

TABLE I

Ketone	Hydrazine	Indole	Reaction temp., °C.	Yield, <sup>a</sup> %	M.p., <sup>b</sup> °C., cor.	Previous m.p., °C.
Acetophenone	$\alpha$ -Methyl- $\alpha$ -phenyl-	1-Methyl-2-phenyl-	100°	73 <sup>d</sup>	100-101	100-101 <sup>e</sup>
Acetophenone	Phenyl-	2-Phenyl-	180	76 <sup>f</sup>	187-188	188-189 <sup>g</sup>
<i>p</i> -Phenylacetophenone	Phenyl-	2,4'-Diphenyl-	185	63 <sup>h</sup>	293-295 <sup>i</sup>	297-298 <sup>j</sup>
Propiophenone	Phenyl-	3-Methyl-2-phenyl-	170	58 <sup>k</sup>	90-92	91-92 <sup>l</sup>
Acetone	Phenyl-	2-Methyl-	203	60 <sup>k</sup>	56-59	60 <sup>m</sup>
Methyl ethyl ketone	Phenyl-	2,3-Dimethyl- <sup>n</sup>	230°	68 <sup>p</sup>	100-102	106 <sup>q</sup>
Isobutyrophenone	Phenyl-	3,3-Dimethyl-2-phenyl indolenine <sup>r</sup>	155°	45	.....	.....

<sup>a</sup> Based on amount of ketone used. <sup>b</sup> All melting points are corrected (Kofler hot-stage). <sup>c</sup> Bath temperature. <sup>d</sup> Sublimed *in vacuo* and recrystallized from cyclohexane. <sup>e</sup> J. Degen, *Ann.*, **236**, 155 (1886). <sup>f</sup> Sublimed *in vacuo*. <sup>g</sup> See ref. (4). <sup>h</sup> Sublimed *in vacuo* and recrystallized from large amounts of ethyl acetate. <sup>i</sup> Microscopic slide, in sealed tube, m.p. 322-326°. <sup>j</sup> N. Bui-Hoi, N. Hoan, and R. Royer, *Bull. soc. chim. France*, [5] **17**, 489 (1950). <sup>k</sup> Sublimed twice *in vacuo*. <sup>l</sup> A. Collet, *Bull. soc. chim. France*, [3] **17**, 74 (1897). <sup>m</sup> E. Fischer, *Ann.*, **236**, 127 (1886). <sup>n</sup> Best yields were obtained when phenylhydrazine and ketone were heated together on the steam-bath for a few minutes before the polyphosphoric acid was added. <sup>o</sup> The reaction is vigorous in spite of cooling but the mixture did not remain at this temperature for more than a few minutes. <sup>p</sup> Sublimed twice *in vacuo* and recrystallized from cyclohexane. <sup>q</sup> E. Fischer, *Ann.*, **236**, 129 (1886), obtained this melting point only after converting the indole to its N-nitroso derivative and reducing the latter after several recrystallizations. <sup>r</sup> See experimental.

use of temperatures much lower than those indicated (110-120°) led to the isolation of small quantities of basic by-products in the case of 2-phenylindole and 3-methyl-2-phenylindole; these substances have thus far not been identified.

The two benzyl ketones, desoxybenzoin and dibenzyl ketone, when allowed to react with polyphosphoric acid and phenylhydrazine, yielded intractable, highly colored, polymeric substances. These results could not be changed by using the separately prepared ketone phenylhydrazones or by varying the temperature conditions. Similar negative results were observed with phenylacetaldehyde and butyraldehyde, both as free aldehydes with phenylhydrazine or as phenylhydrazones. Therefore, it seems probable that polyphosphoric acid will be useless for the preparation of 2-unsubstituted indoles.

#### Experimental

**General Method.**—To a mixture of 0.05 mole of the ketone and 5 ml. of phenylhydrazine was added approximately 20 g. of polyphosphoric acid. The mixture was stirred with a thermometer and warmed gently on a steam- or oil-bath until a sudden rise of temperature indicated beginning of the reaction. By cooling the mixture externally with water at this point, the temperatures were maintained at the level shown in Table I. After the end of the reaction, 100 ml. of cold water was added to the cooled mixture which was then extracted thoroughly with ether. The combined, dried, ether extracts yielded the corresponding indoles which were purified by the methods indicated in Table I. Caution must be used in large scale runs because of the large amount of heat given off by the reaction mixture.

