3.1. Introduction

This chapter deals with the details of the materials used, their purification methods of preparation and characterization of intermediate compounds, different steps involved in the synthesis of indole and pyrazole derivatives and a brief description of various sophisticated instrumental techniques used for characterizations.

3.2. Materials

The solvents and liquid reagents were distilled and the middle portion was used. All reagents used were commercial grade. The silica gel for TLC was obtained from Merck (India) Limited, Bombay. The silica gel (Mesh T/838234) for column chromatography was obtained from Spectrochem Private Limited (India). Solvents used for column separations were distilled twice before use. The spectra were recorded on Shimadzu 8201 FTIR spectrophotometer and Shimadzu 160 A UV – Vis spectrophotometer. Melting points were taken on Electrothermal digital melting point apparatus and are uncorrected. Single spotted TLC determined the completion of the reaction. IR spectra were recorded using KBr disc on a Jasco FTIR - 410.

3.2.1. Solvents

Solvents such as methanol, benzene, hexane, petroleum ether, dichlorobenzene, acetone (S.D. Fine. Chem. India) and tetrahydrofuran, chloroform, ethyl acetate, and acetone (E. Merck) were purified according to standered procedures given by Vogel [185]. Rectified spirit (commercial grade) was dried over calcium oxide and distilled twice to get the pure ethanol. Dimethylformamide (DMF) was distilled under reduced pressure and moisture free condition.

Spectroscopic grade acetone, chloroform, carbon tetrachloride and DMF (S.D. Fine. Chem. India) were used as the solvents for UV and Cyclic voltammetric analyses. These solvents were used without further purification. Deuterated chloroform (CDCl₃, 99.8% containing 0.03V/V of tetramethylsilane (TMS), deuterated sulphoxide (DMSO-d6, containing
0.03V/V of TMS) trifluoroacetic acid (TFA) (Aldrich) were used as the solvents for recording NMR spectra of the samples.

3.2.2 Reagents

1. Aniline: \([C_6H_5 NH_2]\), (E. Merck, India), colorless liquid, b.p: 184°C, d: 1.020, Dried with CaH\(_2\) then distilled at reduced pressure and used.

2. Indole: \([C_8H_7N]\), (E. Merck, India), white solid, m.p: 52-54°C used as received.

3. 4-Bromoaniline: \([C_6H_6BrN]\), (Loba Chemie), m.p: 66°C, white solid crystallized from ethanol

4. Bromobenzene: \([C_6H_5Br]\), (Loba Chemie), b.p: 155.9°C, d: 1.495, Washed vigorously with conc.\(H_2SO_4\), and then 10% \(NaOH\) and \(H_2O\). Dried with CaCl\(_2\), distilled and used.

5. Dimethyl formamide – \(C_3H_7NO\) - Purchased from Merck (India) Limited and used as such without any further purification.

6. Acetanilide - \(C_8H_9NO\) - Purchased from Merck (India) Limited and is used as such without any further purification, m.p: 113°C.

7. Phosphoryl chloride – \(POCl_3\) - Purchased from LOBA Chemie and is used as such without any further purification.

8. t-Butanol - \(C_4H_{10}O\) - Purchased from Merck (India) Limited and purified by distillation, b.p 82°C.

9. Glacial acetic acid - \(CH_3COOH\) - Purchased from Merck (India) Limited and is used as such without any further purification, b.p 118°C.

10. Acetophenone - \(C_8H_8O\) - Purchased from Merck (India) Limited and is used as such without any further purification, b.p 202°C.

11. Phenylhydrazine - \(C_6H_8N_2\) – Purchased from LOBA Chemie and is used as such without any further purification.

12. 1, 10-Phenanthroline- \(C_{12}H_8N_2\) - Purchased from Merck (India) Limited and is used as such without any further purification, m.p 117°C.
13. Benzidine: $\text{C}_{12}\text{H}_{12}\text{N}_2$ - Purchased from Merck (India) Limited and is used as such without any further purification, m.p 122-125°C.

14. Potassium carbonate: $\text{K}_2\text{CO}_3$ - Purchased from LOBA Chemie and is used as such without any further purification, m.p 891°C.

15. Potassium iodide: KI, - Purchased from Merck (India) Limited and is used as such without any further purification, m.p 681°C.

16. Electrolytic copper- Cu, Purchased from Merck (India) Limited and is used as such without any further purification.

3.2.3. Instrumentation

**Infrared (IR) spectra** were recorded on a Shimadzu FT-IR 8400 S spectrometer, where the percentage of transmittance versus wave number (in reciprocal of centimeters) was plotted. Solid samples were recorded as potassium bromide (KBr) disc where as liquid samples as neat or solvent spectra using spectroscopic grade solvent.

**Ultraviolet-visible (UV-Vis) spectra** were recorded on a Shimadzu 1700 UV-Visible spectrophotometer using a closed type quartz tube of 1.0 cm square dimensions. All spectra were recorded at room temperature and at very low concentration of the solute. Spectroscopic grade ethanol, methanol and chloroform were used as solvent for UV spectra.

**Proton ($^1\text{H}$) and carbon-13 ($^{13}\text{C}$) nuclear magnetic resonance (NMR) spectra** were recorded on a NMR-JEOL GSX-400 spectrometer. The proton spectra were recorded using broad band inverse probe where the inner coil is for protons and outer coil for ‘X’ nuclei. Phase coherent solvent suppression was employed in some of the cases where the solvent signal is very strong compared to the sample signals. All the carbon-13 spectra were recorded in the duel (13C/1H) probe where the inner coil is for C-13 and the outer coil for protons. The decoupling of the proton was done employing waltz-16 sequence. The spectral parameters like number of scans, time domain data points etc were adjusted depending on the nature of the sample and the relaxation parameters like T1 and T2 were taken into account for obtaining the required information. The chemical shifts were reported in ppm.
unit with tetramethylsilane as internal standard. DMSO and CDCl₃ were used as solvents. Mass spectra were measured using MALDI-TOF mass spectrometer.

