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KETOVINYLATION OF β-DICARBONYL COMPOUNDS*

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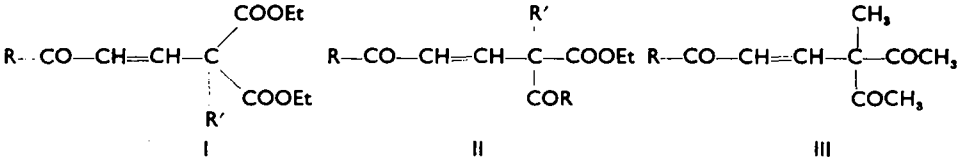
Abstract—The introduction of the ketovinyl group into β-dicarbonyl compounds with only one labile hydrogen proceeds normally, but the presence of two labile hydrogens results in the formation of complex mixtures. Ethyl malonate and ethyl acetoacetate have, however, been successfully ketovinylated. In the former case, α-carbethoxy-δ-keto-β,γ-unsaturated acids are produced in high yield and depending on the conditions of ketovinylation of ethyl acetoacetate either 4-alkyl salicyclic acids or polysubstituted benzene derivatives may be prepared. Further, the ketovinylation products of ethyl malonate and alkyl acetoacetates may be used for the synthesis of either (1) unsaturated aliphatic keto acids or diketones or (2) a variety of α-pyrone derivatives. A mechanism for the ketovinylation of ethyl acetoacetate is proposed and the *trans* configuration of the ketovinylation products established.

β-CHLORVINYLKETONES, RCOCH=CHCl, are easily prepared and highly reactive,[1] the labile halogen atom being readily substituted by different groups (I, SCN, NR_2, OAr, OAlk, SR, etc.) The reaction of β-chlorvinylketones with β-dicarbonyl compounds possessing labile hydrogen atoms, yields polyfunctional compounds with a highly reactive ketovinyl group. This ketovinylation, or the introduction of the ketovinyl group into β-dicarbonyl compounds, is a new example of substitution of the methylene group and may be considered intermediate between alkylation and acylation, the β-chlorvinyl ketones, as far as lability of the halogen is concerned, occupying a position intermediate between the alkyl and acyl halides.

Ketovinylation of β-dicarbonyl compounds with only one labile hydrogen proceeds normally. Various alkylmalonates,[2] α-alkylacetoacetates[3] and α-alkyl benzoyl-

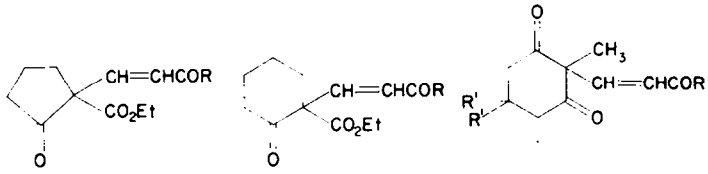


I II III

acetates[4] react to yield δ-keto-α-carbethoxy- and δ-keto-α-acyl-derivatives of β,γ-unsaturated acids I and II. β-Diketones[5] with a single labile hydrogen such as 3-methyl-2,4-pentadione form unsaturated triketones III. Ketovinylation of cyclic β-keto acids[6] and β-diketones[5] also proceed as expected, 2-carbethoxycyclopentanone, 2-carbethoxycyclohexanone and 2-methylcyclohexanedione or dimedone yielding compounds of the type IV, V and VI respectively. Ketovinylation of diacetylacetate (α-acetylacetoacetate) has failed.

* Translated by A. L. Pumpiansky, Moscow.

[1] N. K. Kochetkov, *Uspechi chimii* **24**, 32 (1955).
[2] N. K. Kochetkov and L. I. Kudrjashov, *J. Gen. Chem. U.S.S.R.* **26**, 851 (1956).
[3] N. K. Kochetkov, B. P. Gottich and L. I. Kudrjashov, *J. Gen. Chem. U.S.S.R.* **28**, 1508 (1958).
[4] W. F. Beljaev, M. N. Belokurskaja and N. K. Kochetkov, *J. Gen. Chem. U.S.S.R.* **30**, 1492 (1960).
[5] N. K. Kochetkov, and B. P. Gottich, *J. Gen. Chem. U.S.S.R.* **30**, 948 (1960).
[6] N. K. Kochetkov, B. P. Gottich and R. Stumpf, *J. Gen. Chem. U.S.S.R.* **29**, 1320 (1959).



IV V VI

The yields of products obtained by ketovinylation of β-dicarbonyl compounds with one labile hydrogen depend on the nature of the β-dicarbonyl compound, the α-substituted acetoacetates and alkylmalonates resulting in higher yields than the β-diketones. Table 1 shows that the yield of ketovinylation decreases with increasing enolization. The reason for this correlation is not clear and is being investigated.

In contrast ketovinylation of β-dicarbonyl compounds with two α-hydrogen atoms is involved (see below) and in the case of ethyl acetoacetate and malonate leads to complex mixtures thus invalidating the method. It has, however, proved possible to ketovinylate ethyl malonate by reacting the ethoxymagnesium derivative with β-chlorovinylketones in benzene. This proceeds smoothly to give esters of α-carbethoxy-δ-keto-β,γ-unsaturated acids in high yield.[7] The compounds obtained readily form α-pyrone derivatives (see below). With ferric chloride they turn cherry-red indicating a keto-enol tautomerism.

$$RCOCH{=}CHCH(COOEt)_2 \rightleftharpoons R\text{-}\underset{\displaystyle OH}{\overset{\displaystyle |}{C}}{=}CH{-}CH{=}C(COOEt)_2$$

