

FTIR, FT – RAMAN and Density Functional Theory Calculations on Acetazolamide

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Abstract

FT Raman Spectrum of Acetazolamide has been recorded in the region 3500-50 cm^{-1} . FTIR Spectrum of the compound are recorded over the region on 4000-4000 cm^{-1} . All Sharp bands observed in the spectra are expected to have an accuracy of $\pm 1\text{cm}^{-1}$. Comparing bond angles and bond lengths of HF and B3LYP as a whole the B3LYP calculated value correlates well compared with the experimental Results.

Keywords: Spectrum, Correlates, Sharp bands, FTIR Spectrum

Introduction

FTIR and FTR spectroscopic methods are being extensively used to identify the structural groups present in a compound [1-4]. Many research suggested an interesting method of assigning group frequencies observed in vibrational spectra. During the course of our investigation on the samples of pharmaceutical active compounds, our attention has been turned towards the Acetazolamide drug. It is an anticonvulsant. It is white (or) almost white, crystalline powder, almost odorless, exhibits polymorphism. It is used for controlling certain types of seizures and relieving pain in patients with nerve pain in the Congestive heart failure, Marfan's syndrome, Central sleep apnea. The FTIR spectra of Acetazolamide have been thoroughly investigated and detailed vibrational band assignments have been made. The assignment of the fundamental frequencies is made on the basis of magnitude and relative intensities of the observed bands. Also the variations of the absorbance of maximum wavelength of the drug subjected to different temperature conditions have been analysed using UV-Visible spectral

measurements. In the present work, FTIR, and FTR methods have been employed successfully in the present investigation and the results obtained are discussed.

Experimental

The sample of Acetazolamide was procured from a reputed pharmaceutical firm of Puducherry, India and used as such. The FTIR spectrum of the compound are recorded over the region on 4000-400 cm^{-1} using ABB-BOOMEN series at Pharma Analytical Lab, Puducherry. FT Raman spectrum has been recorded in the region 3500-50 cm^{-1} excited with the 1064 nm radiation using Nd:YAG laser of a Thermo Electron Corporation FTRaman module about 1.5 w power at the sample at SAIF, IIT (M), Chennai. All sharp bands observed in the spectra are expected to have an accuracy of $\pm 1\text{cm}^{-1}$.

The molecular structure of Acetazolamide and pharmaceutical data are presented in Fig.1 and Table 1 respectively. The Vibrational spectra of Acetazolamide is presented in Fig.2.

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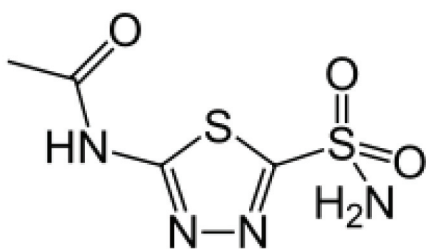


Fig. 1 Molecular Structure of Acetazolamide

Table 1 Pharmaceutical data of Acetazolamide

Name	Acetazolamide
Formula	$C_4H_6N_4O_3S_2$
Molecular weight	222.245 g/mol
IUPAC Name	N-(5-sulfamoyl-1,3,4-thiadiazol-2-yl) Acetamide
Category	Anti convulsant, carbonic anhydrase inhibitors
Dose	250mg daily
Description	White, Crystalline powder, Very slightly soluble in water, slightly soluble in alcohol
Solubility	1 M NH_4OH : Soluble 50 mg/ml, DMSO:Soluble, methanol and ethanol: slightly soluble.
Storage	Store in well closed light resistance containers

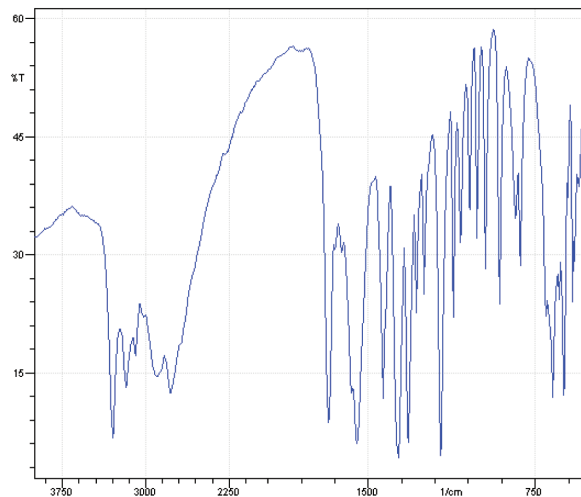
Vibrational Analysis

Fourier transform infrared (FTIR) and UV spectroscopic methods are being extensively used to identify the structural groups present in a compound. The aim of the present work is to make thorough investigation on vibrational frequencies of Acetazolamide. In analogy with the vibrational band assignments of related compounds and the magnitudes and relative intensities of the bands. The vibrational band assignments of the compound are presented in Table 2. A qualitative discussion on the specific modes of vibration is discussed as follows.

