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Expedient synthesis of benzimidazoles using amides

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In the present report an efficient, rapid, facile and inexpensive route for the synthesis of benzimidazoles using 1,2-arylenediamines and *N,N*-dimethylformamide in acidic medium under thermal/microwave condition is developed. This reaction was further explored with the different amides to afford a library of 2-substituted benzimidazoles. The advantage of the present synthetic method includes shorter reaction time, easy work up and excellent yields without using the catalysts.

Introduction

Nitrogen containing heterocyclic compounds have maintained interest of researchers since their structures have led to several applications in various fields.¹⁻⁶ Hence, the synthesis of these compounds has become significantly important in synthetic chemistry. The discovery of *N*-ribosyl-dimethylbenzimidazole, a ligand for cobalt in vitamin B12 has boosted the interest in the development of synthetic strategies for benzimidazole derivatives.⁷ Benzimidazoles have evolved as important scaffolds in medicinal chemistry since from the past several years due to their diverse range of biological activities *viz.*, antiviral,⁸ antimicrobial,⁹ antifungal,¹⁰ antitumor,¹¹ antihistaminic,¹² antihypertensive,¹³ anti-inflammatory,¹⁴ antiulcer¹⁵ and antitubercular.¹⁶

The most popular synthetic procedure for the synthesis of benzimidazoles generally involves condensation reaction of 1,2-phenylenediamine with carboxylic acids¹⁷ (Phillips reaction) or with their derivatives (acid chlorides, nitriles, ortho esters or imidates).¹⁸ These often employ use of strong acids (hydrochloric acid, polyphosphoric acid (PPA), boric acid or *p*-toluene sulphonic acid) as catalyst, sometimes combined with high temperatures (i.e., PPA,

180°C). Benzimidazole derivatives have also been generated from the oxidative condensation of 1,2-arylenediamines with aldehydes using various oxidative and catalytic reagents such as oxygen,¹⁹ nitrobenzene (high boiling oxidant/solvent),²⁰ 1,4-benzoquinone,²¹ benzofuroxan,²² 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ),²³ Zn-proline,²⁴ Pb(OAc)₄,²⁵ MnO₂,²⁶ KHSO₄,²⁷ NaHSO₃,²⁸ IBD (iodobenzene diacetate),²⁹ Na₂S₂O₅,³⁰ oxone,³¹ FeCl₃.6H₂O,³² polyaniline-sulfate salt,³³ H₂O₂/CAN,³⁴ HfCl₄, ZrCl₄,³⁵ ZrOCl₂.8H₂O,³⁶ In(OTf)₃,³⁷ Yb(OTf)₃,³⁸ Sc(OTf)₃,³⁹ Cu(OTf)₂,⁴⁰ Co(OH)₂/CoO(II),⁴¹ CdCl₂,⁴² BF₃-etherate,⁴³ copper complex,⁴⁴ PhI(OAc)₂,^{45(a)} NH₄OAc,^{45(b)} Pd(TMHD)₂ complex,⁴⁶ NaY-zeolite,⁴⁷ chlorotrimethylsilane,⁴⁸ ionic liquid,⁴⁹ Pd-MgO, Pd-C, Au-CeO₂.⁵⁰ Although the above mentioned reaction conditions often efficiently prompted, but suffer from one or more disadvantages such as usage of high boiling solvents, costly catalyst, strong oxidising reagents, prolonged reaction times, laborious work up and purifications.

The invention of simple, mild, practicable, cheap and eco-benign method for the synthesis of benzimidazoles have grabbed the attention of researchers. Microwave assisted organic synthesis has become rapid growing field in organic chemistry as this technique makes reaction time shorter and tolerate wide range of reactions which are best suited to the increased demands of industry.⁵¹ In view of this, we have developed an efficient, facile and inexpensive method for the synthesis of benzimidazole derivatives using 1,2-arylenediamines and *N,N*-dimethylformamide (both as solvent and reagent) under acidic medium in short period of time both by thermal as well as microwave reaction. Also, the reactions of 1,2-phenylenediamine with different amides was carried out under thermal and microwave conditions to get corresponding 2-substituted benzimidazoles.

Results and discussions

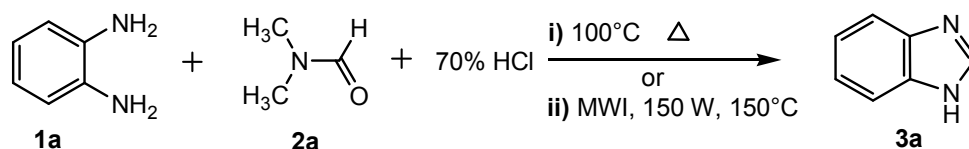
During the course of our investigation, we actually started with the direct conversion (one pot) of aryl/alkyl nitriles to benzimidazoles using 1,2-phenylenediamine and HCl in *N,N*-

dimethylformamide (DMF) as solvent. Initially, we were in the conclusion that the nitrile (-CN) functional group would get converted into carboxylic acid (-COOH) in presence of HCl and thereafter it would condense with 1,2-phenylenediamine resulting in the formation of corresponding 2-substituted benzimidazole derivative.

