280 (8427); 287 (7155). Ultraviolet in water: 280 (8745); 287 (7473).

1-Methyl-2-phenylindole (IX). Ultraviolet in cyclohexane: 297 (22,910). Ultraviolet in dioxane: 297 (22,550). Ultraviolet in ethanol: 297 (21,840).

Carbazole (X). Ultraviolet in cyclohexane: 231 (35,160); 243 (19,780); 253 (12,750); 258 (4400); 280 (8800); 285 (10,560); 289 (15,380); 306 (2510); 317 (3160); 330 (2940). Ultraviolet in hexane[6]: 242 (24,000); 255 (12,000); 273 (4300); 279.5 (12,650); 285.3 (14,000); 291 (19,000); 316.8 (3000). The positions of the 289, 317, and 330 mμ bands in the cyclohexane ultraviolet spectrum agree well with the three fluorescence excitation peaks of carbazole in cyclohexane.

3-Acetylindole. Ultraviolet in cyclohexane: 233 (7250); 249 (weak shoulder); 280 (5800). Ultraviolet in dioxane: 237 (9400); 252 (6380); 288 (11,020). Ultraviolet in ethanol: 240 (12,850); 257 (9300); 293 (12,620). Ultraviolet in water: 241 (7970); 257 (8250); 296 (11,740).

1,2-Dimethylindole (IV). The procedure used by Kissman *et al.*[29] for the synthesis of several alkylindoles (but not including 1,2-dimethylindole) was used to prepare this compound from acetone and 1-methyl-1-phenylhydrazine in the presence of polyphosphoric acid. The product was purified by chromatography on activated alumina with petroleum ether (b.p. 30–60°) as eluent followed by vacuum sublimation at 25°/0.05 mm. to give colorless crystals, m.p. 55° (reported[30] m.p. 56°).

Anal. Calcd. for $C_{10}H_{11}N$: C, 82.83; H, 7.65. Found: C, 83.07; H, 7.90.

Ultraviolet in cyclohexane: 272 (10,810); 280 (11,340); 290 (9210). Ultraviolet in dioxane: 272 (shoulder); 280 (11,100); 290 (9100). Ultraviolet in ethanol: 272 (shoulder); 280 (11,100); 290 (8680). Ultraviolet in water: 272 (shoulder); 280 (10,540); 290 (shoulder).

2,3-Dimethylindole (V). The procedure of Kissman *et al.*[29] was used to prepare this compound. The product was purified by crystallization from cyclohexane followed by vacuum sublimation, m.p. 100–102° (reported[29] m.p. 100–102°). Ultraviolet in cyclohexane: 271 (6412); 282 (6254); 290 (4335). Ultraviolet in ethanol[8]: 283 (6860); 290 (5980).

2-(3-Indolyl)-2,3-dihydroindole (VIII). The previously described method[31,32] was used to prepare this compound. The base was purified by crystallization from cyclohexane, m.p. 107–108° (reported[31] m.p. 108°).

Anal. Calcd. for $C_{16}H_{14}N_2$: C, 82.12; H, 6.03; N, 11.97. Found: C, 82.37, H, 6.29; N, 11.76.

Ultraviolet in cyclohexane: 245 (13,170); 282 (9350); 286 (9350); 305 (shoulder). Ultraviolet in dioxane: 245 (13,170); 282 (9350); 286 (9350). Ultraviolet in ethanol: 245 (11,470); 282 (9350); 286 (9350). Ultraviolet in water: 282 (10,620); 286 (9770).

Solvents. Spectroscopically pure cyclohexane, chloroform, dioxane (Matheson, Coleman, and Bell), benzene and ethanol (prepared in this laboratory) were used in this work. All solvents were regularly checked for purity by fluorescence and ultraviolet absorption.

