

5.1: Introduction

The quinoxaline or benzopyrazine (**figure 5.1.1**) is described as a bioisoster of quinoline, naphthalene, benzothiophene and other aromatic rings such as pyridine and pyrazine.



Figure 5.1.1: Quinoxaline structural constituents

In particular, quinoxalines were found as a core unit in a number of biologically active compounds. Quinoxaline and its derivatives are an important class of benzoheterocycles, which constitute the building blocks of wide range of pharmacologically active compounds (Deshmukh, Mali *et al.* 2007, Olayiwola, Obafemi *et al.* 2010) having antibacterial (Badran *et al.* 2003;El-Gendy *et al.* 1995;El-Hawash *et al.* 1999;Ganapaty *et al.* 2007;Nasr 2002;Refaat *et al.* 2004), antifungal (Sanna *et al.* 1999a;Tandon *et al.* 2006), anticancer (Carta *et al.* 2001;Monge *et al.* 1995;Sanna *et al.* 1999b), antitubercular (Jaso *et al.* 2003), antileishmanial (Guillon *et al.* 2007), antimalarial (Crowther *et al.* 1949;Rangisetty *et al.* 2001) and antidepressant activities (Hassan *et al.* 2006;Sarges *et al.* 1990). Also, some quinoxalin-2-ones and quinoxaline-2,3-diones have been reported to show antimicrobial (Obafemi and Akinpelu 2005;Sarges *et al.* 1990), potent antithrombotic (Ries *et al.* 2003), anti-pain and anti-inflammatory (Su and Bock 2005;Wendt and Ledig 1969) activities. Because of the similarity between some antitubercular drugs and quinoxaline, as well as the presence of the quinoxaline moiety in some broad spectrum antibiotics, it was hoped that quinoxaline analogs would exhibit antitubercular activity (Vicente *et al.* 2009). Some of quinoxaline analogues, such as 2, 3-bis(2-pyridyl)- quinoxaline (DPQ) complexed with transition metals are of current interest in view of its binding to DNA. This may suggest that conjugation of biologically active peptides

with quinoxaline analogs can lead to new therapeutic agents possessing interesting anticancer properties (Staszewska *et al.* 2005).

Quinoxaline derivatives constitute the basis of many insecticides, fungicides, herbicides, as well as being important in human health and as receptor antagonists. Although rarely described in nature, synthetic quinoxaline moiety is a part of number of antibiotics such as echinomycin, levomycin and actinomycin which are known to inhibit the growth of Grampositive bacteria and also active against various transplantable tumors. In addition, quinoxaline derivatives are reported for their application in dyes, efficient electroluminescent materials, organic semiconductors and DNA cleaving agents (Srinivas *et al.* 2008).

Several methods for synthesis are available in literature which involves conventional one pot (Thakuria and Das 2006), and microwave synthesis methods (Gris *et al.* 2008;Rostamizadeh and Jafari 2001;Thakuria and Das 2006). One-pot efficient green synthesis of 1, 4-dihydro-quinoxaline-2, 3-dione derivatives has been achieved in a one-pot reaction at room temperature from substituted *o*-phenylenediamine and oxalic acid under solvent free conditions by a simple grinding method. Quinoxalines are effectively synthesized in a few min by the condensation reaction of *o*-phenylenediamine with α -dicarbonyl compounds in ethanol under microwave irradiation.

A facile synthesis of quinoxaline derivatives (Heravi *et al.* 2006) and quinoxaline-2, 3-diones as NMDA receptor antagonists (Lin 1996) were also reported. *o*-Iodoxybenzoic acid (IBX), a readily available hypervalent iodine reagent, was found to be highly effective in synthesis of quinoxaline derivatives, from 1, 2-diketones and *o*-phenylenediamines at room temperature in very high yield (Heravi *et al.* 2006). Various quinoxaline-2, 3-diones (Lin 1996) were synthesized by rotatory evaporation of 1, 2-diamino aromatic compounds in diethyl oxalate at 50-80 °C. Gallium (III) triflate-catalyzed reactions (Cai *et al.* 2008) of phenylene-1, 2-diamines and 1, 2-diketones produce quinoxalines in excellent to quantitative yields. Attempt to synthesize quinoxaline derivatives at room temperature using molecular iodine as the catalyst are present in the literature as reported by several aromatic as well as aliphatic 1, 2-diketones and aromatic 1, 2- diamines (Bhosale

et al. 2005). More recently nano zirconia catalyzed synthesis of quinoxaline derivatives are also reported (Jafarpour *et al.* 2014).

Most of the reported methods are associated with the use of either carcinogenic organic solvents, expensive and non-commercially available catalysts. Thus there is great scope to develop a convenient and general approach towards the synthesis of quinoxaline derivatives from inexpensive, non-toxic and readily available reagents with improved yields in an ecofriendly fashion.

Recently, metal/metal oxide nanoparticles as efficient heterogeneous catalysts have been used in various organic transformations (Grunes *et al.* 2003). The interesting features inherited with these small particle sizes are their large surface area along with more edges and corners and distinct electronic, thermal and chemical properties (Ramarao *et al.* 2002;Rautio *et al.* 2009;Reetz and Westermann 2000).

