Chemistry of dibenzobarallene

Moustafa A. GOUDA∗**, Moged A. BERGHOT, Khaled M. ELATTAR**
Abd El Galil M. KHALIL

Department of Chemistry, Faculty of Science, Mansoura University,
ET-35516 Mansoura, EGYPT
e-mail: dr_mostafa_chem@yahoo.com

This review represents a systematic and comprehensive survey of the methods of syntheses and chemical reactivity of dibenzobarallene. This compound is an important intermediate for the synthesis of useful and novel heterocycle systems.

Key Words: Dibenzobarallene, synthesis, spectroscopic and kinetic studies, thermodynamic measurements, reactions

Introduction

There is no review summarizing the literature on the synthesis and chemistry of dibenzobarallene. This review therefore aims to cover the work on the synthesis and reaction of dibenzobarallene. Cycloaddition reaction of anthracene and maleic anhydride afforded an anthracene-maleic anhydride adduct.[1] Five methods were reported in the literature for the nomenclature of dibenzobarallene. Accordingly, the title compound has 3 ways for the numbering of atoms (structures **1A**, **1B**, and **1C**). Structure **1A** can be named as dibenzobarallene[1] and 2,3:5,6-dibenzo-bicyclo[2,2,2]octane-7,8-dicarboxylic anhydride.[2] Similarly, structure **1B** was reported to have 2 methods of nomenclature, cis-9,10-dihydroanthracene-9,10-endo-α,β-succinic anhydride[3] and 9,10-dihydro-9,10-ethanoanthracene-11,12-dicarboxylic anhydride.[4] Structure **1C** was named as 9,10,11,15-tetrahydro-9,10-[3',4']-furano-anthracene-12,14-dione.[5]


∗Corresponding author

1A　　　　　**1B**　　　　　**1C**
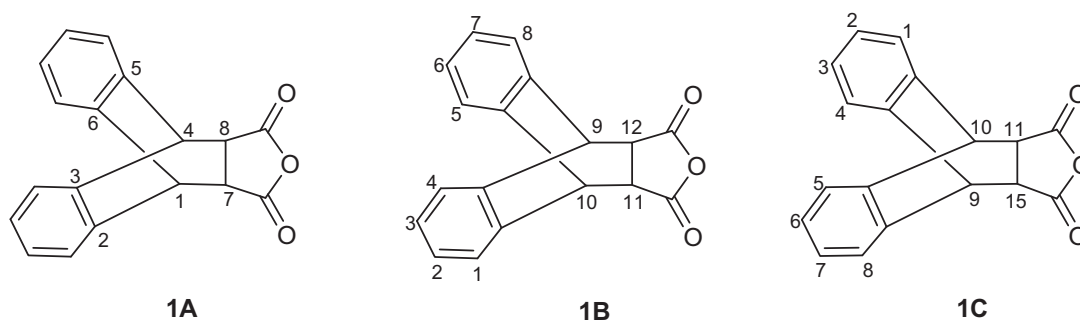
Dibenzobarallene (**1**) has been a key starting material for the synthesis of isoindole-1,3-diones as an antibacterial agent,[6,7] an antiinflamatory,[5] antiarthritics,[5] substituted pyrroloanthracene as immunomodulators,[8] and other bioactive and novel heterocyclic systems.[9,10]

Synthesis

The most convergent and well-established classical approach for the synthesis of dibenzobarallene (**1**) is the Diels-Alder reaction, which involves the cycloaddition reaction of anthracene (**2**) and maleic anhydride (**3**). Thus, anthracene (**2**) and maleic anhydride (**3**) were ground together and fused for 15 min to give **1**.[11,12] Moreover, adduct **1** was achieved through the refluxing of the same reactants in xylene,[13] toluene,[14] benzene,[15] dioxane,[16] or acetic acid[17] as a solvent. The same reaction was activated by cyclopentadienyl ruthenium cations under mild conditions (83 °C).[18] Microwave irradiation of anthracene (**2**) and maleic anhydride (**3**) in xylene also afforded **1**.[19,20] Da Cunha and Garrigues[21] studied the Diels-Alder reaction of anthracene (**2**) and maleic anhydride (**3**) under ultrasonic irradiation.
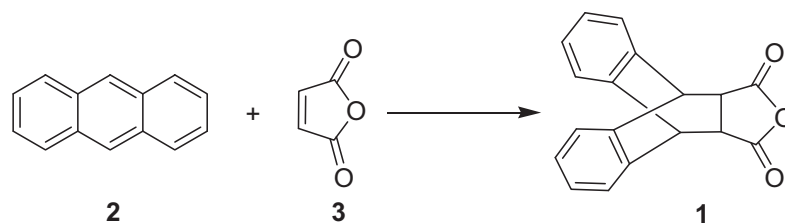
Walter and Helmut reported that photolysis of 9,10-dihydro[1',2']cyclobutanoanthracene-13,14-dione (**4**) afforded compound **1**.[22]
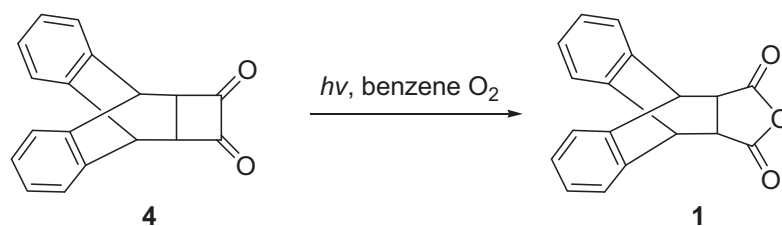
Spectroscopic studies

Molecular and crystal structure of dibenzobarallene

Crystallographic data,[23] bond lengths, and bond angles were determined for **1** by X-ray. The benzene rings are planar and the dihedral angle between them is $53.9°$. The anhydride ring is also planar and forms angles of $57.5°$ and $4.3°$ with the benzene rings.

FTIR spectrum

The acid anhydride can be easily detected due to the appearance of 2 frequency bands in the region of 1850-1750 cm^{-1}. The doublet appears at 1837.63 and 1863.37 cm^{-1} due to the coupled vibrations of 2 (C=O) groups. The high frequency band is assigned to symmetrical vibrations and the lower frequency band to asymmetric vibrations. The splitting of the band is due to Fermi resonance. The absorption bands between 900 and 700 cm^{-1} are characteristic of C–H deformation. The absorption band at 1779.37 cm^{-1} is due to C=O stretching.[24] The absorption bands at 1231.09 and 1290.44 cm^{-1} are assigned to C–O stretching. The absorption band at 3069.88 cm^{-1} is characteristic of C=C–H stretching (Figure 1).
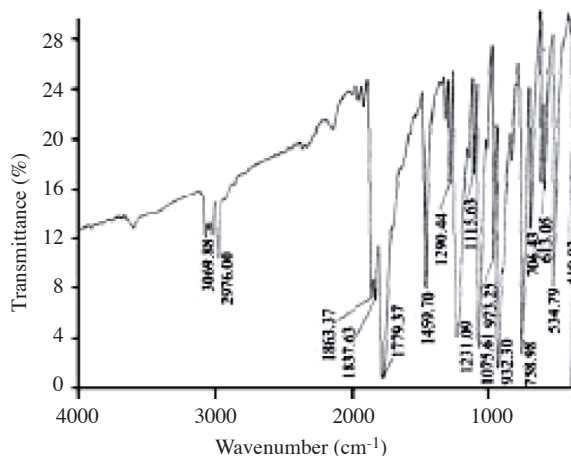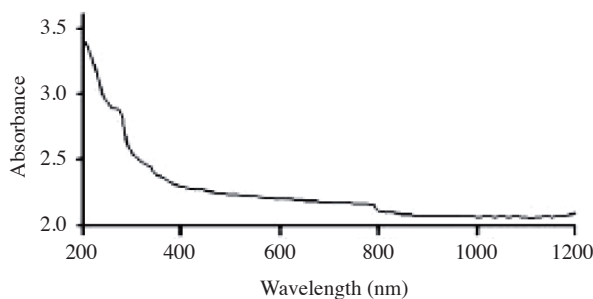

Figure 1. FTIR spectrum of Diels-Alder adduct.

UV spectral studies

UV-visible spectral analysis revealed that the adduct was conveniently transparent at 400-1200 nm with about 75% transmission, suitable for modulation purposes (Figure 2).[24]
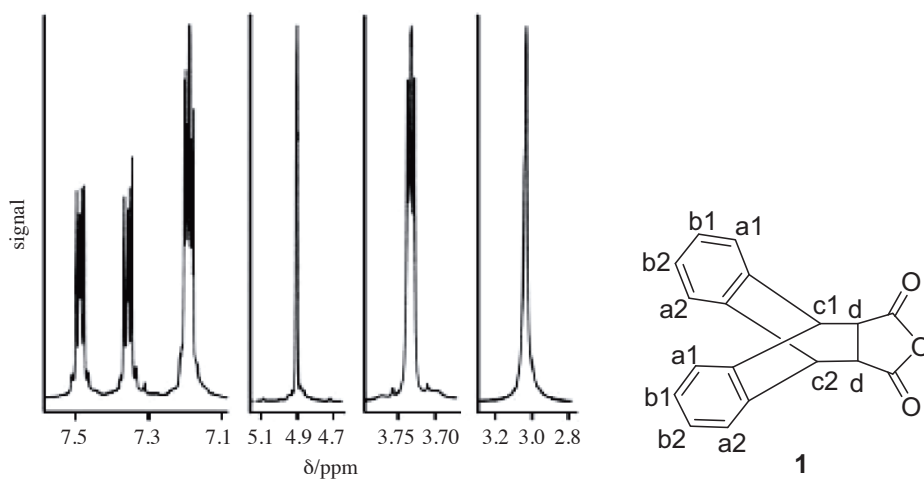
The ^{1}H-NMR spectrum

The ^{1}H-NMR spectrum of dibenzobarallene (**1**) in acetone was recorded using a JEOL instrument, model GSX400 (Figure 3a). The double doublets at δ 7.5 and 7.35 ppm are assigned to the phenyl protons present in the b1 and b2 positions, respectively. The multiplet at δ 7.2 is assigned to the phenyl protons present in positions a1 and a2. The singlet at δ 4.9 ppm is assigned to the benzylic protons present in position c1, and

the other benzylic proton present in position c2 gives a singlet at δ 3.00 ppm. The triplet at δ 3.78 ppm is assigned to the protons present in the d position. It is expected that the benzylic protons present in c1 and c2 give a doublet, but they gave 2 singlet signals at δ 4.9 and 3.00 ppm due to the electronegative phenyl group present adjacent to each proton (Figures 3a and 3b).[24]

Figure 2. UV-visible spectrum of **1**.

Figure 3. a) ^{1}H-NMR spectrum of Diels-Alder adduct, b) Diels-Alder adduct.

A kinetic study

The rates of reaction of anthracene and dimethylanthracene with maleic anhydride and several of its substitution products have been followed by colorimetric procedures. In the presence of a large excess of dienophile, the reactions in chloroform are first-order with respect to diene, but the first-order rate constants are not directly proportional to the dienophile concentration. This kinetic behavior can be explained quantitatively through consideration of the fact that a substantial fraction of the diene in the reaction mixtures is bound in a molecular complex with the dienophile. The mechanism of the reaction is discussed in light of these observations and in terms of the effects of changes in temperature, solvent, and substituents in the reactant molecules on the reaction rates. The possibility that the Diels-Alder adduct may form by reaction of the diene-dienophile complex with a second dienophile molecule has been ruled out on the basis of rate studies.[25]

Thermodynamic measurements

The energy of combustion of the crystalline Diels-Alder adduct of anthracene and maleic anhydride, $C_{18}H_{12}O_3$, was measured with a model 1241 Parr automatic calorimeter and a model 1710 Parr calorimeter controller. The standard molar enthalpy of combustion of the anthracene and maleic anhydride adduct at $p^\circ = 0.1$ MPa was determined to be $\Delta_c H^\circ{}_m$ ($C_{18}H_{12}O_3$, cr, 298.15 K) = –(8380.0 ± 5.9) kJ mol^{-1}. The molar enthalpy of fusion of this adduct at its melting temperature (534.07 K), as measured by a 910 DuPont DSC and a 9900 DuPont thermal analyzer and digital computer, was found to be 36.3 ± 4.2 kJ mol^{-1}. The other thermodynamic properties of the anthracene and maleic anhydride adduct derived from those measured properties are: $\Delta_f H^\circ{}_m$ ($C_{18}H_{12}O_3$, cr, 298.15 K) = –(418.2 ± 6.4) kJ mol^{-1}, and $\Delta_f H^\circ{}_m$ ($C_{18}H_{12}O_3$, cr, 298.15 K) = –(389.7 ± 7.7) kJ mol^{-1}.[26]
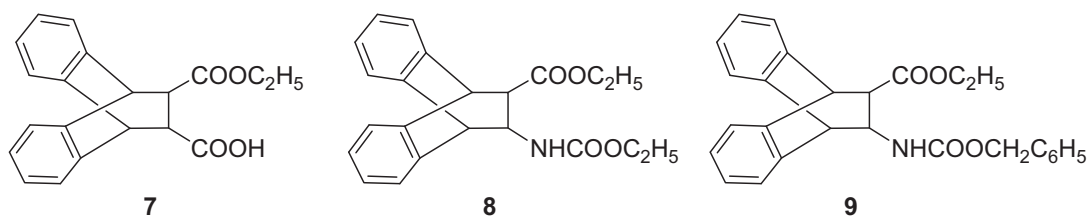
Reactions with

Alkali

The reaction of **1** with aqueous sodium hydroxide or potassium hydroxide solution gave corresponding cis-sodium salt **5**, which afforded corresponding cis-diacid **6** upon acidification with hydrochloric acid.[27,28]


Meanwhile, treatment of **1** with sodium ethoxide followed by acidification with hydrochloric acid gave trans-acid **7**, which, upon treatment with sodium azide followed by ethyl chloroformate, yielded **8**. Reaction of **8** with benzyl alcohol gave **9**.[29]


Phenols

From the reaction of **1** with phenol in the presence of concentrated sulfuric acid, phthalein-like product **10** was obtained. An analogous reaction of fluorescence-like product **11** was formed when **1** was treated with resorcinol. Treatment of **11** with bromine gave **12**, like eosin.[30]
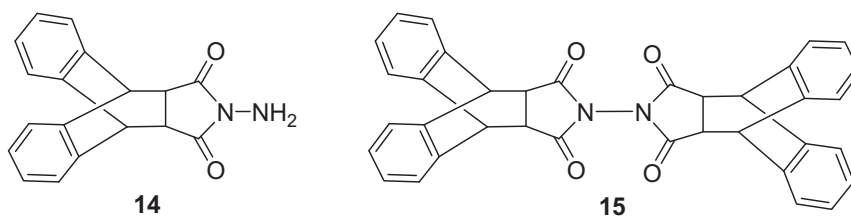
10　　　**11**　　　**12**
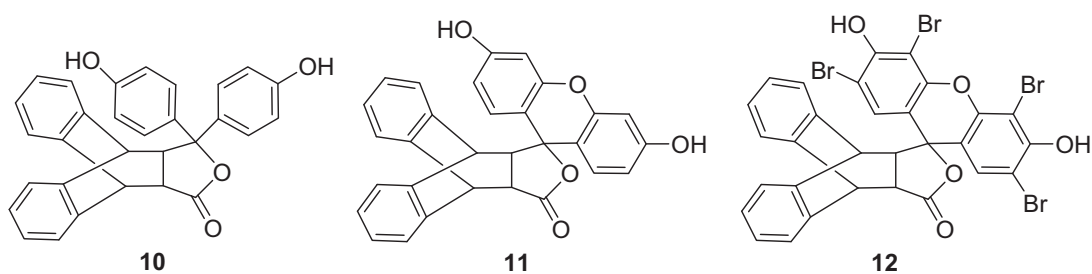
Ethylene glycol

Condensation of **1** with an equivalent amount of ethylene glycol gave polyester resin **13**.[30]


13
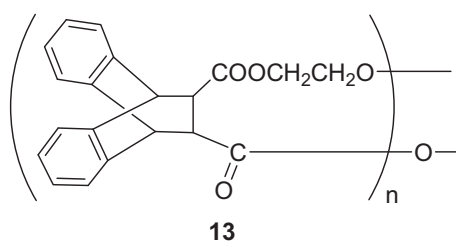
Hydrazine hydrate

Heating **1** with 1 equivalent of 25% hydrazine hydrate for 10 min gave N-aminodicarboximide **14**. On the other hand, refluxing **1** with 85% hydrazine hydrate in ethanol gave corresponding bis-carbohydrazide **15**.[31]


14　　　　　**15**

Phthalazine derivative **16** was achieved via reaction of **1** with hydrazine hydrate in glacial acetic acid.[1] Reaction of **16** with indene **17** in methylene chloride gave diazocyclobutane derivatives **18**.