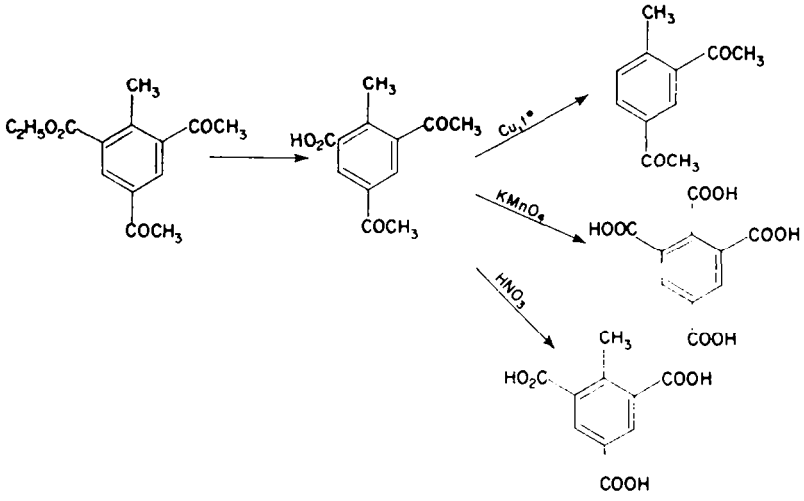
Ketovinylation of ethyl acetoacetate under similar conditions, that is, with ethoxymagnesium derivative failed, but succeeded when treated with methyl-β-chlorovinylketone in boiling dry benzene in the presence of potash giving rise to two compounds.[8,9] One proved to be ethyl 4-methylsalicylate whose structure was established by conversion to methoxyterephthalic acid. The second compound was shown by the following reactions to be 2-methyl-3,5-diacetylbenzoate.

The homologs of methyl-β-chlorovinylketone react similarly with ethyl acetoacetate in the presence of potash following the same scheme to form the two types of compounds.[8,9]

TABLE 1. ENOLIZATION OF β-DICARBONYL COMPOUNDS AND YIELDS OF KETOVINYLATED PRODUCTS

β-Dicarbonyl compound	Enolization (%)		Yields of ketovinylated products
	in abs. alc.	in benzene	
α-Ethyl-acetoacetate	2·8	4·2	55–66
α-n-Butyl-acetoacetate	2·4	6·2	55–66
Carbethoxycyclopentanone	5·9	8·2	64–87
Methylacetylacetone	39·8		44–59
Carbethoxycyclohexanone	61·7	74·8	61–65
Methyldihydroresorcine	93·8		25–26
α-Acetylacetoacetate	96–100		0

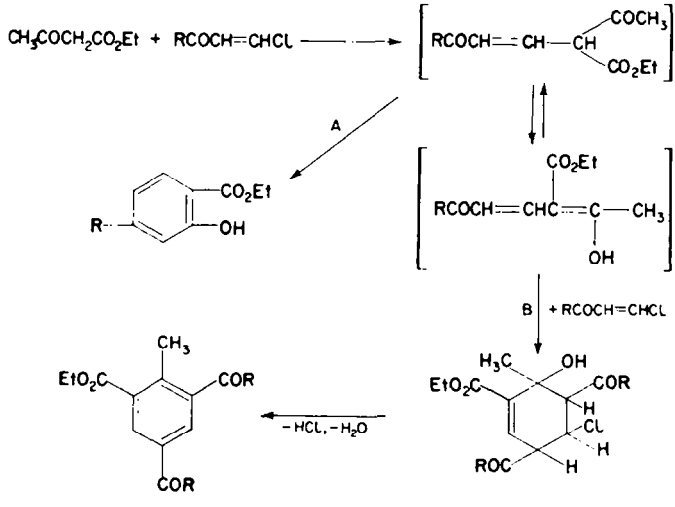
[7] N. K. Kochetkov and L. I. Kudrjashov, *J. Gen. Chem. USSR* **27**, 243 (1957).
[8] N. K. Kochetkov, L. I. Kudrjashov and A. N. Nesmejanov, *Izv. Akad. Nauk. SSSR* 809 (1955).
[9] N. K. Kochetkov, L. I. Kudrjashov and T. M. Senchenkowa, *J. Gen. Chem. USSR* **29**, 650 (1959).



The ratio of the two compounds formed depends on the ratio of ethyl acetoacetate to β-chlorovinyl ketone. Thus, condensation of methyl-β-chlorovinylketone with excess acetoacetate leads to higher yields of 4-methylsalicylate, a tenfold excess yielding 30–40 per cent together with about 20 per cent of 2-methyl-3,5-diacetylbenzoate. On the other hand, decreasing amounts of acetoacetate gives rise to increased yields of 2-methyl-3,5-diacylbenzoate and with ethyl acetoacetate and β-chlorovinylketone in the ratio of 1:1·5 it is the only product being produced in about 80 per cent yield. These alternative routes are of interest in that they facilitate the preparation of 4-alkylsalicylic acids and polysubstituted benzene derivatives.

The formation of these two products may be accounted for as follows: The first condensation product, the ketovinylation of ethyl acetoacetate in the presence of potash, undergoes one of two conversions—either to salicylic acids or polysubstituted benzene derivatives.

Cyclization (route A) following the crotonic acid type condensation proceeds, as it should, with a more active methyl of the acetyl group of the acetoacetate to give



salicylic acid derivatives. In the second type of conversion (route B), undergoes enolization and condenses as a diene with a second molecule of β-chlorovinylketone, this reaction being possible.[1] The unstable adduct so formed loses water and hydrogen chloride and undergoes aromatization to a polysubstituted benzene derivative. In this connexion, the behaviour of the enolic form of γ-ketoalkenylacetoacetate as a diene in the diene synthesis is of interest. Such a type of diene being hitherto unknown and this reaction being a new diene synthesis. While this work was in progress, Braude[10] published the dimerization of mesityl oxide by the action of lithium and postulated the diene condensation with mesityl oxide enolate. Thus, the ketovinylation of compounds involving more than one labile hydrogen is complicated by fast conversion processes of starting products of mono-ketovinylation. The third route consists in the ready cyclization of the above products to α-pyrone derivatives, as shown below.