The crucial role of nanoparticles in organic transformations is their excellent catalytic activity, straightforward recoverability, better selectivity and their versatile role in green chemistry (Cox *et al.* 1988;Gladysz 2002;2001;Pacchioni 2000;Polshettiwar and Varma 2010) Thus, the domain of metal nanoparticle catalysis (Fihri *et al.* 2012;Polshettiwar *et al.* 2009;Polshettiwar *et al.* 2008) should offer opportunities for mining new chemical reactions (Murugadoss *et al.* 2009;Shimizu *et al.* 2009;Witham *et al.* 2010).

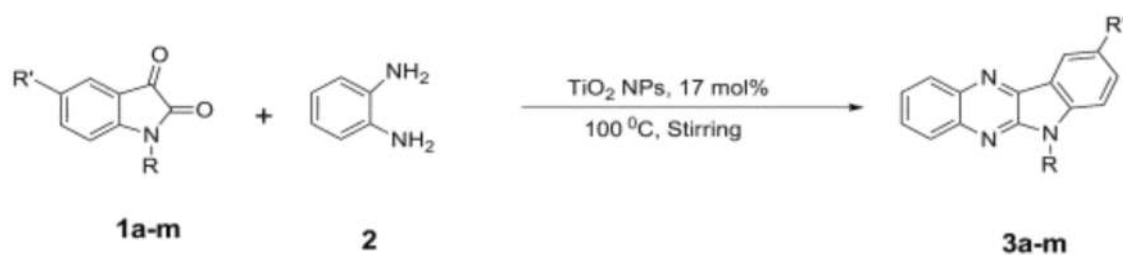
TiO₂ nanoparticles have been widely investigated in the past decades due to their multiple potential applications (Chen and Wang 2006;Rajalakshmi *et al.* 2008;Wang *et al.* 2007). TiO₂ nanoparticle catalyst as an inexpensive, non-toxic, moisture stable, reusable, commercially available white powder is of great interest to many scientists in the recent years. In general, several similar applications of this nanoscale method, as an effective catalyst in green synthetic organic chemistry, have already been highlighted in the literature (Abdolmohammadi 2012;Hosseini-Sarvari 2007;Kantam *et al.* 2006;Kassae *et al.* 2011;Roperov-Vega *et al.* 2010;Shirini *et al.* 2011).

In the context of green chemistry, the solvent free approach is simple with amazing versatility. It reduces the use of organic solvents and minimizes the formation of other waste. The reactions occur under mild conditions and usually require easier workup procedures and simpler equipment. Moreover, it may allow access to compounds that require harsh reaction conditions (Martins *et al.* 2009; Tanaka and Kaupp 2009; Walsh *et al.* 2007).

In view of the above it was thought worthwhile to synthesize some novel quinoxaline derivatives fused with indole nucleus of biocidal interest, and guided by the observation that the presence of two or more different heterocyclic moieties in a single molecule often enhances the biocidal profile remarkably, in order to get targeted products, a greener “NOSE” (nanoparticles-catalyzed organic synthesis enhancement) approach under solvent free conditions has been developed.

5.2: Results and discussion

The condensation of isatin derivatives with *o*-phenylenediamine gives four different products depending on the reaction conditions, so the formation of selectively one of the product was our prime objective and that was achieved by using TiO₂ NPs catalyst under solvent free conditions. Condensation reaction of isatin derivatives **1a-m** with *o*-phenylenediamine **2** in the presence of catalytic amount of TiO₂ NPs under solvent- free conditions at 100 °C, afforded selectively quinoxaline derivatives **3a-m** in excellent yield (**Scheme 5.2.1**)



Scheme 5.2.1

The chemical structure of the respective synthesized quinoxaline derivative was established by their spectral data.

In order to find optimum reaction conditions, several parameters were investigated. Expectedly, efficiency of the catalytic system was affected by the

catalyst amount. Therefore, a set of experiments using different amounts of TiO₂ NPs was taken into account for the condensation reaction of isatin with *o*-phenylenediamine under solvent-free condition at 100 °C (**Table 5.2.1**). The synthetic route was drastically dependent on the presence of catalyst and only poor yield was observed in the absence of catalyst after 120 min (**Entry 1, Table 5.2.1**). It was found that product yield was increased with enhancing catalyst concentration. Only 5 mol % of TiO₂ NPs was sufficient to attain 55% of product yield after 80 min (**Entry 2, Table 5.2.1**). The best yield of 95% was obtained with 17 mol % of TiO₂ NPs (**Entry 6, Table 5.2.1**). However, further addition of catalyst concentration (> 17 mol%) did not improve the reaction rate and product yield (**Entry 7, Table 5.2.1**).

