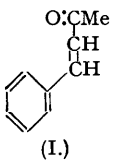
49. *The Absorption Spectra of Organic Compounds containing Nitrogen. Part II. Benzylidene Derivatives of Hydantoin and Thiohydantoin.*

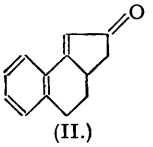
By R. E. Stuckey.

The ultra-violet absorption spectra of derivatives of 5-benzylidenehydantoin and 2-thio-5-benzylidenehydantoin are given. Evidence from the spectra in acid and alkaline solution of various methylation products of these two compounds indicates the probability of varying types of tautomerism. Replacement of oxygen by sulphur in the 2-thio-series causes a general shift of the absorption to longer wave-lengths. Methylation of 2-thio-compounds confirmed the production of derivatives of the thiol form ·N:C(SH)· in contrast to the 2-oxy-compounds which form *N*-methyl products. The chromophoric grouping Ph·C:C·C:O is present in most of the compounds studied, and the characteristic bands reported by Wilds *et al.* (*J. Amer. Chem. Soc.*, 1947, **69**, 1985) are shown although the presence of the hydantoin ring containing the ·NH·CO· group causes modification in the values for $\lambda_{max.}$. Any tautomerism in the hydantoin ring produces spectrum changes which are secondary to the main spectrum of this chromophoric group and hence are more difficult to interpret. The spectra of the analogous open-chain compounds cinnamoylurea and acetylbenzylidenecreatinine, and of the ring compound 2-imino-5-benzylidenethiazolid-4-one are reported.

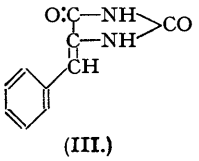
In Part I (*J.*, 1947, 331) the ultra-violet absorption spectra of hydantoin derivatives were studied. A similar examination has now been made for 5-benzylidene- and 2-thio-5-benzylidene-hydantoin where several types of dissociation and enolisation are possible. The absorption spectra of αβ-unsaturated ketones conjugated with an aromatic nucleus have been studied by Wilds *et al.* (*J. Amer. Chem. Soc.*, 1947, **69**, 1985) who found that benzylideneacetone (I) and the ketone (II) had almost identical spectra, with a main maximum at 286—287 mμ, the point of interest in connection with the present work being that ring formation in (II) did not materially affect the spectrum. The spectra of derivatives of 5-benzylidenehydantoin (III) agreed in general with the results of Wilds *et al.* (*loc. cit.*) although, as might be expected, considerable modifications were shown due to the influence of ring formation and of associated ·NH·CO· groups.



(I.)



(II.)



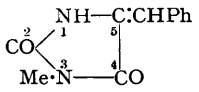
(III.)

Examination of the absorption spectra of the methylated derivatives of hydantoin has given evidence bearing on the type of enolisation occurring in alkaline solution. In the compounds studied, however, the conjugated system Ph·C:C·C:O with two main bands dominates the general spectrum, the changes due to enolisation being secondary and hence more difficult to interpret as will be seen from the results obtained.

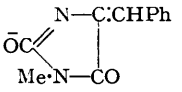
5-Benzylidenehydantoins exist in two stereoisomeric forms and it is to the commoner *cis*-series of compounds (according to Johnson and Bates, *J. Amer. Chem. Soc.*, 1915, **37**, 384) that the present work relates. The absorption spectrum of 5-benzylidenehydantoin in alcohol has been reported by Asahina (*J. Chem. Soc. Japan*, 1930, **5**, 354, using a varying tube thickness method) and by Hahn and Evans (*J. Amer. Chem. Soc.*, 1928, **50**, 806), although graphical results only were given and the effects of acid and alkali were not studied. 5-Benzylidene-hydantoin (III) in alcoholic solution shows a peak absorption, $\lambda_{max.}$ 320 mμ, not altered by the

addition of hydrochloric acid, but decreased and with a broadened band in solution in *N*/100-sodium ethoxide or in aqueous sodium hydroxide. It is difficult to decide whether this change of absorption is due solely to the formation of the ion or whether there is an accompanying enolisation.