The configuration of ketovinylation products

There is no information in the literature on the configuration of β-chlorovinylketones although their synthesis by condensation of acyl chlorides with acetylene in the presence of aluminium chloride,[1] suggests the more stable *trans*-configuration. This has been proved experimentally.[11]

Oxidation of β-methylchlorovinylketone with sodium hypochlorite at room temperature under carefully controlled conditions results in *trans*-β-chloroacrylic acid as the only product. Therefore, methyl-β-chlorovinylketone as well as all its homologs obtained under similar conditions must be *trans*.

The configuration of ketovinylation products of β-dicarbonyl compounds was determined by investigation of infra-red spectra,[12] purely chemical methods being impossible due to ease of isomerization at the double bond. Infra-red spectra of α-ethyl-α-(3-ketobutenyl)-acetoacetate (11, $R = R' = CH_3$, $R'' = C_2H_5$) and (3-ketobutenyl)-methylacetylacetone (111, $R = CH_3$) revealed an intensive band at 986–984 cm^{-1} due to non-planar deformation vibrations of hydrogen atoms and appearing only with *trans*-configuration at the double bond. This indicates that the ketovinylation products (1, 11 and 111) must be *trans* and, hence, the ketovinylation reaction proceeds without change of configuration.

As these compounds were isolated by distillation at high temperatures, isomerization of the primarily reaction products during isolation and purification could not be avoided.

In order to remove all doubt the configuration of phenyl-1-3-ketobutenylsulphone (VII), produced by the reaction of methyl-β-chlorovinylketone and sodium phenylsulphinate[13] under conditions that preclude isomerization during ketovinylation, was determined,

$$CH_3COCH{=}CHSO_2C_6H_5.$$
VII

Infra-red spectra of VII and its dinitrophenylhydrazone reveal an intensive band in the 983 cm^{-1} range, thus indicating a *trans*-configuration. The crystalline sulphone

[10] E. Braude, B. Jofton, L. Lowe and E. Waight, *J. Chem. Soc.* 4054 (1956).
[11] N. K. Kochetkov, B. P. Gottich, M. Ia. Karpeisky and R. M. Chomutov, *Chem. Nauka i prom.* 3, 834 (1958).
[12] N. K. Kochetkov, B. P. Gottich, W. G. Winokurov and R. M. Chomutov *Dokl. Akad. Nauk SSSR* 125, 89 (1959).
[13] N. K. Kochetkov and W. N. Winogradowa, *J. Gen. Chem. U.S.S.R.* 27, 2745 (1957).

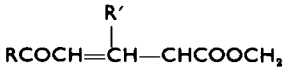
VII when exposed for over 100 hours to ultra-violet irradiation becomes liquid. The infra-red spectra of the liquid sulphone (not distilled to avoid any possible isomerization) and its dinitrophenylhydrazone show no absorption bands in the 990–965 cm^{-1} range, indicating a *cis*-configuration. Therefore, the crystalline sulphone is *trans* and the 983–986 cm^{-1} band is characteristic of the *trans*-double bond in the systems under investigation.

Ketovinylation products have therefore, a *trans*-configuration and the starting β-chlorovinylketones retain their configuration during the reaction. This can be accounted for in terms of the substitution mechanism of the halogen atom in β-chlorovinylketones previously suggested by one of the authors.[1]

Synthesis of unsaturated aliphatic keto-acids and diketones

Esters of δ-keto-α-carbethoxy-β,γ- unsaturated acids (I) and those of δ-keto-α-acyl-β,γ-unsaturated acid (II) produced by ketovinylating alkylmalonates and alkylacetoacetates can be used as starting compounds for the syntheses of unsaturated aliphatic keto acids.

Compounds of the type I on treatment with basic agents undergo a characteristic conversion, one of the carbethoxy groups splitting off, and producing esters of δ-keto-β,γ-unsaturated acids VIII, vinylogs of α-alkylacetoacetates.[14]

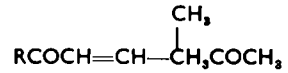


VIII

This conversion is similar to that of acylmalonates,[15] this reaction being a new example of vinylogy. It takes places under the action of potassium hydroxide in methanol and is accompanied by *trans*-esterification of the ester grouping. The use of ethanol leads to poorer results. It is more convenient to obtain esters of δ-keto-β,γ-unsaturated acids VIII from esters of δ-keto-α-acyl-β,γ-unsaturated acids II, by treatment with bases.[16]

Compounds of type II being labile, strong bases (alcoholates and alkali) fail owing to complicated cyclization processes, but with aqueous ammonia and ammonium chloride the reaction produces a high yield of VIII.

There is an optimum ammonia concentration for the conversion of each particular compound, as an increase in molecular weight hinders the formation of VIII. A similar conversion is also observed for triketones[5] of type III. Treatment with aqueous sodium hydroxide at room temperature gives rise to smooth cleavage of acyl groups yielding a high percentage of unsaturated diketones,[5] vinylogs of β-diketones.



IX

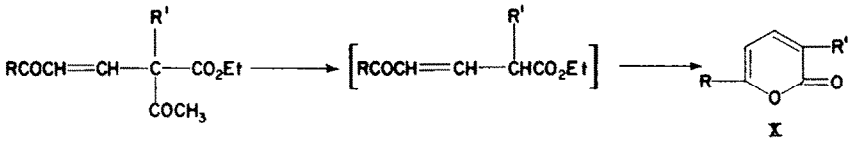
An attempt to degrade the ketovinylation product of ethyl malonate (I, R′ = H) to obtain vinylogs of esters of unsubstituted β-ketoacids failed, but these compounds have been obtained in an indirect way (see below).