However, the TLC pattern showed the presence of nitrile, while the spot corresponding to 1,2-phenylenediamine was missing. By this unusual observation, it was concluded that only 1,2-phenylenediamine was reacted instead of nitrile. Further, the product was isolated and analysed using NMR (^1H , ^{13}C) and mass spectroscopic techniques. Surprisingly, the ^1H and ^{13}C NMR spectra were found to be identical to the earlier reports in the literature for benzimidazole. And also the mass spectral data showed the m/z value at 118 corresponding to the molecular mass of benzimidazole. All these observations proved that an unusual reaction must have occurred between 1,2-phenylenediamine and DMF in presence of HCl that would lead to the formation of benzimidazole serendipitously. However, we could find reports for the synthesis of benzimidazoles from amides (not with DMF) using ethylene glycol (high boiling) as solvent without significant details.⁵² In the present work we have successfully synthesized benzimidazoles using 1,2-arylenediamines and DMF in acidic medium under thermal / microwave condition. Also, we have used a good number of amides to exhibit the substrate scope and made comparative study between conventional and microwave assisted reactions.

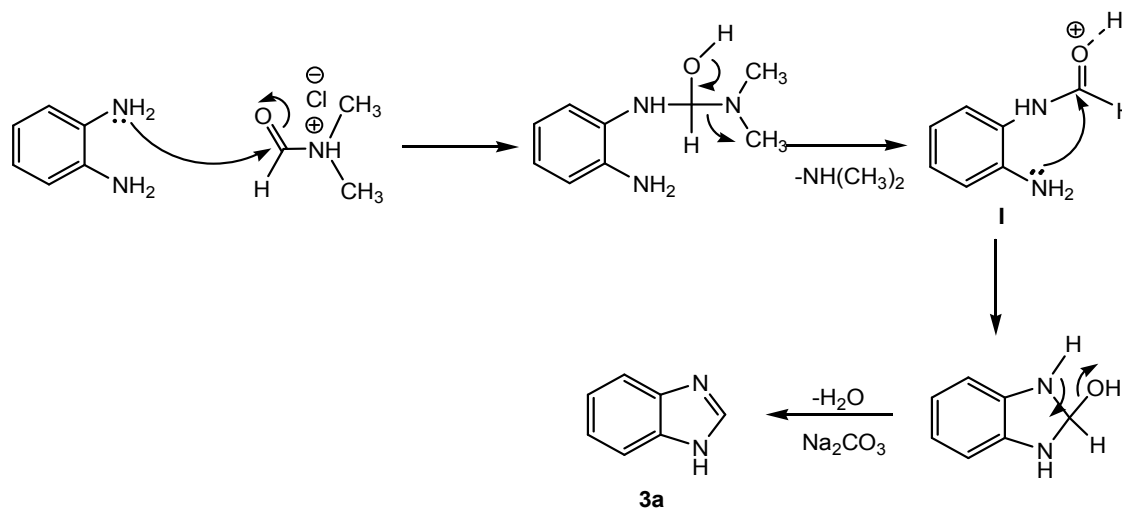
In order to establish the optimal reaction conditions, we opted 1,2-phenylenediamine (**1a**) and DMF (**2a**) as model substrates (**Scheme 1**). Initially, we tried the reaction at room temperature by stirring 1,2-phenylenediamine and DMF in 70% HCl which showed the formation of the desired product; however, the reaction couldn't end up with complete conversion of the reactants into benzimidazole (**3a**) even after stirring for 24 h. Then, the same reaction was attempted under thermal conditions at 100°C. The reaction yielded

benzimidazole with the complete conversion of the reactants in 1 h with 82% yield. Similarly, substituted benzimidazoles (**3b-g**) were prepared using various substituted 1,2-arylenediamines (**1b-g**) and DMF in 1 h with 80-82% yields. Also, we tried to achieve this reaction under microwave condition where the reaction was irradiated by 150 W microwave radiations at 150°C, and interestingly we observed completion of the reaction in 2 min with excellent yields (94-96%) for all 1,2-arylenediamines (**1a-g**, **Table 1**). We even obtained benzimidazole (**3a**) in 2 min when the mixture of 1,2-phenylenediamine (**1a**) and formamide (**4a**) in 70% HCl was irradiated by 150 W microwave radiations at 150°C with 96% yield. We have carried out the reactions between 1,2-phenylenediamine (**1a**) and various C-substituted amides (**4b-n**) in order to get the corresponding 2-substituted benzimidazoles (**5b-n**) by conventional method, but the reactions ended up with moderately good yields (40-78%) and time required for the completion of reactions was in the range from 1-12 h. However, it was surprising to observe that the reactions progressed smoothly under microwave irradiation (150 W) at 150°C for 40-60 min with 80-95% yields (**Table 2**).



