

liter filter flask suitable for the large quantity of solvent required. In this apparatus a solution of 39.7 g. (0.1 mole) of ergosterol in 800 ml. of dioxane containing 50 g. of Raney nickel caused a pressure drop of 7.0 lb. (110% of the theory) of hydrogen when stirred for two hours under 10–15 lb. pressure at room temperature. At this time all hydrogen uptake ceased. From the filtered solution was isolated directly 40.1 g. (100%) of quite pure III, m.p. 170.8–172.4°.

**5-Dihydroergosterol Acetate (IV).**—A solution of 0.199 g. (0.0005 mole) of 5-dihydroergosterol (III) in 5 ml. of acetic anhydride containing one drop of pyridine was refluxed for 20 minutes. On cooling, 0.182 g. (82.5%) of the acetate IV separated as large plates, m.p. 174.6–177.4°,  $[\alpha]_D^{25} -21.2^\circ$  (*c* 2.00, chloroform). The melting point on admixture with an authentic sample prepared by the method of Barton,<sup>14</sup> m.p. 176.0–180.6°, was not depressed.

**$\Delta^{8(14),22}$ -Ergostadien-3 $\beta$ -ol Acetate (VI).**— $\Delta^{8(14),22}$ -Ergostatrien-3 $\beta$ -ol acetate, m.p. 119.0–120.6°,  $[\alpha]_D^{25} -94.0^\circ$  (*c* 1.03, chloroform) was prepared essentially as described by Windaus<sup>8</sup> who reported the physical constants as m.p. 100°,  $[\alpha]_D -80.4^\circ$ .<sup>12</sup>

A solution of 0.700 g. (0.0016 mole) of the acetate (V) in 20 ml. of dioxane was hydrogenated over about 1.5 g. of Raney nickel catalyst as described in the preparation of III (A). After three hours nearly the theoretical quantity of hydrogen had been absorbed and hydrogen uptake ceased. The filtered reaction mixture on concentration to dryness under reduced pressure afforded 0.690 g. of crystalline product as small colorless platelets, m.p. 111.8–114.0° (98%). Recrystallization from ethyl acetate–methanol afforded an 82% recovery of pure  $\Delta^{8(14),22}$ -ergostadien-3 $\beta$ -ol acetate (VI), m.p. 122.6–124.0°,  $[\alpha]_D^{25} -26.5^\circ$  (*c* 1.12, chloroform). The physical constants were not altered by further recrystallization.

*Anal.* Calcd. for  $C_{30}H_{48}O_2$ : C, 81.76; H, 10.98. Found: C, 81.96; H, 10.89.

**Hydrogenation of  $\Delta^{8(14),22}$ -Ergostadien-3 $\beta$ -ol Acetate (VI).**—A solution of 0.220 g. (0.0005 mole) of VI in 10 ml. of anhydrous peroxide-free dioxane was hydrogenated over 0.050 g. of pre-reduced platinum oxide catalyst. After 69 minutes, 12.4 ml. (100%) of the theoretical quantity of hydrogen required for saturation of one double bond had been absorbed. The filtered reaction mixture on concentration afforded quantitatively nearly pure  $\Delta^{8(14)}$ -ergosten-3 $\beta$ -ol acetate, m.p. 101.5–110.0°. Recrystallization from ethyl acetate afforded pure acetate as large glistening plates,

(12) An alternate preparation of this triene will be the subject of a later communication.

m.p. 109.0–110.5°,  $[\alpha]_D +2.7^\circ$  (*c* 1.11, chloroform). The melting point on admixture with an authentic sample, m.p. 109.0–110.5°,  $[\alpha]_D +4.0^\circ$  (*c* 1.01, chloroform), prepared by hydrogenation of ergosterol acetate over platinum in chloroform, was not depressed.

**Hydrogenation of  $\Delta^{8,14,22}$ -Ergostatrien-3 $\beta$ -ol Acetate.**—A solution of 0.397 g. (0.001 mole) of  $\Delta^{8,14,22}$ -ergostatrien-3 $\beta$ -ol acetate (ergosterol-B<sub>1</sub> acetate),<sup>8</sup> m.p. 139.8–142.0°,  $[\alpha]_D -57.9^\circ$  (*c* 1.04, chloroform) in 11 ml. of dioxane was stirred over pre-reduced Raney nickel catalyst (0.58 g.) in an atmosphere of hydrogen for several hours. No hydrogen absorption was observed, and the product isolated on filtration and concentration proved to be unchanged ergosterol-B<sub>1</sub> acetate, m.p. 139.0–144.4°, not depressed on admixture with starting material.