[14] N. K. Kochetkov, L. I. Kudrjashov and R. A. Aleewa, *J. Gen. Chem. U.S.S.R.* **27**, 2166 (1957).
[15] M. Conrad, C. Bischoff and M. Gutzeit, *Liebigs Ann.* **214**, 31 (1882).
[16] N. K. Kochetkov and B. P. Gottich, *J. Gen. Chem. U.S.S.R.* **28**, 2732 (1958).

Synthesis of α-pyrone derivatives

The action of acidic reagents on the ketovinylation products of types I, II, IV, and V has been investigated and in each case cyclization to α-pyrone derivatives takes place.

Heating esters of δ-keto-α-acyl-β,γ-unsaturated acids (II) with mineral acids, (best of all with a mixture of hydrochloric and acetic acid) gives rise to 3,6-disubstituted α-pyrones (X) in a high yield.[17] It has been shown[17] that the reaction proceeds through

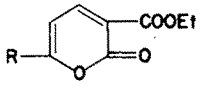


X

a preliminary acidic degradation of II, which is then cyclized in acidic medium to pyrone derivatives.

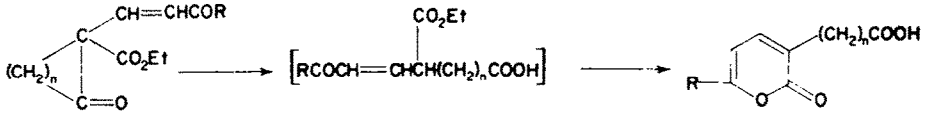
In all cases of acidic degradation investigated no ketonic scission could be effected.

The pyrone derivatives are most readily produced from ketovinylation products of ethyl malonate, that is from esters of δ-keto-α-carbethoxy-β,γ- unsaturated acids (I). The latter are cyclized to esters of 6-substituted pyronecarboxylic acids (XI) under the action of various acidic agents as well as at elevated temperatures.[7] These reactions present difficulties when isolating I in a pure state as on distillation α-pyrone derivatives are readily produced. Compound XI is best produced by heating I with acetic anhydride and acetyl chloride, it not being necessary to purify I first.[18]



XI

The ketovinylation products of cyclic β-ketoacids IV and V when treated with a mixture of hydrochloric and acetic acids also give rise to α-pyrone derivatives. This is accompanied by the simultaneous opening of the alicyclic ring to give previously unavailable (6-alkyl-α-pyronoyl-3)-alkancarboxylic acids XII.[17]



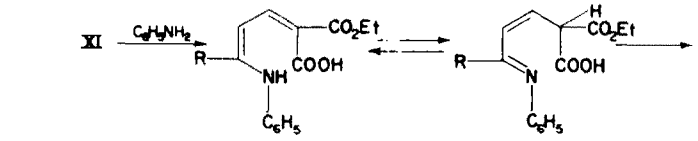
n=3,4 XII

Ketovinylation products of dicarbonyl compounds are therefore useful starting products for the synthesis of a variety of pyrone derivatives.

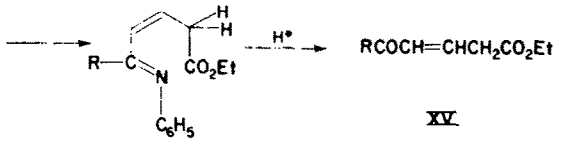
In conclusion, starting with α-pyrone derivatives, namely with 6-alkyl-3-carbethoxy-α-pyrones, we succeeded in obtaining formerly unknown vinylogs of β-ketoacids. This synthesis is possible due to our new method of opening the α-pyrone ring.[19] It has been shown that the reaction of 6-methyl-3-carbethoxy-α-pyrone XI and aniline leads to the opening of the ring to form α-carbethoxy-δ-N-phenylaminosorbic acid

[17] N. K. Kochetkov and B. P. Gottich, *J. Gen. Chem. U.S.S.R.* **29**, 1324 (1959).
[18] N. K. Kochetkov and L. I. Kudrjashov, *J. Gen. Chem. U.S.S.R.* **28**, 1511 (1958).
[19] N. K. Kochetkov and L. I. Kudrjashov, *J. Gen. Chem. U.S.S.R.* **28**, 3020 (1958).

(XII, R = CH_3) which, on careful heating decarboxylates to δ-N-phenylaminosorbic acid (XIV, R = CH_3). The latter on treatment with dilute acids, splits off aniline giving ethyl-5-keto-hexene-3-oate (XV, R = CH_3), a vinylog of ethyl acetoacetate.



XIII



XIV XV

Similarly, other 6-alkyl-3-carbethoxy-α-pyrones give rise to vinylogs of esters of β-ketoacids (XV R = C_3H_7, n—C_5H_{11}).

EXPERIMENTAL

Ketovinylation of esters of alkylmalonic acid. To a suspension of sodium ethyl alkylmalonate (0·2 mole) in benzene (200 cc) cooled with ice, a solution of β-chlorovinylketone (0·2 mole) in dry benzene (100 cc) was gradually added (1 hr) with stirring and the reaction mixture then refluxed for 2–2½ hr. After treatment with water and further extraction with benzene, the solvent was removed and the residue distilled *in vacuo*. The constants, yields, and analyses of the alkyl-(3-ketoalkenyl) malonates produced are listed in Table 2. Ketovinylation of α-alkylacetoacetates, cyclic β-ketoacids, and methylacetoacetone was achieved under similar conditions and the constants, yields, and analyses of the products obtained are listed in Tables 3, 4, 5.

