[CONTRIBUTION FROM THE AMMONIA DEPARTMENT OF E. I. DU PONT DE NEMOURS & COMPANY, INC.]

Optical Crystallographic Studies with the Polarizing Microscope. II. Identification of the Para-bromoanilides of Some Lower Aliphatic Acids[1]

BY W. M. D. BRYANT AND J. MITCHELL, JR.

Para-bromoanilides because of their stability and ease of preparation are excellent derivatives for the identification of organic acids by means of melting point and optical crystallographic properties. Melting points of many fatty acid *p*-bromoanilides are available in the literature[2,3] together with convenient preparative methods, but optical data are limited to those of the acetic and propionic derivatives recently studied in this Laboratory.[1] There was consequently no information available regarding the value of optical crystallographic properties for differentiating between derivatives of structurally isomeric acids. Also, the para-bromoanilides prepared by earlier investigators were confined to the unsubstituted fatty series, so that it was by no means evident that derivatives of substituted acids could be prepared with equal ease.

In the present research para-bromoanilides of nine aliphatic acids were prepared and the optical properties and melting points studied. The group consisted of the two butyric and the four isomeric valeric compounds and in addition the derivatives of methacrylic, methoxyacetic and pyruvic acids, to illustrate the effects of structural isomerism and the substitution of other functional groups for hydrogen. These crystalline derivatives are well suited for optical study. They are easily prepared and quite stable. Interference figures are distinct and usually well centered, thus facilitating the measurement of optical axial angle. This property was particularly useful in the present study because of its sensitivity to changes of composition. The measurement of optic axial angle alone is sometimes sufficient to establish the identity of an unknown acid. Optical character and axial dispersion are valuable properties of this series but are not highly specific of the individual compounds. The refractive indices α, β and γ, however, are useful criteria, and most of the weight of an identification rests upon these constants and optic axial angle. Brief descriptions of crystal habit are included, but as this property is often extremely sensitive to traces of contamination and to minor differences in preparative detail, less reliance is placed upon it and upon the related elongation, as criteria in identification.

Identification of methacrylic and three of the isomeric valeric derivatives is facilitated by the occurrence of metastable phases of considerably different optical properties in crystalline films prepared by fusion. These preparations usually revert to the stable modifications on standing. The metastable methacrylic derivative is stabilized by a trace of impurity. For example, a sample melting 3° lower than the pure substance was definitely dimorphous while under the same conditions the pure material failed to produce a metastable phase. The stable form in the contaminated preparation was scarcely distinguishable by its physical characteristics from the pure material.

It is interesting to note that the Kuehn and McElvain[3] procedure can be used to prepare *p*-bromoanilides of unsaturated acids. It was feared at first that hydrogen chloride, resulting from the action of thionyl chloride on the organic acid, would add at the double bond to form a chloroacyl chloride and give rise to the corresponding *p*-bromoanilide. Analyses of methacrylic *p*-bromoanilide for total halogen, however, have shown that no addition takes place.

Experimental

Materials.—All of the reagents used were from the Eastman Kodak Company with the exception of methacrylic acid, a du Pont product. Some batches of Eastman *p*-bromoaniline contained a purple coloring matter, most of which was removed by one recrystallization from chloroform. It was necessary to subject the *n*-valeric acid used to careful fractionation in order to obtain a sharp melting derivative. All of the remaining chemicals were sufficiently pure as received.

Preparation of the Derivatives.—The *p*-bromoanilides were prepared from the corresponding acids by the method of Robertson[2] as modified by Kuehn and McElvain.[3] Chloroform is a better solvent for the *p*-bromoanilides than benzene and advantageously can replace the latter in preparing derivatives of the lower fatty acids. The methacrylic derivative was analyzed for total halogen by a Parr peroxide bomb method.[4] The analyses showed only

---

[1] A further study of para-bromoanilides. For the first paper of this series, see Bryant, THIS JOURNAL, **60**, 1394 (1938).

[2] Robertson, *J. Chem. Soc.*, **115**, 1210 (1919).

[3] Kuehn and McElvain, THIS JOURNAL, **53**, 1173 (1931).

[4] Bulletin No. 113, Parr Instrument Co., Moline, Illinois, p. 8.

the expected amount of halogen, hence contamination by the chloroisobutyryl derivative must have been negligible.

