The Crystal and Molecular Structure of o-Aminoazotoluene

By Setsuo Kurosaki, Setsuo Kashino and Masao Haisa

Department of Chemistry, Faculty of Science, Okayama University, Tsushima, Okayama 700, Japan

The crystal structure of a carcinogen, o-aminoazotoluene (2′,3-dimethyl-4-aminoazobenzene) has been determined from visually estimated Cu $K\alpha$ X-ray data. The crystals are monoclinic, space group $P2_1/a$, with $a = 12 \cdot 75$ (2), $b = 10 \cdot 52$ (2), $c = 10 \cdot 63$ (1) Å, $\beta = 121 \cdot 2$ (2)° and $Z = 4$. The structure was solved by the Patterson method and refined by block-diagonal least-squares calculations to $R = 0 \cdot 068$ for 1514 non-zero reflexions. The molecules related by a twofold screw axis are linked together by a N(azo)$\cdots$H–N hydrogen bond [N$\cdots$N 3·348 (4) Å, N$\cdots$H–N 166 (4)°, N$\cdots$H 2·35 (5) Å] to form a herringbone chain. The chains across a centre of symmetry are held together to form a two-ply folded sheet parallel to the *ab* plane. The sheets are piled up along the *c* axis. 3-Methyl-4-amino and 2′-methyl-substituted phenyl rings take *p* and *o*-quinonoid forms and make respective dihedral angles of 2·6 and 6·7° with the azo linkage. The large N=N length [1·258 (4) Å] and short N(azo)–C lengths [1·402 (4), 1·413 (4) Å] indicate increased conjugation of the phenyl rings through the azo linkage.

Introduction

Yoshida's (1933) finding that oral administration of 2′,3-dimethyl-4-aminoazobenzene, known commonly as o-aminoazotoluene, produces tumours of the liver in rats represents the first unequivocal demonstration of the hepatocarcinogenicity of an amino azo dye. Arcos & Arcos (1962) have proposed that the carcinogenic activity of azotoluenes depends on the conjugating ability of the methyl group *ortho* to the azo linkage. This work is a part of studies for examining the effects of various ring substituents on the conjugation through the azo linkage and to explore the stacking mode of amino azo dyes in the crystals.

Experimental

o-Aminoazotoluene crystallizes from an ethanol solution as red-brown prisms elongated along **b** and bounded by (100), (010), (001) and some pyramidal planes.

Crystal data

o-Aminoazotoluene (2′,3-dimethyl-4-aminoazobenzene), $C_{14}H_{15}N_3$, M.W. 225·3, m.p. 101–102·5°C; monoclinic, $a = 12 \cdot 75$ (2), $b = 10 \cdot 52$ (2), $c = 10 \cdot 63$ (1) Å, $\beta = 121 \cdot 2$ (2)°, $V = 1220$ Å³, $D_x = 1 \cdot 226$ for $Z = 4$, $D_m = 1 \cdot 21$ g cm⁻³ (by flotation in an aqueous KBr solution); systematic absences: *h0l*, *h* odd; *0k0*, *k* odd; space group $P2_1/a$; μ(Cu $K\alpha$) = 6·1 cm⁻¹, $F(000) = 480$.

A crystal with dimensions $0 \cdot 2 \times 0 \cdot 8 \times 0 \cdot 3$ mm was mounted along **b**. The intensities of 1514 independent reflexions (54·5% of those accessible in the Cu sphere) were measured visually on the *h0l* to *h8l* layers of Weissenberg photographs. After the correction for Lorentz–polarization factors and for spot shape, the intensities were placed on an absolute scale by means of a Wilson plot $(B = 5 \cdot 0 \text{ Å}^2)$.

Structure determination and refinement

Trial coordinates for the non-H atoms were obtained from a sharpened three-dimensional Patterson map. A structure factor calculation based on the Fourier map phased with the trial coordinates yielded an R value of 0·45. The structure was refined by a diagonal least-squares method with isotropic thermal parameters to $R = 0 \cdot 18$. Block-diagonal least-squares refinement with anisotropic thermal parameters gave $R = 0 \cdot 126$. At this stage, a difference Fourier map revealed all the H atoms. In the final cycles of refinement were included all the positional parameters, along with anisotropic thermal parameters for the non-H atoms and isotropic parameters for the H atoms. The weighting scheme adopted was: $w = 1 \cdot 0$ for $0 < |F_o| \le 7 \cdot 0$, and $w = (7 \cdot 0/|F_o|)^2$ for $|F_o| > 7 \cdot 0$. The final R value was 0·068 for 1514 non-zero reflexions.*

The atomic scattering factors were taken from *International Tables for X-ray Crystallography* (1962). The computations were carried out on an NEAC 2200-500 computer at the Okayama University Computer Centre and an NEAC 2200-700 computer at the Computation Centre of Osaka University. The programs used were *RSDLS-3* (Sakurai, 1967), *HBLS-5* and *DAPH* (Ashida, 1973).

