Asian Journal of Chemistry Vol. 20, No. 2 (2008), 1343-1356

Spectral Measurements and Qualitative Analysis of Ceftriaxone and Cefotaxime

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The infrared, Raman and UV-visible spectroscopic measurements are employed for the qualitative analysis of antibiotic drugs *viz.*, ceftriaxone and cefotaxime. The drugs chosen are from the family of cephalosporins, which are antibactericidal in nature. The different functional groups present in the compounds are identified and assigned satisfactorily using the FTIR and FT Raman spectra. UV-visible spectral investigation has been carried out to study the light absorption activity of the drugs at various environmental exposures like infrared radiation and sunlight. Further, the interaction of the drugs with some trace-elemental constituents such as calcium, magnesium, iron and lead has also been analyzed by employing UV-Visible spectral measurements.

Key Words: Ceftriaxone, Cefotaxime, Spectroscopic studies, Absorbance, Trace-elements.

INTRODUCTION

Antibiotics are an important medicine that can destroy bacterial infections[1,2]. They are used to kill the bacteria that have entered the body without harming normal cells by inhibiting steps in the buildings of bacterial cell walls, so that the cell dies and is unable to reproduce. Cephalosporins are a group of semi synthetic antibiotic derived from 'Cephalosporins-C' obtained from the fungus cephalosporium. Cephalosporins are β-lactam compounds in which the β-lactam ring is fused to a 6-membered dihydrothiazine ring, thus forming the cephem nucleus. Side chain modifications to the cephem nucleus confers an improved spectrum of antibacterial activity, pharmacokinetic advantages and additional side effects. Based on their spectrum of activity, cephalosporins can be broadly categorized into 4 generations. This division has a chronological sequence of development and have the same mechanism of action as penicillin *i.e.*, inhibition of bacterial cell wall synthesis. The cephalosporins taken for the present study is similar to ciprofloxacin in a way that both are antibiotics belonging to antibacterial category. Before undertaking the study of cephalosporins, a survey is first made for the relative drug ciprofloxacin[3]. The interaction of

ciprofloxacin with some trace elements such as iron, calcium, magnesium, aluminium was investigated by many researchers in the recent years. Some of the interesting results obtained are as follows.

Research by Kara *et al.*[4] found that when Fe^{2+} was mixed with ciprofloxacin, rapid spectral changes occurred in a manner consistent with oxidation of the Fe^{2+} to Fe^{3+} thus forming Fe^{3+}-ciprofloxacin complex. It was concluded that the formation of a ferric ion-ciprofloxacin complex was most likely responsible for the reduction in ciprofloxacin bioavailability in the presence of iron. Similar studies were also made in norfloxacin and ofloxacin both belonging to antibacterial category. The absorption of norfloxacin, ofloxacin and ciprofloxacin was significantly reduced when they were co-administered with ferrous sulphate. Lomaestro and Bailie[5] found that repeated doses of calcium carbonate, administered 2 h before ciprofloxacin did not significantly alter the relative bioavailability of ciprofloxacin. Research indicated that the risk of this potential interaction diminishing the efficacy of ciprofloxacin can be minimized by taking the calcium at least 2 h away from the drug. Teixeira *et al.*[6] investigated the interaction of antacids containing magnesium and aluminium with ciprofloxacin. It was concluded that individuals taking ciprofloxacin should avoid using aluminium or magnesium based antacids as they significantly impair the absorption of ciprofloxacin.

Studies were carried out by Egyptian researchers, Saleh *et al.*[7] to develop a simple, rapid and accurate spectrophotometric method for the analysis of fifteen cephalosporins. The method depends on the charge-transfer complexation reaction between any of these drugs as an n-electron donor and R-chloranilic acid (ρ-CA) as an acceptor to form a violet chromogen measured at 520 nm. Different variables affecting the reaction were studied and optimized. Under the optimum conditions, linear relationships with good correlation coefficients (0.9986-0.9996) were found between the absorbances and the concentrations of the studied drugs in the range of 4-1200 mg mL^{-1}. The limits of assay detection ranged from 2.54-42.83 mg mL^{-1}. The method was successfully applied to quality-control analysis of the studied drugs in their pharmaceutical formulations. The recovery percentages ranges from 96.76 ± 0.87 to 100.50 ± 1.30 %. The interaction sites were confirmed by UV, IR, ^1H NMR techniques. The cephalosporins chosen for the present study are ceftriaxone and cefotaxime (Fig. 1). Ceftriaxone is a third generation cephalosporin. The molecular formula of ceftriaxone is $C_{18}H_{16}N_8O_7S_3Na_2$ and the molecular weight is 598.55. It is a sterile, semi-synthetic cephalosporin for intravenous, intramuscular administration. It has a broad spectrum activity *in vitro* which includes gram-positive and gram-negative aerobic and some anaerobic bacteria. It has a high degree of stability in presence of β-lactamase and is generally