Table 5.2.1: Effect of TiO₂ NPs (mol %) on the condensation reaction of isatin with *o*-phenylenediamine

Entry	TiO ₂ NPs (mol %)	Time(min)	%Yield
1	0	120	40
2	5	80	55
3	10	55	75
4	12	50	82
5	15	45	89
6	17	45	95
7	20	45	95

The condensation reaction of isatin with *o*-phenylenediamine was examined under different temperatures. Obviously, reaction rate and product yield both were increased with enhancing temperature from 50 to 100 °C. In contrast, at reaction temperatures above 100 °C, there is a decrease in product yield with temperature was observed. On the basis of this study, it would be concluded that the 100 °C was favorable temperature for the condensation reaction of isatin with *o*-phenylenediamine (**Table 5.2.2**).

Table 5.2.2: Effect of temperature on the condensation reaction of isatin with *o*-phenylenediamine

Entry	Temp ⁰ C	Time	%Yield
1	Rt	-	No reaction
2	50	8h	66
3	60	5h	78
4	70	3.5h	79
5	80	1h	85
6	90	1h	90
7	100	45min	95
8	110	45min	91

To investigate the effect of solvents, the condensation reaction of isatin with *o*-phenylenediamine in various organic solvents at refluxing temperature using 17 mol % TiO₂ NPs as the catalyst was carried out (**Table 5.2.3**). About 84% of the expected product **3a** was obtained when the solvent was ethanol (**Entry 1, Table 5.2.3**). Obviously, the polar solvents such as ethanol and acetonitrile were much better than non polar solvents (**Entry 1&2, Table 5.2.3**). It was observed that reaction takes more time to give high yield of product in the presence of solvent, under similar ratio of the reactants ((**Entry 1, 2, 3&4 Table 5.2.3**). This may be due to the competitive adsorption of the solvent with the substrate molecule on the catalyst surface; hence reaction under solvent-free condition gives better yields in short time (**Entry 5, Table 5.2.3**). A possible explanation for higher yield in solvent free conditions is that the eutectic mixture having uniform distribution of the reactants which brings the reacting species in close proximity to react with each other than in the presence of solvent.

A comparison of the efficiency of catalytic activity of the TiO₂ NPs with several other catalysts is presented in **table 5.2.4**. Reaction of isatin with *o*-phenylenediamine was taken into account and the comparison was in terms of

mol % of catalyst, reaction time, and percentage yield. The result showed that TiO₂ NPs was the best catalyst in terms of mol %, reaction time, and percentage yield. Although some of the catalysts led to good yield, some of them are environmentally hazardous and require longer reaction times and higher mol% of catalysts (Table 5.2.4.).

Table 5.2.3: Effect of solvents on the condensation reaction of isatin with *o*-phenylenediamine

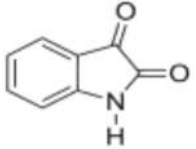
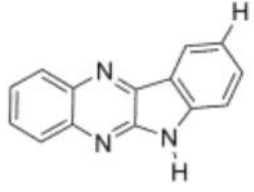
Entry	Solvents	Time	%Yield
1	Ethanol	3h	84
2	Acetonitrile	3h	81
3	Xylene	3h	72
4	Toluene	3h	75
5	Solvent free	45min	95

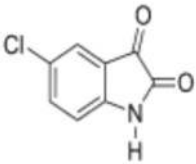
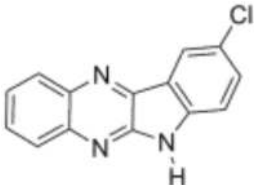
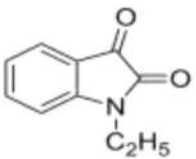
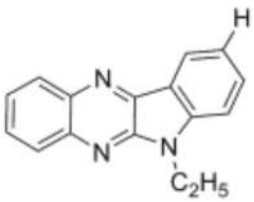
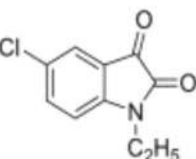
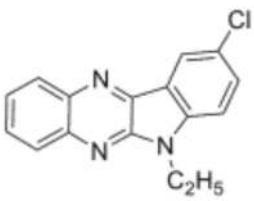
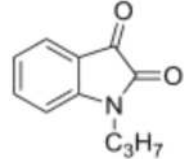
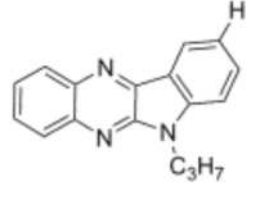
Table 5.2.4: Effect of different catalysts on the condensation reaction of isatin with *o*-phenylenediamine

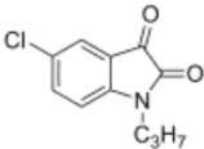
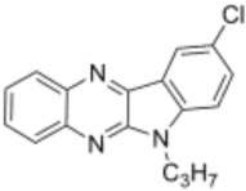
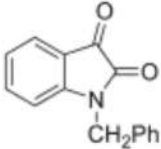
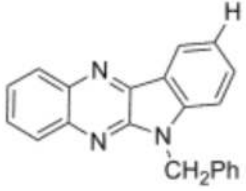
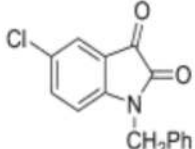
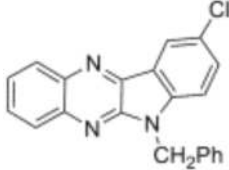
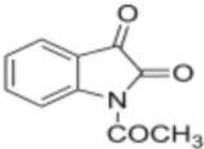
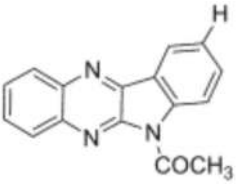
Type of catalyst	Mol %	Time (min)	% Yield
Bentonite clay	20	60	77
K-10 clay	20	60	77
PTSA	30	75	65
NH ₄ Cl	30	75	72
EDTA	40	75	60
Iodine	20	60	72
Yb(OTf)	20	60	80
TiO₂ (Nano)	17	45	95