16　　　**17**　　　**18**
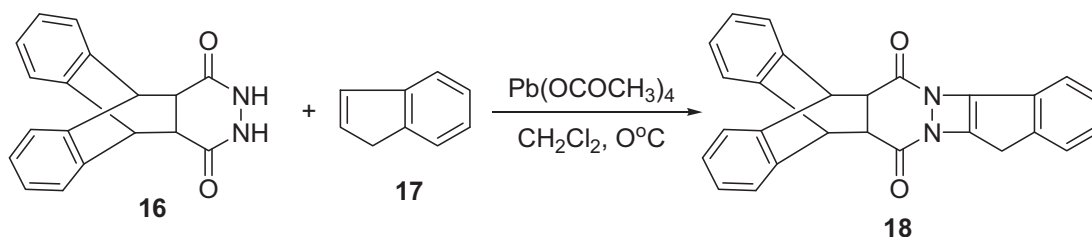
Treatment of **14** with succinic anhydride in dry benzene gave **19**.[32] Acylation of **14** with acetic anhydride gave N,N-diacetyl derivatives **20**.

19   **20**
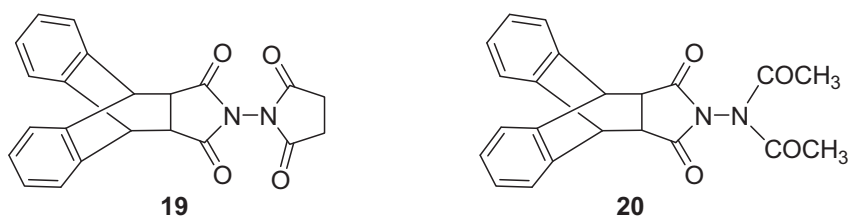
Moreover, reaction of **14** with asymmetric methyl ketones in ethanol gave E-isomer hydrazones **21a**, while Z-isomers **21b** were achieved when the reaction took place in xylene.[33,34]
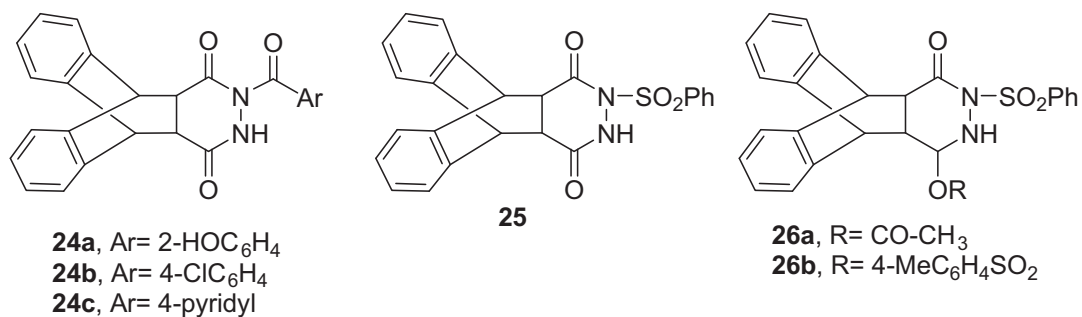

21a (*E*-isomer)   **21b** (*Z*-isomer)

R= Ethyl, phenyl, 2-naphthyl
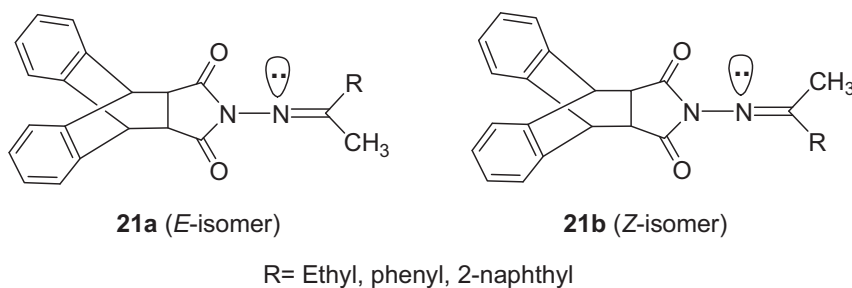
Reduction of both **21a** and **21b** with excess sodium borohydride in methanol yielded products **22**.[33,34] Compound **23** was obtained from the reaction of **14** with diethyl acetylene dicarboxylate in ethanol.[33]

**22**, R= Me, Ph   **23**
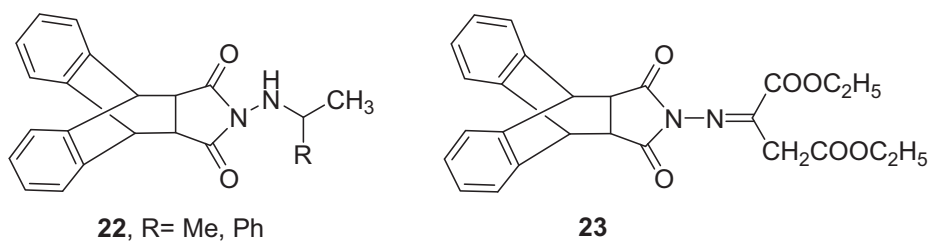
Acid hydrazide

Dibenzobarallene (**1**) was reacted with acid hydrazide such that hydrazide of salicylic acid, p-chlorobenzoic acid, isonicotinic acid, and benzene sulfonic acid yielded phthalazinediones **24a-c** and **25**, respectively. The latter phthalazinedione, **25**, was treated with acetic anhydride and p-toluene sulfonyl chloride to yield O-acetylated and O-sulfonated derivatives **26a** and **26b**, respectively.[35]

24a, Ar= 2-HOC$_6$H$_4$
24b, Ar= 4-ClC$_6$H$_4$
24c, Ar= 4-pyridyl

25

26a, R= CO-CH$_3$
26b, R= 4-MeC$_6$H$_4$SO$_2$

Phthalazinediones **27a-c** were also achieved from the reaction of **1** with hydrazides of N-arylglycine, which, upon treatment with formalin in acetic acid, gave polynuclear heterocyclic system **28a-c**.[35]

27a-c

28a-c

Ar= *p*-ClC$_6$H$_4$, C$_6$H$_5$, *p*-CH$_3$C$_6$H$_4$
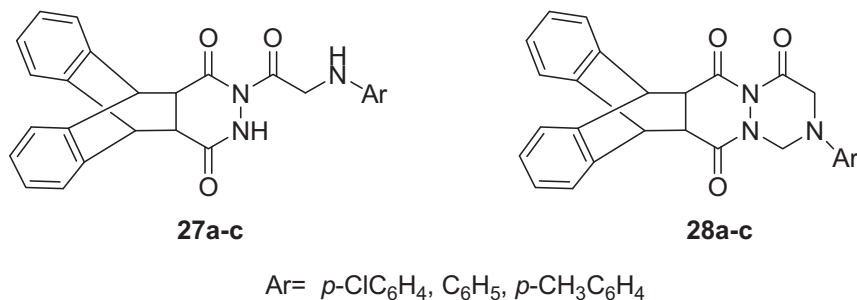
Reaction of **1** with cyanoacetic acid hydrazide afforded 3-oxo-propiononitrile **29**, which, upon treatment with aromatic aldehydes, afforded the corresponding arylidene derivatives **30a** and **30b**.[35] Moreover, **29**[36] underwent the Gewald reaction with cyclohexanone or cyclopentanone to yield polynuclear heterocyclic compounds **31a** and **31b**.[35]

29

30a, Ar= C$_6$H$_5$
**30b**, Ar= 4-CH$_3$O-C$_6$H$_4$

31a; n= 1; **31b**; n= 0
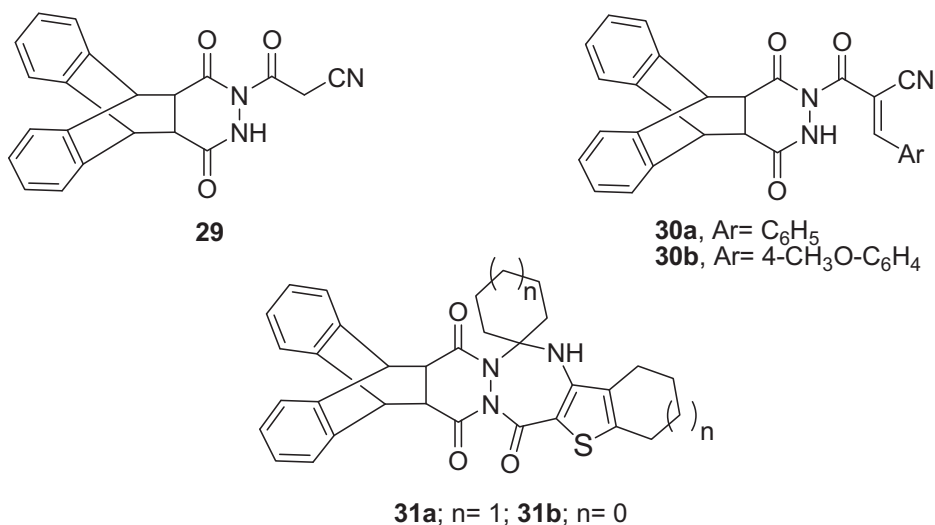
The base-catalyzed reaction of **29** with phenyl isothiocyanate in dry DMF at room temperature yields unstable potassium salt **32**. Treatment of **32** with dilute HCl gave thiocarbamoyl derivative **33**. Cyclization of the potassium salt of thiocarbamoyl derivative **32** with chloroacetyl chloride afforded thiazolidin-5-one derivative **34** (Scheme 1).[37]

2-Arylideno-1,3-thiazolidinone derivatives **35a** and **35b** were obtained by refluxing compound **34** with the appropriate aromatic aldehydes in a mixture of DMF and glacial acetic acid in the presence of a catalytic amount of fused sodium acetate. Condensation of thiazolidin-5-one derivative **34** with isatin or ninhydrin in DMF in the presence of a catalytic amount of TEA gave corresponding arylidene derivatives **36** and **37**, respectively. Thiazolidin-5-one derivative **34** gave unexpected N-substituted isoindole derivative **38** upon treatment with an excess of Vilsmeier reagent at 80 °C (Scheme 2).[37]
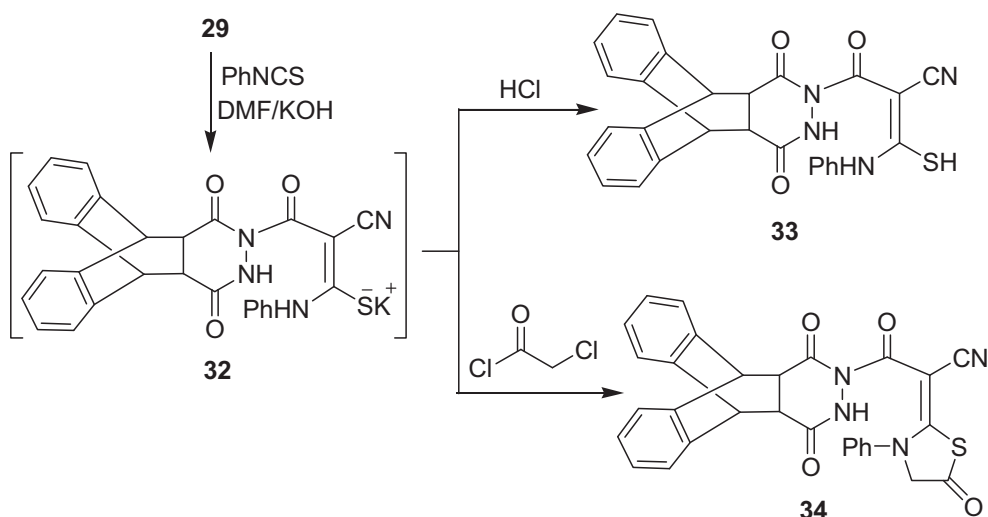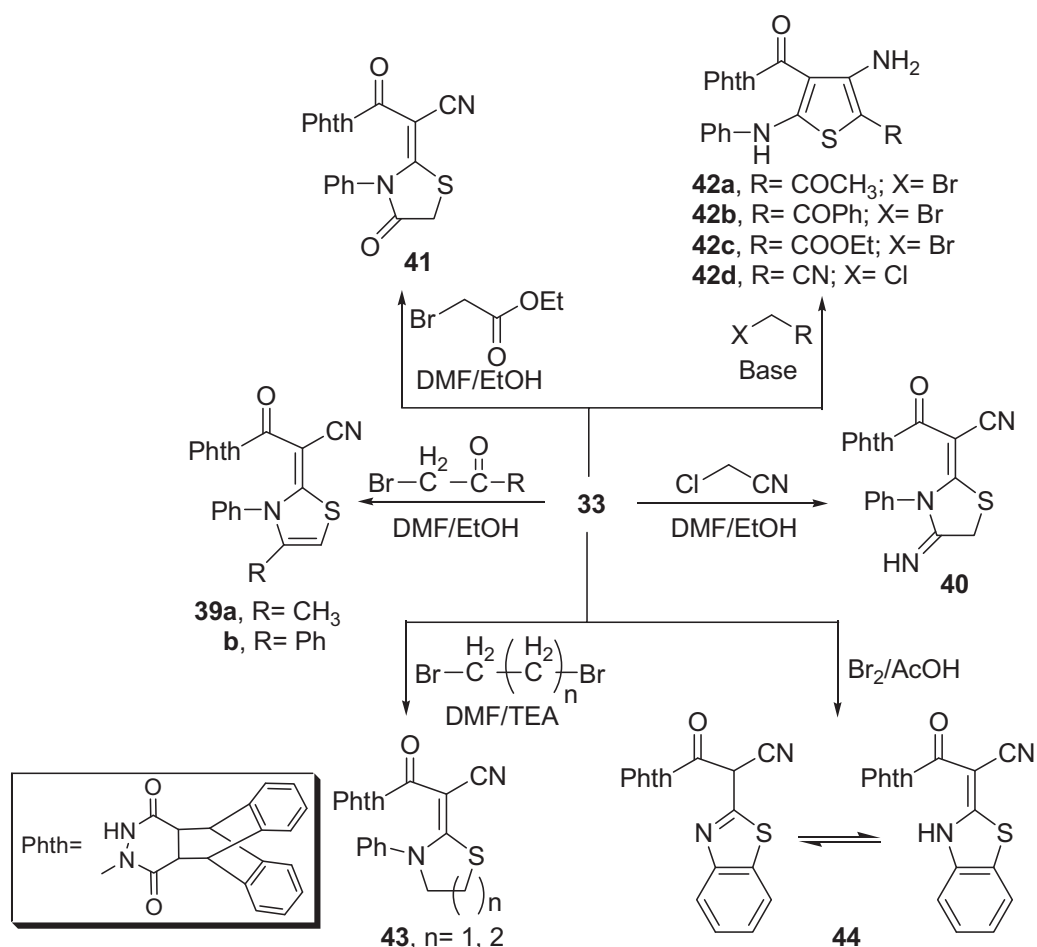
Scheme 1.
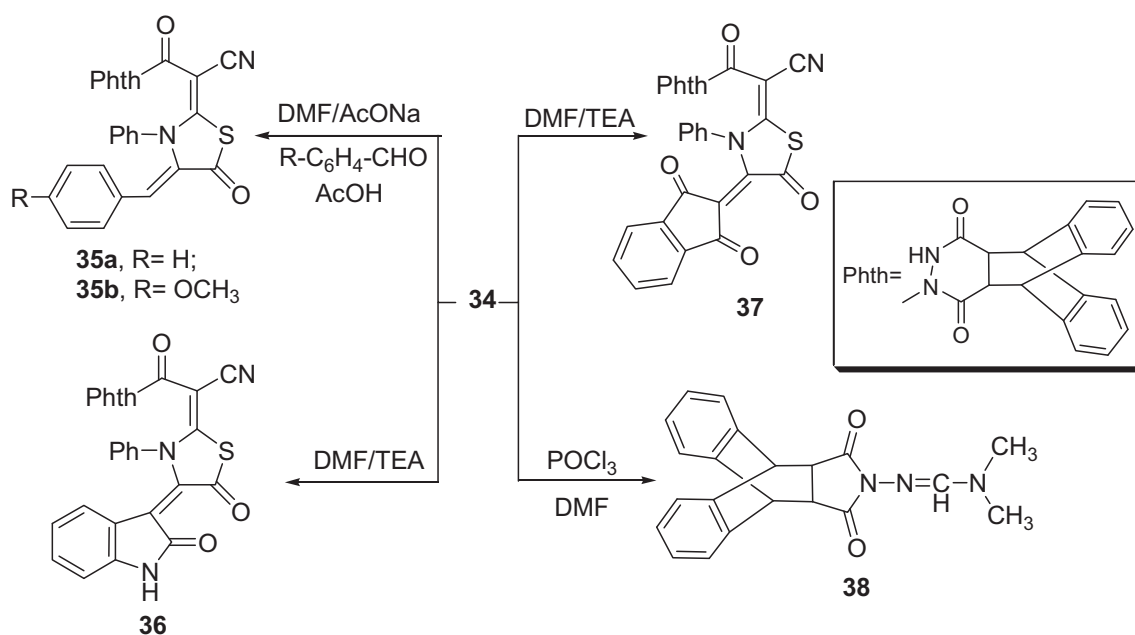
Scheme 2.

