The Cyclization of Substituted N-*Thiocarbamoylglycines, and Some* mero*Cyanine Dyes derived from the Products.*

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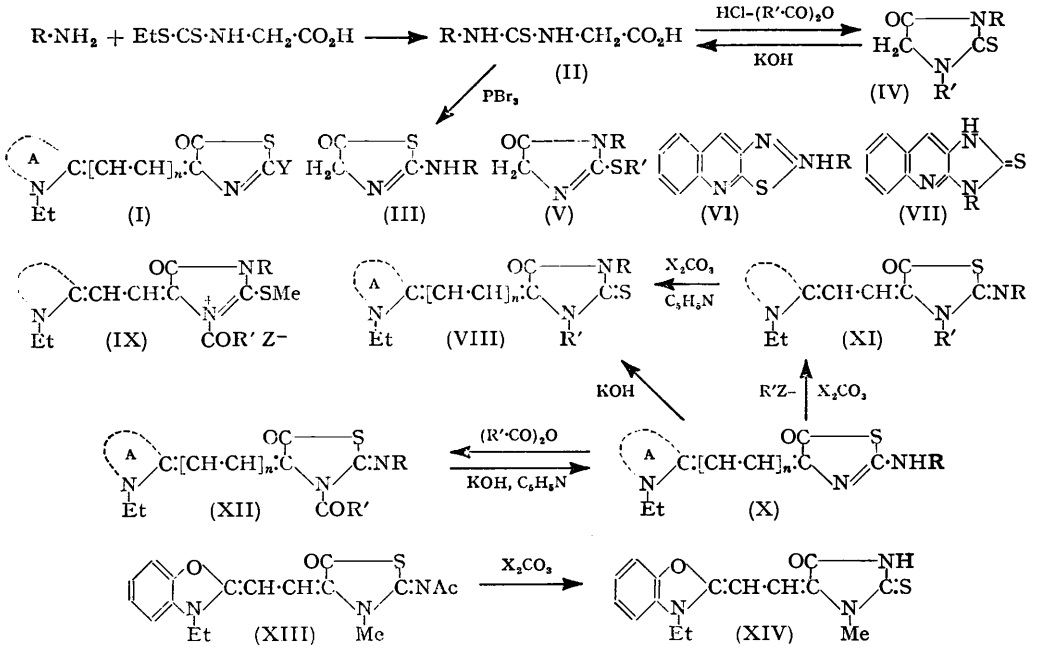
[Reprint Order No. 5067.]

It is shown that substituted *N*-thiocarbamoylglycines (II) cyclize to 2-thiohydantoins, 1-acyl-2-thiohydantoins, and 2-(secondary amino)thiazol-5-ones with mineral acid, acetic anhydride, and phosphorus tribromide respectively. The ultra-violet absorption spectra of 2-thiohydantoins and similar compounds are discussed. *mero*Cyanine dyes are prepared from all these intermediates, and both alkyl and acyl derivatives of thiazol-5-one dyes are described. The absorption maxima of various 2-substituted thiazol-5-one dimethin*mero*cyanines are compared.

SEVERAL series of *mero*cyanine dyes possessing 2-alkoxy-, 2-alkylthio-, 2-(tertiary amino)-, and 2-acylamino-thiazol-5-one nuclei (I) have already been prepared and their action as optical sensitizers for photographic silver halide emulsions is known (Cook, Harris, and Shaw, *J.*, 1949, 1435; Aubert, Knott, and Williams, *J.*, 1951, 2185). One object of the present work was to prepare and examine the properties of the related 2-(secondary amino)thiazol-5-one dyes. Ghosh (*J. Indian Chem. Soc.*, 1937, **14**, 113), by refluxing *N*-thiocarbamoylglycines (II; R = *p*-Me·C_6H_4, etc.) in acetic anhydride, prepared com-

pounds which he formulated as (III; R = *p*-Me·C_6H_4, etc.). These ketomethylene heterocyclic compounds react with dye intermediates possessing electrophilic carbon atoms, to provide *mero*cyanines (I; Y = NHR). *N*-Thiocarbamoylglycines (II) are known also to form thiohydantoins (IV; R′ = H) by cyclization in mineral acid (cf. Ware, *Chem. Reviews*, 1950, **46**, 406). An examination of the products of, and the conditions



and reagents necessary for, the cyclization of (II) was therefore carried out. *N*-Thiocarbamoylglycines were prepared by condensing primary amines with the potassium salt of *N*-(ethylthio-thiocarbonyl)glycine in aqueous alcohol. Aromatic amines provided only 2-thiohydantoins, but alkaline hydrolysis of these (Ghosh, *loc. cit.*) provided *N*-(arylthiocarbamoyl)glycines.

Cyclization of N-*Thiocarbamoylglycines.*—(a) 2-*Thiohydantoins.* *N*-(*p*-Tolylthiocarbamoyl)glycine was taken as a model compound since most of its derivatives are crystalline solids. When it was refluxed in aqueous mineral acid according to the classical method, 2-thio-3-*p*-tolylhydantoin was obtained. By heating the intermediate thiohydantoic acid in acetic anhydride on the steam-bath, the compound described by Ghosh was obtained. It corresponded, by analysis, to 1-acetyl-2-thio-3-*p*-tolylhydantoin (IV; R′ = Ac, R = *p*-Me·C_6H_4), the formation of thiohydantoins in acetic anhydride being conducive to acetylation at the 1-position (Wheeler, Nicolet, and Johnson, *Amer. Chem. J.*, 1911, **46**, 456; Komatsu, *Mem. Coll. Sci. Kyoto*, 1915, **1**, 69, etc.). Acetylation of 2-thio-3-*p*-tolylhydantoin provided the same compound, thus confirming its structure. The 1-acyl group was easily removed by mineral acid (cf. Wheeler, *et al.*, *loc. cit.*). The compounds obtained by Ghosh on refluxing his intermediates with *o*-nitrobenzaldehyde in acetic anhydride were therefore 1-acetyl-5-*o*-nitrobenzylidene-2-thiohydantoins, and reduction of these provided, not (VI), but (VII) or its acetyl derivative. A synthesis of the isomeric 2-acetylthio-4 : 5-dihydro-5-oxo-1-*p* tolylglyoxaline (V; R = *p*-Me·C_6H_4, R′ = Ac) was unsuccessfully attempted : no reaction took place between the thiohydantoin and acetyl chloride, in the presence of pyridine or potassium hydroxide.