**Hydrogenation of  $\Delta^{7,9(11),22}$ -Ergostatrien-3 $\beta$ -ol Acetate.**— $\Delta^{7,9(11),22}$ -Ergostatrien-3 $\beta$ -ol acetate (ergosterol-D acetate) was prepared by the method of Barton,<sup>14</sup> m.p. 165.8–169.0°. Hydrogenation of a 0.175-g. portion over 0.43 g. of Raney nickel in 10 ml. of dioxane by the usual procedure resulted in no hydrogen uptake and quantitative recovery of starting material, m.p. 162.0–168.9°,  $[\alpha]_D +26.7^\circ$  (*c* 0.98, chloroform), not depressed on admixture with an authentic sample.

**Hydrogenation of  $\Delta^{6,7,9(11),22}$ -Ergostatetraen-3 $\beta$ -ol Acetate.**— $\Delta^{6,7,9(11),22}$ -Ergostatetraen-3 $\beta$ -ol acetate (dehydroergosterol acetate) was prepared by mercuric acetate dehydrogenation of ergosterol acetate as described by Bergmann and Stevens,<sup>14</sup> m.p. 146.2–151.0°,  $[\alpha]_D +157^\circ$  (*c* 2.03, chloroform).

A solution of 0.437 g. (0.001 mole) of the tetraene acetate in 12 ml. of dioxane was hydrogenated over 0.63 g. of Raney nickel catalyst. Hydrogen uptake showed a sharp inflection after 1.33 moles had been absorbed, and only a slight further uptake was observed. Filtration and concentration *in vacuo* afforded a quantitative recovery of crystalline product as tiny platelets, m.p. 149.8–156.4°,  $[\alpha]_D^{25} +21.8^\circ$  (*c* 1.97, chloroform). An ultraviolet spectrum measured in ether solution showed strong bands at 235 and 242.5  $m\mu$  ( $\log \epsilon$  3.82), indicating the presence of about 53%  $\Delta^{7,9(11),22}$ -ergostatrienol acetate.

**Acknowledgments.**—We wish to express our appreciation to Mr. Robert Richter for technical assistance. We are indebted to Dr. John Means and his associates of these laboratories for the microanalyses.

(13) W. Bergmann and P. G. Stevens, *J. Org. Chem.*, **13**, 10 (1948).  
BROOKLYN, N. Y. RECEIVED AUGUST 17, 1951

[CONTRIBUTION FROM THE EASTERN REGIONAL RESEARCH LABORATORY<sup>1</sup>]

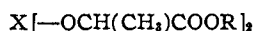
## Diesters of Lactic Acid. Esterification of Lactates with Dibasic Acids

BY C. E. REHBERG AND MARION B. DIXON

Twenty-six esters made by the esterification of lactate esters with dibasic acids are described. Boiling points, refractive indices, densities and viscosities of the esters at different temperatures are given. Potential usefulness of these compounds as plasticizers is suggested.

In the previous paper of this series,<sup>2</sup> the adipates of a number of esters of lactic acid were described, and their potential usefulness as plasticizers was suggested.

The present paper reports work of the same general nature in which instead of adipic acid, various other dibasic acids were used to esterify the hydroxyl group of esters of lactic acid. These products may be represented by the formula



(1) One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. Article not copyrighted.

(2) Rehberg and Dixon, *THIS JOURNAL*, **73**, 5757 (1950).

where X is the divalent acyl radical of a dibasic acid and R is the alcohol radical of the lactic ester. The dibasic acids used were phthalic, maleic, succinic, sebacic, carbonic and benzenephosphonic. Most attention was devoted to phthalic esters because of their importance in the plasticizer industry.