Instrumentation. The Farrand automatic recording spectrofluorometer, used in this work, is equipped with a Hanovia, 150-watt, xenon arc source and a R.C.A. 1P28 photomultiplier tube. The sample can be irradiated at any desired wave length between 220 and 650 mμ through a grating monochromator. The measuring monochromator can be used at any chosen wave length in the same range. Except where stated otherwise, 5-mμ slits were used. A quartz fluorescence macrocell (10 × 20 × 50 mm.), requiring approximately 7 ml. of solution, was used for all measurements. All the spectra were obtained at room temperature and oxygen was not excluded. The instrument was calibrated daily for wave length and fluorescence intensity with quinine sulfate in 0.1*N* sulfuric acid. Ultraviolet absorption spectra were obtained with a Beckman DU spectrophotometer equipped with a Process and Instruments Co. automatic recording unit.

Acknowledgment. This work was aided by a grant from the American Cancer Society, Inc., New York. The spectrofluorometer used in the work was purchased through a field investigation grant, No. CS-9577 from the Public Health Service, National Institutes of Health of the U. S. Department of Health, Education and Welfare, National Cancer Institute.

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[CONTRIBUTION FROM THE PHYSICS LABORATORY, MATERIALS CENTRAL OF WRIGHT AIR DEVELOPMENT DIVISION]

Effect of *cis-trans* Isomerism on the Urea Inclusion Compound Forming Ability of a Molecule; Study of the Maleate-Fumarate System

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Received October 24, 1960

Several maleates and fumarates were investigated to determine their ability to form urea inclusion compounds. Olefinic esters of both acids will form inclusion compounds. However, the shortest chain required to stabilize a particular ester was related to the over-all cross-sectional diameter of the ester. The fumarates, having the more slender conformation, form complexes more readily than the maleates.

Urea inclusion compounds are combinations of two or more compounds, one (guest) of which is contained within the crystalline framework of the other (host). The guest and host are capable of existing separately, and do not unite chemically. They are held together by secondary valence forces and by hydrogen bonding. Unlike ordinary hydrogen-bonded complexes, the size and shape of the guest molecules are critically important in the formation of inclusion compounds.

Urea inclusion compounds of a variety of organic molecules have been prepared and studied. Both olefins and esters have been among them. This research was done to show more precisely the effect of *cis* and *trans* isomerism on the ability of olefins to form urea inclusion compounds as a function of the cross-sectional diameter of the guest. The maleates and fumarates were chosen to demonstrate this effect because the size of the chain could be easily controlled by selection of an appropriate alcohol to esterify the maleic or fumaric acid. The maleates and fumarates are monomers in a variety of copolymerization reactions. The properties of resulting polymers vary depending upon whether a maleate or a fumarate is used. It is, therefore, of interest to distinguish and separate these isomers. The technique of inclusion compound formation accomplishes both.

Saturated organic molecules form inclusion compounds more readily than the unsaturated molecules. Urea inclusion compound forming ability is inversely proportional to the degree of unsaturation[1] because of the deviation from the normal saturated straight chain structure, which appears to have the optimum cross-sectional diameter for inclusion compound formation. The van der Waals forces between the host and guest are weaker for an olefin than for the corresponding saturated compound. These differences have been the basis of a urea complex procedure to separate oleic, linoleic, and linolenic acids which differ in the degree of unsaturation.[1] Complexing also bestows oxidative stability on an olefin because there is not sufficient space to permit oxygen to enter the channel of the complex when the channel is occupied by a guest. In addition, the reaction propagating such an oxidation could not occur between the separated guest molecules in the crystalline honeycomb network of urea.

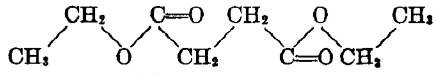
DISCUSSION

A number of *cis* and *trans* isomers of simple monoolefinic esters were examined for complex formation. In all cases the *cis* isomer was a maleate and the *trans* isomer was a fumarate. The fumarate could assume an uninterrupted planar zigzag conformation and consequently had a smaller maximum cross-sectional diameter than the maleate which could not assume the uninterrupted planar zigzag conformation. The various compounds, their cross-sectional diameters and their urea complexing abilities are listed in Table I. The fumarates consistently had a cross-sectional diameter closer to an *n*-hydrocarbon than the maleates. The fumarates arranged in an essentially uninterrupted planar zigzag fashion had a maximum cross-sectional diameter of 5.1Å and the maleates 5.3Å.

