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Optical and related properties of certain Penicillin class of compounds

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ABSTRACT

Antibiotics are the subgroup of organic anti-infective agents that are derived from bacteria or that are toxic to other bacteria. The molecular polarizabilities of a few penicillin group of compounds are estimated by semi-empirical δ-function model and molecular vibration methods. Diamagnetic susceptibilities and Electron ionization cross-sections of these molecules are also evaluated. The results are discussed in relation to bond properties.

Keywords: Polarizability; Susceptibility; Penicillin; Ampicillin; δ-function model.

INTRODUCTION

The discovery of antibiotics greatly improved the quality of human life in the last century. Penicillin, the world's first antibiotic, was discovered by Alexander Fleming [1]. There are four classes of penicillins based on their ability to kill various types of bacteria. From narrow to broad range of effectiveness they include (i) Natural Penicillins (ii) Penicillinase- resistant penicillins (iii) Amino penicillins and (iv) Extended spectrum penicillins. The penicillins may be bactericidal or bacteriostatic. The general structure of penicillin class of compounds is given here.

Computational details

Molecular Polarizability

According to Luken [2] the reactivity of a molecule depends on the most general way on the polarization and polarizability of the different atoms of which it is composed. As per Peacock [3] they are important to discuss the reactivities and to interpret vibrational force constants. Since bond and molecular polarizabilities are measurer of instantaneous electron cloud deformations arising out of the molecular vibrations exited by the incoming optical radiation, the authors have

taken up a systematic study of these properties in the present paper using the quantum mechanical δ-function model and molecular vibration methods.

δ- function model

Lippincott and Stutman [4] have developed a semi-empirical model. The details of this method are reported elsewhere [5-10]. According to this method the parallel component of polarizability Σ_{llp} can be obtained as:

$$\sum \alpha_{llp} = \frac{4nA}{a_0}\left[\frac{R^2}{4} + \frac{1}{2C_R^2}\right]^2 \quad (1)$$

The non-bond region electron contribution to parallel component is given by the relation:

$$\sum \alpha_{ll\,n} = \sum_j f_j \alpha_j \quad (2)$$

The perpendicular component of polarizability is given by the relation:

$$\sum 2\alpha_{\perp} = n_{df}\frac{\sum x_j^2 \alpha_j}{\sum x_j^2} \quad (3)$$

for a given molecule. The mean molecular polarizability of the molecule is obtained as α_M by averaging all these quantities as fallows.

$$\alpha_M = \frac{1}{3}\left(\sum \alpha_{llp} + \sum \alpha_{lln} + \sum 2\alpha_{\perp}\right) \quad (4)$$

The details of the various parameters and the method of calculating are reported by Lippincott et al [4] in detail. The inter nuclear distance data (R) required in the first equation are taken from X-ray crystallographic studies [11-16]. The results of the studies are calculated in Table1.

2.1.2. Molecular Vibration method

Based on the theory of Kerr effect, the authors' school has developed relationships between bond polarizability coefficients and force constant/ means amplitude of vibrations of the corresponding bond. The details of this method are given in references 5 to 10. The appropriate relations are quoted below.

$$b_L - b_T = A\left[\left(x_1 x_2\right)^{\frac{1}{2}}\left(\frac{aN}{K - b}\right)^{\frac{2}{3}}\right]^s \quad (5)$$

$$b_L + 2b_T = Cp^{jB} J_B^{n\gamma} \sigma^{\frac{1}{2}} \quad (6)$$

The individual and longitudinal and transverse bond polarizability coefficients b_L and b_T can be estimated by these two relations and averaged to get bond polarizability ellipsoid components. The mean value of the molecule is given by

$$\alpha_M = \sum_i \frac{n_i\left(b_L + 2b_T\right)_i}{3} \quad (7)$$

where n_i is the number of bonds of the type i. The force constants are barrowed from the nearest environment [17-19]. The authors estimated the mean amplitudes of vibration from I.R. and Raman frequency data. The force constant (k) of each bond, the individual b_L and b_T values and the average polarizability are all reported in Table 2, and comparison of the molecular polarizabilities of the Penicillin class of compounds are all reported Table 3.