Compounds **39a**, **39b**, and **41** were obtained in high yields by refluxing compound **33** with α-halo compounds in an EtOH/DMF mixture. Treatment of thiocarbamoyl derivatives **32** or **33** with choloroacetonitrile gave **41**; this reaction may be explained by the intermediacy of 4-iminothiazolidine derivative **40**. On the other hand, the base catalytic reactions of thiocarbamoyl derivative **33** with α-halo compounds gave corresponding thiophene derivatives **42a-d**. Reaction of thiocarbamoyl derivative **33** with dibromoalkane in ethanol in the presence of TEA gave corresponding cyclic ketene S,N-acetals **43a** and **43b**. Thiocarbamoyl derivative **33** undergoes oxidative cyclization upon treatment with bromine in acetic acid to give benzothiazole derivative **44** (Scheme 3).[37]
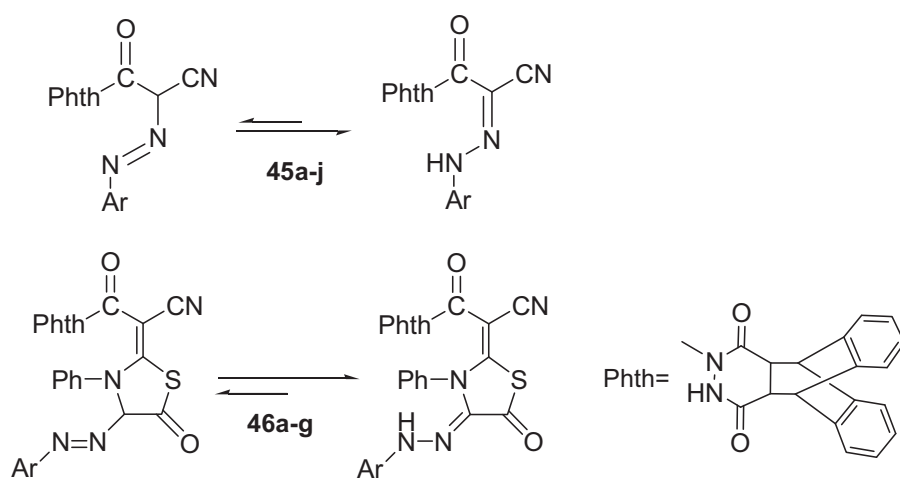
Scheme 3.

The coupling of **29** and **34** with various aryl diazonium chlorides in pyridine afforded 3-oxo2-(4-arylhydrazono)propiononitrile and 3-oxo-2-(4-arylazo-5-oxo-3-phenyl-thiazolidin-2-ylidene)propiononitriles **45a-j** and **46a-g**, respectively (Scheme 4)[38]

Thiosemicarbazide

Thioamide derivative **47**[37] was obtained from the reaction of **1** with thiosemicarbazide. Treatment of **47** with sodium hydroxide solution gave 1,2,4-triazole derivative **48**,[35] which was alkylated with n-pentyl bromide to give S-pentyl derivative **49**.[35]

Compound **47** was reacted with an equimolar amount of α-halo compounds, namely chloroacetone, phenacyl chloride, and ethyl bromoacetate, in ethanol in the presence of sodium ethoxide to afford thiazole and thiazolidinone derivatives **50a**, **50b**, and **51**, respectively. 5-Bromothiazole derivative **52** was obtained by the bromination of **50b** in glacial acetic acid at 90 °C (Scheme 5).[37]

The diazocoupling of **50a** and **50b** with appropriate diazonium chlorides **53** gave corresponding 5-arylazo-thiazole derivatives **54**. The synthesized dyes were applied to polyester as disperse dyes and their antibacterial, color measurement, and fastness properties were evaluated.[39]

45, 46a, Ar= C$_6$H$_5$; **45, 46b**, 4-CH$_3$C$_6$H$_4$; **45, 46c**, 4-OCH$_3$C$_6$H$_4$; **45, 46d**, 4-Cl-C$_6$H$_4$; **45,**

46e, 4-Br-C$_6$H$_4$; **45, 46f**, 4-NO$_2$-C$_6$H$_4$, **45, 46g**; 4-COOEt-C$_6$H$_4$;

45h,   **45i,**   **45j,**

**Scheme 4.**

50a, R= CH$_3$
50b, R= Ph

52

51
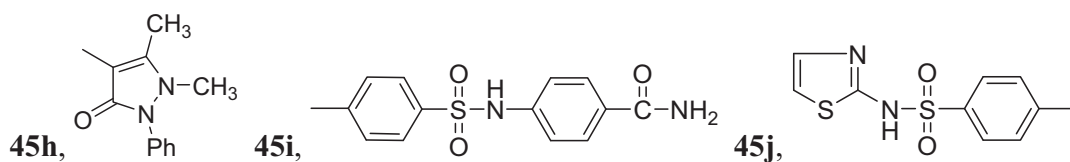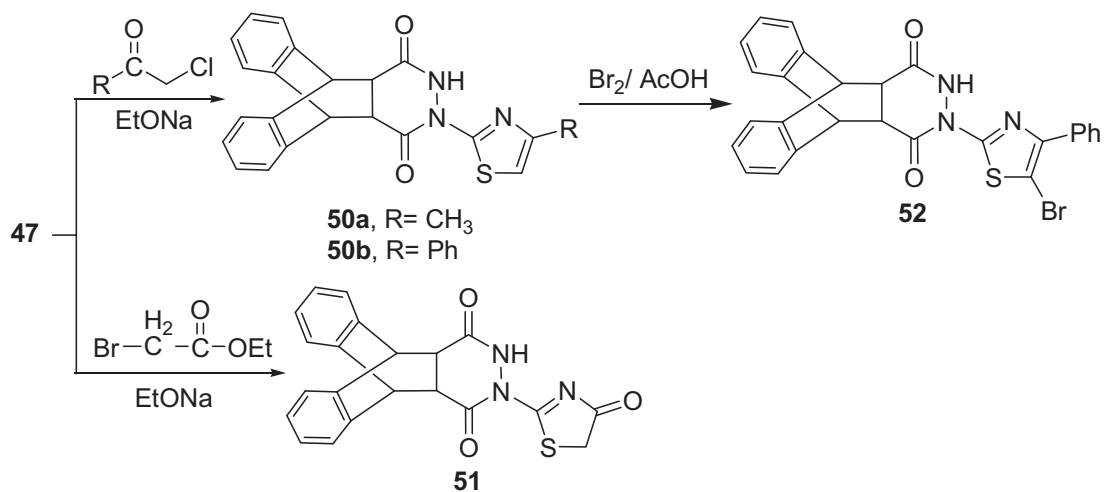
Scheme 5.

Cyclocondensation of **29** with salicylaldehyde in boiling DMF containing a catalytic amount of TEA afforded iminocoumarin derivative **55**, which, upon hydrolysis in a mixture of concentrated HCl and ethanol, gave 2-chromone derivative **56**. The reaction of **29** with elemental sulfur and phenyl isothiocyanate in warmed DMF containing a catalytic amount of TEA gave thiazole derivative **57**. Cyclization of **57** by refluxing with

either triethylorthoformate or acetic anhydride gave 1,2,4-triazepine derivatives **58a** and **58b**. When compound **58b** was heated with dimethylsulfate in DMF followed by stirring with hydrazine hydrate, hydrazone derivative **59** was obtained (Scheme 6).[36]


47   **48**   **49**
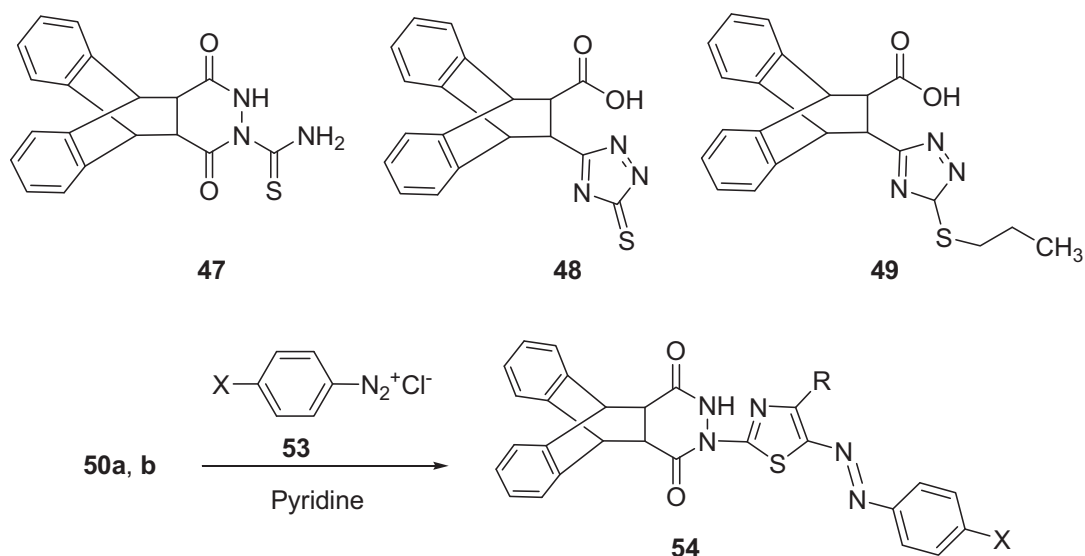
54a, R= CH$_3$, X= H; **54b**, R= CH$_3$, X= CH$_3$; **54c**, R= CH$_3$, X= OCH$_3$; **54d**, R= CH$_3$, X= Cl; **54e**, R= CH$_3$, X= Br; **54f**, R= CH$_3$, X= NO$_2$; **54g**, R= CH$_3$, X= COOEt; **54h** R= Ph, X= H; **54i**, R= Ph, X= CH$_3$; **54j** R= Ph, X= OCH$_3$; **54k**, R= Ph, X= Cl; **54l**, R= Ph, X= Br; **54m**, R= Ph, X= NO$_2$; **54n**, R= Ph, X= COOEt

The coupling of compound **29** with 4,6-dimethyl-1H-pyrazolo[3,4-b]pyridine-3-diazonium chloride (**60**)[40] in pyridine at 0-5 °C afforded corresponding hydrazono compound **61**, which cyclized to the corresponding triazine derivative (**62**) upon refluxing in glacial acetic acid. A suspension of **29** in acetic acid or chloroform reacted readily with bromine to yield dibromopropionitrile derivative **63**. Meanwhile, monobromopropionitrile derivative **64** was not obtained, but when the reaction took place with N-bromosuccinamide in DMF at room temperature, compound **63** was obtained. Condensation of compound **64** with o-phenylenediamine in DMF and in the presence of TEA afforded corresponding aminoquinoxaline derivative **65** (Scheme 7).[36]

Treatment of compound **29** with phenyl isothiocyanate in a DMF/KOH mixture at room temperature gave a nonisolated sodium salt that methylated with methyl iodide to afford novel ketene N,S-acetal **67**. Reaction of **67** with hydrazine hydrate in DMF did not afford 3-aminopyrazole **68** as expected, but rather phthalazinedione derivative **16**[1] was achieved. Propiononitrile derivative **29** treated with carbon disulfide in the presence of 2 equivalents of sodium hydride gave nonisolated sodium salt **70**, which was reacted with halogenated compounds, namely methyl iodide, 1,2-dibromomethane, or 1,3-dibromopropane, to give corresponding ketene dithioacetals **71**, **72a**, and **72b**, respectively. Refluxing of **71** with hydrazine hydrate did not afford aminopyrazole derivative **69** as expected, but rather phthalazine derivative **16** was achieved. The reaction of compound **29** with carbon disulphide and 1 equivalent of sodium hydride in DMF gave nonisolated sodium dithioacetal derivative **73**, which was methylated with dimethyl sulfate to give methyl dithioate derivative **74** (Scheme 8).[36]
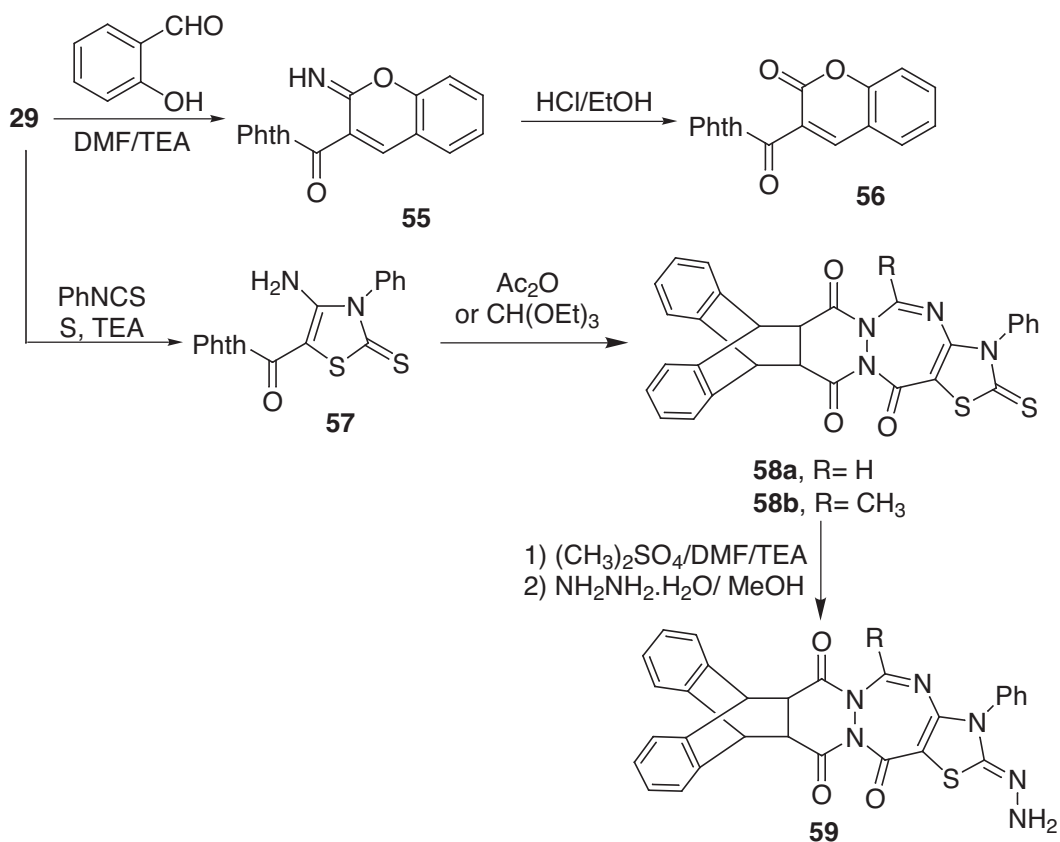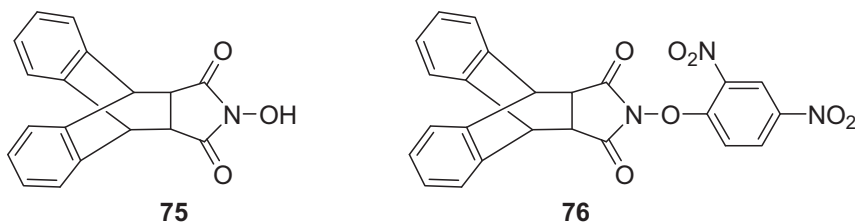
Scheme 6.
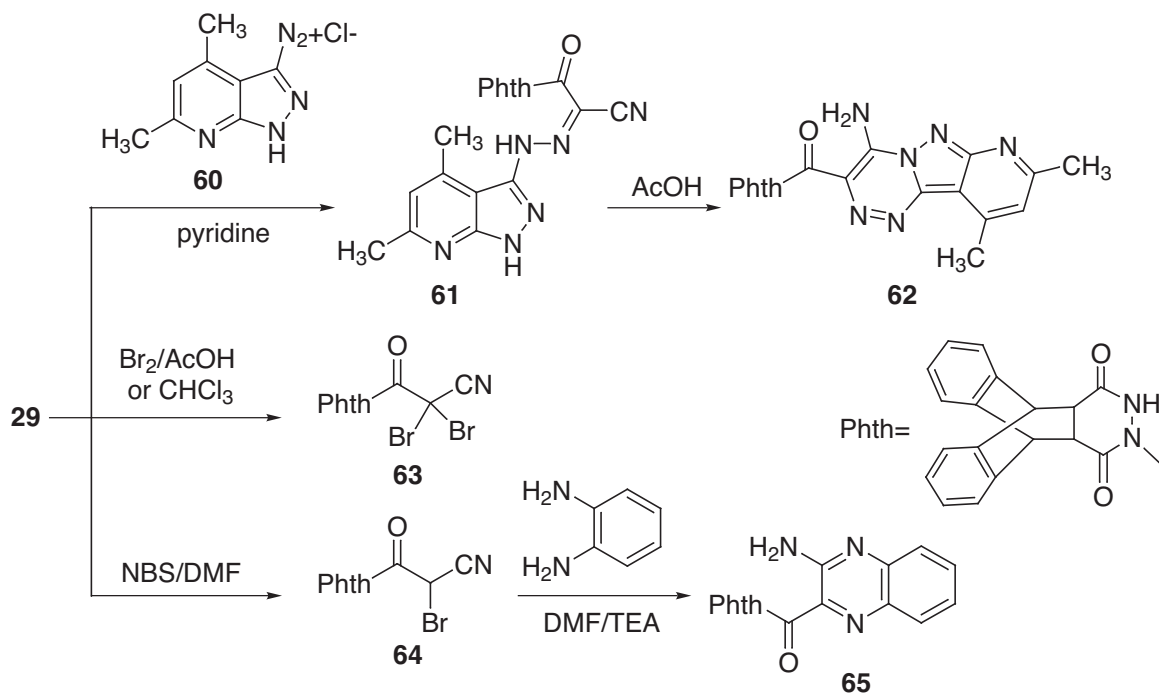
Scheme 7.
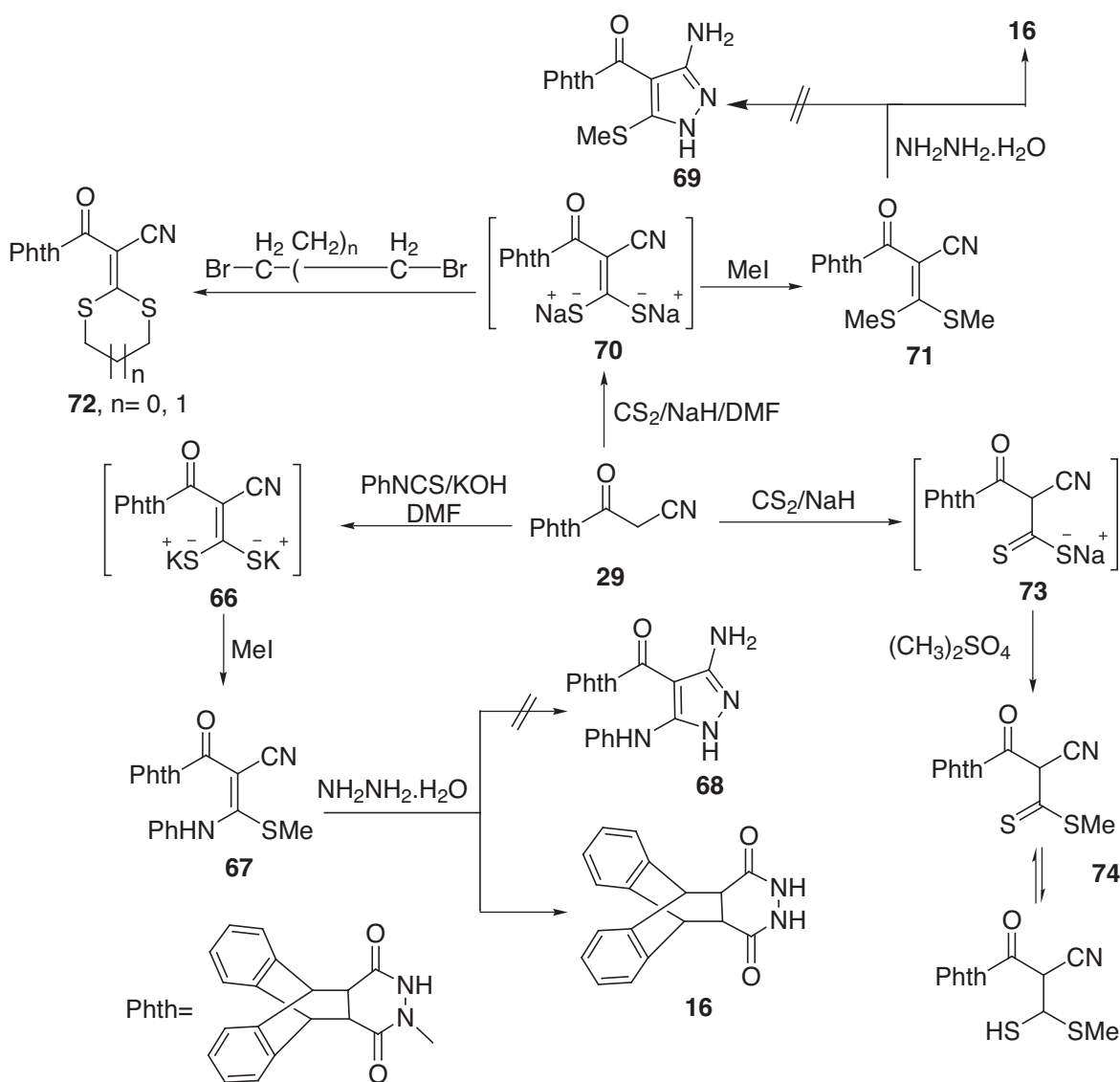
Scheme 8.