well tolerated. Ceftriaxone is freely soluble in water and the pH value is *ca.* 6.7. Cefotaxime is a bactericidal third generation cephalosporin. The molecular formula of cefotaxime is $C_{16}H_{16}N_5O_7S_2Na$ and the molecular weight is 477.44. It has a broad spectrum of activity against gram-positive and gram-negative bacteria particularly against *Enterobacteriaceae*, including β-lactamase producing strains. The bactericidal activity of cefotaxime sodium results from inhibition of cell wall synthesis. Cefotaxime sodium injection contains cefotaxime sodium equivalent to not less than 90 % and not more than 110 % of stated amount of cefotaxime. Cefotaxime is freely soluble in water and the pH value is in between 4.5-6.5.

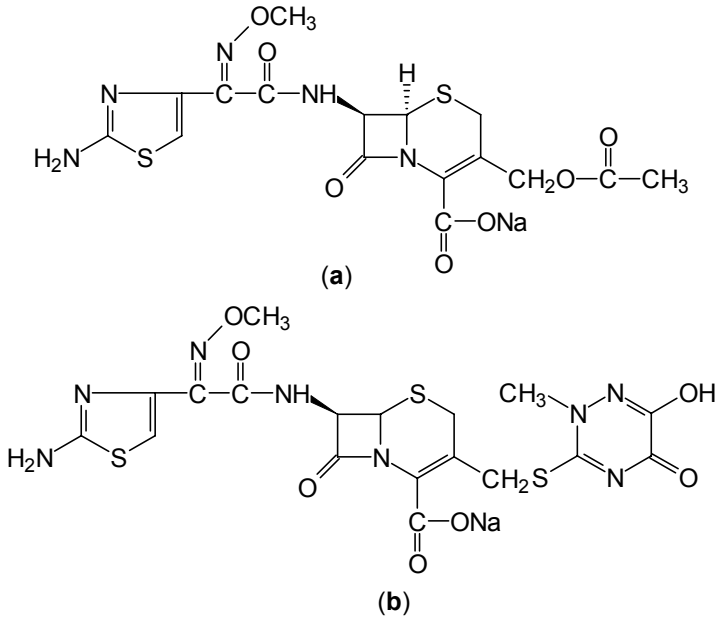

Fig. 1. Molecular structures of (a) ceftriaxone (b) cefotaxime

After having knowledge of the peculiar way of arresting the growth of bacteria by antibiotics and the contribution of spectroscopy to pharmaceutical industry[8,9], attention has been turned towards the spectroscopic methods for the analysis of cephalosporins which comes under the antibiotic category. In this work, the basic functional groups of ceftriaxone and cefotaxime are identified and assigned satisfactorily by employing the FTIR and FT Raman spectra of the compounds. The change in the behavior of the drugs when it is exposed to different environmental conditions is checked using UV-Visible spectral measurements. The behaviour of the antibiotic drugs under the influence of some trace elemental concentrations such as calcium, magnesium, iron and lead has also been analyzed using UV-Visible spectroscopic measurements.

EXPERIMENTAL

The samples of high purity of ceftriaxone and cefotaxime were obtained from Alkem laboratories, Mumbai, India and used as such. The FTIR spectra of the samples were recorded using Nicolet 320 Infrared Spectrophotometer over the region 4000-400 cm^{-1} at Chennai, India. The FT Raman spectra were recorded using Bruker IFS 66V Spectrophotometer over the region 4000-200 cm^{-1} at Sophisticated Analytical Instrumentation Facility (SAIF), IIT, Chennai, India. The UV-visible spectral measurements are carried out using Elico SL-159 UV-visible spectrophotometer at Spectrophysics Research Laboratory, Pachaiyappa's College, Chennai, India.

RESULTS AND DISCUSSION

By observing the nature, shape and intensity of the vibrational bands in FTIR and FT Raman spectra of ceftriaxone and cefotaxime, a satisfactory vibrational band assignment has been made which are presented in Tables 1 and 2.

