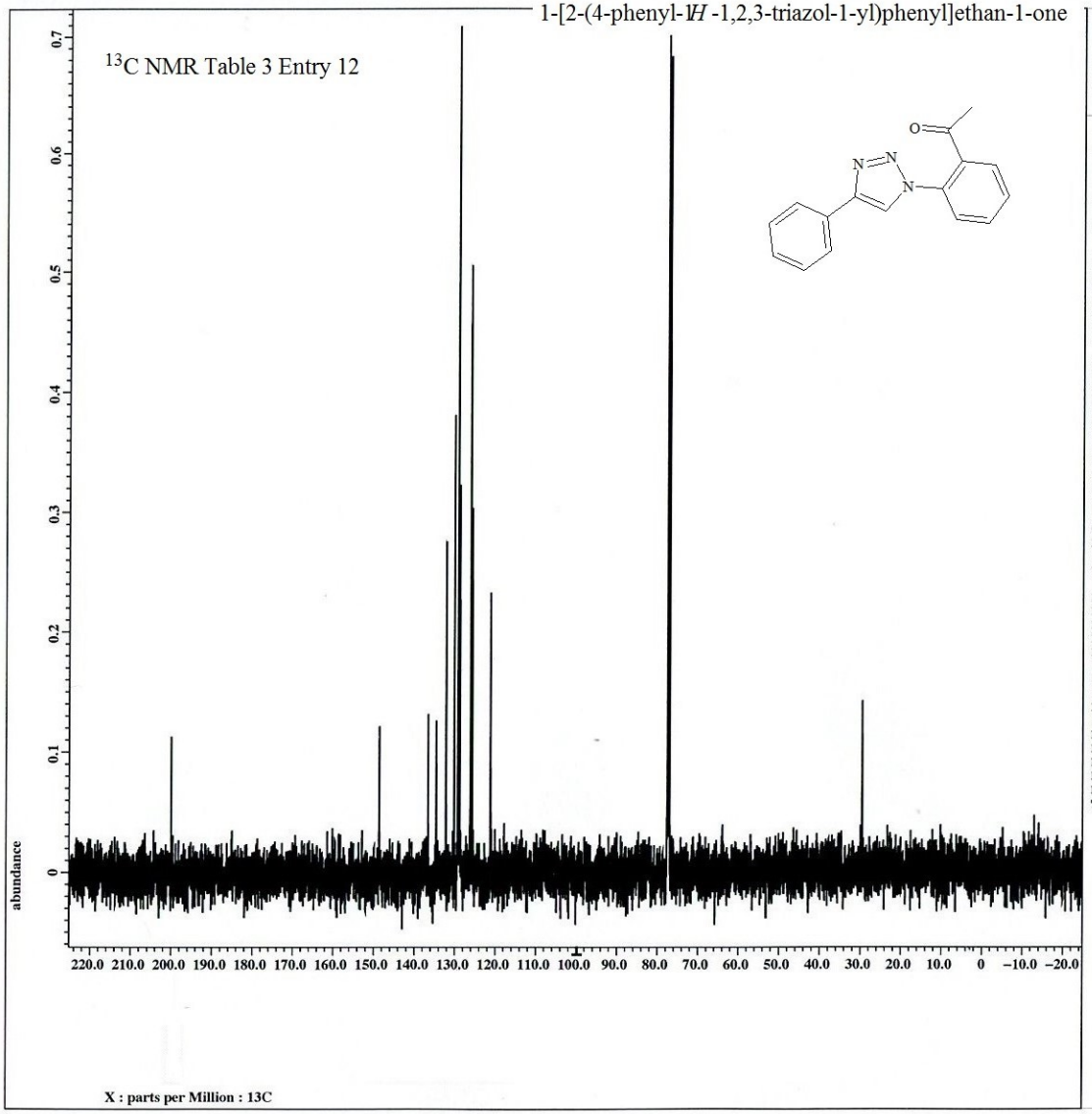


JEOL

Filename	= AK_18_May_14_PROTON-5
Author	= handy
Experiment	= single_pulse.ex2
Sample_id	= AK_18_May_14
Solvent	= CHLOROFORM-D
Creation_time	= 14-MAY-2013 18:22:57
Revision_time	= 26-MAY-2013 18:27:22
Current_time	= 26-MAY-2013 18:27:28
Data_format	= 1D COMPLEX
Dim_size	= 13107
Dim_title	= 1H
Dim_units	= [ppm]
Dimensions	= X
Site	= ECA 500
Spectrometer	= DELTA2_NMR
Field_strength	= 11.7473579[T] (500[MH
X_acq_duration	= 1.74587904[s]
X_domain	= 1H
X_freq	= 500.15991521[MHz]
X_offset	= 5.0[ppm]
X_points	= 16384
X_prescans	= 1
X_resolution	= 0.57277737[Hz]
X_sweep	= 9.38438438[kHz]
Irr_domain	= 1H
Irr_freq	= 500.15991521[MHz]
Irr_offset	= 5.0[ppm]
Tri_domain	= 1H
Tri_freq	= 500.15991521[MHz]
Tri_offset	= 5.0[ppm]
Clipped	= FALSE
Mod_return	= 1
Scans	= 16
Total_scans	= 16
X_90_width	= 13.802[us]
X_acq_time	= 1.74587904[s]
X_angle	= 45[deg]
X_atn	= 3[dB]
X_pulse	= 6.901[us]
Irr_mode	= Off
Tri_mode	= Off
Dante_presat	= FALSE
Initial_wait	= 1[s]
Recvr_gain	= 50
Relaxation_delay	= 4[s]
Repetition_time	= 5.74587904[s]
Temp_get	= 19.5[dC]

1-[2-(4-phenyl-1*H*-1,2,3-triazol-1-yl)phenyl]ethan-1-one

^{13}C NMR Table 3 Entry 12



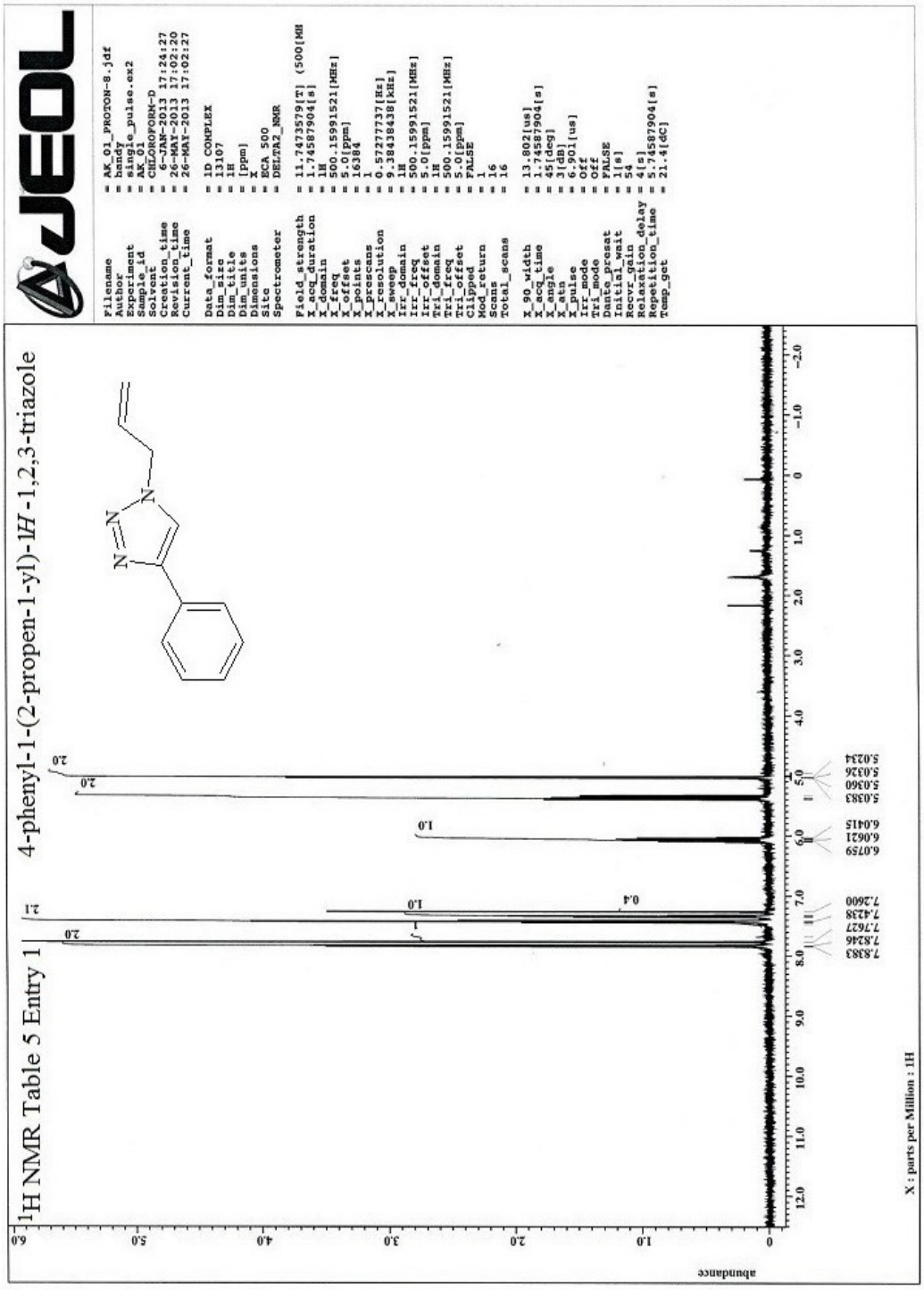
JEOL

```
Filename          = AK_18_May_14_CARBON-4
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_18_May_14
Solvent           = CHLOROFORM-D
Creation_time     = 14-MAY-2013 18:24:15
Revision_time     = 16-MAY-2013 19:50:22
Current_time      = 16-MAY-2013 19:51:30

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 14
Total_scans       = 14

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 56
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 19.6[dC]
```


