THE CRYSTAL STRUCTURE OF SARCOSINE HYDROCHLORIDE

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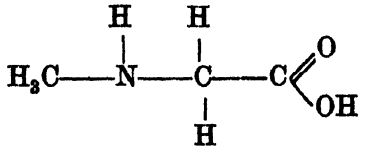
ABSTRACT. Crystals of sarcosine hydrochloride, $C_3H_7O_2N.HCl$, belong to the monoclinic space group $P2_1$ with cell dimensions $a=9.00$ Å, $b=5.93$ Å, $c=5.41$ Å and $\beta=96°$. The number of molecules per unit cell is two. The crystal structure has been solved by two dimensional Patterson and heavy atom Fourier synthesis. The positional co-ordinates of atoms (hydrogen atoms excluded), together with their isotropic temperature factors, have been refined by the method of least-squares, R value at this stage of refinement being 0,18.

The sarcosine molecule is not a zwitterion, the two C—O distances being C(1)—O(1) = 1.19 Å and C(1)—O(2)H = 1.35 Å. The molecules in the crystal are held together by a three-dimensional network of hydrogen bonds of the types N-H---O and O-H---O. The protonated α-amino nitrogen of the C(2)—N^+H_2—C(3) group makes two hydrogen bonds with the two chlorine ions and assume a tetrahedral configuration.

INTRODUCTION

Sarcosine—a methyl derivative of glycine—belongs to a group of biologically important compounds containing 1-carbon pool participating in transmethylation reaction and its chemical formula is,



One of the objects of the study of this compound is to derive information about the influence of the substitution of a methyl group in the amino group of glycine on molecular structure and biological properties. Sarcosine in the form of different hydrohalides and metal complexes is being studied in our laboratory. The present communication deals with the crystal structure of sarcosine hydrochloride.

The needle shaped single crystals of sarcosine hydrochloride were prepared by slow evaporation of an aqueous solution of this compound at room temperature. The unit cell dimensions, as determined from rotation, oscillation and Weissenberg photographs, are :

$$a = 9.00\text{Å}, \quad b = 5.93\text{Å}, \quad c = 5.41\text{Å} \text{ and } \beta = 96°$$

Systematic absence of *okl* reflections for *k odd* and other considerations clearly indicate that the space group of sarcosine hydrochloride is $P2_1$. The density of crystal, as determined by the method of floatation is 1.56g.cm^{-3} while that calculated for two formula units of ($C_3H_7O_2N.HCl$) in the unit cell is 1.46g.cm^{-3}.

Three dimensional intensity data were collected about *b* and *c* axes by multiple film equi-inclination Weissenberg technique. The dimension of the crystals used was so small that the absorption correction was thought unnecessary (the linear absorption co-efficient for Cuk$_\alpha$ being 55 cm^{-1}). The intensities were, however, corrected for spot shape, Lorentz and polarisation factors and put on absolute scale by Wilson's method.

STRUCTURE DETERMINATION

The positions of the two heavy atoms (i.e. chlorine) in the unit cell were located from two Patterson projections along *b* and *c* axes. The (010) projection being centrosymmetric, the structure analysis was first attempted with *hol* reflections only. A minimum function was drawn graphically using a single Cl–Cl peak in the Patterson synthesis projected on (010). Though the minimum function could not reveal the structure satisfactorily, it provided some clue to the structure. At this stage a Fourier synthesis projected on (010) was calculated using about 50% of the observed $|F_0|$ values and the phases of the heavy atoms i.e. two chlorine atoms.