The products obtained by the esterification of dicarboxylic acids with allyl lactate contain two allyl groups in the molecule and are polymerizable. Several such esters have been reported. Thus, allyl lactate has been treated with acid chlorides to produce the carbonate, succinate, fumarate, adipate, sebacate and phthalate.<sup>3</sup> The maleates of allyl<sup>4</sup>

(3) Howald and Jones, U. S. Patent 2,462,042, Feb. 15, 1949.

(4) Jones, U. S. Patent 2,443,915, June 22, 1948.

TABLE I  
 PROPERTIES AND ANALYSES OF DIESTERS OF LACTIC ACID

Components of diesters Acid Lactate	Yield, %	Carbon, %		Hydrogen, %		$n_{20}^D$	$n_{40}^D$	$d_{20}^4$	$d_{40}^4$	Viscosity, cps.	
		Calcd.	Found	Calcd.	Found					20°	40°
Phthalic Methyl <sup>a</sup>	78	56.8	56.6	5.4	5.4	1.4949	1.4875	1.2242	1.2074	7,495	459
Phthalic Ethyl <sup>b</sup>	84	59.1	58.7	6.1	6.3	1.4870	1.4796	1.1715	1.1536	934	127.1
Phthalic Butyl	61	62.5	62.4	..	..	1.4820	1.4748	1.1094	1.0924	283	69.0
Phthalic 2-Ethylbutyl	87	65.2	65.0	8.0	8.0	1.4838	1.4757	1.0878	1.0724	882	165.4
Phthalic <i>n</i> -Octyl	82	67.4	67.1	8.7	8.9	1.4772	1.4700	1.0381	1.0248	250	64.9
Phthalic 2-Ethylhexyl	86	67.4	67.5	8.7	8.7	1.4790	1.4720	1.0423	1.0278	474	105.8
Phthalic Allyl	80	61.5	61.6	5.7	6.0	1.4998	1.4922	1.1693	1.1529	351	75.2
Phthalic 2-Ethoxyethyl	75	58.1	57.6	6.6	6.6	1.4859	1.4788	1.1622	1.1446	725	118
Phthalic 2-Butoxyethyl	60	61.2	61.1	7.5	7.6	1.4802	1.4733	1.1092	1.0920	338	74.2
Phthalic 2-(2-Butoxy- ethoxy)-ethyl	96	60.2	59.9	7.8	7.9	1.4790	1.4722	1.1130	1.0966	298	77.8
Phthalic Tetrahydrofur- furyl	90	60.2	59.8	6.3	6.6	1.5030	1.4978	1.2188	1.2037	31,640	2009
Maleic Ethyl <sup>c</sup>	72	53.2	53.8	6.4	6.5	1.4462	1.4382	1.1244	1.1066	22.88	9.23
Maleic Butyl	84	58.1	57.8	7.6	7.7	1.4488	1.4410	1.0852	1.0677	74.3	19.36
Maleic Isobutyl <sup>d</sup>	83	58.1	57.6	7.6	7.1	1.4475	1.4396	1.0847	1.0678	189.5	42.9
Maleic 2-Ethylhexyl <sup>e</sup>	72	64.4	65.0	9.2	9.2	1.4564	1.4475	1.0134	0.9982	110.4	33.0
Maleic Allyl <sup>f</sup>	46	56.5	56.2	5.9	5.9	1.4652	1.4561	1.1562	1.1382		
Succinic Methyl	65	49.7	49.9	6.3	6.4	1.4408	1.4338	1.1925	1.1730	140.6	29.9
Succinic Ethyl	78	52.8	52.6	7.0	6.7	1.4375	1.4305	1.1344	1.1138	54.0	16.94
Succinic Butyl	87	57.7	57.9	8.1	8.2	1.4400	1.4330	1.0714	1.0529	44.7	16.52
Succinic <i>n</i> -Octyl	98	64.2	64.2	9.5	9.8	1.4460	1.4394	1.0042	0.9878	56.8	21.1
Succinic Allyl	92	56.1	56.6	6.5	6.7	1.4554	1.4472	1.1353	1.1170	48.9	16.9
Sebacic Ethyl	76	59.7	59.4	8.5	8.8	1.4452	1.4382	1.0549	1.0370	58.3	22.6
Sebacic Butyl	84	62.9	63.0	9.2	9.3	1.4465	1.4397	1.0200	1.0033	48.7	20.1
Sebacic <i>n</i> -Octyl	81	67.3	68.0	10.2	10.4	1.4506	1.4438	0.9872	0.9626	63.0	26.9
Sebacic 2-Octyl	93	67.3	67.2	10.2	10.4	1.4475	1.4402	.9740	.9586	90.9	35.4
Carbonic Allyl	83	54.5	54.4	6.3	6.6	1.4468	1.4392	1.1284	1.1089	26.3	10.9
Benzenephos- phonic Butyl <sup>g</sup>	25	58.0	57.8	7.5	7.5	1.4786		1.1082		52.7	