Amide N-H stretching vibrations: For primary amides, two sharp bands of medium intensity are observed due to the asymmetric and symmetric stretching vibrations. In dilute, non-polar solvents, *i.e.*, in the absence of hydrogen bonding, these bands occur in 3500-3400 cm^{-1}. In the solid state and in the presence of hydrogen bonding, these bands are shifted by about 150 cm^{-1}. Both primary and secondary amides may exhibit a number of bands due to different hydrogen-bond states, *e.g.*, dimers, trimers, *etc*. These bands depend on the concentration and solvent used in these studies. Free secondary amides[10] have a sharp strong band at 3460-3300 cm^{-1}. This band may appear as a doublet due to the presence of *cis-trans* isomerism[11]. In the solid or liquid phases, secondary amides generally exhibit a strong band at about 3270 cm^{-1} and a weak band at 3100-3070 cm^{-1}. As a result strong intensity bands occurring at 3272 and 3434 cm^{-1} in the IR spectrum of ceftriaxone are due to N-H symmetric and asymmetric stretching, respectively medium intensity bands occurring at 3346 and 3423 cm^{-1} in the IR spectrum of cefotaxime are due to N-H symmetric and asymmetric stretching vibrations.

Amide C=O stretching vibrations (amide I band): The amide band due to the C=O stretching vibration is often referred to as the amide I band. Primary amides have a strong band due to the (C=O) stretching vibration at 1670-1650 cm^{-1} in the solid phase, the band appearing at 1690-1670 cm^{-1} for a dilute solution using a non-polar solvent[12]. In the solid phase, secondary amides absorb strongly at 1680-1630 cm^{-1} and in dilute solution at 1700-1665 cm^{-1}. The carbonyl absorption band of tertiary amides is independent of physical state, since hydrogen bonding to another amide

TABLE-1
VIBRATIONAL SPECTRAL ASSIGNMENT OF CEFTRIAXONE

Frequency (cm^{-1})		Assignments
FTIR	Raman	
467 vw	-	C-C out-of-plane bending
571 w	579 vw	C-S stretching
606 w	-	C-S stretching/C-C-C out-of-plane bending
648 w	650 vw	C-C-C in plane deformation
735 w	745 vw	C-H out-of-plane deformation
761 w	-	CH_2 rocking
806 w	808 vw	C-H out-of-plane deformation
822 vw	827 vw	C-H out-of-plane deformation
1033 m	1050 vw	C-H in plane deformation
1108 w	1116 vw	C-H in plane deformation
1210 vw	1201 vw	CH_2 wagging
1286 w	1293 vw	C-N stretching
1418 s	1404 w	CH_2 deformation
1443 s	-	C=C stretching
1501 s	1495 m	Amide N-H deformation/C=C stretching/C=N stretching
1536 s	1524 w	Amide N-H deformation/C=C stretching/C=N stretching
1608 vs	1579 vs	Amide N-H deformation/C=C stretching/C=N stretching
1649 vs	1638 m	Amide C=O stretching
1742 s	1717 w	C=O stretching
2891 w	2896 w	CH_3 symmetric stretching
2933 m	2940 w	CH_3 asymmetric stretching
3272 s	-	N-H symmetric stretching/O-H stretching
3434 s	-	N-H asymmetric stretching/O-H stretching

molecule is not possible and occurs in the region 1670-1630 cm^{-1}. The carbonyl absorption band is obviously influenced by solvents with which hydrogen bonds may be formed. The carbonyl stretching vibration frequency of N-acetyl and N-benzyl groups in compounds where the nitrogen atom forms part of a heterocyclic ring increases as the resonance energy is increased, *e.g.* by increasing the number of nitrogen atoms in the ring. In the case of pyrroles, the carbonyl band occurs near 1730 cm^{-1} and in the case of tetrazoles, *ca.* 1780 cm^{-1}. Primary α-halogenated amides absorb at higher frequencies than the corresponding alkyl compound, up to about 1750 cm^{-1} and may, in fact have two carbonyl bands due to the presence of rotational isomerism. The carbonyl band of N-halogen secondary amides also occurs at higher frequencies than that of the corresponding N-alkyl compound. Hydroxamic acids have strong carbonyl absorption at about 1640 cm^{-1}. With this view, a strong intensity band identified at 1649 cm^{-1} in the FTIR spectrum of ceftriaxone and cefotaxime are due to C=O stretching vibrations and further they are confirmed by FT Raman bands.