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* A list of structure factors has been deposited with the British Library Lending Division as Supplementary Publication No. SUP 31925 (8 pp.). Copies may by obtained through The Executive Secretary, International Union of Crystallography, 13 White Friars, Chester CH1 1NZ, England.

Table 1. *Final atomic parameters*

Positional and thermal parameters for the non-hydrogen atoms ($\times 10^4$) with their e.s.d.'s in parentheses. The β_{ij}'s are defined by:

$$\exp(-h^2\beta_{11}-k^2\beta_{22}-l^2\beta_{33}-hk\beta_{12}-hl\beta_{12}-kl\beta_{23}).$$

|	x	y	z	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
N(1)	−254 (2)	−971 (2)	2049 (3)	82 (2)	72 (3)	131 (3)	−15 (4)	107 (4)	−2 (5)
N(2)	714 (2)	−440 (2)	2279 (3)	75 (2)	60 (3)	133 (3)	−8 (4)	97 (4)	8 (4)
N(3)	−2271 (2)	−4882 (3)	−2033 (3)	109 (3)	96 (4)	165 (4)	−38 (5)	139 (6)	−59 (6)
C(1)	−703 (2)	−1946 (3)	997 (3)	80 (2)	63 (3)	115 (3)	−7 (4)	96 (5)	−3 (5)
C(2)	−187 (3)	−2328 (3)	182 (3)	76 (2)	70 (4)	122 (4)	−8 (4)	98 (5)	5 (5)
C(3)	−685 (3)	−3293 (3)	−828 (3)	78 (2)	69 (3)	123 (3)	19 (4)	101 (5)	23 (5)
C(4)	−1739 (3)	−3924 (3)	−1039 (3)	80 (2)	52 (3)	126 (4)	1 (4)	86 (5)	3 (5)
C(5)	−2249 (3)	−3550 (3)	−212 (4)	85 (3)	80 (4)	170 (4)	−23 (5)	139 (6)	−27 (6)
C(6)	−1734 (3)	−2591 (3)	793 (3)	84 (3)	89 (4)	144 (4)	−29 (5)	119 (6)	−24 (6)
C(7)	1184 (2)	508 (3)	3379 (3)	75 (2)	63 (3)	113 (3)	−9 (4)	87 (5)	18 (5)
C(8)	584 (3)	934 (3)	4081 (3)	90 (3)	84 (4)	126 (4)	−20 (5)	111 (5)	−8 (6)
C(9)	1111 (3)	1816 (3)	5174 (3)	102 (3)	86 (4)	135 (4)	−13 (5)	122 (6)	−8 (6)
C(10)	2250 (3)	2315 (3)	5606 (4)	109 (3)	90 (4)	151 (5)	−44 (6)	117 (6)	−43 (7)
C(11)	2835 (3)	1920 (3)	4898 (4)	99 (3)	101 (4)	184 (5)	−63 (6)	129 (7)	−43 (7)
C(12)	2323 (3)	1029 (3)	3771 (4)	85 (3)	72 (4)	161 (4)	−13 (5)	126 (6)	12 (6)
C(13)	−127 (3)	−3705 (3)	−1692 (4)	108 (3)	103 (4)	167 (5)	2 (6)	173 (7)	−18 (7)
C(14)	2977 (3)	639 (4)	2998 (4)	112 (4)	124 (5)	245 (7)	−54 (6)	233 (8)	−59 (9)

(a)