2.2. Diamagnetic Susceptibility

Molecular polarizability and Diamagnetic susceptibility values are important for the evaluation of several kinetic aspects of positive ion chemistry. The quantum mechanical expression derived by Van Vleck [20] is difficult to evaluate. Hence semi-empirical relations based on atomic incremental system and polarizability related methods have been reported literature. Pascal's atomic incremental system and authors' polarizability related system are used here to obtain diamagnetic susceptibility values for the molecules considered earlier.

Pascal's Atomic Incremental system

It is based on the distribution of molecular magnitudes to the atoms of which a molecular constants.

$$\chi_M = n_1\chi_1 + n_2\chi_2 + n_3\chi_3 + ... \quad (8)$$

The details of this method are given by Mulay [21]. Using his data molecular diamagnetic susceptibility values are calculated and presented in Table 4.

Polarizability Related Method:

Kirkwood and Vinti [22] have observed proportionality between χ_M and $(\alpha_M)^{1/2}$. The authors' school based on a systematic study of these values of a variety of organic class of molecules has given the following relation.

$$-\chi_M = \left(\gamma m\sigma^l\right)\alpha_M \quad (9)$$

Here $-\chi$ is the susceptibility, m and γ are constants.σ^1 is the Pauling's percent covalency factor and α_M is the mean molecular polarizability. Using this expression and polarizability values obtained earlier diamagnetic susceptibilities are estimated and given in Table 4.

Electron ionization cross-sections

These parameters for atoms and molecules are of importance for evaluation of radiational chemical data, for mass spectrometric studies of ion-molecular reactions, thermodynamic measurements and for plasma/Space Physics. They constitute one of the fundamental problems connecting electron impact collisions. Baran and Kevan [23] discussed the importance and proposed various correlations between polarizability (α_M), diamagnetic susceptibility ($-\chi_M$) and atomic correlation. Using these relations electron ionization cross-sections are evaluated and given in Table 5.

RESULTS AND DISCUSSION

In general there is a good agreement between the polarizability values obtained by the two methods and similarly between the susceptibility and electron ionization cross-sections obtained by the appropriate relationships. To prove the validity of the theoretical methods the authors

have measured the refractive indices of two molecules Ampicillin and Erythromycin at four different wavelengths. The detail will be commented later. The polarizability results are supported by the values obtained by summing Le Fevre bond polarizability values. Because of the environmental effect there is a little deviation here and there. But for this agreement is quote good.

Interesting part of the result of the present studies on penicillin class of compounds is presented in Table 2. The bond polarizability values are quoted in $10^{-23}cm^3$ units. The b_L values of certain carbon containing bonds give the following information on reactivity nature of the molecules.

The b_L value (0.1448) reported here in between aliphatic and aromatic values of Le Fevre. This shows that the C-CH_3 is a hybrid bond. Since CH_3 is a aliphatic group, the other carbon atom should be aromatic in nature. Otherwise the hybrid nature can not be observed. Since this carbon in the five membered ring is connected to electron rich sulphur atom on one side and is protected from electron withdrawing effect of nitrogen atom by the presence of another carbon atom, the higher electron density at C-CH_3 can be understood. For the C-N bonds the b_L values are 0.2037 inside the five membered ring and 0.1950 outside the ring. Inside the ring the higher value is because of the presents of sulphur atom. The b_L values of C=O and C-O are respectively 0.1869 and 0.1860 because of the environmental effect. Le Fevre has obtained this value form Trioxan/ Dioxan molecules. Whose environment is totally different from the present case. Thus the present studies show that the carbon at C-CH_3 is electrophilic with respect to reactivity in nature.

The graphical relations have shown in Figure 2 reveals that molecular polarizability and diamagnetic susceptibility are related linearly with electron ionization cross-section as said by Beran and Kevan.