Scheme 1

The reaction follows a simple concerted mechanism, wherein the use of HCl enhances the electrophilicity of the carbonyl carbon of amide thereby provoking the attack of lone pair of electrons on nitrogen atom of diamine resulting in the formation of *N*-(2-aminophenyl)formamide (**I**) intermediate which then immediately undergo intramolecular cyclodehydration resulting in the formation of benzimidazole (**3a**, **Scheme 2**).

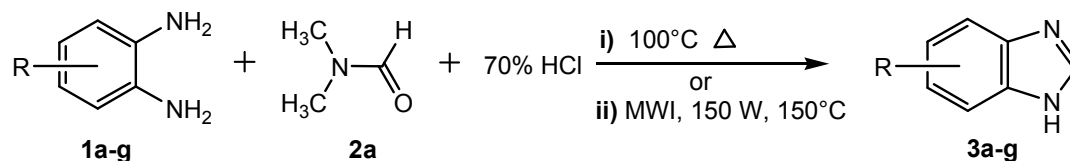


Scheme 2

The reaction of 1,2-arylenediamines (**1a-g**) with DMF (**2a**) are independent of wide range of functional groups leading to the formation of corresponding benzimidazole derivatives (**3a-g**) with excellent (94-96%) yields by microwave (150 W) heating at 150°C for 2 min. The same reaction carried out by conventional heating at 150°C for 10 min afforded only a trace amount and required 1 h at 100°C for completion of reaction with yield ranging from 80-82%. In the case of reaction carried out at 100°C by microwave heating, time required was 30 min to accomplish the reaction. The formation of 2-substituted benzimidazoles (**5b-n**) from 1,2-phenylenediamine (**1a**) and C-substituted amides (**4b-n**) showed completion of reaction in the range between 1-12 h by conventional heating. When the reaction was carried out by microwave irradiation at 100°C for 1 h, only compounds **5b-d** were formed in very low yields (40-50%), but the derivatives **5e-n** did not form. However, the same reaction under microwave irradiation at 150°C for 40 min afforded corresponding 2-substituted benzimidazole derivatives (**5b-k**) with excellent yields (80-95%). It was interesting to note that benzamides (**4g-j**) substituted with electron donating groups furnished reaction with moderate yields when compared to electron withdrawing groups which afforded lower yields and took more time for completion by conventional heating. However, the same

reaction by microwave (150 W) heating at 150°C for 40 min proceeded with good yields. The formation of corresponding bisbenzimidazoles (**5l-n**) from oxalamide, malonamide and succinamide by conventional method was achieved by heating for a longer time (18-24 h) with lower yields (51-55%). But the same reaction was completed in 60 min under microwave irradiation (150 W) at 150°C with good yields (88-92%). As a result from the above observation it can be concluded that the reaction condition is independent on *N*-substituted amides, whereas, C-substituted amides influence the rate of reaction.

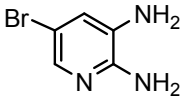
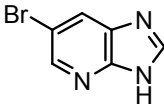
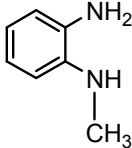
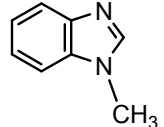
Table 1 Synthesis of benzimidazoles (**3a-g**) from 1,2-arylenediamines (**1a-g**) and DMF (**2a**) under optimized conditions

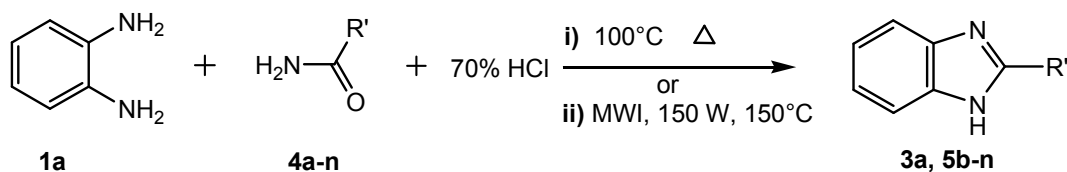


Scheme 3

Entry	1,2-Arylenediamines (1a-g)	Products (3a-g)	Thermal		Microwave	
			Time (hr)	Yield ^a (%)	Time (min)	Yield ^a (%)
1			1	82	2	96
2			1	81	2	95
3			1	82	2	94
4			1	80	2	95
5			1	80	2	95

Table 1 contd.....