Melting Points.—Where comparisons can be made, the melting points given in Table I are in satisfactory agreement with the literature. Those of the remaining derivatives apparently have not been reported previously. In most cases there is a distinct spread between the melting points of the individual *p*-bromoanilides. Even where this fails, the distinct depression obtained on mixing two different *p*-bromoanilides of similar melting points is sufficient to remove ambiguity. For example, a mixture of equal parts by weight of the isobutyric (m. p. 155.0°) and trimethylacetic (m. p. 155.7°) derivatives melts at 147.6°, representing a depression of 8°. Similarly, a mixture of the isovaleric (m. p. 126.7°) and methylethylacetic (m. p. 122.3°) compounds melts at 112.0°.

TABLE I

MELTING POINTS OF *p*-BROMOANILIDES OF ALIPHATIC ACIDS

Derivative	M. p., °C.[a] (this research)	M. p., °C. (literature)
n-Butyric	112.0	115.0[2]
Isobutyric	155.0	150–151,[3] 128[5]
n-Valeric	107.1	108.0[2]
Isovaleric	126.7	128–129[3]
d,l-Methylethylacetic	122.3	
Trimethylacetic	155.7	
Methacrylic	116.0	
Methoxyacetic	85.3	
Pyruvic	167.8	

[a] Melting points determined by means of a carefully calibrated Dennis melting point bar;[1] average uncertainty ± 0.3°.

Apparatus and Technique.—A Bausch and Lomb LC petrographic microscope was used in this research. The optical equipment and methods of calibration, however, were identical with those used with the LD microscope in an earlier study.[1] The technique of optical examination was essentially the same as that previously described.[1] Both individual crystals mounted in Canada balsam and thin crystalline films prepared by fusion were examined. The pronounced birefringence and good optical quality of the latter facilitated conoscopic examination using an oil immersion system of high numerical aperture (1.25 N.A.). This technique permits direct measurement of the acute optic axial angles regardless of size, and in some cases even the obtuse angles. As previously, the quantity measured is 2H, the optic axial angle relative to cedar oil, from which 2V, the true angle within the crystal, may be calculated by means of appropriate formulas.[1] 2V was calculated from the refractive indices α, β and γ by a graphical method using tables and diagrams developed by F. E. Wright.[6]

Refractive indices were measured by the immersion method as outlined in the first paper of this series.[1] Since, however, the solubility of the present group of *p*-bromoanilides is appreciable in many of the usual organic immersion liquids, the aqueous liquids described in an earlier paper[7] were employed. This series has since been extended to n_D 1.760 in intervals of 0.005, using aqueous solutions of barium mercuric iodide. Above 1.760, the organic series was found satisfactory. The liquids of low refractive index used were standardized at 25° using an Abbe refractometer, while those above 1.650 were determined by the method of minimum deviation using a 30° capillary prism[8] suspended from the crystal adjusting device of a Hutchinson Universal Goniometer.[9] This procedure requires only a drop of the liquid and its precision compares favorably with that of the Abbe refractometer.

Optical Crystallographic Data

Optical constants of the group of nine *p*-bromoanilides of aliphatic acids are given in Table II. Comparison of measurements upon the unheated derivatives with the results obtained with preparations previously subjected to fusion has supplied conclusive evidence of the existence of metastable modifications in three of the four isomeric valeric derivatives and in a slightly contaminated sample of the methacrylic compound. The interference figures observed in the freshly prepared crystalline films were distinctly different from those of the original material as illustrated by the optic axial angle data appearing in Table II. After a few days at room temperature, the metastable crystals reverted to the corresponding stable varieties. Since the conditions suitable for the formation of isolated crystals of the metastable varieties were not known, dependable refractive index measurements could not be made. These metastable modifications are tentatively regarded as true polymorphs. Dynamic isomerism, although less likely, is not excluded.

The optical properties measured may be divided into two classes, those characteristic of the series rather than the individual compound, and exemplified by optical character[10] and axial dispersion, and those of a more specific nature including optic axial angle, the principal refractive indices and the more complex forms of dispersion. Acute bisectrix interference figures are more common than the obtuse in all but the methoxyacetic derivative. The strong inclined dispersion of

---

(5) Norton, *Am. Chem. J.*, **7**, 116 (1885).

(6) F. E. Wright, *Am. J. Sci.*, **36**, 509 (1913).

(7) Bryant, THIS JOURNAL, **54**, 3758 (1932).

(8) F. E. Wright, *J. Wash. Acad. Sci.*, **4**, 269 (1914), method 1.

(9) Manufactured by James Swift & Son, Ltd., 81 Tottenham Court Road, London, England.