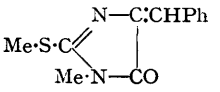
When prepared by an acid condensation process, 5-benzylidenehydantoin is slightly yellow, and repeated crystallisation from alcohol does not remove all colour, although when freshly precipitated by acid from aqueous alkali, the substance appears to be white. Alkaline condensation in the presence of piperidine, however, produces a white or colourless form changing to yellow on heating in acetic acid. Hahn and Edicott (*J. Amer. Chem. Soc.*, **1937**, **59**, 2740) suggested that the yellow and the white form might represent lactim and lactam forms of the hydantoin molecule. The present work did not produce evidence to support this contention as yellow 5-benzylidenehydantoin when allowed to crystallise spontaneously from alcohol produced yellow and white crystals in a manner suggesting that the yellow colour was due to a trace of impurity. Further, solutions prepared from white (alkaline condensation) and yellow (acid condensation) material showed identical spectra under the varying pH conditions studied.



(IV.)



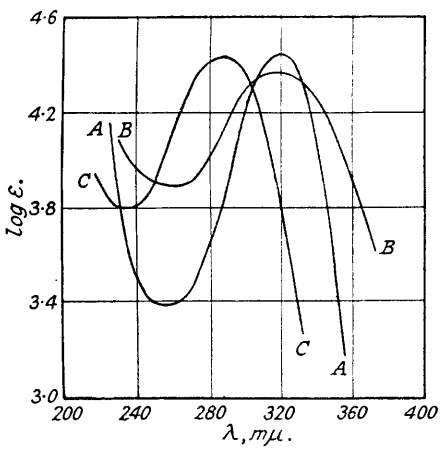
(V.)



(VI.)

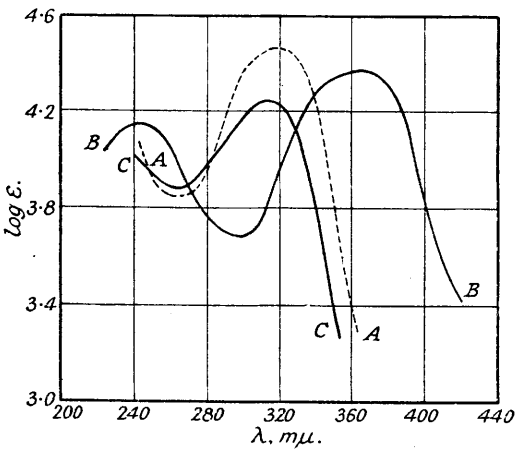
5-Benzylidene-3-methylhydantoin (IV) shows a spectrum in alcohol not vastly different from 5-benzylidenehydantoin. The addition of alkali, however, produces a shift in peak absorption to longer wave-lengths as well as a decrease in $\varepsilon_{max.}$ although a similar absorption shift does not occur with the parent 5-benzylidenehydantoin under the same conditions; this may be due to ionic resonance including possible structures having a double link in the 1 : 2- and in the 2 : 3-position, whereas with 5-benzylidene-3-methylhydantoin a double link is only possible in the 1 : 2-position. For (IV) the most probable ionic structure (V) has the double bond in the 1 : 2-position by analogy with the corresponding 2-thio-5-benzylidene compound which readily forms a 2-mercapto-derivative (VI). It is noteworthy that 3-methylhydantoin shows no spectrum change with varying pH, the change in the corresponding 5-benzylidene compound being attributable to the presence of the doubly linked carbon in the 5-position (IV).

FIG. 1.



A, 5-*Benzylidenehydantoin in alcohol. B*, 5-*Benzylidenehydantoin in* N/100-*alcoholic* NaOEt. *C*, *Cinnamoylurea.*

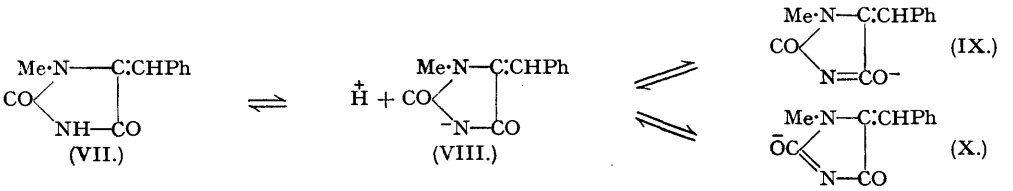
FIG. 2.