JEOL
Filename = AK_01_PROTON-8.jdf
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_1
Solvent = CHLOROFORM-D
Creation_time = 6-JAN-2013 17:24:27
Revision_time = 26-MAY-2013 17:02:20
Current_time = 26-MAY-2013 17:02:27
Data_format = 1D COMPLEX
Dim_size = 13107
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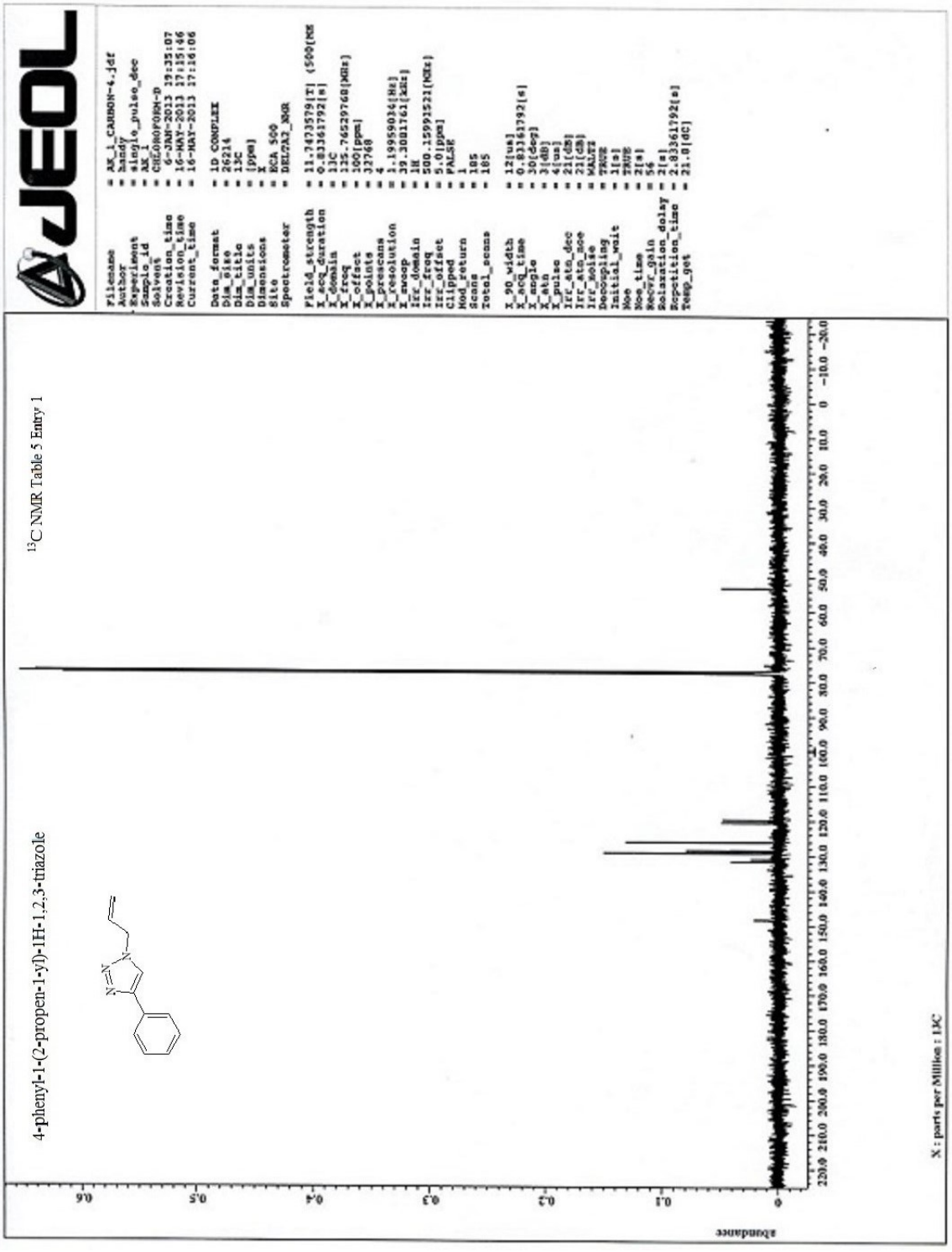
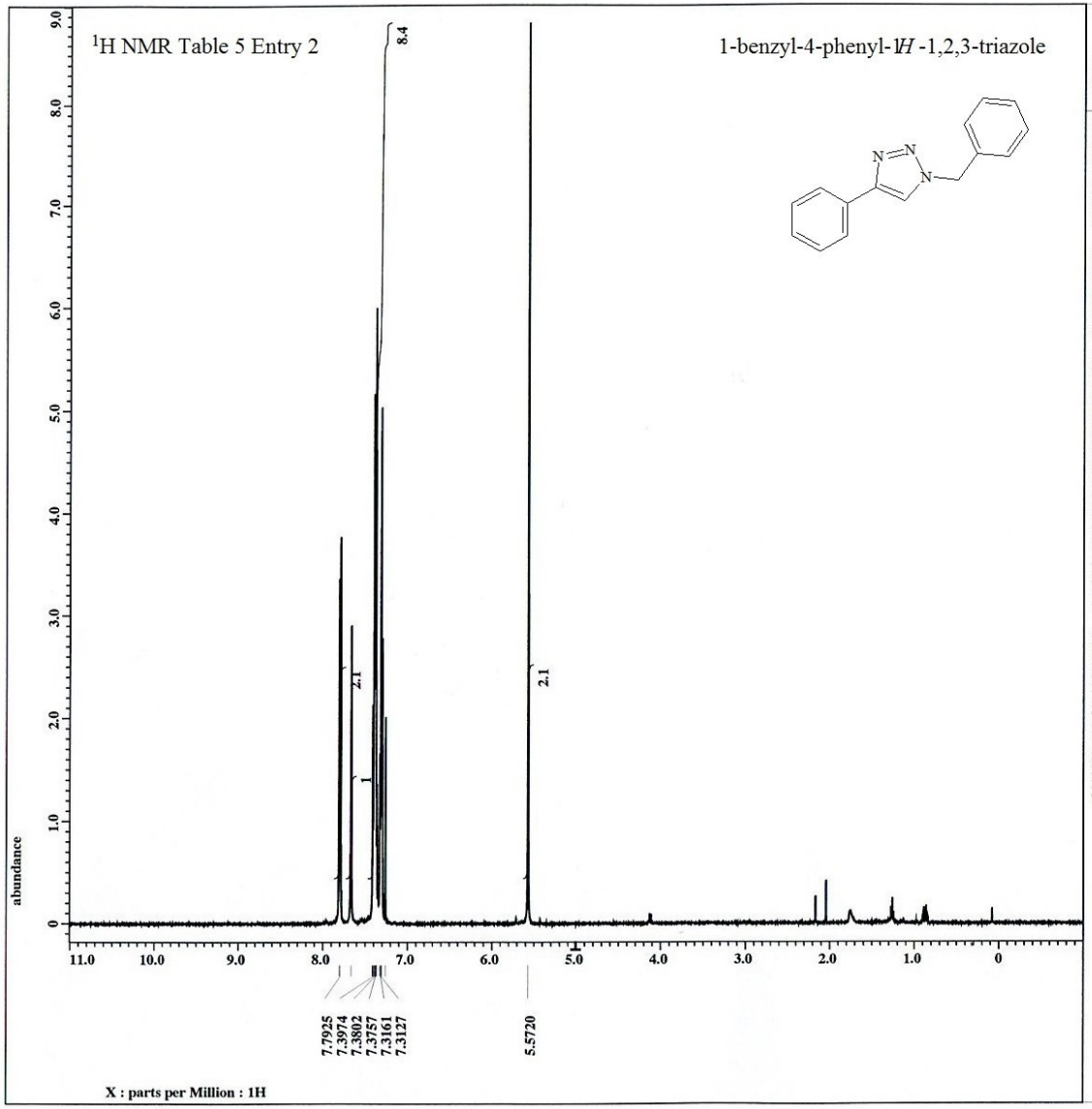
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735791[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 9.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Irr_mode = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 54
Relaxation_delay = 5[s]
Repetition_time = 7.1458790 4[s]
Temp_get = 21.4[dC]
1H NMR Table 5 Entry 1
4-phenyl-1-(2-propen-1-yl)-1H-1,2,3-triazole
abundance
X : parts per Million : 1H
7.8383
7.8246
7.7627
7.4238
7.2600
6.0759
6.0621
6.0415
5.0383
5.0360
5.0326
5.0234
2.0
2.1
1.0
0.4