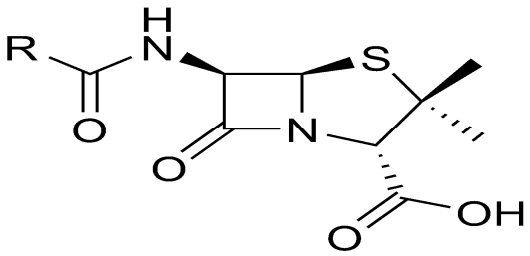

Figure 1. The general structure of penicillin nucleus

Table 1:Molecular polarizabilities of certain penicillin class of compounds
Lippincott δ-function model, α_M x 10^{23} cm^3

Compound name	$\sum \alpha_{\|P}$	$\sum \alpha_{\|ln}$	$\sum 2\alpha_{\perp}$	α_M x$10^{23}cm^3$
Penicillin	10.6313	0.4175	4.7154	5.2546
Oxacillin	6.5608	0.4729	3.3297	3.4545
Ampicillin	6.8762	0.3633	3.0241	3.4212
Sodium salt of Penicillinic acid	3.9361	0.2997	1.6388	1.9582
Du (Phenyl-2-Thiazola[3,2-5] [1,2,4] triazolyl-6)-2 thiazolo carboxylate-4d', Ethyl(PMTT)	6.4062	0.4404	2.4825	3.1097
(E)-N-(Benzo[b]thiophen-3-Yl) methylene-N'-(2,5-Dichloro phenyl)-hydrazine	5.7949	0.4187	2.1600	2.7912

Table 2:Bond polarizability coefficients of penicillin class of compounds Molecular Vibration Method, b_M x10^{23} cm^3

Bond	Stretching Force Constant, K m.dyne.A^{o-1}	b_L	b_T	$(b_L+2\ b_T)/3$
C-N	7.190	0.1950	0.0740	0.1151
S-O	4.938	0.1292	0.0764	0.0940
S-C	2.898	0.1113	0.0809	0.0910
C-C	6.572	0.1448	0.0466	0.0793
C=C	7.459	0.1305	0.0500	0.0769
N-C	2.480	0.2037	0.1284	0.1535
C=O	10.264	0.1869	0.0362	0.0864
C-O	6.227	0.1860	0.0542	0.0981
O-C	5.171	0.1267	0.0908	0.1028
C-H(Methyl)	5.160	0.0750	0.0630	0.0670
N-H	5.382	0.0930	0.0840	0.0873
C=N	7.607	0.1635	0.0669	0.0991
N-O	11.99	0.2090	0.0173	0.0812
C-Cl	3.704	0.2994	0.1055	0.1702
C-Br	1.887	0.4719	0.2912	0.3515
O=C	12.487	0.1176	0.0643	0.0821
N=O	12.28	0.1484	0.0387	0.0808
O-H	6.282	0.1050	0.0980	0.1007
N-N	5.771	0.2320	0.1474	0.1756
N=C	10.069	0.1519	0.0832	0.1061
C-S	3.272	0.1980	0.0327	0.0878

Table 3: Comparison of the molecular polarizabilities of the Penicillin class of compounds, α_M x$10^{23}$$cm^3$

Compound Name	Lippincott Method	Molecular Vibration Method	Le Fevre Method
Penicillin	5.2546	5.5064	5.4672
Oxacillin	3.4545	3.7380	3.5477
Ampicillin	3.4212	3.6677	3.4499 3.8631*
Sodium salt of Penicillinic acid	1.9582	2.0257	1.8219
Du (Phenyl-2-Thiazola[3,2-5][1,2,4] triazolyl-6)-2 thiazolocarboxylate-4d', Ethyl(PMTT)	3.1097	3.4273	3.4812
(E)-N-(Benzo[b]thiophen-3-Yl) methylene -N'-(2,5-Dichlorophenyl)-hydrazine	2.7912	2.8154	3.032