The Fourier synthesis was computed on IBM 1620 using the program written by us here in our laboratory. A tentative model of the structure was derived from the (010) Fourier projection and the minimum function. The *x* and *z* parameters

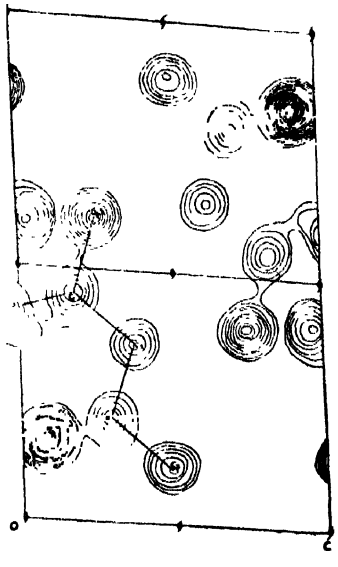


Fig. 1. Sarcosine hydrochloride: Fourier synthesis projected on (010).

of the atoms obtained from the tentative model were used in the calculation of structure factors and the value of the disagreement factor (R) for *hol* reflections only was found to be 36.9%. The atomic parameters were first refined by a difference Fourier synthesis and later by least-squares method. After a few cycles of refinement the R value dropped to 19.8%. A unit weighting scheme was used throughout the refinement. A Fourier synthesis projected on (010) was calculated at this stage of refinement and is shown in fig. 1.

In order to determine the y co-ordinates of the atoms a chlorine-phased Fourier synthesis projected along c axis was calculated. Due to considerable overlapping of electron density peaks, as was observed on this projection and a spurious mirror plane of symmetry normal to b axis, as inherent in such structure, the determination of y co-ordinates of the atoms from $\rho(xy)$ projection became rather difficult. It was, therefore, thought worthwhile to take full advantage of the knowledge of the tentative model derived from the b-axis projection to interpret the Fourier map. Fortunately, this worked all right. The x and y co-ordinates of atoms thus obtained were refined by least-squares method using *hko* data alone. After four cycles of refinement the R value for *hko* reflections was 15.9%. At this stage, three-dimensional refinement of all the atomic parameters was started by least-squares method and after a few cycles of refinement the R value was found to be 18%. The atomic parameters as obtained at this stage of refinement are given in table 1. The intramolecular and intermolecular bond lengths and bond angles are given in tables 2 and 3, respectively, and diagrammatically shown in fig. 2.

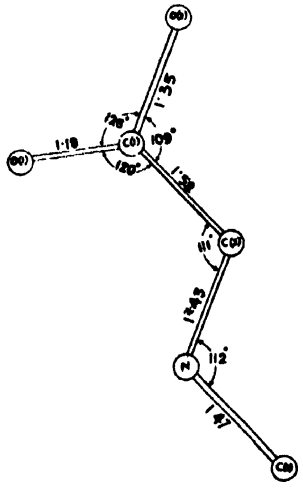


Fig. 2. Sarcosine hydrochloride : Bond lengths and bond angles.

DISCUSSION OF THE STRUCTURE

The two C—O bond lengths C(1)—O(1) = 1.19 Å and C(1)—O(2) = 1.35 Å in the carboxyl group of sarcosine hydrochloride (table 2) indicate that the hydrogen

atom is bound to O(2) and the molecule is not a zwitterion. The C = O double bond length (1.19Å) agrees fairly well with the average value for this bond (1.205Å) deduced by Hahn (1957) from other amino acids. The C—O single bond distance (1.35Å), though shorter than standard C—O bond length (1.41Å) quoted by Pauling (1960), is in good agreement with the average value (1.365Å) cited by Hahn (1957). The C(2)—N^+H_2 bond length (1.43Å) of sarcosine hydrochloride has been found to be much shorter than the average value (1.502Å) of this bond for other amino acids, but it compares well with that in N-acetylglycine (Donohue, *et al* 1962). The bond length C(1)—C(2) = 1.52Å is in good agreement with that for the same bond in other amino acids. The bond distance C(3)—N(1) = 1.47Å between terminal methyl carbon and the amino nitrogen agrees well with the standard C—N bond distance (Pauling, 1960). Of the three angles around the

