ture was treated with methanol and then filtered from an insoluble material. Evaporation of the methanol gave a residue which was chromatographed on activity III Woelm alumina. Elution with benzene gave a solid. Crystallization from benzene–acetone gave 300 mg. of light yellow plates with m.p. 234.5–236.5°; λ_{max}^{MeOH} 207, 268, and 320 mμ (ϵ 48,000, 13,000, and 12,000 respectively); and infrared bands (Nujol) at 3200, 1605 1580, 1535, 1515, and 1495 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_9ClN_2O$: C, 65.42; H, 3.53; Cl, 13.80; N, 10.90. Found: C, 65.51; H, 3.73; Cl, 14.08; N, 10.82.

Reduction of 3-Indolyl 4-(2-Chloropyridyl) Ketone.—Hydrogenation of 250 mg. of 3-indolyl 4-(2-chloropyridyl) ketone in a suspension of 100 mg. of reduced palladium chloride, 900 mg. of barium carbonate, and 25 ml. of ethanol resulted in the uptake of 1.1 equiv. of hydrogen. Filtration of the mixture into chloroform removal of the ethanol by means of an aqueous washing, desiccation over magnesium sulfate, and evaporation gave a solid. When recrystallized from acetone this had an infrared spectrum, melting point, mixture melting point, and an R_f value on silica gel G thin layer chromatograms (eluent, 1% ethanol in chloroform) identical with that of 3-indolyl 4-pyridyl ketone (39).

3-Indolyl 4-Pyridyl Ketone (39).—To a suspension of 5 g. of isonicotinic acid in methylene chloride was added 4.1 g. of triethylamine. This was cooled to 0° in an ice bath and ethyl chloroformate was added over a period of 10 min. The solution was stirred at 0° for 30 min. to complete formation of the mixed anhydride and was rapidly added to a solution of the Grignard reagent of indole in ether prepared from 10.5 g. of indole. The resulting mixture was stirred at room temperature for 2 hr. and then decomposed by the addition of ammonium chloride solution. Extraction with chloroform, followed by desiccation and evaporation, gave a residue which was dissolved in chloroform. Extraction with dilute hydrochloric acid gave an aqueous phase which was washed once with chloroform and then poured into

sodium hydroxide solution to give a solid. Filtration and crystallization from acetone gave 850 mg. of yellow needles. An analytical sample was recrystallized twice from acetone to give white needles with m.p. 235–236°; λ_{max}^{MeOH} 208, 258, and 310 mμ (ϵ 35,500, 23,000, and 11,000, respectively); and infrared bands (Nujol) at 3200, 1605, 1575, 1550, and 1520 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_{10}N_2O$: C, 75.65; H, 4.54; N, 12.61. Found: C, 75.58; H, 4.48; N, 12.55.

1-Benzyl-3-(2-pyridyl)dioxindole (43).—A mixture of 9 g. of picolinic acid and 5 g. of 1-benzylisatin was melted under nitrogen. The melt was then allowed to stand in an oil bath at 180–200° for 2 hr. while carbon dioxide was evolved. The cooled reaction mixture was then dissolved in chloroform and this was extracted several times with 10% aqueous hydrochloric acid. The acidic extracts were basified with sodium hydroxide and then extracted with chloroform. Drying and evaporation of the chloroform gave a solid which was recrystallized from ethanol to give 1.6 g. of product: m.p. 192.5–194°; λ_{max}^{MeOH} 211, 258, and 290 mμ (ϵ 26,000, 6400, and 1050, respectively); infrared (Nujol) at 3450, 1700, 1620, 1590, and 1495 cm.$^{-1}$.

Anal. Calcd. for $C_{20}H_{16}N_2O_2$: C, 75.93; H, 5.18; N, 8.86. Found: C, 75.92; H, 5.10; N, 8.80.

The Base-Catalyzed Alkylation of Fluorene and Indene with Alcohols and Diols

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Fluorene can be alkylated in the 9-position with alcohols, using alkali metal hydroxide as catalyst. If the alkylating agents are diols, 9-(hydroxyalkyl)fluorenes as well as bis(9-fluorenyl)alkanes are obtained as products. Products of the reaction of fluorene with several alcohols and diols are described, as are a number of derivatives of bis(9-fluorenyl)alkanes. The alkylation reaction is also applicable to indene, which is alkylated in the 1- and 3-positions.