** denotes experimental value of Ampicillin.*

Table 4 :Diamagnetic susceptibilities ($-\chi_M X10^6$ cgs emu/mole)

Compound Name	Pascal's Empirical Incremental System	Present Method
Penicillin	275.16	252.98
Oxacillin	211.54	194.60
Ampicillin	176.94	171.86
Sodium salt of Penicillinic acid	97.22	94.91
Du (Phenyl-2-Thiazola[3,2-5][1,2,4] triazolyl-6)-2 thiazolocarboxylate-4d', Ethyl(PMTT)	177.58	178.42
(E)-N-(Benzo[b]thiophen-3-Yl) methylene-N'-(2,5-Dichlorophenyl) -hydrazine	188.52	176.82

Table 5 :Molecular electron ionization cross-sections ($Qx10^{+16}$ cm^2)

Compound Name	Q from α_M	Q from χ_M	Q from atomic Additivity correlation
Penicillin	72.67	70.32	85.68
Oxacillin	47.69	54.09	55.70
Ampicillin	45.79	47.77	54.71
sodium salt of Penicillinic acid	26.42	26.38	30.70
Du (Phenyl-2-Thiazola[3,2-5][1,2,4] triazolyl-6) -2 thiazolocarboxylate-4d', Ethyl(PMTT)	43.20	49.60	56.16
(E)-N-(Benzo[b]thiophen-3-Yl) methylene-N'-(2,5-Dichlorophenyl)-hydrazine	38.57	49.15	48.33

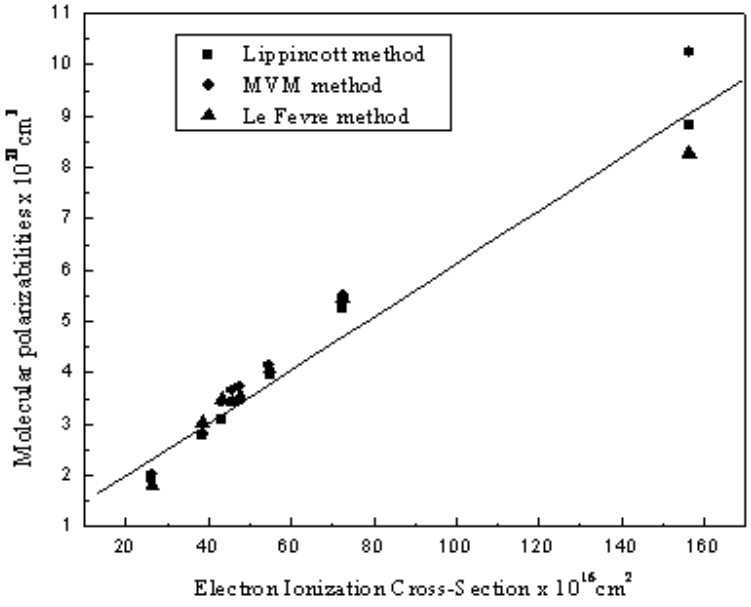

Figure.2(a)