Table 2. Vibrational band assignments of Acetazolamide

Wavenumber (cm^{-1})		Vibrational band assignments
FTIR	FTR	
511(s)		N – C – S in plane bending

555(w)		N – C – O in plane bending
621(s)	623	C – S stretching
673(s)	678	C – S stretching
704(s)	711	C – H out of plane bending
818(m)		N – H out of plane bending
841(m)		C – H out of plane bending
912(s)	913	S – N stretching
974(m)	970	C – H in plane bending
1013(m)		S = O stretching
1045(m)		C – H plane bending
1068(m)	1085	C–H plane bending/ NH_2 twisting
1121(s)	1118	O = S = O symmetric
1176(vs)	1167	C – H in plane bending
1250(m)	1258	C – N stretching
1266(s)		C – N stretching
1321(vs)		O=S=O asymmetric stretching
1366(vs)	1384	CH ₃ symmetric bending



Wavenumber (cm^{-1})		Vibrational band assignments
FTIR	FTR	
1435(s)	1433	CH ₃ asymmetric bending

1553(vs)		N – H in plane bending
1574(s)		C = N stretching
1680(vs)	1674	C=O stretching/NH ₂ scissoring
2925(s)	2931	C – H symmetric stretching
3113(s)		C – H asymmetric stretching
3300(s)		N – H symmetric stretching
3336(w)		N – H asymmetric stretching

vw-very weak, w-weak, m-medium, s-strong, vs-very strong

N-H Stretching Vibrations

N-H stretching frequencies corresponding to the symmetrical and asymmetrical NH stretching vibrations for dilute solutions are occur near 3520 cm⁻¹ to 3480 cm⁻¹. In the spectra of solid samples are observed near 3350 cm⁻¹ to 3180 cm⁻¹ because of Hydrogen bonding [5]. Based on this, in the present investigation, N-H symmetric stretching vibrations are observed at 3300 cm⁻¹ and N-H asymmetric stretching occurred at 3336 cm⁻¹.

C-H Stretching Vibrations

These bands occur in the region 3010 cm⁻¹ – 3200 cm⁻¹. Two moderately intense bands frequently occur in this region [6]. The appearance of two bands is attributed to Fermi resonance between the fundamental aldehydic C-H stretch and the first overtone of the aldehydic C-H bending vibration that usually appears near 1390cm⁻¹. Based on

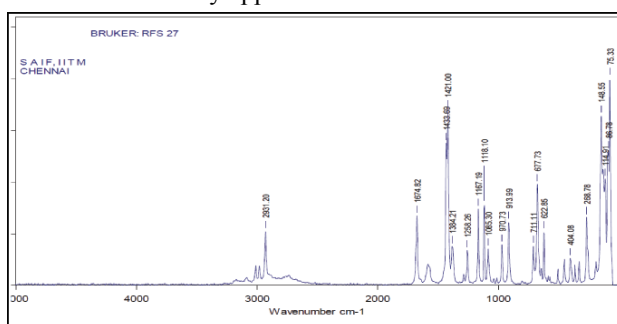


Fig.2 Vibrational spectra of Acetazolamide

this in the present investigation, the FTIR bands observed at 3113 and 2925 cm⁻¹ and FTR band identified at 2931 cm⁻¹ are assigned to C-H stretching vibrations.

C-N Stretching Vibrations

Medium to weak absorption bands for the unconjugated C-N linkage in primary, secondary and tertiary aliphatic amines appear in the region of 1250-1020 cm⁻¹. Aromatic amines display strong C-N stretching absorption in the 1342-1266 cm⁻¹ region [7]. Hence in the present case the FTIR bands observed at 1250 and 1266 cm⁻¹ and Raman band occur at 1258 cm⁻¹ are assigned to C-N stretching vibrations.

C=O Stretching Vibrations

The C=O absorption of lactams, 6 membered rings or larger is near 1650 cm⁻¹. The five membered ring lactams absorb in the range 1750-1700 cm⁻¹. The four membered ring lactams, unfused absorbs at 1760-1730 cm⁻¹ [8]. In the present investigation the FTIR and FTR bands identified at 1680 cm⁻¹ and 1678 cm⁻¹ respectively are assigned to C=O stretching vibrations.

