PREFACE

The present investigations on “CRYSTALLOGRAPHIC STUDIES ON SOME AMINO ACID/VITAMIN COMPLEXES WITH PICRIC ACID” were carried out by the candidate under the supervision of Prof. S. Natarajan, Head, Department of Physics, School of Physics, Madurai Kamaraj University, Madurai, During the period 2003-2006.

This thesis comprises of fourteen chapters. An overview of all the chapters is given below.

In this thesis, the crystal structure elucidation of (i) some amino acid complexes with picric acid and (ii) complexes of some vitamins with picric acid are reported. These are given under Part I and Part II of the thesis. The structure of a complex of 2-methylpyridinium picrate is reported in Part III and in Part IV the common features observed in all the structures are given.

Chapter 1 presents the general introduction to amino acids, vitamins, picric acid, X-ray crystallography and crystal structure determination and the hydrogen bonding features.

PART-I

In Chapter 2, a detailed study of the crystal structure of L-valinium picrate, \((C_7H_{12}NO_2)^+.\!(C_6H_2N_3O_7)^-\), is reported. The title compound was crystallized in the monoclinic space group \(P2_1\). The unit cell dimensions are \(a = 9.9714(13) \text{ Å}, \ b = 6.2930(5) \text{ Å}, \ c = 12.6480(9) \text{ Å}\) and \(\beta = 110.50(1)^\circ\). The crystal structure was solved and refined to an R-value of 0.040 for 1564 unique reflections with \(I > 2\sigma(I)\) and for 217
parameters. The asymmetric part of the unit cell is composed of a valinium cation and a picrate anion. The valinium residue is bonded with picrate anion through O-H⋯O and N-H⋯O hydrogen bonds. The valinium residue is involved in a zigzag (z1) head-to-tail sequence, leading to the formation of a helix along the b-axis.

Chapter 3 deals with the compound DL-valine DL-valinium picrate, \((C_9H_{11}NO_2)\cdot(C_9H_{12}NO_2)^+\cdot(C_6H_2N_3O_7)^-\). It was crystallized in the monoclinic space group P2_1/n. The unit cell dimensions are \(a = 5.3822(3) \text{ Å}, \quad b = 23.221(2) \text{ Å}, \quad c = 16.579(2) \text{ Å} \) and \(\beta = 94.695(7)^\circ\). The crystal structure was solved and refined to an R-value of 0.058 for 2219 reflections with \(I > 2\sigma(I)\) and for 293 parameters. The asymmetric part of the unit cell is composed of a neutral valine residue, a valinium cation and a picrate anion. The valine residue shows gauche II conformation and valinium residue shows trans conformation. The valine residue is involved in a straight (S2) head-to-tail sequence, leading to the formation of an infinite chain along the a-axis. In the present structure class II hydrogen bonding pattern is observed in valine residue and class I hydrogen bonding pattern is observed in valinium residue.

Chapter 4 contains the investigations on the compound DL-phenylalanine DL-phenylalaninium picrate \((C_9H_{11}NO_2)\cdot(C_9H_{12}NO_2)^+\cdot(C_6H_2N_3O_7)^-\). The title compound was crystallized in the triclinic space group P\(\overline{1}\). The unit cell dimensions are \(a = 7.333(3) \text{ Å}, \quad b = 13.737(3) \text{ Å}, \quad c = 15.381(6) \text{ Å}, \quad \alpha = 113.04(2)^\circ, \quad \beta = 94.93(4)^\circ \) and \(\gamma = 105.23(3)^\circ\). The crystal structure was solved and
refined to an R-value of 0.062 for 1945 reflections with I > 2σ(I) and for 362 parameters. The asymmetric part of the unit cell is composed of a neutral phenylalanine residue, a phenylalaninium cation and a picrate anion. The phenylalanine and phenylalaninium residues show gauche I conformation. The phenylalaninium residue forms a strong O-H···O hydrogen bond with a zwitterionic phenylalanine residue, thus leading to dimerisation. An inversion related DL1 head-to-tail sequence is also observed. It is interesting to note that the phenylalaninium residue has a four-centered hydrogen bond.