(b)
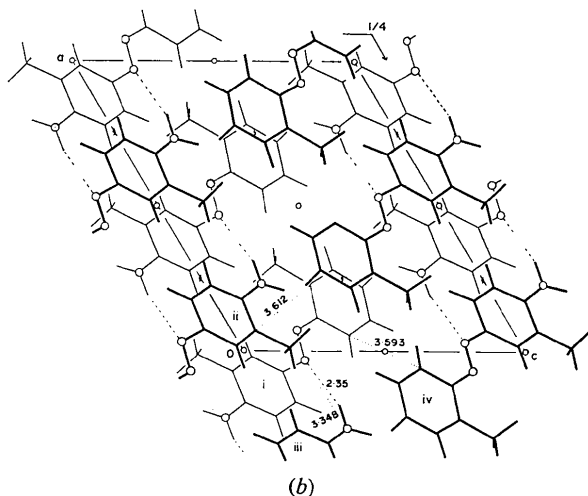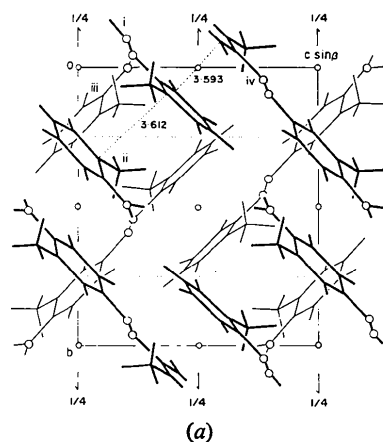
Fig. 1. Projections of the crystal structure, (a) viewed along the a axis, (b) viewed along the b axis. Nitrogen atoms are shown by open circles. Broken lines show hydrogen bonds, and dotted lines intermolecular contacts. Symmetry code: (i) x,y,z; (ii) $-x,-y,-z$; (iii) $-\frac{1}{2}-x,\frac{1}{2}+y,-z$; (iv) $-x,-y,1-z$.

Table 1 (*cont.*)

Positional ($\times 10^3$) and isotropic thermal parameters for the hydrogen atoms

	x	y	z	B (Å²)
H(1)	55 (4)	−190 (3)	36 (4)	3·5 (0·8)
H(2)	6 (4)	−467 (4)	−150 (4)	5·4 (1·0)
H(3)	58 (4)	−323 (4)	−148 (4)	5·0 (1·0)
H(4)	−76 (4)	−367 (4)	−280 (4)	4·3 (0·9)
H(5)	−206 (4)	−501 (4)	−272 (4)	4·7 (1·0)
H(6)	−306 (4)	−529 (4)	−221 (5)	6·3 (1·1)
H(7)	−302 (4)	−404 (4)	−43 (5)	6·3 (1·1)
H(8)	−211 (4)	−228 (4)	148 (4)	6·0 (1·1)
H(9)	−18 (4)	50 (4)	377 (5)	5·4 (1·0)
H(10)	73 (4)	204 (4)	577 (4)	4·7 (1·0)
H(11)	273 (4)	289 (4)	647 (4)	4·9 (1·0)
H(12)	362 (4)	236 (4)	511 (4)	5·1 (1·0)
H(13)	330 (4)	−17 (5)	316 (5)	7·3 (1·2)
H(14)	356 (5)	126 (5)	322 (6)	9·2 (1·4)
H(15)	241 (4)	73 (5)	180 (5)	7·7 (1·3)

Results and discussion

Crystal structure

The final positional and thermal parameters are shown in Table 1. The crystal structure projected down the a and b axes is illustrated, along with the short intermolecular contacts, in Fig. 1. The molecules related by a twofold screw axis are linked together by N$\cdots$H–N hydrogen bonds to form a herringbone chain. The hydrogen bond has dimensions N(1)$\cdots$ N(3$^{\text{iii}}$) 3·348 (4) Å and N(1)$\cdots$H(6$^{\text{iii}}$)–N(3$^{\text{iii}}$) 166 (4)°. The nearest chains across a centre of symmetry are held together by dispersion forces between the phenyl and methyl groups (Fig. 2) to form a two-ply folded sheet parallel to the ab plane. The sheets are piled up along the c axis to fit into each other.

The molecular overlapping of azobenzenes is classified into two types as shown in Fig. 3. (A) involves, remarkably, the component of shift of the molecules perpendicular to the long axes, while (B) involves shift mainly parallel to the long axes. The present compound,

trans-2,2'-dichloroazobenzene (Komeyama, Yama-moto, Nishimura & Hasegawa, 1973) and *trans-p,p'*-dibromoazobenzene (Amit & Hope, 1966) belong to (*A*), while most of the *p*-substituted azo compounds, including 4-phenylazoazobenzene (Gilardi & Karle, 1972), and 6-(*p*-hydroxyphenylazo)uracil (Coulter & Cozzarelli, 1974), belong to (*B*).

Molecular structure

Bond lengths and angles are shown in Fig. 4. The least-squares planes and shifts of the atoms from the planes are summarized in Table 2. The molecule is almost planar, but the 3-methyl-4-amino-substituted Ph(1) and 2'-methyl-substituted Ph(2) rings make dihedral angles of 9·2° with each other. The rings displace to the same side from the plane through C(1), N(1), N(2) and C(7), resulting in a slight bowing of the molecule. The pyramidal nature of the amino group is less than that in *p*-aminoacetophenone (Haisa, Kashino Yuasa & Akigawa, 1976). It is of interest that the bond angles C(2)–C(1)–N(1) and C(8)–C(7)–N(2) are larger than those expected from the sp^2 configuration.

