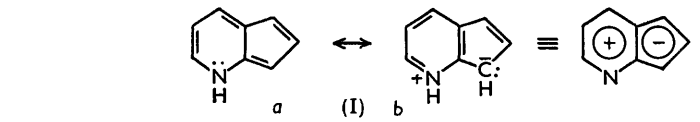
333. *Heterocyclic Analogues of Azulene.**

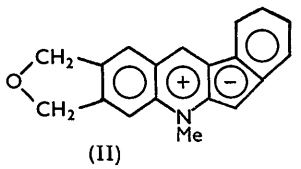
By M. Los and (the late) W. H. Stafford.

Some analogues of benzazulene are prepared containing nitrogen or oxygen in the central benzene ring. They are highly coloured and behave as anhydro-salts. Their properties and spectra are discussed.

Since replacement of a CH=CH group in an aromatic system by NR, S, or O results in a molecule not unlike that of the parent compound, *cyclo*penta[*b*]pyridine (I) might be expected to resemble azulene. Armit and Robinson [1] prepared indenoquinolines (II)



(I)



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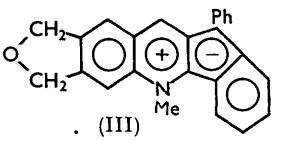

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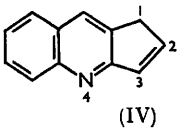


(IV)

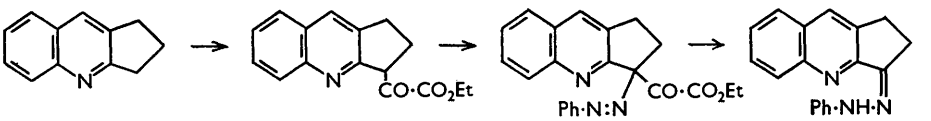
and (III) to prove that aromatic character may be associated with a five-membered ring. Although these compounds were highly coloured, their complexity prevents comparison with the azulenes, and so attempts were made to synthesise simpler analogues. Although neither *cyclo*penta[*b*]pyridine (I) nor its benzo-derivative, β-quinindene (IV), could be obtained, derivatives of the latter have been prepared. When Prelog and Szpilfogel [2] tried to dehydrogenate the dihydro-derivative of (I), only starting material was recovered. Borsche [3] synthesised 2 : 3-dihydro-β-quinindene from *cyclo*pentanone by the Pfitzinger reaction with subsequent decarboxylation of the 9-carboxylic acid so produced. Attempted dehydrogenation of methyl 2 : 3-dihydro-β-quinindene-9-carboxylate by sulphur gave only starting material. The dihydro-compound with *N*-bromosuccinimide gave a compound, presumably the 3-bromo-derivative (cf. the bromination of lepidine [4]), distillation of which caused decomposition and polymerisation (cf. the distillation of 4-iodoethylpyridine [5]); similar results were obtained in attempted dehydrobromination by methanolic potassium hydroxide.

* For a preliminary account, see *Proc. Chem. Soc.*, 1957, 352.

[1] Armit and Robinson, *J.*, 1922, **121**, 827; 1925, **127**, 1604.
[2] Prelog and Szpilfogel, *Helv. Chim. Acta*, 1945, **28**, 1684.
[3] Borsche, *Annalen*, 1910, **377**, 120; *Ber.*, 1908, **41**, 2203.
[4] Campbell, Ackermann, and Campbell, *J. Amer. Chem. Soc.*, 1949, **71**, 2905.
[5] Meisenheimer, *Annalen*, 1920, **420**, 190.

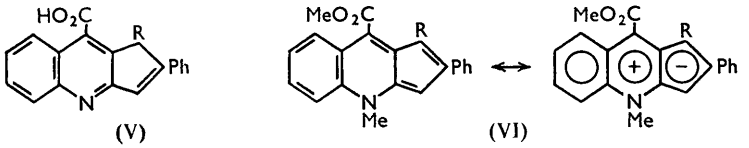
In a different approach we obtained a 64% yield of the 3-benzylidene-2 : 3-dihydro-β-quinindene when dihydro-β-quinindene was heated at 150° in a large excess of benzaldehyde. Ozonolysis of this product could be expected to give 2 : 3-dihydro-3-oxo-β-quinindene. However, ozonolysis in acetic acid [6] gave at most 15% yields of the ketone, and ozonolysis in carbon tetrachloride gave an ozonide which could not be decomposed. Anhydrous ethyl acetate was the best solvent for this ozonolysis provided that an excess of ozone (to which the ketone is sensitive) was avoided: a 64% yield of the ketone was then obtained if the ozonide was decomposed by hydrogen and platinum or palladium–charcoal.