**Chapter 5** gives the detailed structural information about the compound L-leucine L-leucinium picrate \((C_6H_{13}NO_2)_3(C_6H_{14}NO_2)^+\). It was crystallized in the triclinic space group P1. The unit cell dimensions are \(a = 7.1470(5) \, \text{Å}, \quad b = 11.8540(8) \, \text{Å}, \quad c = 15.4561(1) \, \text{Å}, \quad \alpha = 106.45(2)°, \quad \beta = 95.17(1)° \quad \text{and} \quad \gamma = 91.02(2)°\). The crystal structure was solved and refined to an R-value of 0.051 for 3495 reflections with I > 2σ(I) and for 609 parameters. The asymmetric part of the unit cell is composed of a neutral leucine residue, a leucinium cation and a picrate anion. The carboxyl groups of leucine and the leucinium residues are interconnected through O-H···O hydrogen bond by forming hydrogen bonded dimer. The amino group of both leucine and leucinium residues connects carboxyl oxygen atoms of symmetry related leucine residues thus forming infinite chain along the \(a\)-axis. In the present crystal structure, the hydrophobic layer across \(y=1/3\) is sandwiched between hydrophilic layers.
In Chapter 6, the crystal structure of the compound L-asparaginium picrate, \((C_4H_9N_2O_3)^+.(C_6H_2N_3O_7)^-\) is given. The unit cell dimensions of the title compound are \(a = 10.367(4) \text{ Å}, \quad b = 5.1611(7) \text{ Å}, \quad c = 13.120(3) \text{ Å} \) and \(\beta = 93.20(2)^\circ\). The crystal structure was solved and refined to an R-value of 0.068 for 1300 reflections with \(I > 2\sigma(I)\) and for 227 parameters. The asymmetric part of the unit cell is composed of an asparaginium cation and a picrate anion. A zigzag \((Z_1)\) head-to-tail sequence along b-axis is observed in this residue connecting two amino acids related by \(2_1\) operations. Intra-molecular hydrogen bonding between \(\alpha\)-amino group and \(\gamma\)-carbonyl group is also observed.

Chapter 7 presents the structural information about the compound bis(\(\beta\)-alanine) hydrogen picrate, \(2(C_7H_7NO_2).H^+.(C_6H_2N_3O_7)^-\). It was crystallized in the triclinic space group \(P\bar{1}\). The unit cell dimensions are \(a = 4.9515(4) \text{ Å}, \quad b = 11.725(2) \text{ Å}, \quad c = 14.931(2) \text{ Å}, \quad \alpha = 78.00(1)^\circ, \quad \beta = 83.75(1)^\circ\) and \(\gamma = 82.45(1)^\circ\). The crystal structure was solved and refined to an R-value of 0.060 wR for 2537 reflections with \(I > 2\sigma(I)\) and for 255 parameters. The asymmetric part of the unit cell contains two \(\beta\)-alanine residues one picrate anion and one \(\text{H}^+\) ion. Both the hydrogen bonds form dimers between carboxylic acid groups of two alanine residues. Interestingly in residue I, an intra-molecular hydrogen bond is observed. Class II hydrogen-bonding pattern is observed in alanine residue I. While analyzing the residue II, class III hydrogen-bonding pattern is observed.

In Chapter 8, the structural information of the compound DL-methionine DL-methioninium \((C_5H_{11}NO_2S).(C_5H_{12}NO_2S)^+.(C_6H_2N_3O_7)^-\),
picrate is given. The title compound was crystallized in the triclinic space group P\(\overline{1}\). The unit cell dimensions are \(a = 7.076(1) \text{ Å}, b = 12.102(1) \text{ Å}, c = 14.895(2) \text{ Å}, \alpha = 103.90(1) ^\circ, \beta = 97.04(2)^\circ \) and \(\gamma = 101.73(2)^\circ\). The crystal structure was solved and refined to an R-value of 0.072 for 2516 reflections with \(I > 2\sigma(I)\) and for 331 parameters. The asymmetric unit contains independent methionine, methioninium residues and a picrate anion. The amino groups of two residues are involved in hydrogen bonding with the lone oxygen of a picrate anion. It also connects carboxyl oxygen of inversion related residue II and amino group of residue I connects O atom of the residue II leading to a closed loop.

Chapter 9 deals with the compound prolinium picrate, \((C_5H_{10}NO_3)^+(C_5H_2N_3O_7)^-\). It was crystallized in the space group P2\(_1\). The unit cell dimensions are \(a = 10.909(5) \text{ Å}, b = 5.352(5) \text{ Å}, c = 12.474(5) \text{ Å}\) and \(\beta = 109.14(4)^\circ\). The crystal structure was solved and refined to an R-value of 0.062, wR value of 0.164 and GooF value of 1.09 for 1590 unique reflections with \(I > 2\sigma(I)\) and for 226 parameters. The asymmetric part of the unit cell is composed of a prolinium cation and a picrate anion. Both the major and minor conformers of the pyrrolidine ring adopt conformations intermediate between half-chair and envelope. The prolinium cation connects two different picrate anions leading to an infinite chain running along the \(b\)-axis.

PART- II

Chapter 10 presents the crystal structure of the compound nicotinium picrate, \((C_6H_6NO_2)^+(C_6H_2N_3O_7)^-\). The title compound was
crystallized in the space group \( P\bar{1} \). The unit cell dimensions are \( a = 8.063(3) \) Å, \( b = 8.080(3) \) Å, \( c = 12.030(5) \) Å and \( \alpha = 93.27(3) \)º, \( \beta = 95.87(3) \)º, \( \gamma = 113.46(3) \)º. The crystal structure was solved and refined to R-value of 0.045, wR value of 0.118 and Goof value of 1.02 for 1765 unique reflections with \( I > 2\sigma(I) \) and for 228 parameters. Hydrogen bonds from the nicotinic acid cation link two different picrate anions forming a straight chain along the b-axis. The picrate anions are stacked in columns along [010] plane. The nicotinium cation is planar and the planes of nicotinium cation and picrate anion are inclined to one another by 62.9(1)º.