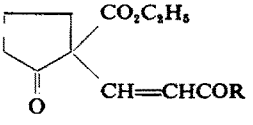
Ketovinylation of methyldihydroresorcine and methyldimedone. In contrast, the sodium derivatives of cyclic β-diketones were prepared in absolute methanol, the alcohol substituted by dioxan and twice

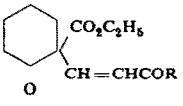
TABLE 2. $RCOCH{=}CHC(CO_2Et)_2$ (R′)

N°	R	R′	Yield (%)	b.p.	d_4^{20}	n_D^{20}	% C		% H	
							Found	Calc.	Found	Calc.
1	CH_3	C_2H_5	56	125–126°/2 mm	1·0598	1·4543	61·33 61·41	60·91	7·95 8·08	7·87
2	CH_3	C_3H_7	56	163°/8 mm	1·0437	1·4553	62·36 62·42	62·19	8·27 8·36	8·20
3	CH_3	C_4H_9	35	154–157°/4 mm	1·0326	1·4559	63·10 63·07	63·35	8·59 8·58	8·51
4	C_2H_5	C_3H_7	94	169–171°/9 mm	1·0350	1·4575	63·27 63·35	63·35	8·64 8·62	8·51
5	C_7H_{15}	C_3H_7	70	177–178°/1 mm	0·9901	1·4581	68·12 67·92	67·76	9·66 9·53	9·66
6	C_6H_5	C_3H_7	64	204–205°/4 mm	m.p. 39°		68·84 68·84	68·66	7·51 7·41	7·28

TABLE 3. $CH_3COCRCO_2C_2H_5$ (CH=CHCOR′)

R	R′	b.p.	d_4^{20}	n_D^{20}	Yield	Analyses	
						Found	Calc.
C_2H_5	CH_3	108–110°/1 mm	1·0550	1·4670	64·5%	C 63·71 H 8·02	C, 63·91, 63·84 H, 8·07, 8·12
C_2H_5	C_2H_5	115–117°/1 mm	1·0415	1·4665	56·5%	C 64·97 H, 8·39	C, 65·32, 65·20 H 7·99, 8·05
C_2H_5	C_3H_7	120–122°/1 mm	1·0270	1·4657	64%	C, 66·11 H, 8·72	C, 66·02, 65·89 H, 8·53, 8·56
n—C_4H_9	CH_3	125–126°/1 mm	1·0274	1·4662	55%	C 66·11 H, 8·72	C, 65·98, 66·13 H, 8·77, 8·90
n—C_4H_9	C_2H_5	129–131°/2 mm	1·0157	1·4660	54%	C, 67·13 H, 9·01	C, 66·97, 67·01 H, 9·39, 9·42
n—C_4H_9	C_3H_7	137–138°/1 mm	1·0007	1·4650	66%	C, 68·06 H, 9·28	C, 68·30, 68·56 H, 9·48, 9·40

TABLE 4. 

R	b.p.	m.p.	d_4^{20}	n_D^{20}	Yield	Analysis	
						Found	Calc.
CH_3	147–149/3 mm	—	1·1112	1·4880	65%	C, 64·28 H, 7·19	C, 64·41, 64·68 H, 7·35, 7·52
C_2H_5	153–155/3 mm	—	1·0958	1·4862	64%	C, 65·53 H, 7·62	C, 65·72, 65·86 H, 7·81, 7·87
C_3H_7	149–152/2 mm	—	1·0767	1·4840	67%	C, 66·63 H, 7·98	C, 66·54, 66·61 H, 7·98, 8·18
C_6H_5	154–156/0·03 mm	60–65°	— 	—	49%	C, 71·33 H, 6·68	C, 71·60, 71·71 H, 6·48, 6·54
CH_3	163–164/4 mm	28·5–29°	—	—	64%	C, 65·56 H, 7·61	C, 65·72, 65·67 H, 7·40, 7·48
C_3H_7	168–169/2 mm	—	1·0722	1·4868	61%	C, 67·72 H, 8·33	C, 67·90, 67·82 H, 8·51, 8·52
C_6H_5	—	72–73°	—	—	65%	C, 71·98 H, 6·71	C, 71·89, 71·99 H, 6·94, 6·89

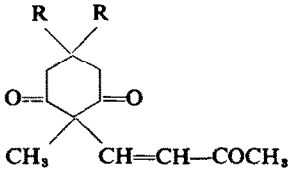
the required amount of methyl-β-chlorovinylketone used. After refluxing and cooling for 4 hr, the precipitate was filtered off, the solvent removed and the residue distilled *in vacuo*. The oils gradually crystallized and were recrystallized from dry ether. Constants, yields, and analyses of compounds obtained are listed in Table 6.

Ketovinylation of ethyl malonate. To magnesium (4·8 g), activated with iodine, a mixture of absolute alcohol (25 cc) and ethyl malonate (33·6 g), were added (heating if necessary to start the reaction) and gradually more alcohol (100 cc) was added with heating until a solution was obtained. Alcohol was then removed *in vacuo* and the residue dissolved in toluene (100 g). To the ethoxymagnesium malonate cooled to −10°, β-chlorovinylketone (0·15 mole) was added with stirring and left overnight. Cold water (100 cc) and conc hydrochloric acid (25 cc) were added, the organic layer isolated and the

TABLE 5. $CH_3COCCOCH_3$ (CH=CHCOR)

R	b.p.	d_4^{20}	n_D^{20}	Yield	Analyses	
					Found	Calc.
CH_3	100–101°/1 mm	1·0609	1·4860	59%	C, 65·91 H, 7·80	C, 66·27, 66·12 H, 7·78, 7·79
C_2H_5	106–107·5°/1 mm	1·0400	1·4822	44%	C, 67·32 H, 8·22	C, 67·56, 67·34 H, 8·24, 8·14
C_3H_7	116–118°/1 mm	1·0215	1·4795	59%	C, 68·55 H, 8·63	C, 68·86, 68·82 H, 8·82, 8·76

TABLE 6.