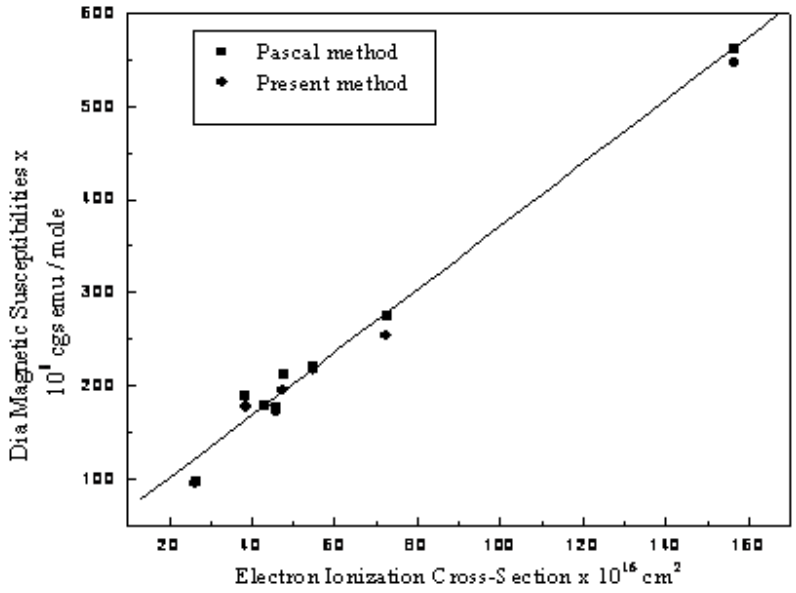

Figure.2(b)

Figure. 2. The Graphical representation of (a) polarizability Vs. Electron ionization cross-section (b) diamagnetic susceptibility Vs. Electron ionization cross-section.

REFERENCES

[1] [Milton wainwright, Social history of medicinine, **2007** 20(3); 615.
[2] E.A.C. Luken, Physical methods in Heterocyclic Chemistry, Vol II, Ed., A.R. Katritzky, Academic Press, New York **1963**.
[3] T.E. Peacock, Electronic properties of Aromatic Heterocyclic Molecules, Academic Press, London **1965**.
[4] E.R. Lippincott, J.M. Stutman, *J. Phys. Chem.*, **1964**. 68 ; 2926.
[5] D.V. Subbaiah, M.S. Sastry, V.R. Murthy, *J. Mol. Struct*., **1982**. 87; 105.
[6] D.V. Subbaiah, M.S. Sastry, V.R. Murthy, *J.Phys. Chem*., **1983**. 87 ; 1730.
[7] D.V. Subbaiah, M.S. Sastry, V.R. Murthy, *Biochem.Biophys.Res.com*., **1993**. 196; 1422.
[8] D.V. Subbaiah, M.S. Sastry, V.R. Murthy, *J. Mol. Struct*., **1994**. 41; 319.
[9] D.V. Subbaiah, M.S. Sastry, V.R. Murthy, *Proc. IEEE, EMBS* ,**1995**. 3 ;73.
[10] D.V. Subbaiah, M.S. Sastry, V.R. Murthy, *Asian Chem. Letters*., 1997. 1; 5.
[11] Tae-Sung yoon , Whanchul Shin, *J. Acta Cryst*., **1996**. C52; 3142.
[12] Leon Dupont, Michel Kohl, Robert Lejeune , *J. Acta Cryst*., **1998**. C54; 1957.
[13] M.O. Boles, R.J. Girven, *J. Acta Cryst.*,**1976**. B32; 2279.
[14] Veronique Gibon, Bernadette Norberg, Guy Evrard, Francois Durant, *J. Acta Cryst*., **1988**. C44; 652.
[15] Par V. Warin Et F. Baert, Et R. Houssin, J.L. Bernier Et J.P. Henichart, *J. Acta Cryst*., **1985**. C41; 1238.
[16] N. Vijayakumar Sonar, Parkin, N. Peter Crooks, *J. Acta Cryst*., **2004**, C60; 550.
[17] M.S. Sastry, Ph.D., Thesis, S.K.University, Anantapur, India .**1985**.
[18] N.L.S. Vidyasagar, Ph.D., Thesis, S.K.University, Anantapur, India., **1996** .

[19] D. Zarena, Ph.D., Theseis, S.K.University, Anantapur, India.,**2007**.
[20] J.H. Van Vleck, Electric and Magnetic Susceptibilities, Oxford University Press, London., **1932**.
[21] L.N. Mulay, Magnetic Susceptibility, Inter Science New York. **1963**.
[22] J.P. Vinti, *Phys.Rev*.., **1932**. 41; 813.
[23] J.A. Beran, L.Kevan, *J. Phys. Chem.* **1960**. 73; 3866.