

A Comparative Analysis of the Energy Optimized Structure of 2-Methyl Pyridinium Picrate with Its Polymorphs

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ABSTRACT-Methyl pyridinium $C_6H_8N^+$, a quaternary ammonium compound, is derived from the N-methylation of pyridine. It is found in some coffee products and is formed during roasting of coffee beans from its precursor chemical, trigonelline. It is under investigation by scientists regarding its potential anti-carcinogenic properties, particularly for its effect on colon cancer. Though the two reported polymorphs of the title compound had crystallized in the same triclinic setting with space group $P\bar{1}$, have quite different inter-axial angles. Theoretical calculations of the molecular structure has been performed using MOPAC2016's PM7 geometry optimization algorithm and structural and energy parameters corresponding to the optimum energy configuration have been computed. The dihedral angle between the methylpyridine and picrate moieties is 10.49° in the isolated molecule. The amino nitrogen the pyridine ring is involved in both N-H...N and N-H...O interactions while the ring carbon (C11) and methyl carbon (C12) make C-H...O hydrogen bonds with the symmetry related molecule. The dipole moment of the molecule is 24.41 debye. The HOMO and LUMO energies are -9.29 eV and -2.48 eV respectively. A conductor like screening model gives the molecular area as 318.23 \AA^2 and molecular volume as 336.96 \AA^3 . A structure overlay analysis of the isolated molecule with its energy minimized counterpart shows a root mean square deviation of 1.93 \AA , indicating the effect of hydrogen bonding interactions and crystal packing effects in the solid state of the structure.

I CHEMICAL CONTEXT

Methyl pyridinium $C_6H_8N^+$, a quaternary ammonium compound, is derived from the N-methylation of pyridine. It is found in some coffee products and is formed during roasting of coffee beans from its precursor chemical, trigonelline. It is studied for its potential anti-carcinogenic [1] properties, particularly for its effect on colon cancer. Picric acid is found to form crystalline picrates of various organic molecules through ionic and hydrogen bonding and π - π interactions and the presence of phenolic OH in the picric acid favors the formation of the salts with various organic bases [2]. The formation of charge transfer complex depending on the nature of the donor-acceptor system and the orientation of anionic and cationic species facilitates the formation of expected N-H...O hydrogen bonds between amino hydrogen and phenolic oxygen [3]. These mechanisms could be the

reason for the formation of polymorphic forms of the title compound. In the light of these, the conformation and geometry of the energy minimized crystal structure of 2-methylpyridinium picrate has been studied with reference to its polymorphs in the crystalline state reported in the literature [4,5].

A. Structural Features

The chemical scheme and the geometry optimized molecular structure of 2-methylpyridinium picrate are illustrated in Figure 1 and Figure 2 respectively. Though the two reported polymorphs of the title compound had crystallized in the same triclinic setting with space group $P\bar{1}$, have quite different inter-axial angles (Table 1). The dihedral angle between the methylpyridine and picrate moieties is 10.49° in the isolated molecule. The amino nitrogen the pyridine ring is involved in both N-H...N and N-H...O interactions while the ring carbon (C11) and methyl carbon (C12) make C-H...O hydrogen bonds with the symmetry related molecules. The structural geometry details have been obtained using PLATON [6].

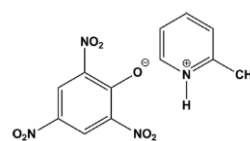


Fig. 1 Chemical scheme

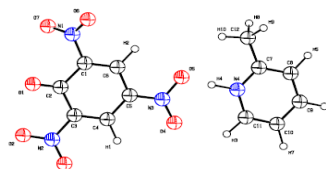


Fig. 2 A view of the geometry optimized structure of 2-methylpyridinium picrate. Hydrogen atoms are shown as small circles of arbitrary radii.

II COMPUTATION OF MULLIKEN POPULATION

The concept of atomic charge which is the net electronic and nuclear charge on each atom is often used to rationalize observed chemical behavior in the molecules

and in the structure activity studies of molecules. Though, in reality, the atomic charge of the atoms of a molecule is not a measurable physical property, a diffuse charge distribution of electrons can arbitrarily be assigned to any atomic center and quantum chemical wave functions can be used to assign atomic charges either based on the orbital occupancy or using the spatial decomposition of the overall electron distribution. The popular charge partitioning scheme is by Mulliken [7] which assigns charge to an atomic center on the basis of the total electron density. The Mulliken population analysis of atomic charges to the investigated molecule using MOPAC2016 [8] gave a net charge of +0.986929 coulomb for the 2-methylpyridinium cation and -0.98693 coulomb for the picrate anion, thereby confirming the experimental observations of +1 and -1.

A. Structure Overlay Studies

A superimposed fit of the structure optimized molecule of the title compound with its energy minimized counterpart using Qmol [9] showed a root mean square deviation (r.m.s.d.) of 1.93Å (Figure 3). On the other hand on overlay of the energy minimized molecule with the unit cell components of polymorph-1 gave r.m.s.d.s 3.336Å and 3.325Å respectively. A similar analysis with the unit cell components of polymorph-2 gave r.m.s.d.s 3.477Å and 3.466Å respectively. These marked deviations in the overlay fit indicate the effect of packing interactions due to N-H...O and C-H...O Hydrogen bonds between the symmetry related molecules in the crystalline state of the molecules.

B. Conformational Analysis

In order to explore, the conformational changes and effect of packing interaction. A semi-empirical PM7 calculation with MOPAC 2016 has been done on the structure. In the calculations the molecule was assumed to be isolated and in an absolute vacuum, therefore resulting in calculated bond length, bond angle and torsion angles that are greater than those observed experimentally. The PM7 method gives the lowest values for the HOMO & LUMO energy levels and dipole moments. No puckering was observed in the rings of the cations and anions and they maintained a planar geometry in the energy optimized structure as well as polymorphs. The total energy of the molecule is -4411.00685 eV and dipole moment is 28.93480 debye. The HOMO and LUMO energy levels are -8.805 eV and -3.084 eV respectively. A conductor like screening model gives the molecular area as 318.23Å² and molecular volume as 336.96Å³.

Table 1: Crystal Data, Data Collection and Refinement

Structure Parameter	Polymorph-1 (Ref[1])	Polymorph-2 (Ref[2])
Crystal system, space group	Triclinic, P -1	Triclinic, P -1
a, b, c (Å)	8.1524 (4) 11.8809 (6) 14.6377 (9)	8.211 (3) 11.806 (4) 14.388 (4)
α,β,γ (°)	102.077 (3) 90.001 (3) 100.692 (3)	85.428 (5) 82.863 (5) 79.726 (4)

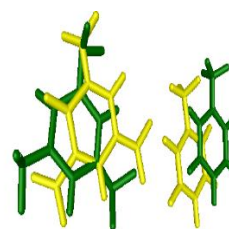


Fig.3 A structure overlay of the optimized molecule of the title compound with its energy minimized counterpart

III CONCLUSION

The geometry optimized structure and energy minimized structures of 2-methylpyridinium picrate molecule have been analyzed by semi-empirical method. The molecular conformation has been compared with its polymorphs. The protonation of the amino atom in the pyridine moiety is found to be the agent for crystal packing interactions in the form of different types of hydrogen bonds and for the structural stability of the crystal in the solid state.

IV REFERENCES

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