Electro chemical stability of compounds measured using Cyclic Voltammetry (CV). CV measurements were carried out on a Autolab potentiostat PGSTAT 12 at a glassy carbon electrode using millimolar solutions in acetonitrile (ACN) containing 0.1M of supporting electrolyte, tetrabutylammonium hexafluorophosphate (TBAPF₆), in a three electrode cell and potentiostat assembly at room temperature. The CV measurements were carried out at a glassy carbon electrode using millimolar solutions in acetonitrile (ACN) containing 0.1M of the supporting electrolyte tetrabutylammonium hexafluorophosphate (TBAPF₆), in a three electrode cell and potentiostat assembly at room temperature. The potentials were measured against platinum as reference electrode and each measurement was calibrated with an internal standard, ferrocene /ferrocenium (Fc) redox system.

Thermal characterization of the samples determined using Differential Scanning Calorimetry (DSC). DSC studies were performed with a NETZSCH DSC 204 thermal analyzer under inert atmosphere. The sample were scanned from 10°C to 380°C at a rate of 10°C min⁻¹. The compounds are analyzed for heating and cooling thermograms (cyclic) in an inert atmosphere from -50°C to 250°C at a rate of 10°C/ min. Glass transition (Tₚ), melting(Tₘ) and crystallization (Tₖ) were measured using DSC.

3.3. Preparation of intermediate compounds
3.3.1. 1,3,5-Tri-bromobenzene (B)

1,3,5 tri-bromobenzene [B] was prepared from 1,3,5-tri-bromoaniline [A] according to available procedure of Vogel. Aniline was brominated using bromine in glacial acetic acid at 0°C to get A. 1,3,5-Tri-aminobenzene undergoing diazotization yielding [B] [185]. The 1,3,5 tri-bromobenzene thus obtained was characterized by FT-IR and NMR spectroscopic methods. The
melting point was found to be 122°C. The scheme 3.1 gives the synthetic route for the preparation of 2, 4, 6-tribromobenzene.

\[
\begin{align*}
\text{A} & \quad \text{NH}_2 \quad \text{Br} \\
\text{Br} & \quad \text{Br} \\
\text{Br} & \\
\end{align*}
\]

1. Diazotisation
2. EtOH

\[
\begin{align*}
\text{A} & \quad \text{NH}_2 \quad \text{Br} \\
\text{Br} & \quad \text{Br} \\
\text{Br} & \\
\end{align*}
\]

Scheme 3.1: Synthetic route for the preparation of 2, 4, 6-tribromobenzene.

### 3.3.2. 4-Bromophenol (C)

4-Bromophenol was prepared from phenol by refluxing calculated amount of \(N\)-bromosuccenimide [NBS] and ammonium acetate in methyl cyanide. Product extracted from ethyl acetate and recrystallized in ethanol. The structure of the compound characterized by melting point, FT-IR and NMR spectroscopic methods. The scheme 3.2 gives the synthetic route for the preparation of 4-bromophenol [185]. Yield 7% and m.p: 77°C.

\[
\begin{align*}
\text{OH} & \\
\end{align*}
\]

NBS, Ammonium acetate
Methyl cyanide

Scheme 3.2: Synthetic route for the preparation of 4-bromophenol

### 3.3.3. 1, 4-Diaminobenzene (D)

Calculated amount of \(p\) – nitroaniline was taken in a 250 mL RB flask and to this 3 mL 20% NaOH and 18.5 mL alcohol were added. The mixture stirred vigorously and heated on a water bath to gentle boiling. The burner was removed from the beneath the bath and 10 g of zinc powder was added in several portions to it. The mixture was refluxed with stirring for 1 h. The hot mixture was filtered at the pump. To the filtrate 2 g sodium hyposulphite was
added and the solution was concentrated under reduced pressure on a steam bath. The solution was allowed to cool in a freezing mixture of ice and salt. The pale yellow crystals were collected on a Buchner funnel. The crude product was recrystallised from hot water. The scheme 3.3 gives the synthetic route for the preparation of 1,4-diaminobenzene [185].

The structure of the compound characterized by melting point, FT-IR and NMR spectroscopic methods. Yield 77% and m.p: 143°C

![Scheme 3.3: Synthetic route for the preparation of 1, 4-diaminobenzene](image_url)

### 3.3.4. 4-Iodoaniline (E)

4-Iodoaniline was prepared according to the known procedure given in Vogel [185]. Aniline (37 g, 0.4 mol) was dissolved in a solvent mixture of (50 g, 0.6 mol) of sodium hydrogen carbonate in 350 mL of water in a one liter beaker provided with a mechanical stirrer. The reaction mixture was cooled to 12-15°C by the addition of a little crushed ice pieces to the reaction mixture. The mixture was stirred well and (85 g, 0.33 mol) powdered resembled iodine introduced into the reaction mixture in portions of 5-6 g at intervals of 2-3 minutes. All the iodine was added within 30 minutes and the stirring was continued for 30 minutes, by which time the colour of the free iodine in the reaction mixture was completed. The crude p-iodoaniline was filtered with suction on a Buchner funnel and dried. After that the crude product was placed in a 500 mL round bottom flask fitted with a reflux condenser and to this light petroleum (b.p 60-80°C) was added. The entire reaction mixture was heated in a water bath and the temperature was maintained at 75-80°C. During heating the flask was shaken frequently and heating was continued for about 15 minutes. The hot clear solutions was
decanted slowly into a beaker set in a freezing mixture of ice and salt and stirred continuously. The \( p \)-iodoaniline was crystallized almost immediately as colorless needles. The crystals were filtered and dried in vacuum.