(10) The optical characters of all of the substances in Table II are positive by the usual test involving the effect of a quartz wedge upon interference figures and also by the approximate test, $\gamma - \beta > \beta - \alpha$. By the exact modification of the latter test described by Wright (*vide supra*, Ref. 6, pp. 529–532) and based on the relation, $1/\beta^2 - 1/\gamma^2 > 1/\alpha^2 - 1/\beta^2$, the *n*-butyric, *n*-valeric and isovaleric derivatives appear negative. However, changes in the refractive indices within the experimental tolerances are sufficient to restore the positive sign in two of the three cases. The optical characters of these three compounds remain in some doubt.

TABLE II

OPTICAL CRYSTALLOGRAPHIC PROPERTIES OF *p*-BROMOANILIDES

Derivative Polymorph	*n*-Butyric	Isobutyric	*n*-Valeric Stable	*n*-Valeric Metastable	Isovaleric Stable	Isovaleric Metastable	*d,l*-Methylethylacetic Stable	*d,l*-Methylethylacetic Metastable
Elongation Bx$_a$ sections	Inclined 20–40° to α or β	$\|\|\beta$	Inclined 50–75° to α	$\|\|\beta$	Inclined 25–40° to β	Inclined 12° to β	$\perp\beta$	$\|\|\beta$
Bx$_0$ sections	$\|\|\beta$	$\|\|\beta$	$\|\|\beta$		$\perp\gamma$		$\perp\beta$	
Refractive indices[a] at 25 ± 3° for λ = 5461 Å.	α 1.478	1.520	1.482		1.488		1.578	
	β 1.615	1.588	1.617		1.615		1.602	
	γ 1.783	1.750 ± 0.005	1.773		1.777		1.66 ± 0.01	
Birefringence λ = 5461 Å.	0.305	0.23	0.291	Strong	0.289	Strong	0.08	Strong
Optical character	Positive?	Positive	Positive?	Positive	Positive?	Positive	Positive	Positive
Optic axial angle[b] λ = 5461 Å.	2H$_a$ 95°	77°	92 ± 3°	66.5°	95.5°	71°	64.5°	82°
	2H$_0$	112 ± 2°			103 ± 2°			
	2V $88^{\circ c,d}$	$73^{\circ c,e}$, $71^{\circ d}$	$85^{\circ c}$, $86^{\circ d}$		$88^{\circ c}$, $89^{\circ d}$, $87^{\circ e}$		$61^{\circ c}$, 64–$72^{\circ d}$	
Dispersion	r > v, slight	r > v, slight	r > v, slight	Weak indeterminate	r > v, slight	r > v	v > r, strong inclined	r > v, strong inclined
Crystal habit	Long, narrow rectangular crystals from C_2H_5OH	Large rectangular crystals from C_2H_5OH	Fine needles from C_2H_5OH and C_6H_6; rectangular plates from acetone		Small, rectangular plates and prisms from C_2H_5OH; larger plates from acetone		Small rectangular plates from C_2H_5OH, C_6H_6 and acetone	

Derivative Polymorph		Trimethylacetic	Methacrylic Stable	Methacrylic Metastable	Methoxyacetic	Pyruvic
Elongation						
Bx$_a$ sections		$\perp\alpha$	$\perp\alpha$	$\|\|\beta$	$\|\|\beta$	$\perp\alpha$
Bx$_0$ sections		$\|\|\beta$	$\|\|\beta$		$\|\|\beta$	$\perp\beta$
Refractive indices at 25 ± 3° for λ = 5461 Å.		α 1.570	1.526		1.503	1.535
		β 1.590	1.656		1.620	1.608
		γ 1.708	>1.85		1.83 ± 0.01	>1.85
Birefringence λ = 5461 Å.		0.138	>0.30	Strong	0.33	>0.31
Optical character		Positive	Positive	Positive	Positive	Positive
Optic axial angle λ = 5461 Å.	2H$_a$	53°	91°	82.5°	92°	67.5°
	2H$_0$				102 ± 2°	
	2V	$50^{\circ c}$, $48^{\circ d}$	$81^{\circ c}$		$85^{\circ c,e}$, $83^{\circ d}$	$63^{\circ c}$
Dispersion		r > v	r > v	r > v	r > v	r > v
Crystal habit		Long rectangular plates from C_2H_5OH; needles from acetone	Needles from C_6H_6 and acetone; rectangular plates from C_2H_5OH		Long needle-like crystals from C_2H_5OH and acetone	Rectangular plates from C_2H_5OH; needles from acetone

[a] Precision ±0.003, except where noted. [b] Precision ±1° for 2H, except where noted. [c] Calculated from 2H$_a$ and β. [d] Calculated from α, β, γ. [e] Calculated from tangent formula using 2H$_a$ and 2H$_0$.

both the stable and metastable methylethylacetic modifications is highly specific of this compound.