The Ph(1) and Ph(2) rings take *p* and *o*-quinonoid forms respectively. The N(3)–C(4) length is significantly shorter than the ordinary single N–C(sp^2) bond length

and such a shortening is observed in some quinonoid compounds, *e.g.* 4-nitroaniline (Trueblood, Goldish, & Donohue, 1961), 2-amino-3-methylbenzoic acid (Brown & Marsh, 1963) and *p*-aminoacetophenone. The C(methyl)–C(ring) lengths are slightly shorter than the value 1·510 Å for C(sp^3)–C(sp^2) proposed by Brown (1959). The N(1)=N(2) bond is significantly long whereas the C–N bonds in the azo linkage are rather short. The torsion angles C(6)–C(1)–N(1)–N(2), C(1)–N(1)–N(2)–C(7) and N(1)–N(2)–C(7)–C(12) are 176·4, 182·2 and 173·7° respectively. These facts indicate the efflux of π-electrons to the C–N bonds and increased conjugation of the phenyl rings through the azo linkage. This structural feature of the molecule is closely related to the conjugation assumed by Arcos &

Table 2. *The least-squares planes and shifts* (Å) *of the atoms from the planes*

$X = ax + cz \cos \beta$, $Y = by$, $Z = cz \sin \beta$. Atoms with an asterisk were used for the calculation of the planes.

(I) Ph(1) ring

$$-0·2482X + 0·6588Y - 0·7102Z + 1·6424 = 0$$

C(1)*	0·009	C(13)	−0·024	H(4)	0·76
C(2)*	−0·004	N(1)	0·007	H(5)	0·21
C(3)*	−0·002	N(3)	0·013	H(6)	0·07
C(4)*	0·003	H(1)	−0·03	H(7)	0·01
C(5)*	0·002	H(2)	−0·85	H(8)	−0·02
C(6)*	−0·008	H(3)	−0·29		

(II) Ph(2) ring

$$-0·1082X + 0·7297Y - 0·6752Z + 1·6321 = 0$$

C(7)*	−0·015	C(12)*	0·012	H(11)	−0·11
C(8)*	0·007	C(14)	0·050	H(12)	0·11
C(9)*	0·005	N(2)	−0·067	H(13)	−0·70
C(10)*	−0·008	H(9)	−0·05	H(14)	0·32
C(11)*	0·001	H(10)	−0·10	H(15)	0·86

(III) Azo system

$$-0·2090X + 0·6791Y - 0·7036Z + 1·7132 = 0$$

N(1)*	0·012	C(2)	0·004	C(14)	−0·197
N(2)*	0·013	C(6)	−0·092	H(1)	0·20
C(1)*	−0·012	C(8)	0·084	H(8)	−0·13
C(7)*	−0·013	C(12)	−0·149	H(9)	−0·20

(IV) Amino group

$$-0·3187X + 0·7055Y - 0·6330Z + 1·8176 = 0$$

N(3)*	−0·069	H(5)*	0·03	H(6)*	0·02
C(4)*	0·028				

Dihedral angles (°) between the planes

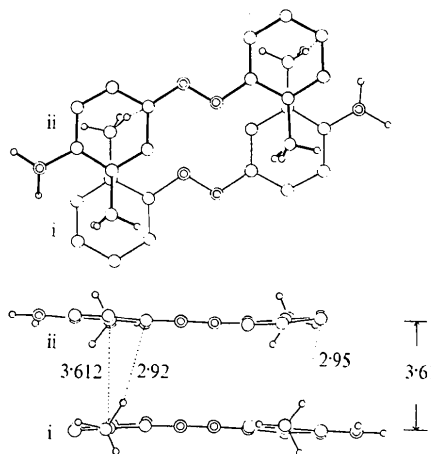| (I) and (II)	(I) and (III)	(II) and (III)
9·2	2·6	6·7