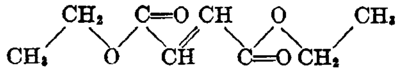
TABLE I

Compound	Cross-Section, Å	Urea Inclusion Compound
Dimethyl fumarate	4.60	−
Diethyl fumarate	5.07	+
n-Dipropyl fumarate	5.06	+
n-Dibutyl fumarate	5.13	+
n-Dioctyl fumarate	5.13	+
n-Didecyl fumarate	5.13	+
Diethyl maleate	5.31	−
n-Dipropyl maleate	5.31	−
n-Dibutyl maleate	5.31	+
n-Dioctyl maleate	5.31	+
n-Didecyl maleate	5.31	+
Diethyl succinate	4.95	+[2]
n-Hydrocarbon (*n*-octane the shortest)	4.62	+

For comparison diethyl succinate and the *n*-hydrocarbons are included in Table I. *n*-Octane is the shortest hydrocarbon that formed a complex that could be isolated under the experimental conditions described. Since both esters measured less than 6Å, each was expected to form an inclusion compound. However, because the maleate deviated more from the optimum cross section of an unbranched planar zigzag hydrocarbon (4.6Å) than the fumarate, it was expected that a maleate complex would form less readily than the corresponding fumarate complex. This was verified experimentally when it was found that diethyl fumarate was the shortest *n*-dialkyl fumarate to form a urea inclusion compound and dibutyl maleate was the shortest *n*-dialkyl maleate to form an inclusion compound. By way of contrast, diethyl succinate is the shortest *n*-dialkyl succinate to form an inclusion compound. The stability of inclusion compounds of the fumarates and succinates are quite similar. Both molecules are capable of assuming a very similar planar zigzag conformation:



Diethyl Succinate



Diethyl Fumarate

In each case the higher homologs formed more stable inclusion compounds than the lower homologs. In Table I the cross section shown is 4.95Å for diethyl succinate and 5.10Å for diethyl fumarate. The former would be expected to be slightly more stable than the latter.

The existence of an ester-urea complex was confirmed by the X-ray powder diffraction pattern

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TABLE II

POWDER PATTERNS OF UREA COMPLEXES OF *n*-ALKYL MALEATES AND FUMARATES

n-Alkyl Esters	2.54–2.56[a]	3.24–3.28	3.34–3.41	3.52–3.54	3.56–3.64	3.68–3.70	3.80–3.85	3.98–4.04	4.07–4.15	4.33–4.46	6.96–7.19
Dipropyl maleate	0.14[c]	—	—	0.07	—	—	—	1.00	—	—	—
Dibutyl maleate+[b]	—	—	0.29	—	0.60	—	0.07	—	1.00	—	0.25
Dioctyl maleate+	0.05	0.10	0.26	—	1.00	—	0.11	—	0.98	—	0.33
Didecyl maleate+	0.31	1.00	0.31	—	0.38	—	0.21	—	0.91	0.47	0.16
Dimethyl fumarate	0.75	0.56	—	—	0.17	0.40	—	1.00	—	—	—
Diethyl fumarate+	0.06	0.12	0.48	0.39	—	—	0.08	—	1.00	0.06	0.11
Dipropyl fumarate+	—	0.07	0.16	1.00	—	0.13	0.08	—	0.96	—	0.46
Dibutyl fumarate+	—	0.08	0.39	—	—	—	0.09	—	1.00	—	0.18
Dioctyl fumarate+	—	—	0.31	0.77	—	—	0.10	—	1.00	—	0.23
Didecyl fumarate+	0.07	0.26	0.49	0.56	—	—	0.07	—	1.00	0.09	0.29
(Urea)	(0.42)	—	—	—	(0.20)	—	—	(1.00)	—	—	—