However, *S*-methylation occurred (cf. Ware, *loc. cit.*) when methyl sulphate reacted with 2-thio-3-*p*-tolylhydantoin in alcoholic potassium hydroxide, the product being 4 : 5-dihydro-2-methylthio-5-oxo-1-*p*-tolylglyoxaline (V; R = *p*-Me·C_6H_4, R′ = Me). The isomeric 1-methyl-2-thio-3-*p*-tolylhydantoin was prepared by Delépine's method (*Bull. Soc. chim.*,

1903, **29**, 1198; Cook and Cox, *J.*, 1949, 2343) from methylaminoacetonitrile and *p*-tolyl *iso*thiocyanate. Of these substituted tolylhydantoins the only compound to form an insoluble silver salt was 2-thio-3-*p*-tolylhydantoin, since substitution in the 1-position, or at the sulphur atom prevents the formation of a free mercapto-group, and so of a silver salt.

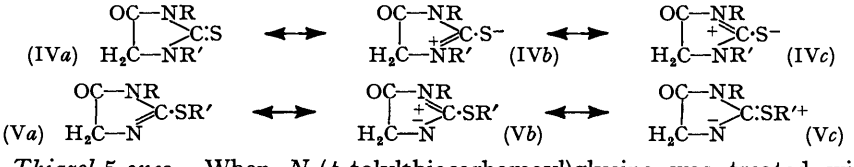
TABLE 1. *Ultra-violet absorption maxima* (mμ, *in* MeOH) *of thiohydantoins and related compounds.*

Compound	Main peak $\lambda_{max.}$	Main peak ε	Subsidiary peak $\lambda_{max.}$	Subsidiary peak ε
2-Thio-3-*p*-tolylhydantoin	262	15,400	227	9,100
1-Methyl-2-thio-3-*p*-tolylhydantoin	265	14,600	233	11,100
1-Acetyl-2-thio-3-*p*-tolylhydantoin	277	14,700	229	12,200
NN'-Diethylthiourea	265	7,300	234	6,300
4 : 5-Dihydro-2-methylthio-5-oxo-1-*p*-tolylglyoxaline	Tail absorption from 225 mμ			
NN'-Diethyl-*S*-methyl*iso*thiourea	Tail absorption from 225 mμ			

The ultra-violet absorption spectra of these compounds (Table 1) and of a group of 5 : 5-disubstituted thiohydantoins examined by Carrington (*J.*, 1947, 684) were similar. The absorption maxima were compared with those of a symmetrically substituted thiourea, and an *iso*thiourea. The two maxima, at 225—235 and 260—280 mμ, shown by thiohydantoins unsubstituted at the sulphur atom were also observed for *NN'*-diethylthiourea and are probably due to the resonance (IV*a* ⟷ *b* ⟷ *c*), greater contributions arising from (IV*b*) than from (IV*c*) because of amide resonance between the $N_{(3)}$ atom and the 4-keto-group in hydantoins. Similar peaks at 225—230 mμ and extinction coefficients have been observed by Ferm, Riebsomer, Martin, and Daub (*J. Org. Chem.*, 1953, **18**, 643) for a number of 1 : 2 : 4 : 4-tetra-alkyldihydroglyoxalines, so that this shorter-wave-length peak may be due to the (IV*b* ⟷ *c*) resonance, or to the polarizable C:N bond.

When R' is a +*M*-group (acetyl) contributions from (IV*b*) will diminish, and a bathochromic shift of the longer-wave-length maximum is observed, *i.e.*, a reduced contribution from a polar structure increases the degeneracy in this part of the molecule. This implies that in 1-alkyl-2-thiohydantoins, the polar structures (IV*b*, *c*) predominate in the hybrid.

Neither 4 : 5-dihydro-2-methylthio-5-oxo-1-*p*-tolylglyoxaline nor *NN'*-diethyl-*S*-methyl-*iso*thiourea has an absorption peak within the range observed, showing that resonance such as (V*a* ⟷ *b* ⟷ *c*) produces only a tail absorption in the ultra-violet. That structures (V*b*, *c*) contribute little to the hybrid is borne out by the less polar nature, including lower melting points and higher solubility in non-polar solvents, of these compounds compared with their thiohydantoin isomers.



(b) *Thiazol-5-ones.* When *N*-(*p*-tolylthiocarbamoyl)glycine was treated with phosphorus tribromide in dioxan (cf. Cook *et al.* and Aubert *et al.*, *locc. cit.*) 2-*p*-toluidinothiazol-5-one hydrobromide (cf. III; R = *p*-Me·C_6H_4) was obtained, and treatment of this compound with sodium hydrogen carbonate solution provided the base as a gum. Sodium carbonate caused rearrangement of the hydrobromide to the 2-thiohydantoin. Other 2-aminothiazol-5-one hydrobromides [those of (II) in which R = alkyl, benzyl, carboxymethyl, or *cyclo*hexyl], obtained from the appropriate *N*-thiocarbamoylglycines, were more stable than the corresponding 2-(tertiary amino)-analogues but the bases were unstable and could not be purified.

2-Thiohydantoin Dyes.—The 2-thiohydantoin dyes (VIII; R' = H) were less soluble and had higher melting points than their 1-acyl analogues (VIII; R' = COR''), or 2-aminothiazol-5-one isomers (X). Whereas the hydantoin dyes (VIII; R' = H) with strongly −*M* heterocycles obeyed Kundt's rule, the absorption maxima of analogous 1-acyl dyes moved hypsochromically with increasing solvent polarity (*i.e.*, the dipolar

extreme structure predominates in these dyes). Acetylation of 2-thiohydantoin dyes provided 1-acyl derivatives and sometimes paler dyes of unknown composition. Quaternization of 1-acyl dyes gave salts (IX) which did not condense further with amines or dye intermediates (cf. Jeffreys, *J.*, 1954, 389), probably because of steric effects.

Thiazol-5-one Dyes.—The 2-aminothiazol-5-one *mero*cyanines (X) isomerized, analogously to the 2-iminothiazolid-5-ones, in alcoholic alkali to 2-thiohydantoin dyes. Alkylated dyes from 2-aminothiazol-5-ones proved to be 2-iminothiazolid-5-ones (XI) by their non-identity with analogous 2-(tertiary amino)thiazol-5-ones, and by their rearrangement to 1 : 3-substituted 2-thiohydantoins (VIII; R′ = alkyl) in pyridine–carbonate solution. This alternative preparation of (XI) is an improvement on the original (Jeffreys, *loc. cit.*) as the more soluble dyes of this type are isolatable, and the yields are higher.