Fig. 2. The molecular overlapping and stacking, together with inter-ring spacings (Å) and intermolecular distances (Å). Hydrogen atoms of the benzene ring are omitted. The symmetry code is given in the legend of Fig. 1.
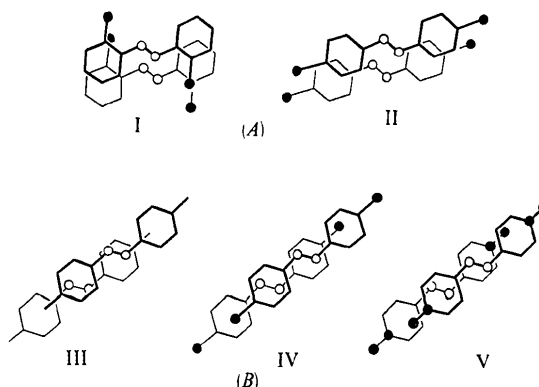

Fig. 3. The molecular overlapping of azobenzenes. Hydrogen atoms are omitted. Nitrogen atoms of the azo linkage are shown by open circles, other non-carbon atoms by closed circles. (I) *trans*-2,2'-Dichloroazobenzene (Komeyama, Yama-moto, Nishimura & Hasegawa, 1973). (II) *trans-p,p'*-Dibromoazobenzene (Amit & Hope, 1966). (III) *p*-Azotoluene (Brown, 1966). (IV) *trans-p,p'*-Dichloroazobenzene (Hope & Victor, 1969). (V) 4,4'-*trans*-Azopyridine N-oxide (Eichhorn, 1959).
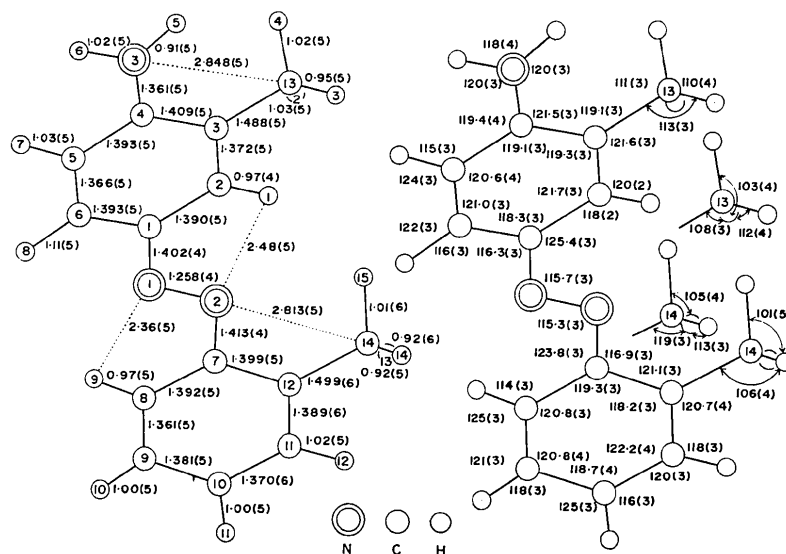
Fig. 4. Bond lengths (Å) and bond angles (°), with their e.s.d.'s in parentheses.

Arcos (1962) in order to explain the carcinogenic activity of the present compound.

References

AMIT, A. G. & HOPE, H. (1966). Acta Chem. Scand. 20, 835–844.

ARCOS, J. C. & ARCOS, M. (1962). Progr. Drug Res. 4, 407–581.

ASHIDA, T. (1973). The Universal Crystallographic Computing System – Osaka. The Computation Center, Osaka Univ.

BROWN, C. J. (1966). Acta Cryst. 21, 153–158.

BROWN, G. M. & MARSH, R. E. (1963). Acta Cryst. 16, 191–202.

BROWN, M. G. (1959). Trans. Faraday Soc. 55, 694–701.

COULTER, C. L. & COZZARELLI, R. (1974). Acta Cryst. B30, 2176–2180.

EICHHORN, E. L. (1959). Acta Cryst. 12, 746–754.

GILARDI, R. D. & KARLE, I. L. (1972). Acta Cryst. B28, 1635–1638.

HAISA, M., KASHINO, S., YUASA, T. & AKIGAWA, K. (1976). Acta Cryst. B32, 1326–1328.

HOPE, H. & VICTOR, D. (1969). Acta Cryst. B25, 1849–1853.

International Tables for X-ray Crystallography (1962). Vol. III, pp. 202–203. Birmingham: Kynoch Press.

KOMEYAMA, M., YAMAMOTO, S., NISHIMURA, N. & HASEGAWA, S. (1973). Bull. Chem. Soc. Japan, 46, 2606–2607.

SAKURAI, T. (1967). The Universal Crystallographic Computing System (I). Tokyo: The Crystallographic Society of Japan.

TRUEBLOOD, N., GOLDISH, E. & DONOHUE, J. (1961). Acta Cryst. 14, 1009–1017.

YOSHIDA, T. (1933). Trans. Jap. Pathol. Soc. 23, 636–638