The purity of the compound was checked by TLC. The structure of the compound characterized by melting point, FT-IR and NMR spectroscopic methods. The scheme 3.4 gives the synthetic route for the preparation of 4-iodoaniline. Appearance: white solid, yield 82\% and m.p: 62\(^\circ\)C.

\[
\text{Scheme 3.4: Synthetic route for the preparation of 4-iodoaniline.}
\]

### 3.3.5. 4, 4′-Diiodobiphenyl (F)

Benzidine (15.6 g, 0.085 mol) was dissolved in a solvent mixture of 5 mL of conc HCl and 5 mL of water in a 250 mL beaker provided with a mechanical stirrer. It was cooled to 0 to 5\(^\circ\)C by immersing in an ice bath and diazotized by the addition of a solution of 1.2 g sodium nitrate in 40 mL of water. Potassium iodide solution (4 g in 10 mL water) was added drop by drop with shaking to the diazo solution. The crude 4, 4′-diiodobiphenyl was separated out, filtered washed and dried to get dark red precipitate. It was recrystallized from alcohol and dried in air [185]. The structure of the compound characterized by melting point, FT-IR and NMR spectroscopic methods. The scheme 3.5 gives the synthetic route for the preparation of 4, 4′-diiodobiphenyl. Yield 82\% and m.p: 62\(^\circ\)C.
Scheme 3.5: Synthetic route for the preparation of 4, 4'-diiodobiphenyl.

3.3.6. Phenylazo -2- naphthol (G)

The compound was prepared according to the procedure given in Vogel [185]. Aniline (5 g, 0.054 mol) was dissolved in a solvent mixture of 16 mL of concentrated HCl and 16 mL of water in a conical flask and the flask was cooled by immersing in an ice bath. Sodium nitrite (4 g, .058 mol) dissolved in 20 mL of water was added in small volume (2-3 mL at a time) to the cold aniline hydrochloride solution. The content of the solution was shaken well and the temperature of the reaction would not allow rising above 10°C. 2-Naphthol (7.8 g, 0.054 mol) was prepared in 45 mL of 10 % sodium hydroxide solution in a 250 mL beaker and the solution was cooled by immersing in an ice bath (And also about 25 g of crushed ice pieces were also added to the solution). The naphthol solution was stirred well by using magnetic stirrer and to this cold diazonium chloride solution was added very slowly. First a red colour developed and red crystals of 1-phenylazo-2-naphthol separated out. It was filtered, washed, dried and recrystallised from glacial acetic acid. The recrystallized product was filtered with suction and washed with a little alcohol to eliminate acetic acid and dry upon filter paper. The completion of the reaction was checked by TLC. The structure of the compound characterized by melting point, FT-IR and NMR spectroscopic methods. The scheme 3.6 gives the synthetic route for the preparation of phenylazo-2-naphthol. Yield 79% and m.p: 131°C.
Scheme 3.6: Synthetic route for the preparation of phenylazo-2-naphthol.

3.3.7. 1-Amino-2-naphthol (H)

The compound was prepared according to the known procedure given in Vogel. Phenylazo-2-naphthol (0.744 g, 0.03 mol) was taken in a 250 mL round bottom flask provided with a reflux condenser and a stirrer. To this 10 mL rectified spirit was added and heated gently to boil until most of the phenylazo-2-naphthol had dissolved. To the boiling solution 5 mL of tin chloride solution (1.7 g of SnCl₂ in 5 mL of concentrated HCl) was added and the entire contents of the flask were refluxed for 30 minutes. All the azo compounds dissolved rapidly, reduced by SnCl₂ and the colour of the solution was changed to pale brown. The solution was then decanted to a beaker and cooled in an ice bath. 1-Amino-2-naphthol hydrochloride separated out as fine greyish white crystals. It was washed several times by 1:1 NaOH solution to convert 1-amino-2-naphthol hydrochloride to 1-amino-2-naphthol. The scheme 3.7 gives the synthetic route, yield 59% and m.p: 142°C.

Scheme 3.7: Synthetic route for the preparation 1-amino-2-naphthol.
3.3.8 4-(2-Phenyl diazenyl)naphthalene-1-ol (I)

The compound was prepared according to the procedure given in Vogel [185]. Aniline (5 g, 0.054 mol) was dissolved in a solvent mixture of 16 mL of concentrated HCl and 16 mL of water in a conical flask and the flask was cooled by immersing in an ice bath. Sodium nitrite (4 g, 0.058 mol) dissolved in 20 mL of water was added in small volume (2-3 mL at a time) to the cold aniline hydrochloride solution. The content of the solution was shaken well and the temperature of the reaction would not allow to rise above 10°C. 1-Naphthol (7.8 g, 0.054 mol) was prepared in 45 mL of 10% sodium hydroxide solution in a 250 mL beaker and the solution was cooled by immersing in an ice bath (And also about 25 g of crushed ice pieces were also added to the solution.) The naphthol solution was stirred well by using magnetic stirrer and to this cold diazonium chloride solution was added very slowly, then first a red colour developed and red crystals of 1-phenylazo-2-naphthol separated out. It was filtered, washed, dried and recrystallised from glacial acetic acid. The recrystallized product was filtered with suction and washed with little alcohol to eliminate acetic acid and dry upon filter paper. The completion of the reaction was checked by TLC. The structure of the compound characterized by melting point, FT-IR and NMR spectroscopic methods. The scheme 3.8 gives the synthetic route for the preparation of 4-(2-phenyl diazenyl)naphthalene-1-ol, Yield 61% and melting point 119°C.