Schoen and Becker[1] reported in 1955 that sodium alkoxide in a solution of the corresponding alcohol will alkylate fluorene in the 9-position. The alkylation of fluorene with sodium ethoxide in ethanol, for example, yielded 9-ethylfluorene. Later Rubin and Becker extended the reaction to include diols. They prepared 1,2-bis(9-fluorenyl)ethane from fluorene, sodium, and ethylene glycol.[2] In all these experiments the amount of alkali metal used was in stoichiometric excess of the amount of fluorene added.

We have pursued the study of the alkylation of fluorene with alcohols and can report that it is not necessary to use as strong a base as alkali metal alkoxide, but that alkali metal hydroxides will do. Also, it is not necessary to use stoichiometric quantities of base; catalytic quantities will do. Four 9-alkylfluorenes were prepared, using methanol, ethanol, 1-butanol, and 2-ethylhexanol. A mixture of C_{10} alcohols[3] was

also treated with fluorene, giving a mixture of 9-isodecylfluorenes.

The reactions were conducted at temperatures of 180–250°, usually in a rocker autoclave, but some reactions of high-boiling alcohols could be carried out in flasks at atmospheric pressure. Data from a number of runs are given in Table I. The data show that catalytic amounts of potassium hydroxide and sodium hydroxide work equally as well as stoichiometric amounts of sodium alkoxide in effecting the reaction of fluorene with alcohols. They also show that lithium hydroxide, calcium oxide, and tributylamine are not catalysts for the reaction.

Like Rubin and Becker,[2] we found that, when a diol is used instead of an alcohol, a bis(9-fluorenyl)alkane (I) is formed. With potassium hydroxide or sodium hydroxide as catalyst, however, there is also an appreciable yield of 9-(hydroxyalkyl)fluorene (II), and the yield of this product increases with increasing catalyst concentration. Alkylation of fluorene with ethylene glycol in the presence of potassium hydroxide

(1) K. L. Schoen and E. I. Becker, *J. Am. Chem. Soc.*, **77**, 6030 (1955).
(2) I. D. Rubin and E. I. Becker, *J. Org. Chem.*, **22**, 1623 (1957).
(3) Union Carbide's C_{10} alcohols, trade name "iso-Decanol."

Alcohol or diol	Fluorene, moles	Base	Moles	Yield of 9-alkyl-fluorene or 9-(hy-droxy-alkyl)-fluorene, %[a]	Yield of bis(9-fluor-enyl)-alkane, %[a]
Methanol[b]	2.0	NaOCH₃	2.30	83	
Methanol	0.5	KOH	0.50	c	
Ethanol	0.5	KOH	0.20	84	
1-Butanol	0.5	KOH	0.11	79	
1-Butanol	0.5	NaOH	0.05	c	
2-Ethylhexanol	2.0	KOH	1.00	95	
Isodecanol	2.0	KOH	0.40	67	
Ethylene glycol	1.0	KOH	0.15	6	62
Ethylene glycol	2.0	KOH	1.50	25	43
Ethylene glycol	1.0	NaOH	0.60	23	40
1,4-Butanediol	2.0	KOH	1.50	21	39
1,5-Pentanediol	1.0	KOH	0.75	13	67
1,6-Hexanediol	1.0	KOH	0.75	...	68

[a] Yields are based on fluorene charged to the reactor. Products were isolated by distillation or crystallization. [b] A comparison experiment using the procedure of ref. 1. [c] Fluorene conversion was complete, but the yield of 9-alkylfluorene was not measured.

gave a 25% yield of 9-(2-hydroxyethyl)fluorene and a 43% yield of 1,2-bis(9-fluorenyl)ethane. 1,4-Butanediol, 1,5-pentanediol, and 1,6-hexanediol were also treated with fluorene in the presence of potassium hydroxide. The results of a number of these runs are also shown in Table I. Properties of the purified 9-alkylfluorenes, bis(9-fluorenyl)alkanes, and 9-(hydroxyalkyl)fluorenes are presented in Table II.

ethane (IIIa). This can be hydrolyzed by hydrobromic acid in acetic acid to 1,2-bis[9-(2-carboxyethyl)-9-fluorenyl]ethane (IIIb). 1,2-Bis[9-(3-aminopropyl)-9-fluorenyl]ethane (IIIc) is prepared by re-