R	b.p.	m.p.	Yield	Analyses	
				Found	Calc.
H	147–154°/4 mm	61–63·5°	26%	C, 68·02 H, 7·26	C, 68·26, 68·53 H, 7·43, 7·44
CH_3	147–149°/2 mm	37–38°	35%	C, 70·24 H, 8·16	C, 70·54, 70·65 H, 8·35, 8·25

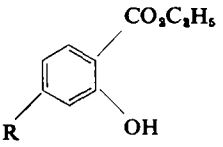
TABLE 7. $R—CO—CH=CH—CH(CO_2C_2H_5)_2$

No.	R	Yield	b.p.	d_4^{20}	n_D^{20}	MRD		% C		% H	
						Found	Calc.	Found	Calc.	Found	Calc.
1	CH_3	69·6	121–122/3 mm	1·1086	1·4646	56·88	55·85	57·66 57·70	57·88	7·04 7·04	7·07
2	C_2H_5	44	130–134/2 mm	1·0857	1·4611	61·25	60·48	59·17 59·30	59·49	7·67 7·69	7·49
3	C_3H_7	67	90–93/0·06 mm	1·061	1·4581	65·47	65·09	60·77 60·55	60·92	7·96 7·82	7·87

water layer extracted with toluene. After removing the solvent, the residue was distilled *in vacuo* in the presence of hydroquinone. Constants, yields, and analyses of the substance obtained are listed in Table 7.

Ethyl 4-alkylsalicylate. To a boiling mixture of ethyl acetoacetate (260 g), ground potash (30 g), and absolute toluene or xylol (100 cc), a solution of β-chlorovinylketone (0·2 mole) in 100 cc of solvent was added dropwise during 8 hr, heating continued for 1 hr, cooled, the residue filtered, washed with benzene, the filtrates evaporated and ethyl 4-alkylsalicylate isolated by distillation. The yield and constants of compounds obtained are listed in Table 8.

TABLE 8.



N°	R	Yield	b.p.	d_4^{20}	n_D^{30}
1	CH_3	39·2	129–132/11 mm	1·0915	1·5174
2	C_3H_5	18	141–142/15 mm	1·0784	1·5162
3	n-C_4H_9	17	138–140/6 mm	1·0836	1·5165
4	n-C_4H_9	18	148·5–150/9 mm	1·0878	1·5118

Ethyl 2-methyl-3,5-diacetylbenzoate. To a mixture of ethyl acetoacetate (260 g), finely ground anhydrous potash (2·76 g) and absolute benzene (180 cc), methyl-β-chlorovinylketone (133 g; 1·3 moles) was added during 1 hr with stirring. After refluxing for 4 hr, water (250 cc) was added, the benzene layer separated, the water layer extracted with ether, the combined extracts evaporated and ethyl 2-methyl-3,5-diacetyl benzoate distilled *in vacuo*, b.p. 160–165°/1 mm, yield 120·5 g (81%). After seeding, the compound crystallized, m.p. 61° and was recrystallized first from petroleum-ether benzene and then from aqueous methanol. (Found: C, 68·05, 67·97; H, 6·57, 6·52. $C_{14}H_{16}O_4$ requires: C, 67·76; H, 6·49%).

Ethyl 2-methyl-3,5-dibenzoylbenzoate was similarly obtained in 85·5% yield, m.p. 104° from aqueous alcohol. (Found: C, 77·79, 77·58; H, 5·51, 5·52. $C_{24}H_{20}O_4$ requires: C, 77·40; H, 5·41%).

Oxidation of methyl-β-chlorovinylketone with sodium hypochlorite. To an aqueous solution (820 cc) containing about 80 g sodium hypochlorite, methyl-β-chlorovinyl-ketone solution (15·6 g) in dioxan (50 cc) was added during 15–20 min keeping the temp at 29–30°. The mixture then stirred for 3½–4 hr at room temp, and the excess sodium hypochlorite eliminated. The solution obtained was reduced *in vacuo* (the water-bath temp not exceeding 40°) to 150–200 cc, acidified with 50% sulphuric acid and repeatedly extracted with ether; dried with $MgSO_4$ and the solvent removed. The solid dissolved in absolute alcohol (75 cc) was neutralized with potassium hydroxyde to pH 7–7·5. After 2 days only a trace of inorganic matter was precipitated from the alcoholic solution (0·04 g) indicating the absence of *cis*-β-chloroacrylic acid as the oxidation product (potassium salt of *cis*-β-chloroacrylic acid is insoluble in absolute ethyl alcohol). After acidifying and removing the solvent, *trans*-β-chloroacrylic acid was isolated from the alcoholic solution (7·8–8·0 g, 50%). After the second recrystallization from dil hydrochloric acid the m.p. of the compound was 84·86°. Lit. m.p. 85·5–86°[20] (Found: Cl, 33·44, 33·25. $C_3H_3O_2Cl$ requires: Cl, 33·28%).

Phenyl-(3-ketobutenyl)-sulphone and its conversions under the action of ultra-violet light. Phenyl-(3-ketobutenyl)-sulphone was prepared according to Kochetkov and Vinogradova[13] in 84% yield, m.p. 61–62°. The 2,4-dinitrophenylhydrazone was obtained from 96% ethyl alcohol in the presence of conc sulphuric acid as orange needles, m.p. 215–216° and crystallized from ethyl acetate. (Found: N, 14·56, 14·43. $C_{16}H_{14}N_4O_6S$ requires; N, 14·35%). (Infra-red spectra, see Fig. 1.) Two 1 g samples of phenyl (3-ketobutenyl) sulphone were each added to cryoscopic benzene (7 cc) in quartz ampoules and exposed to ultra-violet light for 50 hr, (see Fig. 2). One tube was then broken and the benzene removed *in vacuo*. From the residue, a colourless oil, (infra-red spectra of the sample are given in Fig. 2) the original phenyl-(3-ketobutenyl)-sulphone gradually crystallized. The second ampoule was broken after exposure to ultra-violet light for 100 hr. The product was a yellow non-crystallizable oil, (infra-red spectra of the sample are given in Fig. 2) n_D^{20} 1·5560. (Found: C, 57·65, 57·40; H, 4·83, 4·89. $C_{10}H_{10}O_3S$ requires: C, 57·12; H, 4·72%). The 2,4-dinitrophenylhydrazone was obtained as yellow needles, m.p. 189–190° from ethyl acetate. (Found: N, 14·24. $C_{16}H_{14}N_4O_6S$ requires: N, 14·35%). A m.p. of a mixture with 2,4-dinitrophenylhydrazone produced from the starting sulphone showed a depression. The infra-red spectra of the 2,4-dinitrophenylhydrazone are shown in Fig. 1.