**Chapter 11** gives the detailed structural information of the compound thiaminium dipicrate, \((C_{12}H_{18}N_{4}OS)^{2+} \cdot 2(C_{6}H_{2}N_{3}O_{7})^{-}\). The title compound was crystallized in the triclinic space group \( P\bar{1} \). The unit cell dimensions are \( a = 8.269(3) \) Å, \( b = 12.252(4) \) Å, \( c = 16.641(3) \) Å and \( \alpha = 69.35(4) \)º, \( \beta = 86.35(5) \)º, \( \gamma = 72.82(3) \)º. The crystal structure was solved and refined to an R-value of 0.067 for 2399 unique reflections with \( I > 2\sigma(I) \) and for 518 parameters. The present structure consists of divalent thiamine cation with positively charged thiazolium ring with hydroxy ethyl side chain, a protonated pyrimidine ring and two negatively charged picrate anions. The thiazolium ring and hydroxy ethyl side chain show 'positional' disorder about the methylene bridge. The head-to-tail sequence of thiaminium cation through one of the picrate anions is observed. Both the anions are placed nearer to the anionic holes in the thiaminium cation.
**Chapter 12** deals with the compound pyridoxinium picrate, \((C_8H_{12}NO_3)^+.(C_6H_2N_3O_7)^-\), which was crystallized in the triclinic space group \(P\overline{1}\). The unit cell dimensions are \(a = 8.094(3)\,\text{Å},\ b = 8.522(3)\,\text{Å}, \ c = 12.847(5)\,\text{Å}\) and \(\alpha = 87.20(3)\,^\circ,\ \beta = 85.70(3)\,^\circ,\ \gamma = 65.92(3)\,^\circ\). The crystal structure was solved and refined to an R-value of 0.043 for 2057 unique reflections with \(I > 2\sigma(I)\) and for 257 parameters. The asymmetric part of the unit cell is composed of a pyridoxinium cation and a picrate anion. Pyridine N and O5 oxygen form bifurcated hydrogen bonds with picrate anions, thus forming an infinite chain along the a-axis. An intramolecular hydrogen bonding between OH and nearby CH\(_2\)OH group is observed.

**PART-III**

**Chapter 13** presents the structure of the compound 2-methyl pyridinium picrate, \((C_5H_8N)^+.(C_6H_2N_3O_7)^-\). It was crystallized in the triclinic space group \(P\overline{1}\). The unit cell dimensions are \(a = 8.211(5)\,\text{Å},\ b = 11.806(5)\,\text{Å},\ c = 14.388(5)\,\text{Å}\) and \(\alpha = 85.43(5)\,^\circ,\ \beta = 82.86(5)\,^\circ,\ \gamma = 79.73(5)\,^\circ\). The crystal structure was solved and refined to R-value of 0.060, \(wR\) value of 0.167 and GooF value of 1.04 for 3255 unique reflections with \(I > 2\sigma(I)\) and for 414 parameters. The intra molecular contacts between phenolate oxygen and adjacent nitro groups are identified in this structure.

**PART-IV**

The last chapter (**Chapter 14**), brings out the common features observed in all these complexes, such as geometry, conformations and hydrogen bonding patterns of picric acid, amino acids and vitamins.
The research work presented in this thesis has been published in leading international journals and the list of publications are given below:

**LIST OF PUBLICATIONS**

1. L-valinium picrate
   
   **K. Anitha**, B. Sridhar and R.K. Rajaram
   *Acta Cryst.* E60 (2004), o1530-o1532.

2. β-alanine β-alaninium picrate
   
   **K. Anitha**, B. Sridhar and R.K. Rajaram
   *Acta Cryst.* E60 (2004), o1630-o1632.

3. DL-valine DL-valinium picrate
   
   **K. Anitha**, B. Sridhar and R.K. Rajaram
   *Acta Cryst.* E61 (2005), o1722-o1724.

4. DL-phenylalanine DL-phenylalaninium picrate
   
   **K. Anitha**, B. Sridhar and R.K. Rajaram
   *Acta Cryst.* E61 (2005), o589-o591

5. L-asparaginium picrate
   
   **K. Anitha**, S.Athimoolam and R.K. Rajaram
   *Acta Cryst.* E61 (2005), o1463-o1465.

6. L-leucine L-leucinium picrate
   
   **K. Anitha**, S.Athimoolam and R.K. Rajaram
   *Acta Cryst.* E61 (2005), o1604-o1606.

7. Nicotinium picrate
   
   **K. Anitha**, S.Athimoolam and R.K. Rajaram
   *Acta Cryst.* E61 (2005), o2556-o2558.

8. DL-methionine DL-methioninium picrate
   
   **K. Anitha**, S.Athimoolam and R.K. Rajaram
9. Thiaminium dipicrate
   **K. Anitha**, S.Athimoolam and S. Natarajan

10. Pyridoxinium picrate
    **K. Anitha**, S.Athimoolam and S. Natarajan

11. L-prolinium picrate and 2-methyl pyridinium picrate
    **K. Anitha**, S.Athimoolam and S. Natarajan