IIIa, Y = CN
b, Y = COOH
c, Y = CH₂NH₂
d, Y = CH₂NHCOCH₃
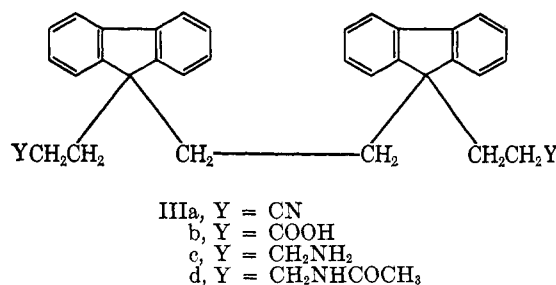
ducing IIIa with hydrogen in acetic anhydride, using Raney nickel as catalyst and sodium acetate as promoter.[5] The initial product is 1,2-bis[9-(n-acetyl-3-aminopropyl)-9-fluorenyl]ethane (IIId), which is hydrolyzed in methanolic sodium hydroxide solution at 200°. The derivatives prepared, and their properties, are listed in Table III.

Alkylation of Indene.—The reactivity of the hydrogens in the 9-position of fluorene is paralleled by the reactivity of the hydrogens in the 1-position of indene. Hence, the alkylation of indene with alcohols can also be accomplished by base catalysis. Because of the mobility of the double bond in the indenyl carbanion formed in the presence of base, it is possible to substitute both the 1- and the 3-positions of indene with alkyl groups.

Thus, when excess 2-ethylhexanol was treated with indene, the major product was 1,3-bis(2-ethylhexyl)-

Table II
9-Substituted Fluorene Derivatives

Compd.[a]	M.p., °C Found	M.p., °C Lit.[c]	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Mol. wt.[b] Calcd.	Mol. wt.[b] Found
FCH₃	48	45–46	93.30	93.72	6.70	6.70		
FCH₂CH₃	−3	...	92.74	92.75	7.26	7.48		
FCH₂CH₂CH₂CH₃	33	...	92.25	92.11	7.74	8.20		
FCH₂C(CH₂CH₃)HCH₂CH₂CH₂CH₃	...	...	90.59	90.55	9.41	9.2		
FCH₂CH₂F	228–229	227–228						
FCH₂CH₂OH	100–101	101[d]						
F(CH₂)₄F	158–161	158–158.5						
F(CH₂)₄OH[e]	48–49	...	85.72	85.96	7.56	7.75	238	235
F(CH₂)₅F	83–84	81–82	...	...	...	...	...	...
F(CH₂)₅OH	...	...	85.71	85.58	7.94	8.12	252	262
F(CH₂)₆F	109–109.5	...	92.75	92.42	7.25	7.43	414	416

[a] F = 9-substituted fluorene. [b] By the freezing point depression of benzene. [c] Ref. 1 and 2. [d] E. J. Greenhow, E. N. White, and D. McNeil, J. Chem. Soc., 2848 (1951). [e] Also synthesized by the lithium aluminum hydride reduction of the methyl ester of 9-(3-carboxypropyl)fluorene.

(CH₂)ₓ   (CH₂)ₓOH
I   II
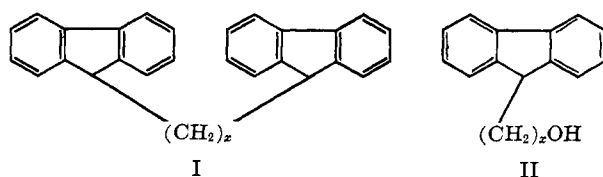
Quite a number of derivatives were made using bis-(9-fluorenyl)alkanes as starting materials. 1,2-Bis(9-fluorenyl)ethane (I, x = 2), for example, can be cyanoethylated according to the method of Bruson,[4] giving 1,2-bis[9-(2-cyanoethyl)-9-fluorenyl]-

(4) H. A. Bruson, J. Am. Chem. Soc., 64, 2457(1942).

indene. However, equimolar quantities of indene and isopropanol gave isopropylindene as the only product isolated, although appreciable proportions of unidentified higher boiling material were also obtained. Reaction conditions and results of the three potassium hydroxide catalyzed alkylations of indene are shown in Table IV along with properties of the products.

Experimental

Here are typical experiments describing the reactions reported and the methods of preparation of the compounds synthesized.

(5) F. E. Gould, G. S. Johnson, and A. F. Ferris, J. Org. Chem., 25, 1658 (1960).