TABLE-2
VIBRATIONAL SPECTRAL ASSIGNMENT OF CEFOTAXIME

Frequency (cm^{-1})		Assignments
FTIR	Raman	
471 vw	475 vw	C-C out-of-plane bending
616 vw	-	C-S stretching
645 vw	655 vw	C-S stretching
700 w	708 vw	C-H out-of-plane deformation
917 vw	910 vw	C-O-C symmetric stretching
1064 s	1065 vw	C-O-C symmetric stretching
1127 vw	1125 vw	C-O-C asymmetric stretching/C-H in plane deformation
1183 vw	1183 vw	C-N stretching
1242 s	1248 vw	C-N stretching/C-O-C asymmetric stretching
1281 m	1283 vw	C-N stretching
1342 s	1343 vw	C-N stretching
1386 m	-	C-H symmetric bending
1437 w	1441 vw	C-H asymmetric bending
1462 w	1458 vw	CH_3 deformation
1486 w	-	C=C stretching
1536 vs	1531 m	Amide N-H deformation/C=N stretching/C=C stretching
1610 s	1592 vs	Amide N-H bending/C=C stretching/C=N stretching
1649 vs	1647 m	Amide C=O stretching/C=C stretching/C=N stretching
1729 vs	1733 vw	C=O stretching
1759 vs	1750 vw	C=O stretching
2891 w	2902 vw	CH_3 symmetric stretching
2935 w	2942 w	CH_3 asymmetric stretching
3346 m	-	N-H symmetric stretching/O-H stretching
3423 m	-	N-H asymmetric stretching/O-H stretching

Amide N-H deformation and C-N stretching vibrations (amide II band): In the solid phase, primary amides have a weak-to-medium intensity band in 1650-1620 cm^{-1} region which is generally close to the strong carbonyl band to be resolved. In dilute solution, this band occurs at 1620-1590 cm^{-1} region. The position of this band is not markedly influenced by the nature of the primary amide, *i.e.* aliphatic or aromatic. This band is known as the amide II band and is due to a motion combining both the N-H bending and the C-N stretching vibrations of the group -CO-NH- in its *trans*-form. The amide II band appears to be mainly due to the N-H bending motion. Secondary amides in the solid phase have a characteristic strong absorption at 1570-1515 cm^{-1} region. In the solid phase, hydroxamic acids have a strong amide II band observed near 1550 cm^{-1}. Amides of the type -CO-NH-NH_2, have a medium-intensity band[13] due to the deformation of the NH_2 group at 1635-1600 cm^{-1}. The amide II band which is strong

occurs in 1545-1520 cm^{-1} region and a weak-to-medium intensity band due to the C-N stretching vibration occurs in 1150-1050 cm^{-1} region. With these references, strong bands observed at 1608, 1536 and 1501 cm^{-1} in the FTIR spectrum of ceftriaxone are due to amide N-H deformation vibrations. The strong bands appearing at 1610 and 1536 cm^{-1} in the FTIR spectrum of cefotaxime are assigned to amide N-H deformation vibrations and they are confirmed by FT Raman bands.

C-H stretching vibrations: The C-H vibration frequencies of the methyl and methylene groups fall in narrow ranges for saturated hydrocarbons[14]. On examination of large number of aliphatic compounds containing methyl group, two distinct bands are found to occur in the region 2975-2840 cm^{-1}. The first of these results from the asymmetric stretching mode in which two C-H bonds of methyl group are extending while the third C-H bond is contracting. The second band arises from the symmetric stretching in which all three of the C-H bonds extend and contract in phase. In strained ring systems, the frequency of the methylene C-H stretching vibration is increased. The CH_3 asymmetric stretching vibration occurs at 2975-2950 cm^{-1} and may easily be distinguished from the nearby CH_2 absorption at about 2930 cm^{-1}. The symmetric CH_3 stretching absorption band occurs at 2885-2865 cm^{-1} and that of the methylene group at 2870-2840 cm^{-1}. Bands due to both alkene and aromatic C-H stretching occur above 3000 cm^{-1}. Although alkane C-H stretching vibrations generally occur below 3000 cm^{-1}, it is noted that alkanes substituted with electronegative atoms or groups absorb above 3000 cm^{-1}. Two bands are usually observed due to the stretching vibrations of the aldehydic C-H, both of which are of weak-to-medium intensity, one at about 2820 cm^{-1} and the other in the region 2745-2650 cm^{-1}. Acetates have medium-to- weak bands near 2990 cm^{-1} due to C-H stretching vibrations of the group and methyl esters[15] have bands near 2960 cm^{-1} due to the CH_3 asymmetric stretching. As a result, the weak bands occurring at 2891 cm^{-1} in the two antibiotic compounds are assigned to CH_3 symmetric stretching. The bands appearing at 2933 and 2935 cm^{-1} in the IR spectra of ceftriaxone and cefotaxime, respectively are due to CH_3 asymmetric stretching vibrations which are confirmed in the Raman spectrum.