<sup>a</sup> M.p. 50–55°. <sup>b</sup> M.p. 55–60°. <sup>c</sup> B.p. 62° (0.02 mm.). <sup>d</sup> B.p. 105° (0.02 mm.). <sup>e</sup> B.p. 150° (0.03 mm.). <sup>f</sup> B.p. 112° (0.02 mm.). <sup>g</sup> B.p. 130° (0.02 mm.).

and butyl<sup>h</sup> lactates have been made with maleic acid or anhydride. The succinate of ethyl lactate has been made from potassium succinate and ethyl  $\alpha$ -chloropropionate<sup>6</sup> and from succinyl chloride and ethyl lactate.<sup>7</sup>

Table I shows the esters included in the present study. All the maleates, as well as the phthalates 2-ethylbutyl and 2-ethylhexyl lactates, were made by use of the acid anhydride. All other esters were made by use of the acid chlorides. The use of the dibasic acid or anhydride instead of the acid chloride resulted in the production of a mixture of esters instead of a single compound. However, in the cases studied, this mixture was as efficient a plasticizer for polyvinyl chloride as was the pure compound.<sup>8</sup>

**Boiling Points.**—Boiling points over a range of pressures were determined for most of the esters. Figures 1 and 2 are Cox charts showing  $1/(t + 223)$ , where  $t$  is the boiling point in °C., plotted versus  $\log P$  (mm.).

A linear relationship was observed between the

(5) Carruthers and Blair, U. S. Patent 2,260,295, Oct. 28, 1941; cf. also Canadian Patent 411,766, April 13, 1943.

(6) Wurtz and Friedel, *Ann. chim.*, [3] **63**, 101 (1861).

(7) Wislicenus, *Ann.*, **133**, 257 (1865).

(8) Rehberg and Dixon, "Plasticizers from Lactic Acid. Direct Esterification of Butyl Lactate with Adipic Acid." Presented before the Division of Paint, Varnish and Plastics Chemistry, 116th National Meeting of the American Chemical Society, Atlantic City, N. J., Sept., 1949. See Abstracts of Papers, p. 23N.

boiling points at 1 mm. of diesters with and without lactic acid groups in the molecule [e.g., dibutyl phthalate as compared to bis-(butyl lactate)-phthalate]. The equation of this relationship is

$$X = 0.64Y + 118$$

where  $X$  and  $Y$  are the boiling points, at 1 mm. pressure, of the esters with and without the lactic acid groups, respectively. Of the twelve pairs of esters for which data were available, the maximum deviation was 5°, and the average deviation was 2.5°. From this equation it can be seen that the increase in boiling point caused by the introduction of lactic acid into the compound varied inversely with the boiling point of the compound. For the esters studied, this increase varied from about 40 to 100°.

Relationships similar to those given above for boiling points exist also for the vapor pressures ( $\log P$ ) of the esters at any fixed temperature.

The refractive index, density and viscosity of each ester were measured at 20 and 40° and are shown in Table I. The usefulness of a compound as a plasticizer is usually increased by a low viscosity and a low temperature-viscosity coefficient. From the viscosity data in Table I it can be seen that methyl groups, branched chains, and especially ring structures tend to contribute high viscosity and high viscosity-temperature coefficient to those compounds in which these structures are found.