O = S = O Stretching Vibration

Two intense infrared bands have been associated with sulphone stretching frequencies; one near 1350 – 1300 cm⁻¹ and the other near 1160 – 1120 cm⁻¹ because of the asymmetric and symmetric SO₂ stretching modes respectively. In the solid state, the range is lowered by 10 – 20 cm⁻¹ due to hydrogen bonding, the lower frequency band being less affected than the higher frequency band. Conjugation, as with the sulphoxide stretching frequency, has no effect on the sulphone stretching frequencies. The effect of group such as oxygen or chlorine attached to the sulphone is analogous to that observed for the sulphoxides, i.e. a shift to higher frequency with increasing electronegativity of the group or atom [9]. Based on this fact in the present investigation the IR band at 1121 cm⁻¹ and FTR band at 1118 cm⁻¹ are assigned to O = S = O symmetric stretching vibrations. A very strong infrared band observed at 1321 cm⁻¹ is assigned to O = S = O asymmetric stretching vibrations.

C = N Stretching

Interaction between ring C=C and C=N stretching vibrations results in two strong medium intensity absorptions about 100 cm⁻¹ apart. These absorptions occur at 1615 – 1575 cm⁻¹ and 1520 – 1465 cm⁻¹, the higher frequency band and its low – frequency band often having another medium intensity band on its lower frequency side which is found at 1590 – 1555 cm⁻¹. A strong band is usually observed in the region 1000 – 985 cm [10] This band may be very weak or undetectable for 3 – substituted pyridines. In the present case, C=N stretching vibration is observed at a frequency 1640 cm⁻¹

NH₂ Group Vibrations

The NH₂ group has two (N-H) stretching vibrations, one being symmetric and other asymmetric. The frequency of asymmetric vibration is higher than that of symmetric one. It has frequency range of 3300 cm⁻¹ to 3700 cm⁻¹.

In addition, NH₂ group has scissoring, rocking, wagging and torsion modes. The NH₂ scissoring mode has been suggested to lie in the region 1590 cm⁻¹ to 1650 cm⁻¹ in benzene derivatives containing an NH₂ group. In the present work NH₂ scissoring band occur at 1677 cm⁻¹. It is noted that frequency 1680 cm⁻¹ is in very strong region. Similarly NH₂ rocking vibration occurs at 1384 cm⁻¹ and NH₂ wagging vibrations occur at 673 cm⁻¹ [11]

Bending Vibrations

The in plane, out of plane bending of a ring hydrogen atom is strongly coupled to adjacent hydrogen atoms. The position of absorption of the out of plane bending band is, therefore, characteristic of the number of adjacent hydrogen atoms on the ring. The bands are frequently intense and may be used for the qualitative determination of the relative concentrations of isomers in mixtures. The absorption band that frequently appears in the spectra of substituted benzenes near 710-675 cm⁻¹ is attributed to out of plane bending [12]. In the present investigation the C-H out of plane bending bands occurs at 704 and 841 cm⁻¹. The IR bands observed at 1045, 1068, 1121 and 1176 cm⁻¹ are assigned to C-H in plane bending vibrations.

In the present work, the FTIR band observed at 1489 cm⁻¹ is referred as N-H in plane bending and bands occurs at 818 cm⁻¹ have been assigned to N-H out of plane bending vibrations respectively. Similarly the other vibrations are observed in the characteristic range.

Methyl Group Vibrations

An examined of a large number of saturated hydrocarbons containing methyl group showed in all cases, 2 distinct bands occurring at 2962 cm⁻¹ and at the first of these results from the asymmetrical stretching mode in which 2 C-H bonds of the methyl group are extending while the third one is contracting. The second arises from symmetrical stretching in which all 3 of the C-H bonds extended and contract in phase. The presence of several methyl groups in a molecule results in strong absorption of these positions. The bands appearing at 2965 cm⁻¹ and 2865 cm⁻¹ in the infrared spectrum of theophylline have been assigned to asymmetric and symmetric C-H stretching respectively [14]. Two bending vibrations can occur within a methyl group. The first of these, the symmetrical bending vibration involves in the in-phase bending of the C-H bonds. The second, the asymmetrical bending vibration occurs near 1375 cm⁻¹, the asymmetrical bending vibration near 1450 cm⁻¹. These symmetric bending are observed in the respective in the infrared spectrum of

theophylline. In the present work the infrared bands observed 1366 cm⁻¹ has been assigned to CH₃ symmetric bending vibration and 1435 cm⁻¹ asymmetric bending vibration of the chosen drug. For the same vibrations the Raman bands are observed at 1384 and 1433 cm⁻¹ respectively. Similarly the other FTIR and FTRaman band observed and are assigned in the characteristic range. Also all the observed band are good in agreement with the literature values.

Structural analysis using density functional theory

Density functional theory (DFT) is a quantum mechanical theory used in physics and chemistry to investigate the electronic structure (principally the ground state) of many-body systems, in particular atoms, molecules and the condensed phases. DFT is among the most popular and versatile methods available in condensed matter physics, computational physics, and computational chemistry.