C-H Deformation vibrations: The methyl group of hydrocarbons give rise to two vibration bands, the asymmetric deformation band occurring at 1465-1440 cm^{-1} and the symmetric band at 1390-1370 cm^{-1}. The presence of adjacent electronegative atoms or groups can alter the position of the methyl symmetric band significantly, its range being 1450-1260 cm^{-1}, whereas the asymmetric band is far less sensitive, its range being 1470-1410 cm^{-1}. *t* -Butyl groups have a strong band near 1365 cm^{-1} and a slightly weaker band near 1390 cm^{-1}. Acetals have a characteristic strong band in

the region 1115-1105 cm^{-1} due to the C-H deformation vibration being perturbed by the neighbouring C-O groups. This band is used to distinguish between acetals and ketals. Aldehydes have a weak-to-medium intensity band due to C-H deformation vibration in the region 975-780 cm^{-1} but because of its variable position and intensity, this band may be difficult to identify. Acetates have a medium-to-strong band near 1375 cm^{-1} due to the CH_3 symmetric deformation and medium-to-weak bands near 1430 cm^{-1} due to the asymmetric deformation. For other saturated esters containing the -CH_2CO-O- group, the CH_2 deformation band occurs near 1420 cm^{-1}. Methyl esters have bands near 1440 and 1425 cm^{-1} due to the -CH_3 deformation vibrations. Methyl rocking vibrations are generally weak and are mass-sensitive. For *n*-alkanes, a band due to the -CH_2- wagging vibration occurs near 1305 cm^{-1}. This band depends on the number of -CH_2- groups present in the compound. In view of this, weak bands observed at 822, 806 and 735 cm^{-1} in the FTIR spectrum of ceftriaxone are allotted as C-H out-of-plane deformation vibrations and medium to weak intensity bands present at 1108 and 1033 cm^{-1} are allotted as C-H in plane deformation vibrations. A strong band occurring at 1418 cm^{-1} in ceftriaxone is due to the -CH_2- deformation vibration. Weak bands present at 1210 and 761 cm^{-1} in the IR spectrum of ceftriaxone are due to CH_2 wagging and CH_2 rocking vibrations, respectively. In the FTIR spectrum of cefotaxime, weak band appearing at 700 cm^{-1} and very weak band appearing at 1127 cm^{-1} are allotted to be due to C-H out of plane deformation and C-H in plane deformation vibrations, respectively. A medium intensity band appearing at 1386 cm^{-1} and a weak intensity band at 1437 cm^{-1} in the FTIR spectrum of cefotaxime are due to C-H symmetric and asymmetric bending, respectively. A weak band appearing at 1462 cm^{-1} is allotted to be due to -CH_3 deformation vibration in cefotaxime.

C=O stretching vibrations: Saturated aliphatic esters absorb strongly at 1750-1725 cm^{-1} with the exception of formates which absorb in the region 1725-1720 cm^{-1}. Electronegative groups or atoms directly bonded to the alcoholic oxygen atom of the ester group tend to increase the frequency of the C=O stretching vibration. Aryl and α,β-unsaturated esters absorb at 1730-1705 cm^{-1}. Further conjugation has almost no effect on the C=O stretching vibration frequency. In non-polar solvents, saturated aliphatic aldehydes absorb strongly in the region[16] 1740-1720 cm^{-1}, aryl aldehydes at 1715-1695 cm^{-1} and α,β-unsaturated aliphatic aldehydes at 1705-1685 cm^{-1}. Ketones and aldehydes have almost identical carbonyl absorption frequencies. Aldehydes usually absorb at about 10 cm^{-1} higher than the corresponding ketone. Saturated aliphatic ketones and cyclic ketones in the pure liquid and solid phases absorb strongly in the range 1725-1705 cm^{-1} due to C=O stretching vibrations. The C=O stretching

vibration for carboxylic acids gives rise to a band which is stronger than that for ketones or aldehydes. In the solid or liquid phases, the C=O group of saturated aliphatic carboxylic acids absorbs very strongly in the region 1725-1700 cm^{-1}. In the present work, a strong band observed at 1742 cm^{-1} in the IR spectrum of ceftriaxone is allotted to be due to C=O stretching vibration. In the IR spectrum of cefotaxime, strong bands observed at 1759 and 1729 cm^{-1} are assigned to be due to C=O stretching vibrations. The C=O stretching vibrations in the FTIR spectra of the two antibiotic samples are confirmed in Raman spectra.