A, 5-*Benzylidene*-3-*methylhydantoin in alcohol. B*, 5-*Benzylidene*-3-*methylhydantoin in* N/100-*alcoholic* NaOEt. *C*, 5-*Benzylidene*-1 : 3-*dimethylhydantoin.*

5-Benzylidene-1-methylhydantoin (VII) has a spectrum in alkaline solution differing considerably from those of 5-benzylidenehydantoin and its 3-methyl derivative. In this case electronic rearrangement in the ion may produce two structures (IX) and (X); resonance may afford an explanation of the spectrum differences, or this may be due to the predominance of structure (IX) containing the system Ph·C:C·C:N·. This anomalous spectrum in alkaline

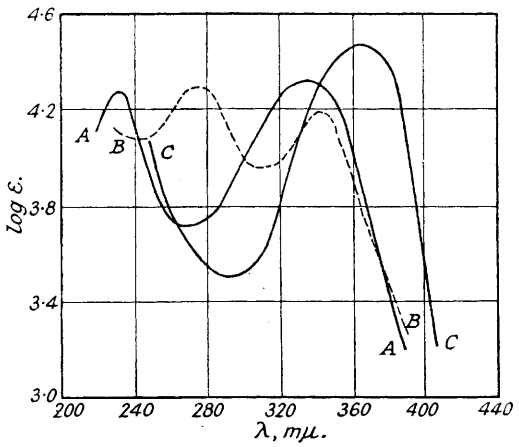
solution is also encountered in the case of the 2-thio-derivative (XII) in which there is a free hydrogen attached to nitrogen in the same relative position.



5-Benzylidene-1 : 3-dimethylhydantoin, as would be expected, shows no alteration of spectrum on change of pH. The value of $\varepsilon_{max.}$ for the main absorption band is lower than the value for this band in the other compounds studied (note also the analogous 2-thio-compound).

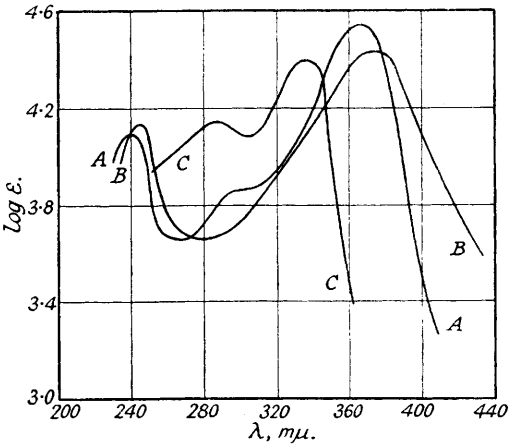
The values of $\lambda_{max.}$ for the main band and for the subsidiary band (where realised) were lower in the case of the 5-benzylidene compounds than for the corresponding 5-anisylidene derivatives (Seikel, *J. Amer. Soc.*, 1937, **59**, 436). Thus in the present work 5-anisylidenehydantoin in alcohol gave $\lambda_{max.}$ 335 mμ, agreeing approximately with that given graphically by

FIG. 3.



A, 5-Benzylidene-1-methylhydantoin in alcohol. B, 5-Benzylidene-1-methylhydantoin in N/100-*alcoholic* NaOEt. *C, Acetylbenzylidenecreatinine in alcohol.*

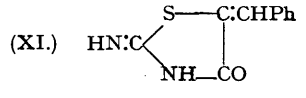
FIG. 4.

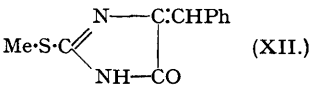


A, 2-Thio-5-benzylidenehydantoin in alcohol. B, 2-Thio-5-benzylidenehydantoin in N/100-*alcoholic* NaOEt. *C, 2-Imino-5-benzylidenethiazolid-4-one.*

Seikel (*loc. cit.*). Thus the introduction of a *p*-methoxy-group into 5-benzylidenehydantoin is responsible for a shift of *ca.* 15 mμ towards the visible, in comparison with 32 mμ for the series of Wild *et al.*