![Scheme 3.8: Synthetic route for the preparation of 4-(2-phenyl diazenyl) naphthalene-1-ol](image)

3.3.9. 4-Amino naphthalene-1-ol (J)

The compound was prepared according to the procedure in Vogel [185]. 4-(2-phenyl diazenyl)naphthalene-1-ol (0.744 g, 0.004 mol) was taken in a 250 mL round bottom flask provided with a reflux condenser and a stirrer. To
this 10 mL rectified spirit was added and heated gently to boil until most of
the phenylazo-2- naphthol had dissolved. To the boiling solution 5 mL of tin
chloride solution (1.7 g of SnCl\textsubscript{2} in 5 mL of concentrated HCl) was added and
the entire contents of the flask were refluxed for 30 minutes. All the azo
compounds dissolved rapidly, reduced by SnCl\textsubscript{2} and the colour of the solution
was changed to brown. The solution was then decanted to a beaker and
cooled in an ice bath. 4-Amino naphthalene-1-ol hydrochloride separated out
as fine greyish crystals. It was washed several times by 1: 1 NaOH solution to
convert 4-Amino naphthalene-1-ol hydrochloride to 4-amino naphthalene-1-
ol. The scheme 3.9 gives the synthetic route for the preparation 4-Amino
naphthalene-1-ol, yield 61% and melting point 139°C.

Scheme 3.9: Synthetic route for the preparation of 4-amino naphthalene-1-ol

3.3.10. Tris(4-bromophenyl)amine (K)

1, 4-Dichlorobenzene (1.47 g, 0.01 mol) was taken in a 250 mL round
bottom flask. To this 1 g K\textsubscript{2}CO\textsubscript{3} and 0.1 g KI were added. To this solution
bromine in acetic acid was added drop by drop with continuous stirring until
the colour of the solution became pale yellow. The stirred solution was then
poured into ice cold water and the crude product of 1,4-dibromobenzene
precipitated out, which was filtered, washed, dried and recrystallised from
ethyl acetate. 1,4-Dibromobenzene appeared as pale yellow solid with
melting point 88°C.

4-Bromoaniline (0.0172 g, 0.01 mol) and 1, 4-dibromobenzene
(0.0472 g, 0.02 mol) were dissolved in 1,2-dichlorobenzene in a 250 mL
round bottom flask. To this 0.1 g CuCl, 0.1 g K\textsubscript{2}CO\textsubscript{3}, 0.001 g KI and 0.001 g
1,10-phenanthroline were added and heated the entire solution at 110°C with
stirring for 10 hours. The completion of the reaction is monitored by TLC.
The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent dichlorobenzene was evaporated under vacuum and the product obtained was filtered washed recrystallised from ethyl acetate and further purified by column chromatography using hexane ethyl acetate as (2:1) as eluent. The scheme 3.10 gives the synthetic route for the preparation 4-amino naphthalene-1-ol. Yield 60%, melting point 141°C.

Scheme 3.10 : Synthetic route for the preparation of tris(4-bromophenyl) amine

3.4. Preparation of pyrazole based intermediate compounds

3.4.1. Acetophenone phenylhydrazone (L)

Acetophenone phenylhydrazone was prepared according to the known procedure in [185]. Acetophenone (12 g, 0.1 mol) and phenyl hydrazine (10.8 g, 0.1 mol) were taken in a 250 mL round bottom flask. The reaction mixture was heated on a water bath to reflux for one hour. The hot mixture was dissolved in 40 mL of rectified spirit and shaken well to induce crystallization. The mixture was cooled in ice, filtered and washed with 12 mL of rectified spirit. The residue was dried in a vacuum desiccator over anhydrous calcium chloride for half an hour. The crude was recrystallised from ethanol and dried in vacuum. The scheme 3.11 gives the synthetic route for the preparation of acetophenone phenyl hydrazone. The yield of the product was 80% with m.p. 106°C. TLC analysis was carried out to check the purity of the compound.
3.4.2. 1,3-Diphenyl pyrazol-4-carboxaldehyde (M)

1,3-Diphenyl pyrazol-4-carboxaldehyde was prepared according to the known procedure [186]. Dimethyl formamide (26.3 g, 0.36 mol) and phosphoryl chloride (41.76 g, 0.36 mol) were cooled separately at 0°C. The Vilsmeier-Haack reagent was prepared by mixing these two cold solutions. Acetophenone phenyl hydrazone (6.3 g, 0.3 mol) was dissolved in 20 mL dimethyl formamide and added drop wise to Vilsmeier-Haack reagent with continuous shaking. It was warmed to room temperature and then refluxed for 6 hours. After cooling at room temperature the mixture was basified with a cold saturated potassium carbonate solution. The precipitate was filtered, strongly washed with water, recrystallised from ethanol and dried in vacuum.

Scheme 3.11: Synthetic route for the preparation of acetophenone phenyl hydrazone

The scheme 3.12 gives the synthetic route for the preparation of 1,3-diphenyl pyrazol-4-carboxaldehyde. The purity of the compound was checked by TLC analysis. The yield of the product was 76% with m.p. 135°C.
3.4.3. N-(4-Bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylene)amine (N)

N-(4-Bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylene)amine was prepared according to the known procedure [186]. 1, 3-Diphenylpyrazole-4-carboxaldehyde (1.24 g, 0.005 mol) was dissolved in boiling ethanol and then 0.2 mL of glacial acetic acid and p-bromoaniline (0.86 g, 0.005 mol) were added. The whole mixture was taken in a 250 mL R.B. flask and then heated to reflux for 7.0 hours. After cooling the reaction mixture at room temperature the precipitate of (4-bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylene)amine was obtained, which was filtered, dried and recrystallised from ethanol. The crystals were dried in vacuum. The scheme 3.13 gives the synthetic route for the preparation of N-(4-bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylene) amine.