Acetylation of thiazol-5-one dyes produced less soluble dyes with higher melting points. These are formulated as 3-acyl-2-iminothiazolid-5-ones (XII), since alkylation occurs at the 3-position, and the acyl dyes are unlike the more soluble, lower-melting 2-(tertiary amino)thiazol-5-ones whose spatial arrangements they would resemble if acylation occurred at the 2-amino-group. Many 3-acyl dyes exhibited a reversal of Kundt's rule, and by comparison with 3-alkyl-2-thiothiazolid-5-ones (Jeffreys and Knott, *J.*, 1952, 4632) energetic degeneracy is achieved in dyes with heterocycles having weaker $-M$ effects.

For comparison with the acetylated dyes, an isomer prepared by methylation of a 2-acetamidothiazol-5 one (Aubert *et al.*, *loc. cit.*) was examined. Methylation had occurred at the 3-position, since the dye (XIII) was hydrolysed and rearranged in aqueous carbonate solution, forming (XIV), which was also synthesized unambiguously from 1-methyl-2-thiohydantoin.

The Colour of Thiazol-5-one Dyes.—The 2-aminothiazol-5-one dyes, together with the other groups of 2-substituted thiazol-5-one *mero*cyanines synthesized by Cook *et al.* and Aubert *et al.*, provide an opportunity for comparing the relative effects of 2-substituents on the colour of analogous dyes. Table 2 shows the long-wave-length absorption maxima

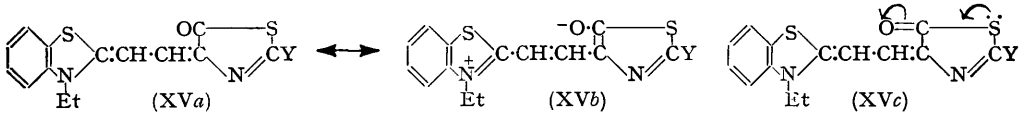
TABLE 2. *Absorption maxima* (mμ, *in* MeOH) *of dimethin*mero*cyanines possessing a 2-substituted thiazol-5-one nucleus* (I; n = 1).

(Except for Y = NHEt, the absorption maxima are taken from Aubert *et al.*, *loc. cit.*).

	Substituent Y				
Heterocycle A	NHAc	SEt	NEt_2	NHEt	OEt
Thiazolidine	480	470	469	460	452
Benzoxazoline	488	491	480	472	460
Benzothiazoline	528	527	519	508 [a]	499
Benzoselenazoline	528	528	517	508 [a]	505
Naphtho(1′ : 2′-4 : 5)thiazoline	—	548	532	520	523
1: 2-Dihydroquinoline	555	546	560	540 [b]	530
1 : 4-Dihydroquinoline	593	591	588	575 [b]	568

[a] Y = n-C_8H_{17}·NH·. [b] Y = *cyclo*-C_6H_{11}·NH·.

of several series of dyes in methanol. The first three columns of the Table indicate that an increase in the $-M$ effect of the 2-substituent causes a hypsochromic shift of $\lambda_{max.}$. The reverse is the case, however, when the substituent is changed from NEt_2 to NHEt to OEt. For a typical dye, the visible absorption is due to resonance involving extreme structures (XV*a*, *b*). The majority of the dyes in Table 2, show bathochromic shifts with increased



solvent polarity, *i.e.*, (XV*b*) is the extreme structure of highest energy. Therefore, any change in the 2-substituent which increases the energy change (XV*a* ⟶ *b*) will cause a hypsochromic shift of $\lambda_{max.}$. As the $-M$ effect of Y increases, one would expect greater contributions to the thiocarboxylate resonance (XV*c*) from the ·$^+$S:C·O$^-$ form, thus

increasing the energy of (XV*b*), with a consequent hypsochromic shift of $\lambda_{max.}$. Although this accounts for the shifts observed between the first three columns, no satisfactory explanation is presented for the remaining absorption changes.

Experimental

Microanalyses are partly by Mr. C. B. Dennis.

Throughout the Tables below the following solvent abbreviations are used : A = ethanol, B = benzene, D = ether, E = ethyl acetate, L = light petroleum (b. p. 60—80°), M = methanol, P = pyridine; EM–L denotes precipitation by light petroleum from ether–methanol.

N-(*Alkylthiocarbamoyl*)*glycines* (Table 3).—These were prepared according to the method of Aubert, Knott, and Williams (*loc. cit.*) for the corresponding *NN*-dialkyl compounds. Potassium hydroxide (16·8 g.) was dissolved in water (45 c.c.) and added to a solution of *N*-(ethylthio-thiocarbonyl)glycine (53·7 g.) in ethanol (90 c.c.). The primary amine was then added, and the solution was refluxed for 24 hr., concentrated, cooled in ice, and acidified with concentrated hydrochloric acid. Scratching caused crystallization, and the solution was later filtered. The product was washed with a little ice-cold water and recrystallized.

3-*Alkyl*(*or aryl*)-2-*thiohydantoins*.—*N*-Thiocarbamoylglycine (5 g.) in 2N-hydrochloric acid (25 c.c.) and ethanol (20 c.c.) was refluxed for ½ hr. On removal of the ethanol *in vacuo*, the 2-thiohydantoin crystallized, and was purified by recrystallization. The following 2-thiohydantoins were prepared : 3-methyl-, m. p. 162° (Marckwald, Neumark, and Stelzner, *Ber.*, 1891, **24**, 3285); 3-*ethyl*-, pale straw-coloured needles (from ethyl acetate–light petroleum), m. p. 144° (Found : N, 19·4. $C_5H_8ON_2S$ requires N, 19·4%); 3-carboxymethyl-, m. p. 212° (decomp.) (Johnson and Renfrew, *J. Amer. Chem. Soc.*, 1925, **47**, 240); 3-*p*-tolyl-, m. p. 228° (Johnson, Pfau, and Hodge, *ibid.*, 1912, **34**, 1044). Dyes derived from these and other 2-thiohydantoins are listed in Table 5.

Table 3. N-*Thiocarbamoylglycines* (II).