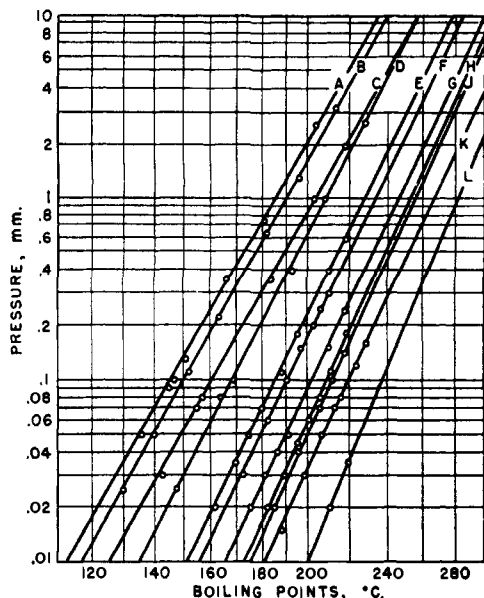


Fig. 1.—Boiling points of phthalates of various lactates: A, methyl; B, ethyl; C, allyl; D, butyl; E, 2-ethylbutyl; F, 2-ethoxyethyl; G, 2-ethylhexyl; H, 2-butoxyethyl; J, *n*-octyl; K, tetrahydrofurfuryl; L, 2-(2-butoxyethoxy)-ethyl.

**Acknowledgment.**—We are grateful to C. O. Willits, C. L. Ogg and their associates in the Analytical and Physical Chemistry Division of this Laboratory for the analytical data in Table I.

### Experimental

**Materials.**—Those lactates not commercially available were made by the alcoholysis of methyl lactate.<sup>2</sup> The carbonate of allyl lactate was prepared by treating allyl lactate with  $\alpha$ -carballyloxyethyl chloroformate (made from allyl lactate and phosgene by the Columbia Chemicals Division of the Pittsburgh Plate Glass Company and furnished to us through the courtesy of Dr. Franklin Strain). Benzenephosphonyl chloride (benzenephosphorus oxydichloride) was kindly furnished by Dr. A. D. F. Toy, of the Victor Chemical Co.

**Procedure.**—Most of the compounds were made by the reaction of equivalent amounts of the acid chloride and the

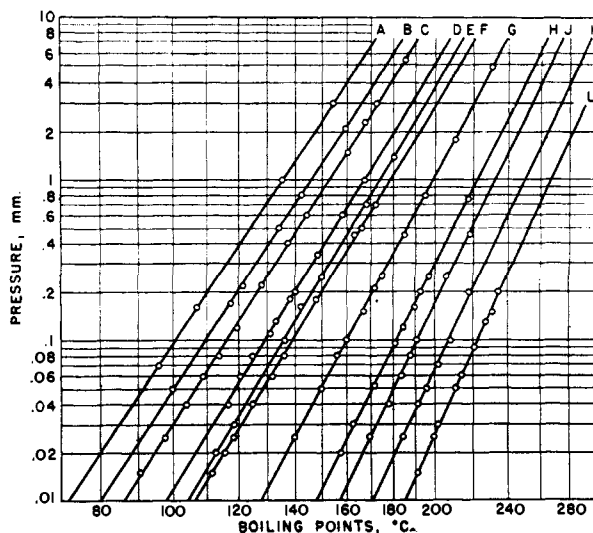


Fig. 2.—Boiling points of dicarboxylic acid esters of various lactates: A, allyl lactate carbonate; B, methyl lactate succinate; C, ethyl lactate succinate; D, allyl lactate succinate; E, butyl lactate maleate; F, butyllactate succinate; G, ethyl lactate sebacate; H, butyl lactate sebacate; J, *n*-octyl lactate succinate; K, 2-octyl lactate sebacate; L, *n*-octyl lactate sebacate.

lactate, in the presence of a slight excess of pyridine. The products were washed, dried and distilled. When the acid anhydrides were used, a 10 to 50% excess of lactate and a catalytic amount of sulfuric acid were used. The mixture was refluxed, vacuum being used as needed to keep the temperature below about 150°. Water was distilled out as fast as formed. When the reaction was complete, the catalyst was neutralized with sodium acetate and volatile materials were removed by vacuum distillation. Attempts to wash the crude products were often unsatisfactory because of the formation of emulsions.

All the products were distilled in an alembic type still specially designed for operation at low pressures.<sup>3</sup> Boiling points at various pressures in the range 0.01–10.0 mm. were determined with the same still and used in the construction of Figs. 1 and 2.

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(9) Ratchford and Rehberg, *Anal. Chem.*, **21**, 1417 (1949).