Hydroxylamine hydrochloride

Refluxing **1** with hydroxylamine hydrochloride in ethanol in the presence of pyridine gave N-hydroxy-succinimide derivative **75**, which, upon refluxing with 2,4-dinitrochlorobenzene, yielded **76**.[41]

Compound **75** reacted with 1,3-dibromopropane, 1-bromobutane, and p-toluene sulfonyl chloride in the presence of TEA to give bromopropoxy, butoxy, and p-tolylsulfonate derivatives **77a-c**, respectively.[6] Compound **77a** reacted with N-phenyl piperazine to yield [(4-phenyl-piperazin-1-yl)propoxy] derivative **78**.


77a; R= CH$_2$CH$_2$CH$_2$Br
77b; R= CH$_2$(CH$_2$)$_2$CH$_3$
**77c**; R= 4-MeC$_6$H$_4$SO$_2$

78
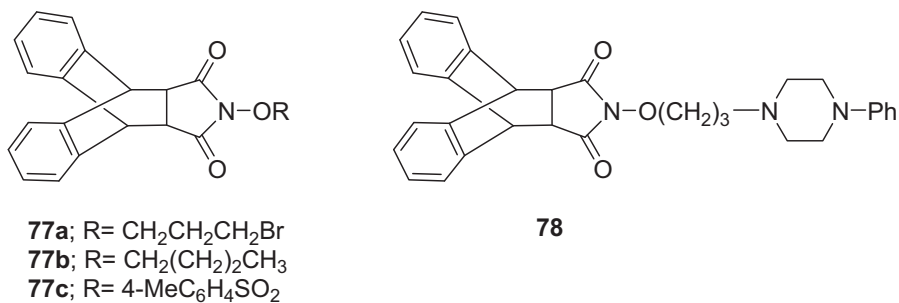
Amino alcohols

The fusion of **1** with ethanolamine gave corresponding derivative **79**.[42−44] Ester derivative **80**[42,45] was obtained from the reaction of **1** with ethanolamine in acetic acid.[6]

79

80
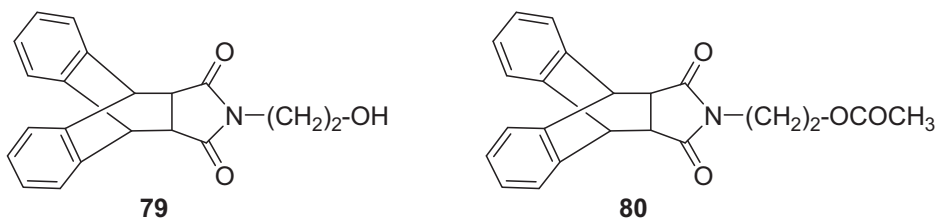
Moreover, 2-amino-2-methylpropane-1,3-diol was reacted with **1** to give diol derivative **81**,[46] and 2-amino-2-hydroxymethyl-1,3-propanediol gave triol derivative **82**.[7,35]


81

82
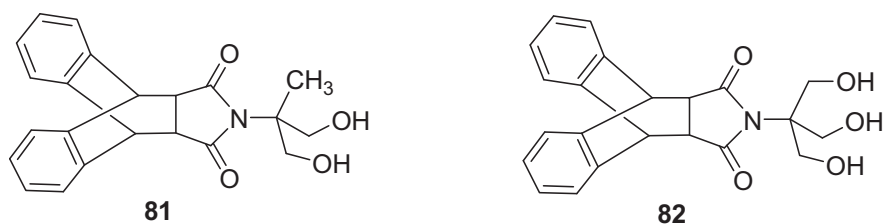
Imide **83** was prepared by condensation of 9,10-dihydroanthracene-9,10-α,β-succinic acid anhydride with (2S,3S)-2-amino-1-phenyl-1,3-propandiol in toluene at reflux. Corresponding amine **84** was obtained by reduction of imide **83** using LiAlH$_4$ as a reagent.[47] These diols were treated with corresponding phosphorochloridite **85**, prepared in situ by standard procedures,[48,49] to give C$_1$-symmetric diphosphites **86** and **87** in good yields (80%-86%) (Scheme 9).[50]

R= (2S,3S)-CH(CH₂OH)CH(Ph)OH
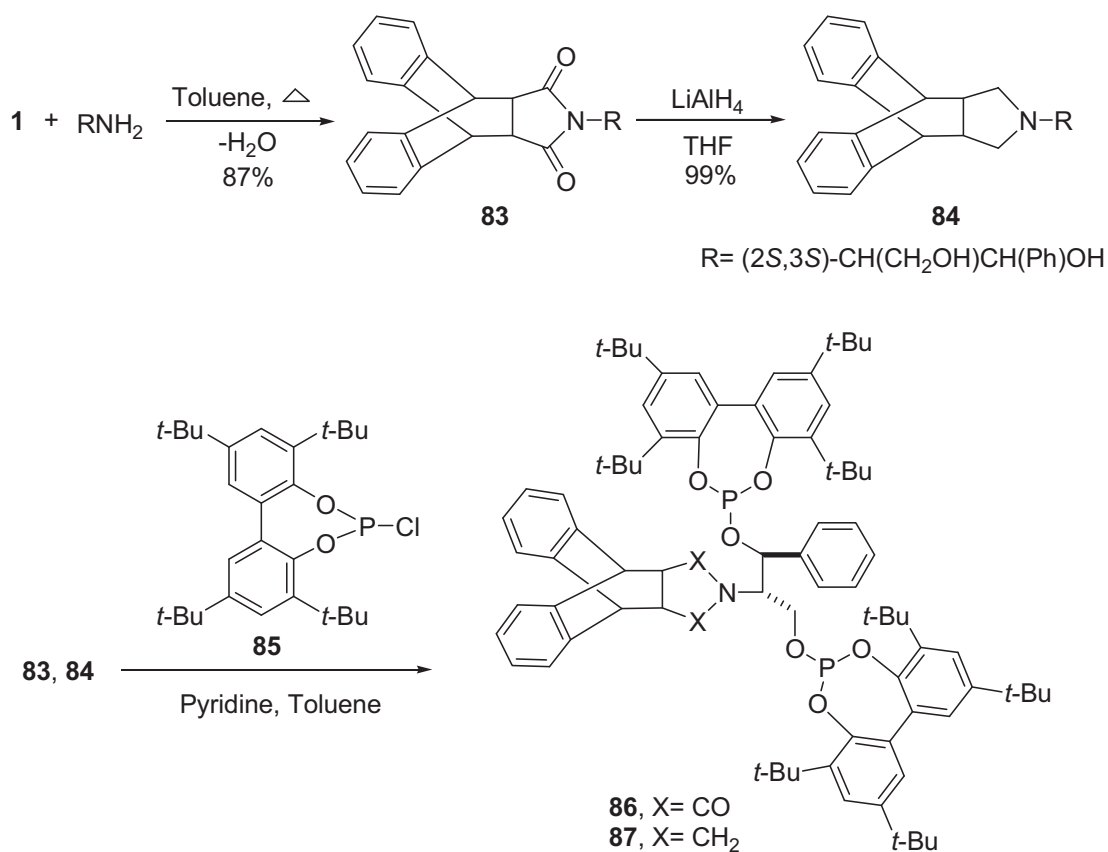
Scheme 9.

p-Aminophenol

Equimolar amounts of **1** and p-aminophenol were heated under reflux in DMF to give succinamide derivative **88**.[44]
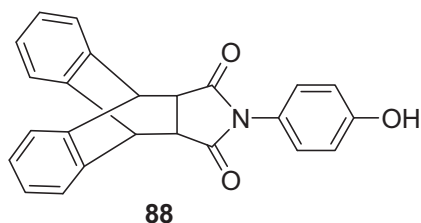

o-Amino- and o-aminothiophenol

The reaction of **1** with o-aminothiophenol in acetic acid gave disulfide **89**, whereas a mixture of **89** and **90** was obtained when the reaction was carried out in DMF or a dioxane/pyridine mixture instead of acetic acid. The formation of **89** may be interpreted through the autoxidation of **90**. On the other hand, 2-hydroxyphenyl derivative **91** was obtained by the refluxing of **1** with o-aminophenol in acetic acid, DMF, or a dioxane/pyridine

mixture. Treatment of compound **91** with p-toluenesulfonyl chloride in DMF in the presence of a catalytic amount of TEA gave corresponding ester derivative **92** (Scheme 10).[7]

Scheme 10.
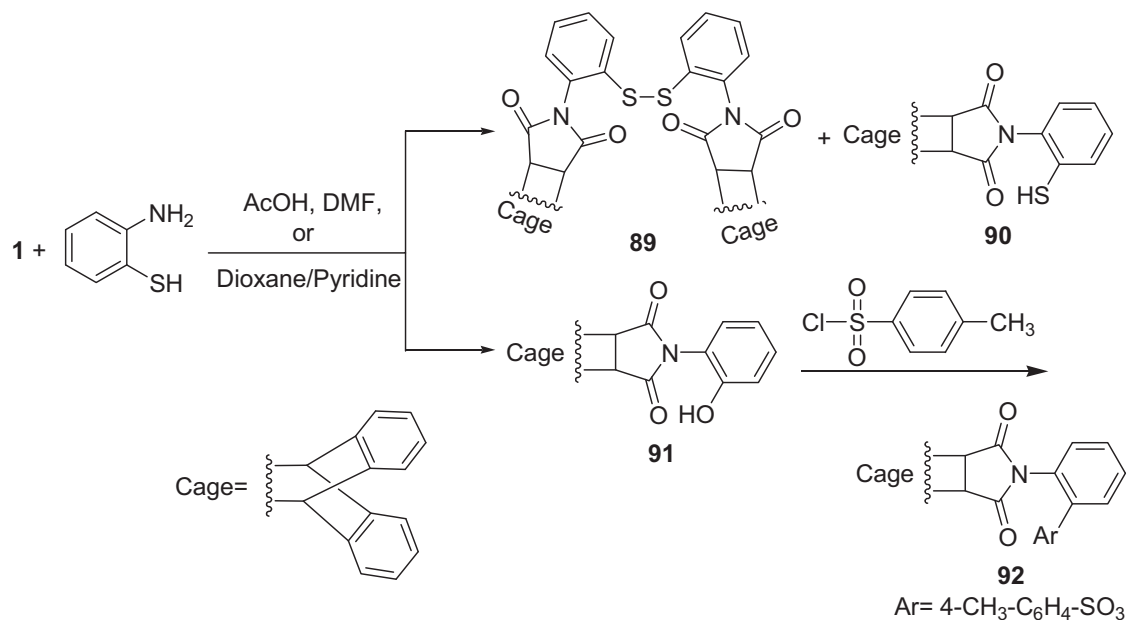
Amino acids

Reaction of **1** with some aliphatic amino acids in dioxane and sodium carbonate (20%) gave corresponding isoindole derivatives **93a-c** after acidification with dilute HCl. Analogously, aromatic amino acids were reacted with **1** in DMF to yield **94a-c**.[44]

93a, n= 1
93b, n= 2
93c, n= 3

94a, $n_1 = n_2 = 0$
94b, $n_1 = 0$, $n_2 = 1$
94c, $n_1 = n_2 = 1$
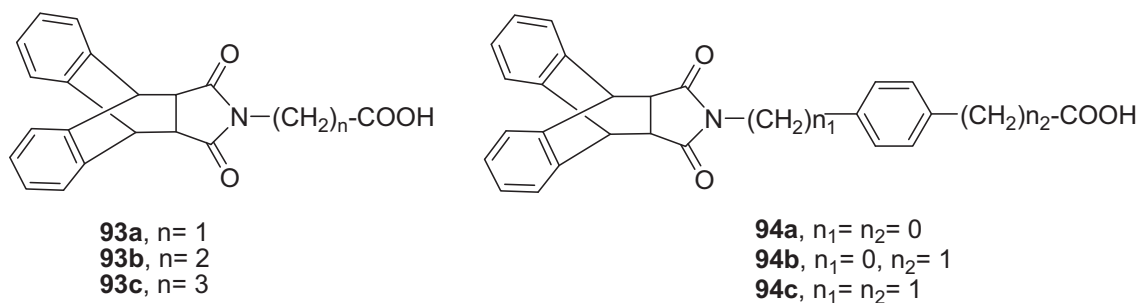
Moreover, glycylglycine was reacted with **1** in dioxane, in the presence of sodium carbonate, to yield **95** after acidification.[44]