Borsche *et al.* claim to have prepared two derivatives of this ketone but not the parent compound. They oxidised 2 : 3-dihydro-β-quinindene with selenium dioxide,[7] and distilled the reaction mixture; the distillate gave a small yield of a red 2 : 4-dinitrophenylhydrazone decomposing at 300°. Our ozonolysis product gave an orange dinitrophenylhydrazone decomposing between 275° and 295°. They [8] also prepared the phenylhydrazone by the series of reactions (A), obtaining it as a yellow powder, m. p. 170—173°, which on recrystallisation from benzene–hexane gave orange-red prisms, m. p. 113—114°. The phenylhydrazone from our ozonolysis product was bright yellow, crystallising from benzene as yellow needles, m. p. 176—177°. Our analyses for these derivatives were unsatisfactory and an alternative procedure was adopted. Oxidation of the benzylidene compound by osmium tetroxide gave a diol which was cleaved by lead tetra-acetate to a ketone identical with that obtained from the ozonolysis.

(A) 

Although substituted indenes are generally obtained from indan-1-one by a Grignard reaction followed by dehydration,[9] reaction of 2 : 3-dihydro-3-oxo-β-quinindene with phenylmagnesium bromide (or reduction by aluminium *iso*propoxide or borohydride) gave an insoluble blue material, not unlike that obtained on bromination. No explanation can be offered for the abnormal reaction.

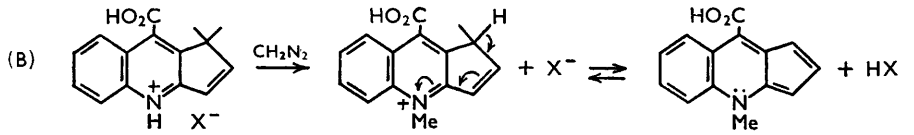
We next elaborated Borsche's synthesis of dihydro-β-quinindene. 3-Phenyl- and 3 : 4-diphenyl-*cyclo*pent-2-enone condensed smoothly with isatin in ethanolic potassium hydroxide to the β-quinindene acids (V; R = H and Ph). The similarity in properties and spectra of the derived methyl esters and ethyl 2-styrylcinchonate and their salts suggests that the double bond is in the 2 : 3- and not the alternative 1 : 2-position (cf. Boyd [10]).



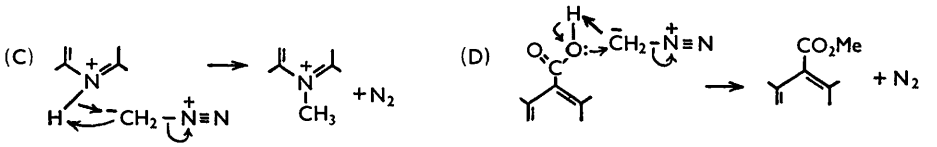
The acids (V) were insoluble in most organic solvents and crystallised only with difficulty (best from pyridine). In dilute solution they showed an intense blue fluorescence. The acid (V; R = H) slowly dissolved in ethereal diazomethane to a dark green solution. Chromatography on alumina separated two products, the colourless methyl ester of acid (V; R = H), and the intense blue anhydro-salt (VI; R = H) which was characterised as its 1 : 3 : 5-trinitrobenzene complex.

[6] Cf. Kaslow and Staynor, *J. Amer. Chem. Soc.*, 1945, **67**, 1716.
[7] Borsche and Hartmann, *Ber.*, 1940, **73**, 839.
[8] Borsche and Manteuffel, *Annalen*, 1938, **534**, 56.
[9] Cf., *e.g.*, Elsner and Parker, *J.*, 1957, 592.
[10] Boyd, *J.*, 1958, 1978.

The overall picture in the formation of the anhydronium salt is process (B). An acid-catalysed process is indicated since the ester of acid (V; R = H) does not react with diazomethane. The reactive species in this reaction, the diazonium ion, could



conceivably be produced by one or both of two processes, (C) and (D), giving both *N*- and *O*-methyl derivatives. Process (C) is shown to go through a zwitterion or intermolecular salt. Alternatively, intermolecular hydrogen-bonding between the carboxyl group and



the nitrogen produces the diazonium ion sufficiently close to both the nitrogen atom and the carboxyl group to allow competitive methylation.