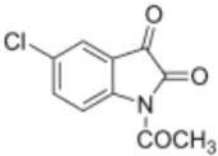
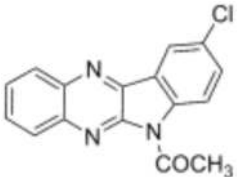
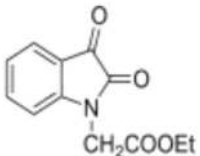
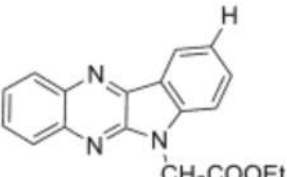
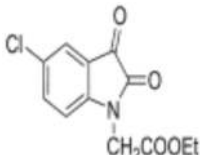
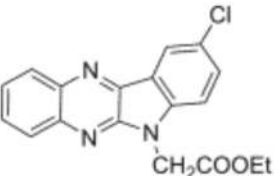
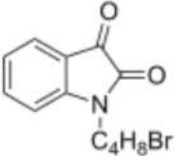
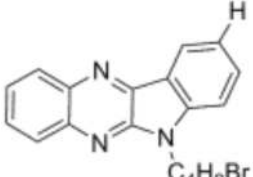
Under the optimized set of conditions, a number of isatin derivatives **1**, viz. isatin (**1a**), 5-chloroisatin (**1b**), *N*-ethylisatin (**1c**), 5-chloro *N*-ethylisatin (**1d**), *N*-propylisatin (**1e**), 5-chloro *N*-propylisatin (**1f**), *N*-benzylisatin (**1g**), 5-chloro *N*-benzylisatin (**1h**), *N*-acylisatin (**1i**), 5-chloro *N*-acylisatin (**1j**), *N*-ethylacetateisatin (**1k**), 5-chloro *N*-ethylacetateisatin (**1l**) and *N*-bromobutylisatin (**1m**) were allowed to undergo condensation reaction with *o*-phenylenediamine **2**, in the presence of TiO₂ NPs at 100°C for 45min. The progress of the reaction was monitored by thin layer chromatography. After completion, 10 ml acetone was added to the reaction mixture; the catalyst was removed and washed with xylene and acetone. Then, the liquid portion was evaporated, dried and recrystallized with ethanol to yield pure quinoxaline derivative **3**, viz. 6*H*-indolo[2,3-*b*]quinoxaline (**3a**), 9-chloro-6*H*-indolo[2,3-*b*]quinoxaline (**3b**), 6-ethyl-6*H*-indolo[2,3-*b*]quinoxaline (**3c**), 9-chloro-6-ethyl-6*H*-indolo[2,3-*b*]quinoxaline (**3d**), 6-propyl-6*H*-indolo[2,3-*b*]quinoxaline (**3e**), 9-chloro-6-propyl-6*H*-indolo[2,3-*b*]quinoxaline (**3f**), 6-benzyl-6*H*-indolo[2,3-*b*]quinoxaline (**3g**), 6-benzyl-9-chloro-6*H*-indolo[2,3-*b*]quinoxaline (**3h**), 1-(6*H*-indolo[2,3-*b*]quinoxalin-6-yl)ethanone (**3i**), 1-(9-chloro-6*H*-indolo[2,3-*b*]quinoxalin-6-yl)ethanone (**3j**), ethyl 2-(6*H*-indolo[2,3-*b*]quinoxaline-6-yl)acetate (**3k**), ethyl 2-(9-chloro-6*H*-indolo[2,3-*b*]quinoxalin-6-yl)acetate (**3l**), 6-(4-bromobutyl)-6*H*-indolo[2,3-*b*]quinoxaline (**3m**). The results are given in table 5.2.5.