95
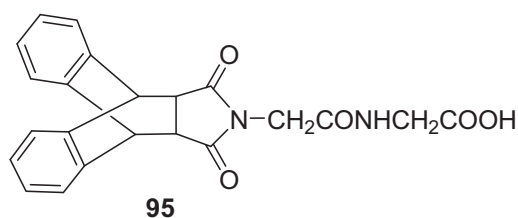
Acid derivative **93b** was converted to propionyl chloride derivative **96** by reaction with thionyl chloride.[6] Treatment of acid chloride **96** with 4-alkyl piperazines, piperidine, morpholine, and aniline gave derivatives 4-alkyl-1-piperazinyl, 1-piperidinyl, 4-morpholinyl, and N-phenyl propionamide **97a**, **97b**, **98a**, **98b**, and **99**, respectively.[6]

96

97a, R= Ph; **97b**, R= CH$_3$

**98c**, X= CH$_2$; **98d**, X= O

99
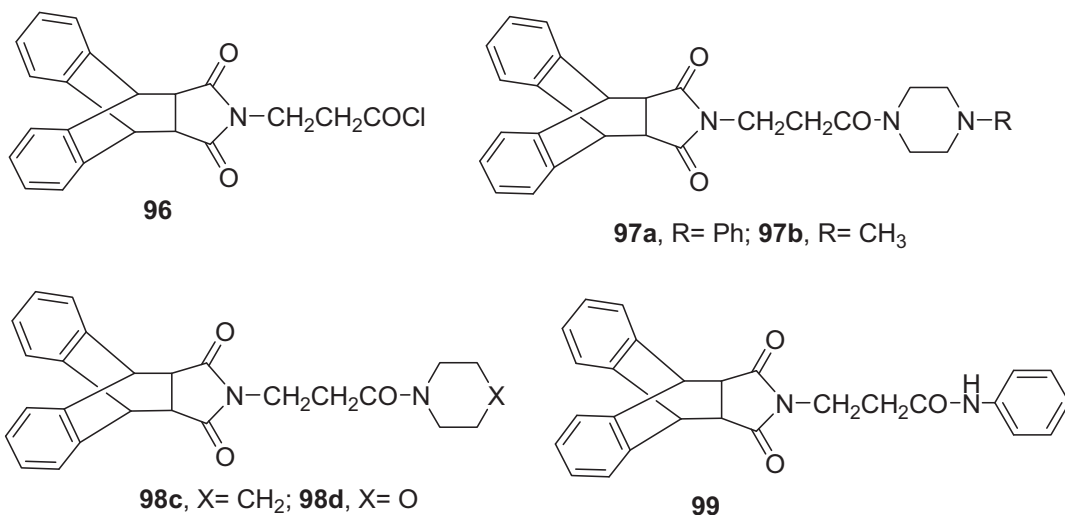
Dibenzobarallene (**1**) was converted into its acid derivative by reaction with L-leucine. The cyclization reaction was carried out in situ using TEA to give succinic imide acid derivative **100**. Compound **100** was converted to acid chloride **101** by reaction with thionyl chloride. The reaction of acid chloride **101** with isoeugenol (**102**) was carried out in chloroform and a novel, optically active isoeugenol ester derivative (**103**) was obtained. 4-Phenyl-1,2,4-triazolin-3,5-dione (PhTD) (**104**) was allowed to react with compound **103** to give only 1 diastereoisomer of **105** via Diels-Alder and ene pathways in a quantitative yield (Scheme 11).[51]

2(S)-3-Phenyl-(9,10-dihydro-9,10-ethanoanthracene-11,12-dicarboximido)propanoic acid (**107**) was synthesized from the reaction of L-phenylalanine (**106**) with **1** in acetic acid under refluxing conditions. Treatment of **107** with thionyl chloride afforded corresponding acid chloride **108**. Compound **108** reacted with 5-aminoisophthalic acid (**109**) in DMAc to give 5-[3-phenyl-2-(9,10-dihydro-9,10-ethanoanthracene-11,12-dicarboximido)propanoylamino]isophthalic acid (**110**) as a chiral monomer in high yield and purity (Scheme 12).[14]
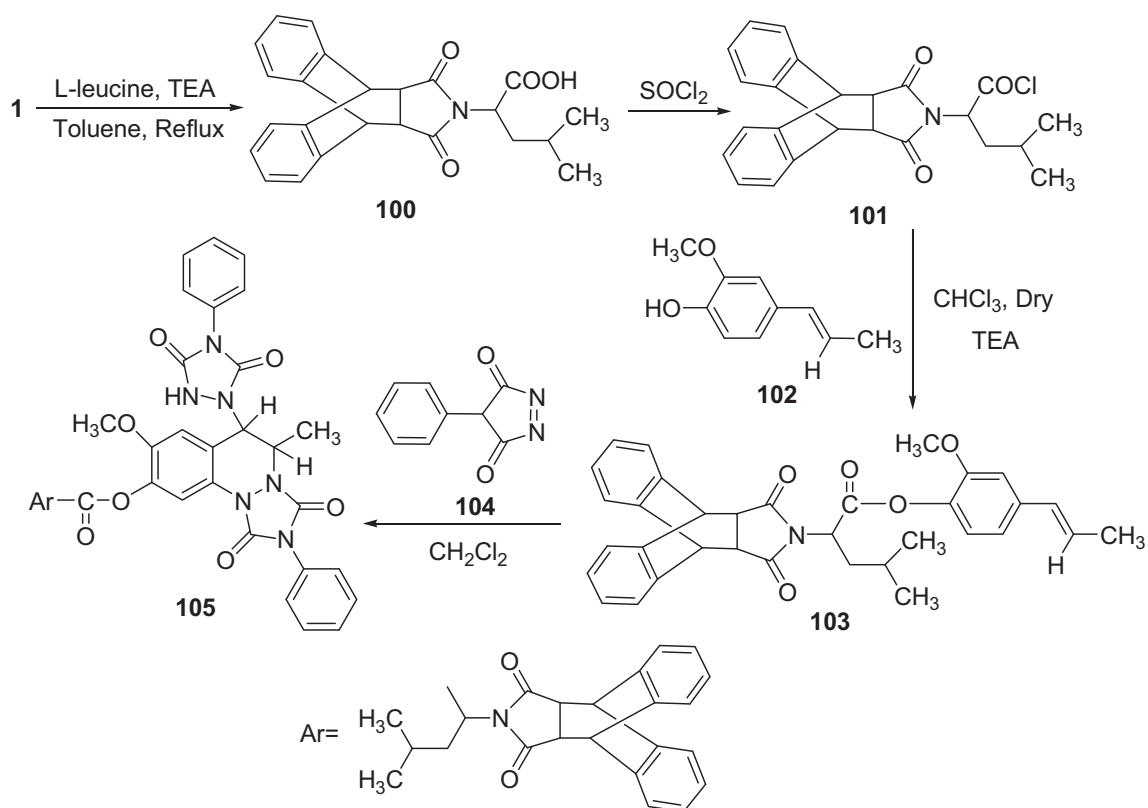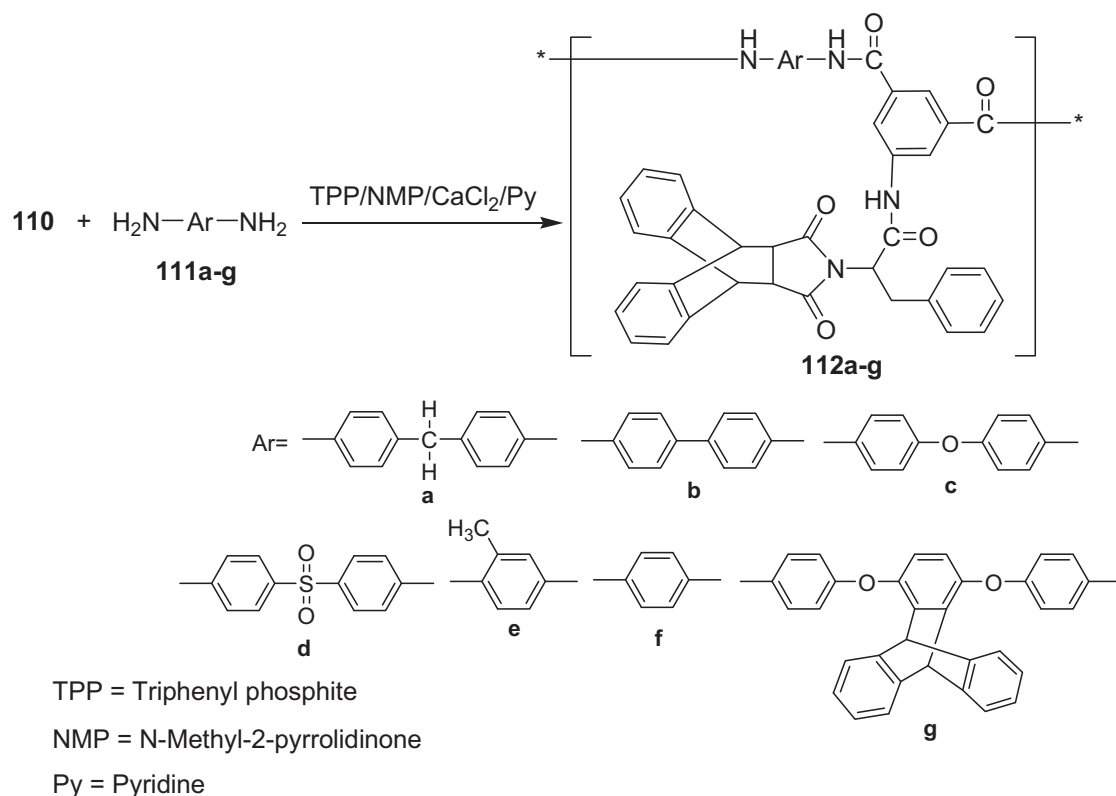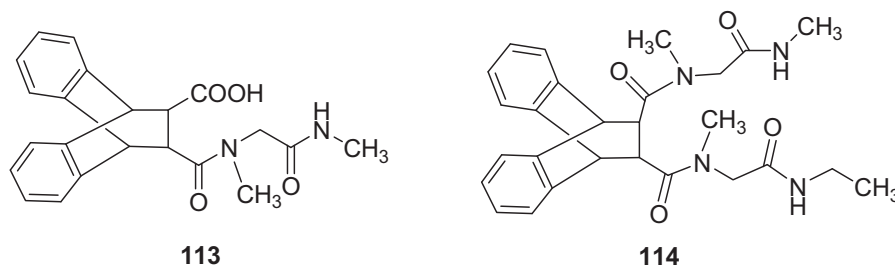
Scheme 11.
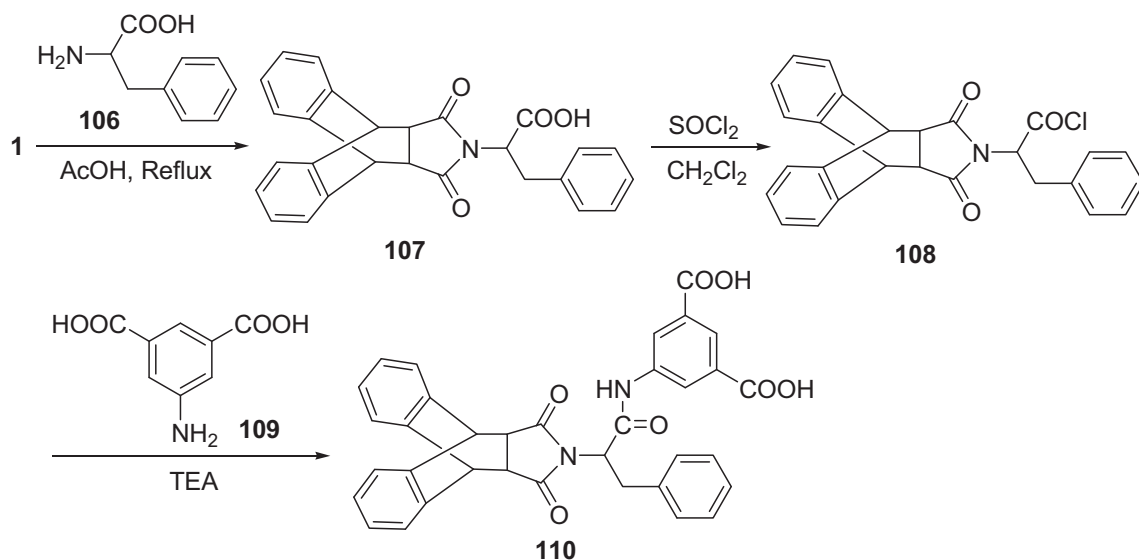
Scheme 12.

A highly effective, very fast microwave method was used to synthesize optically active aromatic polyamides (PAs) **112a-g** under microwave heating for only 3 min by the reaction of **110** with corresponding diamine derivatives **111a-g** (Scheme 13).[14]

Scheme 13. Polycondensation reactions of monomer **100** with aromatic diamines.

Reaction of **1** with sarcosine methylamide trifluoroacetate in DMF in the presence of K_2CO_3 yielded corresponding amide **113**.[52] Treatment of **113** with sarcosine ethyl amide trifluoroacetate in DMF in the presence of DIEA, PyBOP, and K_2CO_3 afforded **114**.[52]

Ethyl-2-amino-4,5,6,7-tetrahydrobenzo[b]thiophene-3-carboxylate (**115**)[53] was reacted with **1** in acetic acid/sodium acetate to yield corresponding tetrahydrobenzothiophene derivative **116**.[7]
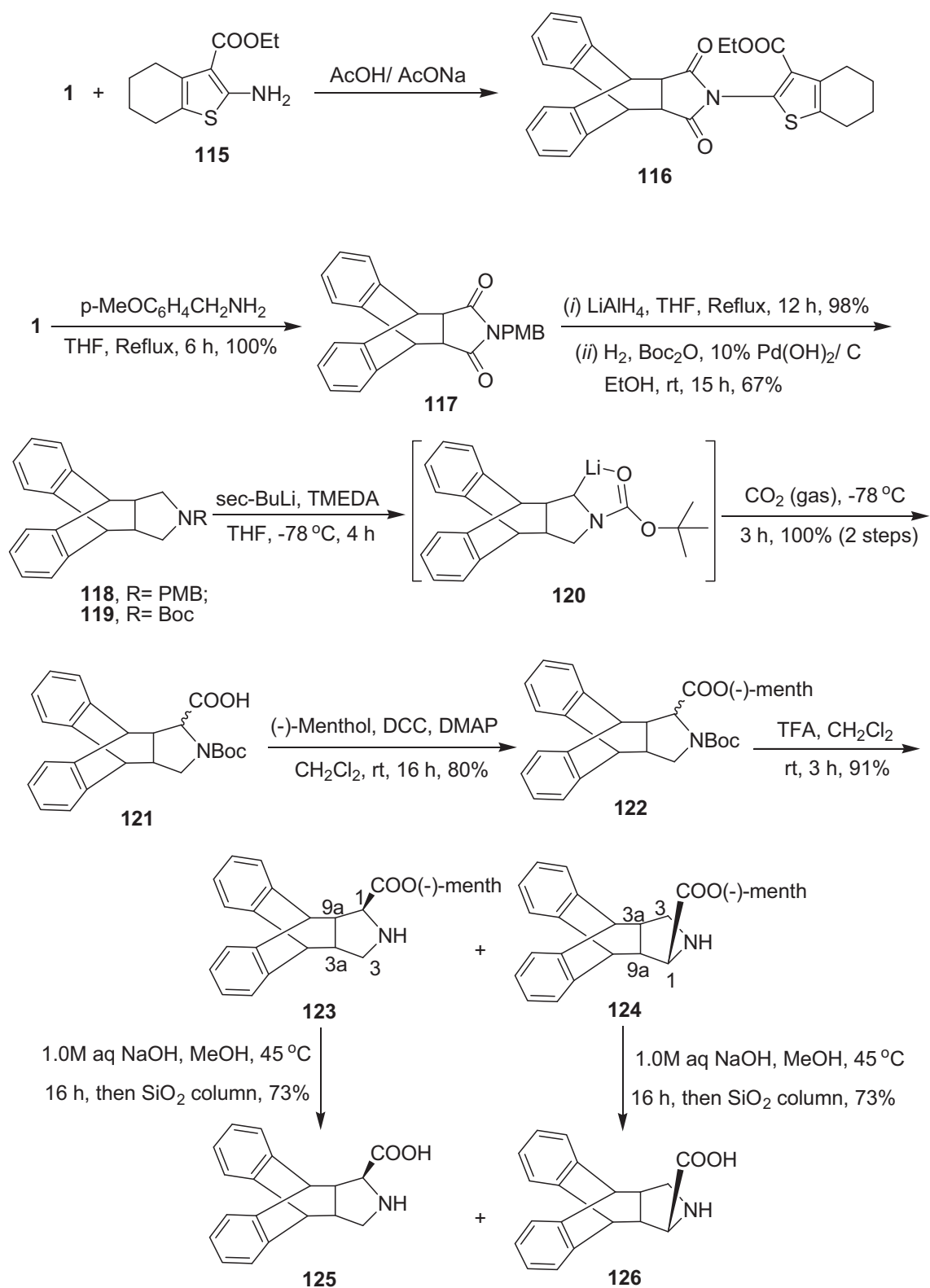
Scheme 14. Synthesis of anthracene-fused proline catalysts **125** and **126**.