R	Appearance	M. p.	Solvent	Yield (%)	Formula	Found (%) N	Reqd. (%) N
Methyl	Prisms	171° (decomp.)	EM–L	68	$C_4H_8O_2N_2S$	18·8	18·9
Ethyl	Prisms	170 (decomp.)	EM–L	72	$C_5H_{10}O_2N_2S$	17·2	17·3
Carboxymethyl	Prisms	170 (decomp.)	EM–L	36	$C_5H_8O_4N_2S$	14·6	14·6
n-Octyl	Waxy needles	125	E–L	20	$C_{11}H_{22}O_2N_2S$	11·5	11·4
Benzyl	Microcrystalline needles	189	EM–L	60	$C_{10}H_{12}O_2N_2S$	12·8	12·5
*cyclo*Hexyl	Microcrystalline needles	156	E–L	40	$C_9H_{16}O_2N_2S$	13·0	13·0
p-Tolyl[a]	Microcrystalline needles	148 (decomp.)	Water	—	$C_{10}H_{12}O_2N_2S$	12·4	12·5
Dimethyl[b]	Microcrystalline needles	177	EM–L	50	$C_5H_{10}O_2N_2S$	17·3	17·3

[a] Ghosh, *loc. cit.*, by hydrolysis of 2-thio-3-*p*-tolylhydantoin. [b] Prepared from dimethylamine.

Table 4. 2-*Aminothiazol-5-one hydrobromides*.

R in (III)	M. p. (decomp.)	Formula	Found (%) N	Found (%) Br	Found (%) S	Required (%) N	Required (%) Br	Required (%) S
Methyl	170°	$C_4H_7ON_2BrS$	13·0	37·3	—	13·3	37·9	—
Ethyl[a]	203	$C_5H_9ON_2BrS$	12·3	34·6	14·2	12·4	35·6	14·2
Carboxymethyl	138	$C_5H_7O_3N_2BrS$	—	31·0	—	—	31·4	—
n-*Octyl*	192	$C_{11}H_{21}ON_2BrS$	—	25·4	—	—	25·9	—
Benzyl[b]	196	$C_{10}H_{11}ON_2BrS$	—	27·2	—	—	27·9	—
cyclo*Hexyl*	231	$C_9H_{15}ON_2BrS$	—	28·1	—	—	28·6	—
p-*Tolyl*	170	$C_{10}H_{11}ON_2BrS$	9·9	24·1	11·3	9·8	27·9	11·2

[a] Found : C, 26·8; H, 4·2. Reqd. : C, 26·7; H, 4·0%. [b] Leaflets from acetic acid.

1-*Acyl*-3-*alkyl*(*or aryl*)-2-*thiohydantoins*.—*N*-Thiocarbamoylglycine (5 g.) in the acid anhydride (30 c.c.) was heated for ½ hr. on the steam-bath, and the solvent was removed at the pump. Oils were obtained which were used without further purification in preparing the dyes. 1-*Acetyl*-2-*thio*-3-p-*tolylhydantoin* was obtained as a solid which recrystallized from

TABLE 5. mero*Cyanines* (VIII) *derived from* 1-, 3-, *and* 1 : 3-*substituted-2-thiohydantoins.*

No.	Heterocycle A	R	R′	Yield (%)	Appearance *	Solvent	M. p.	$\lambda_{max.}$ (mμ, MeOH)	Formula	Found (%) N	Found (%) S	Reqd. (%) N	Reqd. (%) S
(a) 5-(3-*Ethylbenzothiazolin*-2-*ylidene*)-2-*thiohydantoins* (A = benzothiazoline, *n* = 0).													
		Et	H	84	Yellow P	PM	248°	408	$C_{14}H_{15}ON_3S_2$	13·8	—	13·8	—
		Et	Ac	70	Lemon P	E	243	404	$C_{16}H_{17}O_2N_3S_2$	12·3	18·5	12·1	18·4
(b) 5-(3-*Ethyl*-A-*ethylidene*)-2-*thiohydantoins* (*n* = 1).													
1	Thiazolidine	Et	H	90	Yellow N	MEL	205	465	$C_{12}H_{17}ON_3S_2$	14·6	—	14·8	—
2	,,	Et	Ac	61	Orange N	MEL	179	460	$C_{14}H_{19}O_2N_3S_2$ [b]	13·0	19·8	12·9	19·7
3	,,	Et	COEt	47	Khaki N	BL	160	467	$C_{15}H_{21}O_2N_3S_2$	12·3	—	12·4	—
4	Benzoxazoline	Me	H	67	Orange N	PA	304 [a]	470	$C_{15}H_{15}O_2N_3S$	13·9	—	13·9	—
5	,,	H	Me [c]	85	Orange-red N	PM	310 [a]	480	$C_{15}H_{15}O_2N_3S$	14·0	10·6	13·9	10·6
6	,,	Me	Ac	85	Chocolate L	PBL	204	475	$C_{17}H_{17}O_3N_3S$	12·3	9·5	12·2	9·3
7	,,	Et	H	86	Orange-red P	BL	285	476	$C_{16}H_{17}O_2N_3S$	13·4	10·1	13·3	10·1
8	,,	Et	Ac	50	Orange L	BL	212	477	$C_{18}H_{19}O_3N_3S$ [d]	11·8	8·7	11·8	9·0
9	,,	Et	COEt	22	Red L, blue reflex	BL	195	481	$C_{19}H_{21}O_3N_3S$	11·2	—	11·3	—
10	,,	$CH_2{\cdot}CO_2H$	H	10	Orange	MD	279 [a]	480	$C_{16}H_{15}O_4N_3S$	12·1	—	12·2	—
11	,,	$CH_2{\cdot}CO_2H$	Ac	15	Orange-brown	AD	243	475	$C_{18}H_{17}O_5N_3S$	10·9	8·4	10·9	8·3
12	,,	*n*-C_8H_{17}	Ac	25	Orange	A	176	480	$C_{24}H_{31}O_3N_3S$	9·5	—	9·5	—
13	,,	$C_6H_5{\cdot}CH_2{\cdot}$	Ac	66	Orange N	BL	220	480	$C_{23}H_{21}O_3N_3S$	10·1	—	10·0	—
14	,,	*p*-Me·$C_6H_4{\cdot}$	H	90	Red N	PA	288 [a]	482	$C_{21}H_{19}O_2N_3S$	11·0	8·4	11·1	8·5
15	,,	*p*-Me·$C_6H_4{\cdot}$	Me	82	Red N	PA	243	490	$C_{22}H_{21}O_2N_3S$	10·7	8·3	10·7	8·2
16	,,	*p*-Me·$C_6H_4{\cdot}$	Ac	50	Orange L	PA	237	480	$C_{23}H_{21}O_3N_3S$	10·0	7·6	10·0	7·6
17	Benzothiazoline	Me	H	94	Red L	PM	317 [a]	508	$C_{15}H_{15}ON_3S_2$	13·1	—	13·2	—
18	,,	H	Me	90	Slate N	PL	284	512	$C_{15}H_{15}ON_3S_2$	13·2	20·1	13·2	20·2
19	,,	Me	Ac	70	Bronze N	PM	211	510	$C_{17}H_{17}O_2N_3S_2$	11·6	—	11·7	—
20	,,	Et	H	80	Maroon N, blue reflex	PM	308	510	$C_{16}H_{17}ON_3S_2$	12·6	—	12·7	—
21	,,	Et	Ac	71	Blue P	BL	201	512	$C_{18}H_{19}O_2N_3S_2$ [e]	11·3	16·9	11·3	17·2
22	,,	$CH_2{\cdot}CO_2H$	H	25	Maroon L	PL	280	510	$C_{16}H_{15}O_3N_3S_2$	11·7	17·8	11·6	17·7
23	,,	*n*-C_8H_{17}	Ac	30	Orange L	BL	180	510	$C_{24}H_{31}O_2N_3S_2$	9·1	—	9·2	—
24	,,	$C_6H_5{\cdot}CH_2{\cdot}$	Ac	55	Maroon N, bronze reflex	BL	210	510	$C_{23}H_{21}O_2N_3S_2$	9·5	14·4	9·7	14·7
25	,,	*cyclo*-$C_6H_{11}{\cdot}$	Ac	25	Crimson N	BL	221	510	$C_{22}H_{25}O_2N_3S_2$	9·9	—	9·8	—
26	Benzoselenazoline	Et	H	80	Maroon L	PM	310	505	$C_{16}H_{17}ON_3SSe$	11·1	—	11·1	—
27	,,	Et	Ac	80	Indigo L	BL	243	530	$C_{18}H_{19}O_2N_3SSe$	9·9	—	10·0	—
28	Naphth(1′ : 2′-4 : 5)oxazoline	$C_6H_5{\cdot}CH_2{\cdot}$	Ac	60	Orange L	PM	320	490	$C_{27}H_{23}O_3N_3S$	8·8	—	8·9	—
29	Naphtho(1′ : 2′-4 : 5)thiazoline	Et	H	85	Red N	B	213	530	$C_{20}H_{19}ON_3S_2$	10·9	—	11·0	—
30	,,	Et	Ac	57	Maroon N	BL	210	530	$C_{22}H_{21}O_2N_3S_2$	9·7	—	9·9	—
31	1 : 2-Dihydroquinoline	Et	H	81	Blue N	PM	278	540	$C_{18}H_{19}ON_3S$	12·9	—	12·9	—
32	,,	Et	Ac	60	Indigo	PM	207	535	$C_{20}H_{21}O_2N_3S$	11·5	—	11·4	—
33	1 : 4-Dihydroquinoline	Et	H	65	Emerald N	PM	237	574 [f]	$C_{18}H_{19}ON_3S$	9·8	—	9·9	—
34	,,	Et	Ac	16	Dark green N	BL	184	610	$C_{20}H_{21}O_2N_3S$	11·5	—	11·4	—
35	4 : 5-Diphenyloxazoline	Et	H	76	Brick-red P	PM	283	500	$C_{24}H_{23}O_2N_3S$	10·1	—	10·1	—
36	,,	Et	Ac	14	Maroon	BL	200	500	$C_{26}H_{25}O_3N_3S$	9·0	—	9·1	—
37	4 : 5-Diphenylthiazoline	Et	H	86	Emerald L	PM	283	540	$C_{24}H_{23}ON_3S_2$	9·8	—	9·7	—
38	,,	Et	Ac	50	Brown L	BL	210	540	$C_{26}H_{25}O_2N_3S_2$	8·9	13·3	8·8	13·5
(c) 5-[4-(3-*Ethyl*-A)-*but*-2-*en*-1-*ylidene*]-2-*thiohydantoin* (*n* = 2).													
39	Benzothiazoline	Et	H	20	Blue N	BL	254	550	$C_{18}H_{19}ON_3S_2$	11·6	—	11·8	—
40	,,	Et	Ac	15	Indigo N	BL	155	560	$C_{20}H_{21}O_2N_3S_2$	10·8	—	10·5	—