Computational chemistry is a branch of chemistry that uses computers to assist in solving chemical problems. It uses the results of theoretical chemistry, incorporated into efficient computer programs, to calculate the structures and properties of molecules and solids. While its results normally complement the information obtained by chemical experiments, it can in some cases predict hitherto unobserved chemical phenomena. It is widely used in the design of new drugs and materials. Examples of such properties are structure (i.e. the expected positions of the constituent atoms), absolute and relative (interaction) energies, electronic charge distributions, dipoles and higher multipole moments, vibrational frequencies, reactivity or other spectroscopic quantities, and cross sections for collision with other particles.

Ab initio methods are based entirely on theory from first principles. Other (typically less accurate) methods are called empirical or semi-empirical because they employ experimental results, often from acceptable models of atoms or related molecules, to approximate some elements of the underlying theory. Both *ab initio* and semi-empirical approaches involve approximations. These range from simplified forms of the first-principles equations that are easier or faster to solve, to approximations limiting the size of the system (for example, Periodic boundary conditions), to fundamental approximations to the underlying equations that are required to achieve any solution to them at all. For example, most *ab initio* calculations make the Born-Oppenheimer approximation, which greatly simplifies the underlying Schroedinger Equation by freezing the nuclei in place during the calculation. In principle, *ab initio* methods eventually converge to the exact solution of the underlying equations as the number of approximations is reduced. In practice, however, it is impossible to eliminate all approximations, and residual error inevitably remains. The goal of computational chemistry is to minimize this residual error while keeping the calculations tractable.

Density functional theory (DFT) methods are often considered to be *ab initio* methods for determining the

molecular electronic structure, even though many of the most common functionals use parameters derived from empirical data, or from more complex calculations. In DFT, the total energy is expressed in terms of the total one-electron density rather than the wave function. In this type of calculation, there is an approximate Hamiltonian and an approximate expression for the total electron density. DFT methods can be very accurate for little computational cost. Some methods combine the density functional exchange functional with the Hartree-Fock exchange term and are known as hybrid functional methods.

In modern computational chemistry, quantum chemical calculations are typically performed within a finite set of basis functions. In these cases, the wavefunctions under consideration are all represented as vectors, the components of which correspond to coefficients in a linear combination of the basis functions in the basis set used.

A basis set in chemistry is a set of functions used to create the molecular orbitals, which are expanded as a linear combination of such functions with the weights or coefficients to be determined. Usually these functions are atomic orbitals, in that they are centered on atoms, but functions centered in bonds or lone pairs have been used as have pairs of functions centered in the two lobes of a p orbital. Additionally, basis sets composed of sets of plane waves down to a cutoff wavelength are often used, especially in calculations involving systems with periodic boundary conditions.

There are hundreds of basis sets composed of Gaussian-type orbitals (GTOs). The smallest of these are called *minimal basis sets*, and they are typically composed of the minimum number of basis functions required to represent all of the electrons on each atom. A minimum basis set is one in which, on each atom in the molecule, a single basis function is used for each orbital in a Hartree-Fock calculation on the free atom.

The most common addition to minimal basis sets is probably the addition of polarization functions, denoted (in the names of basis sets developed by Pople) by an asterisk, *. Two asterisks, **, indicate that polarization functions are also added to light atoms (hydrogen and helium). These are auxiliary functions with one additional node. When polarization is added to this basis set, a p-function is also added to the basis set. This adds some additional needed flexibility within the basis set, effectively allowing molecular orbitals involving the hydrogen atoms to be more asymmetric about the hydrogen nucleus. This is an important result when considering accurate representations of bonding between atoms, because the very presence of the bonded atom makes the energetic environment of the electrons spherically asymmetric. Similarly, d-type functions can be added to a basis set with valence p orbitals, and f-functions to a basis set with d-type orbitals, and so on. Another, more precise

notation indicates exactly which and how many functions are added to the basis set, such as (p, d).

Another common addition to basis sets is the addition of diffuse functions, denoted in Pople-type sets by a plus sign, +, and in Dunning-type sets by "aug" (from "augmented"). Two plus signs indicate that diffuse functions are also added to light atoms (hydrogen and helium). These are very shallow Gaussian basis functions, which more accurately represent the "tail" portion of the atomic orbitals, which are distant from the atomic nuclei. These additional basis functions can be important when considering anions and other large, "soft" molecular systems [13].