Benzylamines

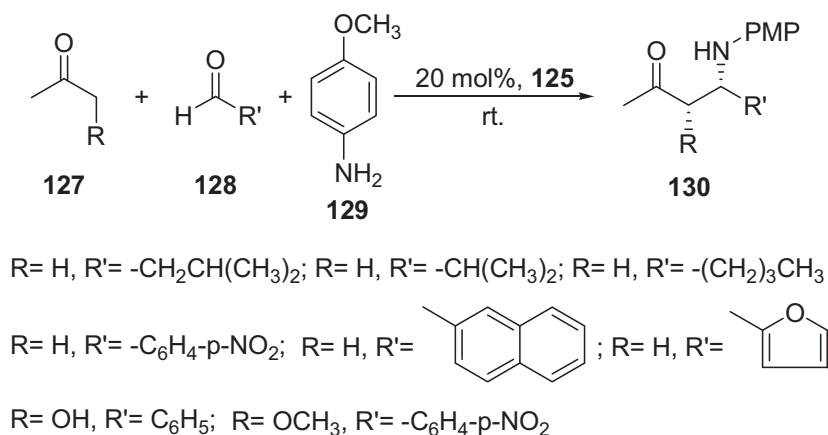A new class of anthracene-fused proline catalysts, **125** and **126**, was prepared via treatment of **1** with an equimolar amount of p-methoxybenzylamine (PMBNH$_2$) in hot THF, producing desired N-PMB-protected imide **117** in an almost quantitative yield. LAH reduction followed by protective-group transformation cleanly provided N-Boc-protected isoindole **119** (66% yield over 2 steps). The crucial attachment of a carboxyl function onto **119** was successfully achieved by using Beak's protocol: N-Boc-directed lithiation/carboxylation.[54,55] Thus, lithiation using sec-BuLi/TMEDA in dry THF at 78 °C for 5 h provided α-lithioamide intermediate **120**, which, upon exposure to bubbling CO$_2$ (gas), gave desired carboxylic acid **121** in an excellent yield. Treatment of **121** with (-)-menthol with the aid of DCC/DMAP gave menthyl ester **122**. TFA-promoted deprotection of the N-Boc group gave nearly equal amounts of free amines **123** and **124** in a combined yield of 91%. Alkaline hydrolysis of the menthyl ester of **123** gave the end product, anthracene-fused proline catalyst **125**, $[\alpha]_D^{22} = +57.6$ (c 0.62, MeOH), in an enantiomerically pure form in 73% yield. In the same manner, catalyst **126**, $[\alpha]_D^{22} = -57.6$ (c 1.31, MeOH), was obtained from **124** (Scheme 14).[56]

The newly formed anthracene-fused chiral proline catalysts were tested in asymmetric 3-component Mannich reactions between ketone donors (**127**), aldehyde acceptors (**128**), and p-anisidine (**129**) (Scheme 15).[56]

R= H, R'= -CH$_2$CH(CH$_3$)$_2$; R= H, R'= -CH(CH$_3$)$_2$; R= H, R'= -(CH$_2$)$_3$CH$_3$

R= H, R'= -C$_6$H$_4$-p-NO$_2$; R= H, R'= [naphthyl] ; R= H, R'= [furyl]

R= OH, R'= C$_6$H$_5$; R= OCH$_3$, R'= -C$_6$H$_4$-p-NO$_2$

Scheme 15. Asymmetric 3-component Mannich reactions between ketone, *p*-anisidine, and aldehyde.

N-((1S)-1-phenylethyl)-9,10-dihydro-9,10-ethanoanthracene-(11S,12S)-dicarboximide (**131**) was obtained by condensation of anhydride **1** and (S)-α-methylbenzylamine in toluene. Further ruthenium-assisted hydrogenation of **131** led quantitatively to the formation of **132** under mild conditions (room temperature and low hydrogen pressure).[57]

131   **132**, Cy= Cyclohexyl
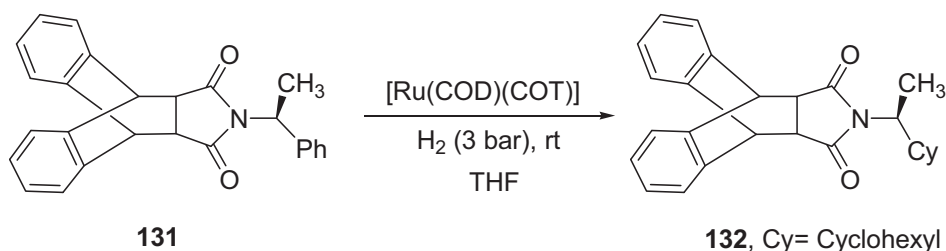
3-[4-(4-Fluorophenyl)piperazin-1-yl]propylamine

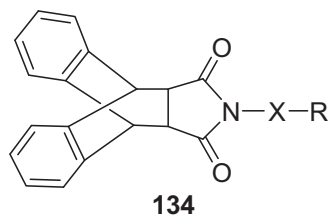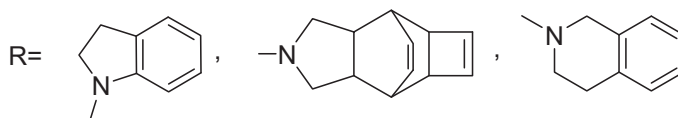Refluxing of **1** with 3-[4-(4-fluorophenyl)piperazin-1-yl]propyl-amine in xylene using a Dean Stark apparatus gave **133**.[8]

133
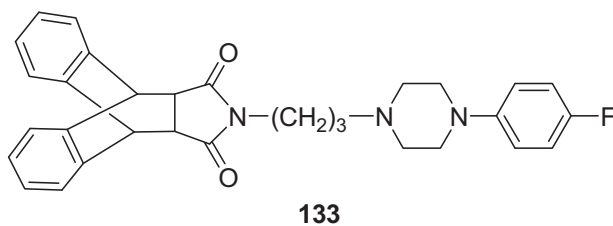
Substituted pyrroloanthracene or its dione derivatives (**134**) were prepared by imidation reaction of the corresponding substituted alkylamines with **1**.[5]

134

X= Straight chain or branched alkyl

R=

Primary aromatic amines

Fusion or refluxing of **1** with some primary aromatic amines in DMF gave the succinamide derivatives **135a** and **135b**. Treatment of **135b** with Grignard compounds afforded **136** in good yield.[58,59]
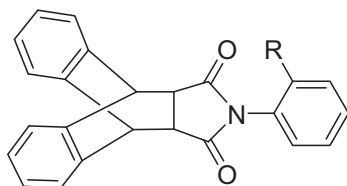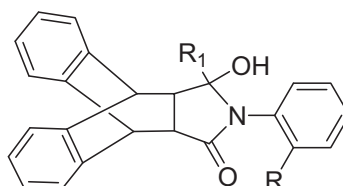
135a, R= H; **135b**, R= CH$_3$ **136**, R= CH$_3$, R$_1$= benzyl, CH$_3$

p-Aminoarylazobenzene derivatives **137** reacted with **1** in DMF or in glacial acetic acid/anhydrous sodium acetate to afford 2-arylazobenzene isoindole derivatives **138a** and **138b**.[7]

Chemistry of dibenzobarallene, *M. A. GOUDA, et al.*

138a, R= H; **138b**, R= CH$_3$

2-Aminopyridine

Compounds **139a** and **139b** were achieved by heating **1** with 2-aminopyridine derivatives at 100-140 °C for 3 h.[60]

139, R= H, CH$_3$
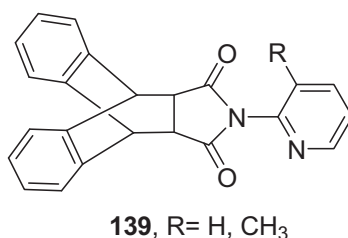
Isoquinolyl amine

Fusion of dibenzobarallene (**1**) with isoquinolyl amine at 100-190 °C for 2 h yielded **140**.[61]
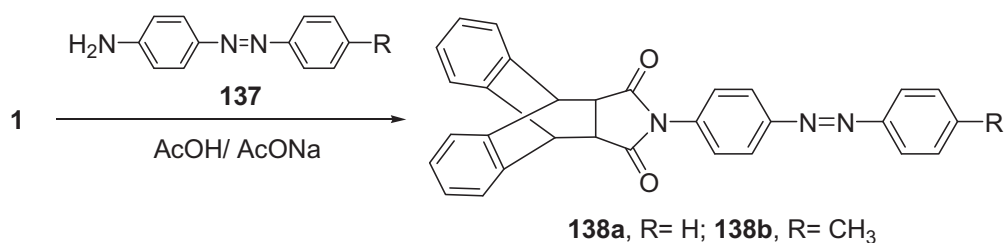

140
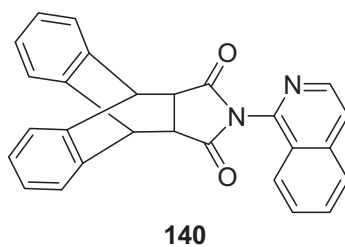
Benzothiazole and amino-1,2,4-triazoles

Isoindoldione derivatives **141** were obtained from the reaction of adduct **1** with 2-amino-6-methylbenzothiazole in DMF.[7] Heating of **1** with 4-amino-1,2-4-triazoles at 130-150 °C yielded **142** (R= H, Me, Et). Moreover, refluxing of **1** with 3-amino-1,2,4-triazole gave in DMF **143**.[7,62]

141   **142**, R= H, Me, Et   **143**
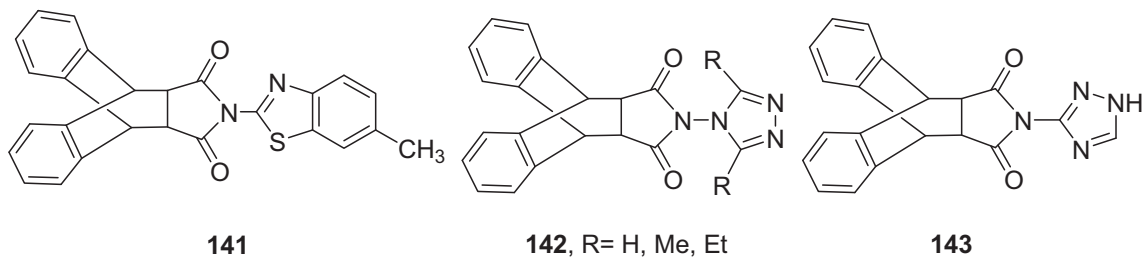
p-Aminoacetophenone

Isoindoledione derivative **144** was obtained by the reaction of **1** with 4-aminoacetophenone. Bromonation of **144** in acetic acid gave dibromo derivative **145**. The latter compound was reacted with o-phenylenediamine to give benzoimidazole derivative **146**.[7]

144

145

146

Diamines

Compound **1** was reacted with p-phenylenediamine in DMF to give bis-product **147**.[44] Reaction of **1** with ethylenediamine in acetic acid[6] gave a mixture of bis-product **148** and ethyl acetamide derivative **149**.[63]

147

148

149

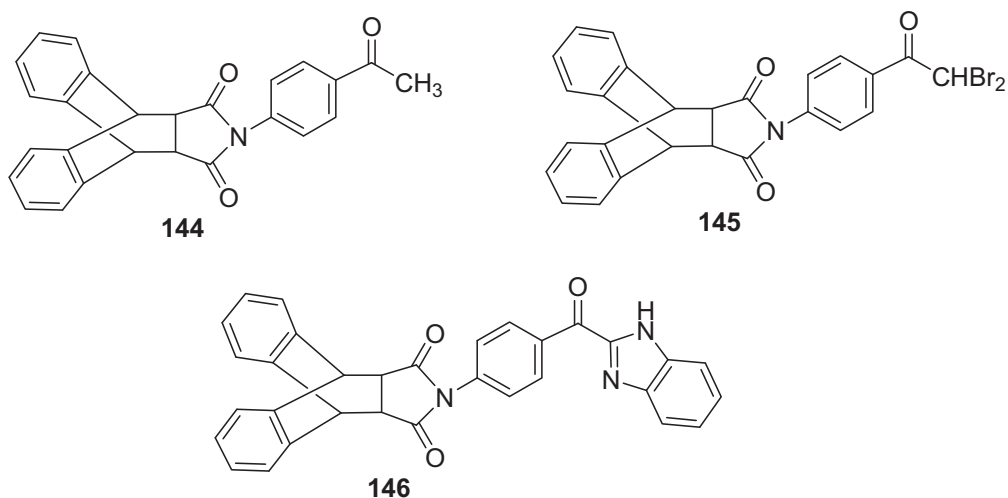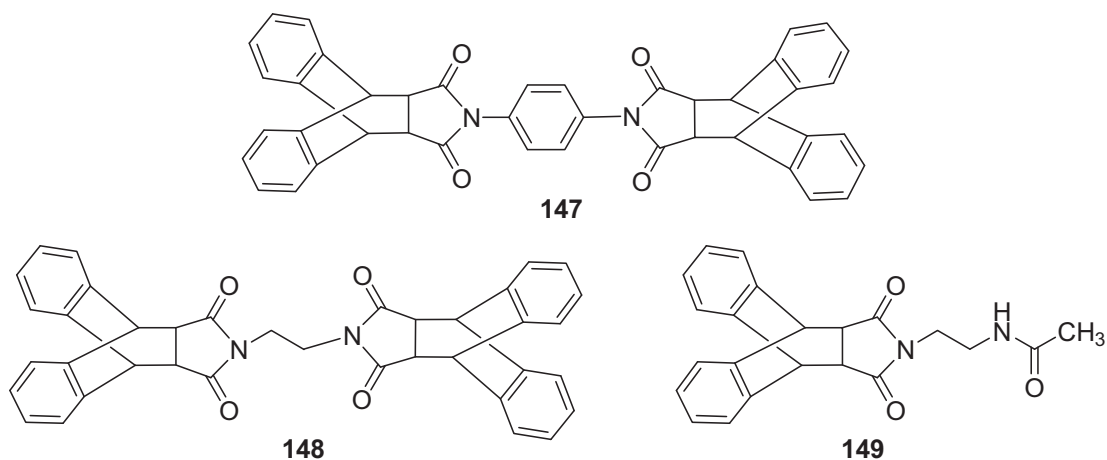The same reaction, as carried out in DMF, gave another mixture of **148**[64−68] and aminoethyl derivative **150**.[6] Compound **148** was obtained only when the reaction took place in a dioxane/pyridine mixture. Reduction of **148** with lithium aluminium hydride gave **151**.[67] The reaction of **1** with o-phenylenediamine in acetic acid[7] gave benzimidazole derivative **152**, whereas isoindoledione derivative **153** was obtained when the reaction took

place in DMF or dioxane/pyridine. The latter derivative was treated with acetyl chloride and TEA to yield **154**. Compound **152** reacted with 2-naphthoquinone-4-sulfonic acid sodium salt in DMF to give **155**.[7]

150

151

152

153

154

155
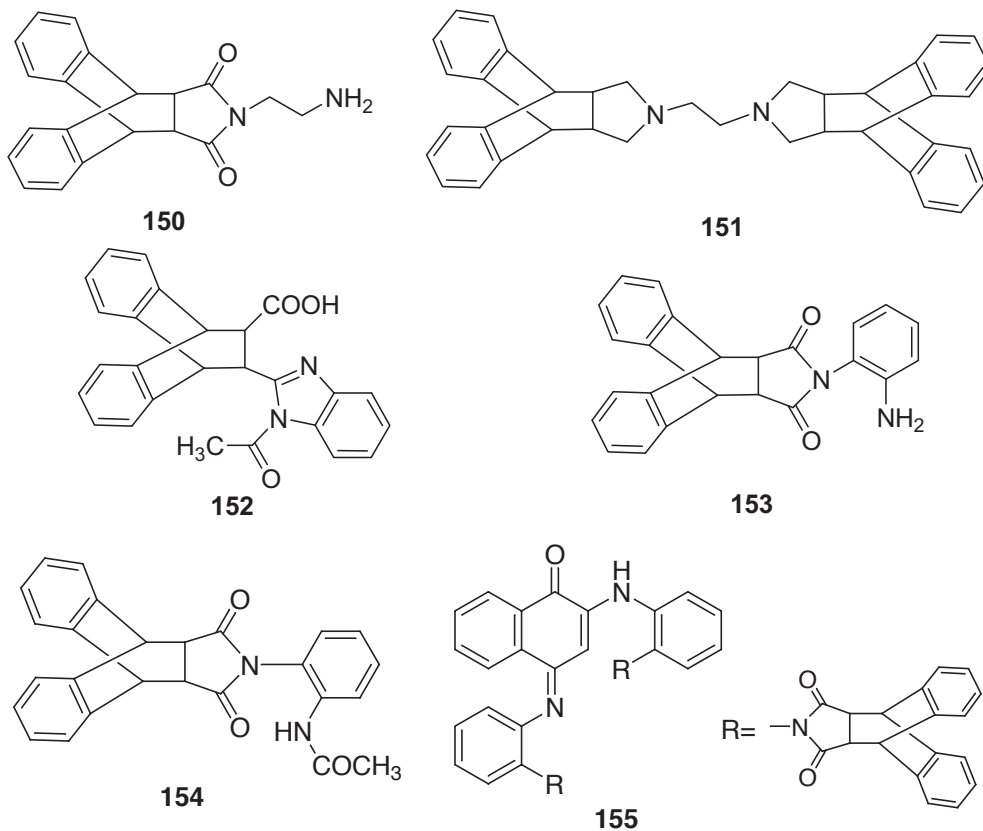
Adduct **1** reacted with N,N-dimethylpropane-1,3-diamine or 2,2,N,N-tetramethylpropane-1,3-diamine in toluene in the presence of a catalytic amount of p-toluene sulfonic acid to yield corresponding isoindole derivatives **156a** and **156b**.[69] Isoindoledione derivatives **156** were stirred in a 10-fold excess of 1,6-dibromohexane without any solvent to give bromohexane derivative **157**.[69]