[a] With decomp. [b] Found: C, 52·0; H, 5·9. Reqd.: C, 51·7; H, 5·9%. [c] From 1-methyl-2-thiohydantoin (Komatsu, *loc. cit.*). [d] Found: C, 61·0; H, 5·2. Reqd.: C, 60·5; H, 5·3%. [e] Found: C, 58·1; H, 5·2. Reqd.: C, 57·9; H, 5·1%. [f] Also (613). The following list is of dyes and absorption maxima (mμ) in benzene, and in aqueous methanol (1 : 2). No. 7, 460, 485; No. 8, 474, 490; No. 20, 490, 520; No. 21, 505, 517; No. 33, 550, (580), 617; No. 34, 570, 585; No. 35, 491, 503; No. 36, 503, 480. * L = leaflets, N = needles, P = prisms.

ethanol as cream leaflets (4·4 g.), m. p. 157° (Found : N, 11·2; S, 12·9. $C_{12}H_{12}O_2N_2S$ requires N, 11·3; S, 12·9%) (cf. Ghosh, *loc. cit.*).

Acetylation of 2-*Thio*-3-p-*tolylhydantoin.*—To a solution of 2-thio-3-*p*-tolylhydantoin (4·1 g.) and potassium hydroxide (1·1 g.) in ethanol (30 c.c.) and water (5 c.c.), cooled in ice, acetyl chloride (1·6 g.) was added. After 1 hr., water was added, and the precipitate filtered off. It was identical with the starting material, as was also the case when the reaction was carried out in dioxan, with pyridine replacing potassium hydroxide.

2-Thio-3-*p*-tolylhydantoin (2·1 g.) in acetic anhydride (30 c.c.), with and without sodium acetate (2·1 g.), was refluxed for 10 min. The solvent was removed at the pump, and the product washed with water. It was identical with 1-acetyl-2-thio-3-*p*-tolylhydantoin, described above.

Hydrolysis of 1-*Acetyl*-3-*methyl*-2-*thiohydantoin.*—1-Acetyl-3-methyl-2-thiohydantoin (1·7 g.), ethanol (4 c.c.), and 2N-hydrochloric acid (6 c.c.) were heated for 10 min. on the steam-bath. The ethanol was removed at the pump, and the precipitate recrystallized from ethyl acetate as needles, m. p. 162°. It was identical with 3-methyl-2-thiohydantoin.