**3,3-Dimethyl-2-phenylindolenine.**—A homogeneous mixture of 14.2 g. of isobutyrophenone, 10.8 g. of phenylhydrazine and 30 g. of polyphosphoric acid was heated with vigorous stirring for a few minutes in an oil-bath at 155°. The color of the mixture changed from light yellow to dark brown. After cooling, there was added 150 ml. of ice-water and enough solid sodium carbonate to make the solution basic. Extraction with ether and removal of the solvent after drying yielded an oil which was distilled to give 9.5 g. (45%) of a slightly yellow liquid; b.p. 141-145° (1.5 mm.).

A picrate<sup>5</sup> melted at 153-155° after two recrystallizations from ethanol.

A perchlorate was prepared by the addition of 60% aqueous perchloric acid to a cold ethanolic solution of the in-

dolenine. It melted at 194-195° after three recrystallizations from ethanol.

*Anal.* Calcd. for C<sub>16</sub>H<sub>16</sub>NCIO<sub>4</sub>: C, 59.72; H, 5.01; N, 4.53. Found: C, 59.65; H, 5.10; N, 4.45.

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#### Heats of Fusion of Aliphatic Polyesters<sup>1</sup>

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RECEIVED APRIL 3, 1952

An investigation,<sup>2</sup> the results of which were published several years ago, yielded discordant values for the heats of fusion of two linear polyesters, poly-(decamethylene adipate) and poly-(decamethylene sebacate). Heats of fusion calculated from the depressions of the melting points  $T_m$  caused by introduction of copolymerized units in the chains were substantially lower than those deduced from the dependence of  $T_m$  on chain length, and from that obtained in one instance from the lowering of  $T_m$  by diluents.<sup>2</sup> In more recent investigations<sup>3,4</sup> the latter method has been chosen in preference to measurements on copolymers principally because of the better definition of the melting points of the polymer-diluent mixtures, and also because of its wider applicability to polymers including those for which random alteration of some of the units, as by copolymerization, is impractical. Furthermore, the use of dilatometric methods permitting gradual melting over periods of several days yields more reliable melting points than the earlier micro method involving comparatively rapid heating of a small sample on the stage of a low power microscope.

In the light of these advances it seemed desirable to repeat the earlier determination of the heat of fusion of an aliphatic linear polyester by the diluent

(1) This work was carried out at Cornell University as part of a research program supported by the Allegheny Ballistics Laboratory, Cumberland, Md., an establishment owned by the United States Navy and operated by the Hercules Powder Company under Contract NOrd 10431.

(2) R. D. Evans, H. R. Mighon and P. J. Flory, *THIS JOURNAL*, **72**, 2018 (1950).

(3) P. J. Flory, L. Mandelkern and H. K. Hall, *ibid.*, **73**, 2532 (1951).

(4) L. Mandelkern and P. J. Flory, *ibid.*, **73**, 3206 (1951).

(5) H. Leuchs, A. Heller and A. Hoffman, *Ber.*, **62**, 877 (1929), used zinc chloride for the preparation of this indolenine which they isolated by means of the picrate, m.p. 158-160°.