The effect of replacement of oxygen by sulphur is fairly well established in that the absorption is displaced towards the visible. In this case the main maximum is displaced by approximately 50 mμ (see Table), and a number of subsidiary effects associated with the band of shorter wavelength become evident (Figs. 4, 5, and 6); an inflection, log $\varepsilon_{max.}$ *ca.* 3·9, $\lambda_{max.}$ *ca.* 300—310 mμ, is present in many of the spectra. Again in the 2-thio-series, as with the parent 5-benzylidenehydantoins, absorption changes due to ionisation and enolisations and to the replacement of oxygen by sulphur are secondary effects. The main chromophoric grouping Ph·C:C·C:O again dominates the spectrum and, in fact, if the whole hydantoin ring system is substituted by an





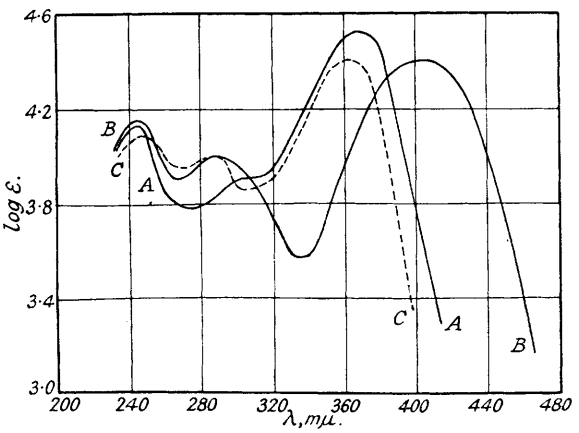
isomeric 5-membered ring system the two main bands characterising the basic spectrum are still present. This is well borne out by a comparison of the spectra of 2-thio-5-benzylidenehydantoin with the 5-benzylidene derivative of 2-iminothiazolid-4-one (XI).

Absorption maxima and wave-lengths.

	$\lambda_{max.}$, mμ.	log $\varepsilon_{max.}$
5-Benzylidenehydantoin :		
In alcohol	320	4·45
In N/100-alcoholic NaOEt	318	4·38
5-Benzylidene-3-methyl-hydantoin :		
In alcohol	317	4·46
In N/100-alcoholic NaOEt	363	4·39
	240	4·15
5-Benzylidene-1-methyl-hydantoin :		
In alcohol	335	4·32
	235	4·28
In N/100-alcoholic NaOEt	340	4·20
	273	4·30
5-Benzylidene-1 : 3-dimethyl-hydantoin :		
In alcohol and N/100-NaOEt	313	4·26
Cinnamoylurea :		
In alcohol, N/100-NaOEt, and N-aqueous HCl	288	4·45
Acetylbenzylidenecreatinine :		
In alcohol	364	4·48
2-Thio-5-benzylidene-hydantoin :		
In alcohol	365	4·53
	~	3·86
	240	4·08
In N/100-alcoholic NaOEt	373	4·43
	245	4·13
2-Imino-5-benzylidene-thiazolid-4-one :		
In alcohol	335	4·38
	287	4·15
* 2-Thio-5-benzylidene-3-methylhydantoin :		
In alcohol and N/100-HCl	370	4·52
	~	3·90
	245	4·13
In N/100-NaOEt	405	4·40
	290	3·98
	245	4·16
2-Methylthio-5-keto-4-benzylidene-1-methyl-dihydroglyoxaline :		
In alcohol, N/100-HCl and N/100-NaOEt	363	4·40
	286	4·00
	245	4·08
2-Thio-5-benzylidene-1: 3-dimethylhydantoin :		
In alcohol, N/100-HCl and N/100-NaOEt	368	4·48
	~	3·95
2-Methylthio-5-keto-4-benzylidenedihydro-glyoxaline :		
In alcohol and N/100-HCl	362	4·45
	267	4·0
	240	4·05
In N/100-NaOEt	382	4·20
	308	4·22
	250	4·0

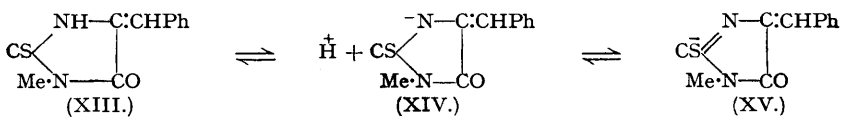
* Reported graphically by Butcher *et al.* (*J. Amer. Chem. Soc.*, 1945, **67**, 1736).