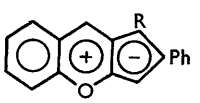
A similar reaction is observed with 8-hydroxyquinoline which yields the highly coloured *N*-methylquinolinium 8-oxide on treatment with diazomethane.

The anhydronium salt was also prepared by a three-stage process. The acid (V; R = H) with methanol and sulphuric acid yielded its methyl ester; with methyl iodide in benzene this gave the ester methiodide whence dilute sodium carbonate solution afforded the anhydronium salt (VI; R = H) whose trinitrobenzene complex was identical with that obtained by use of diazomethane. These reactions were also carried out with the homologous acid (V; R = Ph), with analogous results.

The acids (V; R = H or Ph) gave only small yields of decarboxylated material when distilled with soda-lime under reduced pressure. Less drastic methods failed completely. The methiodides of the resulting bases again gave intensely blue anhydronium salts on treatment with dilute carbonate solution.

All the anhydro-salts obtained from β-quinindene derivatives were violet or blue. In common with the azulenes, they formed crystalline, stable 1 : 3 : 5-trinitrobenzene complexes. Of the salts themselves, only one (VI; R = Ph) was obtained crystalline: it appeared to be stable. The other anhydronium salts were oils which decomposed in 24 hours; sunlight appeared to accelerate this. Azulenes and ylides suffer similarly and this has been attributed to the susceptibility of the carbanion to atmospheric oxidation.[11] With acids the blue anhydro-compounds form yellow salts possessing an intense blue fluorescence in solution.

Like Boyd,[10] we have prepared the analogous pyrylium compounds (VII; R = H and Ph). They were obtained in excellent yield by heating the salicylidene derivatives of 3-phenyl- and 3 : 4-diphenyl-*cyclo*pent-2-enone in acetic–hydrochloric acid. They are highly coloured (brownish-purple; blue-black) and much less basic than the nitrogen analogues: although they dissolve in strong mineral acids to give yellow, fluorescent pyrylium salts, they dissociate completely on dilution with water or attempted recrystallisation from an organic solvent.



(VII)

Spectra.—Azulenes show broad absorption in the visible and two bands in the ultraviolet region of the spectrum.[12] The visible part of the spectrum of azulene shows regular

[11] Saxena, Ph.D. Thesis, Edinburgh, 1955.
[12] See Gordon, *Chem. Rev.*, 1952, **50**, 185.

displacements with substitution. Direct comparison with our heterocyclic systems must be deferred until analogous azulenes are available, but some observations can already be made. (*a*) The β-quinindenes and the *cyclo*pentapyrans show the same general three-banded spectra as 5 : 6-benzazulene, the most closely related azulene known. (*b*) The relative displacements of the visible absorption band conform with expectations from azulene derivatives, except for identical visible absorption of compounds (VI; R = H and Ph), probably owing to molecular overcrowding which would prevent coplanarity of the 1-phenyl group with the rest of the molecule. (*c*) A direct comparison can be made between the analogous *cyclo*pentapyridines (VI; H in place of CO_2Me) and *cyclo*pentapyrans (VII). All show essentially the same three-banded spectra. The large difference

Ultraviolet and visible spectra (for ethanol solutions).

Compound	$\lambda_{max.}$ (mμ) and log ε (in parentheses)		
5 : 6-Benzazulene [13]	553(2·51)	352(3·55)	286(4·72) 252(4·46)
(VI; R = H) *	574(3·06)	396(4·32)	297(4·51) 232(4·45)
(VI; R = Ph) *	574(3·06)	396(4·41)	285(4·59)
4-Methyl-2-phenyl-β-quinindene *	532(3·01)	390(4·20), 370(4·30)	279(4·47)
4-Methyl-1 : 2-diphenyl-β-quinindene *	554(3·21)	372(4·33)	285(4·58)
(VII; R = H)	470(2·71)	387(4·37), 368(4·56)	256(4·52)
(VII; R = Ph)	512(2·92)	366(4·47)	265(4·54)

* 1 : 3 : 5-Trinitrobenzene complexes.

in $\lambda_{max.}$ (see Table) in the visible part of the spectrum must be attributed to the difference in the heteroatoms. Oxygen, being more electronegative than nitrogen, will show a greater tendency to develop an electron pair, so that there will be a greater contribution from the purely covalent structure (cf. Ia) and a smaller contribution from the dipolar structure (cf. Ib) and hence a decrease in depth of colour and basicity in the oxygen series.