Entry	1,2-Arylenediamines (1a-g)	Products (3a-g)	Thermal		Microwave	
			Time (hr)	Yield ^a (%)	Time (min)	Yield ^a (%)
6	 1f	 3f	1	81	2	95
7	 1g	 3g	1	82	2	96

^a Isolated yield**Table 2** Synthesis of 2-substituted benzimidazoles (**5b-n**) from 1,2-phenylenediamine (**1a**) and C-substituted amides (**4a-n**)**Scheme 4**

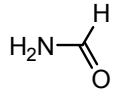
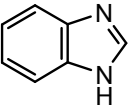
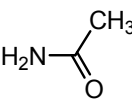
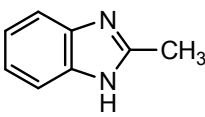
Entry	Amides (4a-n)	Products (5a-n)	Thermal		Microwave	
			Time (hr)	Yield ^a (%)	Time (min)	Yield ^a (%)
1	 4a	 3a	1	81	2	96
2	 4b	 5b	3	78	40	95

Table 2 contd.....

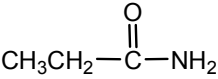
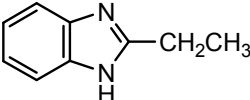
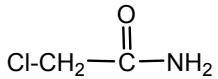
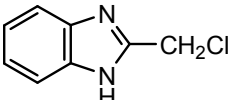
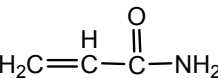
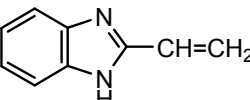
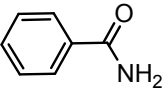
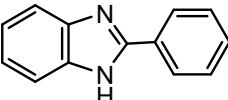
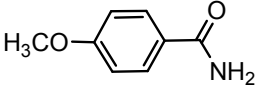
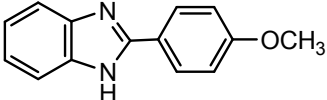
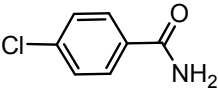
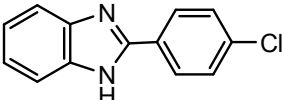
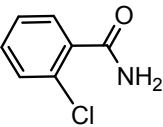
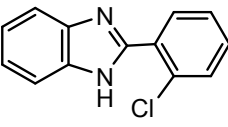
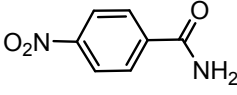
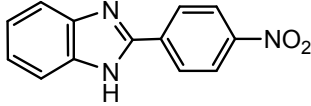
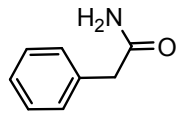
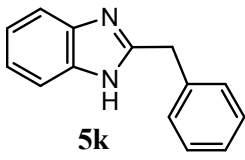
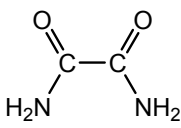
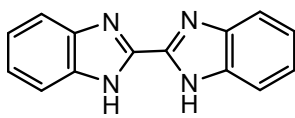
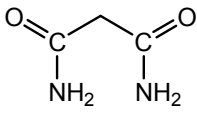
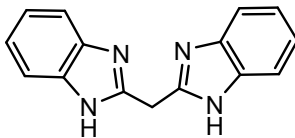
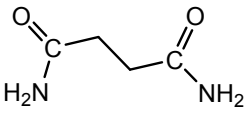
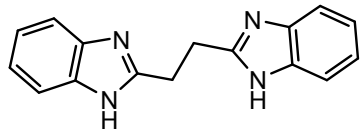
Entry	Amides (4a-n)	Products (5a-n)	Thermal		Microwave	
			Time (hr)	Yield (%)	Time (min)	Yield (%)
3	 4c	 5c	4	75	40	92
4	 4d	 5d	4	72	40	94
5	 4e	 5e	5	70	40	91
6	 4f	 5f	5	65	50	90
7	 4g	 5g	6	74	50	92
8	 4h	 5h	7	70	50	86
9	 4i	 5i	10	60	50	84

Table 2 contd.....

Entry	Amides (4a-n)	Products (5a-n)	Thermal		Microwave	
			Time	Yield ^a (%)	Time (min)	Yield ^a (%)
10	 4j	 5j	12	40	50	80
11	 4k	 5k	8	70	40	92
12	 4l	 5l	24	51	60	88
13	 4m	 5m	18	55	60	92
14	 4n	 5n	18	54	60	91

^a Isolated yield

Conclusion

A facile and inexpensive method for the synthesis of benzimidazoles using 1,2-arylenediamines and DMF in 70% HCl by conventional as well as microwave condition is reported. The synthesis of 2-substituted benzimidazoles from various C-substituted amides is demonstrated successfully. The reactions carried out under microwave irradiation afforded benzimidazoles in short period of time with excellent yields. Hence, this methodology would make an interesting strategy for the synthesis of various substituted benzimidazoles.