The purity of the product was checked by TLC. The yield of the product was 60% with m.p. 127°C.

![Scheme 3.13: Synthetic route for the preparation of N-(4-bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylene)amine](image)

3.4.4. [(4-Iodophenyl)-(1,3-diphenyl-1H-pyrazol-4-yl)methylene]amine (O)

1,3-Diphenyl pyrazol-4-carboxaldehyde (1.24 g, 0.005 mol) was dissolved in boiling ethanol in a 250 mL round bottom flask. To this 0.2 mL glacial acetic acid and p-iodoaniline (1.09 g, 0.005 mol) were added and the...
entire reaction mixture was heated to reflux for 10 hours. After cooling the reaction mixture to room temperature, the precipitate of the [(4-iodophenyl)-(1,3-diphenyl-1H-pyrazol-4-yl)methylene]amine obtained, which was filtered, washed and recrystallised from rectified spirit [186]. The scheme 3.14 gives the route for the synthesis. Purity of the compound was checked by TLC analysis. The yield of the product was 64% with m.p. 129 °C.

Scheme 3.14: Synthetic route for the preparation of [(4-iodophenyl)-(1,3-diphenyl-1H-pyrazol-4-yl)methylene]amine.

3.4.5. 4-[(1,3-Diphenyl-1H-pyrazol-4-yl)methyleneamino] naphthalene-1-ol (P)

1,3-Diphenyl pyrazol-4-carboxaldehyde (1.24 g, 0.005 mol) was dissolved in ethylacetate 0.2 mL of glacial acetic acid and 4-amino-1-naphthol (0.795 g, 0.53 mol) were added to above solution. The whole mixture was taken in a 250 mL R.B flask and then heated to reflux for 8 hours. Ethyl acetate was then distilled off and precipitate of 4-[(1,3-diphenyl-1H-pyrazol-4-yl) methylene amino]naphthalene-1-ol, obtained was washed, dried and recrystallised from ethanol. The scheme 3.15 gives the route for the synthesis. The yield of the product was 78% with m.p. 135 °C. Purity of the compound was checked by TLC analysis.
Scheme 3.15: *Synthetic route for the preparation of 4-[(1,3-diphenyl-1H-pyrazol-4-yl) methyleneamino]naphthalene-1-ol*

3.4.6. 1-[(1,3-Diphenyl-1H-pyrazol-4-yl)methyleneamino] naphthalene-1-ol (Q)

1,3-Diphenyl pyrazol-4-carboxaldehyde (1.24 g, 0.005 mol) was dissolved in ethylacetate 0.2 mL of glacial acetic acid and 1-amino-2-naphthol (0.795 g, 0.53 mol) were added to above solution. The whole mixture was taken in a 250 mL R.B flask and then heated to reflux for 8 hours. Ethyl acetate was then distilled off and precipitate of 1-[(1,3-diphenyl-1H-pyrazol-4-yl)methyleneamino]naphthalene-1-ol obtained was washed, dried and recrystallised from ethanol. The scheme 3.16 gives the route for the synthesis. The yield of the product was 61% with m.p 143°C. Purity of the compound was checked by TLC analysis.

Scheme 3.16: *Synthetic route for the preparation of 1-[(1,3-diphenyl-1H-pyrazol-4-yl) methyleneamino]naphthalene-2-ol.*
3.5. Preparation of indole based intermediate compounds

3.5.1. Indole-3-aldehyde (R)

Indole-3-aldehyde was prepared according to the known procedure [187]. Freshly distilled Dimethyl Formamide (DMF) (274 g, 3.74 moles) was taken in a 1 liter round bottom three-necked flask fitted with an efficient mechanical stirrer and also fitted with a dry tube containing Drierite and a 150 mL dropping funnel. The flask and its contents were cooled in an ice bath for about half an hour. Freshly distilled phosphorous chloride (144 g, 0.94 mol) which was cooled and it is subsequently added with stirring to the cold DMF over a period of half an hour to get the Vilsmeir-Haack reagent. The pinkish colour of the formylation complex was observed during this step. A cold solution of 100 g (0.85 mol) of indole in 100 mL (0.95 g, 1.3 moles) of DMF was added drop by drop to the cold yellow solution of Vilsmeir-Haack reagent with efficient stirring over a period of 1 hour. During which time the temperature should not rise above 10°C. The solution was well mixed, the dropping funnel is replaced with a thermometer and the temperature of the viscous solution is brought to 35°C. The syrup is stirred efficiently at this temperature for 1 hour and the clear yellow solution to become an opaque, canary-yellow paste. At the end of the reaction period about 300 g of crushed ice is added to the paste with careful stirring, producing a clear cherry-red aqueous solution.

To the above solution NaOH solution (375 g, 9.4 moles in 1 liter of water) was added drop wise with stirring until about one third of it has been added. The remaining two third was added rapidly with efficient stirring and the resulting suspension heated rapidly to the boiling point and allowed to cool to room temperature, after which it was placed in a refrigerator overnight. The precipitate collected on a filter and resuspended in 1 liter water. Most of the inorganic materials dissolved and the product was then collected on a filter, washed with water and air dried to get pure indole-3-aldehyde and recrystallised from alcohol. The scheme 3.17 gives the synthetic
3.5.2. \( N\)-(1H-Indol-3-yl)methylene)-4-bromobenzenamine (S)

Indole-3-aldehyde (7.25 g, 0.05 mol) was dissolved in boiling ethanol. To this 0.2 mL glacial acetic acid and 4-bromoaniline (18.55 g, 0.05 mol) were added. The reaction mixture was refluxed for 7 hours with stirring. After cooling the reaction mixture to room temperature, the precipitate of aldimine derivative, \( N\)-[(1H-indol-3-yl) methylene]-4-bromobenzenamine, were obtained and recrystallised from ethyl acetate. The scheme 3.18 gives the synthetic route for the preparation of \( N\)-[(1H-indol-3-yl) methylene]-4-bromobenzenamine. Purity of the compound was checked by TLC analysis and the structure of the compound is confirmed by further spectroscopic methods. Yield: 73%, m. p. 131-133°C.
3.6. Synthesis of Hole Transporting Materials (HTM)


3.6.1.1. 1,3,5-Tris[[N-(1,3-diphenyl-1H-pyrazol-4-yl) methylene]-4-aminophenyl] benzene (TDPMAB).