Acknowledgment.—The authors thank Mr. A. N. Oemler of this Laboratory for his aid in the preparation of the derivatives and for analyses of the methacrylic derivative for halogens.

Summary

1. Optical crystallographic data and melting points of the *p*-bromoanilides of nine lower aliphatic acids have been determined.

2. Metastable crystalline modifications of the *n*-valeric, isovaleric, *d,l*-methylethylacetic, and methacrylic derivatives have been obtained from the molten material.

3. The unsaturated methacrylic derivative was successfully prepared by the regular procedure, without formation of the chloroisobutyric derivative.

WILMINGTON, DELAWARE RECEIVED AUGUST 17, 1938

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF WISCONSIN]

The Method of Garelli and Racciu for the Preparation of Piperazine: A Criticism

BY DEAN B. ROLLINS AND H. N. CALDERWOOD[1]

With regard to a paper[2] describing a simple and inexpensive dehydration method for obtaining piperazine disulfate by heating monoethanolamine with sulfuric acid, we wish to call attention to the fact that the authors do not prove that the reaction product obtained by them is piperazine disulfate. The solubilities reported and the percentages of nitrogen and sulfate, their only analytical data for the product they designate as piperazine disulfate, hold also for β-aminoethylsulfuric acid. Their only other description, the rhombohedral crystals from dilute ethanol, is characteristic of β-aminoethylsulfuric acid,[3,4] the crystals of piperazine disulfate from dilute ethanol being monoclinic.

The interaction of monoethanolamine and fuming sulfuric acid to form β-aminoethylsulfuric acid was reported in 1918.[4] Believing that Garelli and Racciu might have developed conditions leading to the formation of piperazine disulfate, we attempted to prepare the compound according to the method sketched by them, but in twenty-three experiments, under various time and temperature conditions and with different amounts and concentrations of sulfuric acid, we were unable to obtain even a trace of piperazine, the resulting product in every case being β-aminoethylsulfuric acid.

Our reagents were monoethanolamine, 99.54% purity, from the Carbide and Carbon Chemicals Corporation, and C. P. grade sulfuric acid in concentrations from 88.3 to 20% fuming. Samples of both our crude and recrystallized products analyzed for nitrogen by the semi-micro Dumas method and for sulfur by both wet and dry oxidation gave the results recorded in Table I. These values being valid for both β-aminoethylsulfuric acid and piperazine disulfate, other properties of our purified product were compared with the corresponding properties of an authentic sample of piperazine disulfate.

TABLE I

ANALYSES OF CRUDE AND PURIFIED PRODUCTS

Material	Crude I	Crude II	Purified I	Purified II	Calcd. $C_2H_7NO_4S$
Sample, g.	0.07025	0.07753	0.07117	0.07054	
Nitrogen, %	9.96	9.94	10.13	10.05	9.93
Sample, g.	0.2710	0.2652	0.2745	0.2714	
Sulfur, % Wet			22.40	22.48	22.68
Sulfur, % Dry	22.34	22.37			

Our product purified by recrystallization from dilute ethanol formed rhombohedral crystals sintering at 230°, as recorded in the literature for β-aminoethylsulfuric acid,[3,4] whereas piperazine disulfate from dilute ethanol gave white monoclinic crystals which began to darken at 325° and charred at 330°. Our purified product gave no precipitate with barium chloride, even after standing at room temperature for ten hours, nor with benzenesulfonyl chloride, whereas piperazine disulfate gave immediately after the addition of barium chloride a copious precipitate of barium sulfate, and with benzenesulfonyl chloride gave a copious white crystalline precipitate melting at 281°.[5] The molecular weight of our purified

---

[1] Present address: 3105 Cross Street, Madison, Wisconsin.

[2] Garelli and Racciu, *Atti. accad. sci. Torino*, **69**, 162-165 (1934).

[3] Gabriel, *Ber.*, **21**, 1056 and 2667 (1888).

[4] Frankel and Cornelius, *ibid.*, **51**, 1660 (1918).

[5] Hans T. Clarke, "A Handbook of Organic Analysis," Edward Arnold and Company, London, 4th ed., 1926, p. 207.