Experimental

General information

All the reagents were of analytical grade and were used directly when required. Microwave irradiation experiments were carried out using CEM Discover SP Microwave Synthesizer equipped with IR sensor to monitor reaction temperatures. Thin-layer chromatography (TLC) was performed on 0.20mm Aluchrosep silica gel 60 F₂₅₄ plates (S.D. Fine, Mumbai). Melting points were determined in open capillaries and are uncorrected. The IR spectra were recorded on Nicolet Impact 410 FT IR spectrometer using KBr pellets. The ¹H NMR spectra were recorded at 400 MHz on Bruker Avance FT NMR spectrometer in DMSO-*d*₆ with TMS as internal standard. ¹³C NMR spectra were recorded at 100 MHz on Bruker Avance FT NMR spectrometer in DMSO-*d*₆ with TMS as internal standard. The mass spectra were recorded on Shimadzu GC-MS operating at 70 eV.

Conventional method for the synthesis of benzimidazoles (3a-g)

1,2-Arylenediamine (**1a-g**, 4.62 mmol), DMF (1 ml, 13.87 mmol) and 70% HCl (10 ml) were heated in a round bottom flask at 100°C for 1 h. The completion of the reaction was monitored by TLC using mixture of ethyl acetate, hexane (1:1) as eluent. The reaction mixture was cooled to room temperature and quenched by adding water (10 ml). The aqueous solution was neutralised by adding solid Na₂CO₃ till slightly basic pH (8-9) to get the

precipitate. The solid separated was filtered, washed repeatedly with water, dried and recrystallized using ethanol to afford pure benzimidazole derivatives (**3a-g**) in excellent yields. Synthesis of benzimidazole (**3a**) from 1,2-phenylenediamine (**1a**) and formamide (**4a**) was carried out using similar procedure.

Conventional method for the synthesis of 2-substituted benzimidazoles (5b-n)

1,2-Phenylenediamine (**1a**, 0.50 g, 4.62 mmol), substituted amide (**4b-n**, 4.62 mmol) and 70% HCl (10 ml) were heated in a round bottom flask at 100°C. The completion of the reaction was monitored by TLC using mixture of ethyl acetate, hexane (1:1) as eluent. The reaction mixture was cooled to room temperature and water (10 ml) was added. Then, the aqueous solution was neutralised by adding solid Na₂CO₃ till slightly basic pH (8-9) to get the precipitate. The solid separated was filtered, washed repeatedly with water, dried and recrystallized using ethanol to afford **5b-n**.

Microwave assisted procedure for the synthesis of benzimidazoles (3a-g)

1,2-Arylenediamine (**1a-g**, 0.92 mmol), DMF (1 ml, 2.78 mmol) and 70% HCl (5 ml) was introduced into a CEM microwave reaction vessel (10 ml) equipped with magnetic stirrer. The reaction vessel was sealed and the reaction mixture was pre-stirred for 1 min at room temperature. Then, the reaction mixture was irradiated by 150 W microwave radiations for 2 min at 150°C. The completion of reaction was monitored by TLC using ethyl acetate, hexane (1:1) solvent mixture as eluent. The reaction mixture was cooled to room temperature and water (10 ml) was added. Then, the reaction mixture was neutralised by solid Na₂CO₃ till slightly basic pH (8-9) to get the precipitate. The solid separated was filtered, washed repeatedly with water, dried and recrystallized using ethanol to afford **5b-n**. Synthesis of benzimidazole (**3a**) from 1,2-phenylenediamine (**1a**) and formamide (**4a**) was carried out using similar procedure.

Microwave assisted procedure for the synthesis of 2-substituted benzimidazoles (5b-n)

1,2-Phenylenediamine (**1a**, 0.10 g, 0.92 mmol), substituted amide (**4b-n**, 0.92 mmol) and 70% HCl was introduced into a 10 ml CEM microwave reaction vessel equipped with magnetic stirrer. The reaction vessel was sealed and the reaction mixture was pre-stirred for 1 min at room temperature. Further, the reaction mixture was irradiated by 150 W microwave radiations for 40 min at 150°C for compounds **5b-k** and 60 min for compounds **5l-n**. The completion of reaction was monitored by TLC using ethyl acetate, hexane (1:1) solvent mixture as eluent. The reaction mixture was cooled to room temperature and similar work up procedure was followed as mentioned above for the benzimidazoles (**3a-g**).

The physical data (mp, NMR) of all the known compounds were found to be identical with those reported earlier in the literature.

1H-Benzo[d]imidazole (3a)

White solid; mp: 169-171°C (lit.⁵³: 172°C). IR (KBr): 3112 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.43 (s, 1H, NH), 8.19 (s, 1H, C₂H), 7.58-7.56 (dd, 2H, *J* = 2.8 Hz, C₄H & C₇H), 7.19-7.15 (m, 2H, C₅H & C₆H). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 141.85, 138.08, 121.63, 115.44. *m/z* 118 (M⁺, 100%), 91 (24), 78 (40), 63 (64).