Table 5.2.5: Synthesized quinoxaline derivatives **3a-m**

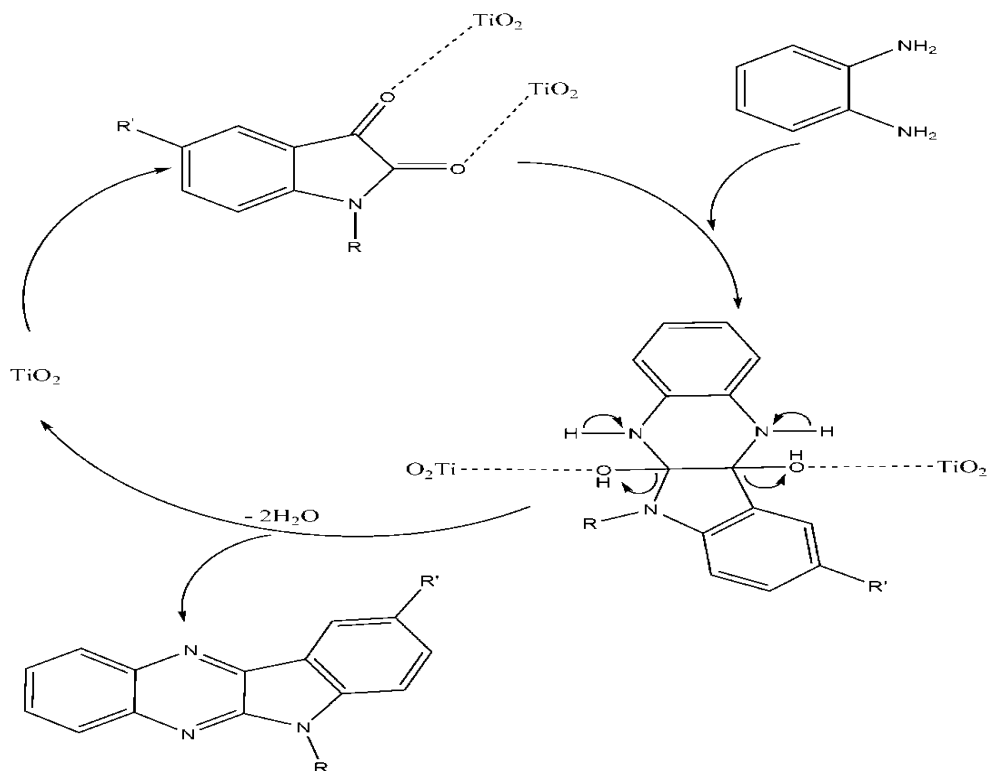
Entry	Isatin derivative	Product	% Yield	Mp (°C)
1	 <p>1a</p>	 <p>3a</p>	95	244

2	 1b	 3b	95	256
3	 1c	 3c	90	180 (Bajpai <i>et al.</i> 2014)
4	 1d	 3d	92	146
5	 1e	 3e	94	218

6	 1f	 3f	91	244
7	 1g	 3g	90	176
8	 1h	 3h	92	206
9	 1i	 3i	88	266

10	 <p style="text-align: center;">1j</p>	 <p style="text-align: center;">3j</p>	80	318
11	 <p style="text-align: center;">1k</p>	 <p style="text-align: center;">3k</p>	94	160 (Bajpai <i>et al.</i> 2014)
12	 <p style="text-align: center;">1l</p>	 <p style="text-align: center;">3l</p>	92	248
13	 <p style="text-align: center;">1m</p>	 <p style="text-align: center;">3m</p>	88	184 (Bajpai <i>et al.</i> 2014)

A plausible mechanism for the formation of quinoxaline derivatives is shown in **scheme 5.2.2**. The reaction follows a mechanism of acid-catalyzed condensation reactions. TiO_2 coordinates with carbonyl oxygen atom of isatin derivatives, thus increasing the electrophilicity of the carbonyl carbon. Due to which partial polarization of carbonyl group takes place that results nucleophilic attack of *o*-phenylenediamine to carbonyl carbon atom. The resultant amino-1, 2-diol readily undergoes dehydration to give quinoxaline derivative as the end product.



Scheme 5.2.2: Plausible mechanism for the formation of quinoxaline derivatives **3a-m**

TiO_2 NPs were characterized by XRD, TEM and FTIR analysis. It has been observed that the sample of TiO_2 NPs was highly crystalline as evident from XRD pattern in which broad peaks with high intensity extended over the 2θ scale. The peaks observed at $2\theta = 26.9^\circ, 35.9^\circ, 40.8^\circ, 43.3^\circ, 53.7^\circ, 62.3^\circ, 69.0^\circ$ and 76.35° corresponding the lattice planes (110), (101), (111), (210), (211), (310), (301), (202). These peaks clearly indicate the formation of rutile phase of TiO_2 NPs (Thamaphat *et al.* 2008). The broadening of peaks indicates the smaller particle

size of TiO₂ NPs (**Figure 5.2.1**). The average particle size has been estimated by using *Debye-Scherrer formula*.

$$D = 0.94 \lambda / \beta \cos \theta$$

Where, λ is wave length of X-Ray (0.1540 nm), β is FWHM (full width at half maximum), θ is diffraction angle and D is particle diameter size. On the basis of this investigation the average particle size was found 99 nm.