[a] Interplanar spacings in angstrom using CuK$_\alpha$ radiation. [b] Complex formers. [c] Relative intensities, 1.0 the strongest.

of the crystalline adduct. The X-ray data for the fumarates and maleates are listed in Table II. The three interplanar spacings unambiguously indicative of urea occurred at 2.82–2.84Å, 3.07–3.10 and 3.98–4.04. Only the latter is listed in Table II. The unambiguous interplanar spacings characteristic of the inclusion compounds of both fumarates and maleates occurred at 3.34–3.41Å, 3.80–3.85, 4.07–4.15, and 6.96–7.19. An interplanar spacing at 3.56–3.64Å was present for all the maleate inclusion compounds and absent from the fumarate inclusion compounds. Uncomplexed urea also had an interplanar spacing in this region. A fumarate inclusion compound may thus be distinguished from a maleate inclusion compound when no free urea is present. Owing to the high stability of these complexes at room temperature, X-ray intensity data are unsuitable for estimating the relative ease of dissociation by the method described in previous publications.[3,4] This difference may in part be due to the fact that all fumarate and maleate homologs differ from one another by at least two carbon atoms. (All esters are symmetric.) Because the stability of the inclusion compound is proportional to the consecutive number of $-CH_2-$ groups of the guest molecule, the two-carbon atom increase in the fumarates or maleates causes an appreciable increase in the stability of the inclusion compound. Since the method of estimating stability depends upon the relative amount of inclusion compound and dissociated urea, the shortest fumarate and maleate inclusion compounds which first form are sufficiently stable and show no evidence of dissociated urea. In those cases where the above X-ray method failed to give evidence of dissociated urea, the complexes could be equilibrated at temperatures above the 4° used in this work. Since the ionization constant is proportional to the temperature, an equilibration temperature could be chosen which would permit sufficient dissociation of the more stable complexes. A Russian technique using differential thermal analysis[5] is recommended as an alternative method of determining accurately the relative stability of urea complexes.

In the several homologous series studied earlier,[3,4,6] including eight families of homologous monoesters, the members of each family differed by a single carbon atom only. The change in stability of the members of a homologous series differing by a single carbon atom was more gradual than the change in stability of the inclusion compounds of the homologous series in which the members had a two carbon atom difference. Hence the shorter homologs of all the former classes of monoesters which formed an inclusion compound showed interplanar spacings characteristic of dissociated urea.

It has been reported[7] that the structural isomers, di-*n*-amyl maleate and di-*n*-amyl fumarate, are easily distinguished by the relative ease and abundance of complex formed as well as by the relative solubility of these complexes. The fumarate formed more easily and in greater abundance than the maleate, and the inclusion compound of the maleate was considerably more soluble in methanol than that of the fumarate. We confirmed these results by using the di-*n*-butyl analogs. We found that the fumarate not only formed a complex in much greater abundance over the corresponding maleate but the fumarate was also *ca.* 30% less soluble than the maleate.

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TABLE III

PHYSICAL PROPERTIES OF PREPARED ESTERS

	B.P./Mm. Index of Refraction		n_D^t		Specific Gravity, d_4^t		Sapon. Equiv.	
Ester	Obs.	Lit.	Obs.	Lit.	Obs.	Lit.	Obs.	Calcd.
Dipropyl maleate[9]	117–119/5.7	102–103/3.0	1.439625	1.440427	1.0189_{25}	$1.0305_{18.4}$	100.5	100.1
Dipropyl fumarate[10]	104–106/1.2	None	1.441025	1.438027	1.0059_{25}	$1.0213_{20.8}$	100.6	100.1
Diethyl fumarate	90–91/3.7	98–99/14.0[11]	1.437925	1.438027[10]	1.0450_{25}	1.0496_{25}[12]	86.1	86.1
Dimethyl fumarate	192–193/760 (m.p. 105°)	192/760[13] (m.p. 102°)	—	—	—	—	—	—