5-Methyl-1H-benzo[d]imidazole (3b)

White solid; mp: 114-116°C (lit.⁵³: 116°C). IR (KBr): 3154 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.28 (s, 1H, NH), 8.01 (s, 1H, C₂H), 7.44 (d, 1H, *J* = 6.4 Hz, C₇H), 7.34 (s, 1H, C₄H), 6.98 (d, 1H, *J* = 6.4 Hz, C₆H), 2.39 (s, 3H, CH₃). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 141.49, 130.75, 123.08, 114.83, 21.17. *m/z* 132 (M⁺, 89%), 131 (100), 78 (43), 63 (47).

4,6-Dimethyl-1H-benzo[d]imidazole (3c)

White solid; mp: 142-144°C (lit.⁵⁴: 146°C). IR (KBr): 3114 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.52 (s, 1H, NH), 8.14 (s, 1H, C₂H), 7.16 (s, 1H, C₇H), 6.81 (s, 1H, C₅H),

2.46 (s, 3H, CH₃), 2.35 (s, 3H, CH₃). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 140.73, 138.69, 135.51, 130.93, 124.74, 123.73, 111.77, 21.15, 16.60. *m/z* 146 (M⁺, 100%), 145 (65), 91 (18), 78 (10), 63 (19).

5-Chloro-1*H*-benzo[*d*]imidazole (3d)

White solid; mp: 121-123°C (lit.⁵³: 125°C). IR (KBr): 3127 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.60 (s, 1H, NH), 8.26 (s, 1H, C₂H), 7.68 (s, 1H, C₄), 7.62 (d, 1H, *J* = 15.6 Hz, C₆H), 7.20 (d, 1H, *J* = 15.6 Hz, C₇H). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 143.41, 121.96, 120.18, 118.48, 113.01, 111.55. *m/z* 154 (M⁺, 32%), 152 (M⁺, 100), 127 (7), 125 (19), 90 (19), 78 (29), 63 (57).

5-Nitro-1*H*-benzo[*d*]imidazole (3e)

Pale yellow solid; mp: 207-209°C (lit.⁵³: 208°C). IR (KBr): 3125 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 13.01 (s, 1H, NH), 8.54 (s, 1H, C₂H), 8.51 (s, 1H, C₄H), 8.11 (d, 1H, *J* = 6.8 Hz, C₆H), 7.77 (d, 1H, *J* = 6.8 Hz, C₇H). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 146.72, 143.01, 142.58, 117.52, 114.96, 112.66. *m/z* 163 (M⁺, 47%), 133 (25), 117 (26), 90 (42), 78 (63), 63 (100).

6-Bromo-1*H*-imidazo[4,5-*b*]pyridine (3f)

Light brown solid; mp: 222-224°C (lit.⁵⁵: 227°C). IR (KBr): 3136 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 13.14 (s, 1H, NH), 8.48 (s, 1H, C₂H), 8.42 (s, 1H, C₇H), 8.28 (s, 1H, C₃H). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 150.02, 145.49, 143.99, 133.15, 126.25, 112.67. *m/z* 199 (M⁺, 97%), 197 (M⁺, 100), 172 (17), 170 (18), 118 (50), 91 (25), 78 (24), 63 (58).

1-Methyl-1*H*-benzo[*d*]imidazole (3g)

Brown semisolid; mp: 59-62°C (lit.⁵⁶: 60°C). IR (KBr): 3152 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 7.82 (s, 1H, C₂H), 7.80 (d, 1H, C₄H), 7.36 (d, 1H, C₇H), 7.31-7.28 (m, 2H, C₅H & C₇H), 3.68 (s, 3H, CH₃). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 143.81, 143.52, 134.58,

123.20, 122.02, 121.55, 112.65, 30.96. m/z 132 (M^+ , 100%), 131 (55), 104 (35), 90 (9), 78 (29), 63 (46).

2-Methyl-1*H*-benzo[*d*]imidazole (5b)

White solid; mp: 173-175°C (lit.⁵³: 177°C). IR (KBr): 3185 (NH) cm^{-1} . ^1H NMR (400 MHz, DMSO- d_6): δ 12.20 (s, 1H, NH), 7.48-7.42 (dd, 2H, C₄H & C₇H), 7.09-7.06 (m, 2H, C₅H & C₆H), 2.46 (s, 1H, CH₃). ^{13}C NMR (100 MHz, DMSO- d_6): δ 151.15, 138.91, 130.90, 114.17, 14.54. m/z 132 (M^+ , 71%), 131 (52), 104 (9), 90 (7), 78 (72), 63 (100).

2-Ethyl-1*H*-benzo[*d*]imidazole (5c)

White solid; mp: 176-178°C (lit.⁵³: 176°C). IR (KBr): 3192 (NH) cm^{-1} . ^1H NMR (400 MHz, DMSO- d_6): δ 12.13 (s, 1H, NH), 7.47-7.40 (dd, 2H, C₄H & C₇H), 7.07-7.09 (m, 2H, C₅H & C₆H), 2.83-2.78 (q, 2H, $J = 6.0$ Hz, CH₂), 1.31-1.28 (t, 3H, $J = 6.0$ Hz, CH₃). ^{13}C NMR (100 MHz, DMSO- d_6): δ 156.05, 141.02, 120.94, 115.38, 21.89, 12.14. m/z 146 (M^+ , 59%), 145 (100), 131 (20), 118 (10), 104 (7), 92 (8), 78 (35), 63 (60).