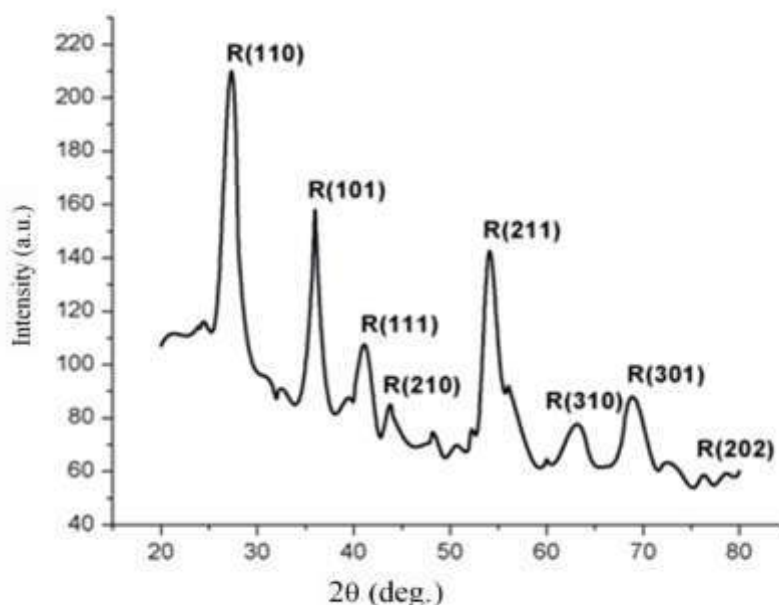


Figure 5.2.1: XRD spectra of TiO₂ NPs

Transmission electron microscopy (TEM) analysis was carried out to confirm actual particle size of TiO₂ NPs. **Figure 5.2.2** indicates the particles were agglomerated and non-homogenous. The average particle size was found 94 nm (**Figure 5.2.2**).

FT-IR spectra of synthesized TiO₂ NPs showed the peaks around 3000 and 1620 cm⁻¹ which arises due to the stretching and bending vibration of the -OH group. While the presence of broad peak at 666 cm⁻¹ in the IR-spectrum of pure TiO₂ NPs, represents stretching vibrations of Ti-O-Ti. Surface area analysis was done by nitrogen absorption using BET surface analyzer and the surface area was found to be 25.32 m²/g.

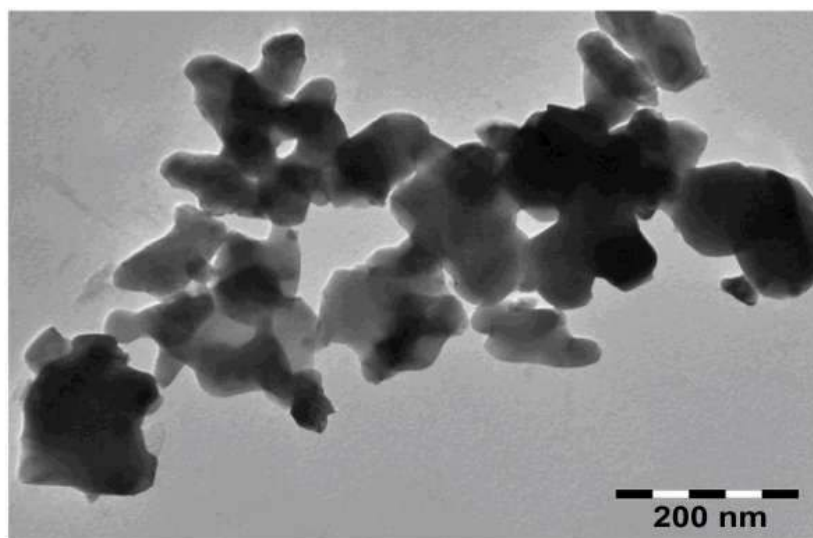


Figure 5.2.2: TEM image of TiO₂ NPs

5.3: Experimental

5.3.1: Typical procedure for the synthesis of rutile phase TiO₂ NPs (Sharma *et al.* 2010)

In 200 ml of double distilled ice cold water, 10 ml of TiCl₄ was added dropwise. The resulting mixture was stirred at room temperature. Now, 6ml of ammonia solution was added in dropwise manner with vigorous stirring. The whole reaction mixture was stirred for 4h, centrifuged, filtered, washed several times by ethanol, dried and calcinated at 900 °C. The synthesized TiO₂ NPs was characterized by XRD, TEM and FT- IR analysis.

5.3.2: General procedure for the synthesis of quinoxaline derivatives 3a-m

To a mixture of isatin derivatives **1a-m** (1.0 mmol) and *o*- phenylenediamine **2** (1.0 mmol), 17 mol% of TiO₂ NPs were added [**Scheme 5.2.1**]. The mixture was heated and stirred at 100 °C for 45min. The progress of the reaction was monitored by thin layer chromatography (n-hexane: ethyl acetate, 1:1). After completion, 10 ml acetone was added to the reaction mixture; the catalyst was removed by filtration and washed with xylene and acetone. Then, the liquid portion was evaporated and dried. The crude products were recrystallised from ethanol. The

chemical structures of all synthesized compounds were established by their spectral data.

6H-Indolo[2,3-b]quinoxaline (3a)

Brown- yellow solid, **IR (KBr) ν** : 3400, 3090, 3019, 2960, 2849, 1660, 1614, 1567, 1484, 1323, 1210, 1169, 1005, 875, 744, 718, 633, 580 cm^{-1} . **^1H NMR (300 MHz, DMSO) δ** : 6.80- 8.23 (m, 8H, aromatic protons), 12.53 (s, 1H, NH) ppm. **^{13}C NMR (75.45 MHz, DMSO) δ** : 113.6, 114.9, 117.6, 117.7, 117.8, 121.4, 123.3, 124.9, 126.3, 127.5, 128.1, 129.1, 129.2, 129.9, 130.3, 130.9, 131.1, 131.5, 138.6, 142.3, 147.7, 154.2, 154.6 ppm. Anal. Calcd for $\text{C}_{14}\text{H}_9\text{N}_3$: C, 76.70; H, 4.14; N, 19.17 Found: C, 76.73; H, 4.15; N, 19.1.