The most common minimal basis set is STO-nG, where n is an integer. This n value represents the number of Gaussian primitive functions comprising a single basis function. Commonly used minimal basis sets of this type are:

- STO-3G
- STO-4G
- STO-6G
- STO-3G* - Polarized version of STO-3G

Here is a list of commonly used split-valence basis sets of this type:

- 3-21g
- 3-21g* - Polarized
- 3-21+g - Diffuse functions
- 6-31g

Therefore in the present investigation DFT calculation has been used to study the vibrational spectra and other parameters of the chosen compound Acetazolamide.

Results and discussion

The DFT calculations were performed using Gaussian 03W [14] program package, invoking gradient geometry optimization [15]. The infrared intensities and Raman scattering activities have been computed at the HF/6-31G(d,p), HF/6-311G(d,p) and B3LYP/6-31G(d,p), B3LYP/6-311G(d,p) levels of theory. It has been utilized the gradient corrected density functional theory [16] with three-parameter hybrid functional for exchange part and the Lee-Yang-Parr correlation function [17] for the computation of vibrational frequencies and energies of optimized structure. The optimized structural parameters have been evaluated for the calculations of vibrational frequencies by assuming Cs point group symmetry.

The labeling of atoms in Acetazolamide using B3LYP/6-311G(d,p) set is presented in Fig.3.3. The optimized geometrical parameters (bond length and angles) by HF, DFT/B3LYP with 6-31G(d,p) and 6-311G(d,p) as basis set are presented in Table 3.3. It compares the calculated bond lengths and angles for AZM with those of experimentally available from X-ray data for acetazolamide.

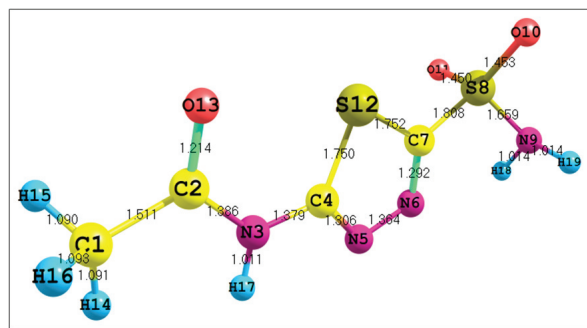


Fig. 3.3 Labeling atoms in Acetazolamide

The geometric structure is monoclinic, the space group C_2 with the cell dimensions: $a = 42.9$, $b = 41.8$, $c = 72.9 \text{ \AA}$ and $\beta = 104.5^\circ$. From the theoretical values, we find that most of the optimized bond lengths are slightly shorter as well as longer than the experimental value at HF and B3LYP levels due to the theoretical calculation belong to isolated molecules in gaseous phase and the experimental results belong to molecule in solid state. Comparing bond angles and bond lengths of HF and B3LYP as a whole the B3LYP calculated value correlates well compared with the experimental results.

Table 3.3 Bond length and bond angles of Acetazolamide

Bond length(A°)					
C1-C2	1.506	1.506	1.512	1.511	1.510
C1-H14	1.085	1.085	1.092	1.091	1.090
C1-H15	1.079	1.079	1.093	1.090	1.090
C1-H16	1.085	1.085	1.093	1.093	1.090
C2-N3	1.375	1.377	1.386	1.386	1.350
C2-O13	1.193	1.187	1.221	1.214	1.210
N3-C4	1.372	1.373	1.379	1.379	1.390
N3-H17	0.996	0.996	1.012	1.011	0.970
C4-N5	1.281	1.278	1.312	1.306	1.320
C4-S12	1.733	1.732	1.750	1.750	1.740
N5-N6	1.357	1.356	1.367	1.364	1.260
N6-C7	1.266	1.263	1.298	1.293	1.320
C7-S8	1.780	1.781	1.804	1.808	1.760
C7-S12	1.735	1.734	1.753	1.752	1.790
S8-N9	1.617	1.614	1.666	1.659	1.660
S8-O10	1.424	1.415	1.459	1.453	1.420
S8-O11	1.422	1.416	1.457	1.450	1.420
N9-H18	0.999	0.998	1.017	1.014	0.970
N9-H19	0.998	0.999	1.016	1.014	0.970
BOND ANGLE($^\circ$)					
C2-C1-H14	110.3	110.3	113.7	113.6	109.5

C2-C1-H15	108.7	108.7	108.6	108.5	109.6
C2-C1-H16	110.4	110.1	108.6	108.6	109.5
H14-C1-H15	109.6	109.7	109.2	109.5	109.4
H14-C1-H16	108.3	108.4	109.2	109.0	109.4
H15-C1-H16	109.6	109.7	107.4	107.5	109.5
C1-C2-N3	114.7	114.4	115.7	115.5	120.0
C1-C2-O13	124.1	124.2	123.4	123.5	120.0
N3-C2-O13	121.2	121.3	120.9	121.0	120.0
C2-N3-C4	125.3	125.5	124.5	124.7	120.0
C2-N3-H17	120.5	120.4	121.0	120.9	120.0
C4-N3-H17	114.2	114.2	114.5	114.5	120.0