4-phenyl-1-(2-propen-1-yl)-1H-1,2,3-triazole
^{13}C NMR Table 5 Entry 1
JEOL
Filename = AK_1_CARBON-4.jdf
Author = kandy
Experiment = single_pulse_dec
Sample_id = AK_1
Solvent = CHLOROFORM-D
Creation_time = 6-JAN-2013 19:35:07
Revision_time = 16-MAY-2013 17:15:46
Current_time = 16-MAY-2013 17:16:06
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735791[T] (500[MH
X_acq_duration = 0.83361792[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 1.19959036[Hz]
X_sweep = 39.30811761[kHz]
IR_domain = 1H
Irr_freq = 500.15991523[MHz]
Irr_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 185
Total_scans = 185
X_90_width = 12[us]
X_acq_time = 0.83361792[s]
X_angle = 30[deg]
X_atn = 3[dB]
X_pulse = 4[us]
Irr_atn_dec = 21[dB]
Irr_atn_noe = 21[dB]
Irr_mode = MALTZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe = TRUE
Noe_time = 2[s]
Rec_gain = 56
Relaxation_delay = 2[s]
Repetition_time = 2.83361792[s]
Temp_get = 21.0[dC]
Abundance
X : parts per Million : 13C



JEOL

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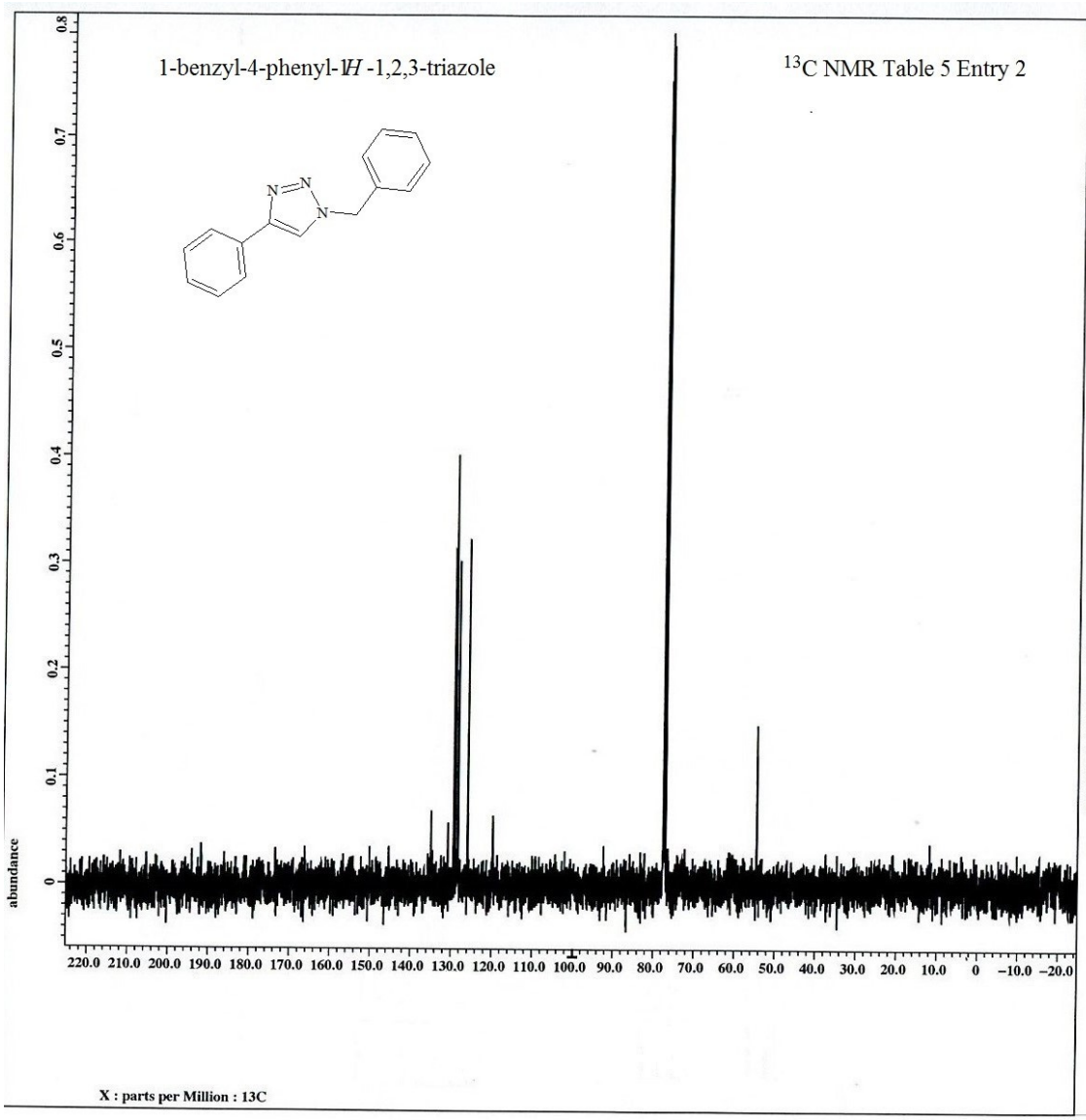
Filename          = AK_2__PROTON-5.jdf
Author            = handy
Experiment        = single_pulse.ex2
Sample_id         = AK_2(II)_
Solvent           = CHLOROFORM-D
Creation_time     =  6-JAN-2013 20:24:27
Revision_time     = 26-MAY-2013 16:51:07
Current_time      = 26-MAY-2013 16:51:18