TABLE III

BIS[9-(SUBSTITUTED)-9-FLUORENYL]ALKANES

Compd.[a]	M.p., °C.	Carbon, %		Hydrogen, %		Nitrogen, %	
		Calcd.	Found	Calcd.	Found	Calcd.	Found
NCCH₂CH₂FCH₂CH₂FCH₂CH₂CN	275–277	89.94	89.95	6.03	6.10	6.03	6.20
NCCH₂CH₂F(CH₂)₄FCH₂CH₂CN	181–182	87.78	87.73	6.54	6.78	5.68	5.89
NCCH₂CH₂F(CH₂)₅FCH₂CH₂CN	120–121	87.61	88.01	6.76	6.69	5.53	5.65
NCCH₂CH₂F(CH₂)₆FCH₂CH₂CN	125–126	87.66	87.38	6.96	6.90	5.38	5.57
HOOCCH₂CH₂FCH₂CH₂FCH₂CH₂COOH	285–287	81.27	81.02	5.98	6.09	…	…
HOOCCH₂CH₂F(CH₂)₄FCH₂CH₂COOH	261–263	81.48	81.49	6.45	6.51	…	…
HOOCCH₂CH₂F(CH₂)₅FCH₂CH₂COOH	180–181	81.58	81.34	6.66	6.69	…	…
HOOCCH₂CH₂F(CH₂)₆FCH₂CH₂COOH	218–219	81.67	81.75	6.86	7.11	…	…
CH₃CONHCH₂CH₂CH₂FCH₂CH₂FCH₂CH₂CH₂NHCOCH₃	267–269	82.0	81.8	7.2	7.1	5.0	4.7
H₂NCH₂CH₂CH₂FCH₂CH₂FCH₂CH₂CH₂NH₂	208–210	86.4	86.0	7.7	7.5	5.9	6.0

[a] F = 9,9-disubstituted fluorene.

TABLE IV

ALKYLATION OF INDENE WITH ALCOHOLS USING POTASSIUM HYDROXIDE CATALYSIS

Alcohol	Product isolated	Yield,[a] %	B.p., °C. (mm.)	$n^{20}D$	Carbon, %		Hydrogen, %		Mol. wt.[b]	
					Calcd.	Found	Calcd.	Found	Calcd.	Found
2-Ethylhexanol	1,3-Bis(2-ethylhexyl)indene	74	166–168 (0.4)	1.5102	88.16	88.15	11.84	11.88	340	330
Isopropanol	Isopropylindene	26	101–103 (10)	1.5451	91.08	90.93	8.92	9.00	158	162
Cyclohexanol	1,3-Bis(cyclohexyl)indene	26	168–169 (0.6)	1.5609	89.94	89.68	10.06	10.12	280	273

[a] Yields are based on fluorene charged to the reactor. Products were isolated by distillation. [b] By the freezing point depression of benzene.

9-Ethylfluorene. Autoclave Preparation.—A 1-l. autoclave was charged with 83 g. of 95% fluorene, 275 g. of absolute denatured ethanol, and 11 g. of KOH pellets, then sealed and heated to 200–218° for 20 hr. at a maximum pressure of 540 p.s.i.g. The cooled reaction mixture was diluted with water and the crude product was extracted with isopropyl ether. The yield of 9-ethylfluorene obtained by distillation was 78 g. (84% based on fluorene) (see Table I and II).

1,2-Bis(9-fluorenyl)ethane and 9-(2-Hydroxyethyl)fluorene.— Fluorene (95%, 175 g., 1.0 mole), 310 g. (5 moles) of ethylene glycol, and 10 g. of 85% potassium hydroxide (0.15 mole) were charged to a 1-l. rocker autoclave, which was then pressurized with 25 p.s.i.g. of air. These components were heated to 210–220° for 20 hr., and the product was added to 1 l. of water and filtered. The solids were washed twice with water, slurried in methanol, and filtered, leaving 129 g. of solid. The solid was slurried in refluxing methanol for 3 hr. After cooling, the mixture was filtered and there was obtained 110 g. (0.31 mole) of 1,2-bis(9-fluorenyl)ethane, for a yield of 62% based on fluorene.

The methanol washes were combined and the methanol was evaporated. The resulting crystals were washed with cyclohexane, then recrystallized from cyclohexane. There was obtained 13 g. (0.06 mole) of 9-(2-hydroxyethyl)fluorene, a yield of 6%.