FIG. 5.



A, 2-*Thio*-5-*benzylidene*-3-*methylhydantoin in alcohol*. *B*, 2-*Thio*-5-*benzylidene*-3-*methylhydantoin in* N/100-*alcoholic* NaOEt. *C*, 2-*Methylthio*-5-*keto*-4-*benzylidene*-1-*methyldihydroglyoxaline*.

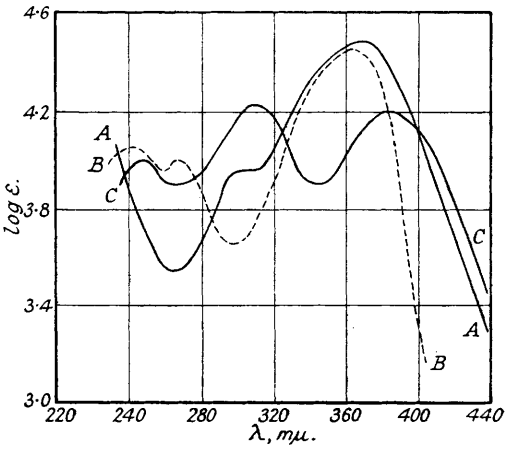
In the group of thio-compounds under investigation there is a greater opportunity for studying the electronic changes occurring owing to the fact that methylation produces mercapto-compounds, •N:C(SMe)•, whereas derivatives of the keto-form •NMe•CO• are produced by methylation of the parent benzylidenehydantoins. This is exemplified by the methylation of 2-thio-5-benzylidenehydantoin which produces 2-methylthio-5-keto-4-benzylidenedihydro-glyoxaline (XII).



The spectra of 2-thio-5-benzylidene-3-methylhydantoin (XIII) are shown in Fig. 5 for acid and alkaline solution. In alkaline solution the main change occurs in the longer wave-length band, this being shifted 35 mμ towards the visible with a small decrease in $\varepsilon_{max.}$. This would suggest an enolisation in solution with the ion (XV) predominating in any ionic resonance. Comparison with the spectra of 2-methylthio-5-keto-4-benzylidene-1-methyldihydroglyoxaline (VI), which does not change with alteration in pH, shows that the spectrum of the methyl derivative of the thio-form differs from the spectrum of the thio-ion (XV). The values for $\varepsilon_{max.}$ for the two structures are identical, but the ionic structure has $\lambda_{max.}$ 42 mμ nearer the visible (see Table). A subsidiary band becomes evident in the ion which is also present in the methylthio-derivative.

The glyoxaline (XII) shows an anomalous spectrum in alkaline solution comparable with that of 5-benzylidene-1-methylhydantoin under the same conditions. In the case of the thio-compound a completely conjugated ring structure is present in addition to the grouping Ph·C:C·C:N· which is common to both. 2-Thio-5-benzylidenehydantoin and its 1 : 3-dimethyl derivative show spectra which are analogous to the parent oxy-compounds. One difference is that in 2-thio-5-benzylidenehydantoin the peak absorption shifts to longer wave-lengths in alkaline solution, in addition to the small decrease in $\varepsilon_{max.}$.

FIG. 6.



A, 2-*Thio-5-benzylidene*-1 : 3-*dimethylhydantoin*. *B*, 2-*Methylthio-5-keto-4-benzylidenedihydroglyoxaline in alcohol*. *C*, 2-*Methylthio-5-keto-4-benzylidenedihydroglyoxaline in* N/100-*alcoholic* NaOEt.

Wilds *et al.* (*loc. cit.*) found the peak wave-length for the group Ph·C:C·C:O to be 275—300 mμ subject to certain variations, although most of the compounds studied in the present work showed peak absorption nearer the visible. This could be due either to the urea grouping or to the presence of the ring. To obtain information on these possibilities the analogous straight-chain compound, cinnamoylurea was made and its spectra examined (Fig. 1; see Table). It showed $\lambda_{max.}$ at 288 mμ, in complete agreement with the values of Wilds *et al.* for benzoylacetone and indicating that the shift in benzylidenehydantoin was due, partly at least, to ring formation.