C-O-C stretching vibrations: Acid anhydrides have a strong band in the range 1135-980 cm^{-1} due to the C-O-C stretching vibration which appears at 1300-1210 cm^{-1} for strained-ring compounds. Cyclic anhydrides have a strong band at 955-895 cm^{-1} and often a weak band near 1060 cm^{-1} due to the stretching vibration of the C-O-C group. The band due to the C- O-C asymmetric stretching vibration for aliphatic esters occurs at 1275-1185 cm^{-1} and that due to the symmetric stretching vibration occurs at 1160-1050 cm^{-1}. Both these bands are strong, the former band being usually more intense than that due to the C=O stretching vibration. As a result, strong bands present at 1064 and 1242 cm^{-1} in the FTIR spectrum of the antibiotic sample cefotaxime are assigned as C-O-C symmetric and asymmetric stretching vibrations, respectively. Very weak bands present at 917 and 1127 cm^{-1} in the FTIR spectrum of cefotaxime are assigned as C-O-C symmetric and asymmetric stretching vibrations, respectively.

C-S stretching vibrations: All aliphatic thiocyanates[17] have a strong band at 405-400 cm^{-1} due to the in-plane deformation vibration of the -SCN group. Primary aliphatic thiocyanates have a band of medium-to-strong intensity near 620 cm^{-1} due to the C-S stretching vibration. Both aliphatic and aromatic sulphides have a weak-to-medium band due to the C-S stretching vibration in the region 710-570 cm^{-1}, primary sulphides absorbing at the higher frequency end of the range and tertiary sulphides at the lower end. For compounds in which the C-S group is adjacent to a C=O group, the C-S band is normally above 710 cm^{-1}. In view of this, weak bands observed at 606 and 571 cm^{-1} are due to C-S stretching vibrations in ceftriaxone. Very weak bands observed at 616 and 645 cm^{-1} in cefotaxime are due to C-S stretching vibrations.

C-N stretching vibrations: Secondary aliphatic amines have two bands of medium intensity at 1190-1170 and 1145-1130 cm^{-1} region due to C-N stretching vibrations. For aromatic and unsaturated amines =C-N, two bands are observed at 1360-1250 and 1280-1180 cm^{-1} due to conjugation of the electron pair of the nitrogen with the ring imparting double-bond character to the C-N bond. The C-N band for tertiary aromatic amines is found at 1380-1330 cm^{-1}. Amides of the type -CO-NH-NH_2 have a weak-to-medium

intensity band due to the C-N stretching vibration occurring at 1150-1050 cm^{-1}. The weak band present at 1286 cm^{-1} in the IR spectrum of ceftriaxone is due to C-N stretching vibrations. A strong band present at 1342 cm^{-1}, medium intensity band present at 1281 cm^{-1} and very weak band present at 1183 cm^{-1} in the IR spectrum of cefotaxime are due to C-N stretching vibrations which are in conformity with the Raman spectra.

C=C and C=N stretching vibrations: Generally, the ring carbon-carbon stretching vibrations occur in the region 1625-1430 cm^{-1}. For aromatic six-membered rings, *e.g.* benzenes and pyridines, bands of variable intensity are observed at 1625-1590, 1590-1575, 1525-1470 and 1465-1430 cm^{-1} due to aromatic C=C stretching vibrations. Interactions between ring C=C and C=N stretching vibrations of pyridine compounds result in two strong-to-medium intensity absorptions about 100 cm^{-1} apart. These absorptions occur at 1615-1575 and 1520-1465 cm^{-1}; the higher-frequency band often having another medium-intensity band on its low-frequency side which is found at 1590-1555 cm^{-1}. Pyrimidines absorb strongly at 1600-1500 cm^{-1} due to the C=C and C=N ring stretching vibrations. Thiazoles comes under the category of five-membered ring compounds and they have medium intensity band in the region 1550-1505 cm^{-1} due to C=N stretching vibrations[18]. As a result, very strong intensity bands present at 1608, 1536 and 1501 cm^{-1} in the FTIR spectrum of ceftriaxone are assigned to C=C and C=N stretching vibrations. In the IR spectrum of cefotaxime, absorption bands appearing at 1649, 1610 and 1536 cm^{-1} are due to C=C and C=N stretching vibrations and which are further confirmed by FT Raman bands. Absorption bands present at 1443 and 1486 cm^{-1} in the FTIR spectra of ceftriaxone and cefotaxime, respectively are due to C=C stretching vibrations.