9-Chloro-6H-indolo[2,3-b]quinoxaline (3b)

Yellow solid, **IR (KBr) ν** : 3418, 3155, 3025, 2969, 2884, 1645, 1605, 1578, 1482, 1352, 1212, 1157, 1032, 880, 759, 742, 642 cm^{-1} . **^1H NMR (300 MHz, DMSO) δ** : 6.82- 8.11 (m, 7H, aromatic protons), 12.57 (s, 1H, NH) ppm. **^{13}C NMR (75.45 MHz, DMSO) δ** : 113.6, 114.9, 117.6, 117.7, 117.8, 120.2, 121.4, 123.3, 124.9, 126.3, 127.5, 128.1, 129.1, 129.2, 129.9, 130.3, 130.9, 131.1, 131.5, 138.6, 140.4, 142.3, 146.0, 147.7, 154.2, 152.6 ppm. Anal. Calcd for $\text{C}_{14}\text{H}_8\text{ClN}_3$: C, 66.28; H, 3.18; N, 16.56 Found: C, 66.30; H, 3.17; N, 16.56.

9-Chloro-6-ethyl-6H-indolo[2,3-b]quinoxaline (3d)

Brown solid, **IR (KBr) ν** : 3286, 3164, 3116, 2980, 2960, 2885, 2837, 1650, 1604, 1567, 1473, 1352, 1268, 1161, 1018, 944, 866, 763, 739, 647, 630 cm^{-1} . **^1H NMR (300 MHz, DMSO) δ** : 1.47-1.52 (t, $J= 7.2$, 3H), 4.47-4.54 (q, $J= 6.9$, 2H), 7.36-8.41(m, 7H, aromatic protons) ppm. **^{13}C NMR (75.45 MHz, DMSO) δ** : 13.5, 36.2, 110.3, 120.6, 122.4, 126.1, 126.4, 127.7, 129.1, 129.7, 130.7, 138.9, 139.3, 140.7, 142.1, 145.2 ppm. Anal. Calcd for $\text{C}_{16}\text{H}_{12}\text{ClN}_3$: C, 68.20; H, 4.29; N, 14.91 Found: C, 68.21; H, 4.31; N, 14.90.

6-Propyl-6H-indolo[2,3-b]quinoxaline (3e)

Dark yellow solid, **IR (KBr) ν** : 3173, 3120, 3059, 3037, 3009, 2885, 2972, 2873, 1650, 1600, 1569, 1473, 1356, 1264, 1156, 1019, 947, 863, 759, 746, 641, 509

cm⁻¹. ¹H NMR (300 MHz, DMSO) δ: 1.05-1.10 (t, *J*= 7.2 Hz, 3H), 1.70-1.81 (m, 2H), 3.18-3.23 (t, *J*=6.9, 2H), 6.68- 8.52 (m, 8H, aromatic protons) ppm. ¹³C NMR (75.45 MHz, DMSO) δ: 11.7, 22.3, 45.0, 111.2, 114.5, 115.0, 123.4, 127.5, 129.2, 131.1, 131.5, 131.6, 131.8, 148.7, 155.3, 155.8 ppm. Anal. Calcd for : C₁₇H₁₅N₃: C, 78.13; H, 5.79; N, 16.08 Found: C, 78.11; H, 5.79; N, 16.10.

9-Chloro-6-propyl-6*H*-indolo[2,3-*b*]quinoxaline (3f)

Reddish yellow solid, IR (KBr) ν: 3184, 3120, 3059, 3037, 2882, 2980, 2873, 1650, 1600, 1567, 1469, 1352, 1284, 1144, 1002, 947, 860, 759, 746, 651, 522 cm⁻¹. ¹H NMR (300 MHz, DMSO) δ: 1.05-1.10 (t, *J*= 6.9 Hz, 3H), 1.70-1.81 (m, 2H), 3.19-3.23 (t, *J*=6.9 Hz, 2H), 6.75- 8.60 (m, 7H, aromatic protons) ppm. ¹³C NMR (75.45 MHz, DMSO) δ: 11.5, 21.9, 45.1, 112.4, 114.9, 117.0, 123.2, 127.3, 129.4, 131.0, 131.2, 134.6, 148.6, 153.8, 155.1 ppm. Anal. Calcd for C₁₇H₁₄ClN₃: C, 69.03; H, 4.77; N, 14.21 Found: C, 69.00; H, 4.78; N, 14.24

6-Benzyl-6*H*-indolo[2,3-*b*]quinoxaline (3g)