Data_format       = 1D COMPLEX
Dim_size          = 13107
Dim_title         = 1H
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 1.74587904[s]
X_domain          = 1H
X_freq            = 500.15991521[MHz]
X_offset          = 5.0[ppm]
X_points          = 16384
X_prescans        = 1
X_resolution      = 0.57277737[Hz]
X_sweep           = 9.38438438[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Tri_domain        = 1H
Tri_freq          = 500.15991521[MHz]
Tri_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 16
Total_scans       = 16

X_90_width        = 13.802[us]
X_acq_time        = 1.74587904[s]
X_angle           = 45[deg]
X_atn             = 3[dB]
X_pulse           = 6.901[us]
Irr_mode          = Off
Tri_mode          = Off
Dante_presat      = FALSE
Initial_wait      = 1[s]
Recvr_gain        = 50
Relaxation_delay  = 4[s]
Repetition_time   = 5.74587904[s]
Temp_get          = 21.5[dC]
```



JEOL

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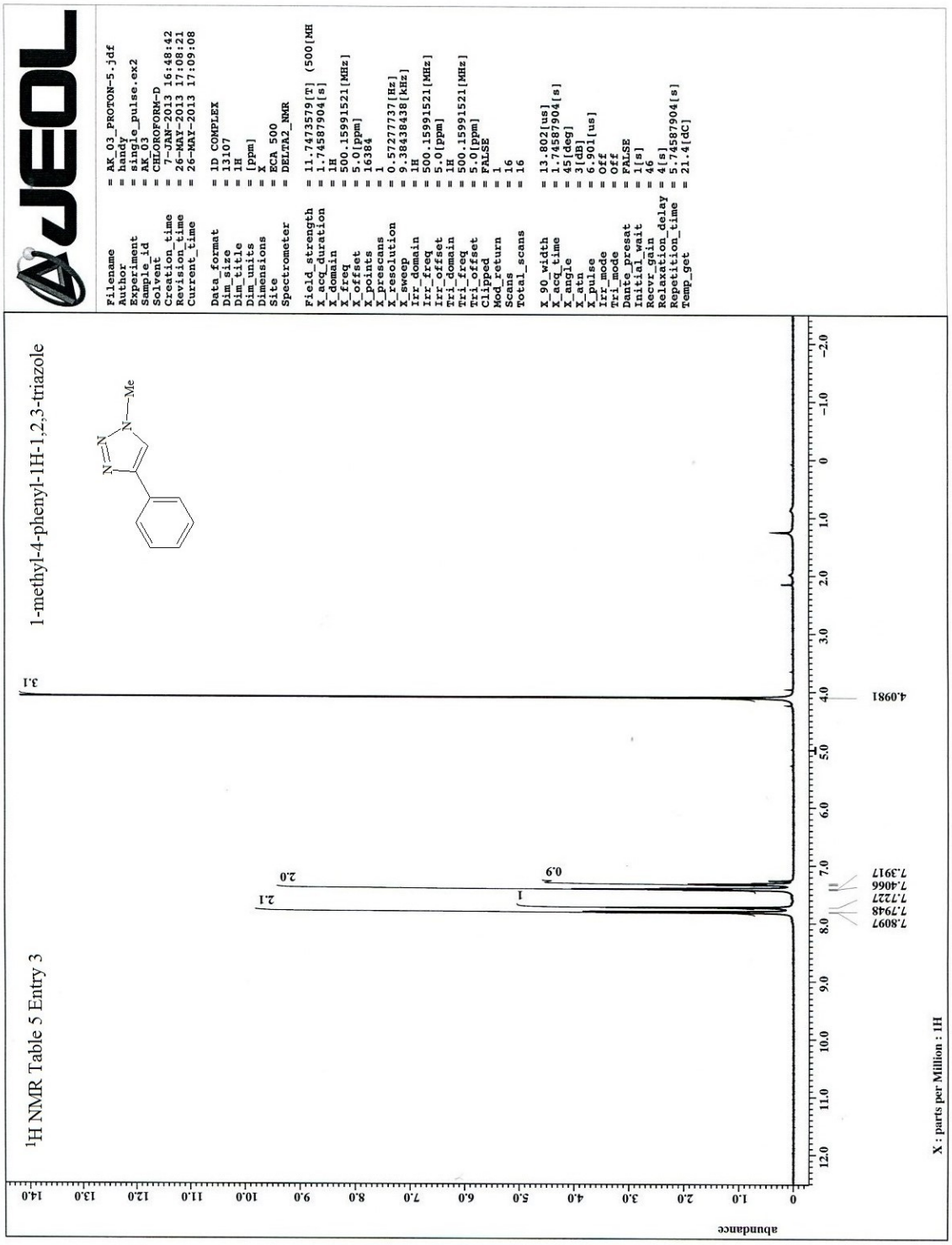
Filename          = AK_2__CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_2(II)_
Solvent           = CHLOROFORM-D
Creation_time     =  6-JAN-2013 20:26:40
Revision_time     = 16-MAY-2013 17:08:47
Current_time      = 16-MAY-2013 17:09:43

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 18
Total_scans       = 18

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 56
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.7[dC]
```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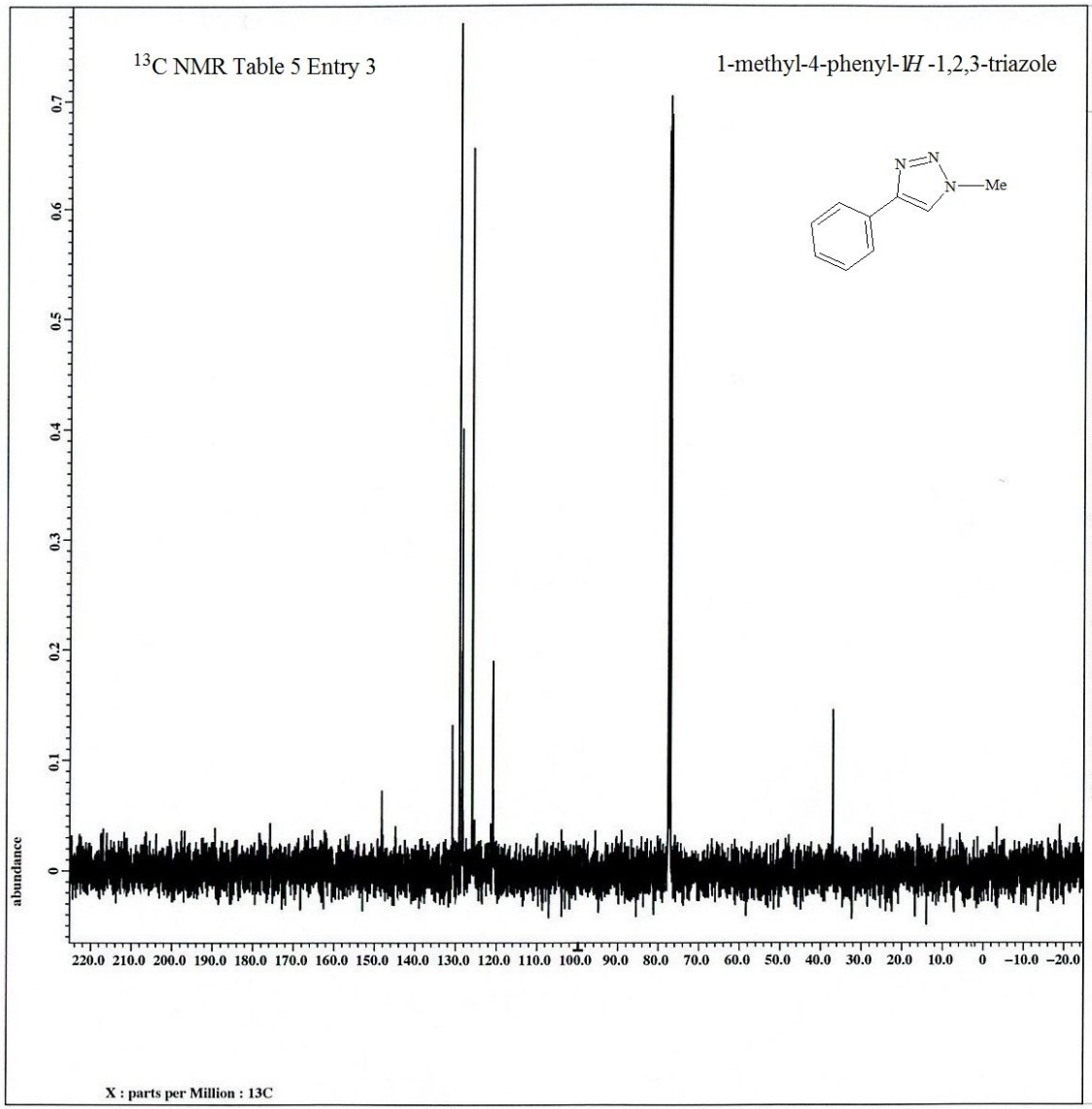
Filename = AK_03_PROTON-5.jdf
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_03
Solvent = CHLOROFORM-D
Creation_time = 7-JAN-2013 16:48:42
Revision_time = 26-MAY-2013 17:08:21
Current_time = 26-MAY-2013 17:09:08
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735791T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Irr_mode = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 46
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.4[dC]
1H NMR Table 5 Entry 3
1-methyl-4-phenyl-1H-1,2,3-triazole
Me
3.1
2.0
2.1
0.9
1
4.0981
7.8097
7.7948
7.7227
7.4066
7.3917
abundance
X : parts per Million : 1H