Experimental

M. p. (uncorr.) taken on a hot stage.

2 : 3-*Dihydro*-β-*quinindene*.—2 : 3-Dihydro-β-quinindene-9-carboxylic acid was prepared in 90% yield.[3] Refluxing in methanol–sulphuric acid gave the *methyl ester* crystallising from aqueous methanol as prisms, m. p. 74—75° (Found: C, 73·7; H, 5·9; N, 5·9. $C_{14}H_{13}O_2N$ requires C, 73·9; H, 5·7; N, 6·2%). The acid (52 g.) was heated in a vacuum until the evolution of carbon dioxide had ceased and the residue was distilled. The distillate was dissolved in ether, washed with sodium carbonate solution and water, and dried (Na_2SO_4). Removal of the solvent gave a viscous oil which was distilled under reduced pressure to give 2 : 3-dihydro-β-quinindene (30 g., 71%), m. p. 59—60° (lit., m. p. 59—60°).

3-*Benzylidene*-2 : 3-*dihydro*-β-*quinindene*.—2 : 3-Dihydro-β-quinindene (30 g.) and freshly distilled benzaldehyde (50 g.) were heated at 150° for 4 hr., water distilling as it was formed. Excess of benzaldehyde was removed by distillation, and the residue triturated with ethanol (30 ml.). The solid was collected and recrystallised from ethanol in which it had a strong blue fluorescence. 3-*Benzylidene*-2 : 3-*dihydro*-β-*quinindene* (29 g., 64%) crystallised as colourless needles, m. p. 119—120° (Found: C, 88·7; H, 5·9; N, 5·4. $C_{19}H_{15}N$ requires C, 88·7; H, 5·8; N, 5·4%). The *methosulphate* separated from ethanol as yellow plates, m. p. 170—220° (Found: C, 65·6; H, 5·4; N, 3·6; S, 8·5. $C_{21}H_{21}O_4NS$ requires C, 65·8; H, 5·5; N, 3·7; S, 8·4%).

2 : 3-*Dihydro*-3-*oxo*-β-*quinindene*.—(*a*) Ozonised oxygen (~5%) was passed through a solution of the benzylidene compound (2 g.) in anhydrous ethyl acetate (80 ml.) at 0° until issuing in excess (starch–iodide). After nitrogen had been passed through the solution for 15 min., Adams catalyst (25 mg.) was added and a slow stream of hydrogen bubbled through the solution for 1 hr. Ethanol (25 ml.) was added and the solution heated to boiling and filtered. Removal of the solvent gave a yellow residue. Crystallisation from ethanol gave

[13] Kloster-Jenson, Kovats, Eschenmoser, and Heilbronner, *Helv. Chim. Acta*, 1956, **39**, 1058.

2 : 3-*dihydro*-3-*oxo*-β-*quinindene* (0·9 g., 64%) as colourless plates, m. p. 183—184° (decomp.) (Found: C, 77·6, 77·8, 77·4; H, 4·8, 5·2, 4·7; N, 8·0, 7·6, 6·7. $C_{12}H_9ON$ requires C, 78·7; H, 4·9; N, 7·7%). The 2 : 4-*dinitrophenylhydrazone* crystallised from acetic acid as yellow-orange needles, decomp. 275—295° (Found: C, 57·5, 57·7, 57·5; H, 3·9, 4·8, 3·8; N, 17·5, 18·2, 18·8. $C_{18}H_{13}O_4N_5$ requires C, 59·5; H, 3·6; N, 19·3%), the *phenylhydrazone* from benzene as yellow needles, m. p. 176—177° (Found: C, 78·3, 78·0; H, 6·0, 5·7; N, 11·5. $C_{18}H_{15}N_3$ requires C, 79·1; H, 5·5; N, 15·4%), and the *oxime* from ethanol as colourless prisms, m. p. 230—232° (decomp.) (Found: C, 72·2; H, 4·6; N, 11·8. $C_{12}H_{10}ON_2$ requires C, 72·8; H, 5·0; N, 14·1%).