Parameters	HF/6-31 G(d,p)	HF/6-311 G(d,p)	B3LYP/6-31 G(d,p)	B3LYP/6-311 G(d,p)	Std. value
N3-C4-N5	119.9	120.0	120.4	120.5	129.6
N3-C4-S12	124.9	124.8	123.9	123.9	129.6
N5-C4-S12	115.2	115.2	115.7	115.6	100.8
C4-N5-N6	112.0	112.1	111.7	111.8	
N5-N6-C7	113.0	113.0	112.6	112.7	120.7
N6-C7-S8	121.2	121.3	121.0	121.0	100.1
N6-C7-S12	115.3	115.3	115.7	115.7	129.9
S8-C7-S12	123.5	123.5	123.3	123.3	129.9
C7-S8-N9	105.1	105.2	104.3	104.6	
C7-S8-O10	105.9	106.8	106.4	106.4	105.7
C7-S8-O11	106.8	106.1	107.2	107.0	105.8
N9-S8-O10	108.1	108.0	107.7	107.6	
N9-S8-O11	108.0	108.1	107.5	107.4	105.7
O10-S8-O11	121.8	121.7	122.4	122.5	
S8-N9-H18	114.5	114.2	111.7	112.4	120.0
S8-N9-H19	114.4	114.2	111.7	112.5	120.0
H18-N9-H19	114.5	114.0	111.9	112.6	120.0
C4-S12-C7	84.5	84.5	84.3	84.2	96.5

Table 3.4 Computed values of Acetazolamide at HF/6-31G(d,p) level

FT-IR ^a	Computed ^a	Corrected ^a	Red. ^b	Frc. ^c	I R _d	R ^e
503	556	502	9.0	1.6	27	3.9
534	592	534	1.5	0.3		1.4
551	611	552	3.2	0.7	26	1.1
586	650	586	3.0	0.7	16	1.1
597	661	597	2.1	0.5	2.4	0.1
617	684	617	7.7	2.1	10	0.4
642	711	642	9.8	2.9	33	2.2
651	722	652	5.3	1.6		15
675	746	674	5.2	1.7		2.8

690	764	690	6.7	2.3	64	4.3
792	876	791	9.0	4.0	3.9	1.9
875	969	875	4.9	2.7	78	11
958	1060	957	5.8	3.8	3.3	6.4
985	1091	985	1.6	1.1	32	1.6
1051	1163	1050	1.7	1.4	7.7	0.8
1085	1201	1084	1.2	1.0	1.0	2.4
1099	1217	1099	11	10	25	1.4
1143	1267	1144	9.3	8.8	72	18
1162	1287	1162	14	13		7.2
1220	1351	1219	2.2	2.3		0.8
1315	1457	1316	6.8	8.5		0.8
361	1508	1362	13	18		3.4
1388	1538	1389	1.2	1.7	31	5.6
1434	1588	1434	1.1	1.7	32	12
1452	1608	1452	1.0	1.5	9.7	17
1463	1621	1464	2.4	3.7	12	36
1566	1733	1565	3.5	6.2		56
1568	1735	1567	11	19	8.1	29
1577	1745	1576	1.1	2.0	62	2.7
3300	3330	3007	1.1	7.2	4.0	75

FTIR^a, Computed^a and Corrected^a - Frequencies(cm⁻¹);

Red.^b - Reduced masses(amu);

Frc.^c - Force constants (m Dyne A⁻¹) ;

IR.^d - IR intensity(Km mole⁻¹);

R.^e - Raman scattering activities(A⁴ amu⁻¹)

Table 3.5 Computed values of Acetazolamide at HF/6-311G(d,p) level

FT-IR ^a	Computed ^a	Corrected ^a	Red. ^b	Frc. ^c	IR ^d	R ^e
503	557	503	8.2	1.5	31	4.0
524	581	524	1.5	0.3	97	
553	613	553	3.3	0.7	20	1.3
586	648	586	3.1	0.7	12	1.1
595	659	595	2.2	0.5	1.6	0.1
609	673	609	7.0	1.8	6.3	
634	702	634	9.8	2.8	25	2.6
651	720	651	6.5	2.0		15
675	746	674	4.4	1.4		2.6
686	760	687	6.1	2.1		3.9
790	874	790	8.8	3.9	4.2	1.8
873	966	872	4.8	2.6	74	11
954	1057	954	5.8	3.8	2.6	6.4
979	1084	978	1.6	1.1	40	1.5