EXPERIMENTAL.

5-Benzylidenehydantoin was prepared by the piperidine condensation method of Boyd and Robson (*Biochem. J.*, 1935, **29**, 542) and by acetic-acid condensation (Wheeler and Hoffman, *Amer. Chem. J.*, 1911, **45**, 368). When allowed to crystallise spontaneously the first crystals on the side of a beaker were strongly yellow, the colour decreasing in crystals subsequently produced until a colourless product was finally obtained. The pure compound from both sources had m. p. 221°, not changed on admixture. Condensation of hydantoic acid and benzaldehyde by the method of Wheeler and Hoffman (*loc. cit.*) in an attempt to form benzylidenehydantoic acid produced a 25% yield of 5-benzylidenehydantoin; similar condensations in the presence of piperidine after Boyd and Robson (*loc. cit.*) were also unsuccessful.

5-Benzylidene-3-methylhydantoin, also prepared by an acid condensation from 3-methylhydantoin and benzaldehyde, agreed with Litzinger's product (*J. Amer. Chem. Soc.*, 1934, **56**, 673) obtained by direct methylation of 5-benzylidenehydantoin.

5-Benzylidene-1 : 3-dimethylhydantoin was made by a modification of the method of Hahn and Evans (*J. Amer. Chem. Soc.*, 1928, **50**, 806). 5-Benzylidenehydantoin (6 g.) was dissolved in methyl alcohol (60 c.c.) containing potassium hydroxide (4 g.), a little water being added if necessary; methyl iodide (15 g., excess) was added, and the mixture refluxed for 2 hours. The resulting solution, con-

taining mono- and di-methyl compounds together with some unchanged 5-benzylidenehydantoin, was evaporated to about half bulk and filtered. The filtrate was poured into excess of water, precipitating a yellow oily solid which was separated from the mother-liquor by decanting and crystallised several times from alcohol, producing white crystals, m. p. 88—89°. A Zeisel determination of methoxy-groups gave negative results, showing that the methyl groups were attached to nitrogen.

5-Benzylidene-1-methylhydantoin was prepared by hydrolysis of *N*-acetyl-5-benzylidenecreatinine (5 g.) (cf. Nicolet and Campbell, *J. Amer. Chem. Soc.*, 1928, **50**, 1155) by boiling with barium hydroxide (40 g.) in water (150 c.c.). The ammonia evolved was collected in standard sulphuric acid and the distillation was stopped when one molecular proportion had been absorbed (about 4 hours). Glacial acetic acid was added to the residue in the flask until it was distinctly acid, and the product warmed and filtered off. The product was recrystallised from alcohol (twice), and then had m. p. 193°.

Cinnamoylurea, prepared previously by Cavallito and Smith (*J. Amer. Chem. Soc.*, 1941, **63**, 996), from cinnamic acid, thionyl chloride, and urea, was obtained in the present work by refluxing cinnamoyl chloride (10 g.) and urea (7·5 g.) for 4 hours in benzene (25 c.c.). The benzene was evaporated, the residue washed with ether and hot water, and the product crystallised from absolute alcohol.

Thio-compounds.—The method of Johnson and Nicolet (*J. Amer. Chem. Soc.*, 1912, **34**, 1048) was used for the preparation of (VI) and (XII). Condensation of 2-thio-3-methylhydantoin and benzaldehyde in the presence of sodium acetate and glacial acetic acid (cf. Wheeler and Hoffman, *loc. cit.*) gave 2-thio-5-benzylidene-3-methylhydantoin. *2-Thio-5-benzylidene-1 : 3-dimethylhydantoin* was prepared similarly by condensation of 2-thio-1 : 3-dimethylhydantoin and benzaldehyde. The compound, after being washed with alkali and acid and crystallised from alcohol, formed yellow crystals, m. p. 139° (Found: C, 61·7; H, 5·1. $C_{12}H_{12}ON_2S$ requires C, 62·0; H, 5·2%).

Absorption Spectra.—Determinations were made using a Hilger medium quartz spectrograph and Spekker photometer (cf. Part I, *loc. cit.*).

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