

STUDIES ON THE FRIES REARRANGEMENT. PART I

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Fries rearrangement takes place with esters of $\alpha\beta$ -hexenic acid and β -isopropylacrylic acid, but no identifiable product could be isolated from the corresponding reaction with oleic acid.

It was observed by Fries and Fink (*Ber.*, 1908, **41**, 4271) that acyl derivatives of phenols, when heated with anhydrous aluminium chloride, were converted smoothly into the isomeric *o*- or *p*-hydroxy-ketones, or more often into a mixture of the two. The chief variation in the results is in the ratio of the *ortho* and the *para* isomers, which is influenced to a great extent by the nature of the solvent, the amount of the catalyst and the temperature at which the reaction is conducted (Barch, *J. Amer. Chem. Soc.*, 1935, **57**, 2330; Ralston *et al.*, *J. Org. Chem.*, 1940, **5**, 645; Rosenmund and Schnurr, *Annalen*, 1928, **460**, 56); as a rule, low temperature favours *para* substitution and high temperature, *ortho* substitution.

Considerable amount of work in this field has been carried out with esters of saturated aliphatic carboxylic acids (cf. Adams, "Organic Reactions," Vol. I, pp. 357-363), but esters of purely aliphatic unsaturated acids do not appear to have been tried, excepting a few esters of cinnamic acid which have been found to rearrange (Rosenmund and Schnurr, *loc. cit.*).

In the present paper this reaction has therefore been extended to esters of three unsaturated acids, viz. $\alpha\beta$ -hexenic acid, β -isopropylacrylic acid and oleic acid.

Six esters of $\alpha\beta$ -hexenic acid with phenol, *o*-, *m*- and *p*-cresol, resorcinol mono-methyl ether and hydroquinone monoethyl ether have been obtained. In the case of β -isopropylacrylic acid only four esters with phenol, *o*-, *m*- and *p*-cresol have been prepared. In the case of oleic acid only three esters, viz. *o*-, *m*- and *p*-cresyl oleate have been prepared.

The main rearrangement products (about 50-60%) of $\alpha\beta$ -hexenic and β -isopropylacrylic esters are *ortho*-hydroxy ketones which have been characterised through their 2:4-dinitrophenylhydrazones. In the case of oleic esters, no identifiable product could be obtained on treatment with anhydrous aluminium chloride owing to the high temperature distillation in vacuum which resulted in dark resinous products.

EXPERIMENTAL

Acids

$\alpha\beta$ -Hexenic acid was prepared according to Auwers' general method (*Annalen*, 1923, **432**, 46). *n*-Butyraldehyde (54 g.), malonic acid (78 g.) and pyridine (88.5 g.) were heated together on the water-bath for 6 hours till the evolution of CO₂ had ceased. Pyridine was removed under reduced pressure and the reaction mixture was slowly added to

well cooled 50% sulphuric acid (200 c.c.) when shining, colourless crystals of $\alpha\beta$ -hexenic acid separated out, m. p. 31-32°, yield 65 g.

β -isoPropylacrylic acid was prepared as above from isobutyraldehyde, malonic acid and pyridine, b. p. 115°/5 mm.

Chlorides

$\alpha\beta$ -Hexenoyl chloride was obtained from $\alpha\beta$ -hexenic acid (65 g.) and thionyl chloride (102 g.) by heating on the water-bath for 2 hours, b. p. 59°/40 mm. (after first distilling off the excess of thionyl chloride under reduced pressure), yield 70 g.

β -isoPropylacrylyl chloride was prepared as above from thionyl chloride and β -iso-propylacrylic acid, b. p. 65°/40 mm.

Oleic acid chloride (Aschan, Ber. 1898, 31, 2349), b. p. 116°/1 mm. (Aschan, 213°/13.5 mm.).

TABLE I

Name of esters.	B.p.	Mol. formula.	F o u n d		R e q u i r e d	
			C.	H.	C.	H.
A. Hexenic esters:						
1. Phenyl	182°/13 mm.	C ₁₂ H ₁₄ O ₂	75.31%	7.52%	75.70%	7.36%
2. o-Cresyl	157°/6	C ₁₃ H ₁₆ O ₂	76.10	7.99	76.40	7.84
3. m-Cresyl	176°/15	„	76.20	8.10	„	„
4. p-Cresyl	149°/2	„	75.91	8.15	„	„
5. Resorcinol monomethyl ether	152°/1	C ₁₃ H ₁₆ O ₃	70.42	7.52	70.90	7.27
6. Hydroquinone monoethyl ether	183°/12	C ₁₄ H ₁₈ O ₃	71.80	8.00	72.20	7.70
B. isoPropylacrylic esters:						
7. Phenyl	119°/4	C ₁₂ H ₁₄ O ₂	75.29	7.31	75.70	7.36
8. o-Cresyl	153°/4	C ₁₃ H ₁₆ O ₂	76.00	7.49	76.40	7.84
9. m-Cresyl	128°/1	„	75.92	7.52	76.40	„
10. p-Cresyl	134°/2	„	76.10	8.10	„	„
C. Oleic esters:						
11. o-Cresyl	191°/5	C ₂₅ H ₄₀ O ₂	80.22	13.55	80.64	13.33
12. m-Cresyl	249°/4	„	80.18	13.60	„	„
13. p-Cresyl	230°/13	„	80.30	13.49	„	„