JEOL

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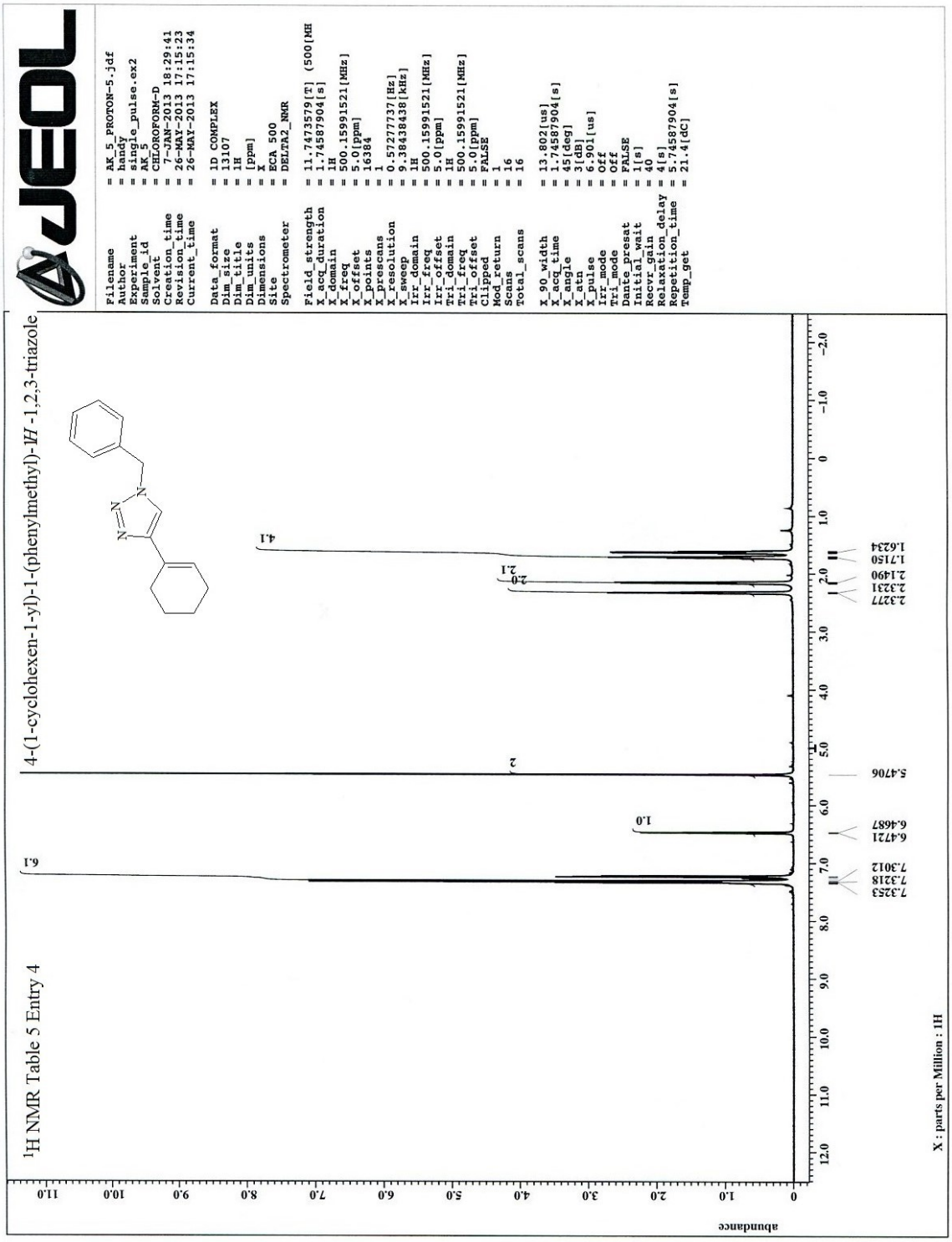
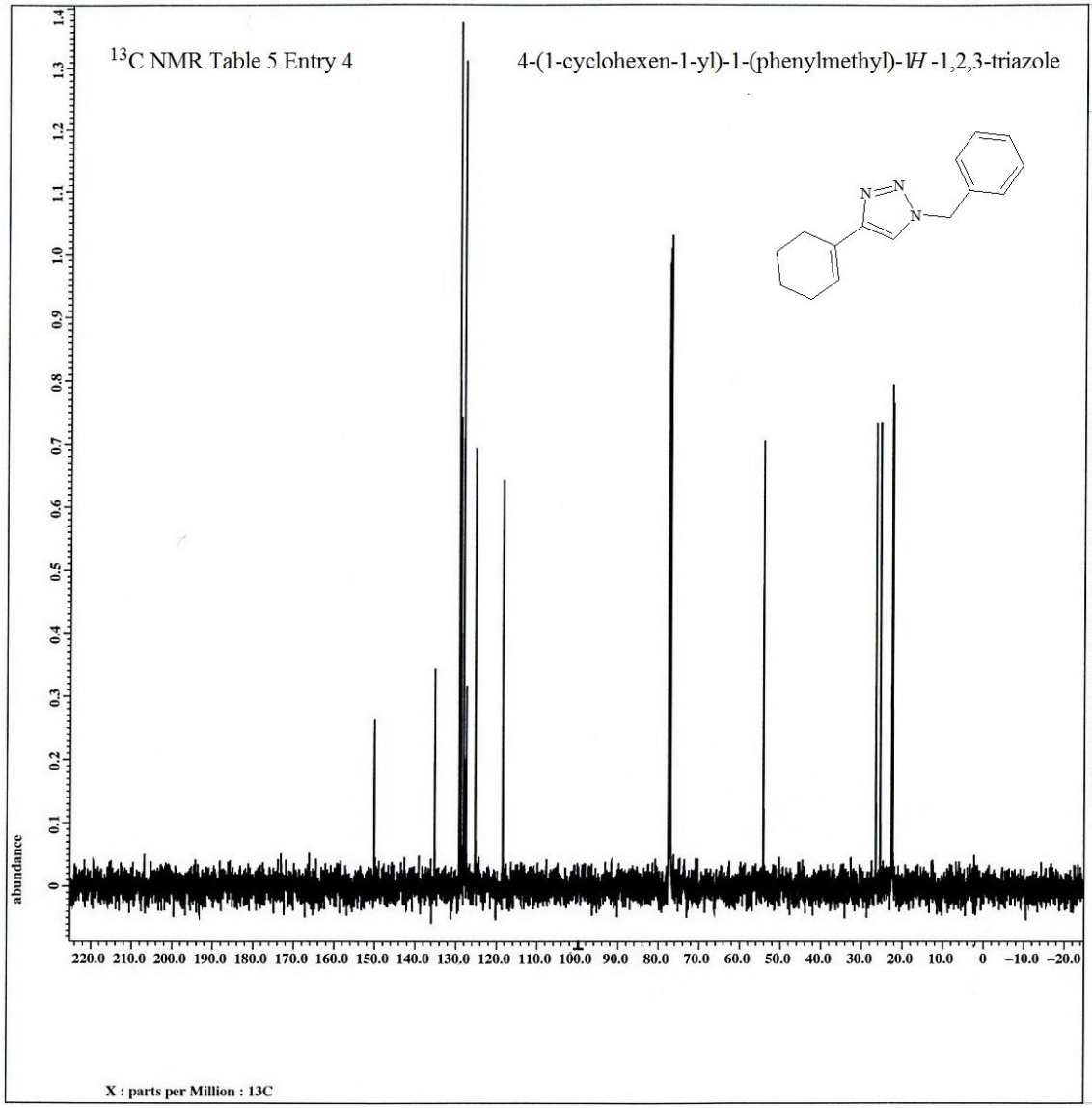
Filename          = AK_03_CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_03
Solvent           = CHLOROFORM-D
Creation_time     =  7-JAN-2013 16:55:03
Revision_time     = 16-MAY-2013 17:35:43
Current_time      = 16-MAY-2013 17:36:59