2-(Chloromethyl)-1*H*-benzo[*d*]imidazole (5d)

Yellow solid; mp: 156-158°C (lit.⁵⁷: 160°C). IR (KBr): 3211 (NH) cm^{-1} . ^1H NMR (400 MHz, DMSO- d_6): δ 12.50 (s, 1H, NH), 7.56-7.52 (dd, 2H, C₄H & C₇H), 7.22-7.11 (m, 2H, C₅H & C₇H), 4.91 (s, 2H, CH₂). ^{13}C NMR (100 MHz, DMSO- d_6): δ 150.09, 141.59, 138.00, 124.10, 116.52, 42.06. m/z 168 (M^{+2} , 10%), 166 (M^+ , 30%), 131 (100), 104 (14), 77 (18), 63 (19).

2-Vinyl-1*H*-benzo[*d*]imidazole (5e)

White solid; mp: 180-182°C (lit.⁵⁸: 184°C). IR (KBr): 3223 (NH) cm^{-1} . ^1H NMR (400 MHz, DMSO- d_6): δ 12.27 (s, 1H, NH), 7.62-7.56 (dd, 2H, C₄H & C₇H), 7.12-7.10 (m, 2H, C₅H & C₆H), 6.77-6.73 (dd, 1H, $J_{trans} = 16.8$ Hz, $J_{cis} = 9.7$ Hz), 6.26 (dd, 1H, $J_{trans} = 16.8$ Hz, $J_{gem} = 1.8$ Hz), 5.66 (dd, 1H, $J_{cis} = 9.7$ Hz, $J_{gem} = 1.8$ Hz). ^{13}C NMR (100 MHz, DMSO- d_6): δ

141.68, 138.79, 123.20, 122.02, 121.55, 112.65. m/z 144 (M^+ , 83%), 143 (100), 117 (23), 104 (7), 91 (11), 63 (46).

2-Phenyl-1*H*-benzo[*d*]imidazole (5f)

White solid; mp: 294-296°C (lit.⁵⁹: 292°C). IR (KBr): 3223 (NH) cm^{-1} . ^1H NMR (400 MHz, DMSO- d_6): δ 12.95 (s, 1H, NH), 8.20-8.17 (dd, 2H, C_2H & C_6H), 7.63-7.48 (m, 5H, C_4H , C_7H , C_3H , C_4H & C_5H), 7.23-7.19 (m, 2H, C_5H & C_6H). ^{13}C NMR (100 MHz, DMSO- d_6): δ 151.14, 143.17, 130.10, 129.76, 128.86, 128.50, 127.36, 122.03. m/z 194 (M^+ , 100%), 166 (7), 104 (6), 90 (10), 78 (46), 63 (70).

2-(4-Methoxyphenyl)-1*H*-benzo[*d*]imidazole (5g)

White solid; mp: 222-224°C (lit.⁵⁹: 226°C). IR (KBr): 3158 (NH) cm^{-1} . ^1H NMR (400 MHz, DMSO- d_6): δ 12.86 (s, 1H, NH), 7.98 (d, 2H, $J = 7.2$ Hz, C_2H & C_6H), 7.72-7.68 (dd, 2H, C_4H & C_7H), 7.20-7.14 (m, 2H, C_5H & C_6H), 6.85 (d, 2H, $J = 7.2$ Hz, C_3H & C_5H), 3.75 (s, 3H, OCH_3). ^{13}C NMR (100 MHz, DMSO- d_6): δ 160.75, 153.02, 142.28, 130.86, 129.68, 128.72, 128.55, 122.59, 56.07. m/z 224 (M^+ , 100%), 193 (54), 117 (32), 104 (8), 91 (10), 78 (31), 63 (63).

2-(4-Chlorophenyl)-1*H*-benzo[*d*]imidazole (5h)

White solid; mp: 295-297°C (lit.⁵⁹: 294°C). IR (KBr): 3211 (NH) cm^{-1} . ^1H NMR (400 MHz, DMSO- d_6): δ 13.02 (s, 1H, NH), 8.16 (d, 2H, $J = 7.6$ Hz, C_2H & C_6H), 7.82-7.78 (dd, 2H, C_4H & C_7H), 7.66 (d, 2H, $J = 7.6$ Hz, C_3H & C_5H), 7.26-7.22 (m, 2H, C_5H & C_6H). ^{13}C NMR (100 MHz, DMSO- d_6): δ 150.28, 143.63, 134.66, 129.88, 128.98, 128.27, 122.64, 118.59. m/z 230 (M^{+2} , 23%), 228 (M^+ , 70%), 193 (45), 117 (12), 104 (12), 91 (23), 78 (45), 63 (100).