TABLE II

Products of Fries rearrangement of the esters

Name of the <i>o</i> -hydroxyketone.	Dinitrophenylhydrazone.		% Nitrogen	
	B. p.	M. p.	Mol. formul.	Found. Reqd.
A. Hexenic esters :				
1. 2'-Hydroxyphenylhexene-2-one-1	136°/1 mm.	158°	C ₁₈ H ₁₈ O ₅ N ₄	15.00 15.13
2. 2'-Hydroxy-6'-methylphenylhexene-2-one-1	149°/4	181°	C ₁₉ H ₂₀ O ₅ N ₄	14.37 14.58
3. 2'-Hydroxy-3'-methylphenylhexene-2-one-1	144°/1	214°	"	14.66 "
4. 2'-Hydroxy-4'-methylphenylhexene-2-one-1	152°/1	204°	"	14.20 "
5. 2'-Hydroxy-3'-methoxyphenylhexene-2-one-1	131°/11	209°	C ₁₉ H ₂₀ O ₆ N ₄	13.75 14.00
6. 2'-Hydroxy-4'-ethoxyphenylhexene-2-one-1	170°/13	219°	C ₂₀ H ₂₂ O ₆ N ₄	13.22 13.52
B. isoPropylacrylic esters :				
7. 2'-Hydroxyphenyl-4'-dimethylbutene-2-one-1	91°/1	201°	C ₁₈ H ₁₈ O ₅ N ₄	14.92 15.13
8. 2'-Hydroxy-6'-methylphenyl-4'-dimethylbutene-2-one-1	78°/2	205°	C ₁₉ H ₂₀ O ₅ N ₄	14.39 14.58
9. 2'-Hydroxy-3'-methylphenyl-4'-dimethylbutene-2-one-1	89°/4	208°	"	14.27 "
10. 2'-Hydroxy-4'-methylphenyl-4'-dimethylbutene-2-one-1	81°/2	216°	"	14.90 "

Amides

$\alpha\beta$ -Hexenic amide was obtained by the usual method by the addition of concentrated ammonia to the acid chloride, in shining crystals. Recrystallised from hot water it melts at 98°-99°. (Letch and Linstead *J. Chem. Soc.*, 1932, 449 report its m.p. as 122°). (Found : N, 12.62. C₈H₁₁ON requires N, 12.39 per cent).

β -isoPropylacrylic amide was prepared as above, m. p. 71°-72°. (Found : N, 12.10. C₈H₁₁ON requires N, 12.39 per cent).

Esters

General Method of Preparation.—To 0.1 mole of the appropriate phenol, taken in a round-bottom, flask, fitted with a dropping funnel and a reflux condenser, was added dropwise 0.11 mole of the acid chloride and the mixture warmed on the water-bath till the evolution of hydrogen chloride had ceased. After cooling, the mixture was extracted with ether, washed with 1% solution of sodium hydroxide and finally with water and dried over anhydrous sodium sulphate. The ether was removed by distillation and the residue distilled under reduced pressure. Average yields 65-75% of theory.

Fries Rearrangement of the above esters

Finely powdered anhydrous aluminium chloride (0.1 *M*) was taken in a 250 c.c. round-bottom flask fitted with a dropping funnel and a reflux condenser and 0.06 *M*

of the ester was added slowly. The evolution of hydrogen chloride commenced at 60° (external temp.). When the reaction had subsided, the bath temperature was raised to 100° for completing the reaction. To the reddish puffy mass obtained dilute hydrochloric acid was added to decompose the aluminium chloride compound. The oil which separated was extracted with ether, washed successively with water, 1% sodium carbonate solution and finally with water. After dehydration over anhydrous sodium sulphate the ether was distilled off and the residue distilled in vacuum.

The distillate gave an intense red-violet coloration with ferric chloride and on addition of dilute caustic soda a yellowish red precipitate indicating that it is an *o*-hydroxy ketone (cf. Pyman, *J. Chem Soc.*, 1930, 280).

The *ortho*hydroxy ketones, thus obtained, were all converted into their 2 : 4-dinitrophenylhydrazones which were recrystallised from toluene.

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