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 14
Total_scans       = 14

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 56
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.5[dC]
```


JEOL
Filename = AK_5_PROTON-5.jdf
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_5
Solvent = CHLOROFORM-D
Creation_time = 7-JAN-2013 18:29:41
Revision_time = 26-MAY-2013 17:15:23
Current_time = 26-MAY-2013 17:15:34
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Irr_mode = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recyr_gain = 40
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.4[dC]
1H NMR Table 5 Entry 4
4-(1-cyclohexen-1-yl)-1-(phenylmethyl)-1H-1,2,3-triazole
6.1
1.0
2
2.0
2.1
4.1
7.3253
7.3218
7.3012
6.4721
6.4687
5.4706
2.3277
2.3231
2.1490
1.7150
1.6234
abundance
X : parts per Million : 1H



JEOL

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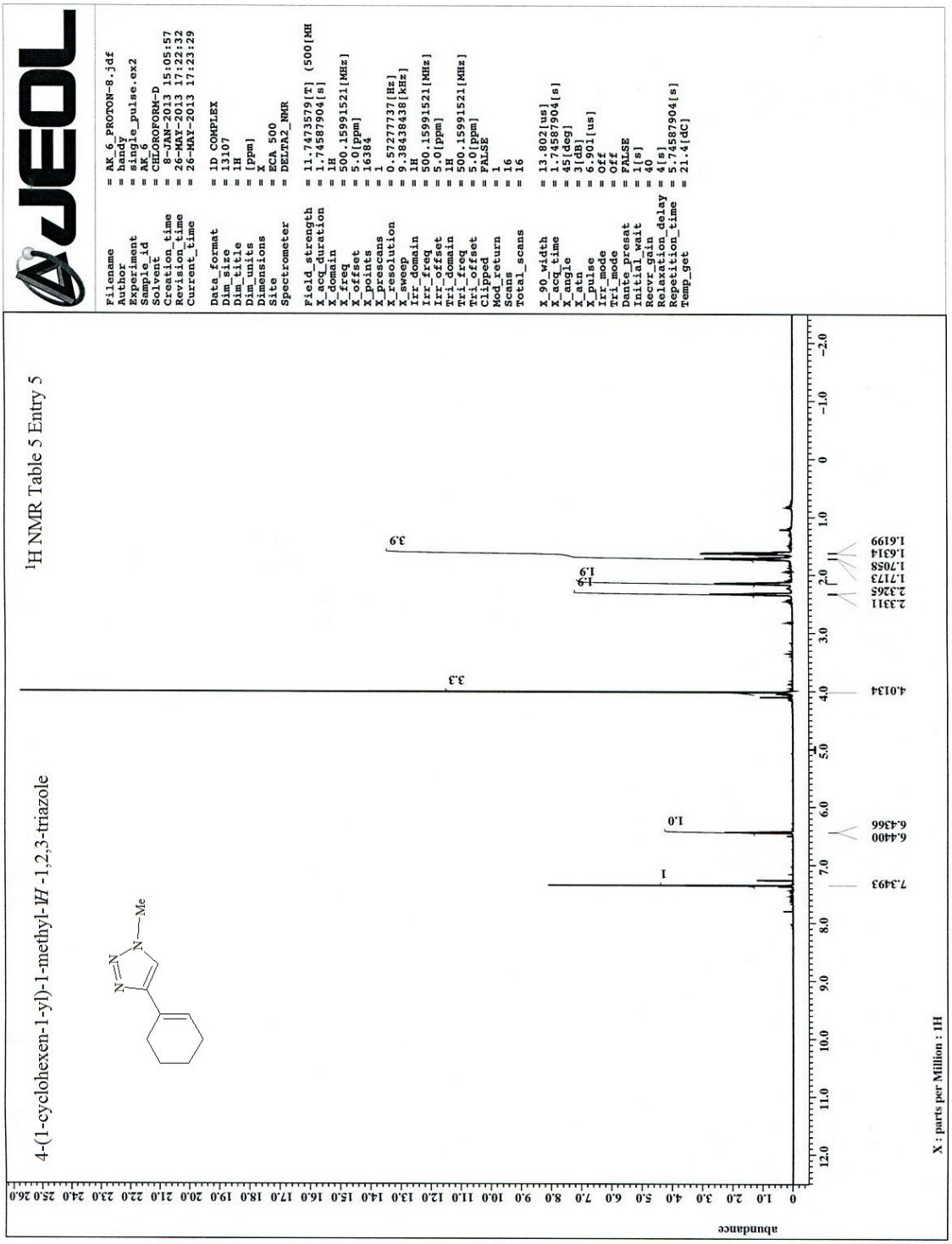
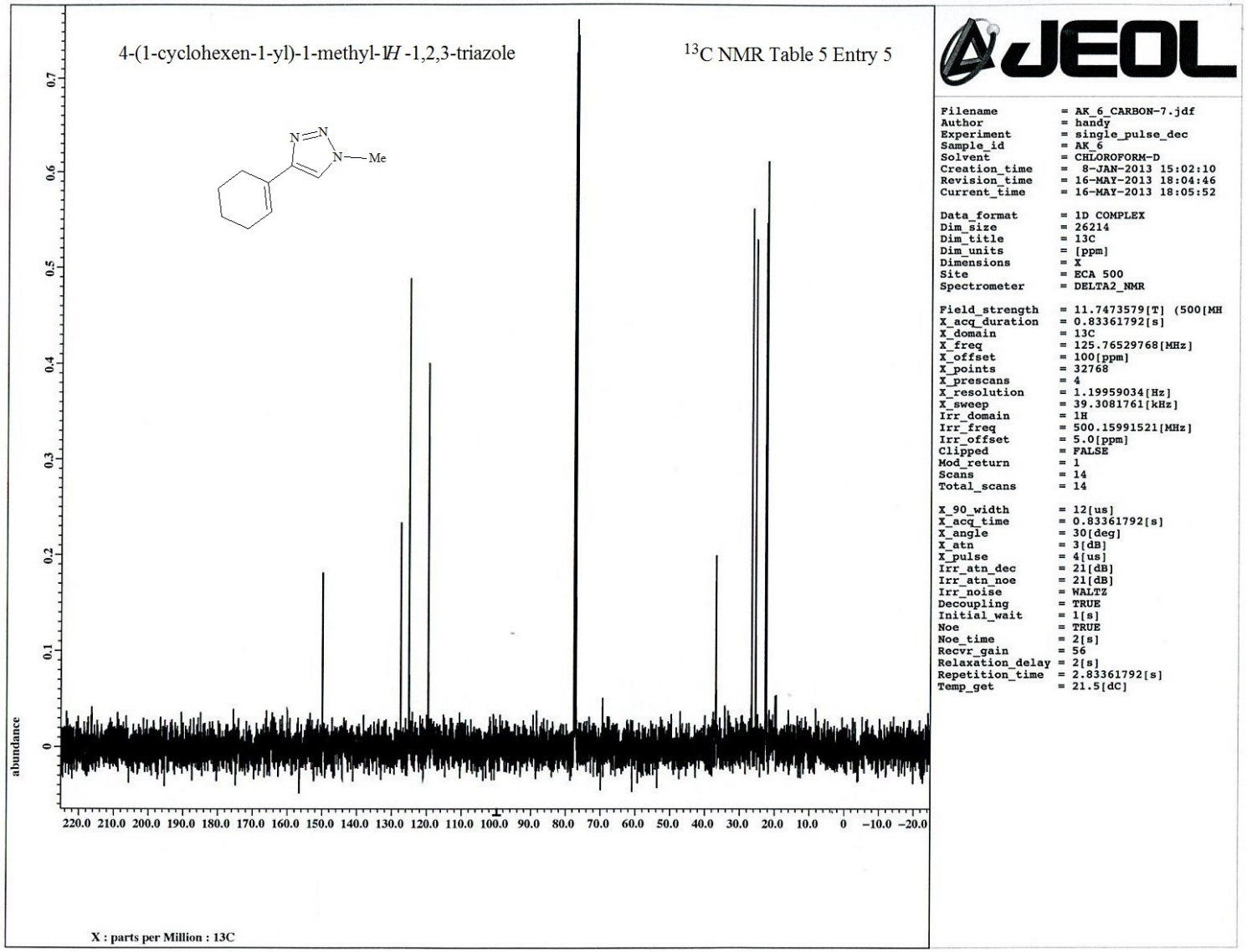
Filename          = AK_5_CARBON-4.jdf
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_5
Solvent           = CHLOROFORM-D
Creation_time     =  7-JAN-2013 18:33:09
Revision_time     = 16-MAY-2013 17:48:13
Current_time      = 16-MAY-2013 17:49:06

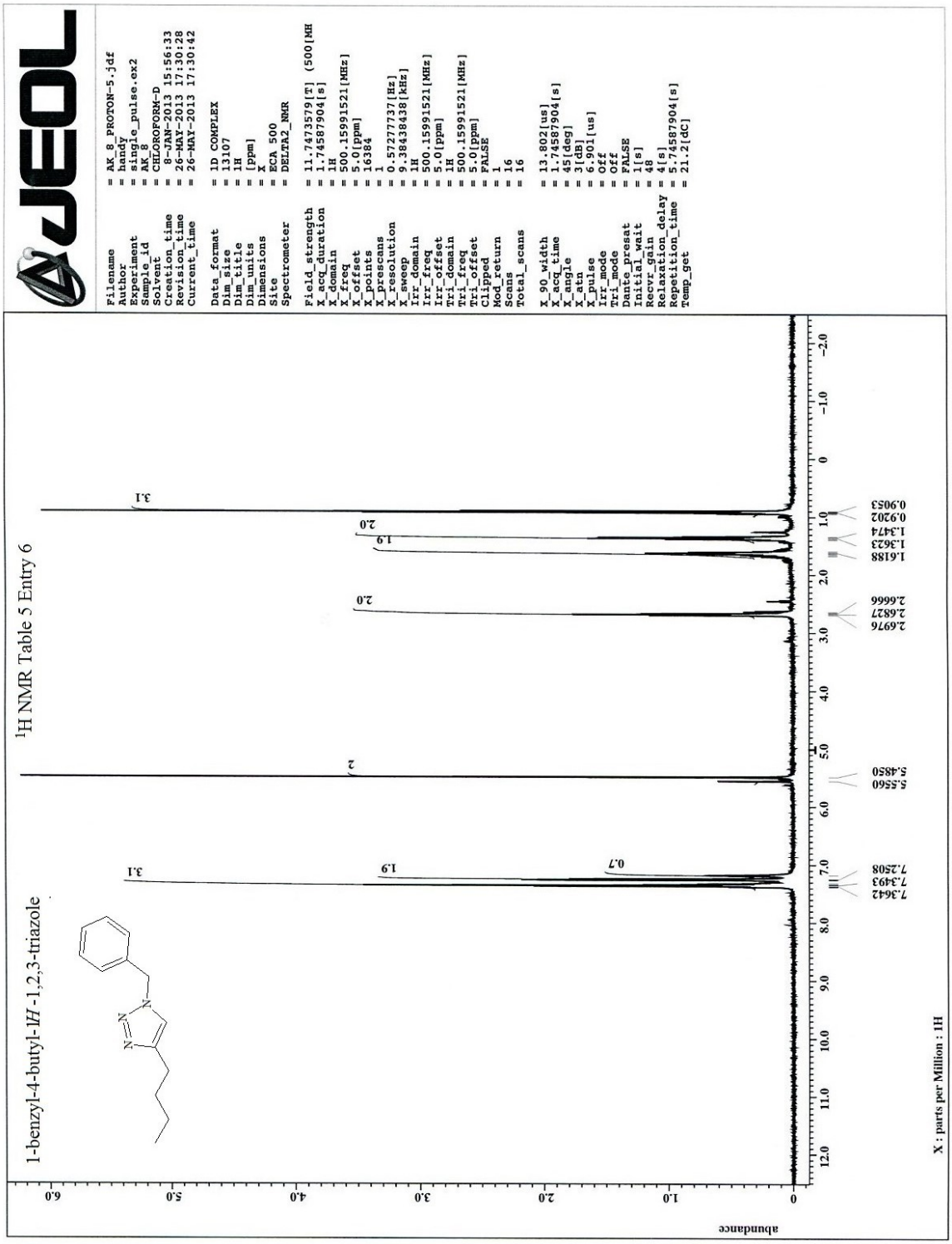
Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 14
Total_scans       = 14

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 58
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 21.5[dC]
```