2-(2-Chlorophenyl)-1H-benzo[d]imidazole (5i)

White solid; mp: 236-238°C (lit.⁵⁹: 234°C). IR (KBr): 3209 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 13.11 (s, 1H, NH), 7.94 (d, 1H, *J* = 7.8 Hz, C₆H), 7.74-7.72 (dd, 2H, C₄H & C₇H), 7.55-7.51 (m, 3H, C₅H, C₆H & C₅H), 7.27-7.18 (m, 2H, C₂H & C₃H). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 151.09, 143.72, 139.47, 132.77, 130.58, 129.09, 128.97, 126.61, 123.59, 120.46, 118.74. *m/z* 230 (M⁺, 22), 228 (M⁺, 65%), 117 (9), 104 (29), 91 (7), 78 (15), 63 (100).

2-(4-Nitrophenyl)-1H-benzo[d]imidazole (5j)

Yellow solid; mp: 312-314°C (lit.⁵⁹: 316°C). IR (KBr): 3196 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 13.02 (s, 1H, NH), 8.44 (d, 2H, *J* = 6.8 Hz, C₃H & C₅H), 7.76 (d, 2H, *J* = 6.8 Hz, C₂H & C₆H), 7.72-7.70 (dd, 2H, C₄H & C₇H), 7.26-7.22 (m, 2H, C₅H & C₆H). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 152.64, 148.37, 143.69, 135.64, 128.34, 122.72, 119.61. *m/z* 239 (M⁺, 100%), 193 (38), 117 (27), 104 (8), 91 (11), 78 (29), 63 (49).

2-Benzyl-1H-benzo[d]imidazole (5k)

White solid; mp: 184-186°C (lit.⁵⁷: 187°C). IR (KBr): 3119 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.26 (s, 1H, NH), 7.52-7.50 (dd, 2H, C₄H & C₇H), 7.40-7.38 (dd, 2H, C₃H & C₅H), 7.23-7.20 (m, 2H, C₂H & C₆H), 7.12-7.07 (m, 2H, C₅H & C₆H), 4.15 (s, 2H, CH₂). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 153.43, 143.37, 137.61, 134.83, 134.38, 128.69, 128.40, 126.44, 121.53, 120.85, 118.19, 110.84, 34.88. *m/z* 208 (M⁺, 54%), 207 (79), 131 (7), 103 (19), 91 (17), 78 (55), 63 (100).

2-(1H-Benzo[d]imidazol-2-yl)-1H-benzo[d]imidazole (5l)

Pale yellow solid; mp: >370°C (lit.⁵²: 400°C). IR (KBr): 3216 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.27 (s, 2H, NH), 7.78-7.55 (dd, 4H, C₄H & C₇H), 7.17-7.08 (m, 4H,

C₅H & C₆H). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 153.29, 141.59, 138.00, 124.89, 116.25. *m/z* 234 (M⁺, 8%), 162 (28), 134 (20), 118 (10), 106 (31), 91 (19), 78 (50), 63 (61), 44 (100).

Bis(1*H*-benzo[*d*]imidazol-2-yl)methane (5m)

White solid; mp: >370°C (lit.⁵²: 389°C). IR (KBr): 3230 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.07 (s, 2H, NH), 7.73-7.62 (dd, 4H, C₄H & C₇H), 7.21-7.11(m, 4H, C₅H & C₆H), 3.79 (s, 2H, CH₂). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 152.88, 143.82, 138.12, 124.20, 116.00, 39.00. *m/z* 248 (M⁺, 22%), 131 (9), 118 (8), 78 (73), 63 (100).

2-(2-(1*H*-Benzo[*d*]imidazol-2-yl)ethyl)-1*H*-benzo[*d*]imidazole (5n)

White solid; mp: 316-318°C (lit.⁶⁰: 315°C). IR (KBr): 3217 (NH) cm⁻¹. ¹H NMR (400 MHz, DMSO-*d*₆): δ 12.15 (s, 2H, NH), 7.76-7.66 (dd, 4H, C₄H & C₇H), 7.29-7.21 (m, 4H, C₅H & C₆H), 2.84-2.76 (t, 4H, *J* = 15.6 Hz, CH₂). ¹³C NMR (100 MHz, DMSO-*d*₆): δ 151.05, 142.95, 139.62, 123.59, 115.65, 33.03. *m/z* 262 (M⁺, 7%), 196 (33), 132 (100), 104 (31), 90 (9), 77 (31), 63 (21).

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Graphical Abstract

Expedient synthesis of benzimidazoles using amides

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In the present report an efficient, rapid, facile and inexpensive route for the synthesis of benzimidazoles using 1,2-arylenediamines and amides in acidic medium under thermal/microwave conditions is developed.