(*b*) Osmium tetroxide (1 g.) was added to a solution of the benzylidene compound (2 g.) in anhydrous ether (200 ml.) containing anhydrous pyridine (5 ml.), and the mixture kept at room temperature for 3 hr. The chocolate-brown precipitate (2·37 g.) was collected, washed with ether, added to potassium hydroxide (1 g.) and mannitol (10 g.) in water (100 ml.) and chloroform (30 ml.), and shaken for 24 hr. The chloroform layer was separated, dried, and evaporated, to give a solid residue. A light petroleum (b. p. 40—60°) extract precipitated cis-2 : 3-*dihydro*-3-*hydroxy*-3-(α-*hydroxybenzyl*)-β-*quinindene* which was recrystallised from benzene–1-methylheptane as white plates, m. p. 139—140° (Found: C, 78·1; H, 6·0; N, 4·7. $C_{19}H_{17}O_2N$ requires C, 78·3; H, 5·8; N, 4·8%).

This glycol (0·22 g.) and lead tetra-acetate (0·33 g.) in benzene (50 ml.) were shaken for 3 hr. After removal of the benzene, the residue crystallised from ethanol as colourless plates, m. p. 183—184° (decomp.) alone or mixed with the ozonolysis product.

2-*Phenyl*-β-*quinindene*-9-*carboxylic Acid* (V; R = H).—Solutions of isatin (5·3 g.) in 30% potassium hydroxide solution (30 ml.) and 3-phenyl*cyclo*pent-2-enone [14] (5·0 g.) in ethanol (65 ml.) were heated under reflux for 6 hr. The ethanol was then distilled off, water (200 ml.) added, and the solution filtered. Addition of excess of 50% acetic acid precipitated a green-yellow solid which was collected and washed with water (500 ml.) and ethanol (50 ml.). This 2-*phenyl*-β-*quinindene*-9-*carboxylic acid* (7 g.) is pure enough for most purposes but recrystallises from pyridine as yellow needles, m. p. 260—290° (decomp.) (Found: C, 75·0; H, 4·9; N, 4·1. $C_{19}H_{13}O_2N,H_2O$ requires C, 74·9; H, 4·9; N, 4·6%).

Methyl 4-*Methyl*-2-*phenyl*-β-*quinindene*-9-*carboxylate* (VI; R = H).—(*a*) 2-Phenyl-β-quinindene-9-carboxylic acid was added to an excess of diazomethane in dry ether. The acid disappeared within 4 hr. with slow evolution of nitrogen. The intense red-purple solution was filtered and the solvent removed. A light petroleum (b. p. 40—60°) extract deposited colourless crystals from a vivid blue solution. These crystals recrystallised from methanol as colourless prisms, m. p. 135—136°, not depressed on admixture with the methyl 2-phenyl-β-quinindene-9-carboxylate obtained as in (*b*) below. The supernatant liquid was evaporated and the residue chromatographed in benzene on alumina, giving a green and a colourless band, the latter having a strong blue fluorescence in ultraviolet light. Elution with benzene gave the green band as a vivid blue solution and the colourless band as a highly fluorescent solution. The colourless band gave a further quantity of the methyl ester. The oil obtained from the blue solution formed a *complex* with 1 : 3 : 5-trinitrobenzene from methanol; this recrystallised from methanol as brown-black needles, m. p. 154—155° (Found: C, 61·2; H, 3·8; N, 10·2. $C_{27}H_{20}O_8N_4$ requires C, 61·4; H, 3·8; N, 10·6%).

(*b*) 2-Phenyl-β-quinindene-9-carboxylic acid with methanol and sulphuric acid gave the *methyl ester*, m. p. 135—136°, identical with that obtained as above (Found: C, 79·7; H, 4·9; N, 4·4. $C_{20}H_{15}O_2N$ requires C, 79·7; H, 5·0; N, 4·7%). The ester was boiled under reflux in benzene containing an excess of methyl iodide for 3 hr. The *methiodide* was collected and recrystallised from aqueous methanol as yellow prisms which did not melt up to 320° (Found: C, 57·1; H, 4·4; N, 2·6; I, 22·2. $C_{21}H_{18}O_2NI$ requires C, 56·9; H, 4·1; N, 3·2; I, 28·6%). The methiodide was suspended in 10% sodium carbonate solution and shaken with chloroform. The chloroform layer was separated, dried, and evaporated, to give a blue oil which readily formed a trinitrobenzene complex in methanol: the brown-black crystals had m. p. 154—155° undepressed on admixture with the complex obtained as in (*a*).

Methyl 4-*Methyl*-1 : 2-*diphenyl*-β-*quinindene*-9-*carboxylate* (VI; R = Ph).—Isatin (18 g.) and 3 : 4-diphenyl*cyclo*pent-2-enone [15] (20 g.) gave 1 : 2-*diphenyl*-β-*quinindene*-9-*carboxylic acid* (20 g., 65%), crystallising from pyridine as bright yellow needles, m. p. 282—284° (Found:

[14] Mousseron and Rouzier, *Bull. Soc. chim. France*, 1953, 190.
[15] Japp and Knox, *J.*, 1905, **87**, 673.