1,4-Bis(9-fluorenyl)butane and 9-(4-Hydroxybutyl)fluorene.— Fluorene (2 moles), 6 moles of 1,4-butanediol, and 1.5 moles of KOH were subjected to 250° for 6 hr. The initial part of the work-up was the same as in the above reaction. The solids remaining after the methanol wash amounted to 80 g. (0.21 mole) of 1,4-bis(9-fluorenyl)butane, m.p. 158–161°, 21% yield.

The methanol washes were combined and the methanol was distilled. The residue was fractionally distilled, and 185 g. (0.78 mole) of 9-(4-hydroxybutyl)fluorene, distilling at 174–176° (1 mm.), was obtained. The yield was 39%. Recrystallization of a portion from cyclohexane gave an analytical sample, m.p. 48–49°. The infrared spectrum of the material is consistent with the suggested structure. For comparison, a sample of the material was synthesized by the lithium aluminum hydride reduction of the methyl ester of 9-(3-carboxypropyl)fluorene. The substances were identical.

1,2-Bis[9-(2-cyanoethyl)-9-fluorenyl]ethane.—To 36 g. (0.1 mole) of 1,2-bis(9-fluorenyl)ethane in 750 ml. of dioxane was added 20 ml. of 32% Triton B (benzyltrimethylammonium hydroxide) in methanol. With continued stirring, 50 g. of acrylonitrile was added slowly, and the temperature rose from 27 to 37°. The reaction mixture was filtered and the solids obtained were recrystallized from dioxane, yielding 26 g. (0.056 mole) of of 1,2-bis[9-(2-cyanoethyl)-9-fluorenyl]ethane, m.p. 275–277°. The infrared spectrum of this material showed the characteristic nitrile absorption band at 4.45 μ.

1,2-Bis[9-(2-carboxyethyl)-9-fluorenyl]ethane.—1,2-Bis[9-(2-cyanoethyl)-9-fluorenyl]ethane (300 g., 0.646 mole), 750 g. of 48% hydrobromic acid, and 750 g. of glacial acetic acid were refluxed vigorously for 4 days. The product was filtered, and the solids obtained were water washed and recrystallized from the dioxane, giving 277 g. (0.552 mole) of 1,2-bis[9-(2-carboxyethyl)-9-fluorenyl]ethane, m.p. 285–287°, for a yield of 85%. The infrared spectrum of this material was consistent with the proposed structure.

1,2-Bis[9-(N-acetyl-3-aminopropyl)-9-fluorenyl]ethane.—1,2-Bis[9-(2-cyanoethyl)-9-fluorenyl]ethane (10 g.) in 100 g. of acetic anhydride was hydrogenated in a Parr hydrogenator using 3 g. of Raney nickel catalyst and 2 g. of sodium acetate promoter.[5] The solid product mixed with catalyst was filtered off, and the product separated by dissolving it in hot dioxane. Crude 1,2-bis-[9-(N-acetyl-3-aminopropyl)-9-fluorenyl]ethane (9 g.), m.p. 255–262°, was recovered for a yield of 75%. An analytical sample, m.p. 267–269°, was obtained by recrystallization from dioxane.

1,2-Bis[9-(3-aminopropyl)-9-fluorenyl]ethane.—1,2-Bis[9-(N-acetyl-3-aminopropyl)-9-fluorenyl]ethane (10 g., 0.018 mole), 8 g. (0.2 mole) of sodium hydroxide, 10 g. (0.55 mole) of water, and 200 ml. of methanol were heated to 196–205° in a rocker autoclave for 10 hr. The reaction mixture was poured into 750 ml. of water, and 6 g. (0.013 mole) of crude 1,2-bis[9-(3-aminopropyl)-9-fluorenyl]ethane precipitated for a crude yield of 72%. This material was recrystallized to give an analytical sample, m.p. 208–210°. The infrared spectrum was consistent with that expected for 1,2-bis[9-(2-aminopropyl)-9-fluorenyl]ethane.

1,3-Bis(2-ethylhexyl)indene. Bench Preparation.—Indene (0.84 mole), 2-ethylhexanol (500 ml.), and KOH (0.38 mole) were charged to a 1-l. flask and heated to reflux for 12 hr. with stirring. The water formed was removed with an appropriate trap. The product was diluted with 250 ml. of isopropyl ether and washed with water. The organic layer was distilled, yielding 0.62 mole (74%) of 1,3-bis(2-ethylhexyl)indene. An analytically pure sample was obtained by redistillation at 166–168° (0.4 mm.). The ultraviolet absorption spectrum had a maximum at 257 μ. The infrared absorption spectrum agreed with the proposed structure.