	1159	1047	1.8	1.4	6.7	
	1199	1082	1.2	1.0	1.9	2.5
	1208	1090	10.5	9.0	21	1.3
	1263	1141	9.4	8.9	90	19
	1281	1156	13.7	13.3		6.7
	1341	1211	2.2	2.3		0.8
	1446	1305	7.2	8.9		0.9
	1499	1354	13.9	18.5		2.8
	1525	1377	1.2	1.7	38	2.7
	1580	1427	1.1	1.7	31	11
	1598	1443	1.0	1.5	10	10
	1611	1454	2.4	3.6	5.2	38
	1723	1556	3.6	6.4		28
	1741	1572	1.1	2.0	62	2.6
	1982	1790	9.9	23.1		6.6
-	3182	2874	1.0	6.2	3.8	133
	3244	2930	1.1	6.8	10	61
-	3306	2985	1.1	7.0	5.5	73

FTIR^a, Computed^a and Corrected^a - Frequencies(cm⁻¹);

Red.^b - Reduced masses(amu);

Frc.^c - Force constants (m Dyne A⁻¹) ;

IR.^d - IR intensity(Km mole⁻¹);

R.^e - Raman scattering activities(A⁴ amu⁻¹)

Table 3.6 Computed values of Acetazolamide at B3LYP/6-31G(d,p) level

FT-IR ^a		Corrected ^a	Red. ^b	Frc. ^c	IR ^d	R ^e
522	543	523	1.7	0.3	61	1.6
528	549	528	4.8	0.8	18	1.1
565	588	565	4.5	0.9	30	2.1
580	603	580	8.7	1.8	4.8	0.7
599	623	599	1.9	0.4	26	0.2
615	639	614	6.4	1.5	4.4	1.1
636	662	636	7.8	2.0		28
663	689	662	7.2	2.0	18	9.2
675	700	674	2.9	0.8		4.5
777	806	776	8.6	3.3	11	1.2
817	848	816	2.8	1.2	12	13
935	972	936	4.3	2.4	2.1	6.3
977	1016	977	1.7	1.0	24	3.0
	1058	1018	1.6	1.1	10	0.1
	1072	1031	11	7.8	16	8.2
	1102	1060	1.2	0.8	2.4	4.4
	1131	1088	10	7.9	94	49
1112	1157	1113	13	10		12
1178	1226	1179	2.3	2.0	92	6.6

	1325	1275	5.8	6.0		0.3
	1372	1320	12	13		8.4
	1414	1360	1.2	1.4	29	26
	1444	1389	3.0	3.7	21	61
	1480	1424	1.0	1.3	7.2	16
	1482	1426	9.3	12	12	46
	1500	1443	1.1	1.5	9.7	20
	1560	1501	3.6	5.2		
	1600	1540	1.1	1.6	40	5.3
	1788	1720	10	19		50
	3066	2950	1.0	5.7	3.2	
113	3145	3026	1.1	6.4	1.2	97
	3152	3032	1.1	6.4	10	69
	3514	3380	1.0	7.6	41	88

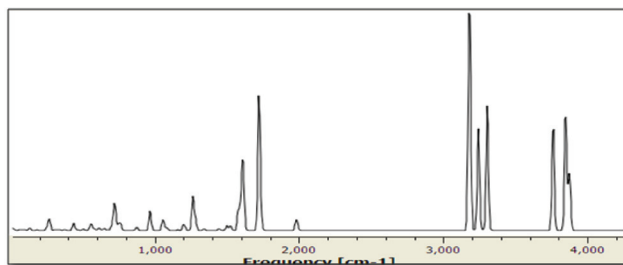
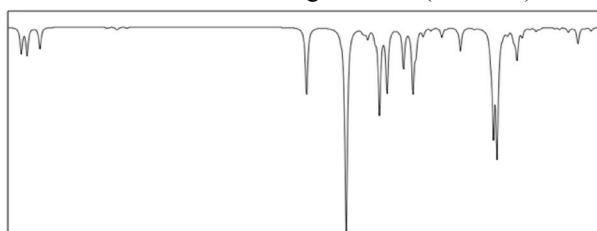
FTIR^a, Computed^a and Corrected^a - Frequencies(cm⁻¹);
 Red.^b - Reduced masses(amu);
 Frc.^c - Force constants (m Dyne A⁻¹);
 IR.^d - IR intensity(Km mole⁻¹);
 R.^e - Raman scattering activities(A⁴ amu⁻¹)