Cleavage of α-alkyl-α-(3-ketoalkenyl)-malonates in the presence of alkali. α-Alkyl-α-(3-keto-alkenyl)-malonate (0·12 mole) was gently refluxed for 30 min in a solution of potassium hydroxide

[20] H. J. Backer and A. E. Beute, *Rec. Trav. Chim.* **54**, 167 (1935).

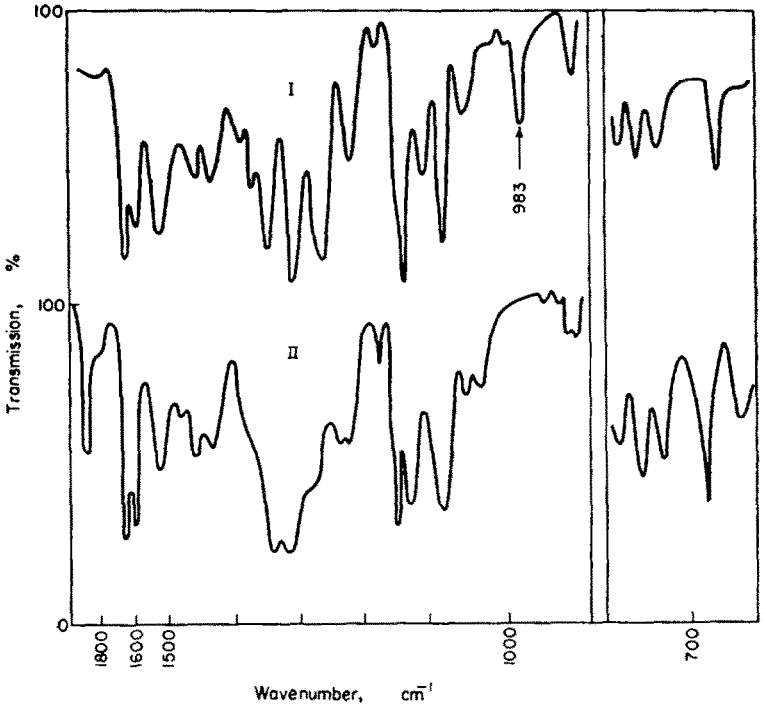


FIG. 1. Infra-red spectra: I—2,4-dinitrophenylhydrazone of *trans*-phenyl-(3-ketobutenyl)-sulphone; II—2,4-dinitrophenylhydrazone of *cis*-phenyl-(3-ketobutenyl)-sulphone.

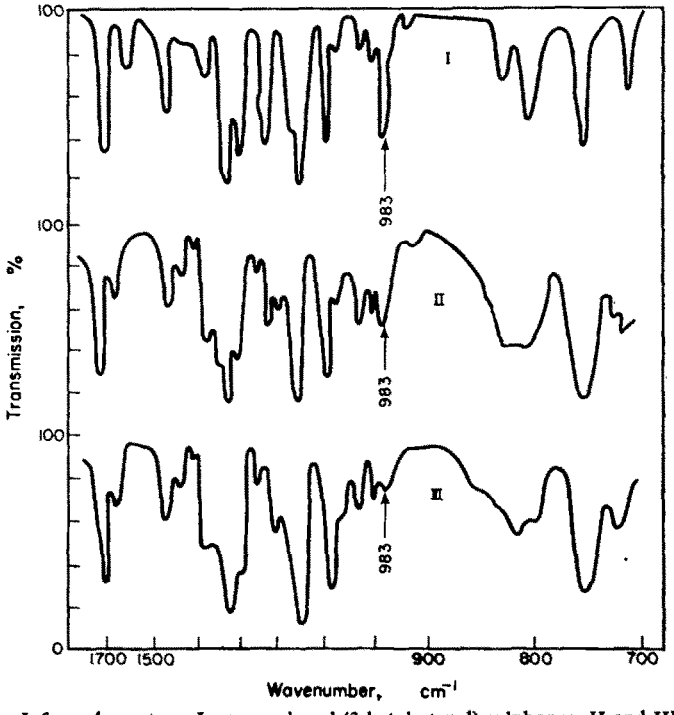


FIG. 2. Infra-red spectra: I—*trans*-phenyl-(3-ketobutenyl)-sulphone; II and III—sulphone after action of ultra-violet light for 50 and 100 hr respectively.

(26·5 g) dissolved in the minimum of water. After 1 hr it was filtered, the filtrate evaporated *in vacuo*, 200 cc water added, acidified with 10% hydrochloric acid to pH 3–4, extracted with ether, the ether removed and the residue distilled *in vacuo*. Yields, constants, and analyses of compounds obtained are listed in Table 9.