N-(4-Bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylene)amine (12.06 g, 0.03 mol) and 1,3,5-tribromobenzene (3.11 g, 0.01 mol) were dissolved in DMF in a 250 mL round bottom flask. To this solution 0.1 g of electrolytic copper, 0.01 g of KOH and 0.001 g of 1,10-phenanthroline were added. The reaction mixture was heated at 140°C with stirring for 25 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base.

Scheme 3.19: Synthetic route for the preparation of TDPMAB
The solvent DMF was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-hexane (1:3) as eluent. The scheme 3.19 gives the route for the synthesis. Yield 60%, melting point 138°C.

3.6.1.2. \(\text{N}^1,\text{N}^4\)-Bis(1, 3-diphenyl-1H-pyrazol-4-yl)benzene-1,4-diamine (BDPMBD)

1, 3-Diphenyl-pyrazol-4-carboxaldehyde (49.6 g, 0.2 mol) was dissolved in boiling ethanol and then 0.2 mL of glacial acetic acid and p - phenylene diamine (10.8 g, 0.1 mol) were added. The whole mixture was taken in a 250 mL R.B flask and then heated to reflux for 7 h. After cooling the reaction mixture to room temperature, the precipitate obtained was filtered, washed, dried and recrystalised from ethanol. The yield of the product was found to 79% and the m.p was 117°C. The scheme 3.20 gives the synthetic route for the preparation. Purity of the compound was checked by TLC analysis.

![Scheme 3.20: Synthetic route for the preparation of BDPMBD](image)
3.6.1.3. \( \text{N',N'-Bis(1,3-diphenyl-1H-pyrazol-4-ylmethylene)} \)
\( \text{biphenyl-4,4'-diamine (BDPMBPD)} \)

1, 3-Diphenyl pyrazol-4-carboxaldehyde (4.96 g, 0.02 mol) was dissolved in boiling ethanol and 0.2 mL glacial acetic acid and benzidine (1.84 g, 0.02 mol) were added to it. The whole mixture was taken in a 250 mL R.B flask and then heated to reflux for 8 h. After cooling the reaction mixture to room temperature, the precipitate formed was filtered, washed and recrystallised from ethanol. The m.p of the product was found to be 138°C and the yield was 62%. The scheme 3.21 gives the synthetic route for the preparation of the compound. Purity of the compound was checked by TLC analysis.

\[
\begin{align*}
\text{Ethanol} & \quad + \\
\text{Acetic acid} & \quad \text{BDPMBPD}
\end{align*}
\]

Scheme.3.21: Synthetic route for the preparation of BDPMBPD

3.6.1.4. \( \text{4, 4''-[Bis (1,3-diphenyl-1H pyrazol-4-yl methylene)-(1,1', 4', 1'', 1''')} quaterphenylamine. (BDPMQ)} \)

\( \text{[(4-Iodophenyl)-(1,3-diphenyl-1H-pyrazol-4-yl)methylene]amine} \) (8.44 g, 0.02 mol) and 4,4'- diiodobiphenyl (4.05 g, 0.01 mol) were taken in a 250 mL R.B flask and 10 mL of nitobenzene was added to it as solvent. To
this solution 0.1 g of electrolytic copper, 0.01 g of K₂CO₃ and 0.001 g of 1, 10-phenanthroline were added. The reaction mixture was heated at 115°C with stirring for 20 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent nitrobenzene was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-hexane (1:3) as eluent. The yield of the product was 70% with m.p 181°C. The scheme 3.22 gives the route for the synthesis.

![Scheme 3.22: Synthetic route for the preparation of BDPMQ](image)

### 3.6.1.5. Tris{4-[(1,3-diphenyl-1H-pyrazol-4-yl)methylene]-4'-aminobiphenyl}amine (TDPMAA).

N-(4-Bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylene) -amine (12.06 g, 0.03 mol) and tris(4-bromophenyl)amine (4.82 g, 0.01 mol) were dissolved in Dimethyl Sulphoxide (DMSO) in a 250 mL round bottom flask. To this solution 0.1 g of electrolytic copper, 0.01 g of KOH and 0.001 g of 1, 10-phenanthroline were added. The reaction mixture was heated at 120°C
with stirring for 20 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent DMSO was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-hexane (1:2) as eluent. The scheme 3.23 gives the route for the synthesis. Yield 55%, melting point 250°C.

Scheme 3.23: Synthetic route for the preparation of TDPMAA
3.6.1.6. N',N',N',N'- Tetra[N-(1, 3-diphenyl-1H-pyrazol-4-yl methylene)4-amino phenyl]benzene-1,4-diamine (TDPMAPBD)

N-(4-Bromophenyl)-(1,3-diphenyl-1H-pyrazol-4-ylmethylen) amine (1.604 g, 0.004 mol) and 1,4-diaminobenzene (0.108 g, 0.001 mol) were dissolved in 20 mL Dimethyl Formamide (DMF) in a 250 mL round bottom flask. To this solution 0.1 g of cuprous chloride, 0.01 g of K$_2$CO$_3$, 0.01 g KI and 0.001 g of 1,10-phenanthroline were added. The reaction mixture was heated at 130°C with stirring for 24 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base.