4 : 5-*Dihydro*-2-*methylthio*-5-*oxo*-1-p-*tolylglyoxaline* (V; R = *p*-Me·C_6H_4, R′ = Me).—To 2-thio-3-*p*-tolylhydantoin (4·1 g.) and potassium hydroxide (1·1 g.) in ethanol (30 c.c.) and water (5 c.c.), methyl sulphate (2·52 g.) was added drop by drop, the solution being cooled in ice. After ½ hr. water (150 c.c.) was added, and the precipitate filtered off. It recrystallized from benzene–light petroleum as a cream-coloured powder (3·9 g.), shrinking at 93°, m. p. 113° (Found : N, 12·6; S, 14·5. $C_{11}H_{12}ON_2S$ requires N, 12·7; S, 14·6%).

1-*Methyl*-2-*thio*-3-p-*tolylhydantoin.*—Methylaminoacetonitrile (2·5 g.) in ether (10 c.c.) was added to cooled, stirred *p*-tolyl *iso*thiocyanate (5·3 g.) in ether (10 c.c.) under nitrogen. After 1 hr., the oil which had formed was separated and refluxed for 1 hr. with 2N-hydrochloric acid (50 c.c.). The product was filtered off (4·6 g.) and recrystallized from *iso*propanol as cream leaflets, m. p. 149° (Found : N, 12·8; S, 14·6. $C_{11}H_{12}ON_2S$ requires N, 12·7; S, 14·6%).

2-(*Secondary Amino*)*thiazol*-5-*one Hydrobromides.*—The *N*-thiocarbamoylglycine (0·01 mol.) was suspended in dioxan (20—40 c.c.), and phosphorus tribromide (0·01 mol.) was added slowly with cooling and stirring. On addition of ether (20—40 c.c.) the required *hydrobromide* (see Table 4) separated as a white powder in 90—100% yield. It was washed well with ether, and dried in a vacuum desiccator. 2-Dimethylaminothiazol-5-one hydrobromide was obtained as a deliquescent solid by a similar procedure (Aubert, Knott, and Williams, *loc. cit.*). Dyes derived from thiazol-5-one intermediates are listed in Table 7.

Dye Syntheses.—mero*Cyanines* were prepared by heating the appropriate keto-methylene compound (0·01 mol.) with a 2-alkylthiobenzothiazole quaternary salt (0·01 mol.) and triethylamine (0·01 mol.) in ethanol on the steam-bath for 15 min. *Dimethin-* and *tetramethin*-mero*cyanines* were prepared similarly, by employing 2-2′-acetanilidovinyl and 2-(4-acetanilidobuta-1 : 3-dienyl)heterocyclic quaternary salts in place of the 2-alkylthio-intermediate, with a reaction time of 5—10 min. With the hydrobromides of keto-methylene compounds, 0·02 mol. of triethylamine was used.

4-(3-*Ethylbenzoxazolin*-2-*ylidene-ethylidene*)-4 : 5-*dihydro*-2-*methylthio*-5-*oxo*-1-p-*tolylglyoxaline* [Derived from (V; R = *p*-Me·C_6H_4, R′ = Me)].—4 : 5-Dihydro-2-methylthio-5-oxo-1-*p*-tolylglyoxaline (1·1 g.) and 2-2′-acetanilidovinylbenzoxazole ethiodide (2·2 g.) with triethylamine (0·7 c.c.) in ethanol (10 c.c.) were refluxed for 10 min., chilled, and filtered. The *dye* recrystallized from benzene–light petroleum as an orange powder (0·5 g.), m. p. 194° (Found : N, 10·7; S, 8·2. $C_{22}H_{21}O_2N_3S$ requires N, 10·7; S, 8·2%). It had $\lambda_{max.}$ 473 mμ (ε 7·7 × 10^4 in MeOH).

TABLE 6. *Acetylation of 2-thiohydantoin dyes.*

Dye acetd., no.	Product, no.[a]	Appearance (From BL)	M. p.	$\lambda_{max.}$ (mμ, MeOH)	Formula	Found (%) N	Found (%) S	Reqd. (%) N	Reqd. (%) S
7	8			As for Dye 8, Table 5					
14	Unknown	Orange[b]	197°	460	$C_{23}H_{21}O_3N_3S$	10·1	7·6	10·0	7·6
20	21			As for Dye 21, Table 5					
35	Unknown	Yellow	194	454	$C_{26}H_{25}O_3N_3S$	9·1	6·9	9·1	7·0
37	Unknown	Orange[b]	240	488	$C_{26}H_{25}O_2N_3S_2$	7·5	12·5	8·8	13·5

[a] Yields : No. 8, 80%; No. 21, 68%. [b] Leaflets.

Acetylation of 2-*Thiohydantoin Dyes* (Table 6).—The appropriate dimethin*mero*cyanine (0·5 g.) was refluxed for 15 min. with sodium acetate (0·5 g.) in acetic anhydride (15 c.c.). If the product did not crystallize on cooling, the solution was poured into water and shaken for ½ hr. The *dye* was filtered off, washed, and recrystallized.

TABLE 7. mero*Cyanines derived from* 2-*aminothiazol*-5-*ones* (X).