TABLE 9. R-COCH=CHR'CO_2CH_3

N°	R	R'	Yield %	b.p.	d_4^{20}	n_D^{20}	MRD		% C		% H	
							Found	Calc.	Found	Calc.	Found	Calc.
1	CH_3	C_2H_5	63	104–105/6 mm	1·0210	1·4625	45·87	44·96	63·63 63·75	63·51	8·18 8·28	8·29
2	CH_3	C_3H_7	60	105–106/5 mm	1·0033	1·4605	50·33	49·58	65·48	65·19	8·90	8·75
3	C_2H_5	C_3H_7	94	111–112/4 mm	0·9944	1·4683	55·45	54·20	66·50 66·62	66·64	9·08 9·11	9·15
4	C_7H_{15}	C_3H_7	63	145/1 mm	0·9508	1·4638	77·86	77·29	71·87 71·79	71·60	10·54 10·56	10·52

Cleavage of α-alkyl-α-(3-ketoalkenyl)-acetoacetates with aqueous ammonia

Ethyl α-(3-ketobutenyl)-butyrate. Ammonium chloride (32 g) was dissolved in water (150 cc), aqueous ammonia (34 cc, *d* 0·9) added, the solution heated to 45° and poured into α-ethyl-α-(3-ketobutenyl)-acetoacetate (56·4 g, 0·25 mole). The reaction was carried out with stirring for 15–17 min at 50–55°, then cooled to room temp. An oil separated, the water layer was extracted with ether, the solvents removed and the residue distilled *in vacuo*. Other α-ethyl-α-(3-ketoalkenyl)-acetoacetates were cleaved in a similar manner, an optimum ammonia concentration being chosen for each particular case. Yields, constants and analyses of compounds obtained are listed in Table 10.

TABLE 10. RCOCH=CHCHR'$CO_2C_2H_5$

R	R'	b.p.	d_4^{20}	n_D^{20}	Yield	Analyses	
						Found	Calc.
CH_3	C_2H_5	85–88°/1 mm	1·0058	1·4560	70%	C, 64·96, 64·92 H, 8·78, 8·95	C, 65·19 H, 8·75
C_2H_5	C_2H_5	88–91°/1 mm	0·9907	1·4562	70%	C, 66·27, 66·43 H, 9·27, 9·14	C, 66·64 H, 9·15
C_3H_7	C_2H_5	92–94°/1 mm	0·0726	1·4561	41·5%	C, 67·85, 67·89 H, 9·68, 9·61	C, 67·89 H, 9·50

TABLE 11. RCOCH=CHCH(CH_3)$COCH_3$

R	b.p.	d_4^{20}	n_D^{20}	Yield	Analyses	
					Found	Calc.
CH_3	74–75·5°/1 mm	0·9979	1·4756	76·5%	C, 68·54 H, 8·63	C, 68·22, 68·45 H, 8·52, 8·62
C_2H_5	82–83°/1 mm	0·9809	1·4748	76·5%	C, 70·10 H, 9·15	C, 69·92 H, 9·38
C_3H_7	87–88·5°/1 mm	0·9648	1·4723	81·5%	C, 71·39 H, 9·59	C, 71·22, 71·44 H, 9·60, 9·89

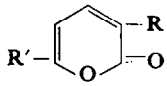
Unsaturated δ-diketones. To potassium hydroxide solution (0·13 mole) in water (65 cc) methyl-(3-ketoalkenyl)-acetylacetone (0·06 mole) was added, the mixture being stirred at 10–15° for 20 min, the undissolved oil extracted with ether, and the remaining solution acidified with 50% sulphuric acid. An oil separated, the water layer was extracted with ether, the ether removed and the residue distilled in a nitrogen atmosphere *in vacuo*. The constants, yields, and analyses of compounds obtained are listed in Table 11.

3,6-*Disubstituted, α-pyrones*

Synthesis of 3,6-dialkyl-α-pyrones from α-ethyl-α-(3-ketoalkenyl)-acetoacetates. α-Ethyl-α-(3-ketoalkenyl)-acetoacetate (0·16 mole) was refluxed for 3½ hr with a mixture of conc hydrochloric (80 cc) and glacial acetic acids in amounts necessary to keep the reaction mixture homogeneous. The mixture was then poured into water, (150–200 cc), the oil separated, the water layer extracted with ether, the ether removed, and the residue distilled *in vacuo*. The constants, yields, and analyses of compounds obtained are listed in Table 12. 3,6-Disubstituted pyrones are formed under similar conditions from ketovinylation products of cyclic-β-ketoacids. Thus, for example, 1-carbethoxy-1-(3-ketohexenyl)-cyclopentanone-2 gives ω-(6-propyl-α-pyronoyl-3)-butyric acid in 56% yield, the constants and analyses being listed in Table 12.

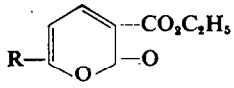
6-*Alkyl-3-carbethoxy-α-pyrones.* 3-Ketoalkenylmalonate (0·03 mole) was refluxed for 2 hr with acetyl chloride (5 cc), the 6-alkyl-3-carbethoxy-α-pyrone produced being isolated either by precipitation with petroleum ether or distillation. The yields, constants, and analyses of compounds obtained are listed in Table 13.

TABLE 12.



R′	R	b.p.	d_4^{20}	n_D^{20}	Yield	Analyses	
						Found	Calc.
CH_3		87–88°/1 mm	1·0643	1·5168	71%	C, 69·54 H, 7·29	C, 69·56, 69·68 H, 7·48, 7·43
C_2H_5	C_2H_5	74–76°/1 mm	1·0492	1·5105	67·5%	C, 71·02 H, 7·95	C, 70·85, 70·76 H, 8·02, 8·11
C_3H_7		79–81°/1 mm	1·0167	1·5060	71%	C, 72·26 H, 8·48	C, 72·43, 72·51 H, 8·79, 8·72
C_3H_7	$(CH_2)_3COOH$	195–202°/2 mm	—	1·5232	56%	C, 64·28 H, 7·19	C, 64·70, 64·75 H, 7·43, 7·48

TABLE 13.



N°	R	Yield %	m.p.	b.p.	d_4^{20}	n_D^{20}	% C		% H	
							Found	Calc.	Found	Calc.
1	CH_3	53	86°	—	—	—	59·24 59·19	59·34	5·30 5·46	5·53
2	C_2H_5	92	—	162–163/7 mm	1·1767	1·5265	60·95 60·88	61·21	6·38 6·40	6·17
3	C_3H_7	68	—	164–166/6 mm	1·1285	1·5770	62·88 62·95	62·84	6·83 6·88	6·71