Scheme 3.24: Synthetic route for the preparation of TDPMAPBD
The solvent DMF was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-cyclohexane (1:2) as eluent. The schematic synthesis for the preparation of the compound is given in the scheme 3.24, Yield 61% and melting point 138°C.

3.6.1.7. 1,3,5-Tris[4-(1,3-diphenyl-1H-pyrazol-4-yl methylene amino)naphthyl-1-oxy]benzene (TDPMANB)

4-[(1,3-Diphenyl-1H-pyrazol-4-yl)methyleneamino]naphthalene-1-ol (0.117 g, 0.4 mol) and 1,3,5-tribromobenzene (0.1 mol, 3.14 g) were dissolved in 20 mL Dimethyl Sulphoxide (DMSO) in a 250 mL round bottom flask. To this solution 0.1 g of cuprous chloride, 0.01 g of K₂CO₃, 0.01 g KI and 0.001 g of 1, 10-phenanthroline were added. The reaction mixture was heated at 125°C with stirring for 20 hours.

Scheme 3.25: Synthetic route for the preparation of TDPMANB
The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent DMSO was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-cyclohexane (1:4) as eluent. The schematic synthesis for the preparation of the compound is given in the scheme 3.25. Yield of the product was 49% and melting point 167°C.

3.6.1.8. 1,3,5-Tris[1-(1,3-diphenyl-1H-pyrazol-4-yl methylene amino)naphthyl-2-oxo]benzene (TDPMANB1)

4-[(1,3-Diphenyl-1H-pyrazol-4-yl)methyleneamino]naphthalene-1-ol (0.117 g, 0.4 mol) and 1,3,5-tribromobenzene (0.1 mol, 3.14 g) were dissolved in 20 mL Dimethyl Sulphoxide (DMSO) in a 250 mL round bottom flask. To this solution 0.1 g of cuprous chloride, 0.01 g of K₂CO₃, 0.01 g KI and 0.001 g of 1, 10-phenanthroline were added. The reaction mixture was heated at 125°C with stirring for 20 hours.

Scheme 3.26: Synthetic route for the preparation of TDPMANB1
The completion of the reaction is monitored by TLC. It was hot filtered to remove the copper compounds and the base. The solvent DMSO was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. The product was dissolved in 10 mL THF and reprecipitated from methanol and further purified by chromatography on silica gel using ethyl acetate-cyclohexane (1:4) as eluent. The scheme is given in the scheme 3.26. Yield of the product was 51% and melting point 130°C.

3.6.1.9. \( N^1,N^4\)-Bis((1,3-(bis(1'-methoxy biphenyl)-1H-pyrazol-4-yl)methylene) benzene-1,4-diamine (BMBPMBD)

\( N^1,N^4\)-Bis(1,3-diphenyl-1H-pyrazol-4-ylmethylene)benzene-1,4-diamine (3.64 g, 0.054 mol) was dissolved in acetic acid in a 250 mL round bottom flask provided with a reflux condenser and magnetic stirrer and to this 0.5 mL of dry pyridine (dried over KOH pellets) was added. The flask was partially immersed in cold water and to this 30 mL of bromine was added carefully with stirring. The stirring was continued for 1 hour and after that the reaction mixture was heated for 1 hour at 80°C. It was pour into cold water and the precipitate of \( N^1,N^4\)-bis((1,3-(4-bromophenyl)-1H-pyrazol-4-yl)methylene)benzene-1,4-diamine was filtered, washed first with alkaline (NaOH) water, finally water, dried and recrystallised from ethyl acetate.

\( N^1,N^4\)-Bis((1,3-(bis(4-bromophenyl)-1H-pyrazol-4-yl)methylene) benzene-1,4-diamine (8.84 g, 0.01 mol) and 1-bromo-4-methoxy benzene (7.48 g, 0.04 mol) were dissolved in 20 mL dichloro benzene in a 250 mL round bottom flask. To this solution 0.1 g of electrolytic copper, 0.01 g of KOH and 0.001 g of 1, 10-phenanthroline were added. The reaction mixture was heated at 115°C with stirring for 26 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent dichloro benzene was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl
acetate-hexane (1:1) as eluent, yield 51%, melting point 118°C. The scheme 3.27 gives the synthetic route for the preparation of the compound

![Scheme 3.27: Synthetic route for the preparation of BMBPMBD.](image)

3.6.1.10. 1,3,5-Tris[4-(1,3-diphenyl-1H-pyrazol-4-yl methylene amino)phenyl-1-oxy] benzene (TDPMAPOB).

4-(1,3-Diphenyl-1H-pyrazol-4-yl methylenamino) phenol (1.017g, 0.04 mol) and 1,3,5-tribromobenzene (3.14 g, 0.01 mol) were dissolved in 20 mL Dimethyl Sulphoxide (DMSO) in a 250 mL round bottom flask. To this 0.1 g of CuCl, 0.01 g of K₂CO₃, 0.01 g KI and 0.001 g of 1,10-phenanthroline were added. The reaction mixture was heated at 120°C with stirring for 18
hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent DMSO was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-cyclohexane (1:3) as eluent. The schematic synthesis for the preparation of the compound is given in the scheme 3.28. Yield of the product was 55% and melting point 126°C.

Scheme 3.28: Synthetic route for the preparation of TDPMAPOB.