Yellow solid, IR (KBr) ν: 3286, 3171, 3090, 2996, 2886, 2839, 1648, 1612, 1567, 1482, 1357, 1268, 1175, 1026, 942, 802, 753, 743, 647, 581 cm⁻¹. ¹H NMR (300 MHz, DMSO) δ: 5.71 (s, 2H), 7.24- 8.50 (m, 13H, aromatic protons) ppm. ¹³C NMR (75.45 MHz, DMSO) δ: 44.9, 110.1, 119.6, 121.1, 122.7, 126.1, 127.1, 127.6, 127.8, 128.7, 129.3, 130.9, 136.4, 139.5, 140.0, 140.6, 144.2, 145.8 ppm. Anal. Calcd for C₂₁H₁₅N₃: C, 81.53; H, 4.89; N, 13.58 Found: C, 81.55; H, 4.86; N, 13.59.

6-Benzyl-9-chloro-6*H*-indolo[2,3-*b*]quinoxaline (3h)

Light yellow solid, IR (KBr) ν: 3300, 3184, 3100, 2976, 2890, 2839, 1650, 1614, 1567, 1478, 1363, 1281, 1167, 1016, 950, 823, 753, 745, 643, 581 cm⁻¹. ¹H NMR (300 MHz, DMSO) δ: 5.67 (s, 2H), 7.22- 8.42 (m, 12H, aromatic protons) ppm. ¹³C NMR (75.45 MHz, DMSO) δ: 45.0, 111.1, 120.7, 122.3, 122.4, 126.4, 126.8, 127.1, 127.8, 127.9, 128.8, 129.2, 130.7, 136.0, 138.8, 139.6, 140.8, 142.2, 145.8 ppm. Anal. Calcd for: C₂₁H₁₄ClN₃: C, 73.36; H, 4.10; N, 12.22 Found: C, 73.36; H, 4.11; N, 12.22.

1-(6*H*-Indolo[2,3-*b*]quinoxalin-6-yl)ethanone (3i)

Light yellow solid, **IR (KBr) ν** : 3238, 3106, 3039, 2994, 2983, 2956, 2835, 1670, 1645, 1614, 1543, 1452, 1370, 1272, 1153, 1009, 899, 828, 748, 650 cm^{-1} . **^1H NMR (300 MHz, DMSO) δ** : 1.90 (s, 3H), 7.28- 8.82 (m, 8H, aromatic protons) ppm. **^{13}C NMR (75.45 MHz, DMSO) δ** : 23.7, 115.1, 122.9, 123.1, 127.7, 128.5, 129.5, 130.2, 130.7, 132.0, 132.3, 136.8, 146.1, 154.4, 156.8, 167.9 ppm. Anal. Calcd for $\text{C}_{16}\text{H}_{11}\text{N}_3\text{O}$: C, 73.55; H, 4.24; N, 16.08; O, 6.12 Found: C, 73.52; H, 4.24; N, 16.08; O, 6.15.

1-(9-Chloro-6*H*-indolo[2,3-*b*]quinoxalin-6-yl)ethanone (3j)

Brown solid, **IR (KBr) ν** : 3363, 3241, 3183, 3041, 2973, 2939, 2868, 1669, 1636, 1615, 1533, 1480, 1369, 1270, 1147, 1032, 954, 880, 752, 732, 666 cm^{-1} . **^1H NMR (300 MHz, DMSO) δ** : 1.91 (s, 3H), 7.29- 8.83 (m, 7H, aromatic protons) ppm. **^{13}C NMR (75.45 MHz, DMSO) δ** : 23.7, 115.1, 122.9, 123.1, 127.7, 128.5, 129.5, 130.2, 130.7, 131.9, 132.3, 136.8, 145.3, 154.4, 156.8, 167.9 ppm. Anal. Calcd for $\text{C}_{16}\text{H}_{10}\text{ClN}_3\text{O}$: C, 64.98; H, 3.41; N, 14.21; O, 5.41 Found: C, 65.00; H, 3.40; N, 14.20; O, 5.42.

Ethyl 2-(9-chloro-6*H*-indolo[2,3-*b*]quinoxalin-6-yl)acetate (3l)

Light yellow solid, **IR (KBr) ν** : 3400, 2980, 2927, 2855, 1731, 1661, 1606, 1567, 1465, 1375, 1203, 1158, 760, 743, 635 cm^{-1} . **^1H NMR (300 MHz, DMSO) δ** : 1.22-1.27 (t, $J=7.2$ Hz, 3H), 4.19-4.26 (q, $J=7.2$ Hz, 2H), 7.32- 8.48 (m, 7H, aromatic protons), ppm. **^{13}C NMR (75.45 MHz, DMSO) δ** : 14.1, 42.2, 61.8, 109.2, 119.8, 121.5, 122.8, 126.2, 127.7, 128.8, 129.3, 131.0, 139.7, 140.1, 140.3, 144.1, 145.5, 168.0 ppm. Anal. Calcd for $\text{C}_{18}\text{H}_{14}\text{ClN}_3\text{O}_2$: C, 63.63; H, 4.15; N, 12.37; O, 9.42 Found: C, 63.65; H, 4.14; N, 12.36; O, 9.43.

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