EXPERIMENTAL

Dialkyl fumarates and dialkyl maleates. Fumaric or maleic acid (0.3 mole) and a primary normal alcohol (0.6 mole) with 5 ml. of concd. sulfuric acid was refluxed in a flask fitted with a Dean and Stark distilling receiver and a condenser until 10.8 ml. (0.6 mole) of water was collected in the trap. The contents of the flask were washed first with 10% aqueous sodium hydroxide and then with distilled water. The crude ester was washed, dried, isolated by a previously described method[8] and then distilled. The following esters were prepared in this manner: di-*n*-propyl fumarate, diethyl fumarate, dimethyl fumarate, di-*n*-propyl maleate, and diethyl maleate. All remaining esters were obtained from the Rubber Corporation of America. The properties of the prepared esters are listed in Table III.

Urea inclusion compounds. To 4.5 ml. of urea-methanol solution (0.15 g. urea/ml. of methanol) in a screw cap test tube was added 30 drops of ester. The tube was capped and shaken vigorously for 30 seconds and then allowed to stand for 24 hr. at 4°. The crystals that formed were filtered by suction, washed with 10 ml. of absolute ethanol, cooled to 4°, and vacuum dried at 1 mm. for 24 hr. over anhydrous calcium chloride at 4°.

X-Ray powder diffraction diagrams. The dried urea inclusion compounds were finely ground with a mortar and pestle and applied to the surface of a roughened glass slide. The interplanar spacings and relative intensities were obtained using the North American Philips X-Ray Diffraction Apparatus which was operated at 35,000 volts and 15 milliamperes with a scanning rate of 1° per min. using a CuK α radiation source.

Cross-sectional diameter of maleates and fumarates. Stuart-Briegleb scalar molecular models were arranged in an essentially planar zigzag conformation for the fumarates; the maximum cross section of the molecule was measured between machinists parallel bars. For the maleates a series of conformers were similarly arranged and measured. The conformer with the smallest maximum cross-sectional diameter was chosen.

WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, RENSSELAER POLYTECHNIC INSTITUTE]

Synthesis of Some Substituted Alkyl Derivatives of Phthalic and Isophthalic Acids

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Received June 23, 1960

The utility of the Meerwein reaction in the synthesis of substituted alkyl derivatives of the phthalic acids is illustrated by the synthesis of 3,4-dicarboxycinnamic acid from dimethyl 4-aminophthalate and acrylonitrile. In a reaction similar to the Meerwein reaction, 5-acetylisophthalic acid has been prepared from dimethyl 5-aminoisophthalate and acetaldoxime. New syntheses of dimethyl 4-aminophthalate, dimethyl 5-nitroisophthalate, and dimethyl 5-aminoisophthalate are also reported. 3,4-Dicarboxycinnamic acid has been reduced to 3,4-dicarboxyhydrocinnamic acid and 5-acetylisophthalic acid has been reduced to 1-(3,5-dicarboxyphenyl)ethanol.

The Meerwein reaction was discovered in 1939 by Hans Meerwein[2] and since that time has received considerable attention both from a synthetic viewpoint[3] and from a mechanistic viewpoint.[4] Our interest in the reaction has been a synthetic one, more especially for the synthesis of some substituted alkyl derivatives of the various phthalic acids. There are relatively few examples of substituted alkyl derivatives of phthalic acid in the literature and most of these were obtained by rather involved syntheses. Indeed, there are no general methods available for introducing a substituted alkyl chain into a phthalic acid molecule. It occurred to us that the Meerwein reaction is ideally suited for this purpose. Furthermore, if the starting amines were not contaminated with position isomers, the resulting Meerwein product would also be isomerically pure. The present study is concerned with Meerwein and Meerwein-like

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(1) Abstract in part from the Ph.D. Thesis of R. A. Clendinning, June 1959. Present address: Research Dept., Union Carbide Plastics Company, Bound Brook, N. J.

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