JEOL
Filename = AK_6_PROTON-8.jdf
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_6
Solvent = CHLOROFORM-D
Creation_time = 8-JAN-2013 15:05:57
Revision_time = 26-MAY-2013 17:22:32
Current_time = 26-MAY-2013 17:23:29
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735791[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Ir_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Irr_mode = Off
Tri_mode = Off
Dante_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 40
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.4[dC]
1H NMR Table 5 Entry 5
4-(1-cyclohexen-1-yl)-1-methyl-1H-1,2,3-triazole
Me
abundance
X : parts per Million : 1H
3.3
1.0
1.9
1.9
3.9
1
1.0
7.3493
6.4400
6.4366
4.0134
2.3311
2.3265
1.7173
1.7058
1.6314
1.6199


4-(1-cyclohexen-1-yl)-1-methyl-1H-1,2,3-triazole
13C NMR Table 5 Entry 5
N
N
N
Me
abundance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
220.0 210.0 200.0 190.0 180.0 170.0 160.0 150.0 140.0 130.0 120.0 110.0 100.0 90.0 80.0 70.0 60.0 50.0 40.0 30.0 20.0 10.0 0 −10.0 −20.0
X : parts per Million : 13C
JEOL
Filename = AK_6_CARBON-7.jdf
Author = handy
Experiment = single_pulse_dec
Sample_id = AK_6
Solvent = CHLOROFORM-D
Creation_time = 8-JAN-2013 15:02:10
Revision_time = 16-MAY-2013 18:04:46
Current_time = 16-MAY-2013 18:05:52
Data_format = 1D COMPLEX
Dim_size = 26214
Dim_title = 13C
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.7473579[T] (500[MH
X_acq_duration = 0.83361792[s]
X_domain = 13C
X_freq = 125.76529768[MHz]
X_offset = 100[ppm]
X_points = 32768
X_prescans = 4
X_resolution = 1.19959034[Hz]
X_sweep = 39.3081761[kHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 14
Total_scans = 14
X_90_width = 12[us]
X_acq_time = 0.83361792[s]
X_angle = 30[deg]
X_atn = 3[dB]
X_pulse = 4[us]
Irr_atn_dec = 21[dB]
Irr_atn_noe = 21[dB]
Irr_noise = WALTZ
Decoupling = TRUE
Initial_wait = 1[s]
Noe = TRUE
Noe_time = 2[s]
Recvr_gain = 56
Relaxation_delay = 2[s]
Repetition_time = 2.83361792[s]
Temp_get = 21.5[dC]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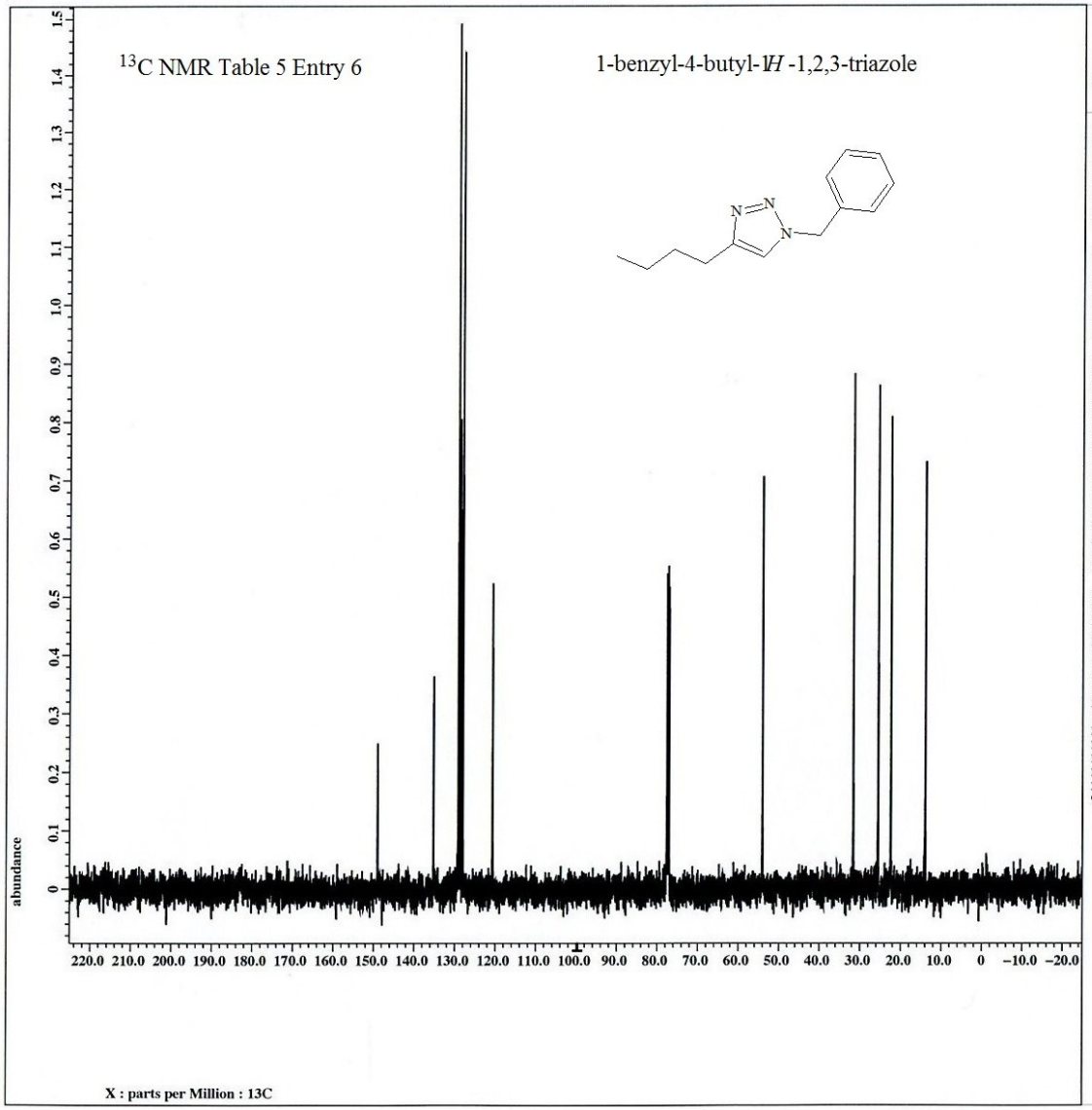
Filename = AK_8_PROTON-5.jdf
Author = handy
Experiment = single_pulse.ex2
Sample_id = AK_8
Solvent = CHLOROFORM-D
Creation_time = 8-JAN-2013 15:56:33
Revision_time = 26-MAY-2013 17:30:28
Current_time = 26-MAY-2013 17:30:42
Data_format = 1D COMPLEX
Dim_size = 13107
Dim_title = 1H
Dim_units = [ppm]
Dimensions = X
Site = ECA 500
Spectrometer = DELTA2_NMR
Field_strength = 11.74735791[T] (500[MH
X_acq_duration = 1.74587904[s]
X_domain = 1H
X_freq = 500.15991521[MHz]
X_offset = 5.0[ppm]
X_points = 16384
X_prescans = 1
X_resolution = 0.57277737[Hz]
X_sweep = 9.38438438[kHz]
Irr_domain = 1H
Irr_freq = 500.15991521[MHz]
Irr_offset = 5.0[ppm]
Tri_domain = 1H
Tri_freq = 500.15991521[MHz]
Tri_offset = 5.0[ppm]
Clipped = FALSE
Mod_return = 1
Scans = 16
Total_scans = 16
X_90_width = 13.802[us]
X_acq_time = 1.74587904[s]
X_angle = 45[deg]
X_atn = 3[dB]
X_pulse = 6.901[us]
Irr_mode = Off
Tri_mode = Off
Date_presat = FALSE
Initial_wait = 1[s]
Recvr_gain = 48
Relaxation_delay = 4[s]
Repetition_time = 5.74587904[s]
Temp_get = 21.2[dC]
1-benzyl-4-butyl-1H-1,2,3-triazole
1H NMR Table 5 Entry 6
abundance
X : parts per Million : 1H
7.3642
7.3493
7.2508
5.5560
5.4850
2.6976
2.6827
2.6666
1.6188
1.3623
1.3474
0.9202
0.9053
3.1
1.9
0.7
2
2.0
1.9
2.0
3.1

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Filename          = AK_8_(SOLID)_CARBON-4
Author            = handy
Experiment        = single_pulse_dec
Sample_id         = AK_8_(SOLID)
Solvent           = CHLOROFORM-D
Creation_time     = 25-JAN-2013 18:02:47
Revision_time     = 16-MAY-2013 18:28:51
Current_time      = 16-MAY-2013 18:29:33

Data_format       = 1D COMPLEX
Dim_size          = 26214
Dim_title         = 13C
Dim_units         = [ppm]
Dimensions        = X
Site              = ECA 500
Spectrometer      = DELTA2_NMR

Field_strength    = 11.7473579[T] (500[MH
X_acq_duration    = 0.83361792[s]
X_domain          = 13C
X_freq            = 125.76529768[MHz]
X_offset          = 100[ppm]
X_points          = 32768
X_prescans        = 4
X_resolution      = 1.19959034[Hz]
X_sweep           = 39.3081761[kHz]
Irr_domain        = 1H
Irr_freq          = 500.15991521[MHz]
Irr_offset        = 5.0[ppm]
Clipped           = FALSE
Mod_return        = 1
Scans             = 14
Total_scans       = 14

X_90_width        = 12[us]
X_acq_time        = 0.83361792[s]
X_angle           = 30[deg]
X_atn             = 3[dB]
X_pulse           = 4[us]
Irr_atn_dec       = 21[dB]
Irr_atn_noe       = 21[dB]
Irr_noise         = WALTZ
Decoupling        = TRUE
Initial_wait      = 1[s]
Noe               = TRUE
Noe_time          = 2[s]
Recvr_gain        = 58
Relaxation_delay  = 2[s]
Repetition_time   = 2.83361792[s]
Temp_get          = 22.1[dC]
```