O-H stretching vibrations: In very dilute solution in non-polar solvents, the normal O-H absorption of alcohols of type R-OH···O=C< falls in the region 3600-3450 cm^{-1}. The relative intensity of the band due to the hydroxyl stretching vibration decreases with increase in concentration, with additional broader bands appearing at lower frequencies 3580-3200 cm^{-1}. The precise position of the O-H band is dependent on the strength of the hydrogen bond. Hydroxyl groups which are hydrogen-bonded to aromatic ring π-electron systems absorb at 3580-3480 cm^{-1}. Peracids have a medium intensity band at 3280 cm^{-1} due to O-H stretching vibrations. Carboxylic acids in the liquid and solid phases exhibit a broad band at 3300-2500 cm^{-1} due to the O-H stretching vibration[19], which sometimes, in the lower half of the frequency range, has two or three weak bands superimposed on it. As a result, strong intensity bands identified at 3434 and 3272 cm^{-1} are allotted as O-H stretching vibrations in ceftriaxone and medium intensity bands identified at 3423 and 3346 cm^{-1} are allotted as O-H stretching vibrations in cefotaxime.

C-C and C-C-C bending vibrations: The C-C deformation bands for the alkane groups occur below 600 cm^{-1} and are of weak intensity[20]. Straight-chain alkanes have two bands, one at 540-485 cm^{-1} and the other near 455 cm^{-1} due to C-C deformation vibrations. The former band is usually slightly more intense than the second band and tends to the higher-frequency end of the range as the length of the chain increases. Ethyl-substituted benzenes have a medium-to-strong absorption at 565-540 cm^{-1} and isopropyl benzenes have a medium-intensity absorption band at 545-520 cm^{-1}. Both these vibrations are due to the in-plane bending of the =C-C-C group. In the present work, very weak bands occurring at 467 and 471 cm^{-1} in the FTIR spectra of ceftriaxone and cefotaxime, respectively are due to C-C out-of-plane bending vibrations. The weak bands occurring at 648 and 606 cm^{-1} in the FTIR spectrum of ceftriaxone are due to C-C-C in plane and out of plane deformation vibrations, respectively.

UV-Visible spectra and study on storage condition & bound drugs-trace elements interaction: The UV-Visible spectral measurements are carried out on ceftriaxone and cefotaxime and by verifying the Beer's law, the absorption peaks are identified. The antibiotic samples are dissolved in double distilled water and a stock solution is prepared. From the stock solution, a solution is made whose concentration is 0.055 mgm/mL for ceftriaxone as for this concentration onwards only a smooth spectrum has been obtained. The spectral recording shows the absorption peak at 264 nm. Similarly, a solution of concentration 0.062 mg/mL for cefotaxime is made and the absorption peak is obtained at 266 nm from the spectra[11]. Hence the absorption peaks observed at 264 and 266 nm for ceftriaxone and cefotaxime, respectively are identified as λ_{max}.

Pharmacopoeia is an official code containing a selected list of the established drugs and medicinal preparations with the descriptions of their physical properties and tests for their identity, purity, potency and ideal storage condition. In present work, UV-Visible spectroscopy is used for analyzing the prescribed storage condition and the alteration in the nature and quality of the drugs when they are not kept so[21]. The antibiotic drugs ceftriaxone and cefotaxime have to be kept in light resistance containers at a cool and dark place. To investigate whether there is an alteration in the nature of both the samples, a part of the sample is exposed to sun and a part of the sample is exposed to infrared radiation for a period of 3 h. Each sample is diluted for the same concentration and the UV-Visible spectral recordings are made. As in the previous case here also the absorption peaks are found in the same positions at 264 and 266 nm for ceftriaxone and cefotaxime but there is a marked change in the optical density of the drugs when they are exposed to different environmental conditions. Figs. 2 and 3 presents the variation of absorbance of wavelength maximum with concentration under different storage conditions for the two drugs.

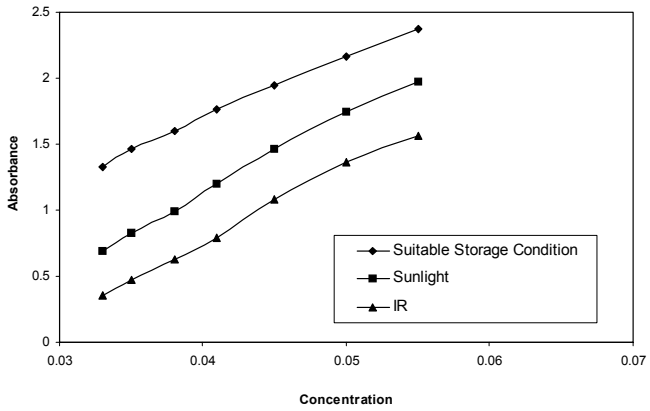

Fig. 2. Light absorption characteristics of λ_{max} at different environmental hazards (ceftriaxone)