156a, X= H; **156b**, X= CH$_3$

157
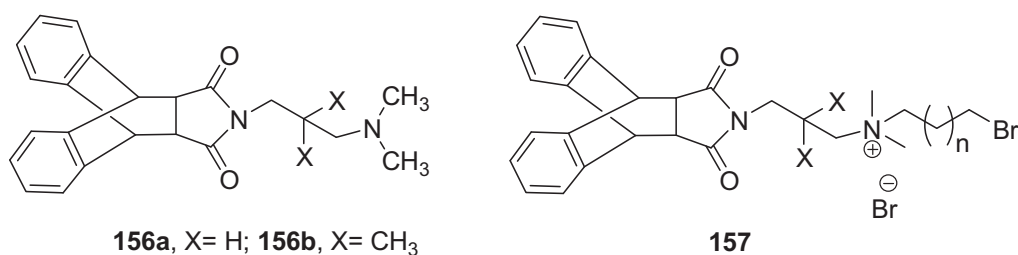
Bis-isoindoledione derivative **158** was achieved by the reflux of **1** with a half-equivalent of dibromohexane in acetonitrile in the presence of a catalytic amount of KI and K$_2$CO$_3$. Furthermore, **158** was achieved by the reaction of **157** with **156** under previous conditions.[69]

158, X= H, CH₃
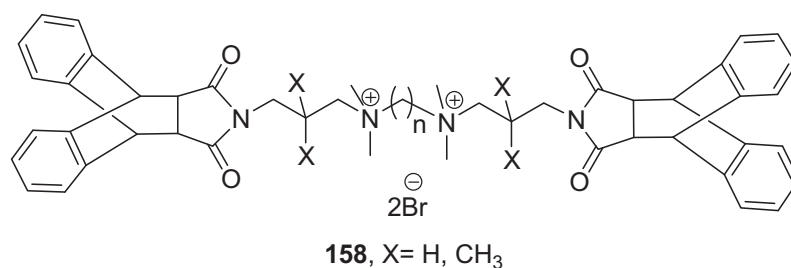
Urea

Compound **1** was fused with urea to give succinamide derivative **159**, which was added to formalin to give **160**.[70,71] The latter compound was reacted with various amines to give **161** (R= phenyl, substituted phenyl, 1-naphthyl), which was prepared directly from the Mannich reaction of **159** with formalin and amines.

159   **160**   **161**
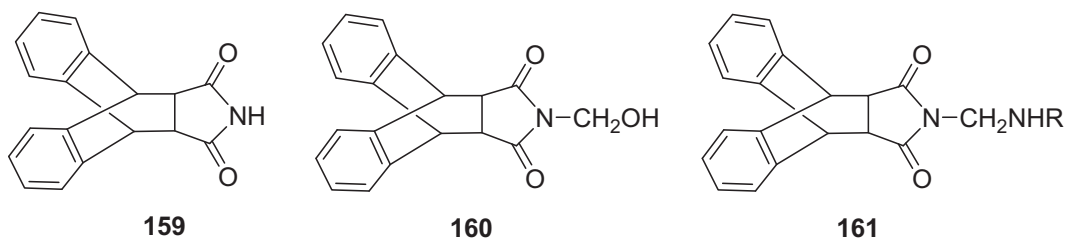
Grignard reagents

Compound **162** was prepared by reaction of **1** with Grignard reagent.[72]

162
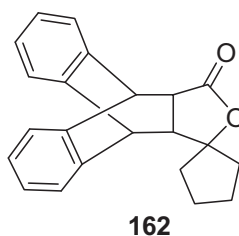
1,8-(Bis-trimethylsilyl)octa-2,6-diene

Adduct **1** was reacted with 1,8-(bis-trimethylsilyl)-octa-2,6-diene to yield γ-keto acid derivative **163**.[73]

163
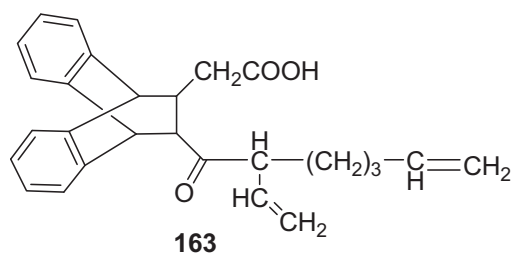
Reduction

Hydrogenation of **1** in the presence of Raney nickel gave **164**. On the other hand, treatment of **1** with hydrogen in the presence of a Ru-catalyst afforded **165**.[74] Reduction of **1** with sodium boronhydride gave **166**, which, upon treatment with n-butyl tin oxide and carbon disulfide, yielded **167**.[75]

164   **165**

166   **167**
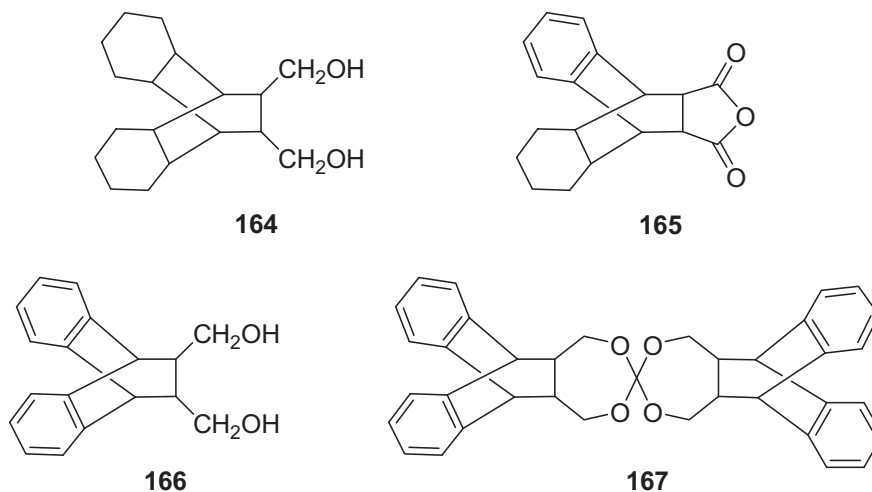
Compound **166** was prepared by reduction of **1** with lithium aluminum hydride.[75] Reaction of **166** with p-toluenesulfonyl chloride in pyridine gave compound **168**.[76,77] The latter compound was refluxed with LiBr in acetone to give 9,10-ethanoanthracene derivative **169**.[77] Treatment of **168** with Na_2Se in 1-methoxy-2-(2-methoxyethoxy)ethane gave selenolane derivative **170**.[77]

168   **169**

170   **171**
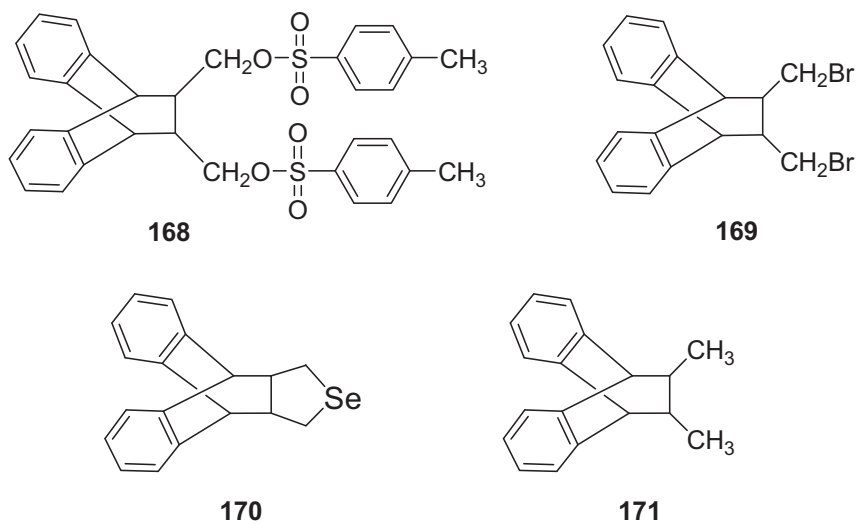
9,10-Dimethyl ethanoanthracene **172** was prepared by reduction of compound **168** with $LiAlH_4$ in THF.[76]

172
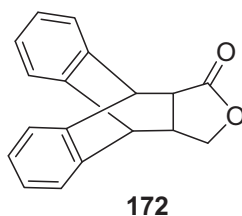
Jones and Wilson[78] reported that reduction of anhydride **1** with sodium borohydride afforded lactone **172** in excellent yield. However, treatment of a slurry of lactone **172** with lithium diisopropylamide in THF at 0 °C led to complete solubilization and generation of an intense yellow solution. Addition of a slight excess of methyl iodide, allyl iodide, butenyl bromide, or benzyl bromide afforded C-alkylated lactones **173-176** in good yields. Reaction of **172** with tributylin chloride gave stannane **177** in a disappointingly low yield. However, reaction with diethyl chlorophosphate gave α-phosphonate **178** in good yield, while chlorotrimethylsilane yielded C-silyl lactone **179** as the sole product in excellent yield (84%) (Table).[78]
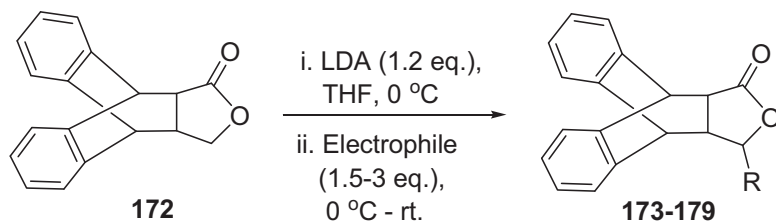
Table. Results of the compounds obtained from the reaction of lactone **172** with different electrophiles.

Electrophile	R	Product	Yield
CH_3I	CH_3	**173**	76%
$CH_2=CHCH_2I$	$CH_2=CHCH_2$	**174**	71%
$CH_2=CHCH_2CH_2Br$	$CH_2=CHCH_2CH_2$	**175**	75%
$PhCH_2Br$	$PhCH_2$	**176**	78%
Bu_3SnCl	Bu_3Sn	**177**	21%
$(EtO)_2P(O)Cl$	$(EtO)_2P(O)$	**178**	74%
$(CH_3)_3SiCl$	$(CH_3)_3Si$	**179**	86%

Nitration

Nitration of **1** with nitric acid in the presence of concentrated sulfuric acid gave dinitro derivative **180**.[79]

180
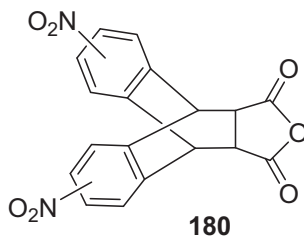
Sulfonation

Sulfonation of **1** with concentrated sulfuric acid in acetic anhydride afforded disulfonated product **181**.[80]

181
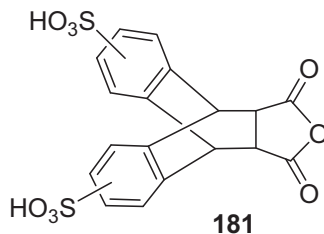
Treatment of **181** with barium carbonate yielded the corresponding barium salt, which was converted to sodium carbonate **182**.[80]

182
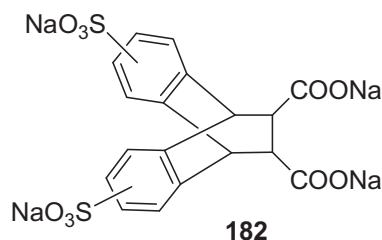
Friedel-Crafts reaction

Compounds **183a** and **183b** were prepared by the Friedel-Crafts reaction of **1** with benzene or toluene in the presence of AlCl$_3$.[81,82]

183a, R= H; **183b**, R= CH$_3$
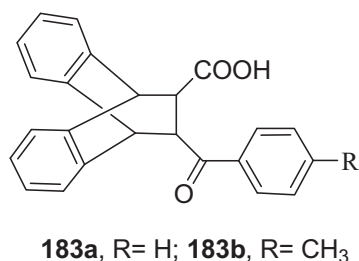
Esterification

Compound **1** was esterified by reaction with alcohol in the presence of concentrated sulfuric acid to give diester **185** (R= Me and Et). Treatment of **185** with hydrazine hydrate yielded diacid hydrazide **186**.[83] Dihydrazide **186** was reacted with acetyl acetone to afford pyrazole derivative **187**. Compound **186** was also reacted with aromatic aldehydes to afford diarylidene hydrazonyl derivatives **188**.[83]

185

186

187

188

Ar= ph, 4-Cl-C$_6$H$_4$, 4-CH$_3$OC$_6$H$_4$
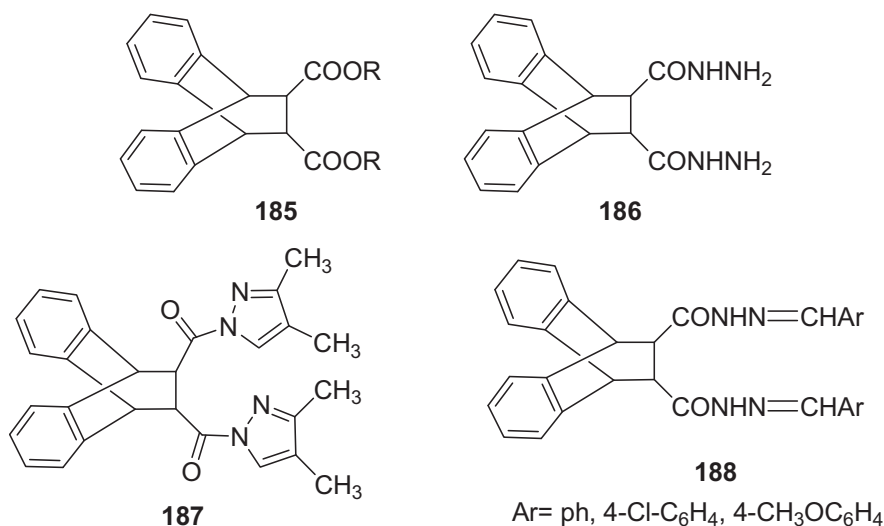
Moreover, the reaction of dihydrazide derivatives **186** with isothiocyanate derivatives furnished corresponding dithiosemicarbazides **189**.[83] The latter adduct, **189**, cyclized with alcoholic KOH followed by acidification with dilute HCl to yield ditriazole derivative **190**.[83] Saponification of **185** (R= Me) with KOH in methanol gave the corresponding potassium salt, which, upon acidification with dilute HCl, yielded diacid **6**.[84] The refluxing of compound **6** with SOCl$_2$ gave the acid chloride, which reacted with amines in THF to afford bis-amide ethanoanthracene derivatives **191a** and **191b**.[84]

189, R= Me, Ph, COPh

190, R= Me, Ph, COPh

191a, R= R`= CH$_3$
191b, R= H, R`= CH$_3$
191c, R= H , R`= CH$_2$-Ph
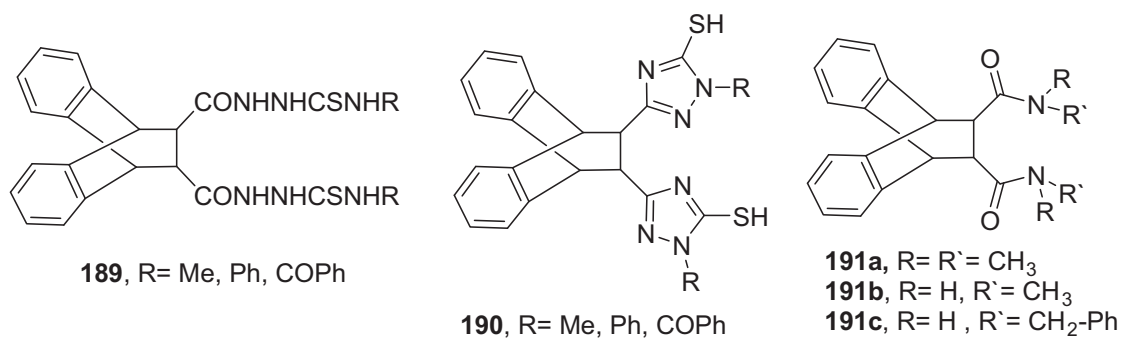
Conclusion

The present review has illuminated different aspects of dibenzobarallene chemistry and has outlined its importance as a valuable synthetic building block for the synthesis of a wide range of various heterocyclic systems. Five methods for dibenzobarallene's nomenclature were reported. Synthesis of the titled compound was achieved by reacting maleic anhydride and anthracene through Diels-Alder, fusion, refluxing "in different solvent," catalysis, microwave irradiation, and photolysis reactions. This review discussed spectroscopic and kinetic studies as well as thermodynamic measurements. Finally, the reactivity of dibenzobarallene was discussed through nucleophilic and electrophilic reactions.