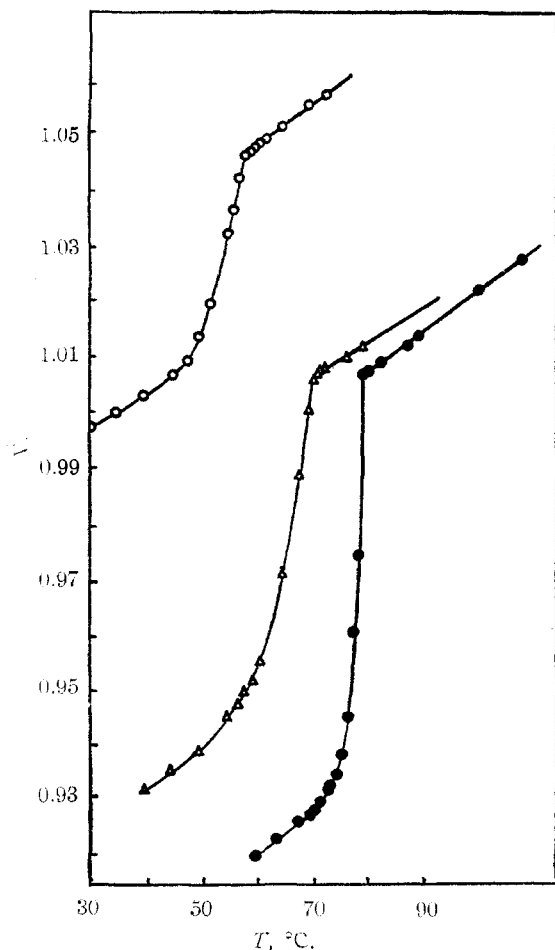


Fig. 1.—Specific volume-temperature curves for pure poly-(decamethylene adipate), ●; for its mixture with 60% dimethyl formamide ( $v_1 = 0.603$ ), ○; and for its mixture with 18% diphenyl ether ( $v_1 = 0.180$ ), Δ. Points were taken in order of ascending temperature.

method. Accordingly, the melting points of various mixtures of poly-(decamethylene adipate) with dimethylformamide and with diphenyl ether have been carefully measured dilatometrically, the temperature being raised in one degree increments every 24 hours in the vicinity of  $T_m$ . Typical dilatometric results are shown in Fig. 1 for the undiluted polyester and for two mixtures with diluents. The melting point  $T_m^0$  for the pure polymer,  $79.5 \pm 0.5^\circ$ , is in good agreement with the value previously reported,<sup>2</sup> which also was obtained dilatometrically. Melting points observed for various mixtures are given in Table I. They are shown graphically in Fig. 2 where the quantity  $(1/T_m - 1/T_m^0)/v_1$  is plotted against  $v_1/T_m$  as suggested by the theoretical relation<sup>5</sup>

$$\frac{1}{T_m} - \frac{1}{T_m^0} = (R/h_u)(v_u/v_1)(v_1 - \chi_1 v_1^2) \quad (1)$$

where  $h_u$  is the heat of fusion per polymer unit,  $v_u$  is the molar volume of a unit and  $v_1$  is the molar volume of the solvent,  $v_1$  is its volume fraction present in the solution, and  $\chi_1$  is an interaction parameter,<sup>6</sup> given in the previous<sup>3,4</sup> notation as  $\kappa_1 - \psi_1 + \frac{1}{2}\psi_2$ , or where  $B'$  represents the standard state free

(5) P. J. Flory, *J. Chem. Phys.*, **17**, 223 (1949).

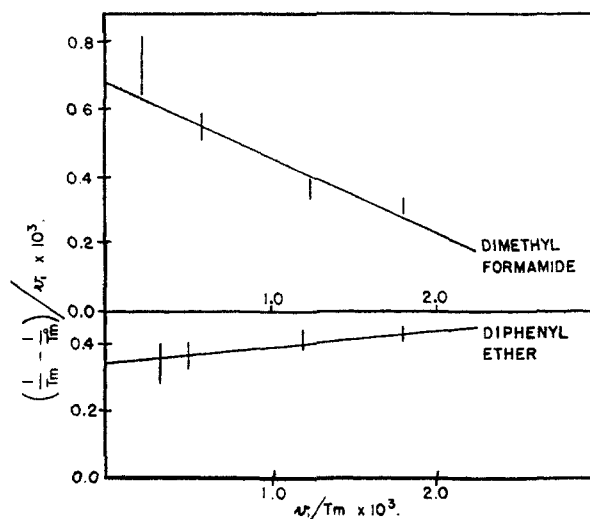


Fig. 2.—Treatment of melting points of mixtures for the purpose of evaluating the heat of fusion (from intercepts) and the interaction parameter  $B'$  (from slopes).