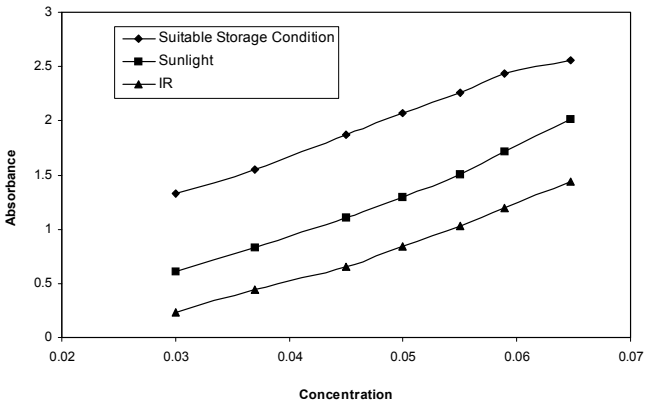

Fig. 3. Light absorption characteristics of λ_{max} at different environmental hazards (cefotaxime)

Antibiotics are an important medicine which can kill bacteria that has entered the body, without harming normal cells. The change in the activity of the cell or tissue produced by the drug is termed as response. There are many factors which influence the response of the drug as age, body weight, sex, time and place factors, physiological factors, combination of drugs, *etc*. More than fifty chemical elements are found in human body which are required for growth, repair and regulation of vital body function. Among these calcium, phosphorus, potassium, magnesium, iron, iodine, *etc.* are required in quantities less than a few mg/day and they are termed trace elements. In this work, UV-Visible spectral measurements are carried out to study the interaction of ceftriaxone and cefotaxime with the trace-elements calcium, magnesium, iron and lead.

The solution containing calcium salt is prepared for various concentration. To each concentration same amount of drug is added and the spectrum is recorded. It is observed that the absorption level of the peak decreases as the amount of the trace elemental ion increases for both the antibiotic samples. The experiment is repeated for the other trace elements magnesium, iron and lead. The absorbance of the two drugs decreases with the increase in concentration of all the trace elemental constituents.

Human body contains more quantity of calcium compared to magnesium. Magnesium is present in a higher quantity than iron and the quantity of lead is the least. The UV-visible spectra of the interaction of drugs with trace elements reveal that the absorbance of drugs by calcium was highest followed by magnesium. The drugs absorbed by iron were less compared to calcium or magnesium and the absorbance of the samples by lead was the least of all. Hence it is found that the light absorption characteristics of these antibiotics were to vary in the same manner according to amounts of calcium, magnesium, iron and lead present in a normal human body. Thus the absorption of the drugs are very much influenced by the trace elemental interactions in the body. Tables 3 and 4 summarizes the variation in the absorption level of the drugs with trace elemental interaction.

TABLE-3
LIGHT ABSORPTION ACTIVITY OF CEFTRIAXONE WITH CONCENTRATION OF TRACE ELEMENTAL IONS

Trace elemental concentration (mgm/mL)	Absorbance of wavelength maximum (λ_{max} = 264 nm)			
	Calcium	Magnesium	Iron	Lead
0.093	1.883	1.802	1.504	1.382
0.097	1.808	1.700	1.482	0.733
0.102	1.787	1.683	1.275	0.700
0.106	1.742	1.666	1.088	0.674
0.111	1.652	1.615	0.913	0.587
0.115	1.641	1.585	0.821	0.565

TABLE-4
LIGHT ABSORPTION ACTIVITY OF CEFOTAXIME WITH CONCENTRATION OF TRACE ELEMENTAL IONS

Trace elemental concentration (mgm/mL)	Absorbance of wavelength maximum (λ_{max} = 266 nm)			
	Calcium	Magnesium	Iron	Lead
0.093	2.410	2.152	1.765	1.402
0.097	2.326	2.040	1.726	1.252
0.102	2.194	1.927	1.670	1.226
0.106	2.078	1.745	1.595	1.181
0.111	1.987	1.689	1.504	1.167
0.115	1.844	1.526	1.481	1.145

Conclusion

Thus the FTIR, FT Raman and UV-Visible spectral measurements are employed in the qualitative analysis of the antibiotic compounds ceftriaxone and cefotaxime. The interaction of the compounds with four different trace elements as calcium, magnesium, iron and lead are also analyzed by employing UV-Visible spectral measurements. The light absorption characteristics of the drugs are studied under various exposure conditions by utilizing UV-Visible spectroscopic techniques.

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(*Received*: 24 February 2007; *Accepted*: 4 October 2007) AJC-5977