Table 1

Sarcosine hydrochloride : atomic coordinates and isotropic temperature factors

Atom	*x/a*	*y/b*	*z/c*	B(Å^2)
Cl	.1602	.2548	.0760	1.28
O(1)	.4066	.7888	−.0483	1.59
O(2)	.6009	.7341	.2558	1.55
N(1)	.2087	.7604	.2804	2.19
C(1)	.4612	.7923	.1613	1.00
C(2)	.3617	.7981	.3704	0.52
C(3)	.1142	.7360	.4842	1.67

Table 2

Sarcosine hydrochloride : intermolecular bond lengths and bond angles

Bond length in Å		Bond angle in degrees	
C(1)—O(1)	1.19	O(1)—C(1)—O(2)	126°
C(1)—O(2)	1.35	O(1)—C(1)—C(2)	120°
C(1)—C(2)	1.52	O(2)—C(1)—C(2)	109°
C(2)—N(1)	1.43	C(1)—C(2)—N(1)	111°
N(1)—C(3)	1.47	C(2)—N(1)—C(3)	112°

Table 3

Sarcosine hydrochloride : intermolecular bond lengths and bond angles

Hydrogen bond distance (Å)		Hydrogen bond angles	
O(2)—H—O(1)	2.87	C(1)—O(2)—O(1)	108°54′
N(1)—H—Cl_I	3.15	C(2)—N(1)—Cl_{II}	93°10′
N(1)—H—Cl_{II}	3.21	C(2)—N(1)—Cl_{II}	110°12′
		C(3)—N(1)—Cl_I	95°22′
		C(3)—N(1)—Cl_{II}	106°23′

Cl_I and Cl_{II} are related by a unit translation along *b* axis.

carboxyl carbon C(1), the two on the either side of the C(1) = O(1) double bond, i.e. O(1)—C(1)—O(2) = 126° and O(1)—C(1)—C(2) = 120° are, as expected, greater than the remaining angle 0(2)—C(1)—C(2) = 109°. As in other amino-acids the bond angle C(1)—C(2)—N in sarcosine hydrochloride is almost tetrahedral within the range of experimental error. The bond angle C(2)—N—C(3) which is expected to be 120°, as in N-acetylglycine, has been found to be 112°. It appears that the amino nitrogen in this case has assumed more or less a tetrahedral configuration.

The molecular arrangement of sacrosine hydrochloride projected on (010) is shown in fig. 3. There are altogether three hydrogen atoms in the molecule

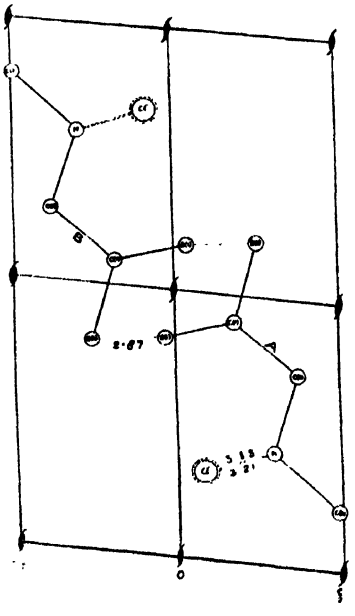


Fig. 3. Sarcosine hydrochloride : Molecular packing viewed along *b* axis.

available for hydrogen bond formation, one from the carboxyl oxygen and two from amino nitrogen of C—N^+H_3- group. The carboxyl oxygen O(2) of one mole-

cule forms a hydrogen bond with the carboxyl oxygen O(1) of the other symmetry related molecule. The O(2)—H---O(1) hydrogen bond distance is 2.87Å (Table 3). The protonated amino nitrogen of the C(2)—N^+H_2- CH_3 group forms two hydrogen bonds with two chlorine ions and assumes a tetrahedral configuration. The two N—H--Cl^- distances are 3.15Å and 3.21Å (table 3).

Three dimensional refinement of the structure on a fast computer is in progress. An elaborate account of the structural details and conformation will be published elsewhere shortly.

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