energy of mixing per unit volume.<sup>6</sup> Presuming the internal energy contribution to  $B'$  to be dominant, we choose  $v_1/T_m$  as the abscissa variable, although over the small temperature range involved  $v_1$  would serve equally well. The uncertainties in the ordinate values are indicated by the lengths of the vertical lines representing the experimental data. Intercepts of the straight lines drawn through the points for the mixtures containing dimethylformamide and diphenyl ether yield, respectively,  $h_u = 10,300 \pm 600$  cal./mole and  $10,100 \pm 600$  cal./mole. From the mean of these results, the heat of fusion per gram is 35.8 cal. The depressions observed previously on copolymers yielded the much lower value of 13.4 cal./g. On the other hand, the heat of fusion calculated from the change in  $T_m$  with molecular weight was 37.5 cal./g., in good agreement with the present value. Measurements of a preliminary nature<sup>2</sup> on the depression of  $T_m$  for poly-(decamethylene sebacate) by diethyl sebacate and by benzophenone led to a similar heat of fusion of 36 cal./g.

$$\chi_1 = B'v_1/RT \quad (2)$$

We conclude that the copolymer melting point method for securing the heat of fusion is untrustworthy,<sup>7</sup> probably because of the difficulty of detecting the required melting point,<sup>5</sup> which is defined as that at which the most perfect crystallites disappear. In the case of a copolymer these should consist of those sequences of the primary unit of exceptionally great length, which, being present in exceedingly minute quantity, melt undetected.<sup>3</sup> Even with the more refined dilatometric procedure the

(6) P. J. Flory and W. R. Krigbaum, *Ann. Rev. Phys. Chem.*, **2**, 383 (1951).

(7) O. B. Edgar and R. Hill, *J. Polymer Sci.*, **8**, 1 (1952), have recently reported heats of fusion for poly-(ethylene terephthalate), poly-(ethylene adipate), and poly-(ethylene sebacate) as determined by the copolymer melting point depression method. The values obtained are expectedly low (11.5, 22.1 and 14.5 cal./g., respectively) and may be in error in a manner corresponding with our observations on this method.

melting points of copolymers are ill-defined.<sup>3</sup> It is difficult to understand, however, why the lowering of  $T_m$  with reduction in degree of polymerization<sup>2</sup> does not appear to be subject to a corresponding error.

According to the results shown in Fig. 2, dimethylformamide is a far more potent solvent for the polyester than is diphenyl ether. Values of  $B'$  estimated from the slopes of the lines are  $+8.0$  cal./cc. and  $-1.8$  cal./cc., respectively.

TABLE I

MELTING TEMPERATURE OF POLYMER-DILUENT MIXTURES

Dimethylformamide		Diphenyl ether	
$\eta_1$	$T_m, ^\circ\text{C.}$	$\eta_1$	$T_m, ^\circ\text{C.}$
0.078	$72.5 \pm 0.5$	0.123	$74.5 \pm 0.5$
.202	$66.5 \pm .5$	.180	$71.5 \pm .5$
.422	$61.5 \pm .5$	.410	$59.5 \pm .5$
.603	$57.5 \pm .5$	.594	$50.5 \pm .5$

**Experimental.**—Decamethylene glycol and adipic acid, both carefully purified, were polymerized by heating without added catalysts at 160 to 217° under a reduced pressure of pure nitrogen for a total of 33 hours. A 2% excess of glycol over the amount required stoichiometrically was used in order to compensate loss of glycol by volatilization. The final viscosity at 109° was 1800 poises, corresponding to a number average molecular weight of 11,500.<sup>8</sup>

The solvents, dimethylformamide and diphenyl ether, were of reagent grade. The former was redistilled. Polymer-diluent mixtures were prepared by heating the ingredients with stirring as previously described.<sup>3</sup> The dilatometric procedures have been described elsewhere also.<sup>3,4</sup>

(8) P. J. Flory, *THIS JOURNAL*, **62**, 1057 (1940).

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### Steroids Derived from Bile Acids. XVII. Dehydrobromination of 3-Keto-4-bromosteroids with 2,4-Dinitrophenylhydrazine<sup>1</sup>

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RECEIVED FEBRUARY 11, 1952

When 3-keto-4-bromosteroids are treated with 2,4-dinitrophenylhydrazine in acetic acid hydrogen bromide is eliminated and a  $\Delta^4$ -steroidal hydrazone is formed.<sup>3a,b</sup> The probable mechanism of this reaction has been discussed. Djerassi<sup>4</sup> believed that hydrogen bromide was eliminated before formation of the hydrazone. Mattox and Kendall<sup>5</sup> suggested that the hydrazone was formed with the atom of bromine at C-4 still intact and that subsequently hydrogen bromide was lost.