No.	Heterocycle A	R	Yield, %	Appearance *	Solvent	M. p.	$\lambda_{max.}$ (mμ, MeOH)	Formula	Found (%) N	Found (%) S	Reqd. (%) N	Reqd. (%) S
(a) 2-(*Secondary amino*)-4-(3-*ethylbenzothiazolin*-2-*ylidene*)*thiazol*-5-*ones* (A = benzothiazoline, n = 0).												
41	—	Et	59	Yellow P	BL	170°	414	$C_{14}H_{15}ON_3S_2$ [a]	13·8	21·1	13·8	21·0
42	—	n-C_8H_{17}	20	Yellow N	BL	180	413	$C_{20}H_{27}ON_3S_2$	—	16·5	—	16·5
(b) 2-(*Secondary amino*)-4-(3-*ethyl*-A-*ethylidene*)-*thiazol*-5-*ones* (n = 1).												
43	Thiazolidine	Et	30	Red N	BL	184	460	$C_{12}H_{17}ON_3S_2$	14·8	—	14·8	—
44	,,	*cyclo*-C_6H_{11}	80	Orange N	M	62	462	$C_{16}H_{23}ON_3S_2$	12·6	—	12·5	—
45	Benzoxazoline	Me	85	Orange L	BL	207	472	$C_{15}H_{15}O_2N_3S$	13·8	—	13·9	—
46	,,	Et	94	Maroon, P, purple reflex	BL	162	472	$C_{16}H_{17}O_2N_3S$ [b]	13·1	10·2	13·3	10·1
47	,,	CH_2CO_2H	32	Maroon P	PM	195 †	470	$C_{16}H_{15}O_4N_3S$	12·2	—	12·2	—
48	,,	*cyclo*-C_6H_{11}	68	Orange P	M	158	470	$C_{20}H_{23}O_2N_3S$	11·5	—	11·4	—
49	,,	*p*-Me·C_6H_4·	58	Magenta N	M	215	490	$C_{21}H_{19}O_2N_3S$	11·1	8·5	11·1	8·5
50	Benzothiazoline	Me	88	Maroon N	BL	199	497	$C_{15}H_{15}ON_3S_2$	13·2	—	13·2	—
51	,,	Et	60	Maroon N	BL	105	497	$C_{16}H_{17}ON_3S_2$	12·7	19·1	12·7	19·3
52	,,	n-C_8H_{17}	16	Red	BL	192	498	$C_{22}H_{29}ON_3S_2$	10·0	—	10·1	—
53	,,	C_6H_5·CH_2·	35	Purple P	BL	158	494	$C_{21}H_{19}ON_3S_2$ [c]	10·5	16·2	10·7	16·3
54	,,	*p*-Me·C_6H_4·	52	Slate N	M	190	510	$C_{21}H_{19}ON_3S_2$	10·7	—	10·7	—
55	Benzoselenazoline	n-C_8H_{17}	15	Maroon	BL	217	508	$C_{22}H_{29}ON_3SSe$	9·0	—	9·1	—
56	Naphtho(1′:2′-4:5)thiazoline	Et	25	Chocolate	BL	186	520	$C_{20}H_{19}ON_3S_2$	10·9	—	11·0	—
57	1:2-Dihydroquinoline	*cyclo*-C_6H_{11}	10	Indigo	M	280	540	$C_{22}H_{25}ON_3S$	11·0	—	11·1	—
58	1:4-Dihydroquinoline	*cyclo*-C_6H_{11}	60	Green L	M	156	575	$C_{22}H_{25}ON_3S$	11·1	—	11·1	—
59	4:5-Diphenyloxazoline	Et	52	Orange-brown N	BL	225	506	$C_{24}H_{23}O_2N_3S$	10·2	7·9	10·1	7·7
(c) *Other* 2-*amino*-4-(3-*ethyl*-A-*ethylidene*)*thiazol*-5-*ones*.												
60	Benzoxazoline	Me_2 [d]	63	Orange-red N	BL	208	480	$C_{16}H_{17}O_2N_3S$	13·2	—	13·3	—
61	Benzothiazoline	Me_2 [d]	75	Green N	BL	217	505	$C_{16}H_{17}ON_3S_2$	12·9	—	12·7	—

[a] Found: C, 55·3; H, 5·0. Reqd.: C, 55·1; H, 4·9%. [b] Found: C, 61·1; H, 5·4. Reqd. C, 61·0; H, 5·4%. [c] Found: C, 64·1; H, 5·0. Reqd.: C, 64·1; H, 4·8%. [d] 2-(Tertiary amino) thiazol-5-ones prepared according to Aubert *et al.*, *loc. cit.* The following list is of dyes and absorption maxima (mμ) in benzene, and in aqueous methanol (1:2). No. 46, 469, 486; No. 51, 497, 512; No. 58, 557, 605; No. 59, 501, 509.

* L = leaflets, N = needles, P = prisms. † With decomp.

TABLE 8. *Acylation of* 2-(*secondary amino*)*thiazol*-5-*one* mero*cyanines*.

No.	Heterocycle A	R	R′	Yield (%)	Appearance *	Solvent	M. p.	$\lambda_{max.}$ (mμ, MeOH)	Formula	Found (%) N	Found (%) S	Reqd. (%) N	Reqd. (%) S
(a) 3-*Acetyl*-4-(3-*ethylbenzothiazoline*-2-*ylidene*)-2-*ethyliminothiazolid*-5-*one* (XII; A = benzothiazoline, n = 0).													
62	—	Et	Me	96	Lemon N	PM	211°	409(393)	$C_{16}H_{17}O_2N_3S_2$	12·0	—	12·1	—
(b) 3-*Acyl*-4-(3-*ethyl*-A-*ethylidene*)-2-*iminothiazolid*-5-*ones* (XII; n = 1).													
63	Thiazolidine	*cyclo*-C_6H_{11}	Me	40	Steel blue P	M	168	459	$C_{16}H_{25}O_2N_3S_2$ [a]	11·0	16·8	11·1	16·9
64	Benzoxazoline	Me	Me	62	Orange	PM	250	493	$C_{17}H_{17}O_3N_3S$	12·2	—	12·2	—
65	,,	Et	Me	77	Orange L	PA	239	483	$C_{18}H_{19}O_3N_3S$	11·9	—	11·8	—
66	,,	*p*-Me·C_6H_4·	Me	81	Orange N	M	215	491	$C_{23}H_{21}O_3N_3S$	10·0	7·8	10·0	7·6
67	,,	*cyclo*-C_6H_{11}	Et	43	Orange-brown	A	200	482	$C_{23}H_{27}O_3N_3S$	9·9	7·4	9·9	7·5
68	Benzothiazoline	Me	Me	66	Gold L	P	282	526	$C_{17}H_{17}O_2N_3S_2$	—	17·6	—	17·8
69	,,	C_6H_5·CH_2·	Et	88	Blue P	BL	195	505	$C_{24}H_{23}O_2N_3S_2$	9·3	14·2	9·4	14·2
70	Naphtho(1′:2′-4:5)thiazoline	Et	Me	70	Bronze N	PM	233	540	$C_{22}H_{21}O_2N_3S_2$	9·9	—	9·9	—
71	1:4-Dihydroquinoline	*cyclo*-C_6H_{11}	Me	50	Dull green	EL	127	580	$C_{24}H_{27}O_2N_3S$	9·9	—	10·0	—
72	4:5-Diphenyloxazoline	Et	Me	57	Red N	BAL	240	485	$C_{26}H_{25}O_3N_3S$	8·8	6·7	9·1	7·0

[a] Found: C, 56·9; H, 6·7. Reqd.: C, 57·0; H, 6·6%. The following list is of dyes and absorption maxima (mμ) in benzene, and aqueous methanol (1:2) No. 67, 484, 482; No. 69, 519, 490; No. 71, 584, 582; No. 72, 495, 480. * L = leaflets, N = needles, P = prisms.