3.6.1.11. \(\text{N'}\text{,N'}\text{-Bis((1,3-(Bis(1'-methoxybiphenyl)-1H-pyrazol-4-yl)methylene) biphenyl-4,4'-diamine (BBMBPMBD)}\)

\(\text{N'}\text{,N'}\text{-Bis(1, 3-diphenyl-1H-pyrazol-4-yl methylene)biphenyl-4,4'-diamine (3.47 g, 0.054 mol) was dissolved in acetic acid in a 250 mL round bottom flask provided with a reflux condenser and magnetic stirrer and to this 0.5 mL of dry pyridine (dried over KOH pellets) was added. The flask was partially immersed in cold water and to this 30 mL of bromine was added.}$$
carefully with stirring. The stirring was continued for 1 hour and after that the reaction mixture was heated for 1 hour at 80°C. It was pour into cold water and the precipitate of $N_1,N_4$-bis((1,3-(bis(4-bromophenyl)-1$H$-pyrazol-4-yl)methylene)biphenyl-1,4-diamine was filtered, washed first with alkaline (NaOH) water, finally water, dried and recrystallised from ethyl acetate.

![Scheme 3.29: Synthetic route for the preparation of BBMBPMBD](image)

$N_1,N_4$-Bis((1,3-(bis(4-bromophenyl)-1$H$-pyrazol-4-yl)methylene)biphenyl-4,4'-diamine (0.01 mol, 9.60 g) and 1-bromo-4-methoxy benzene (7.48 g, 0.04 mol) were dissolved in 20 mL dichloro benzene in a 250 mL round bottom flask. To this solution 0.1 g of electrolytic copper, 0.01 g of
KOH and 0.001 g of 1, 10-phenanthroline were added. The reaction mixture was heated at 115°C with stirring for 26 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent dichloro benzene was evaporated under vacuum and the solid was triturated with ethyl acetate and filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-hexane (1:1) as eluent, yield 52%, melting point 138°C. The scheme 3.29 gives the synthetic route for the preparation of the compound.

3.6.2. Synthesis of indole based hole transporting materials

3.6.2.1. \(1,3,5\text{-Tris}[N-(1H\text{-indol-3-yl})\text{methylene}-4\text{-aminophenyl}]\) benzene (TIMAPB).

\(N-(1H\text{-indol-3-yl})\text{methylene}-4\text{-bromobenzenamine}\) (8.97 g, 0.03 mol) and \(1,3,5\text{-tribromobenzene}\) (3.15 g, 0.01 mol) were dissolved in DMF. To this solution 0.1 g of electrolytic copper, 0.01 g of KOH, and 0.001 g of 1, 10-phenanthroline were added and the reaction mixture was heated for 24 hours at 140°C with continuous stirring to get the compound \(1,3,5\text{-tris}[N-(1H\text{-indol-3-yl})\text{methylene}-4\text{-aminophenyl}]\) benzene. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent DMF was evaporated under vacuum and the solid was triturated with ethyl acetate and filtered. The product was dissolved in 10 mL THF and reprecipitated out of methanol and further chromatographed using ethyl acetate-hexane (1:4) as eluent to obtain 52% yield with melting point: 182°C. The scheme 3.30 gives the synthetic route for the preparation of \(1,3,5\text{-tris}[N-(1H\text{-indol-3-yl})\text{methylene}-4\text{-aminophenyl}]\) benzene. Completion of the reaction is monitored by TLC analysis. The structure of the prepared compound is further confirmed by spectroscopic methods.
3.6.2.2. Tris{4-[N-(1H-indol-3-yl)methylene]-4'-aminobiphenyl} amine (TIMABPA).

\( N-(1H\text{-indol-3-yl}) \) methylene-4-bromobenzenamine (8.97 g, 0.03 mol) and tris(4-bromophenyl)amine (4.82 g, 0.01 mol) were dissolved in Dimethyl Formamide (DMF) in a 250 mL round bottom flask. To this solution 0.1 g of electrolytic copper, 0.01 g of KOH and 0.001 g of 1,10-phenanthroline were added. The reaction mixture was heated at 110°C with stirring for 20 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent DMF was evaporated under vacuum and the solid was titurated with ethyl acetate and filtered. Then the product was dissolved in 10mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-cyclohexane (1:3) as eluent. The scheme 3.31 gives the route for the synthesis, yield 60%, melting point 140°C.
Scheme 3.31: Synthetic route for the preparation of TIMABPA.

3.6.2.3. \(N',N',N',N'-\) Tetra[\(N-(1H\text{-indol-3-yl})\text{methylene}\)-4-amino phenyl]benzene-1,4- diamine (TIMABD)

\(N-(1H\text{-indol-3-yl})\text{methylene}\)-4-bromobenzenamine (11.96 g, 0.04 mol) and 1, 4-diaminobenzene (1.08 g, 0.01 mol) were dissolved in Dimethyl Formamide (DMF) in a 250 mL round bottom flask. To this solution 0.1 g of cuprous chloride, 0.01 g of K\(_2\)CO\(_3\), 0.01 g KI and 0.001 g of 1, 10-phenanthroline were added. The reaction mixture was heated at 110°C with stirring for 16 hours. The completion of the reaction is monitored by TLC. The reaction mixture was hot filtered to remove the copper compounds and the base. The solvent DMF was evaporated under vacuum and the solid was titurated with ethyl acetate, filtered. Then the product was dissolved in 10 mL THF and reprecipitated out of methanol and further purified by chromatography on silica gel using ethyl acetate-cyclohexane (1:4) as eluent. The structure of the prepared compound is further confirmed by spectroscopic methods.
Scheme 3.32: Synthetic route for the preparation of TIMABD.

The schematic synthesis for the preparation of the compound is given in the scheme 3.32, yield 61%, melting point 159°C.