Isolation and identification of the 3-hydrazone of the 4-bromosteroid as an intermediate compound did not appear feasible since at room temperature the organically bound bromine rapidly appeared in solution as bromide ion.

It seemed probable that the bromohydrazone

(1) Abridgment of portion of thesis submitted by Mr. McGuckin to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

(2) Fellow in Biochemistry.

(3) (a) V. R. Mattox and E. C. Kendall, *THIS JOURNAL*, **70**, 882 (1948); (b) V. R. Mattox and E. C. Kendall, *J. Biol. Chem.*, **195**, 601 (1950).

(4) Carl Djerassi, *THIS JOURNAL*, **71**, 1003 (1949).

(5) V. R. Mattox and E. C. Kendall, *ibid.*, **72**, 2290 (1950).

would be stable in relatively non-polar solvents, such as chloroform or benzene, but attempts to prepare this intermediate product in such solvents were unsuccessful. For this reason the postulated compound was prepared indirectly by bromination at C-4 of methyl 3,11-diketo-12 $\alpha$ -bromocholanate 3-(2,4-dinitrophenylhydrazone) in chloroform. The 3-hydrazone of the 4-bromosteroid was isolated<sup>5</sup> in crystalline form and its physical characteristics were determined. When this compound was dissolved in acetic acid hydrogen bromide was spontaneously eliminated and the  $\Delta^4$ -steroidal hydrazone was separated in excellent yield.

It has now been shown that when the 3-keto-4-bromosteroid was added to 2,4-dinitrophenylhydrazine in a 1:1 mixture of acetic acid and chloroform at 0° the 3-hydrazone of the 4-bromosteroid was formed and that at this temperature hydrogen bromide was very slowly eliminated. After the acetic acid had been removed by washing at 0° with water, the compound was obtained in a yield of 80% and was found to be identical with the material previously prepared by bromination of the saturated steroidal hydrazone. The separation of this unstable intermediate product furnishes additional support for the mechanism of the reaction suggested by Mattox and Kendall.

**Methyl 3,11-Diketo-4,12 $\alpha$ -dibromocholanate 3-(2,4-Dinitrophenylhydrazone).**—To a solution of 500 mg. of 2,4-dinitrophenylhydrazine in 150 ml. of chloroform and 150 ml. of acetic acid which was freed of air with a stream of carbon dioxide and cooled to 0°, 559 mg. of methyl 3,11-diketo-4,12 $\alpha$ -dibromocholanate was added and the mixture was agitated at intervals to effect complete solution. After 1.5 hours at 0°, 300 ml. of water was added, the chloroform solution was separated, washed quickly with dilute acetic acid, 0.10 *N* sulfuric acid, dilute sodium bicarbonate solution and water, and was filtered through a pad of sodium sulfate. The solution was concentrated immediately under reduced pressure to about 5 ml., diluted with 25 ml. of absolute ether and cooled in a Dry Ice-acetone-bath. The yellow crystals (591 mg.) which separated melted at 135–137°;  $\lambda_{\text{max}}^{\text{chloroform}}$  361  $\mu$ ,  $\epsilon$  26,400;  $[\alpha]_D -162 \pm 2^\circ$  (chloroform).

The melting point, optical activity and absorption spectra of the compound, in both the ultraviolet and infrared regions, were identical with those of an authentic sample which had been prepared by Dr. V. R. Mattox in this Laboratory by bromination of the saturated hydrazone.

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### High Vapor Pressure of *n*-Hexadecafluoroheptane<sup>1</sup>

BY H. T. MILTON AND GEORGE D. OLIVER  
RECEIVED MARCH 5, 1952

Recently the vapor pressure of this compound below two atmospheres was published with other thermodynamic properties.<sup>2</sup> In the course of testing a method to determine critical temperature and pressure, by means of vapor pressure measurements in the region of the critical point, vapor pressure data were measured on *n*-hexadecafluoroheptane from two atmospheres to the critical point.

(1) This document is based on work performed for the Atomic Energy Commission by Carbide and Carbon Chemicals Division Union Carbide and Carbon Corporation, Oak Ridge, Tennessee.

(2) G. D. Oliver and J. W. Grisard, *THIS JOURNAL*, **73**, 1688 (1951).