3-Acetyl-1-benzyl-4-(3-ethylbenzoxazolin-2-ylidene-ethylidene)-4 : 5-dihydro-2-methylthio-5-oxo-glyoxalinium Toluene-p-sulphonate (IX; R = benzyl, R′ = Me, Z = toluene-*p*-sulphonate).—Dye 13, Table 5 (1·4 g.), and methyl toluene-*p*-sulphonate (0·7 g.) were heated at 160° for 3 hr. A glass was obtained which recrystallized from ethanol–ether as orange needles, m. p. 189° (Found : C, 61·2; H, 5·2; N, 7·2; S, 10·6. $C_{31}H_{31}O_6N_3S_2$ requires C, 61·5; H, 5·1; N, 6·9; S, 10·6%). It was insoluble in benzene and only slightly soluble in hot water.

Alkylation Experiments.—*4-(3-Ethylbenzothiazolin-2-ylidene-ethylidene)-3-methyl-2-methyl-iminothiazolid-5-one.* 4-(3-Ethylbenzothiazolin-2-ylidene-ethylidene)-2-methylaminothiazol-5-one (dye 50, Table 7) (1·6 g.) and methyl toluene-*p*-sulphonate (0·95 g.) were heated at 140° for ½ hr. The cooled mass was dissolved in ethanol (25 c.c.) and poured into an excess of aqueous sodium carbonate. The *dye* which was precipitated recrystallized from benzene–light petroleum as maroon needles, m. p. 181° (Found : C, 58·2; H, 5·2; N, 12·7; S, 19·6. $C_{16}H_{17}ON_3S_2$ requires C, 58·0; H, 5·1; N, 12·7; S, 19·3%). It had $\lambda_{max.}$ 510 mμ in MeOH.

In a similar manner the following were prepared : *4-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-2-ethylimino-3-methylthiazolid-5-one,* maroon needles, m. p. 185° (from benzene–light petroleum), $\lambda_{max.}$ 517 mμ in MeOH (Found : N, 12·3; S, 18·8. $C_{17}H_{19}ON_3S_2$ requires N, 12·2; S, 18·6%); *3-ethyl-4-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-2-ethyliminothiazolid-5-one,* magenta needles, m. p. 184° (from benzene–light petroleum), $\lambda_{max.}$ 520 mμ in MeOH (Found : N, 11·6; S, 17·8. $C_{18}H_{21}ON_3S_2$ requires N, 11·7; S, 17·8%).

Rearrangement of 2-Aminothiazol-5-one and 2-Iminothiazolid-5-one mero*Cyanines.*—4-(3-Ethylbenzothiazolin-2-ylidene-ethylidene)-2-methylaminothiazol-5-one (dye 50, Table 7) (0·5 g.) and potassium hydroxide (0·5 g.) in ethanol (40 c.c.) and pyridine (30 c.c.) were heated on the steam-bath for 3 hr. The solution was poured into water and the dye was filtered off. It recrystallized from pyridine–ethanol as red leaflets, m. p. 317° (decomp.), and was identical with an authentic sample of 5-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-3-methyl-2-thiohydantoin (dye 17, Table 5).

In the same way 4-(3-ethylbenzoxazolin-2-ylidene-ethylidene)-2-*p*-toluidinothiazol-5-one (dye 49, Table 7) in alcoholic potassium hydroxide, heated on the steam-bath for ½ hr., isomerized to 5-(3-ethylbenzoxazolin-2-ylidene-ethylidene)-2-thio-3-*p*-tolylhydantoin (dye 14, Table 5), identical with an authentic specimen.

4-(3-Ethylbenzothiazolin-2-ylidene-ethylidene)-3-methyl-2-methyliminothiazolid-5-one (0·2 g.), dissolved in pyridine (10 c.c.) with aqueous sodium carbonate (2N; 5 c.c.), was heated for 1 hr. on the steam-bath. The product was precipitated with water, washed with ethanol, and recrystallized from pyridine–methanol as maroon needles, m. p. 235°. It was identical with an authentic sample of 5-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-1 : 3-dimethyl-2-thiohydantoin (Jeffreys, *loc. cit.*; Table 1, dye 4).

In the same way, 4-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-2-ethylimino-3-methylthiazolid-5-one isomerized to 3-ethyl-5-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-1-methyl-2-thiohydantoin (Jeffreys, *loc. cit.*; Table 1, dye 9).

Acylation of 2-(Secondary Amino)thiazol-5-one Dyes (Table 8).—The appropriate *mero*cyanine (0·5 g.) and sodium acetate (0·5 g.) in acetic anhydride (15 c.c.) were refluxed for 15 min. If the product did not crystallize on cooling, the solution was poured into water and shaken for ½ hr. The dye was filtered off, washed, and recrystallized. Propionylation was carried out similarly in propionic anhydride, but without sodium propionate.

Hydrolysis of a 3-Acetylthiazolid-5-one mero*Cyanine.*—3-Acetyl-4-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-2-methyliminothiazolid-5-one (Table 8, dye 68) (0·3 g.) and potassium hydroxide (0·3 g.) in pyridine (30 c.c.) and water (5 c.c.) were heated for 1 hr. on the steam-bath. The solution was neutralized with concentrated hydrochloric acid and poured into water. The dye which was precipitated recrystallized from benzene–light petroleum as maroon leaflets, m. p. 199°, and was identical with an authentic sample of 4-(3-ethylbenzothiazolin-2-ylidene-ethylidene)-2-methylaminothiazol-5-one (Table 7, dye 50).

2-Acetimido-4-(3-ethylbenzoxazolin-2-ylidene-ethylidene)-3-methylthiazolid-5-one (XIII).—2-Acetamido-4-(3-ethylbenzoxazolin-2-ylidene-ethylidene)thiazol-5-one (Aubert *et al., loc. cit.*) (1·6 g.) and methyl toluene-*p*-sulphonate (1·0 g.) were heated for 3 hr. at 140°. The mixture fused and solidified. It was dissolved in ethanol and poured into aqueous sodium carbonate. The dye was filtered off and recrystallized from benzene–light petroleum as red-bronze leaflets (1·2 g.), m. p. 233° (Found : N, 12·3; S, 9·3. $C_{17}H_{17}O_3N_3S$ requires N, 12·2; S, 9·3%). It had $\lambda_{max.}$ 504 mμ in MeOH.

This dye (0·3 g.) in ethanol (15 c.c.) with aqueous sodium carbonate (N; 10 c.c.) was refluxed for 2 hr. The solution was cooled and filtered, and the product recrystallized from pyridine–

methanol as red needles, m. p. 310°. It was identical with 5-(3-ethylbenzoxazolin-2-ylidene-ethylidene)-1-methyl-2-thiohydantoin (XIV; Table 5, dye 5).

The author is indebted to Dr. E. B. Knott for helpful discussion and to Mr. A. Pilbeam for the preparation of some intermediates.

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HARROW, MIDDLESEX. [*Received, January 27th,* 1954.]