C, 75·3; H, 5·7; N, 3·4. $C_{25}H_{17}O_2N,2H_2O$ requires C, 75·2; H, 5·3; N, 3·5%), and giving with diazomethane the *methyl ester*, m. p. 170—172° (Found: C, 83·0; H, 4·7; N, 3·3. $C_{26}H_{19}O_2N$ requires C, 82·8; H, 5·1; N, 3·7%), and the blue *methyl* 4-*methyl*-1 : 2-*diphenyl*-β-*quinindene*-9-*carboxylate*, black prisms (from methanol), m. p. 178—179° (Found: C, 82·9; H, 5·1; N, 3·7. $C_{27}H_{21}O_2N$ requires C, 82·8; H, 5·4; N, 3·6%). Methyl 1 : 2-diphenyl-β-quinindene-9-carboxylate gave an orange *methiodide*, m. p. 215° (decomp.) (Found: C, 62·7; H, 4·6; N, 2·4; I, 19·4. $C_{27}H_{22}O_2NI$ requires C, 62·5; H, 4·2; N, 2·7; I, 24·5%). With sodium carbonate solution the methiodide gave the blue anhydro-salt identical with that obtained by use of diazomethane.

4-*Methyl*-1 : 2-*diphenyl*-β-*quinindene*.—A mixture of soda-lime (2 g.) and 1 : 2-diphenyl-β-quinindene-9-carboxylic acid (0·5 g.) was covered with soda-lime (1 g.) in a hard-glass tube attached to a U-tube immersed in ice-water and evacuated (water-pump). The tube was heated gradually. A buff-coloured solid which collected in the U-tube was extracted in ether, washed with sodium carbonate solution, and dried. The *product* remaining on removal of the solvent crystallised from ethanol as colourless needles (0·1 g.), m. p. 187—188° (Found: C, 90·0; H, 5·8; N, 4·4. $C_{24}H_{17}N$ requires C, 90·3; H, 5·3; N, 4·4%). The methiodide crystallised from chloroform–ether as yellow prisms, m. p. 193—194° (decomp.), and with sodium carbonate solution gave the blue 4-methyl-1 : 2-diphenyl-β-quinindene characterised as its *trinitrobenzene complex* which crystallised from methanol as black prisms, m. p. 181—182° (Found: C, 68·2; H, 4·0; N, 9·9. $C_{31}H_{22}O_6N_4$ requires C, 68·1; H, 4·0; N, 10·3%).

4-*Methyl*-2-*phenyl*-β-*quinindene*.—Decarboxylation of 2-diphenyl-β-quinindene-9-carboxylic acid, as above, gave a product which could not be purified and was converted into its methiodide which crystallised from ethanol–ether as yellow-green prismatic needles, m. p. 203—205°, and with sodium carbonate gave the blue 4-methyl-2-phenyl-β-quinindene characterised as its *trinitrobenzene complex*, black prisms (from methanol), m. p. 144—145° (Found: C, 63·7; H, 3·6; N, 12·6. $C_{25}H_{18}O_6N_4$ requires C, 63·8; H, 3·8; N, 11·9%).

2-*Phenylbenzo*[b]cyclo*penta*[e]*pyran*.—The procedure was identical with that described by Boyd.[10] Our product had m. p. 208—209°. Boyd gives m. p. 207—207·5°.

1 : 2-*Diphenylbenzo*[b]cyclo*penta*[e]*pyran*.—3 : 4-Diphenyl*cyclo*pent-2-enone (3 g.) and salicylaldehyde (1·6 g.) in ethanol in the presence of a small quantity of piperidine acetate were boiled under reflux for 3 hr. Removal of the solvent left a dark red oil which was dissolved in acetic acid (45 ml.) and concentrated hydrochloric acid (5 ml.). After 2 hours' heating at 90°, the solution was poured into water (250 ml.), and the purple precipitate collected, washed with water, and dried (P_2O_5). The solid (3 g., 73%) crystallised from ethanol as blue-black prisms (dark red by transmitted light), m. p. 155—156° (Found: C, 88·8; H, 5·0. $C_{24}H_{16}O$ requires C, 90·0; H, 5·0%).

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