Abbreviations

FTIR, Fourier transform infrared spectroscopy; D-A, Diels-Alder; p°, standard pressure (chosen value of pressure denoted by p° in 1982); MPa, 1 MPa = 1,000,000 Pa = pascal; $\Delta_c H°_m$, standard molar enthalpy of combustion; DuPont DSC, differential scanning calorimetry; $\Delta_f H°_m$, enthalpy of fusion; LiAlH$_4$, lithium aluminum hydride; PhTD, 4-phenyl-1,2,4-triazoline-3,5-dione; DMAc, dimethyl acetamide; (PA)s, polyamides; DIEA, N,N-diisopropylethylamine; PyBOP, (benzotriazol-1-yloxy)tri-pyrrolidinophosphonium hexafluorophosphate; (PMBNH$_2$), p-methoxy-benzyl-amine p-methoxybenzylamine; N-PMB-protected imide, N-(p-methoxybenzyl)-4,9[1',2']benzeno-3a,4,9,9a-tetrahydro-1H-benz[f]isoindole-1,3(2H)-dione; N-Boc-directed N-(tert-butoxycarbonyl)-4,9[1',2']benzeno-1,3,3a,4,9,9a-hexa-hydro-1H-benz[f]isoindole; Boc$_2$O, di-tert-butyl dicarbonate or di-tert-butyl pyrocarbonate Boc anhydride; sec-BuLi/TMEDA, N,N,N',N'-tetramethylethylendiamine (secondary butyl lithium); DCC, N,N'-dicyclohexyl-carbodiimide C/DMAP 4-dimethylaminopyridine; $[\alpha]_D^{22}$, specific rotation; Boc$_2$O, di-tert-butyl dicarbonate TMEDA, N,N,N',N'-tetramethyl ethylendiamine; Ru catalyst, rhodium catalyst.

Acknowledgement

References

1. Srivastava, A.; Srivastava, V.; Verma, S. A. *Pol. J. Chem.* **1994**, *68*, 29-35; *C.A.* **1994**, *121*, 157621t.

2. Kalindjian, S. B.; Bodkin, M. J.; Buck, I. M.; Dunstone, D. J.; Low, C. M. R.; McDonald, I. M.; Pether, M. J.; Steel, K. I. M. *J. Med. Chem.* **1994**, *37*, 3671-3673.

3. Diels, O.; Alder, K.; Bechmann, S. *Ann.* **1931**, *486*, 191-202; *C.A.* **1931**, *25*, 3646.

4. Niculae, B.; Iuliu, M. G.; Colin, S.; Maria, M. *Rom. Ro.* **1979**, *67*, 317; *C.A.* **1982**, *96*, 29976r.

5. Schwenner, E.; Ladouceur, G.; Kabbe, H. J.; Aune, T. M. *(Bayer A.G., Germany), U.S.* **1995**, 14,5411960; *C.A.* **1995**, *123*, 111851f.

6. Khalil, A. M.; Berghot, M. A.; Gouda, M. A. *Chem. Paper* **2010**, *64*, 637-644.

7. Khalil, A. M.; Berghot, M. A.; Gouda, M. A. *Eur. J. Med. Chem.* **2010**, *45*, 1552-1559.

8. Schwenner, E.; Ladouceur, G.; Kabbe, H. J.; Aune, T. M. *(Bayer A.G., Germany), PCT Int. Appl.* **1995**, 74,9515946; *C.A.* **1995**, *123*, 314021.

9. Kalindjian, S. B.; Steel, K. I. M.; Tozer, M. J.; Hudson, M. L. *PCT Int. Appl.* **1993**, *9505*, 359; *C.A.* **1995**, *123*, 256366m.

10. Kalindjian, S. B.; Low, C. M. R.; McDonald, I. M.; Hull, R. A. D.; Shankley, N. B.; Buck, I. M.; Steel, K. I. M.; Davies, J. M. R.; Dunstone, D. J. *PCT Int. Appl.* **1992**, *9316*, 982; *C.A.* **1994**, *120*, 244394u.

11. Hiyama, H.; Sagara, T. *Kagaku Kugyo (Osaka)* **1958**, *32*, 308-311; *C.A.* **1959**, *53*, 4741n.

12. Hiyama, H.; Aihara, T. *Jpn. Pat.* **1959**, 2235; *C.A.* **1960**, *54*, 11499f.

13. Bechmann, W. E.; Kloetzek, M. E. *J. Am. Chem. Soc.* **1938**, *60*, 481-485.

14. Mallakpour, S.; Rafiee, Z. *Reactive & Funct. Poly.* **2009**, *69*, 252-258.

15. Diels, O.; Alder, K. *Ber.* **1931**, *64*, 2194-2200; *C.A.* **1932**, *26*, 446.

16. Kalindjian, S. B.; Buck, I. M.; Cushnir, J. R.; Dunstone, D. J.; Hudson, M. L.; Low, C. M. R.; McDonald, I. M.; Pether, M. J.; Steel, K. I. M.; Tozer, M. J. *J. Med. Chem.* **1995**, *38*, 4294-302.

17. Bechmann, W. E.; Scott, L. B. *J. Am. Chem. Soc.* **1948**, *70*, 1458-1461.

18. Glatzhofer, D. T.; Liang, Y.; Funkhouser, G. P.; Khan, M. A. *Organometallics* **1994**, *13*, 315-21.

19. Razzaq, T.; Kremsner, J. M.; Kappe, C. O. *J. Org. Chem.* **2008**, *73*, 6321-6329.

20. Giguere, R. J.; Bray, T. L.; Duncan, S. M.; Majetich, G. *Tetrahedron Lett.* **1986**, *27*, 4945-4948.

21. Da Cunha, L.; Garrigues, B. *Bull. Soc. Chim. Belg.* **1997**, *106*, 817-823; *C.A.* **1998**, *128*, 204747v.

22. Reid, W.; Schinzel, H. *Liebigs Ann. Chem.* **1982**, *8*, 1569-1572; *C.A.* **1982**, *97*, 162536j.

23. Bulgarovskaya, I. V.; Zvonkova, Z. V.; Ilina, I. G. *Zh. Strukt. Khim.* **1979**, *20*, 889-93; *C.A.* **1980**, *92*, 163780t.

24. Madhurambal, G.; Ramasamy, P.; Srinivasan, P. A.; Mojumdar, S. C. *J. Thermal Analy. & Calorimetry* **2006**, *86*, 601-604.

25. Ogimachi, N.; Andrews, L. J.; Keefer, R. M. *J. Am. Chem. Soc.* **1955**, *77*, 4202-4206.

26. Kar, M.; Lenz, T. G. *J. Chem. Thermodynamics* **1992**, *24*, 151-157.

27. Bechmann, W. E.; Cole, W. *J. Org. Chem.* **1939**, *4*, 60-67.

28. Vaughan, W. R.; Andersen, K. S. *J. Org. Chem.* **1956**, *21*, 673-683.

29. Hammer W. J. *U.S. Pat.* **1976**, 3,950,407; *C.A.* **1976**, *85*, 20952v.

30. Ardashev, B. I.; Zarefyan, A. S. *Khim. Tekhnol. Nauch-Tekh. Sb.* **1966**, *4*, 61-63; *C.A.* **1967**, *67*, 81980c.

31. Augustin, M.; Reinemann, P. *Z. Chem.* **1972**, *12*, 101-102; *C.A.* **1972**, *77*, 61341y.

32. Verma, S. M.; Sinha, K. O. P.; Rao, C. K. *Can. J. Chem.* **1974**, *52*, 2399-2402.

33. Alaka, S.; Vandana, S.; Verma, S. M. *Indian J. Chem.* **1997**, *36B*, 236-241.

34. Alaka, S.; Vandana, S.; Verma, S. M. *Indian J. Chem.* **2001**, *40B*, 20-24.

35. Khalil, A. M.; Berghot, M. A.; Gouda, M. A. *J. Serb. Chem. Soc.* **2011**, *76*, 329-339.

36. Khalil, A. M.; Berghot, M. A.; Gouda, M. A. *Eur. J. Med. Chem.* **2009**, *44*, 4448-4454.

37. Khalil, A. M.; Berghot, M. A.; Gouda, M. A. *Eur. J. Med. Chem.* **2009**, *44*, 4434-4440.

38. Khalil, A. M.; Berghot, M. A.; Gouda, M. A. *Monatsheft* **2009**, *140*, 1371-1379.

39. Khalil, A. M.; Berghot, M. A.; Gouda, M. A.; El Bialy, S. A. *Monatsh. Chem.* **2010**, *141*, 1353-1360.

40. Fleckenstein, E.; Mohr, R. *Ger. Offen. Pat.* **1974**, 2,238,406; *C.A.* **1974**, *81*, 65179g.

41. Saikia, R.; Singh, A. K.; Bhattacharjee, G. *Ind. J. Chem.* **1988**, *27A*, 790-793.

42. Schumann, E. L.; Roberts, E. M.; Claxton, G. P. *U.S. Pat.* **1964**, 7,3123618,0303; *C.A.* **1964**, *60*, 82797.

43. Wehner, W.; Michaelis, K. P.; Schneider, R. *Eur. Pat. Appl.* 30 pp.; *C.A.* **1981**, *94*, 193202.

44. Weber, E.; Finge, S.; Csoergh, I. *J. Org. Chem.* **1991**, *56*, 7281-7288.

45. Schmidt, M.; Wank, J.; Reese, E.; Freitag, D.; Wangermann, K.; Cohnen, W. *Ger. Offen.* **1981**, 2,931,172; *C.A.* **1981**, *94*, 193202q.

46. Srivastava, N.; Verma, S. M. *Nat. Acad. Sci. Lett.* **1991**, *14*, 413-416; *C.A.* **1992**, *117*, 7280j.

47. Johansson, M. J.; Schwartz, L.; Amedjkouh, M.; Kann, N. *Tetrahedron Asymm.* **2004**, *15*, 3531-3538.

48. Buisman, G. J. H.; Kamer, P. C. J.; van Leeuwen, P. W. N. M. *Tetrahedron Asymm.* **1993**, *4*, 1625-1634.

49. Guiu, E.; Aghmiz, M.; Diaz, Y.; Claver, C.; Meseguer, B.; Militzer, C.; Castillon, S. *Eur. J. Org. Chem.* **2006**, 627-633.

50. Sanhes, D.; Gual, A.; Castillon, S.; Claver, C.; Gomez, M.; Teuma, E. *Tetrahedron Asymm.* **2009**, *20*, 1009-1014.

51. Mallakpour, S. E.; Hajipour, A. R.; Mahdavian, A. R.; Rafiemanzelat, F. *Polym. Int.* **1999**, *48*, 109-116.

52. Turk, J. A.; Smithrud, D. B. *J. Org. Chem.* **2001**, *66*, 8328-8335.

53. Gewald, K. *Z. Chem.* **1962**, *2*, 305-306; *C.A.* **1963**, *58*, 6770f.

54. Beak, P.; Zajdel, W. J.; Reitz, D. B. *Chem. Rev.* **1984**, *84*, 471-523.

55. Beak, P.; Basu, A.; Gallagher, D. J.; Park, Y. S.; Thayumanavan, S. *Acc. Chem. Res.* **1996**, *29*, 552-560.

56. Sasaoka, A.; Uddin, M. I.; Shimomoto, A.; Ichikawa, Y.; Shiro, M.; Kotsuki, H. *Tetrahedron Asymm.* **2006**, *17*, 2963-2969.

57. Sanhes, D.; Favier, I.; Saffon, N.; Teuma, E.; Gomez, M. *Tetrahedron Lett.* **2008**, *49*, 6720-6723.

58. Srivastav, K. K.; Verma, K. A.; Verma, S. M. *Ind. J. Chem.* **1993**, *32B*, 1143-1148.

59. Singh, S.; Verma, S. M. *Ind. J. Chem.* **1981**, *20B*, 873-877.

60. Mahanti, S.; Verma, S. M. *Ind. J. Chem.* **1982**, *21B*, 1098-1110.

61. Verma, A. K.; Mahanti, S.; Verma S. M. *Ind. J. Chem.* **1989**, *28B*, 457-461.

62. Verma, S. M.; Singh, R. *Ind. J. Chem.* **1978**, *16B*, 60-63.

63. Goldfarb, D. S. *U.S. Pat. Appl. Publ.* **2008**, 57,341615,1222; *C.A.* **2009**, *151*, 92846.

64. Kitahonoki, K.; Kido, R. *Ger. Pat.* **1975**, 1,695,796; *C.A.* **1975**, *83*, 9778f.

65. Kitahonoki, K.; Kido, R. *U.S. Pat.* **1970**, 3,513,174; *C.A.* **1970**, *73*, 455604y.

66. Kitamogi, K.; Kido, R. *Japan Pat. (Shionogi and Co., Ltd.) Jpn. Tokkyo Koho* **1967**, 3, JP 42009574,0517; *C.A.* **1967**, *68*, 49357.

67. Keizo, K.; Ryonosuke, K. *Ger. Pat.* **1975**, 1,695,796; *C.A.* **1975**, *83*, 9778f.

68. Staniek, P.; Stoll, K. *Ger. Offen.* **1996**, 19,520,262; *C.A.* **1996**, *124*, 147807f.

69. Muth, M.; Bender, W.; Scharfenstein, O.; Holzgrabe, U.; Balatkova, E.; Trankle, C.; Moher, K. *J. Med. Chem.* **2003**, *46*, 1031-1041.

70. Chen, G.; Zhong, W.; Xuexioa, G. *Hauxue Xuebao* **1982**, *2*, 450-454; *C.A.* **1982**, *96*, 1767n.

71. Cheng, S.; Zhang, M.; Sun, L.; Di, X.; Wang, P. *Hauxue Shiji* **1990**, *12*, 49-50; *C.A.* **1990**, *113*, 114994j.

72. Gu, M.; Wang, L.; Zhou, C.; Liu, W.; Zhang, Z.; Dong, T. *Xuebao Ziran Kexueban* **1989**, *28*, 315-319; *C.A.* **1990**, *112*, 216584x.

73. Pellissier, H.; Wilmouth, S.; Santelli, M. *Bull. Soc. Chim. France* **1995**, *132*, 637-641; *C.A.* **1996**, *124*, 45706u.

74. Kolobielski, M. *J. Org. Chem.* **1963**, *28*, 1883-1885.

75. Park, Y. J.; No, K. H.; Kim, J. H.; Suh, I. H. *Bull. Korean Chem. Soc.* **1992**, *13*, 375-381; *C.A.* **1992**, *117*, 191822m.

76. Weber, E.; Csoregh, I.; Ahrendt, J.; Finge, S.; Czugler, M. *J. Org. Chem.* **1988**, *53*, 5831-5839.

77. Baraillon, B.; Caire, J. C.; Saquet, M.; Thuillier, A. *J. Chem. Res. Synop.* **1986**, *3*, 98-99.

78. Jones, S.; Wilson, I. *Tetrahedron Lett.* **2006**, *47*, 4377-4380.

79. Horyna, J. *Czech. Chem. Soc.* **1982**, *202*, 272; *C.A.* **1982**, *97*, 215809j.

80. Horyna, J. *Czech. Chem. Soc.* **1982**, *202*, 264; *C.A.* **1982**, *97*, 215810c.

81. Yates, P.; Eaton, P. *J. Am. Chem. Soc.* **1960**, *82*, 4436-4437.

82. Wu, X.; Kang, W.; Zhu, D.; Zhu, C.; Liu S. *J. Organometallic Chem.* **2009**, *694*, 2981-2986.

83. Sarhan, A. O.; El-Emary, T.; Hussein, M. A. *Ind. J. Chem.* **1997**, *36B*, 1009-1015.

84. Alibert, S.; Rouvier, C. S.; Pradines, B.; Houdoin, C.; Parzy, D.; Wojciechowska, K. J.; Barbe, J. *J. Med. Chem.* **2002**, *45*, 3195-3209.