Table 3.6 Computed values of Acetazolamide at B3LYP/6-31G(d,p) level

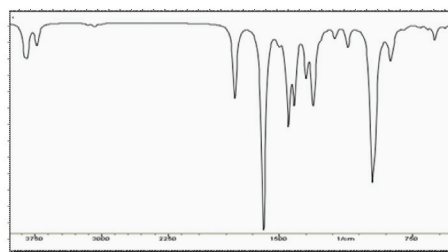
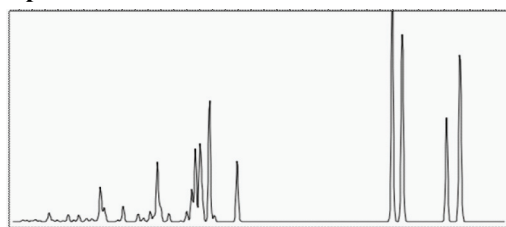
FT-IR ^a	Computed ^a	Corrected ^a	Red. ^b	Frc. ^c	IR ^d	R ^e
526	546	525	2.0	0.3	44	0.9
530	550	529	3.6	0.6	27	1.2
563	584	562	4.0	0.8	16	2.0
576	600	577	8.2	1.7	6.2	0.6
601	626	602	2.0	0.4	29	0.6
613	636	612	5.1	1.2	2.3	1.3
630	656	631	6.2	1.5	202	26
655	682	656	3.6	1.0	386	7.2
659	685	659	5.9	1.6	88	5.4
775	805	774	8.4	3.2	7.7	0.7
811	843	811	3.3	1.3	21	14
935	970	933	4.3	2.4	0.9	6.9
972	1011	972	1.7	1.0	32	2.4
1016	1056	1016	1.7	1.1	9.1	0.2
1022	1062	1022	11	7.3	14	7.5
1054	1095	1054	1.2	0.8	2.7	3.7
1081	1125	1082	10	7.9	117	53
1103	1147	1103	13	10	103	9.5
1172	1219	1172	2.3	2.0	103	6.7
1263	1312	1262	6.2	6.3	188	0.7
1305	1357	1306	12	13	203	7.1
1352	1403	1350	1.2	1.4	38	15
1382	1436	1382	2.9	3.5	13	79
1413	1469	1413	1.1	1.4	12	19

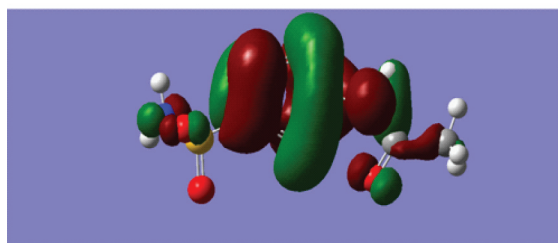
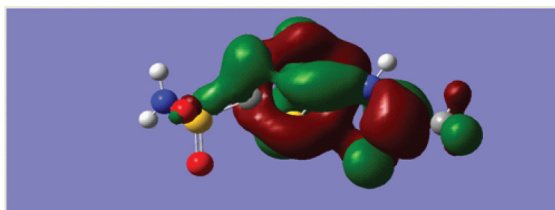
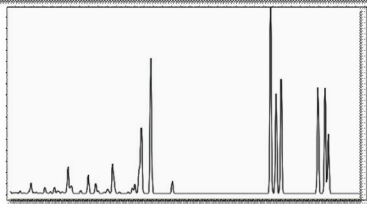
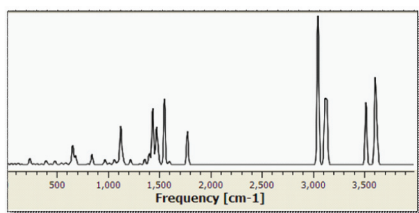
1417	1474	1418	5.3	6.8	9.8	32
1434	1490	1433	1.1	1.4	11	15
1492	1550	1491	3.2	4.6	538	91
1539	1599	1538	1.1	1.6	44	3.9
1706	1774	1706	9.9	18	160	46
2925	3048	2932	1.0	5.6	3.1	
-	3116	2998	1.1	6.2	6.2	83
3113	3135	3016	1.1	6.3	6.5	81
3336	3517	3383	1.0	7.6	47	87

FTIR^a, Computed^a and Corrected^a - Frequencies(cm⁻¹);
 Red.^b - Reduced masses(amu);
 Frc.^c - Force constants (m Dyne A⁻¹);
 IR.^d - IR intensity(Km mole⁻¹);
 R.^e - Raman scattering activities(A⁴ amu⁻¹)



FTIR spectra of Acetazolamide





Conclusion

Thus a complete vibrational band assignment of Acetazolamide has been carried out using FTIR and FTR spectra on the basis of their relative intensity, characteristic positions, correlation and vibrational bands of the related compounds. The structural analysis of the compound has been made using DFT method and the calculated frequencies are agreed very well with the literature values.

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